How Oil from the North went South

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EPRG Presentation
University of Cambridge

March 3, 2008
Introduction

• The Economics of oil supply
  – Finding and producing oil
  – Significance of giant oil fields
  – Features impacting cost
• Peak oil
  – Hubbert’s peak
  – Global view
  – Alternative forecasts
  – History repeats
• Cost and Price
• Alaska’s oil resources
  – Background
  – Anchor fields
  – The resource
  – Investment
  – New focus
• Canada’s oil sands
  – The resource
  – Calgary Stampede
• Petroleum end-use
• Conclusion
Figure 1 - Global Oil Supplies, A Division of Opinion

Year of Production

- Actual
- Campbell 1997
- 2007 EIA Reference Case
The Economics of Oil Supply

- Finding Oil
  - Source rocks, reservoirs, and cap rocks
  - Exploration risk
  - Evolving technology
  - “Dad” Joiner and the East Texas oil field
  - Impact of successful oil finds
  - The great discoveries
  - Has been the least cost source of energy
The Economics of Oil Supply

• Finding Oil
  ✓ Source rocks, reservoirs, and cap rocks
  ✓ Exploration risk
  ✓ Evolving technology
  ✓ “Dad” Joiner and the East Texas oil field
  ✓ Impact of successful oil finds
  ✓ The great discoveries
  ✓ Has been the least cost source of energy
The Economics of Oil Supply

- **Significance of giant oil fields**
  - What are giant and super-giant fields?
  - Dominant supply source in 1970s, Nehring study
  - 1978, 81% of reserves from such fields
  - 22 largest fields are in OPEC, 19 in Persian Gulf
  - 3 remaining, two in Russia, one in U.S.
  - Only three super-giants discovered since 1970
The Economics of Oil Supply

• **Features impacting cost**
  - Size of the field
  - Depth of the “pay”
  - Amount of re-injection
  - Location
    - Distance from market
    - Offshore-onshore
    - Ocean depth
  - Complexity of the geological formation
  - Quality of the crude oil
    - Density
    - Viscosity
    - Contaminants
Peak Oil

- **Hubbert’s Peak**
  - 1956 prediction put U.S. “peak” in 1971
  - Methodology revealed in 1982

- **Campbell’s 1997 update**
  - U.S. forecast, using Hubbert methodology
  - Naïve methodology, based on a logistic curve
  - Used Petroconsultants data
  - Extended to world production

- **Alternative forecasts**
  - EIA annual international projection
  - CERA – IHS Energy (Petroconsultants)
Figure 2 - Hubbert’s Peak – U.S. Oil (Liquids) Production

Difference 3.6 MMB/D
“Peak oil” Enthusiasts See a Malthusian Future
Figure 3 - CERA (Jackson) 2006 Rebuttal of Peak Oil
Deutche Bank, 2/27/08:

“Leading oil executives, notably the CEOs of TOTAL and ConocoPhillips, are talking peak oil - and being specific: a maximum of 100mmb/d of oil supply, ever. (The current market is 88mmb/d, growing 1.5mmb/d per year.) By contrast econometric models - the IEA, ExxonMobil, our own - show world oil demand surpassing 100mmb/d by around 2015. However typically these models assume supply will continue to grow, and do not address the issue of price. Here we assume the market is limited at 100mmb/d - and speculate on what will happen to oil prices.”

DB’s Conclusion: Oil could go to $125 to $150 per barrel.
## History Repeats?

Comparison of 1985 Oil Production and Consumption From Forecasts Published in 1977 and 1978 (in million of barrels per day net of CPE)

<table>
<thead>
<tr>
<th>Organization</th>
<th>Demand</th>
<th>Non-OPEC</th>
<th>OPEC</th>
<th>Gap</th>
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<tbody>
<tr>
<td>CIA</td>
<td>70.5</td>
<td>21.5</td>
<td>44.2</td>
<td>5.3</td>
</tr>
<tr>
<td>EIA/DOE</td>
<td>68.1</td>
<td>23.8</td>
<td>39.8</td>
<td>4.5</td>
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<tr>
<td>CRS</td>
<td>67.8</td>
<td>25.0</td>
<td>42.8</td>
<td>-</td>
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<tr>
<td>Exxon</td>
<td>64.0</td>
<td>24.0</td>
<td>40.0</td>
<td>-</td>
</tr>
<tr>
<td>PIRA</td>
<td>61.0</td>
<td>24.4</td>
<td>36.6</td>
<td>-</td>
</tr>
<tr>
<td>Pet. Economist</td>
<td>61.0</td>
<td>25.5</td>
<td>35.5</td>
<td>-</td>
</tr>
<tr>
<td><strong>Actual</strong></td>
<td><strong>41.4</strong></td>
<td><strong>25.0</strong></td>
<td><strong>16.4</strong></td>
<td>-</td>
</tr>
</tbody>
</table>

Source: Van Vactor and Tussing 1987
Cost and Price

Professor Morris Adelman:

“No mineral, including oil, will ever be exhausted. If and when the cost of finding and extraction goes above the price consumers are willing to pay, the industry will begin to disappear. How much oil is still in the ground when extraction stops, and how much was there before extraction began, are unknown and unknowable. The amount extracted from first to last depends on cost and price.”

A strong inference:

If longer-term marginal costs of finding and developing oil supplies correspond to prices observed in the last year then global oil demand (and therefore production) will have peaked or will peak in the near future and decline.

But, what is long-run marginal cost? And, what are the costs of substitutes?
Figure 4 - Oil used in U.S. Power Generation
Figure 5 - The Simple Economics of Oil Price Movements

The diagram illustrates the relationship between price (P) and quantity (Q) for oil price movements. The short-run marginal cost (SRMC) and long-run marginal cost (LRMC) curves are depicted, along with the demand curves D1 and D2. The price levels P1 and P2, and quantity levels Q1 and Q2, are highlighted to show the market equilibrium and potential shifts in demand or supply.
Comments on Oil Supply Price Elasticity

• In response to lower prices the industry appears skillful at cutting cost and finding innovative ways to maintain production.

• Likewise, higher prices do not stimulate supply quickly, due to:
  ✓ Natural decline in oil and gas fields
  ✓ Long lead times to find and develop conventional fields leading to capacity constraints and infrastructure shortages
  ✓ Aggressive taxation or other means to capture rents for publicly owned or leased resources
  ✓ Costs of specialized materials and personnel rise right along with prices
  ✓ Wealth impact on some OPEC members
Alaska Development

- Arctic oil and gas resources
- Alaska oil producing regions
- Cook Inlet production
- North Slope Fields
  - Prudhoe Bay
  - Kuparuk River
  - Point Thompson
North Slope
Russian Far East
Western Siberia
McKenzie Delta
Oil Sands
Chukchi Sea
North Sea

The Arctic region is often defined as that area where the average temperature for the warmest month is below 10°C.
Figure 6 - Cook Inlet Oil Production and Prices

Correlation Coefficient: 0.03
Alaska became a state in 1959. To assure its financial solvency, Alaska was allowed to select portions of federal land for state ownership.

The individual responsible for selecting the land was an oilman, Tom Marshall. When he selected a block of 1.5 million acres on the North Slope in 1961, it was referred to by Alaskan politicians as “Marshall’s folly” or “Marshall’s icebox.”

In 1966-67 Alaska received $6.1 million in bonus bids to drill on the North Slope. Successful bidders were Richfield Oil Company and BP.

BP floated a drilling rig down the McKenzie River from Canada and drilled two unsuccessful wells. The company gave up.

In the winter or 1968-69 Richfield drilled one “last hole” and discovered the Prudhoe Bay oil field.

Following the discovery of Prudhoe Bay Alaska received $900 million in bonus bids in 1969 for leases surrounding the discovery. The original set of leases, however, held 97% of the Prudhoe Bay field.

In 1982 the industry paid $2.1 billion for offshore leases, built an island and drilled “mukluk” the most expensive dry hole in history.
Figure 7 - Components of North Slope Oil Production
North Slope Development and Investment Plans and Costs

- Around Prudhoe Bay
- Beaufort Sea
- ANWR
- NPRA
- Chukchi Sea
Prospective Discoveries

- **CHUKCHI SEA**
  - 9.5 BBO, 50.0 TCFG

- **NPRA**
  - 6.5 BBO, 31.0 TCFG

- **BEAUFORT SEA**
  - 4.95 BBO, 21.0 TCFG

- **CENTRAL ARCTIC**
  - 3.15 BBO, 33.3 TCFG

- **ANWR 1002**
  - 6.25 BBO, 2.0+ TCFG

Map showing the locations of potential discoveries in the Arctic region.
Figure 8 - DOE’s Analysis of North Slope Central Area
Supply Response
Cost Reductions and Innovations

- Ice Pads and Roads
- 3-D seismic surveys
- Directional and multilateral drilling
- Injections of water and natural gas
The area around Prudhoe Bay has between 50 and 60 billion barrels of oil in place. 15.4 billion barrels have been produced and 6.2 billion remain as reserves and are likely to be produced.

The oil lies in a series of deposits at various depths under 1,800 feet of permafrost. In general, the closer to the surface the lower quality the oil and the more costly to produce.

The least developed resource is the heavy viscous oil of the shallower West Sak and Ugnu formations -- about 23 billion barrels in place. Development of these resources depends on favorable economics and technological advance. It is now expected that only about 15% of the oil will be recovered.

So far, there has been little industry enthusiasm for developing the North Slope’s heavy oil deposits despite high prices.
Summary on the North Slope

• The North Slope’s development history demonstrates that initial estimates of oil reserves are underestimated. However, the oil becomes increasingly costly to develop and produce.

• USGS geological assessments provide only a 2% chance that an additional giant field will be found in the Prudhoe Bay area.

• BP and ExxonMobil, two of the companies most familiar with the region are not bidding on new leases, but have focused investments elsewhere, such as Canada’s oil sands.

• The failure to open ANWR has been a setback to development.

• Further exploration in the NPRA and the Chukchi Sea may find more gas than oil.

• The North Slope’s resurgence will depend on completing a natural gas pipeline from Alaska to the lower-48.

• High state taxes and regulatory delays have reduced incentives for development, but they are not the only constraints.
Canada’s Oil Sands

- Oil-in-place (as bitumen) is estimated at 1.7 to 2.5 trillion barrels
- Reserves based on current projects, 8.9 billion barrels
- Canada’s National Energy Board (NEB) posts 173 billion barrels as “established” reserves
- First development - Suncor followed by Syncrude a consortium of 8 companies, including ExxonMobil and ConocoPhillips
- Production is expected to rise from 1.3 MMB/D in 2008 to 2.8 MMB/D in 2015
- There are similarities and differences to the U.S. oil shale development of the 1970s.
<table>
<thead>
<tr>
<th></th>
<th>CAPEX</th>
<th>Economic</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>$C/daily bbl</td>
<td>Threshold</td>
</tr>
<tr>
<td></td>
<td>(thousand)</td>
<td>WTI US$ bbl</td>
</tr>
<tr>
<td>Mining, extraction, &amp; upgrading</td>
<td>$90-$100</td>
<td>$55-$65</td>
</tr>
<tr>
<td>In-Situ</td>
<td>$28-$33</td>
<td>$50-$60</td>
</tr>
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</table>

Source: NEB
Figure 9 - Thermal Energy Requirements for Oil Sands
Percentage of Btu Input Compared to Output

- Surface
- In-Situ Low
- In-Situ High

Hydrocracking
Petroleum coking
Bitumen upgrading
Extraction

Source: Petroleum News, 2/10/08, p. 19
BP Can Pump Four Million Barrels a Day Until 2020, Even Without New Finds

BP replaced its annual production by 112 per cent in 2007, taking its proved reserves of oil and gas to 17.8 billion barrels.

It also added some 2.4 billion new barrels to its non-proved resource base which now stands at a further 42.1 billion barrels of oil equivalent. Assuming a $60 oil price, the strength of this position - reinforced by recent access to new opportunities in Oman, Libya and Colombia, along with heavy oil in Canada - supports production potential of around 4.3 million barrels a day by 2012, BP chief executive Tony Hayward said today.

BP News Release 2/27/08
Hybrid Cars

- Present designs replace the internal combustion machine with gasoline driven electric motors, but do not attempt to use battery-stored electricity.
- The cars get better gasoline mileage, but do not have fuel switching capability.
- Nonetheless, their successful introduction is a significant steppingstone to technologies that will replace gasoline.
- US Hybrid Sales have increased from 10,000 in 2000 to 355,000 in 2007.
Plug In Hybrid Electric Vehicles (PHEVs)

• PHEV’s have gasoline electric generators that charge on-board high-tech lithium-ion (Li-ion) batteries. Or, motorists can charge the battery using a standard household electric plug. The household charge will allow driving on the battery before the generator takes over. (70% of all car trips in the U.S. are less than 40 miles.)

• The following cars plan to use the PHEV technology:
  - Toyota Prius will add 7 miles by battery
  - GM’s concept car, the Volt due in 2010, will allow 40 miles by battery
  - Ford Escape
  - Saturn Vue
  - Subaru G4e

• The National Resources Defense Council and other environmental groups have challenged the advantages of PHEVs, because they may depend on electricity generated with coal. This is not, however, a marginal analysis - natural gas is usually the marginal fuel.

• GM has made data on the Volt’s intended performance available and is used in the following calculations.
Table 2 - Resource Marginal Cost
Electric Batteries Compared to Transport Fuel from Oil Sands
(Assumes $60 crude oil, $8 per million Btu natural gas)

<table>
<thead>
<tr>
<th></th>
<th>Gas Generator</th>
<th>With distribution</th>
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<tbody>
<tr>
<td>Fixed Costs</td>
<td>$0.022</td>
<td>$0.022</td>
</tr>
<tr>
<td>Fuel Costs</td>
<td>$0.056</td>
<td>$0.056</td>
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<tr>
<td>Trans. &amp; Dist.</td>
<td></td>
<td>$0.021</td>
</tr>
<tr>
<td>Total</td>
<td>$0.078</td>
<td>$0.099</td>
</tr>
<tr>
<td>kWh per 40 miles</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Cost</td>
<td>$0.624</td>
<td>$0.792</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>Diesel*</th>
<th>Gasoline*</th>
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<tbody>
<tr>
<td>Threshold/bbl</td>
<td>$60.00</td>
<td>$60.00</td>
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<tr>
<td>Conversion</td>
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<td>$12.00</td>
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<tr>
<td>Distribution</td>
<td></td>
<td>$6.30</td>
</tr>
<tr>
<td>Total</td>
<td>$60.00</td>
<td>$78.30</td>
</tr>
<tr>
<td>Per gallon</td>
<td>$1.43</td>
<td>$1.86</td>
</tr>
<tr>
<td>At 30 mpg</td>
<td>$1.91</td>
<td>$2.49</td>
</tr>
<tr>
<td>Battery Running Cost %</td>
<td>32.8%</td>
<td>31.9%</td>
</tr>
</tbody>
</table>

*Excludes taxes
Li-ion battery technology

• Critical to the success of PHEVs are efforts to make Li-ion batteries safe, lightweight, powerful, and cost-effective.

• GM is co-developing (with spin-offs from MIT) the nanophosphate battery, based on batteries used for rechargeable power tools. This battery is expected to double present storage relative to weight.

• In December Stanford announced its researches had developed a Li-ion battery based on silicon lithium nanowires that improves existing laptop batteries by a factor of 10 to 1 in performance versus weight. It is estimated to take 5 years to market. Researchers believe it could easily be sized up for cars.
Pellet stoves - inconvenient but cheap

• Pellet stoves burn small manufactured pellets and are automated to maintain flow into the burner and regulate temperature. Pellets can be made from wood, sawdust, nut shells, and similar waste biomaterials. Modern stoves have catalytic converters to minimize pollutants.

• Heating costs for a building 2,000 to 3,000 square feet:
  - Stove $1,700 to $3000
  - Monthly electricity $9
  - Fuel $240 to $400 per year

• Costs are approximately 5 times cheaper than heating oil.

• Stoves require loading of pellets (about 40 pounds) every day or two and weekly cleaning.
### Table 3 - Estimates of Oil Revenue and Investment

<table>
<thead>
<tr>
<th></th>
<th>2007 Production (MB/D)</th>
<th>2007 Value (Bilions)</th>
<th>Annual Investment (Bilions)</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saudi Arabia</td>
<td>8,686</td>
<td>$220</td>
<td>$10</td>
<td>4.5%</td>
</tr>
<tr>
<td>Alaska North Slope</td>
<td>695</td>
<td>$18</td>
<td>$3</td>
<td>17.2%</td>
</tr>
<tr>
<td>Canadian Oil Sands</td>
<td>1,200</td>
<td>$32</td>
<td>$19</td>
<td>59.0%</td>
</tr>
<tr>
<td>Global E&amp;P*</td>
<td>84,000</td>
<td>$2,220</td>
<td>$369</td>
<td>16.6%</td>
</tr>
</tbody>
</table>

*Investment Includes natural gas
• While the “peak oil,” thesis is clearly refutable as it stands, oil fields have a natural decline and there is a valid point about the increasing cost of developing low quality oil reserves. It is, however, difficult to distinguish long-run costs as compared to short-run costs.

• Natural gas supplies appear to be much larger than those of conventional oil and unconventional gas resources may be far less costly to develop.

• Converting low-quality hydrocarbon resources, such as oil shale or oil sands, to useable fuels is a high-cost solution compared to a number of new transportation technologies and, even older low-tech solutions.

• The development of low-cost light weight electricity storage batteries suggest current oil prices will not be competitive in the long-term. Oil will continue to lose market share, if prices remain high.

Conclusion
The side effects of low-quality resource conversion are serious. The conversion from oil sands to usable fuels requires more gas on the margin than the conversion to electricity for the same mileage. Plus, using the fuel in vehicles more than doubles emissions.

2007 could easily be the year of peak oil production because of faltering demand.

Energy is moving from the North to the South - from the Arctic to Silicone Valley. High prices have unleashed new technologies which will end the “age of oil.”