GEOLOGICAL SURVEY OF CANADA
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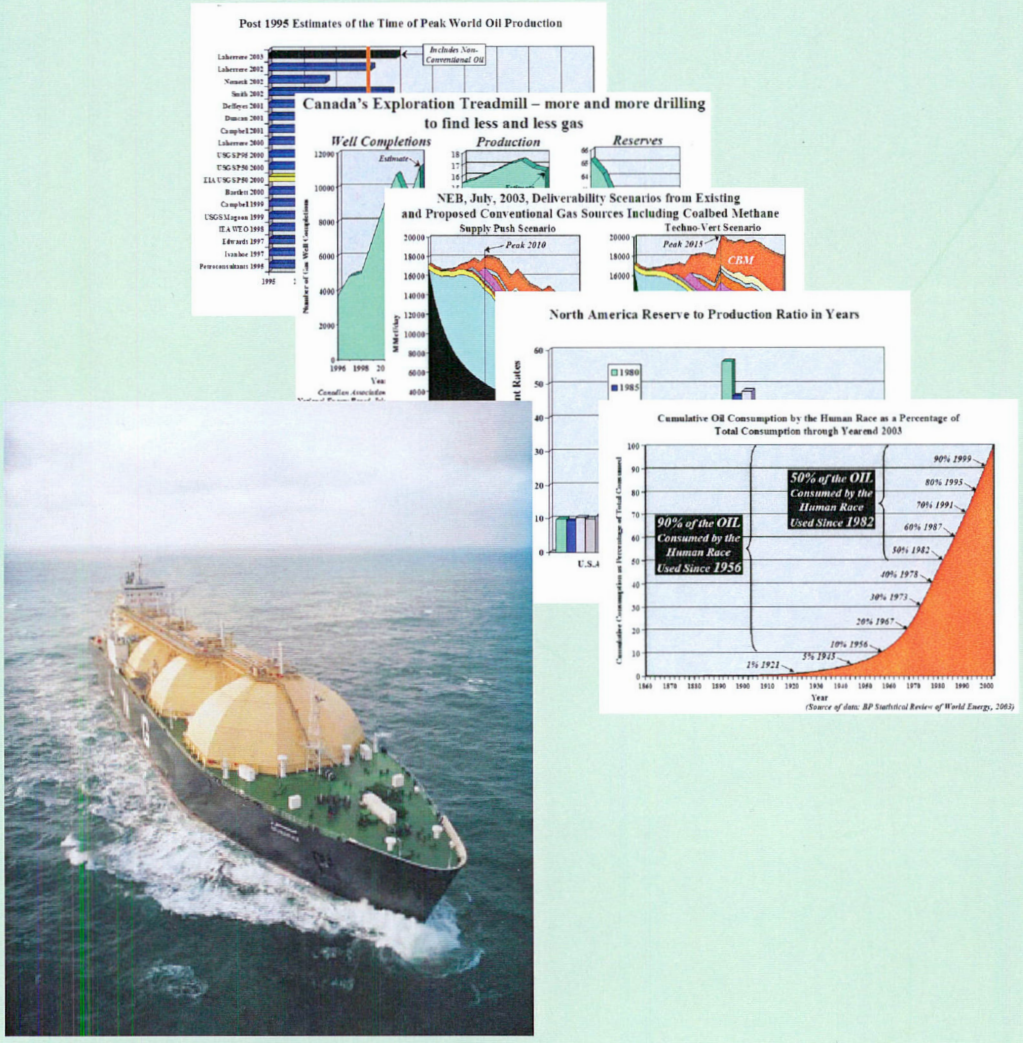
ENERGY SUPPLY/DEMAND TRENDS AND FORECASTS: IMPLICATIONS FOR A SUSTAINABLE ENERGY FUTURE IN CANADA AND THE WORLD

J. DAVID HUGHES



Updated with latest forecasts through January 2004

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Open File 1798 is a reproduction of slides from an evolving presentation on energy supply/demand issues which has been given at numerous venues in Canada and the United States over the past 15 months. The current slide deck contains the latest forecasts and historical energy information available through January 2004. Important new information is anticipated from the U.S. Department of Energy's Energy Information Administration in May 2004, and from the B.P. Statistical Review of World Energy in June 2004. A revised and updated version of this Open File which integrates this new information will be made available in August of 2004.

Abstract

An analysis of world and North American energy production and consumption over the past several decades indicates strong growth. Even with the growth of "zero emission" nuclear and large hydro, hydrocarbons (oil, gas and coal) made up more than 85% of world primary energy consumption in 2002, and are forecast to make up more than 85% of a greatly expanded energy demand by 2025. Energy demand in the developing world is forecast by the Energy Information Administration to grow by 94% through 2025, when this region will account for nearly half of the world's energy consumption. The question is, are these forecast growth rates sustainable, given the magnitude and distribution of the world's remaining energy reserves, and what are some of the political and social ramifications of maintaining this rate of consumption? Natural gas in North America is of particular concern, as it is largely a Continental market (with the exception of about 1% LNG at present) and demand, particularly for electricity generation, is forecast to grow dramatically over the next two decades. This presentation focuses on the "Big Picture" and how Canada fits into it, as well as what must be considered going forward to assure a sustainable energy future.

HUGHES, J.D.
2004: ENERGY SUPPLY/DEMAND TRENDS AND FORECASTS: IMPLICATIONS FOR A SUSTAINABLE ENERGY FUTURE IN CANADA AND THE WORLD (updated with latest forecasts through January 2004), Geological Survey of Canada, Open File 1798, 47 p.

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Energy Supply/Demand Trends and Forecasts: *Implications for a Sustainable Energy Future in Canada and the World*

Geological Survey of Canada
Open File 1798
January, 2004

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Natural Resources Canada
GEOLOGICAL SURVEY OF CANADA
CALGARY

Ressources naturelles Canada
COMMISSION GÉOLOGIQUE DU CANADA
CALGARY

Foreword

Third party data and forecasts updated to 2004 where possible are used throughout the following presentation

Interpretations and conclusions drawn from these data are the sole responsibility of the author and not the Geological Survey of Canada or Natural Resources Canada

This presentation is offered as a foundation for discussion on issues that the author feels must be considered in managing the transition to a more sustainable energy future

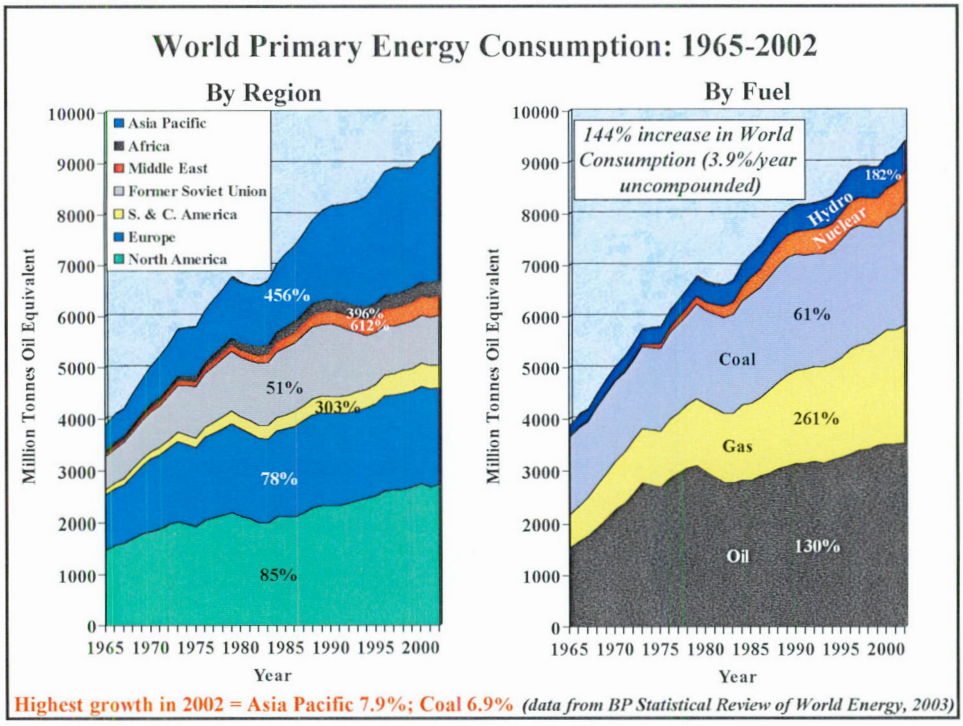
Points to be covered:

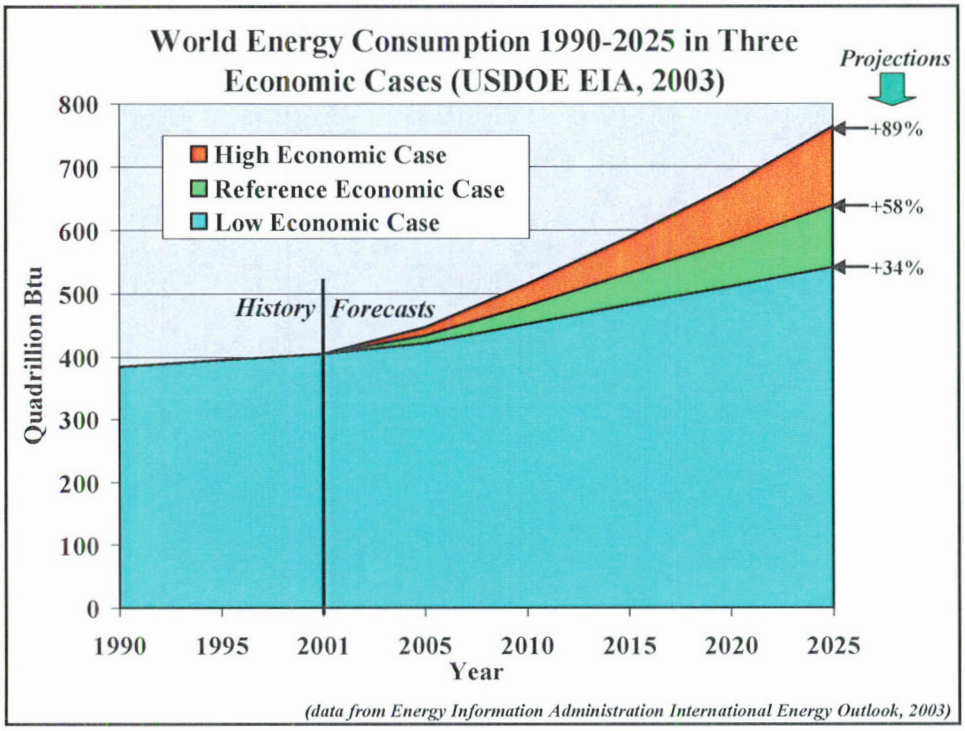
- **Patterns of Energy Consumption and Production:**
  - *History – what actually happened "Hindsight"*
  - *Forecasts – always arguable and debatable:*
    - *"economists vs. geologists"*
    - *"geologists vs. geologists"*
    - *"optimists vs. pessimists"*

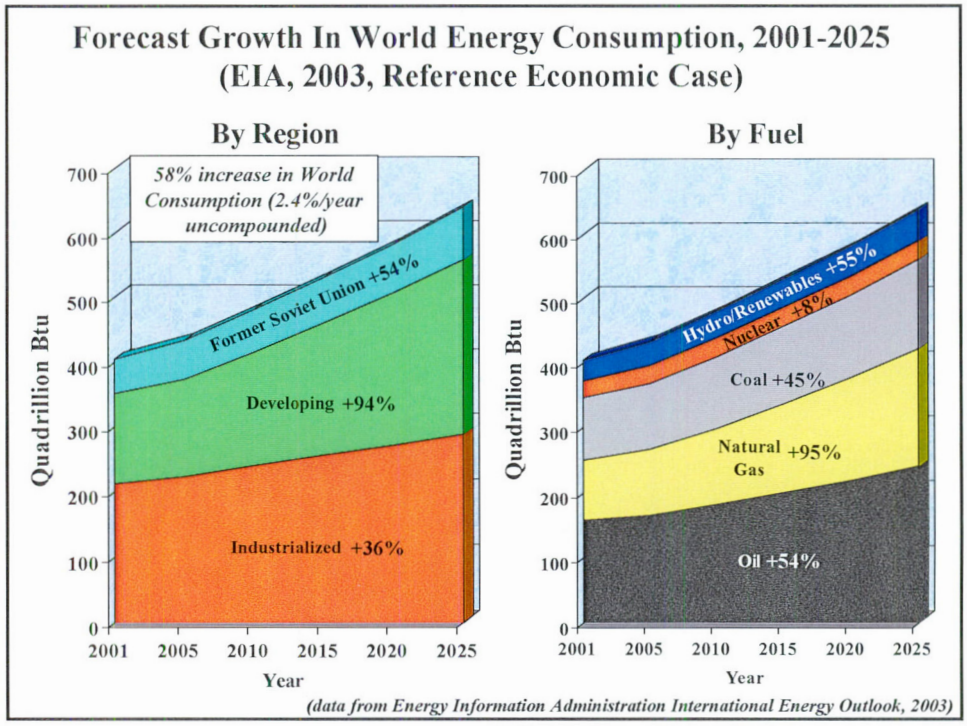
- **Magnitude and Distribution of Remaining Energy Reserves and Resources:**
  - *Implications for security of energy supply*

- **Where does Canada Stand in All This?**

- **Some thoughts on the way forward:** ***Challenges and Changes for a Sustainable Energy Future***




World Energy Consumption 1990-2025 in Three Economic Cases (USDOE EIA, 2003)
Projections
High Economic Case
Reference Economic Case
Low Economic Case
+89%
+58%
+34%
History
Forecasts
Quadrillion Btu
800
700
600
500
400
300
200
100
0
1990
1995
2001
2005
2010
2015
2020
2025
Year
(data from Energy Information Administration International Energy Outlook, 2003)


Forecast Growth In World Energy Consumption, 2001-2025 (EIA, 2003, Reference Economic Case)
By Region
58% increase in World Consumption (2.4%/year uncompounded)
Former Soviet Union +54%
Developing +94%
Industrialized +36%
Quadrillion Btu
700
600
500
400
300
200
100
0
2001
2005
2010
2015
2020
2025
Year
By Fuel
Hydro/Renewables +55%
Nuclear +8%
Coal +45%
Natural Gas +95%
Oil +54%
Quadrillion Btu
700
600
500
400
300
200
100
0
2001
2005
2010
2015
2020
2025
Year
(data from Energy Information Administration International Energy Outlook, 2003)

Summary

- Hydrocarbons provided 87% of the world's primary energy in 2002

- Forecasts suggest that more than 87% of a greatly expanded energy demand will be provided by hydrocarbons in 2025

- Most of the balance of energy supply will be provided by large hydro and nuclear – sources with their own environmental problems

- Is this Sustainable?

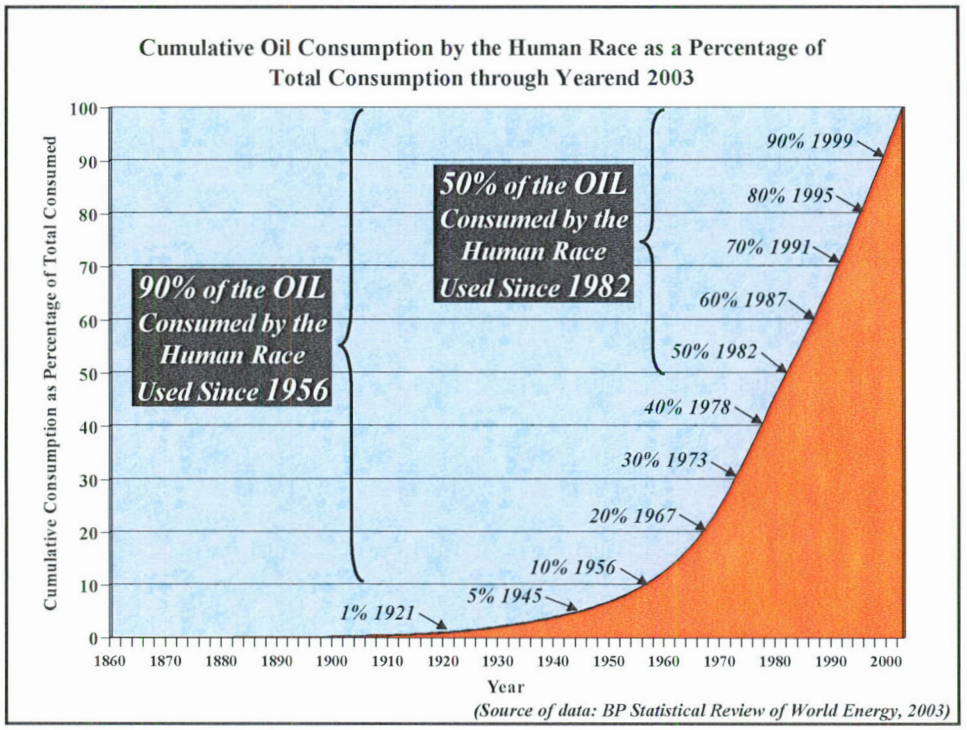
..... Lets look in more detail at oil, gas and coal

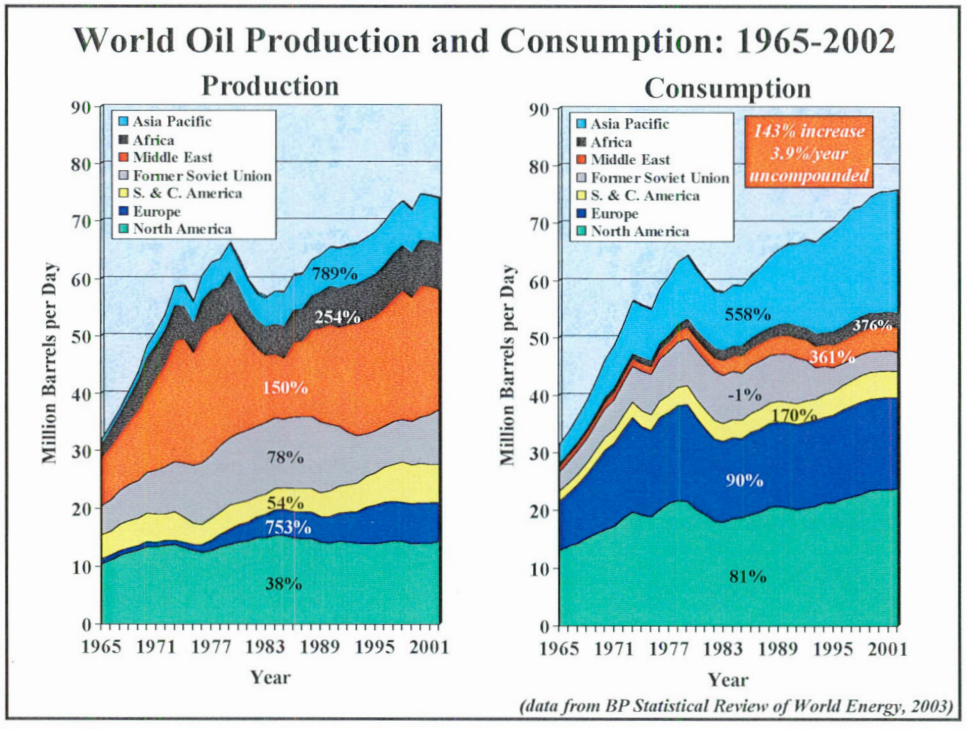
OIL

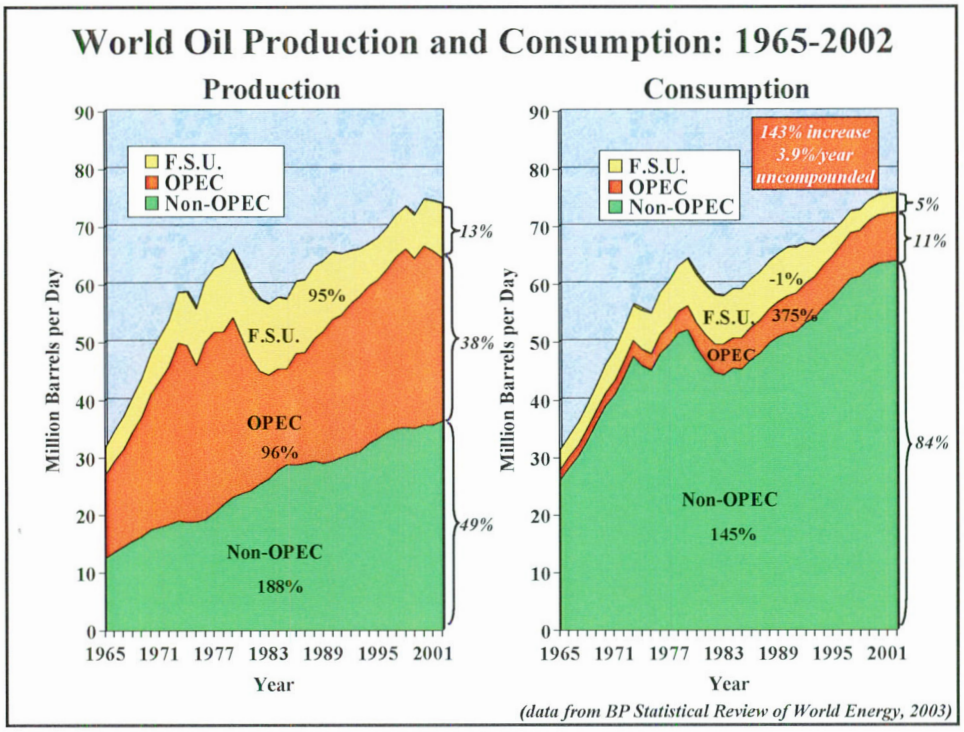
- The largest source of energy in the world *(37.4% of primary energy consumption in 2002)*

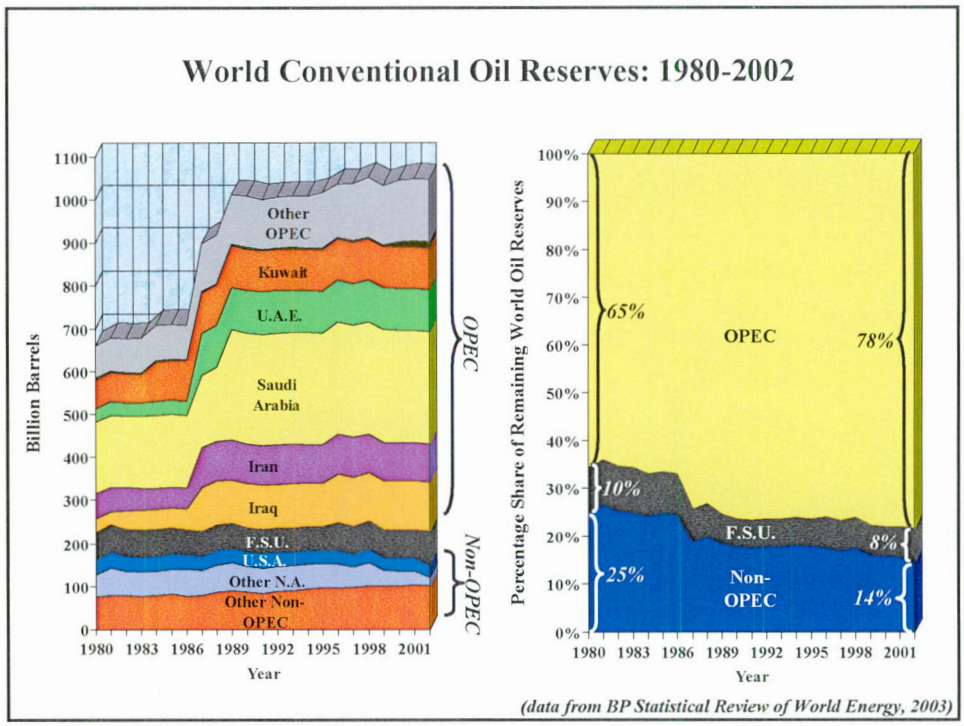
- The ultimate fuel for international trade – *easily moved by tanker and pipeline*

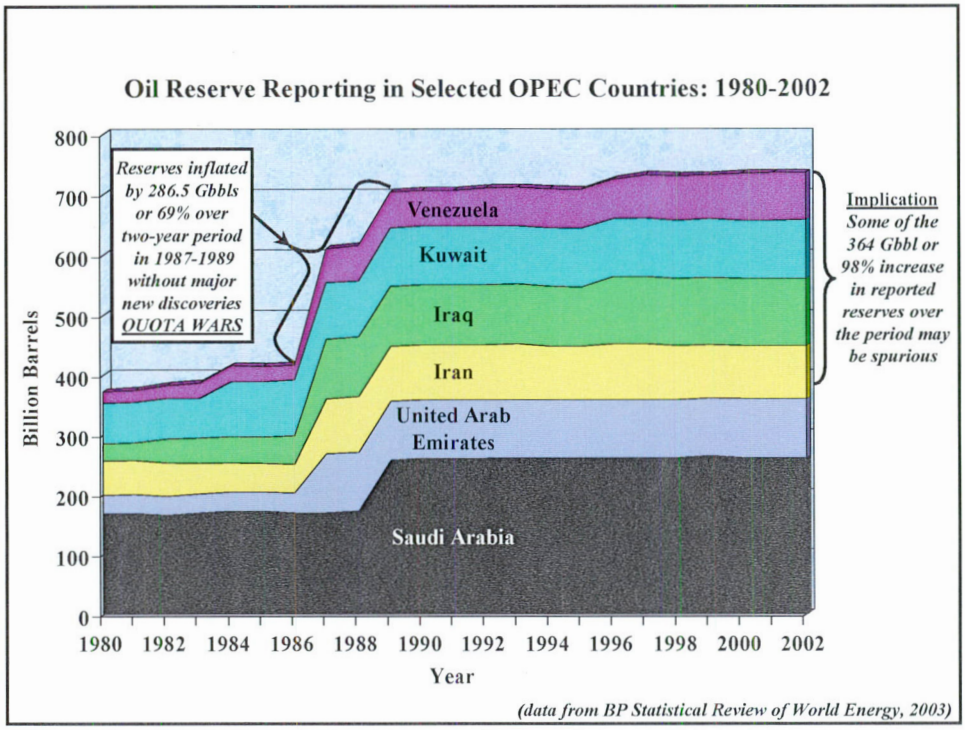
- Highly subject to Geopolitics – *the OPEC cartel (Middle Eastern countries are among the most politically unstable and heavily armed countries on Earth)*

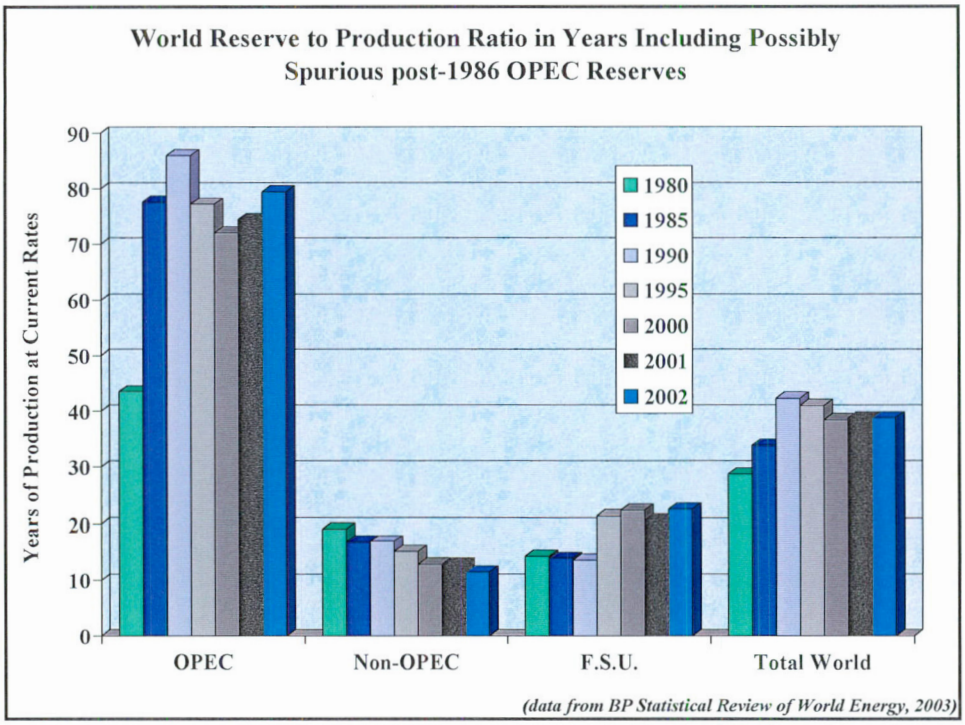

Cumulative Oil Consumption by the Human Race as a Percentage of Total Consumption through Yearend 2003
Cumulative Consumption as Percentage of Total Consumed
90% of the OIL Consumed by the Human Race Used Since 1956
50% of the OIL Consumed by the Human Race Used Since 1982
1% 1921
5% 1945
10% 1956
20% 1967
30% 1973
40% 1978
50% 1982
60% 1987
70% 1991
80% 1995
90% 1999
Year
(Source of data: BP Statistical Review of World Energy, 2003)

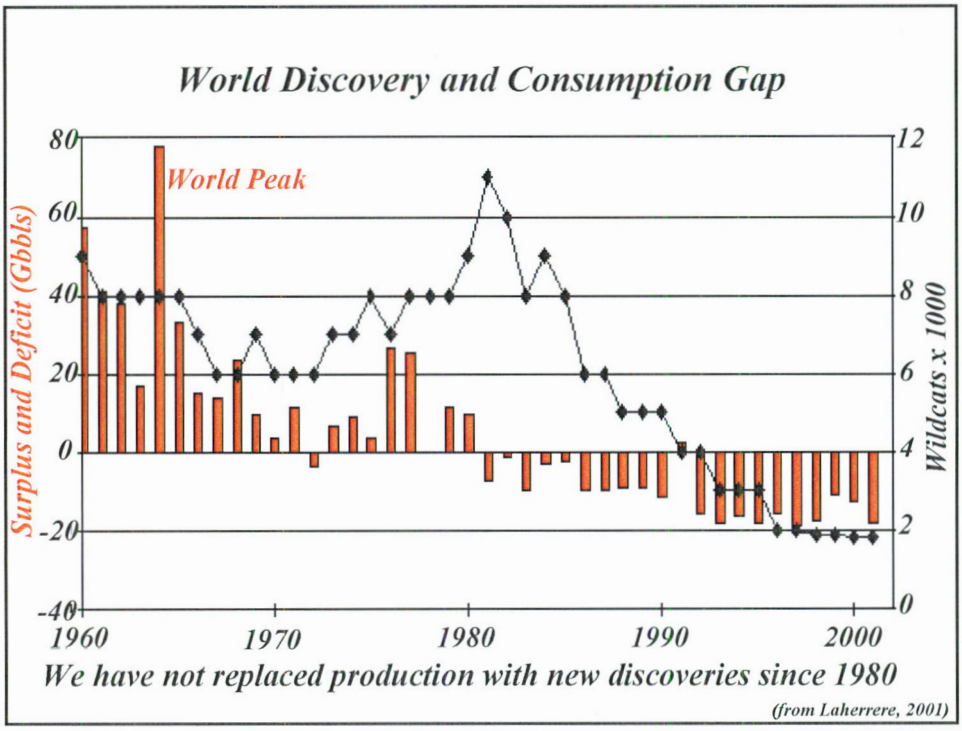

World Oil Production and Consumption: 1965-2002
Production
Consumption
Asia Pacific
Africa
Middle East
Former Soviet Union
S. & C. America
Europe
North America
Million Barrels per Day
789%
254%
150%
78%
54%
753%
38%
143% increase
3.9%/year
uncompounded
558%
376%
361%
-1%
170%
90%
81%
Year
(data from BP Statistical Review of World Energy, 2003)


World Oil Production and Consumption: 1965-2002
Production
Consumption
F.S.U.
OPEC
Non-OPEC
Million Barrels per Day
Year
95%
F.S.U.
OPEC
96%
Non-OPEC
188%
13%
38%
49%
143% increase
3.9%/year
uncompounded
-1%
375%
145%
5%
11%
84%
1965 1971 1977 1983 1989 1995 2001
(data from BP Statistical Review of World Energy, 2003)


World Conventional Oil Reserves: 1980-2002
Billion Barrels
Year
Other OPEC
Kuwait
U.A.E.
Saudi Arabia
Iran
Iraq
F.S.U.
U.S.A.
Other N.A.
Other Non-OPEC
OPEC
Non-OPEC
Percentage Share of Remaining World Oil Reserves
65%
OPEC
78%
10%
F.S.U.
8%
25%
Non-OPEC
14%
1980 1983 1986 1989 1992 1995 1998 2001
(data from BP Statistical Review of World Energy, 2003)


Oil Reserve Reporting in Selected OPEC Countries: 1980-2002
Billion Barrels
800
700
600
500
400
300
200
100
0
1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002
Year
Reserves inflated by 286.5 Gbbls or 69% over two-year period in 1987-1989 without major new discoveries
QUOTA WARS
Venezuela
Kuwait
Iraq
Iran
United Arab Emirates
Saudi Arabia
Implication
Some of the 364 Gbbl or 98% increase in reported reserves over the period may be spurious
(data from BP Statistical Review of World Energy, 2003)


World Reserve to Production Ratio in Years Including Possibly Spurious post-1986 OPEC Reserves
Years of Production at Current Rates
90
80
70
60
50
40
30
20
10
0
1980
1985
1990
1995
2000
2001
2002
OPEC
Non-OPEC
F.S.U.
Total World
(data from BP Statistical Review of World Energy, 2003)



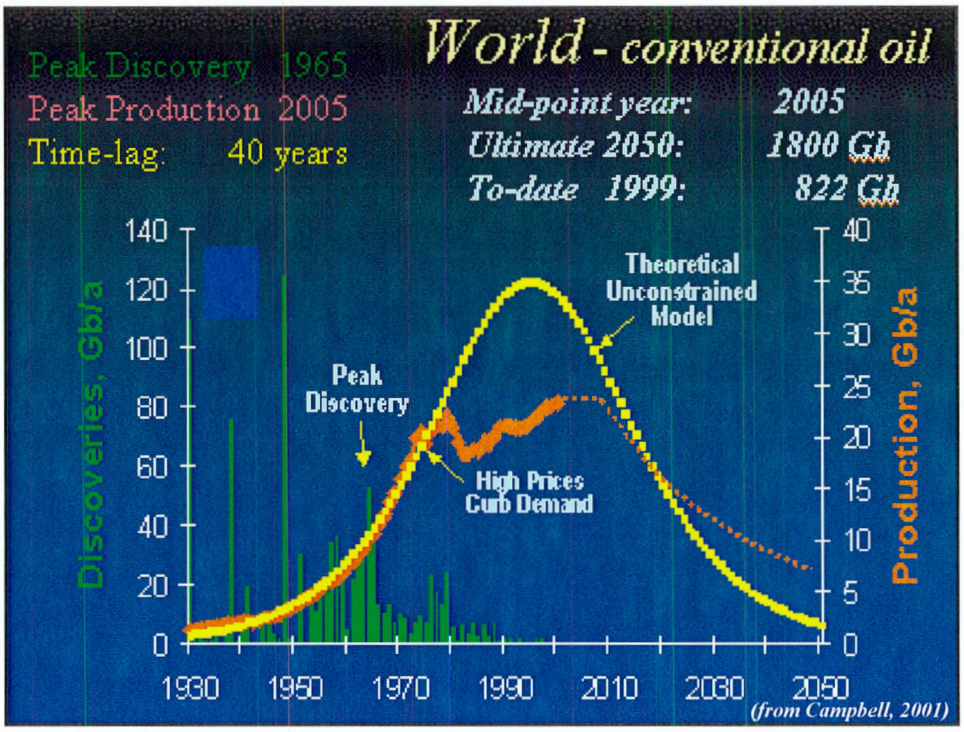
World Oil Production Peak

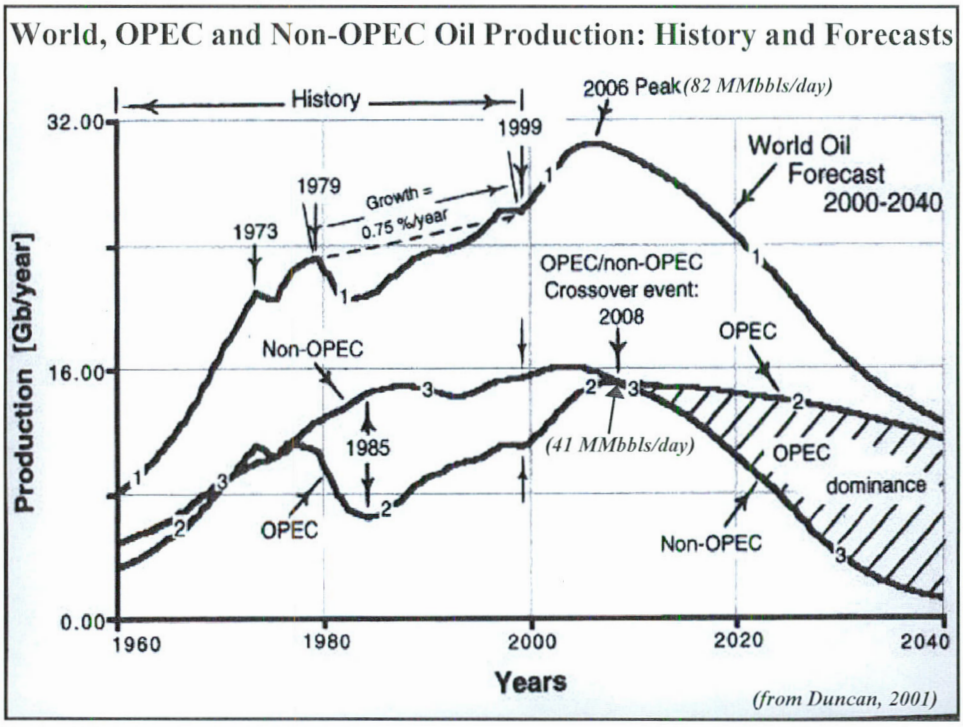
WHEN?

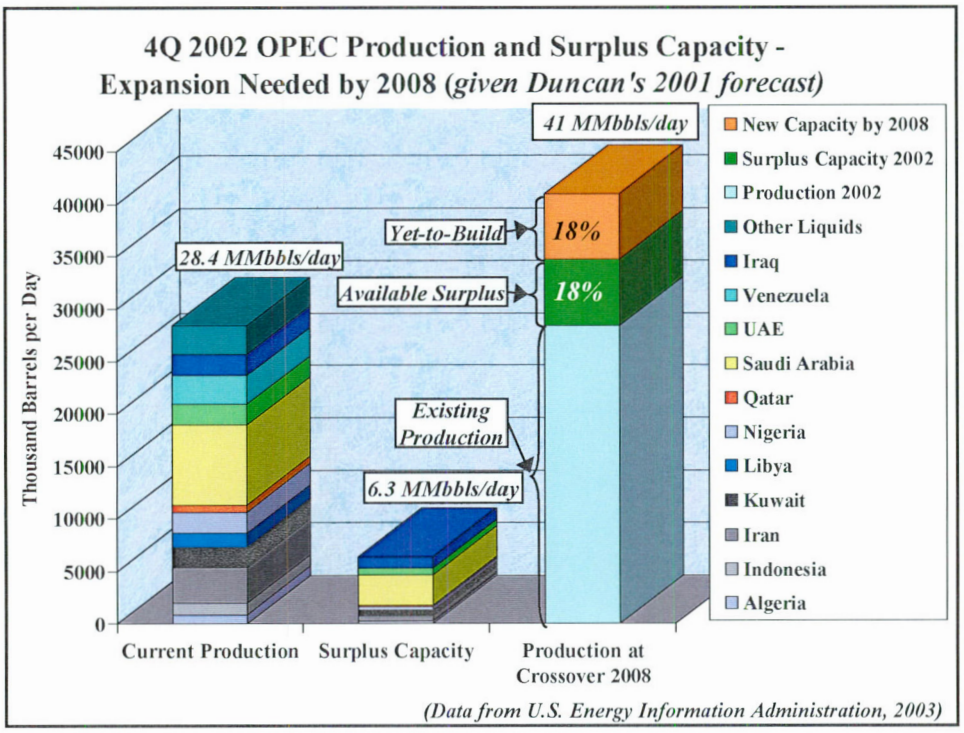
- **Debatable, because of the variables,** ***BUT IT IS HIGHLY LIKELY TO HAPPEN***

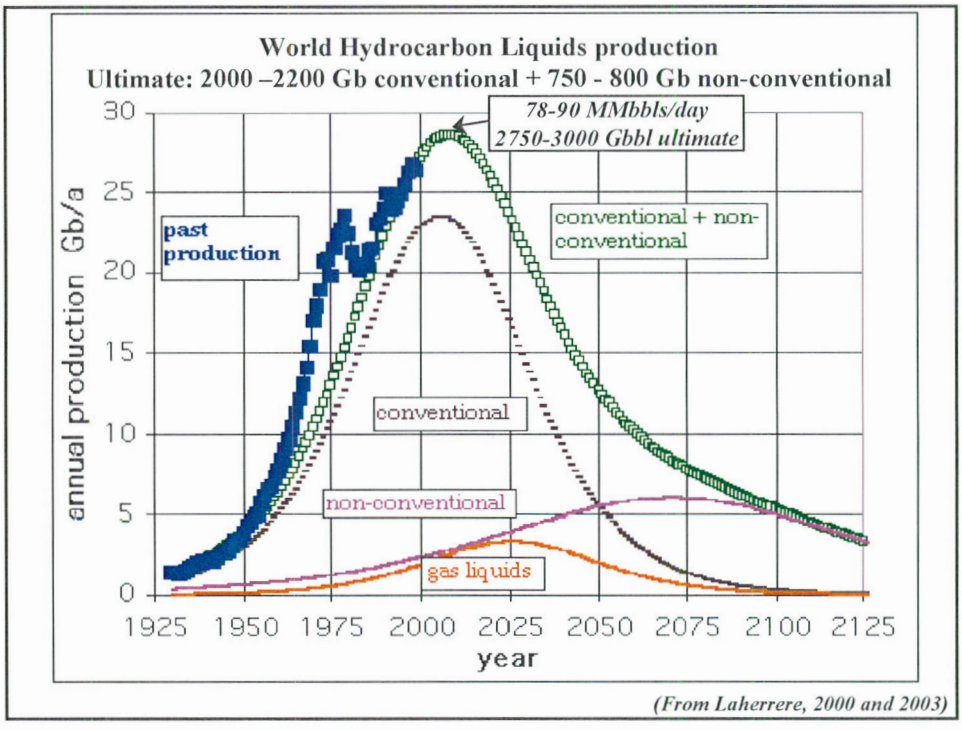
DEPENDS ON:

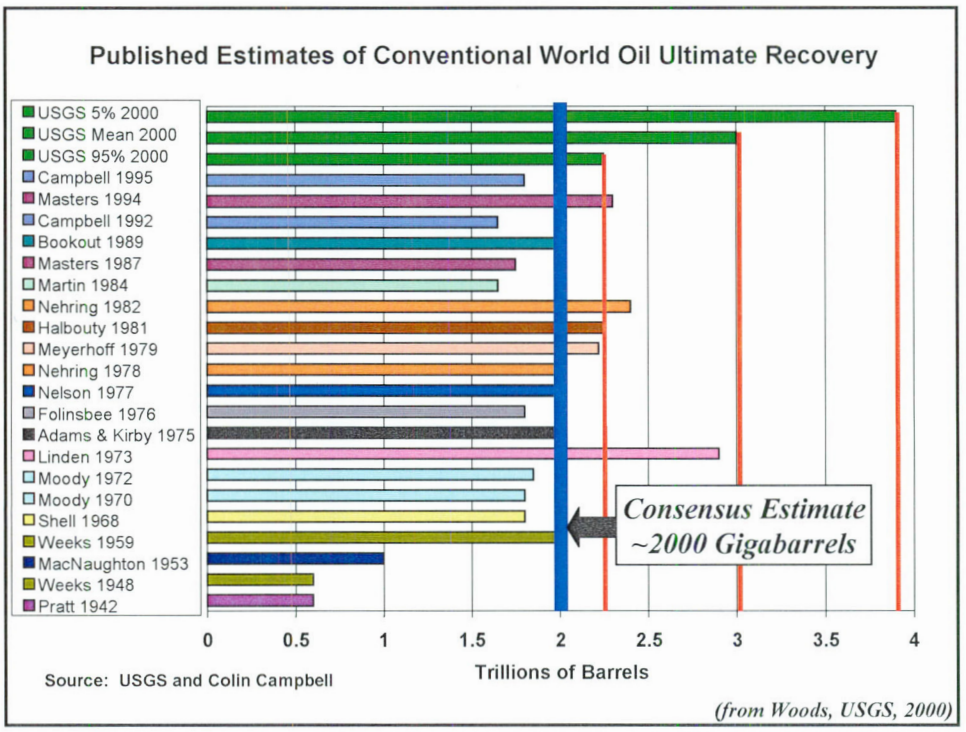
- **ULTIMATE RECOVERABLE RESERVES** - *a function of:*
  - **Mother Nature's Endowment** *(total discovered and undiscovered resources)*
  - **Technology and Price** *(determines economics)*
  - **Reserve Appreciation in known pools** *(through more drilling, better technology and higher prices)*
- **RATE OF CONSUMPTION** - *a function of:*
  - **Price** *(controls economic growth and encourages/discourages conservation)*
  - **Infrastructure** *for production*
  - **Depletion rates** *of producing pools*

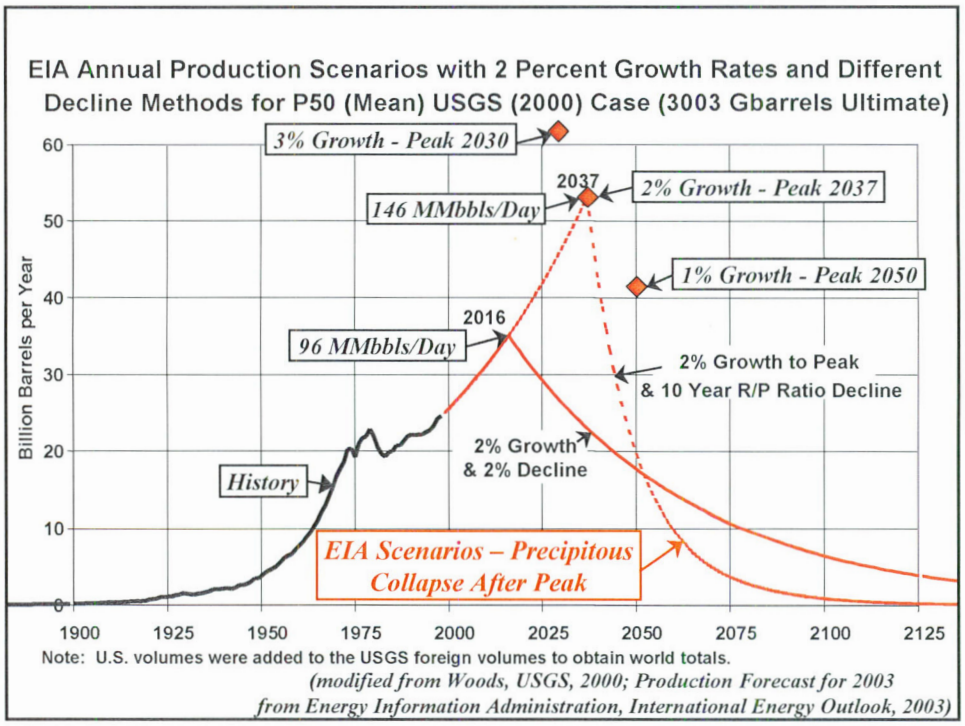

World - conventional oil
Peak Discovery 1965
Peak Production 2005
Time-lag: 40 years
Mid-point year: 2005
Ultimate 2050: 1800 Gb
To-date 1999: 822 Gb
Discoveries, Gb/a
Production, Gb/a
Theoretical Unconstrained Model
Peak Discovery
High Prices Curb Demand
140
120
100
80
60
40
20
0
40
35
30
25
20
15
10
5
0
1930
1950
1970
1990
2010
2030
2050
(from Campbell, 2001)

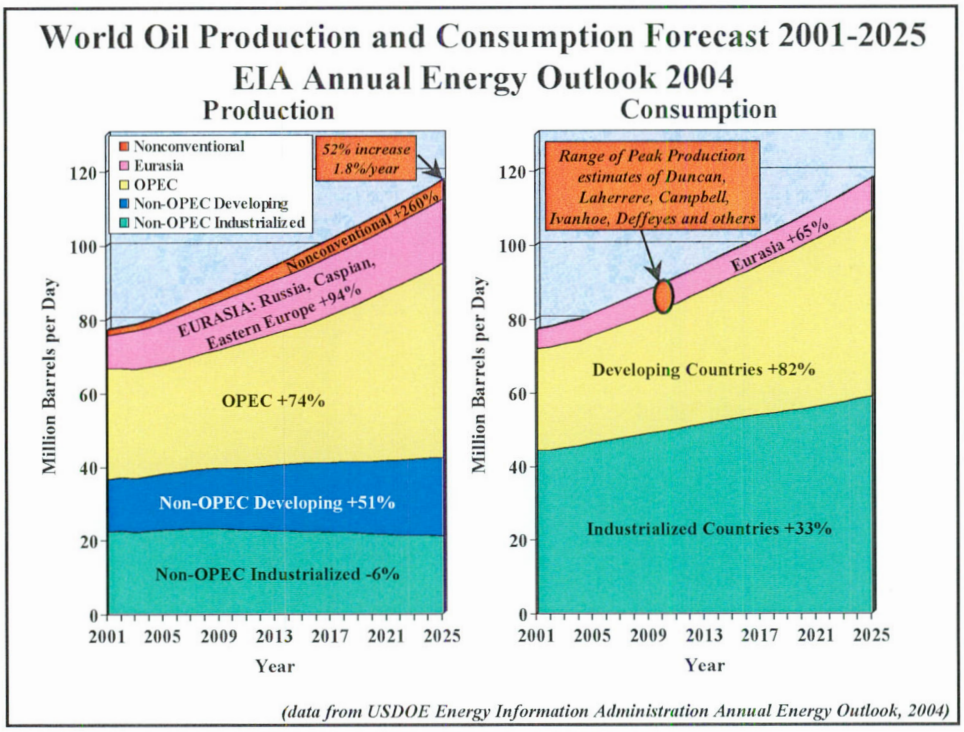

World, OPEC and Non-OPEC Oil Production: History and Forecasts
History
2006 Peak (82 MMbbls/day)
1999
World Oil Forecast 2000-2040
1979
Growth = 0.75 %/year
1973
OPEC/non-OPEC Crossover event:
2008
Non-OPEC
OPEC
1985
(41 MMbbls/day)
OPEC dominance
Non-OPEC
Production [Gb/year]
32.00
16.00
0.00
1960
1980
2000
2020
2040
Years
(from Duncan, 2001)

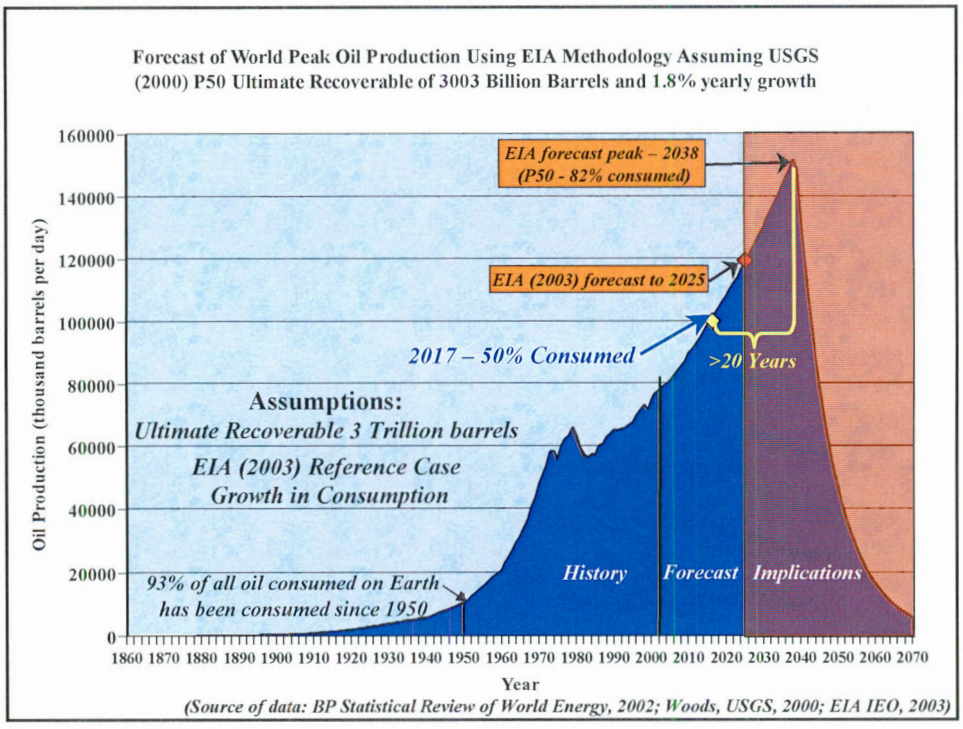

4Q 2002 OPEC Production and Surplus Capacity -
Expansion Needed by 2008 (given Duncan's 2001 forecast)
Thousand Barrels per Day
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
41 MMbbls/day
28.4 MMbbls/day
Yet-to-Build
18%
Available Surplus
18%
Existing Production
6.3 MMbbls/day
Current Production
Surplus Capacity
Production at Crossover 2008
New Capacity by 2008
Surplus Capacity 2002
Production 2002
Other Liquids
Iraq
Venezuela
UAE
Saudi Arabia
Qatar
Nigeria
Libya
Kuwait
Iran
Indonesia
Algeria
(Data from U.S. Energy Information Administration, 2003)


World Hydrocarbon Liquids production
Ultimate: 2000 –2200 Gb conventional + 750 - 800 Gb non-conventional
annual production Gb/a
30
25
20
15
10
5
0
78-90 MMbbls/day
2750-3000 Gbbl ultimate
past production
conventional + non-conventional
conventional
non-conventional
gas liquids
1925
1950
1975
2000
2025
2050
2075
2100
2125
year
(From Laherrere, 2000 and 2003)

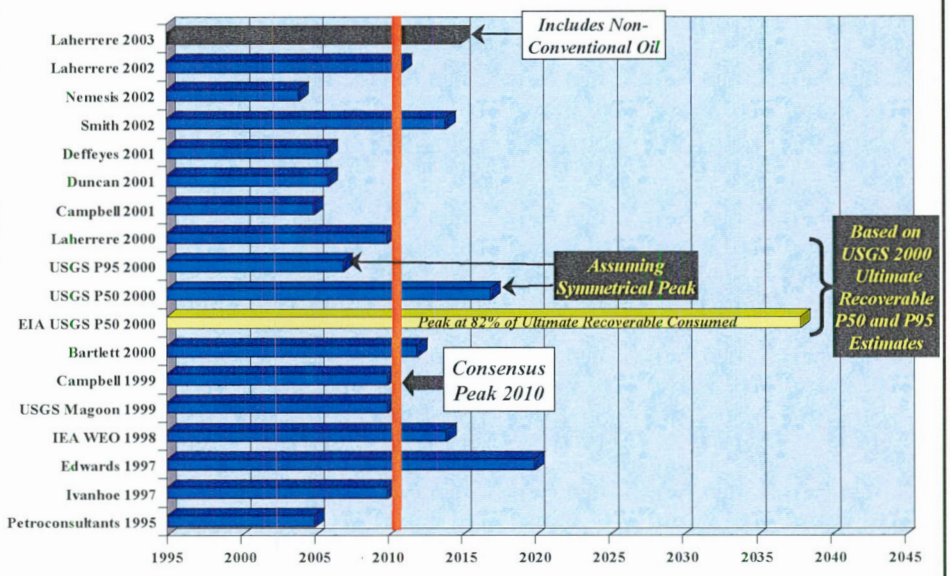

Published Estimates of Conventional World Oil Ultimate Recovery
USGS 5% 2000
USGS Mean 2000
USGS 95% 2000
Campbell 1995
Masters 1994
Campbell 1992
Bookout 1989
Masters 1987
Martin 1984
Nehring 1982
Halbouty 1981
Meyerhoff 1979
Nehring 1978
Nelson 1977
Folinsbee 1976
Adams & Kirby 1975
Linden 1973
Moody 1972
Moody 1970
Shell 1968
Weeks 1959
MacNaughton 1953
Weeks 1948
Pratt 1942
Consensus Estimate
~2000 Gigabarrels
0
0.5
1
1.5
2
2.5
3
3.5
4
Trillions of Barrels
Source: USGS and Colin Campbell
(from Woods, USGS, 2000)


EIA Annual Production Scenarios with 2 Percent Growth Rates and Different Decline Methods for P50 (Mean) USGS (2000) Case (3003 Gbarrels Ultimate)
3% Growth - Peak 2030
2037
2% Growth - Peak 2037
146 MMbbls/Day
1% Growth - Peak 2050
2016
96 MMbbls/Day
2% Growth to Peak
& 10 Year R/P Ratio Decline
2% Growth
& 2% Decline
History
EIA Scenarios – Precipitous Collapse After Peak
Billion Barrels per Year
60
50
40
30
20
10
0
1900
1925
1950
1975
2000
2025
2050
2075
2100
2125
Note: U.S. volumes were added to the USGS foreign volumes to obtain world totals.
(modified from Woods, USGS, 2000; Production Forecast for 2003
from Energy Information Administration, International Energy Outlook, 2003)


World Oil Production and Consumption Forecast 2001-2025
EIA Annual Energy Outlook 2004
Production
Consumption
Nonconventional
Eurasia
OPEC
Non-OPEC Developing
Non-OPEC Industrialized
52% increase
1.8%/year
Nonconventional +260%
EURASIA: Russia, Caspian, Eastern Europe +94%
OPEC +74%
Non-OPEC Developing +51%
Non-OPEC Industrialized -6%
Million Barrels per Day
Year
Range of Peak Production estimates of Duncan, Laherrere, Campbell, Ivanhoe, Deffeyes and others
Eurasia +65%
Developing Countries +82%
Industrialized Countries +33%
(data from USDOE Energy Information Administration Annual Energy Outlook, 2004)

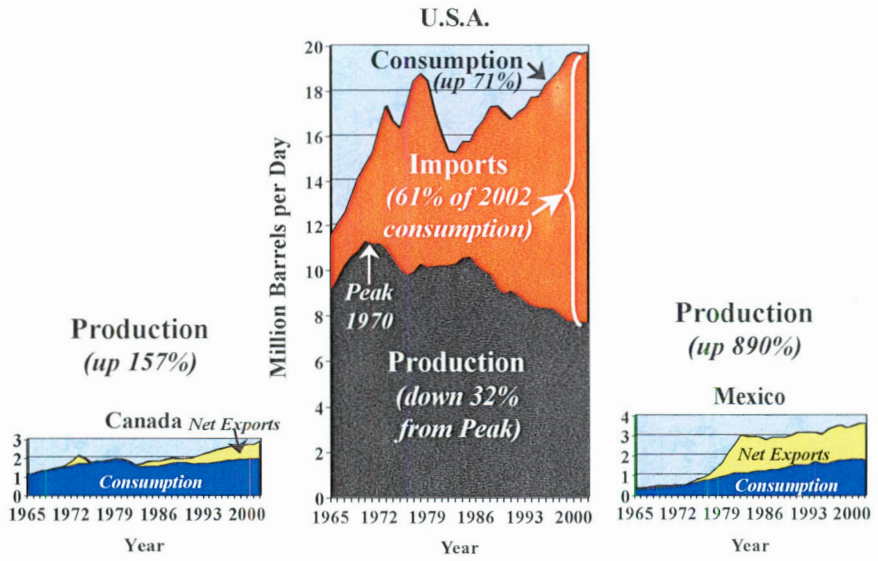

Forecast of World Peak Oil Production Using EIA Methodology Assuming USGS (2000) P50 Ultimate Recoverable of 3003 Billion Barrels and 1.8% yearly growth
Oil Production (thousand barrels per day)
Year
EIA forecast peak – 2038 (P50 - 82% consumed)
EIA (2003) forecast to 2025
2017 – 50% Consumed
>20 Years
Assumptions:
Ultimate Recoverable 3 Trillion barrels
EIA (2003) Reference Case Growth in Consumption
93% of all oil consumed on Earth has been consumed since 1950
History
Forecast
Implications
(Source of data: BP Statistical Review of World Energy, 2002; Woods, USGS, 2000; EIA IEO, 2003)

Post 1995 Estimates of the Time of Peak World Oil Production

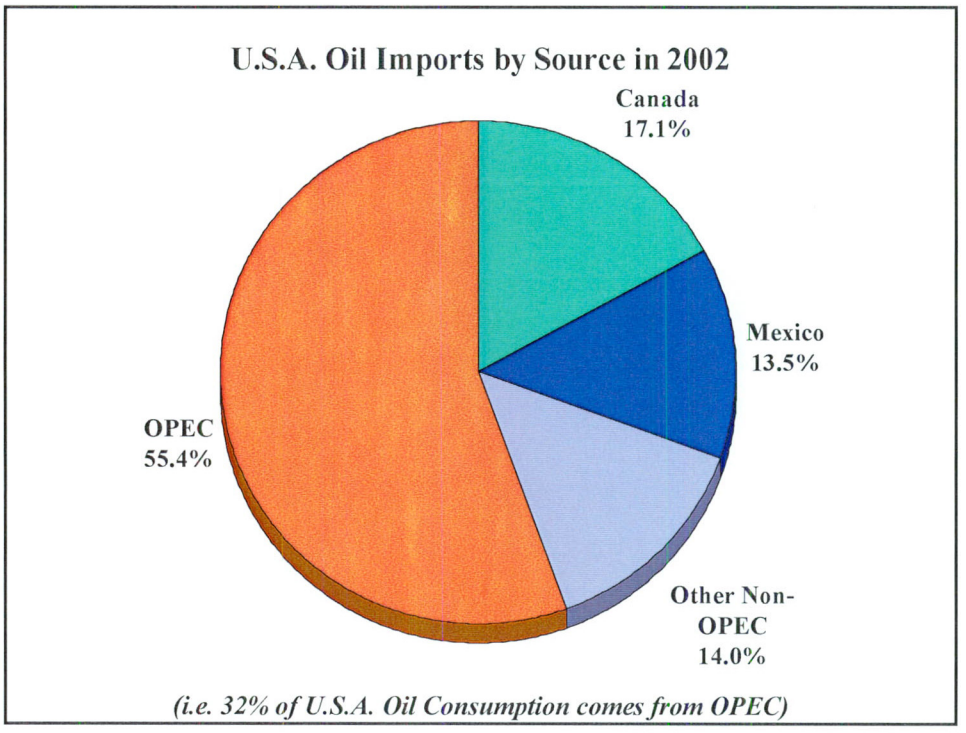


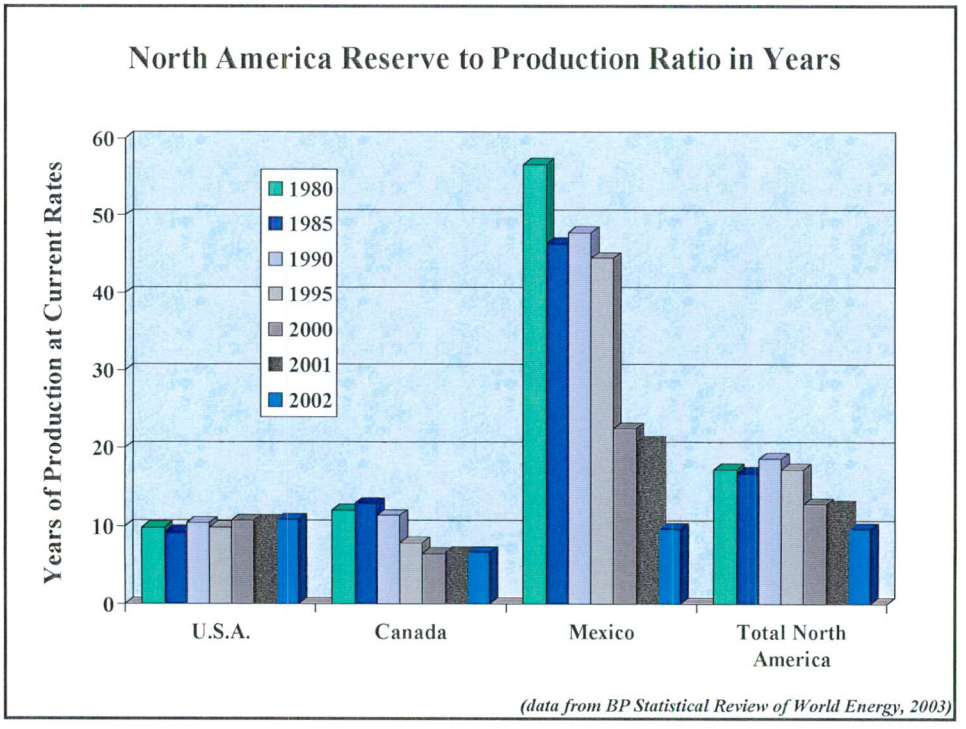
(Source Bentley, 2002; Woods, USGS, 2000; EIA IEO, 2003 and others)

North American Oil Consumption and Movements: 1965-2002

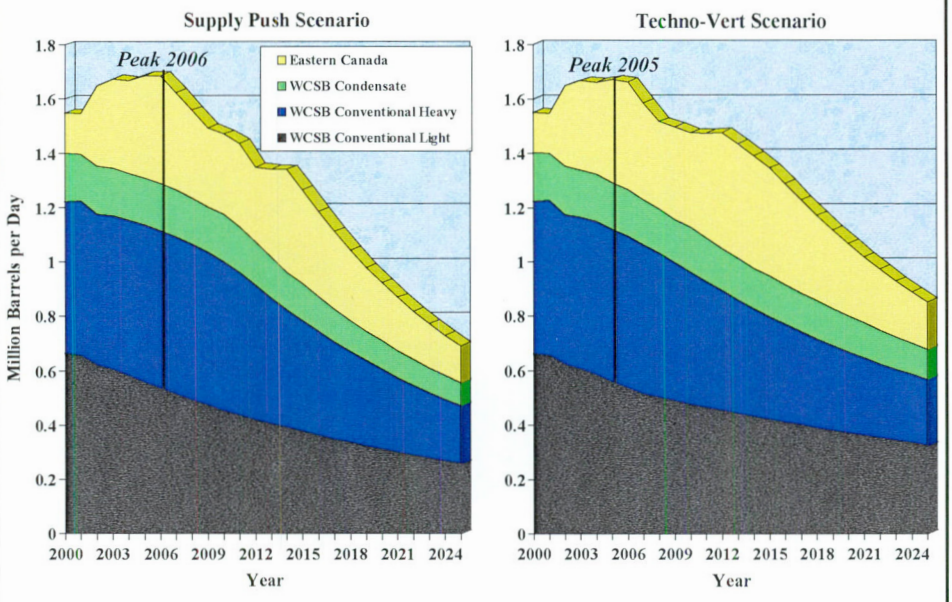


(data from BP Statistical Review of World Energy, 2003)


U.S.A. Oil Imports by Source in 2002
Canada
17.1%
Mexico
13.5%
OPEC
55.4%
Other Non-
OPEC
14.0%
(i.e. 32% of U.S.A. Oil Consumption comes from OPEC)


North America Reserve to Production Ratio in Years
Years of Production at Current Rates
60
50
40
30
20
10
0
1980
1985
1990
1995
2000
2001
2002
U.S.A.
Canada
Mexico
Total North
America
(data from BP Statistical Review of World Energy, 2003)

Canada Scenarios of Oil Production Excluding Oil Sands (NEB, 2003)



(data from National Energy Board, July, 2003)

Yes, But We've Got the OIL SANDS – More Oil than Saudi Arabia!

- **The Oil Sands cannot significantly offset declines in world production because of the lead times and capital investment required.** Massive expansions in the Oil Sands and Venezuelan Orinoco extra-heavy oil belt could increase combined production from 1.2 million barrels per day at present to as much as six million barrels per day by 2025, which is only 5% of EIA forecast World Demand in 2025.

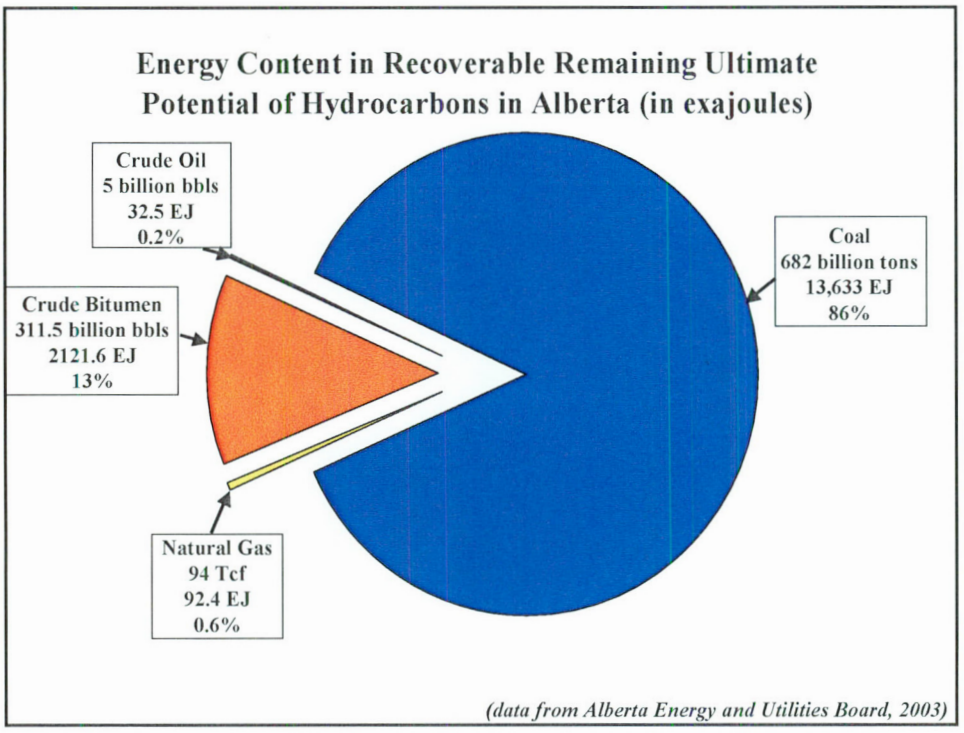
- **Oil from the oil sands is very energy intensive** – Forecast four- to five-fold growth to 2025 will require between 1.6 and 2.3 bcf/day of natural gas, which is approximately equivalent to the planned maximum capacity of the MacKenzie Valley pipeline of 1.9 bcf/day, or about one-fifth of forecast Canadian domestic consumption.

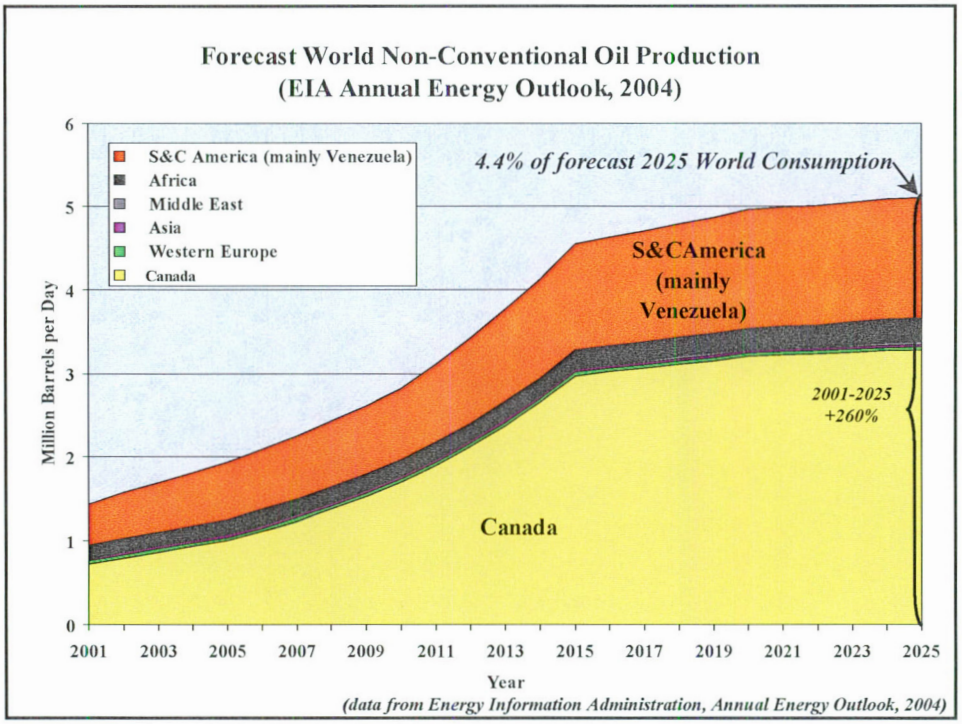
- **Expansion of capacity is limited by natural gas supply and natural gas price,** which could destroy economics if there are shortfalls in supply, **barring widespread application of non-thermal processes, or switching to alternative fuels.**

- **Expansion of capacity is limited by water supply** (need 2.5 - 3 barrels of water for every barrel of oil[1]), let alone future expansion **unless technologies to reduce water consumption and/or recycle water can be employed.**

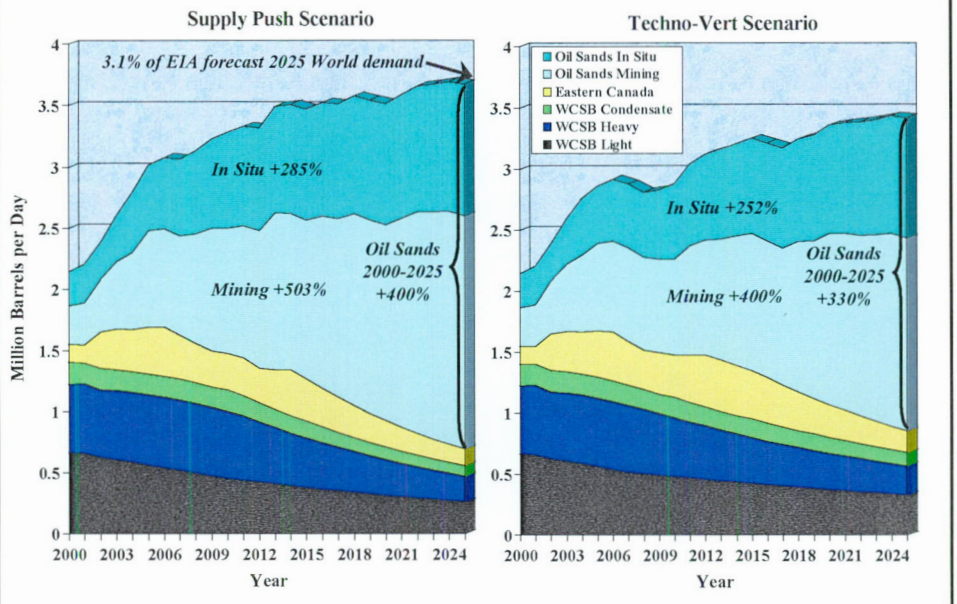
- **Expansion of refining capacity may also be limited by projected shortfalls of condensate/light crude diluent for blending** which are forecast to occur in the 2004-2006 timeframe (National Energy Board, 2003), requiring higher-cost alternatives.

([1]personal communication, Alberta Geological Survey, 2002)


Energy Content in Recoverable Remaining Ultimate Potential of Hydrocarbons in Alberta (in exajoules)
Crude Oil
5 billion bbls
32.5 EJ
0.2%
Crude Bitumen
311.5 billion bbls
2121.6 EJ
13%
Natural Gas
94 Tcf
92.4 EJ
0.6%
Coal
682 billion tons
13,633 EJ
86%
(data from Alberta Energy and Utilities Board, 2003)

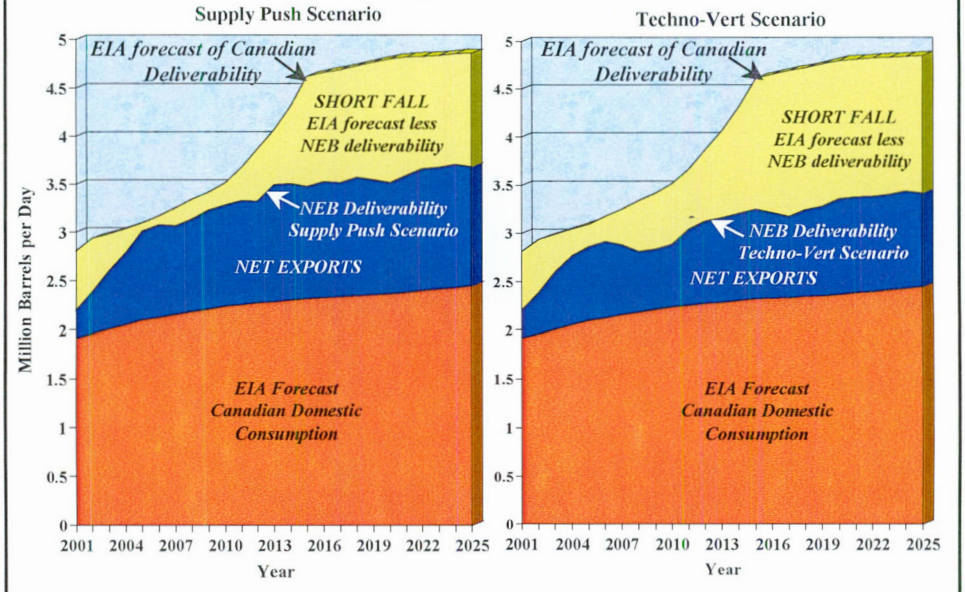

Forecast World Non-Conventional Oil Production
(EIA Annual Energy Outlook, 2004)
S&C America (mainly Venezuela)
Africa
Middle East
Asia
Western Europe
Canada
4.4% of forecast 2025 World Consumption
S&CAmerica (mainly Venezuela)
2001-2025 +260%
Canada
Million Barrels per Day
0
1
2
3
4
5
6
2001
2003
2005
2007
2009
2011
2013
2015
2017
2019
2021
2023
2025
Year
(data from Energy Information Administration, Annual Energy Outlook, 2004)

Canada Scenarios of Oil Production Including Oil Sands (NEB, 2003)



(data from National Energy Board, July, 2003)

Shortfalls in Oil Exports from Canada given EIA (2004) production Estimates and NEB (2003) Deliverability Scenarios



(data from Energy Information Administration Annual Energy Outlook, 2004, and National Energy Board, July, 2003)

GAS

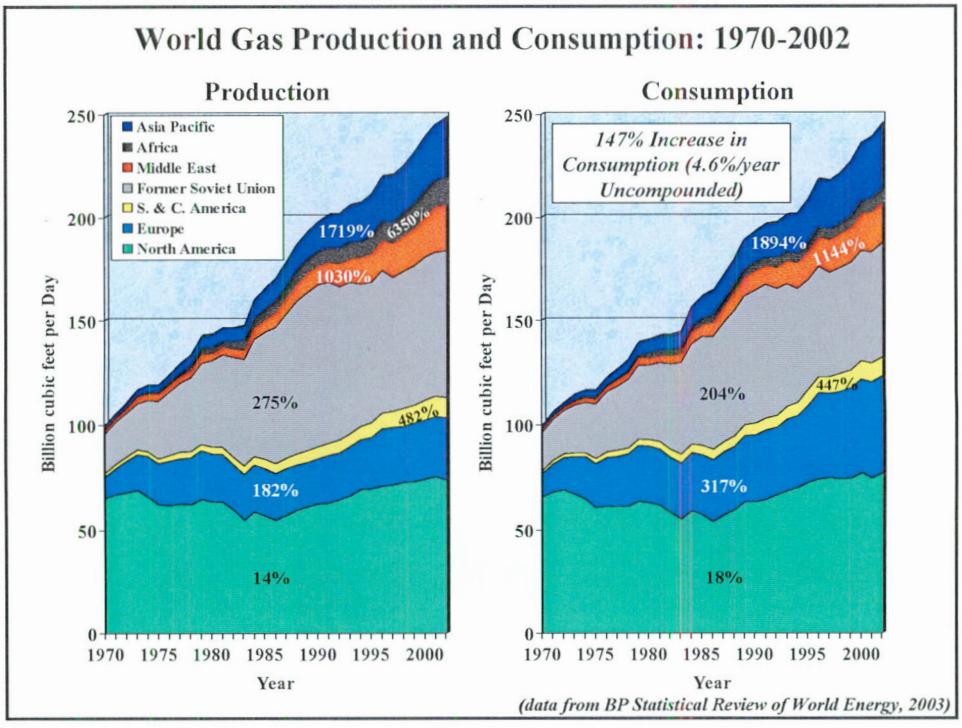
- **The third largest source of energy in the world** *after oil and coal (24.3% of primary energy consumption in 2002)*

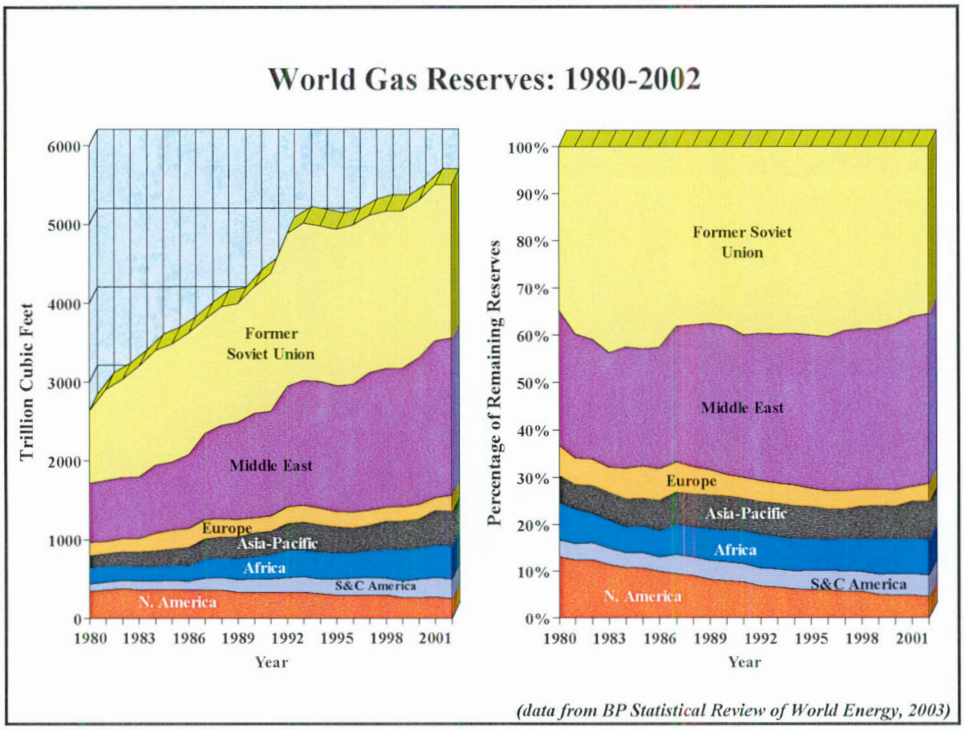
- **Largely landlocked when it comes to international trade,** *unlike oil and coal – less than 6% of 2002 consumption was moved by Liquefied Natural Gas (LNG)*

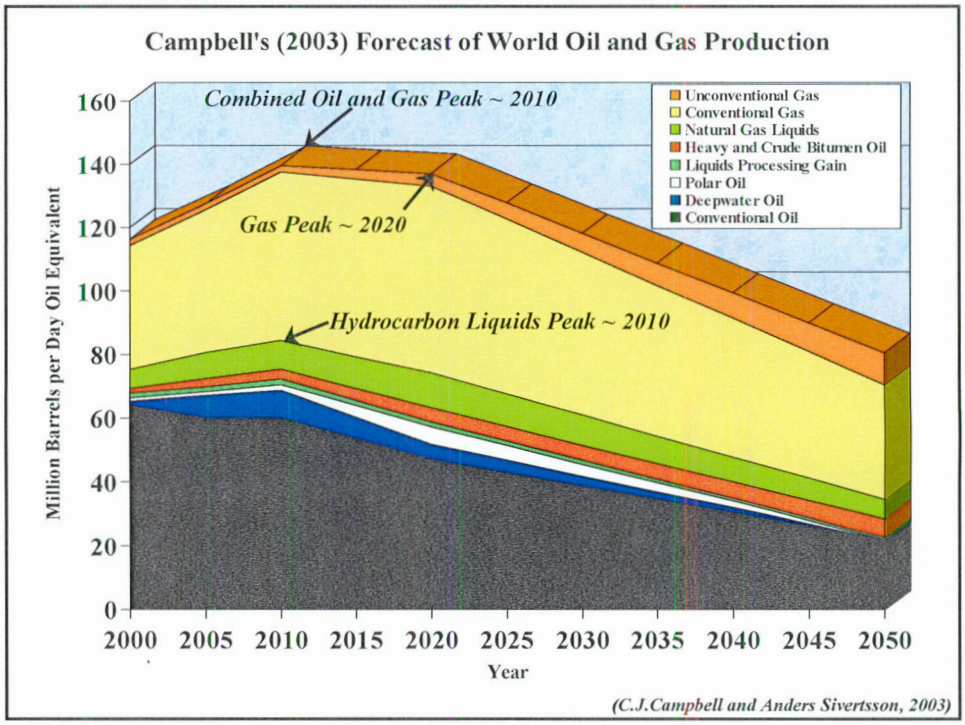
- **Natural Gas is difficult to store by comparison to Oil and Coal** *(approximately 3.2 Tcf of "working" storage in North America or 50 days of U.S. Supply) - North America is a Continental gas market- about 1% of North American (ie. U.S.A.) consumption was moved as LNG in 2002*

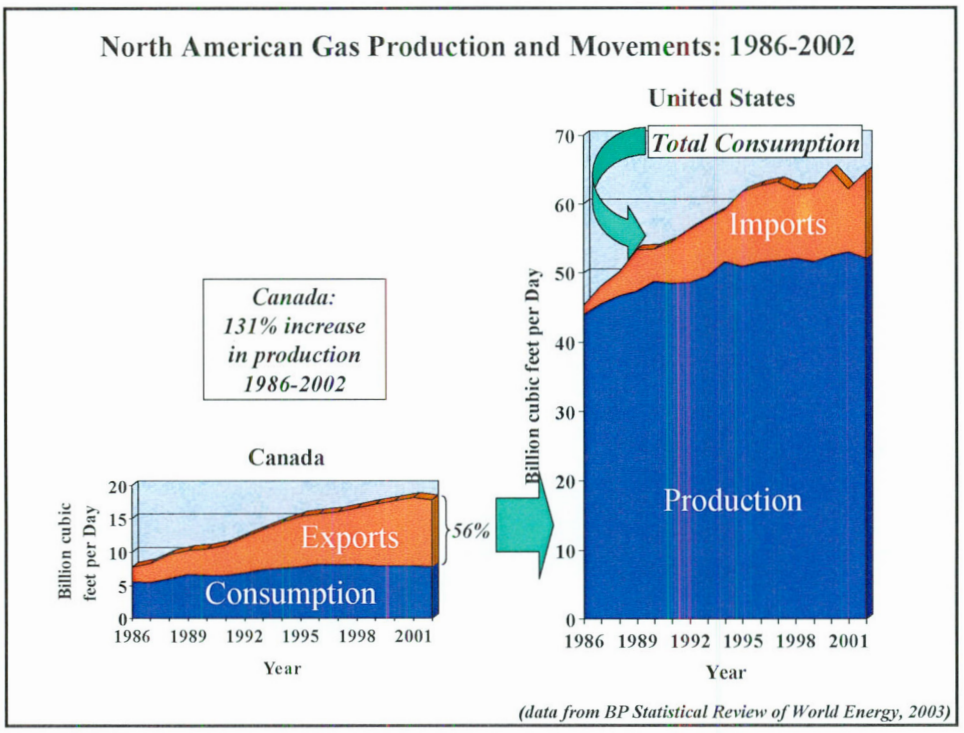
- **LNG entails an energy loss of between 15 and 25% for liquefaction, transportation and regasification,** *with associated greenhouse gas emissions – especially significant is the phenomenon of "boil-off", which releases methane, a greenhouse gas more than 20 times as potent as CO_2, from the LNG ships which contain LNG at –165 degrees Celsius*

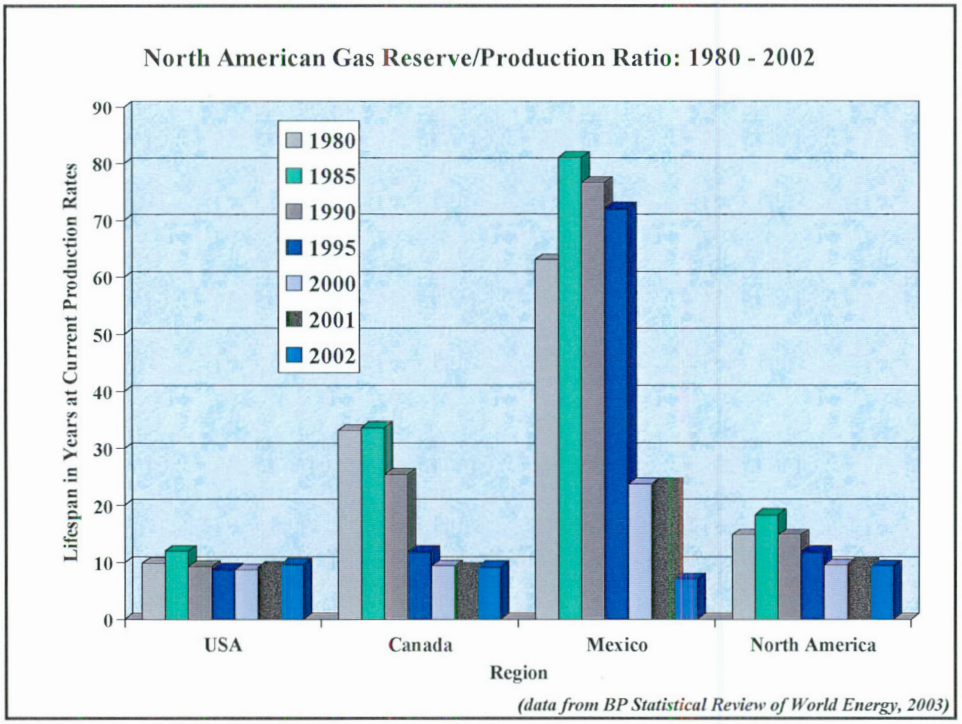
- **LNG is subject to Geopolitics** *as three-quarters of remaining natural gas reserves are located in the Former Soviet Union and the Middle East*

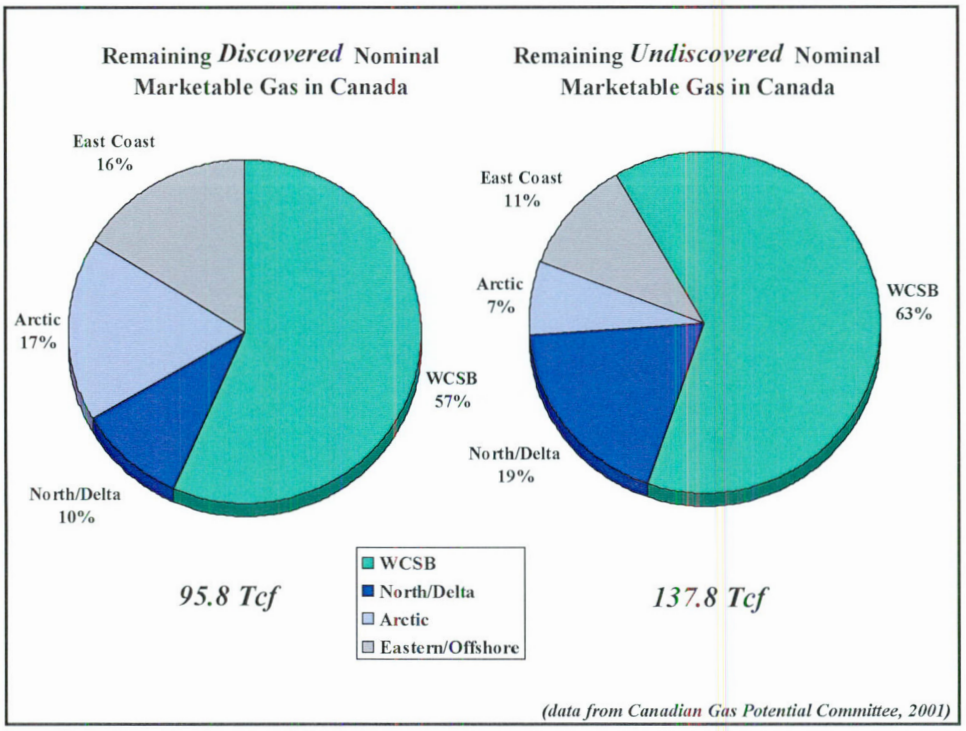


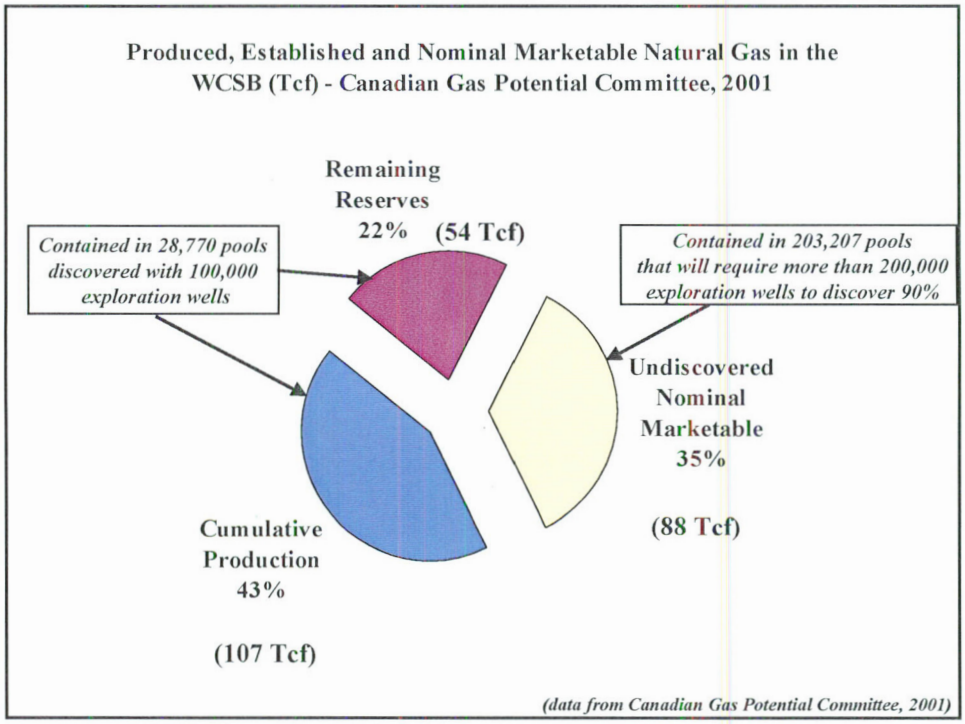

World Gas Reserves: 1980-2002
Trillion Cubic Feet
6000
5000
4000
3000
2000
1000
0
Former
Soviet Union
Middle East
Europe
Asia-Pacific
Africa
S&C America
N. America
1980 1983 1986 1989 1992 1995 1998 2001
Year
Percentage of Remaining Reserves
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Former Soviet
Union
Middle East
Europe
Asia-Pacific
Africa
S&C America
N. America
1980 1983 1986 1989 1992 1995 1998 2001
Year
(data from BP Statistical Review of World Energy, 2003)


Campbell's (2003) Forecast of World Oil and Gas Production
Million Barrels per Day Oil Equivalent
160
140
120
100
80
60
40
20
0
Combined Oil and Gas Peak ~ 2010
Gas Peak ~ 2020
Hydrocarbon Liquids Peak ~ 2010
Unconventional Gas
Conventional Gas
Natural Gas Liquids
Heavy and Crude Bitumen Oil
Liquids Processing Gain
Polar Oil
Deepwater Oil
Conventional Oil
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Year
(C.J.Campbell and Anders Sivertsson, 2003)

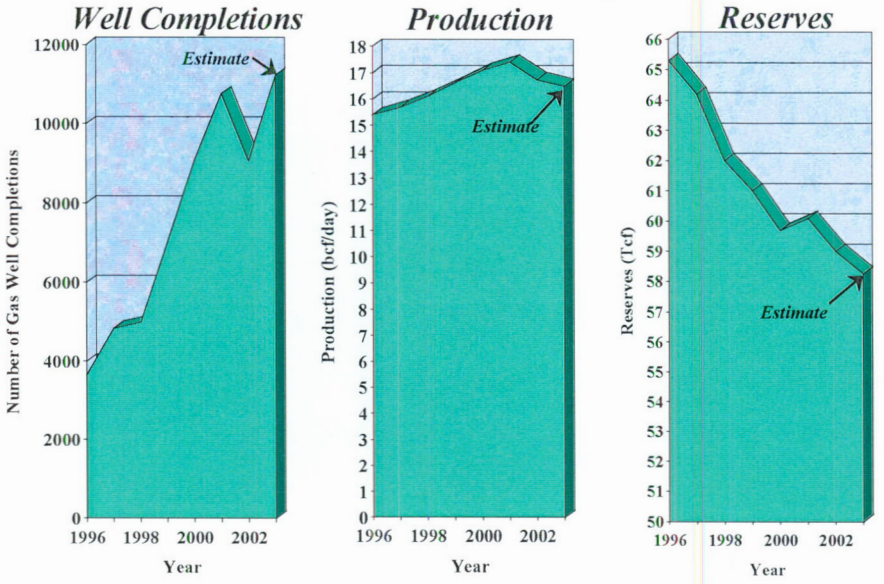

North American Gas Production and Movements: 1986-2002
United States
Total Consumption
Imports
Production
Billion cubic feet per Day
70
60
50
40
30
20
10
0
1986 1989 1992 1995 1998 2001
Year
Canada: 131% increase in production 1986-2002
Canada
Billion cubic feet per Day
20
15
10
5
0
Exports
Consumption
56%
1986 1989 1992 1995 1998 2001
Year
(data from BP Statistical Review of World Energy, 2003)


North American Gas Reserve/Production Ratio: 1980 - 2002
Lifespan in Years at Current Production Rates
90
80
70
60
50
40
30
20
10
0
1980
1985
1990
1995
2000
2001
2002
USA
Canada
Mexico
North America
Region
(data from BP Statistical Review of World Energy, 2003)


Remaining *Discovered* Nominal Marketable Gas in Canada
East Coast 16%
Arctic 17%
WCSB 57%
North/Delta 10%
95.8 Tcf
Remaining *Undiscovered* Nominal Marketable Gas in Canada
East Coast 11%
Arctic 7%
WCSB 63%
North/Delta 19%
137.8 Tcf
WCSB
North/Delta
Arctic
Eastern/Offshore
(data from Canadian Gas Potential Committee, 2001)

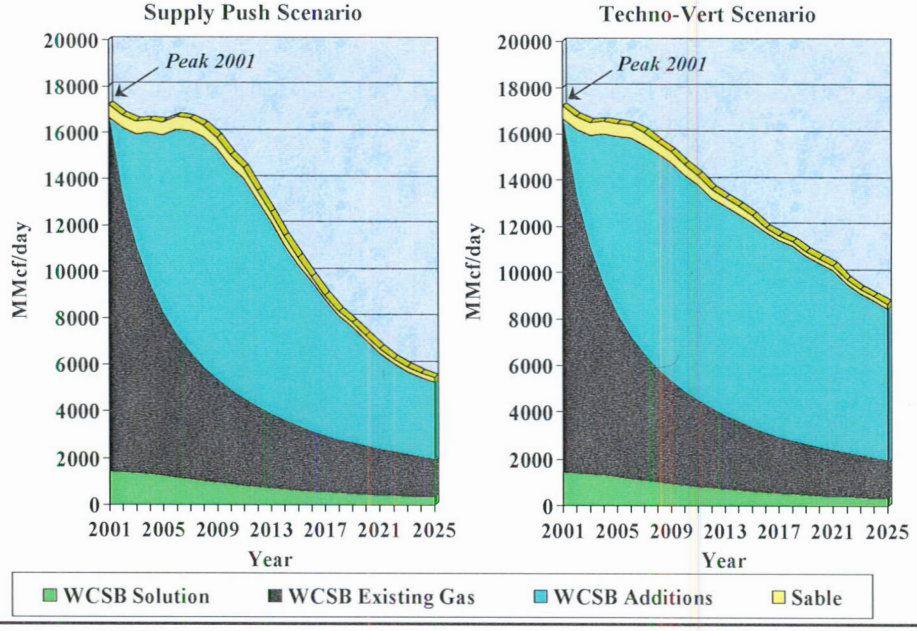

Produced, Established and Nominal Marketable Natural Gas in the WCSB (Tcf) - Canadian Gas Potential Committee, 2001
Remaining Reserves 22% (54 Tcf)
Contained in 28,770 pools discovered with 100,000 exploration wells
Contained in 203,207 pools that will require more than 200,000 exploration wells to discover 90%
Undiscovered Nominal Marketable 35%
(88 Tcf)
Cumulative Production 43%
(107 Tcf)
(data from Canadian Gas Potential Committee, 2001)

Canada's Exploration Treadmill – more and more drilling to find less and less gas



Canadian Association of Petroleum Producers 2003 (1996-2002 well completions; 1996-2001 production; 1996-2002 reserves); National Energy Board, July, 2003 (2002 production, 2003 estimate); Petroleum Services Association of Canada, 2003 (2003 drilling)

NEB, July, 2003, Deliverability Scenarios from Existing Gas Sources

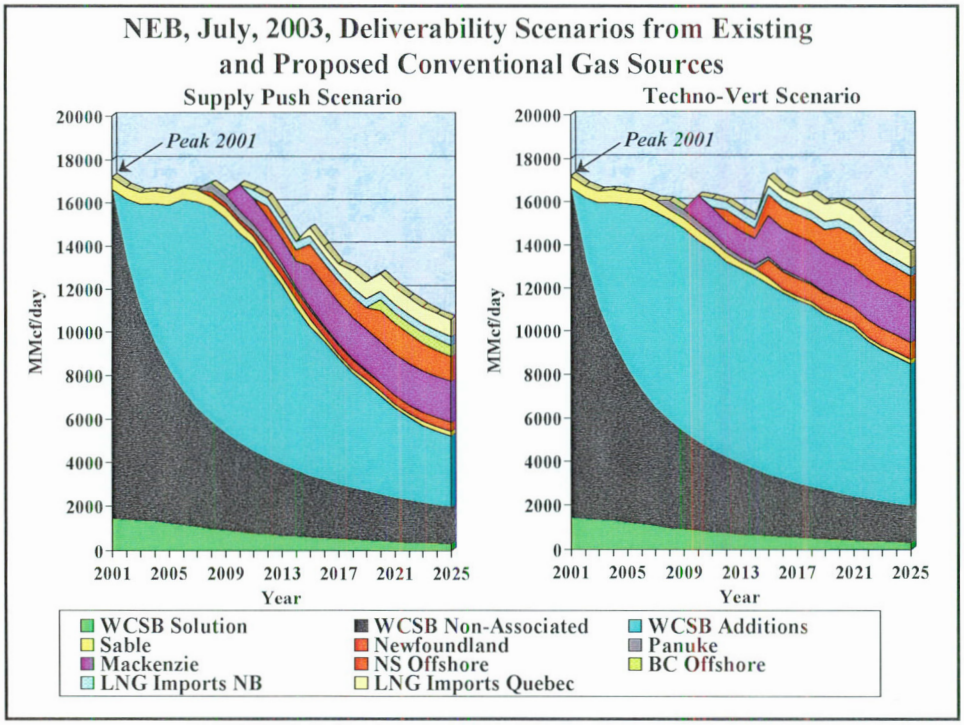


Productivity Assumptions of NEB Scenarios for the Western Canada Sedimentary Basin

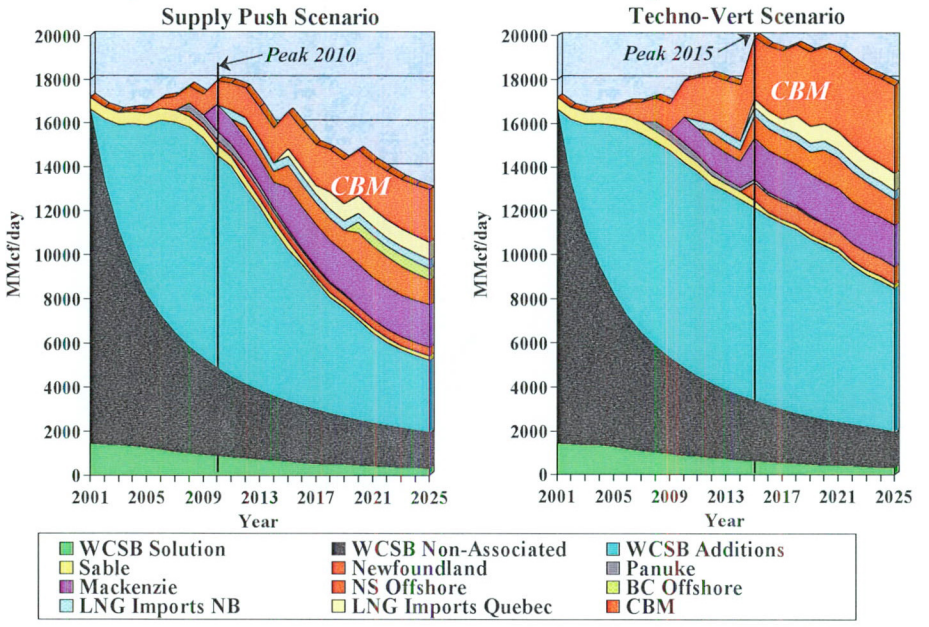
- **WCSB drilling rates will be sustained at the record levels of 2001** until 75% of the ultimate recoverable resource has been produced.
- **Initial productivity of new wells will remain at current levels** Initial productivity has declined from an average 700 mcf/day in 1997 to 350 mcf/day in 2003 – this trend may continue in the future.
- **Decline rates in new wells will remain at current levels**
  First year decline rates have increased from <20% in 1990 to nearly 35% in 2000 - this trend may continue in the future.

The overall decline rate of the WCSB has increased from 13% in 1992 to 23% in 2002 – this means 3.2 Bcf/day of production must be replaced each year to keep production flat, which hasn't happened since 2001. NEB (December, 2003) expects production to decline by 3% through 2005.

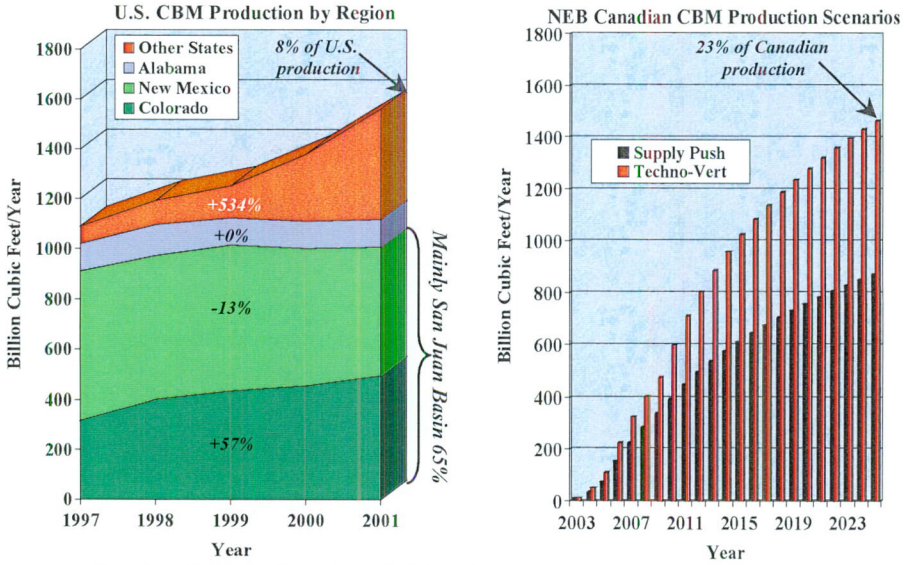
(assumptions included in National Energy Board Report of July, 2003, and data provided in December, 2003, National Energy Board Report)



NEB, July, 2003, Deliverability Scenarios from Existing and Proposed Conventional Gas Sources Including Coalbed Methane

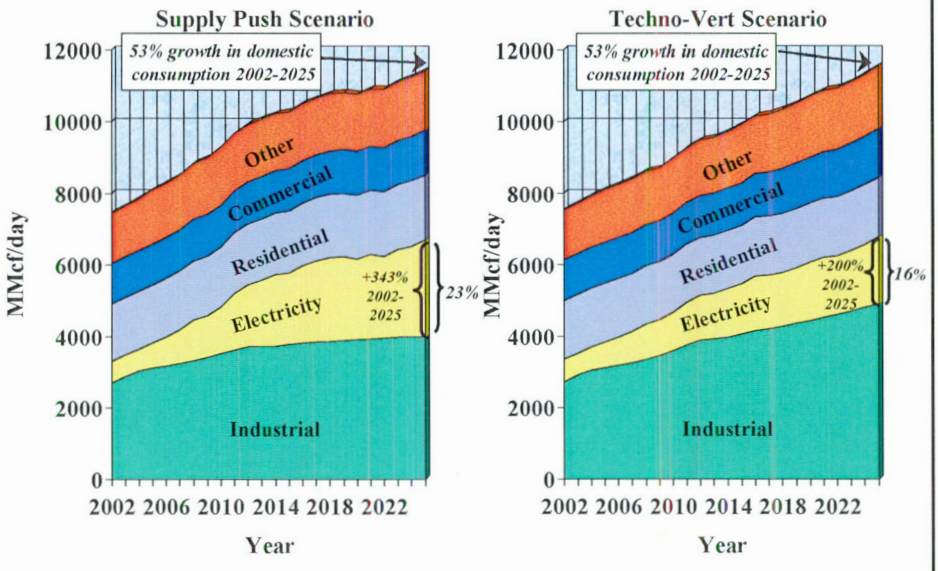


Actual Coalbed Methane Production in the U.S. 1997-2001 Compared to NEB Coalbed Methane Production Scenarios 2003-2025



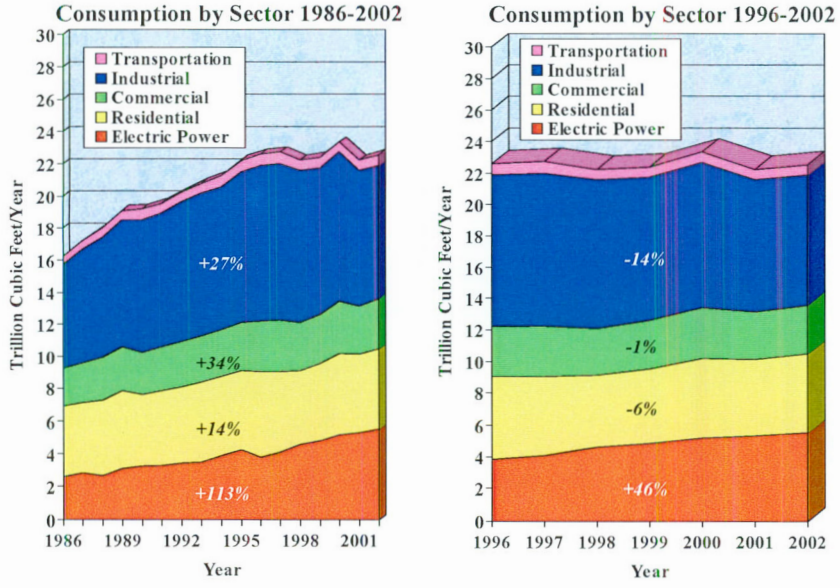
(data from Energy Information Administration, 2004, and National Energy Board, July, 2003)

NEB, 2003, Canadian Domestic Natural Gas Demand Scenarios by Sector, 2002-2025

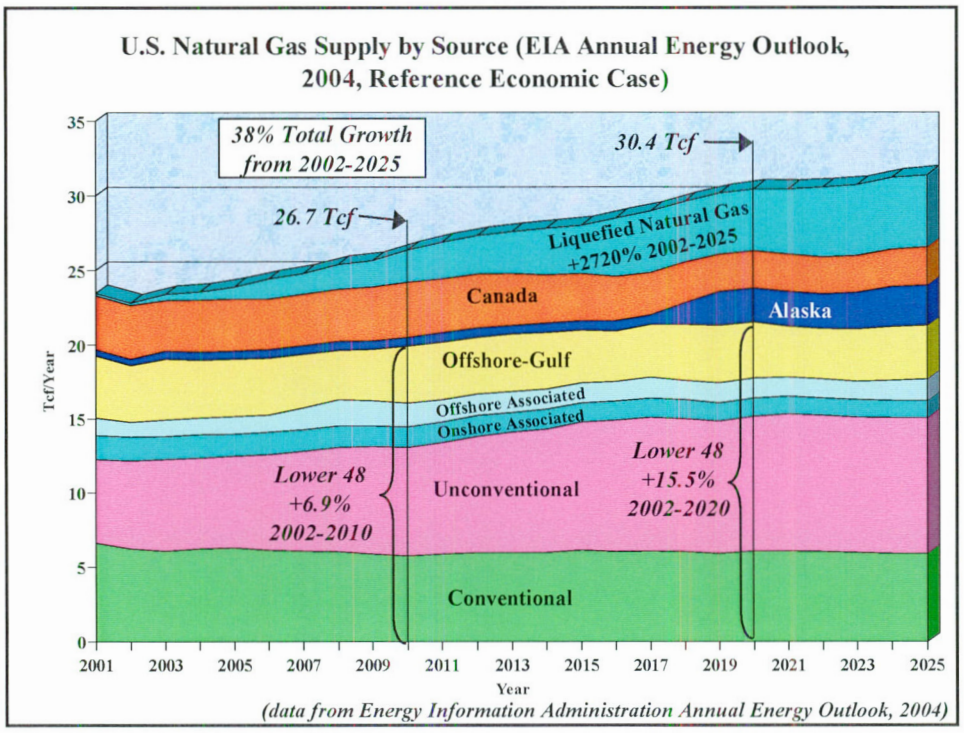


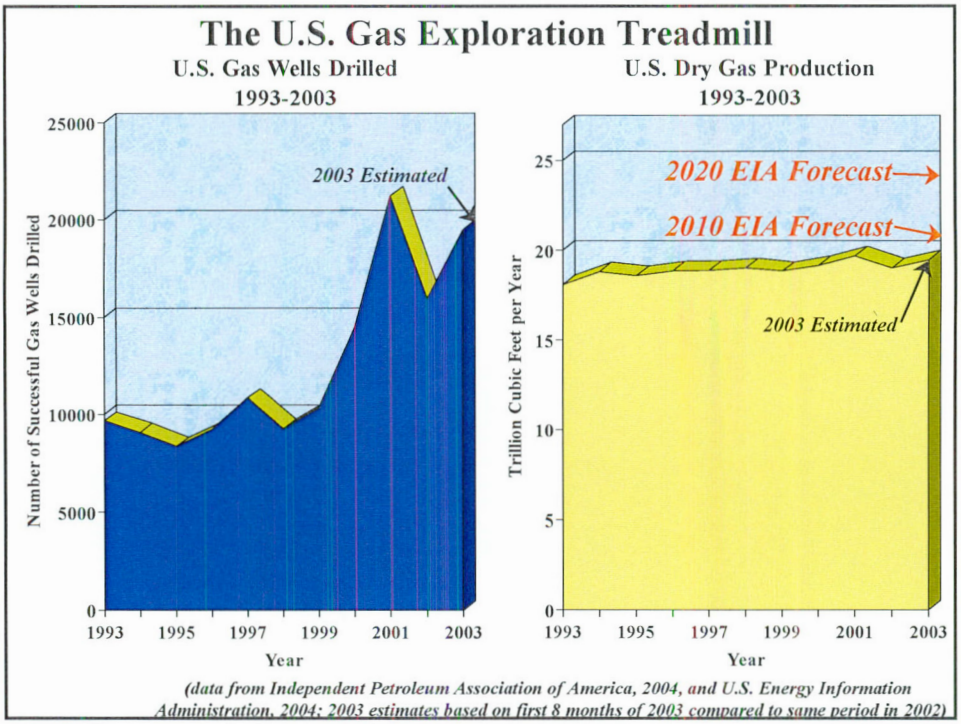
(data from National Energy Board, July, 2003)

U.S. Gas Consumption by Sector, 1986-2002

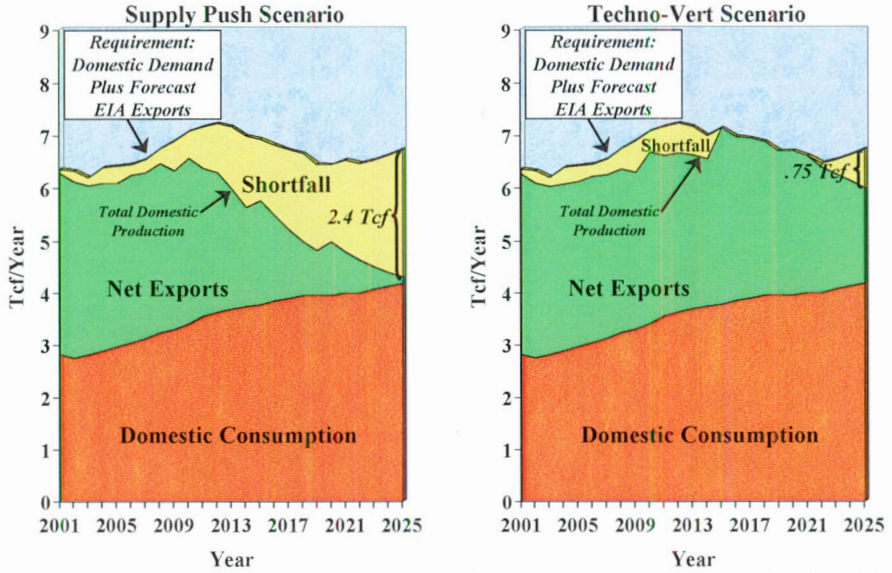


(data from Energy Information Administration, 2003)


U.S. Natural Gas Supply by Source (EIA Annual Energy Outlook, 2004, Reference Economic Case)
38% Total Growth from 2002-2025
30.4 Tcf
26.7 Tcf
Liquefied Natural Gas +2720% 2002-2025
Canada
Alaska
Offshore-Gulf
Offshore Associated
Onshore Associated
Lower 48 +6.9% 2002-2010
Unconventional
Lower 48 +15.5% 2002-2020
Conventional
Tcf/Year
Year
(data from Energy Information Administration Annual Energy Outlook, 2004)


The U.S. Gas Exploration Treadmill
U.S. Gas Wells Drilled 1993-2003
2003 Estimated
Number of Successful Gas Wells Drilled
Year
U.S. Dry Gas Production 1993-2003
2020 EIA Forecast
2010 EIA Forecast
2003 Estimated
Trillion Cubic Feet per Year
Year
(data from Independent Petroleum Association of America, 2004, and U.S. Energy Information Administration, 2004; 2003 estimates based on first 8 months of 2003 compared to same period in 2002)

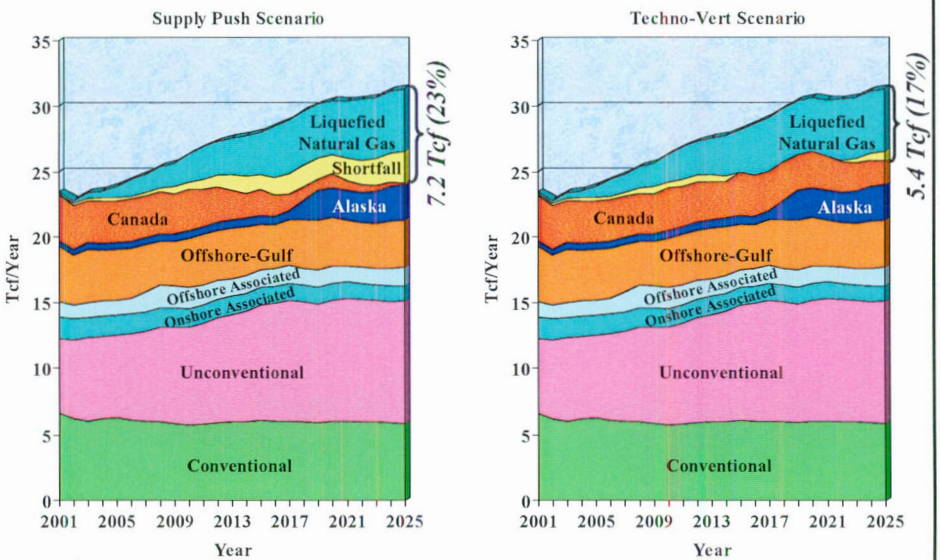
Canadian Shortfalls in Gas Supply Given Domestic Production Scenarios and Forecast EIA (AEO 2004) Reference U.S. Import Requirements



Note: Forecast Canadian LNG Imports are Excluded from Domestic Production

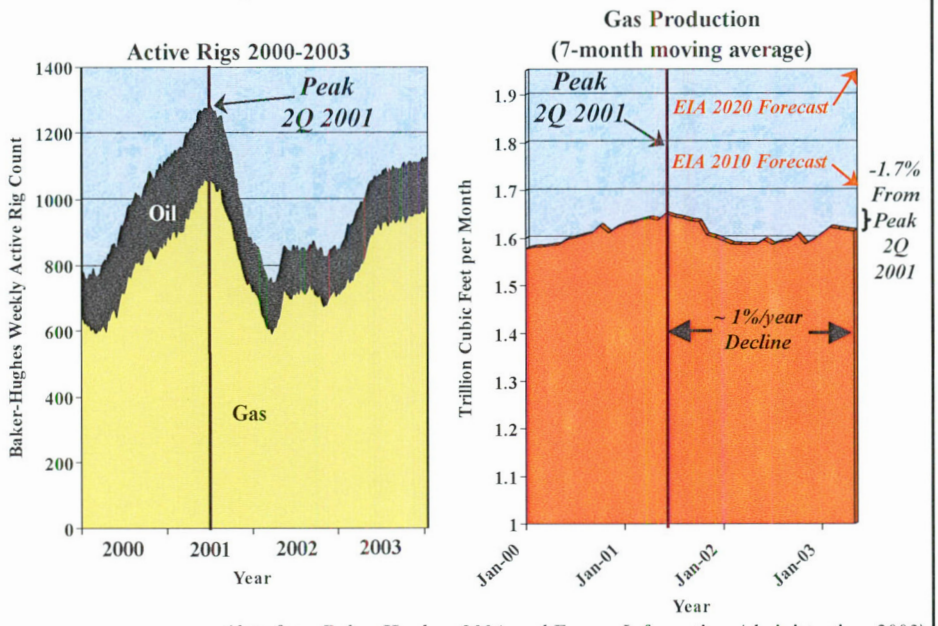
(data from National Energy Board, July, 2003, and EIA Annual Energy Outlook, 2004)

U.S. Supply with Canadian Imports and Shortfalls Given NEB, 2003, Supply Scenarios, EIA Production Growth Scenarios and EIA Reference Case Import Requirements



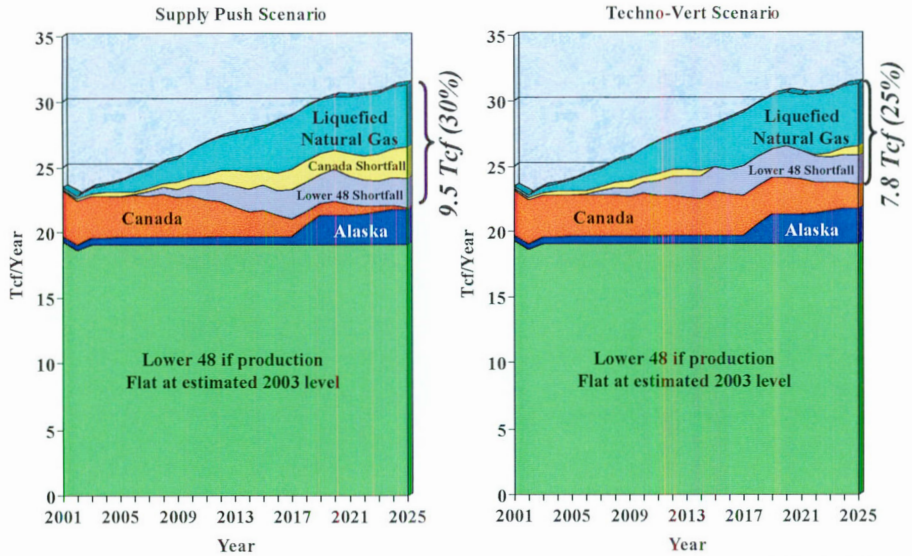
(data from Energy Information Administration Annual Energy Outlook, 2004, and National Energy Board, July, 2003)

U.S. Active Drilling Rig Count and Dry Gas Production 2000-2003
(2003 U.S.A. Decline Rate is now 28%)



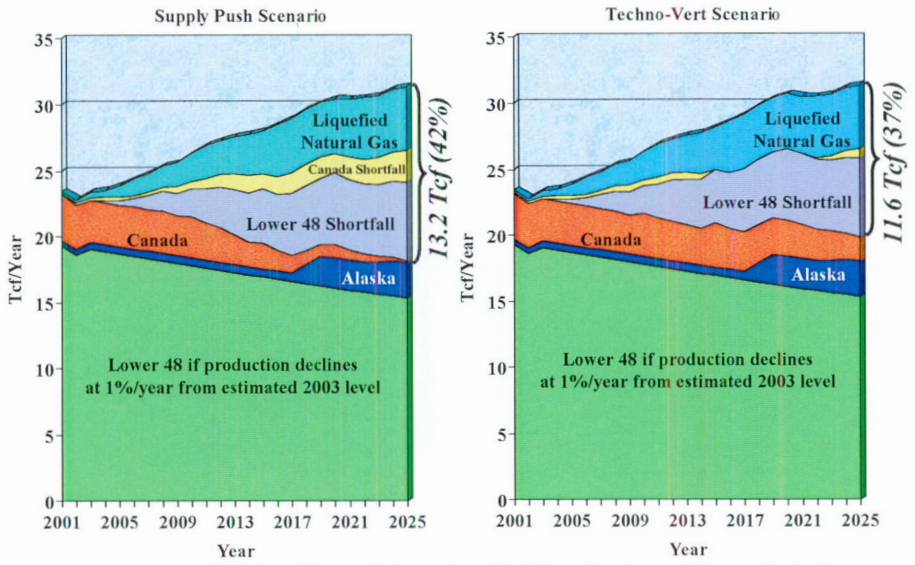
(data from Baker-Hughes, 2004, and Energy Information Administration, 2003)

U.S. Supply with Canadian Imports and Shortfalls Assuming NEB, 2003, Canadian Supply Scenarios, Flat Lower 48 Production and EIA Reference Case Import Requirements



(data from Energy Information Administration Annual Energy Outlook, 2004, and National Energy Board, July, 2003)

U.S. Supply with Canadian Imports and Shortfalls Assuming NEB, 2003, Canadian Supply Scenarios, a 1% Decline in Lower 48 Production and EIA Reference Case Import Requirements



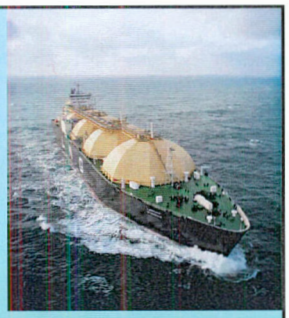
(data from Energy Information Administration Annual Energy Outlook, 2004, and National Energy Board, July, 2003)

FUTURE OUTLOOK:

- *IMPLICATIONS* – If supply and demand forecasts are to be believed, there appear to be serious supply shortfalls in Continental natural gas coming – *Canada is unlikely to be able to fill the supply gap*

- *SOLUTIONS* - probably involve a portfolio of options:
  - LNG – *already factored into existing forecasts; GEOPOLITICAL + NIMBY IMPLICATIONS*
  - Unconventional Gas - *already factored into existing forecasts in a big way*
  - Fuel Switching – *to oil or coal – capacity quite limited without new capital investment*
  - Destroy Demand – *move gas intensive industries offshore (fertilizer and petrochemical plants) - this is already happening; GEOPOLITICAL IMPLICATIONS*
  - Other Conservation

LNG Logistics



OPERATING COSTS (FREEPORT, TEXAS[1]):

- Production =	*$US .50-$1.00/mcf*
- Liquefaction =	*$US .80-$1.00/mcf*
- Shipping =	*$US .50-$1.45/mcf*
- Receiving =	*$US .24-$.40/mcf*
- TOTAL =	**$US 2.04-$3.85/mcf**

SCALEUP TO COMPLETELY COVER A NORTH AMERICA SHORTFALL OF 13 TCF/YEAR WITH LNG WOULD REQUIRE A TRIPLING OF THE WORLD'S LNG CAPACITY. REQUIREMENTS WOULD BE IN THE ORDER OF:

- *212 new 3bcf capacity Ships*
- *35 1bcf/day North America-based receiving terminals*
- *18 Foreign based 5 Train liquefaction terminals*
- *Capital investment in the order of $US90+ Billion*
- **TIME TO BUILD TOTAL CAPACITY = 10-20+ YEARS**
- **OVERCOMING NIMBY SYNDROME IN LOCATING NEW TERMINALS**
- **ACCEPTING THE GEOPOLITICAL IMPLICATIONS OF DEPENDENCY ON OFFSHORE SUPPLY SOURCES**

([1]Reimer, Freeport LNG, 2003)

COAL

- Two-thirds of the world's remaining hydrocarbon energy

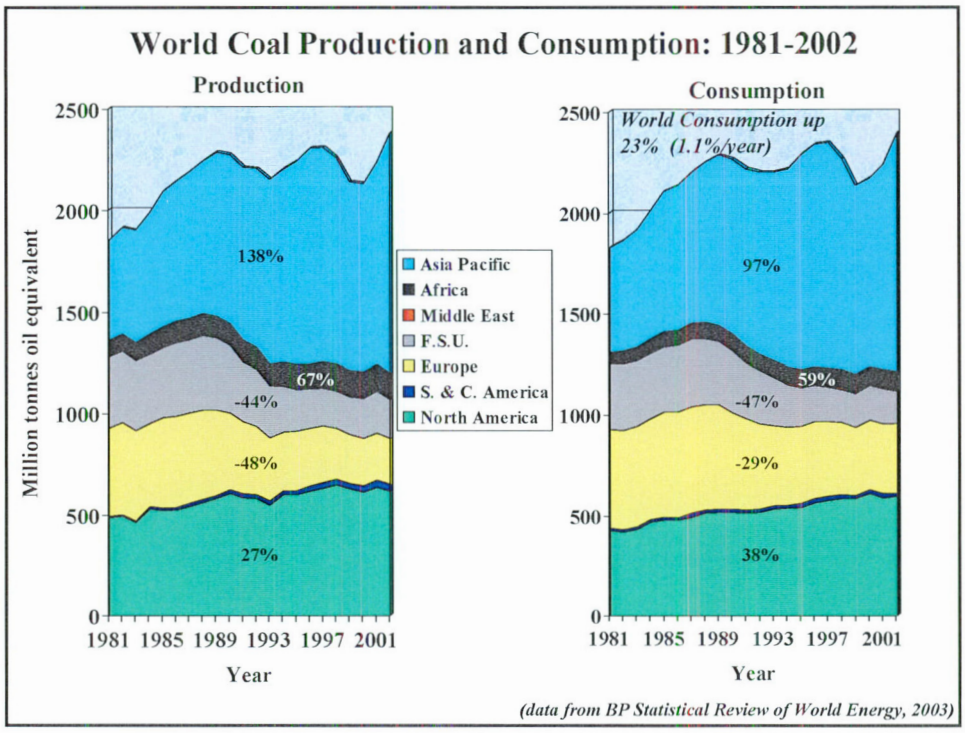
- 25.5% of the world's primary energy consumption in 2002

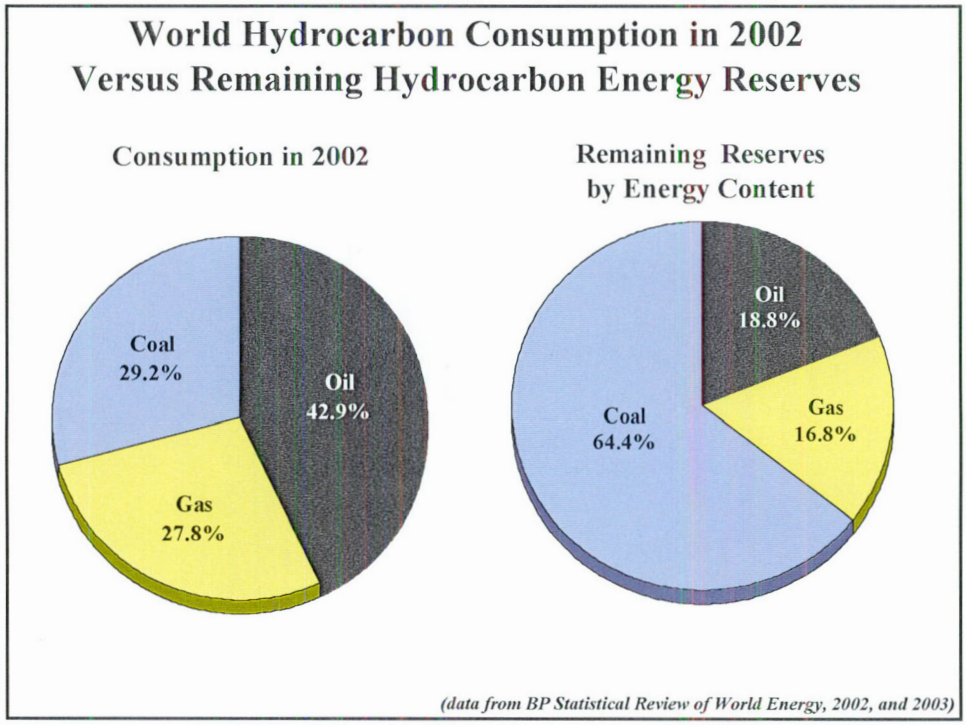
- Used for electricity generation (more so than any other fuel), primary heat and in the steel industry

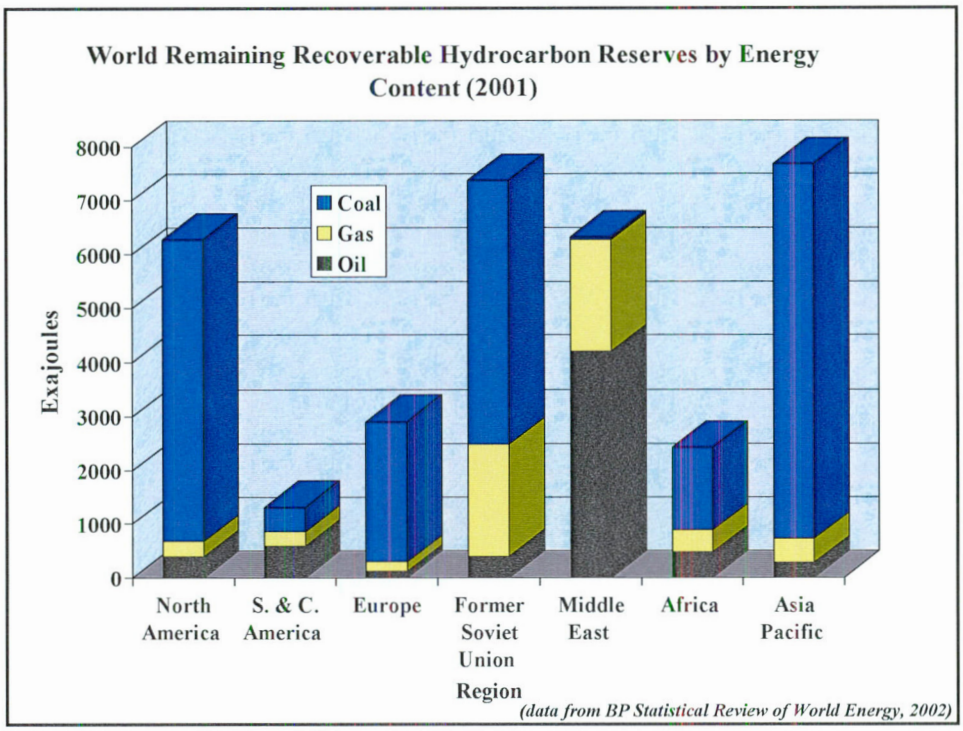
- Lowest cost heat source: $0.34-1.26US/gigajoule versus $4.75US/gigajoule for gas and $4.70US/gigajoule for oil

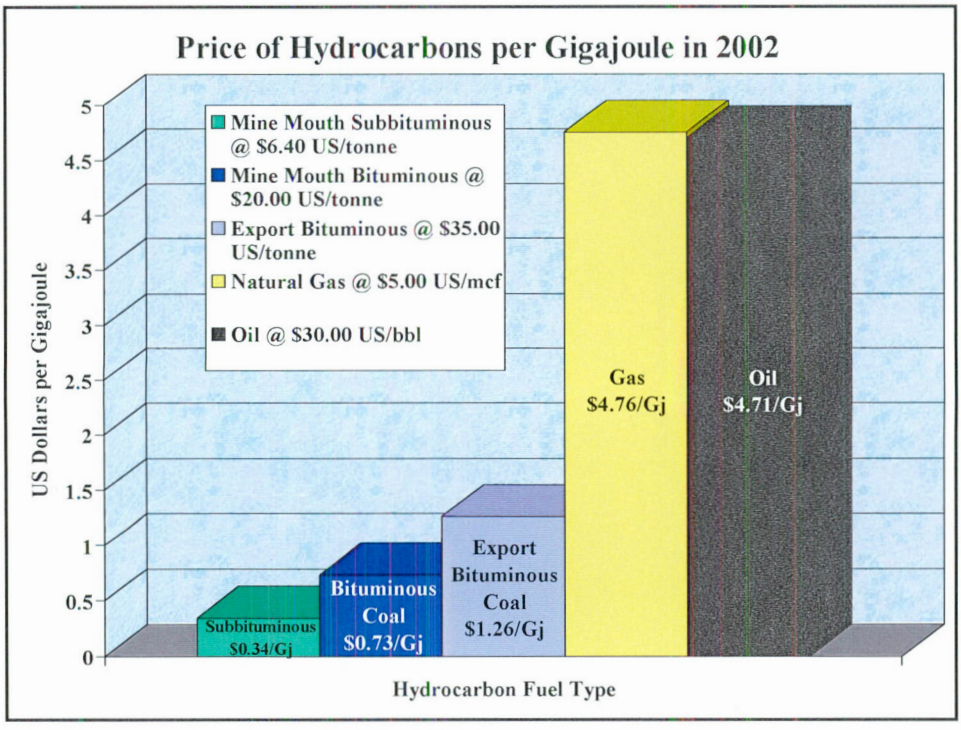
- Double the carbon footprint of gas using conventional technology – with advanced "clean coal" technologies the carbon footprint can be reduced almost to that of gas (but costs $$$)

- Fastest growing hydrocarbon fuel source in 2002 (6.9%)


World Coal Production and Consumption: 1981-2002
Production
Consumption
Million tonnes oil equivalent
2500
2000
1500
1000
500
0
1981 1985 1989 1993 1997 2001
Year
138%
67%
-44%
-48%
27%
World Consumption up
23% (1.1%/year)
97%
59%
-47%
-29%
38%
Asia Pacific
Africa
Middle East
F.S.U.
Europe
S. & C. America
North America
(data from BP Statistical Review of World Energy, 2003)


World Hydrocarbon Consumption in 2002
Versus Remaining Hydrocarbon Energy Reserves
Consumption in 2002
Coal
29.2%
Oil
42.9%
Gas
27.8%
Remaining Reserves
by Energy Content
Oil
18.8%
Gas
16.8%
Coal
64.4%
(data from BP Statistical Review of World Energy, 2002, and 2003)


World Remaining Recoverable Hydrocarbon Reserves by Energy Content (2001)
Exajoules
8000
7000
6000
5000
4000
3000
2000
1000
0
Coal
Gas
Oil
North America
S. & C. America
Europe
Former Soviet Union
Middle East
Africa
Asia Pacific
Region
(data from BP Statistical Review of World Energy, 2002)


Price of Hydrocarbons per Gigajoule in 2002
US Dollars per Gigajoule
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Mine Mouth Subbituminous @ $6.40 US/tonne
Mine Mouth Bituminous @ $20.00 US/tonne
Export Bituminous @ $35.00 US/tonne
Natural Gas @ $5.00 US/mcf
Oil @ $30.00 US/bbl
Subbituminous $0.34/Gj
Bituminous Coal $0.73/Gj
Export Bituminous Coal $1.26/Gj
Gas $4.76/Gj
Oil $4.71/Gj
Hydrocarbon Fuel Type

ELECTRICITY

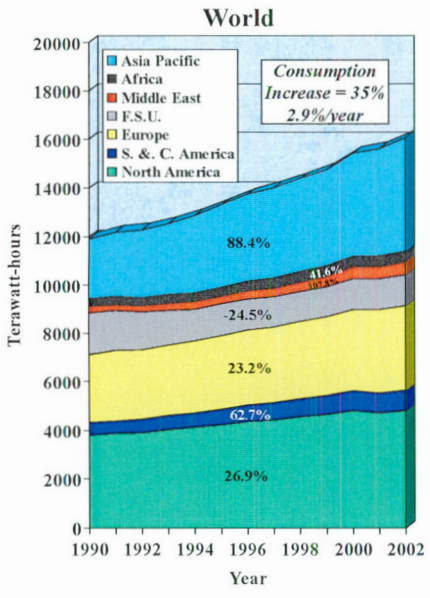
- Availability of reliable electricity defines our modern civilization

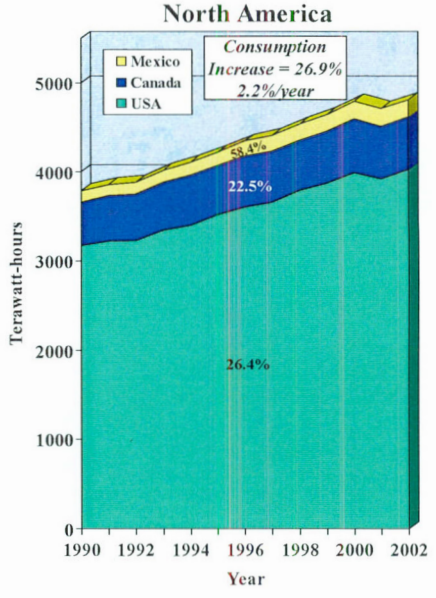
- Electricity in essence cannot be stored in bulk – it must be generated on demand

- We convert hydrocarbons to electricity at an energy penalty of from 30 to 70%

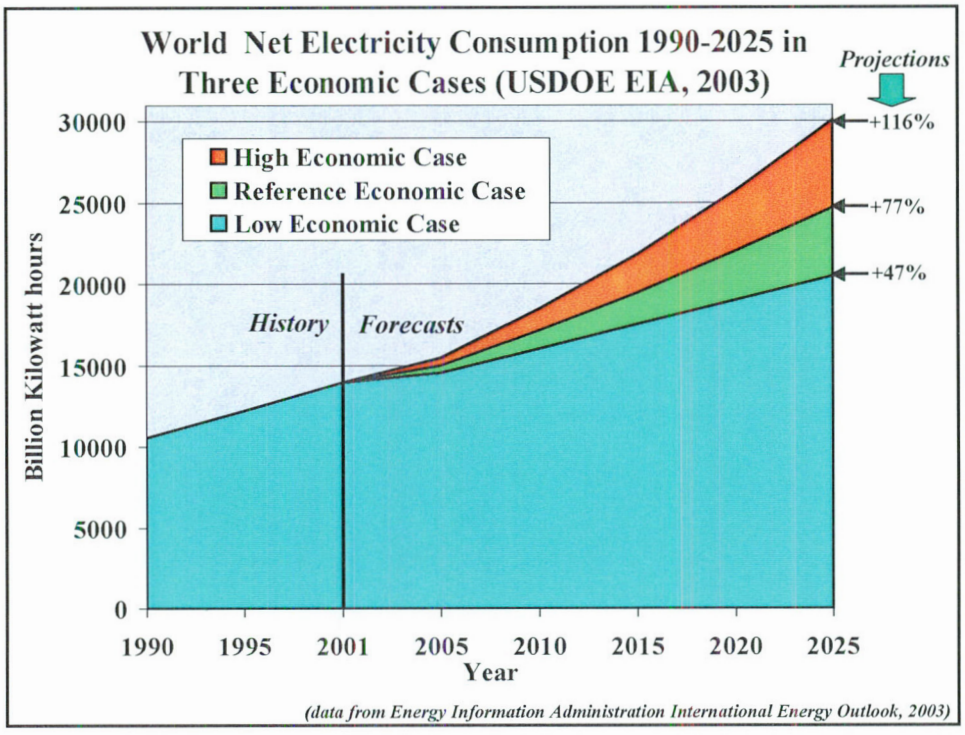
- Electricity is transmitted to points of use with losses depending on transmission distance – *IT IS NOT A WORLD TRADABLE COMMODITY*

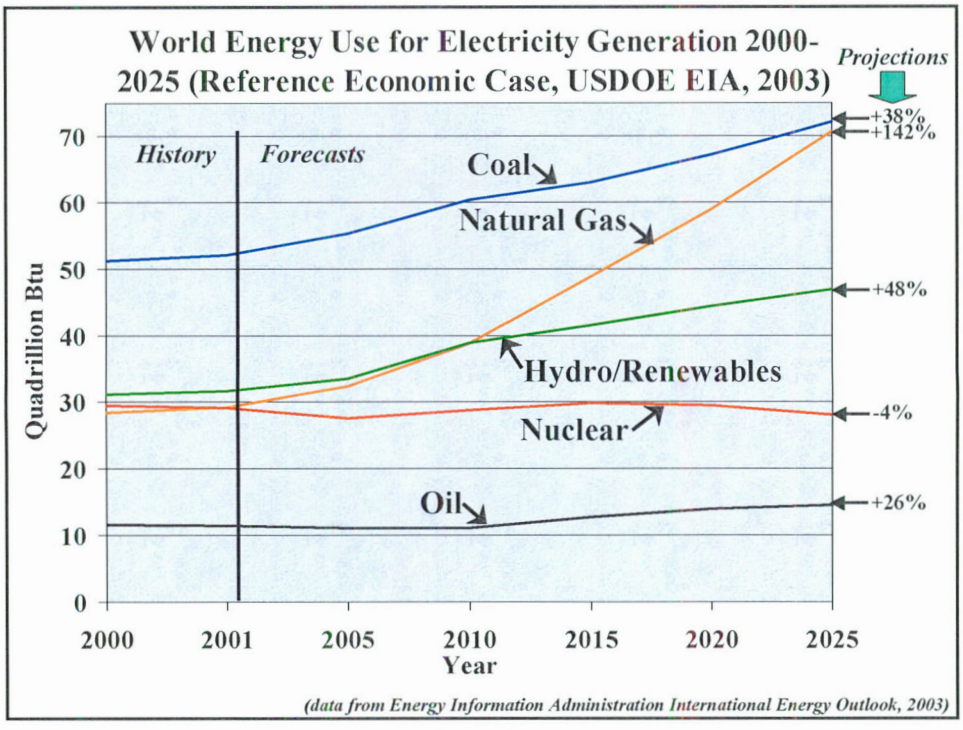
Generation of Electricity: 1990-2002



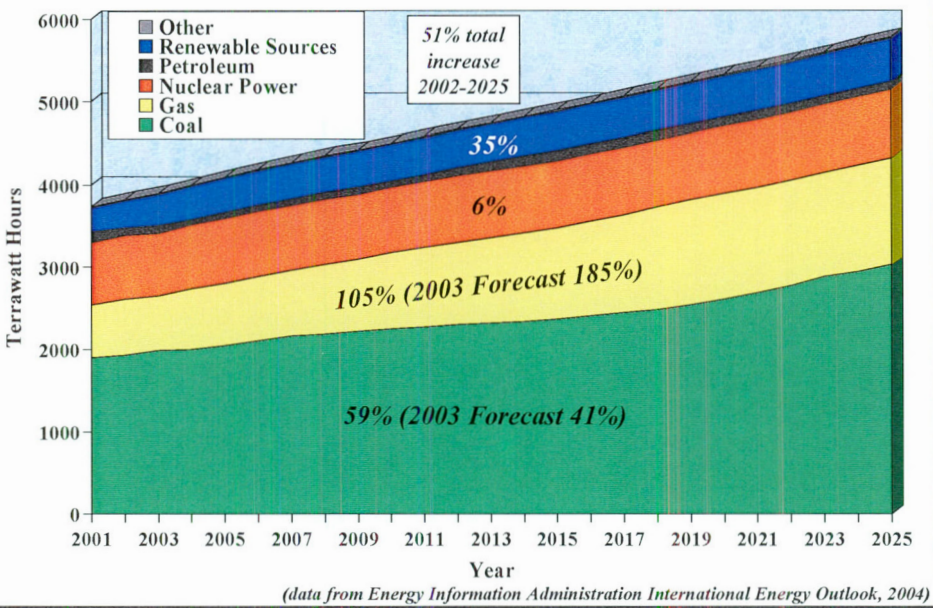


(data from BP Statistical Review of World Energy, 2003)


World Net Electricity Consumption 1990-2025 in Three Economic Cases (USDOE EIA, 2003)
Projections
High Economic Case
Reference Economic Case
Low Economic Case
+116%
+77%
+47%
History
Forecasts
Billion Kilowatt hours
30000
25000
20000
15000
10000
5000
0
1990
1995
2001
2005
2010
2015
2020
2025
Year
(data from Energy Information Administration International Energy Outlook, 2003)

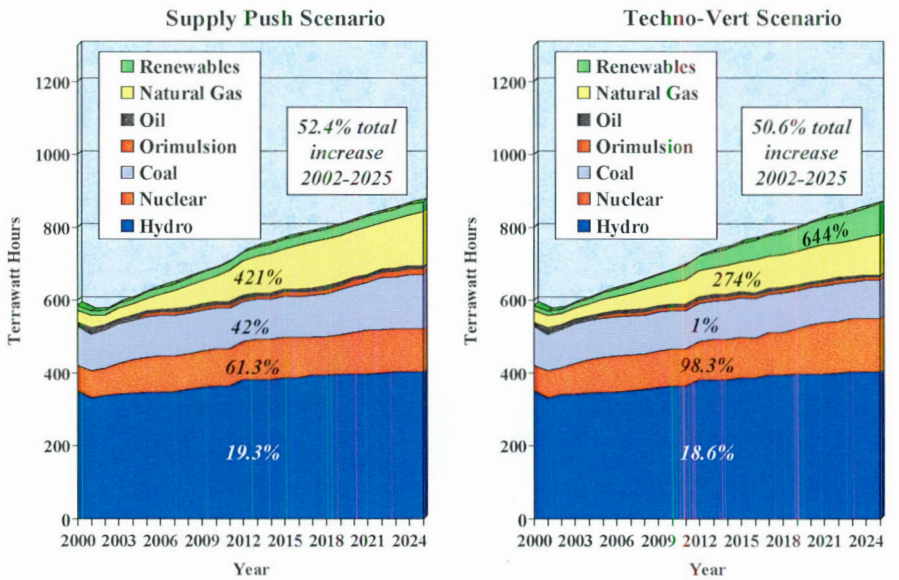

World Energy Use for Electricity Generation 2000-2025 (Reference Economic Case, USDOE EIA, 2003)
Projections
History
Forecasts
Coal
Natural Gas
Hydro/Renewables
Nuclear
Oil
+38%
+142%
+48%
-4%
+26%
Quadrillion Btu
70
60
50
40
30
20
10
0
2000
2001
2005
2010
2015
2020
2025
Year
(data from Energy Information Administration International Energy Outlook, 2003)

Forecast U.S. Electricity Generation by Fuel Type 2001-2025 (EIA Annual Energy Outlook, 2004, Reference Economic Case)



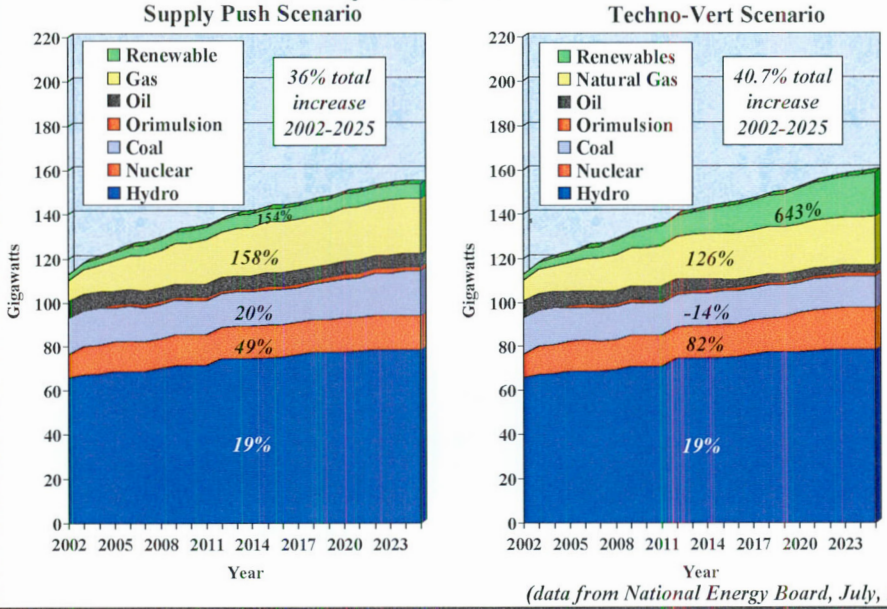
(data from Energy Information Administration International Energy Outlook, 2004)

Canadian Electricity Generation Scenarios by Fuel, 2000-2025



(data from National Energy Board, July, 2003)

Canadian Electricity Generation Capacity Scenarios by Fuel, 2002-2025



(data from National Energy Board, July, 2003)

Implementation Times and Other Considerations For New Electricity Infrastructure

FACTOR	*GAS*	*COAL*	*NUCLEAR*	*HYDRO*
Capital Cost	LOW-MOD	MOD-HIGH	HIGH - VERY HIGH	VERY HIGH
Fuel Cost	VERY HIGH	LOW	VERY LOW	VERY LOW
Environmental Footprint	LOW	MOD(now) LOW(future)	VERY LOW[1]	VERY LOW[2]
Time to startup (years)	**1-2+**	**5-7+**	**5-12+**	**6-10+**

[1] If the as yet unsolved problem of waste disposal is not considered
[2] If the environmental costs of flooding river valleys, siltation and ecosystem impacts are not considered

Implications for Sustainability - *OIL*

THERE IS A DISCONNECT BETWEEN WORLD OIL RESERVES AND FORECAST OIL CONSUMPTION:

- World Oil Production could peak in the 2008-2012 timeframe (consensus) – even the Optimist's Reference Case says 2017 if peak symmetrical or 2038 if peak at 82% of Ulitimate Recoverable Conventional Oil consumed.

- OPEC has most of what's left and could become the dominant oil supplier before the end of the decade, but will need to rapidly expand its production capacity which could be problematic.

- Industrialized countries will be in competition with rapidly growing consumers in the Developing World over a finite supply, with attendant impacts on economic growth due to oil price (which will shape the world oil production profile at peak).

- Even with a four- or five-fold expansion of production from the Oil Sands, Canada will be a small player in World Oil Supply (about 3% of forecast 2025 World Demand with export capacity of about 1% of forecast 2025 World Demand).

- Supply from Unconventional Oil is unlikely to compensate for the decline in Conventional Oil Production. The two largest sources of Unconventional Oil, the Oil Sands and the Orinoco Extra-Heavy Oil Belt of Venezuela, given massive expansions in both areas, will represent about 5% of forecast 2025 World Demand.

Implications for Sustainability - *GAS*

THERE IS A DISCONNECT BETWEEN NORTH AMERICAN GAS DELIVERABILITY AND FORECAST CONSUMPTION:

- Several existing producing areas in North America are in or near decline.

- Higher cost frontier and offshore conventional production and non-conventional production from coalbed methane, tight gas and shale gas likely cannot forestall the declines in conventional production for long and cannot provide for forecast aggressive domestic demand and export growth, unless as-yet-unproven windfalls result from hydrates, coalbed methane, shale gas etc.

- Canada may not be able to meet its own forecast needs and U.S. forecast expectations for exports after 2004, depending on the success of the development of non-conventional gas, the pace of new conventional development, the realization (or lack thereof) of optimistic supply additions in the Lower 48, and the development of LNG import capacity in Eastern Canada.

- Solutions include LNG imports, (which would mean large investments in new infrastructure), ***demand destruction,*** (move intensive fertilizer/petrochemical industries offshore), ***additional non-conventional gas, fuel switching and other conservation.***

Implications for Sustainability - *ELECTRICITY*

- ***The North America Electric Reliability Council (NERC, December, 2003) forecasts supply growth of 10+% (126 gigawatts) through 2007 of gas-fired generation*** - 57 gigawatts of new gas-fired capacity was completed in 2002

- ***Electricity generation accounted for 25% of U.S. gas consumption in 2002*** *(EIA, 2003) and is expected to account for 25% or more through 2025 (EIA, 2004)*

- ***Forecast shortfalls in supply of natural gas could jeopardize future availability of a secure electricity supply*** unless new supplies can be secured

- ***Renewable energy - biomass, wind and photovoltaics must be emphasized but will realistically only provide a relatively small incremental supply*** (eg. Wind represents about 0.3% of Canada's generating capacity at present).

- ***Nuclear is limited by capital cost, public perceptions and environmental impact*** (Waste storage at Yucca Mtn. will cost $US50billion+ to build and will be completely filled with U.S. wastes since the beginning of the Atomic Age). The EIA (2003) forecasts declines in world electricity generation from nuclear by 2025. The EIA AEO 2004 reference economic case indicates no new U.S. nuclear plants through 2025.

- ***Large Hydro is limited by lack of available sites and environmental costs***

Implications for Sustainability - *COAL*

- ***Two-thirds of World's remaining hydrocarbon energy (90% of North America's)***

- ***Lowest cost hydrocarbon energy*** - cost is 7% to 26% that of gas and oil at $US5/mcf and $US30/bbl, ***but double the carbon footprint of gas with old technologies***

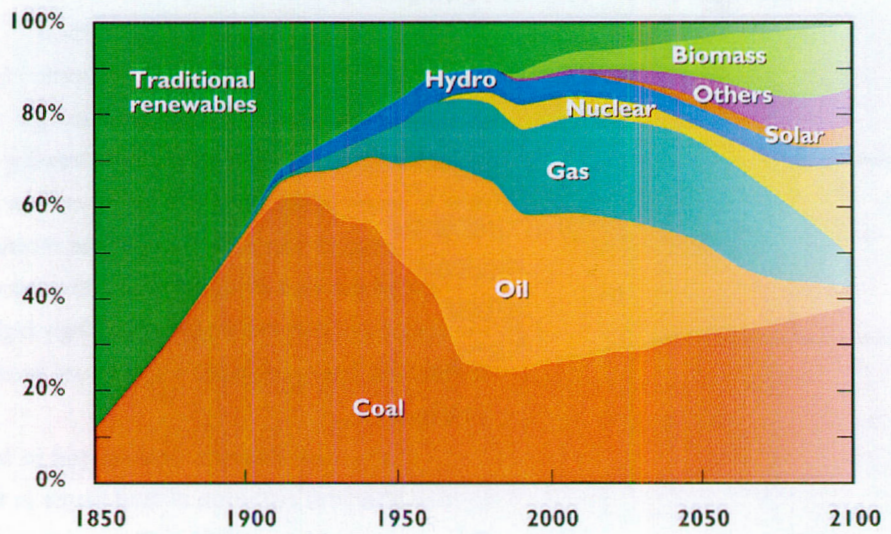
- ***New more efficient utilization technologies, with reduced GHG emissions, are the key to expanded coal use:***

  - ***Higher Efficiency Generation*** new existing technologies can raise thermal efficiency from 32% to 45% with a corresponding reduction in GHG emissions of 30%, but they are expensive (SCPC, IGCC) – ***expected future improvements in efficiency to 50% (2010) and 60% (2020) (Vision 21 USDOE)***

  - ***Petrochemicals from Coal – gasification, liquefaction, in situ gasification for deep coal utilization***

  - ***Hydrogen from coal*** (competes with H_2 from natural gas @ $4.00US/mcf – China produces 5 Mt of H_2/year from coal for fertilizers) or in conjunction with electricity generation (IGCC, ZECA - higher cost)

  - ***"Zero Emission" utilization through CO_2 sequestration*** in coal seams, depleted oil and gas reservoirs and saline aquifers



World Primary Energy Shares - 1850 to 2100
Given Oil and Gas Supply Limitations

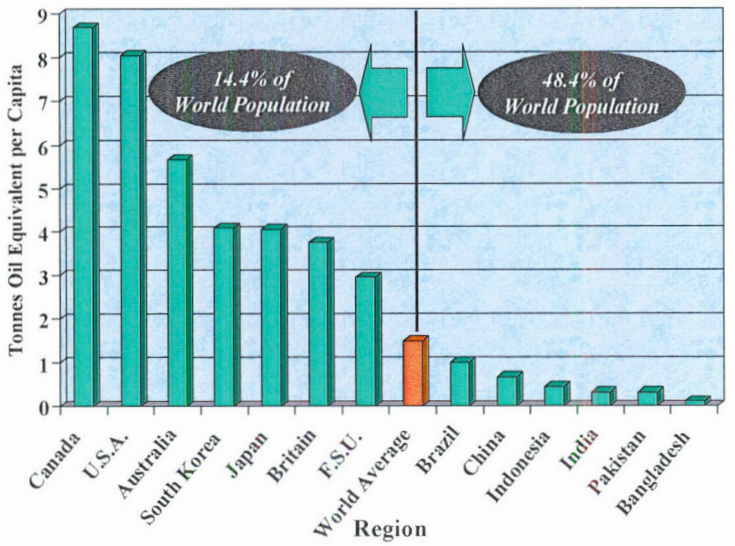
Source - World Coal Institute

The Last Piece of the Energy Sustainability Puzzle:

POPULATION GROWTH
and
ASPIRATIONS OF GROWTH IN ENERGY CONSUMPTION

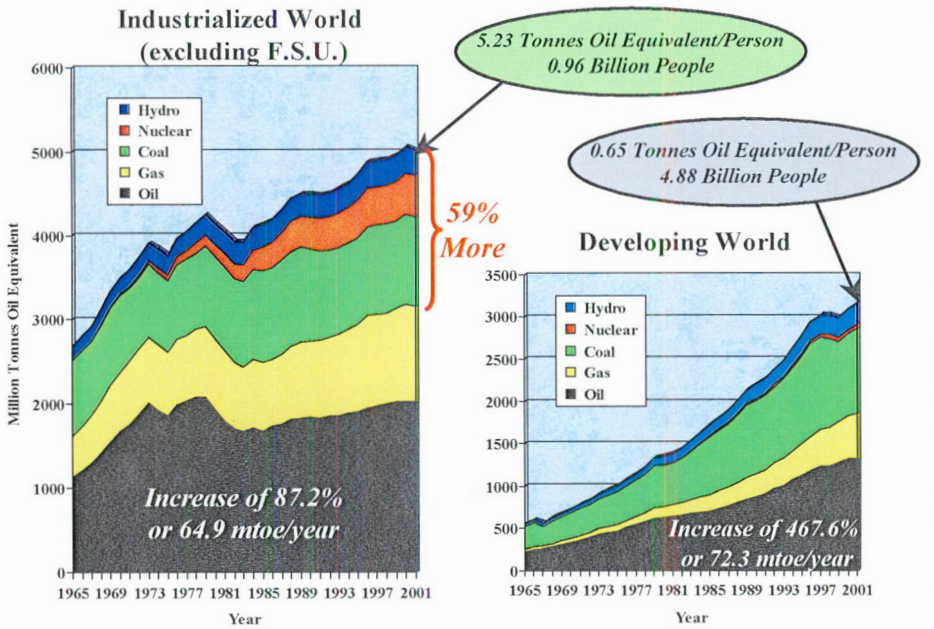
There is a Great Inequity in Energy Consumption Worldwide

Primary Per Capita Energy Consumption of Selected Countries in 2001

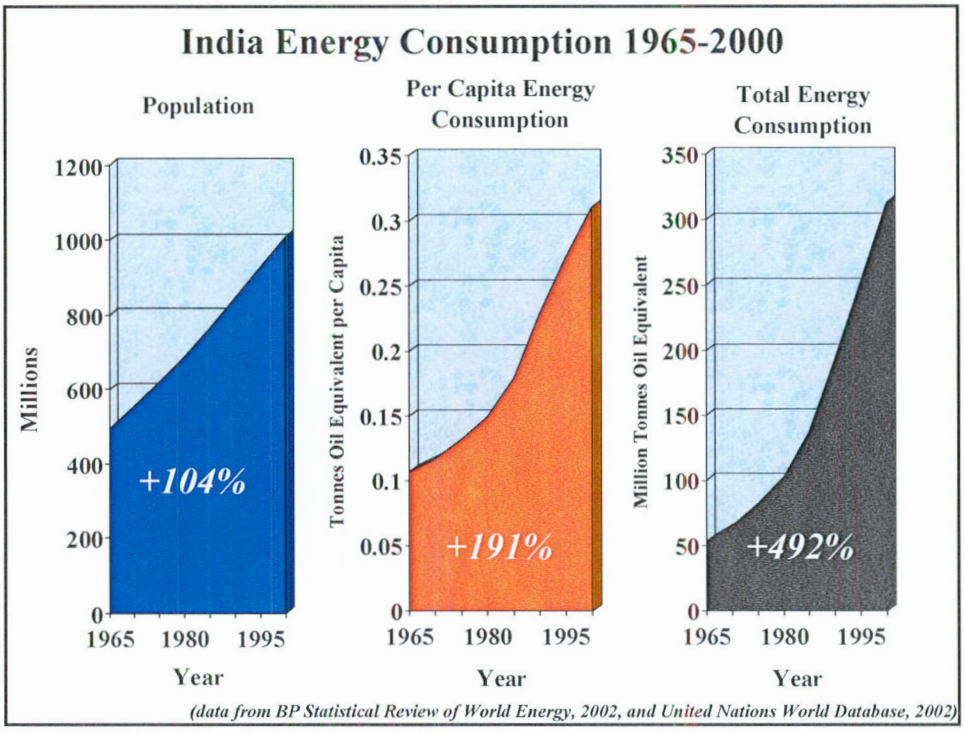


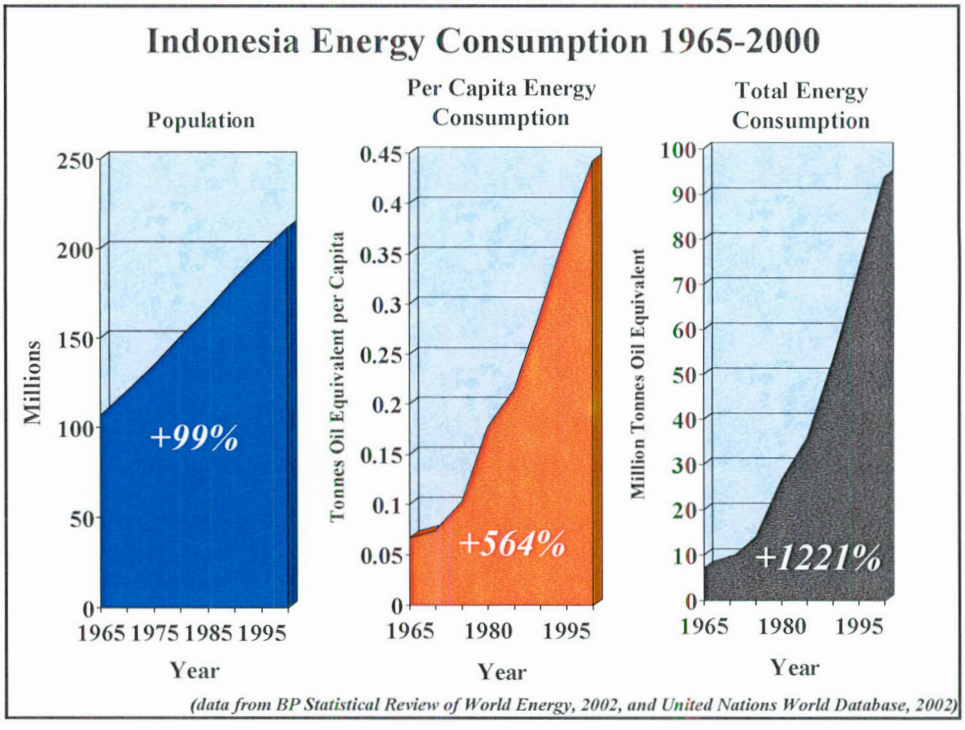
(data from BP Statistical Review of World Energy, 2002, and United Nations World Database, 2002)

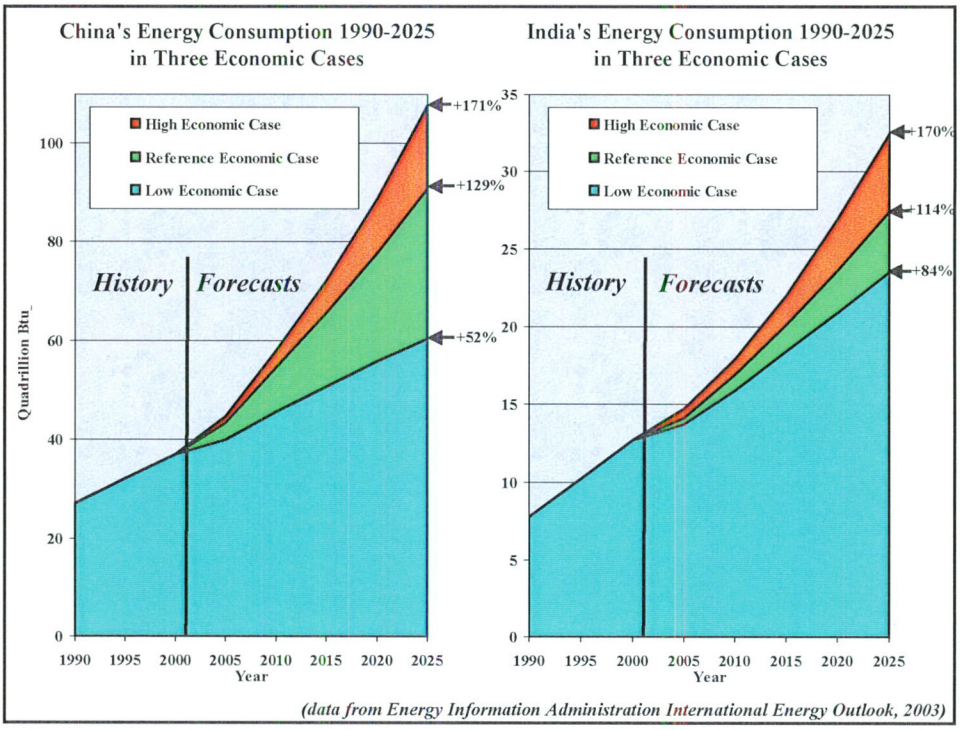
Primary Energy Consumption by Economic Development: 1965-2001



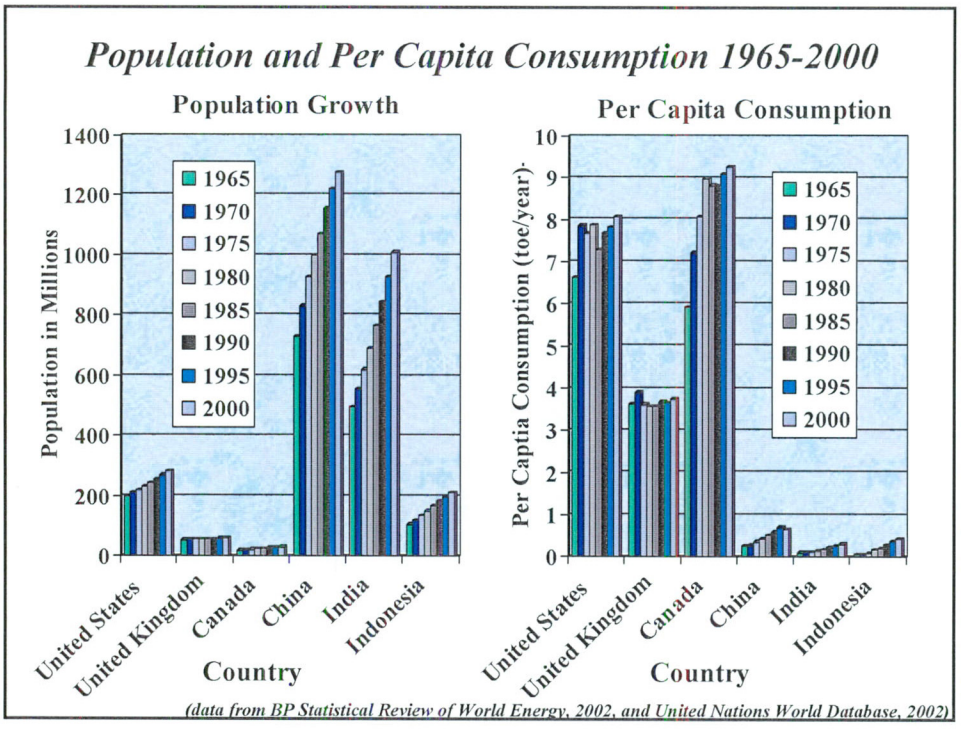
(data from BP Statistical Review of World Energy, 2002, and United Nations World Database, 2002)


India Energy Consumption 1965-2000
Population
Millions
1200
1000
800
600
400
200
0
+104%
1965 1980 1995
Year
Per Capita Energy Consumption
Tonnes Oil Equivalent per Capita
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
+191%
1965 1980 1995
Year
Total Energy Consumption
Million Tonnes Oil Equivalent
350
300
250
200
150
100
50
0
+492%
1965 1980 1995
Year
(data from BP Statistical Review of World Energy, 2002, and United Nations World Database, 2002)


Indonesia Energy Consumption 1965-2000
Population
Millions
250
200
150
100
50
0
+99%
1965 1975 1985 1995
Year
Per Capita Energy Consumption
Tonnes Oil Equivalent per Capita
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
+564%
1965 1980 1995
Year
Total Energy Consumption
Million Tonnes Oil Equivalent
100
90
80
70
60
50
40
30
20
10
0
+1221%
1965 1980 1995
Year
(data from BP Statistical Review of World Energy, 2002, and United Nations World Database, 2002)

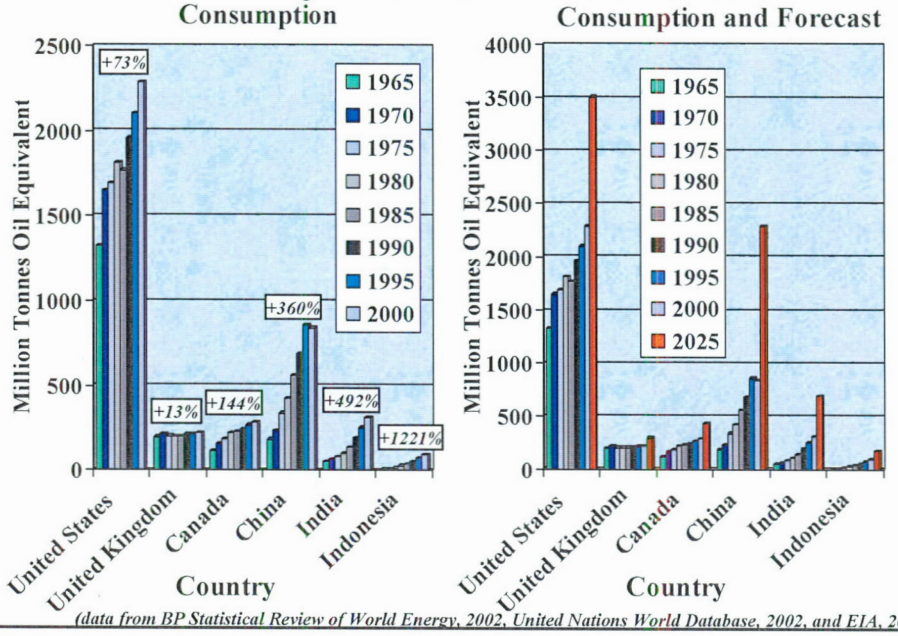


(data from Energy Information Administration International Energy Outlook, 2003)



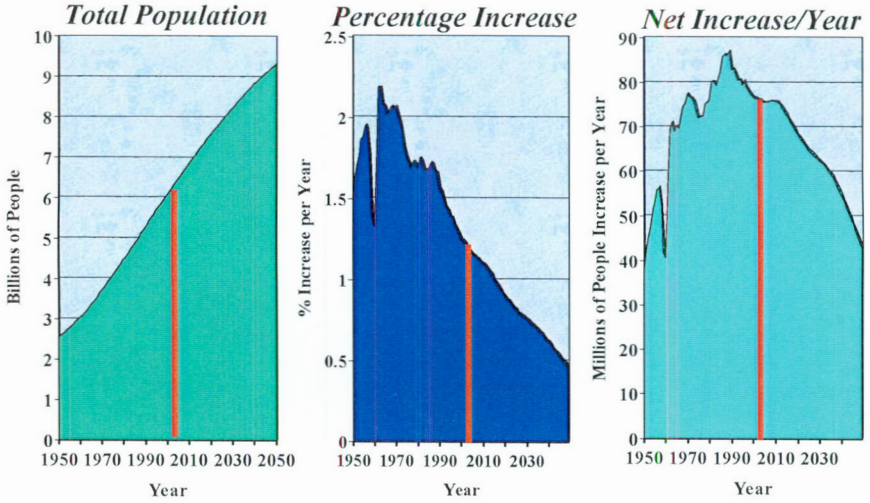
(data from BP Statistical Review of World Energy, 2002, and United Nations World Database, 2002)

Energy Consumption, 1965-2000, and EIA Reference Case Forecast to 2025



(data from BP Statistical Review of World Energy, 2002, United Nations World Database, 2002, and EIA, 2003)

World Population Increase 1950-2050



(Source U.S. Bureau of Census, 2003)

The Way Forward

- **Business as usual is not a sustainable option** – the ultimate resource potential of oil and gas is arguable but we are definitely dealing with a finite resource - the implication of this is that we are running out of the *CHEAP OIL* that fueled the rapid growth in per capita consumption and lifestyle of the last century. Production from crude bitumen resources is not scalable to offset declines in conventional production.
- ***GAS* availability in North America is highly correlated with electricity reliability and cost** - replacement of declining low-cost conventional gas and meeting future demand growth with higher cost conventional and non-conventional supplies represents an *EXTREME CHALLENGE* and, even if it is doable, likely means much higher-cost electricity and higher costs for all other gas uses. LNG imports face infrastructure limitations, siting and Geopolitical obstacles which will likely limit LNG's ability to fill the supply gap. Banking on windfalls from as-yet-unproven hydrates, CBM, shale gas etc. could prove dangerous if the required production levels are not realized.

The Way Forward

- **The first step is to recognize the problem,** and begin making the changes and creating the infrastructure that will be required for transit to a more sustainable energy future
- **The most cost-effective approach is energy conservation** - reduce consumption on all levels
- **A longer term vision is required than the lifespan of a typical government** – ***THERE IS NO SILVER BULLET*** – all options must be objectively assessed and deployed as incremental contributions to a solution
- **A sustainable energy future is not out of reach – but we have to be thinking in the 10-20+ year timeframe to develop the infrastructure for alternatives as well as technologies and incentives to reduce consumption**

THERE HAVE BEEN NUMEROUS PREVIOUS LONG-TERM ENERGY SUSTAINABILITY INITIATIVES BY GOVERNMENTS

HOW DID THEY DO?

The Best Laid Plans of Mice and Men…

1970: "Fusion Power within 30 years" – *2003: Commercial Fusion Power still decades away or never*

1974: Nixon's Project Independence – "Hydrogen Fuelled Vehicles", "Shift Away from Foreign Oil", "In the year 1980 the U.S. will not be dependent on any other country" – *1980: Oil Imports at 6.89 million barrels per day or 40.3% of consumption; 2003: Negligible Hydrogen Fuelled Vehicles; Oil Imports up by 95% to 61% of consumption*

1974 Policy Makers: "U.S. Oil Production could increase to more than 17 million barrels a day by 1985" - *1985: U.S. Oil Production at 10.7 million barrels a day; 2002: U.S. Oil Production at 7.698 million barrels a day*

1975: Energy Policy and Conservation Act – "27.5 mpg passenger vehicles by 1985" – *2003: Vehicle fleet at 20.4 mpg*

1979: Power Plant and Industrial Fuel Act banned burning of Natural Gas after 1990 for Electricity Generation (repealed by Reagan in 1987) – *2003: 151% increase in U.S. generation of electricity from natural gas with forecast 99% growth to 2025 in the face of supply shortfalls*

(Legislative history from Time Magazine, July 13, 2003; Present and past production statistics from BP Statistical Review of World Energy, 2003; Forecasts from Energy Information Administration, 2004)

The Best Laid Plans of Mice and Men...

1980: Carter pushed legislation with a goal to "derive 20% of energy from the sun by 2000" – *2003: .07% of U.S. Consumption achieved from the sun*

Reagan White House mid 1980's – "the ranges that any reasonable person is considering include zero (imports) by 2000" - *2002: Imports at 12.01 million barrels per day or 61% of consumption.*

Bush Administration 2003 – ***"clean, safe, renewable and commercially available fusion energy by the middle of this century"***

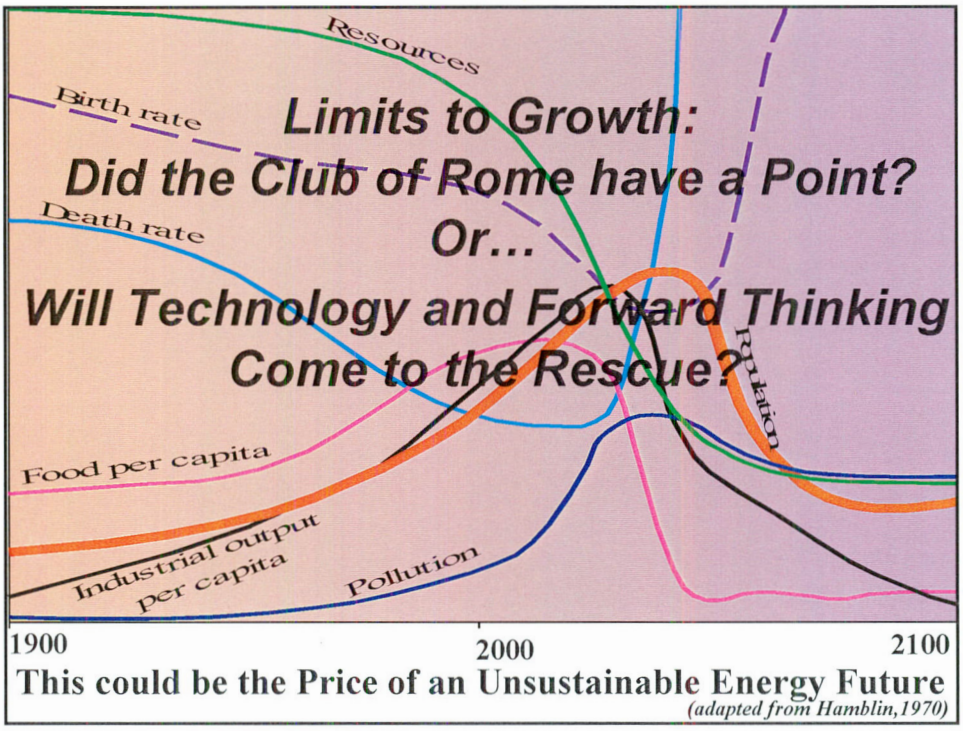
Bush Administration 2003 – Freedom CAR and Fuel Initiative "Hydrogen can displace today's oil imports of more than 11 MMbbls/day by 2040" – *Hydrogen is an ENERGY CARRIER not an ENERGY SOURCE, which is mainly produced from Natural Gas, but could be produced from Coal, Biomass or Electrolysis; Replacing America's transportation infrastructure with Hydrogen from electrolysis would require a several-fold increase in electricity generation infrastructure* – ***FUELED BY WHAT?***

2003: Texas Democrat Raymond Green on conservation: ***"WE COME FROM A BIG STATE THAT WANTS BIG TRUCKS AND BIG CARS"***

(Legislative history from Time Magazine, July 13, 2003; Present and past production statistics from BP Statistical Review of World Energy, 2003; Forecasts from Energy Information Administration, 2004)

THE STAKES ARE EXTREMELY HIGH
AND
THE TRACK RECORD IS POOR

WE HAVE TO DO MUCH
BETTER TO ENSURE
A SUSTAINABLE ENERGY FUTURE



This could be the Price of an Unsustainable Energy Future

(adapted from Hamblin, 1970)