The Economic and Environmental Challenges for America's Energy Future

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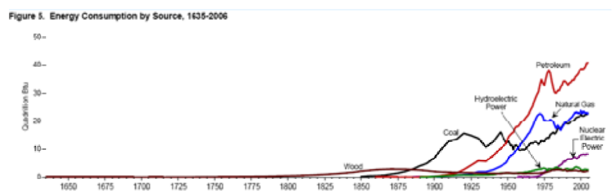
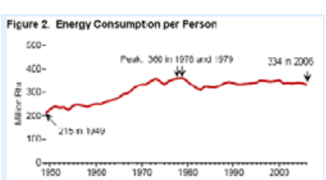
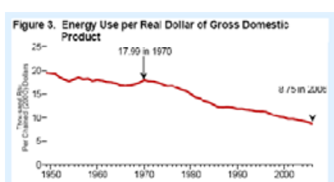
Outline of Talk

- US energy history
  - Consumption, production and pricing by fuels
- Have fossil fuels become increasingly scarce?
  - Evidence from oil, natural gas, coal, and "near oil" markets
- Will the world ever run out of fossil fuels?
- What explains recent price oil price increases and decreases?
  - The role of OPEC, speculators, national oil companies (NOCs)
- What can US do to limit price levels and volatility?
- The environmental challenge of fossil fuels and how to solve it
- The growing cost of inaction on climate policy

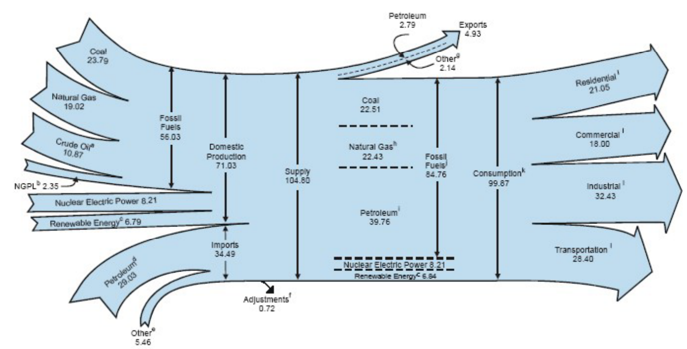
1 BTU = heat required to change the temperature of one pound of water one degree Fahrenheit at sea level







Energy Measured in Quadrillion BTU in 2006



Petroleum Sector

Figure 4. Energy Consumption by Primary Energy Source

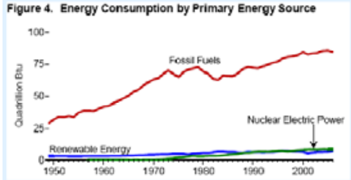


Figure 14. Petroleum Overview

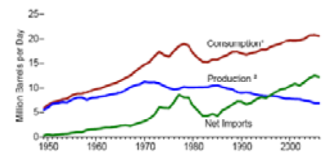


Figure 15. 48 States and Alaskan Crude Oil Production

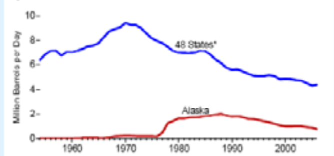
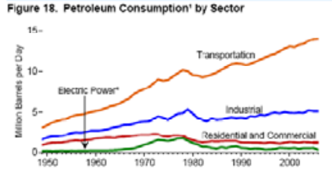
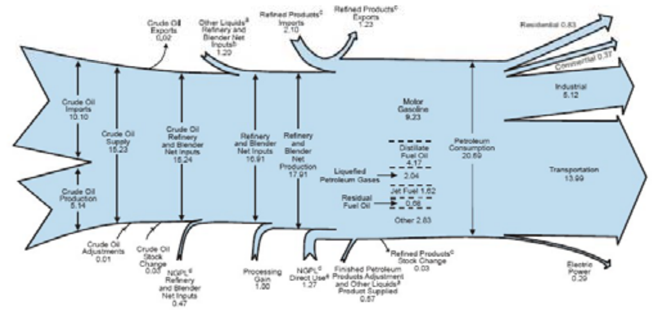


Figure 18. Petroleum Consumption by Sector



Petroleum Flow in Millions of Barrels per Day in 2006



Natural Gas Sector

Figure 34. Natural Gas Overview

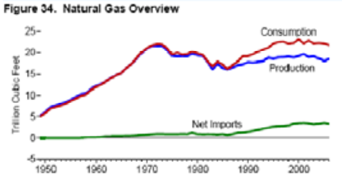
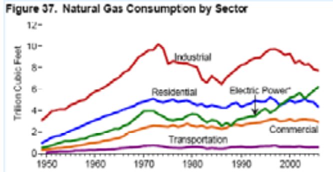


Figure 36. Net Imports as Share of Consumption

Figure 37. Natural Gas Consumption by Sector



Coal Sector

Figure 38. Coal Overview

Figure 39. Coal Consumption by Sector

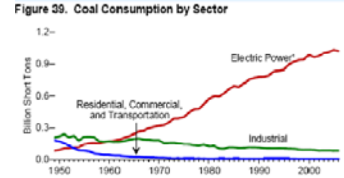


Figure 41. Production by Mining Method

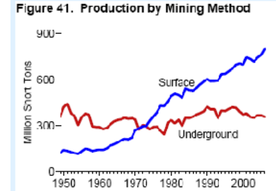
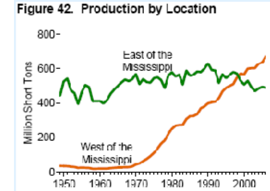


Figure 42. Production by Location



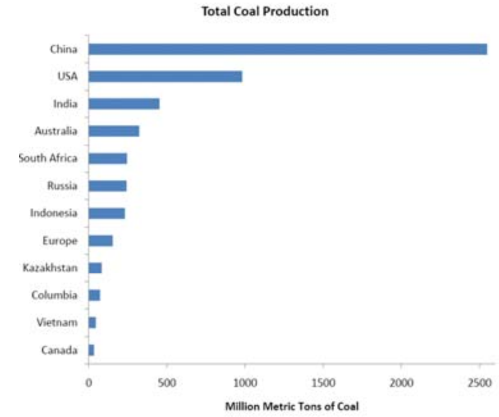
The Role Coal in US Energy Future

- The United States has the largest coal reserves in the world
  - It is inexpensive to extract from surface mines in western US
    - Powder River Basin in Montana and Wyoming

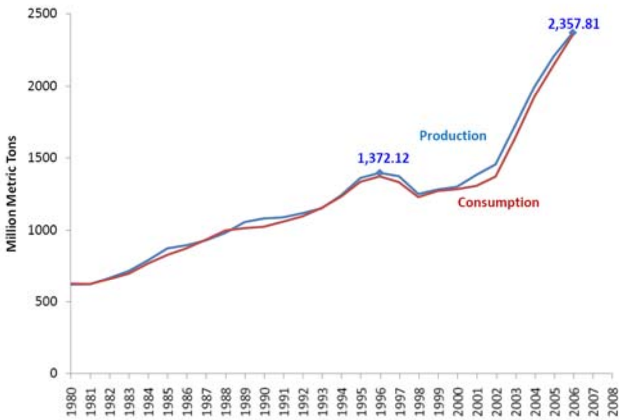
	billion tonnes	%
U.S.	243	26.2
China	192	20.8
Russia	157	17.0
World	925	100.0

Source: BP (2008) & IEA (2007).

China's Role in World Coal Market



China's Coal Production and Consumption



Source: 1980 to 2006 data from LBL China Energy Databook V7.

China's power generation installed capacity

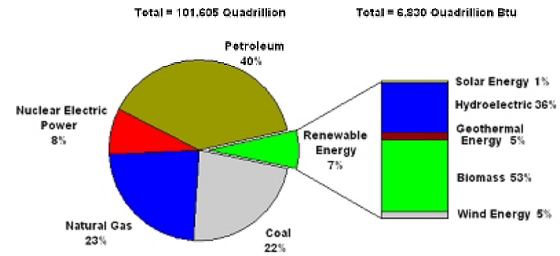
Year	Increased installed capacity by the year end (GW)	Total installed capacity by the year end (GW)
2000		319.321
2001	19.166	338.487
2002	18.084	356.571
2003	34.837	391.408
2004	49.292	440.700
2005	66.000	508.387
2006	101.170	618.355
2007	94.935	713.290
2008	79.240	792.530
2010		850 (expected)
2020		1200 (expected)

Installed Capacity in California is approximately 60 GW

Installed Capacity in United States

- Approximately 1,000 GW installed capacity in the United States
- Peak load growth is at least 2 to 3 percent per year on average
  - Likely to be even larger with global climate change
  - Roughly 20 to 30 GW of new capacity must be installed each year to meet load growth
- Coal-fired power plants are least-cost new capacity option at current natural gas and oil prices

Renewable Energy in US

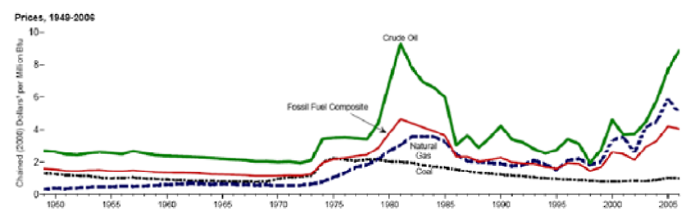


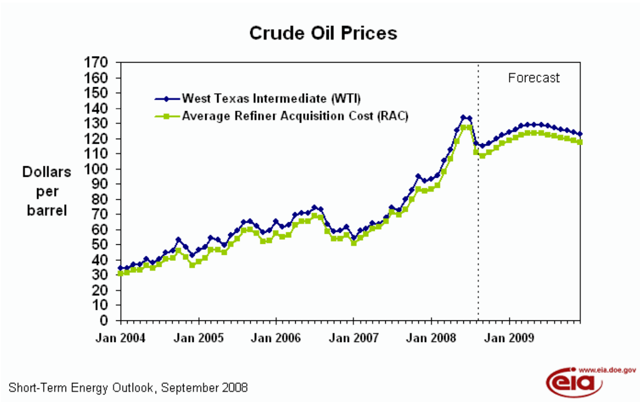
Conclusion: What is considered renewable energy in political circles currently has a very minor role US energy sector—Solar and Wind energy

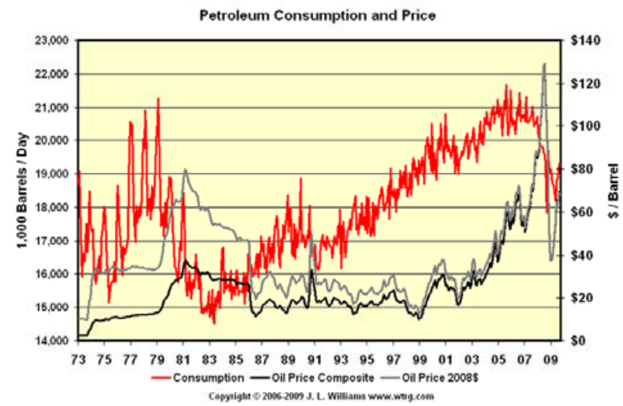
Coal Facts

- Hard to see how coal will not continue to be a major input fuel to produce electricity
- Even very ambitious renewable energy goals requires substantial new fossil fuel facilities
  - Current US installed capacity of wind ~20 GW
  - Current US installed capacity of solar ~0.5 GW
  - Current US installed capacity of coal ~350 GW
- Capacity factor = (Annual Energy Produced)/(8760 x Capacity of Unit)
  - Coal capacity factor = 0.90
  - Wind capacity factor = 0.25

Fossil Fuel Prices





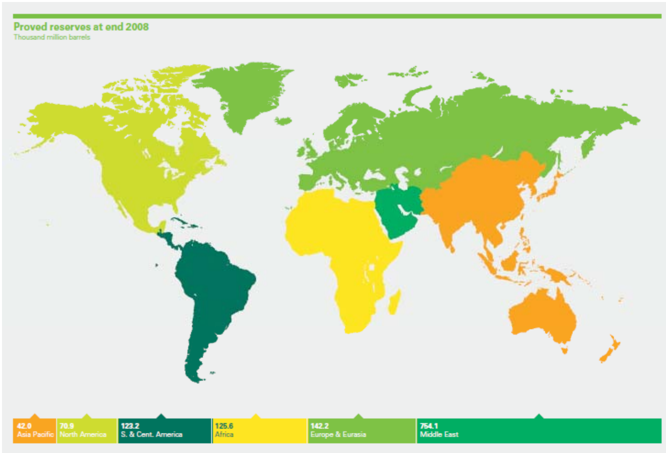


Summary of World Fossil Fuels Market

- Falling real prices of oil since 1979
- Increasing real prices starting in 2002
- Real prices slightly higher that 1980-81 levels
- What explains higher prices since 2002?
  - Price increase in summer 2008 and price crash in autumn of 2008
  - Will forecasted higher real prices occur or will lower current prices persist
- Is the world running out of fossil fuels?

Just What are Proven Reserves?

- Estimate of resource that is recoverable using *existing technology* at *pre-specified price*
- Example—European Coal
  - Before 1800, concern expressed that Europe would run out of coal
  - Billions of tons of coal left in ground in Europe
    - Not economic to extract and burn given current oil and natural gas prices
- Technological change continually occurring in exploration, extraction, and recovery of oil, natural gas, and other fossil fuels



Reserves Are An Economic Commodity

- "The total mineral in the earth is an irrelevant non-binding constraint. If expected finding-development costs exceed the expected net revenues, investment dries up and the industry disappears. Whatever is left in the ground is unknown, probably unknowable, but surely unimportant; a geological fact of no economic interest."
  —Morris Adelman, noted energy economist
- Estimates of world oil "ultimate reserves" based on something that creators of these numbers do not know: future science and technology
  - Ultimate reserves are fundamentally unknowable and guesses are bound to be wrong

Technical Change versus Depletion

- In 1875, John Strong Newberry, Chief Geologist of State of Ohio predicted rapid depletion of oil
  - Similar claims continue to present time
- While it cannot be denied that oil and natural gas reserves are being consumed
  - Technological change rapidly adding to reserves
- Continual competition between technological change and depletion of oil and gas reserves extracting using existing technology
  - Until recently technological change appears to be winning

Don't Bet Against Innovation

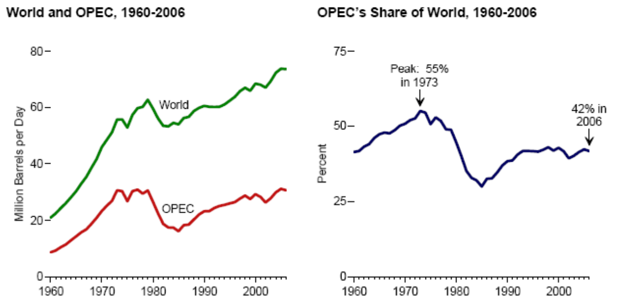
- In 1980 Julian Simon (economist) bet against Paul Ehrlich (biologist) that any basket of 5 metals (chosen by Ehrlich) worth $1000 in 1980 would be worth less in real dollars in 1990

Metal	1980 price (1980 dollars)	1990 price (1980 dollars)	Percentage change
Copper (195.56 lbs.)	$200	$163	-18.5%
Chrome (51.28 lbs.)	$200	$120	-40%
Nickel (63.52 lbs.)	$200	$193	-3.5%
Tin (229.1 lbs.)	$200	$56	-72%
Tungsten (13.64 lbs.)	$200	$86	-57%

- In 1990, Ehrlich lost the bet and paid change in price of $576.07 to Simon

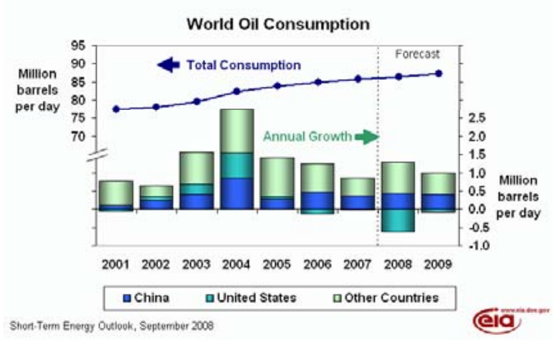
Explaining the Recent Real Price Increase

(World Oil Production)



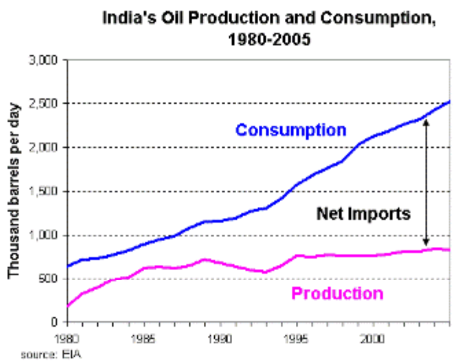
Factor 1: Despite having the vast majority of world's proven reserves, OPEC is producing a declining share world oil consumption

Explaining the Recent Real Price Increase



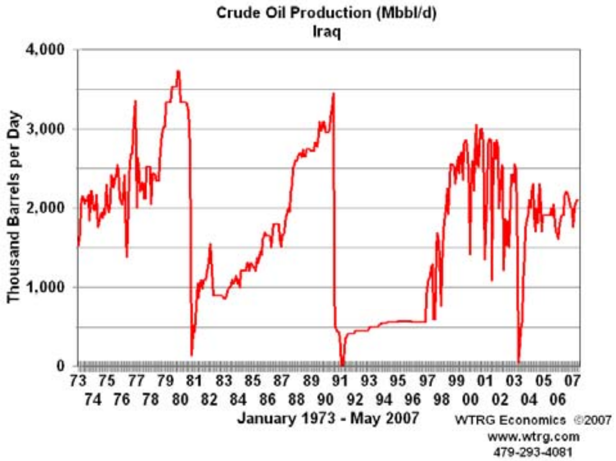
Factor 2: China accounted for 40% of world oil demand growth over past 5 years

Explaining the Recent Real Price Increase



Factor 3: Consumption growth in India has also accelerated recently

Factor 4: Wars in Middle East Do Not Help



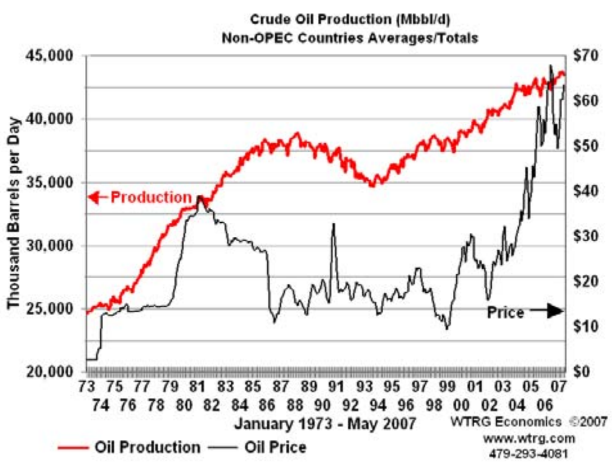
Is it Just About Supply and Demand?

- World supply historically planned for industrialized country demand growth
  - See consumption growth in China in 2000 and 2001
- Much more rapid demand growth in China and India occurred from 2002 onward
  - Due in part to below world-pricing of oil domestically in these countries
- Conclusion: Short-run supply growth relatively constant and unexpected rapid demand growth
  - Substantially higher real price of oil

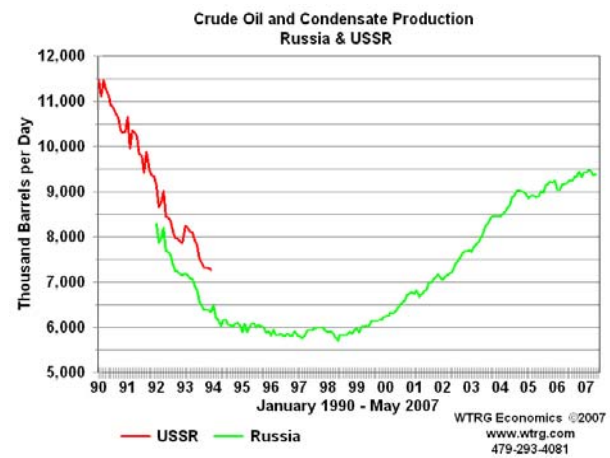
OPEC—A Poorly Enforced Cartel

- Much easier to maintain an agreement to raise prices above competitive levels with unexpectedly high demand
  - Particularly if production is subject to capacity constraints
- Sustained period of extremely low real oil prices during mid-1980s to early 2000 led to very little exploration and drilling activity for oil or natural gas

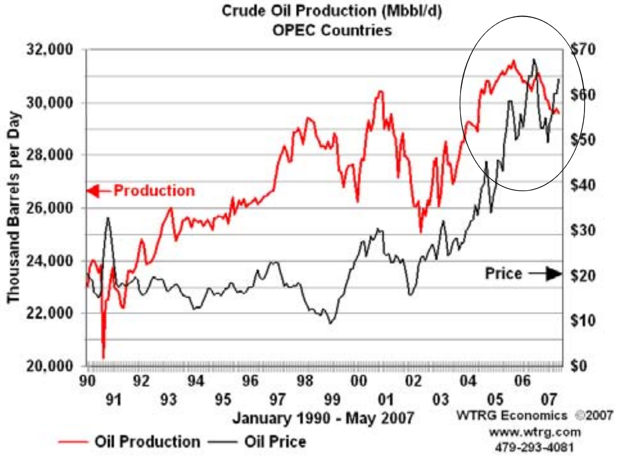
How Competitive Suppliers Respond to Higher Prices



How Competitive Suppliers Respond to Higher Prices



How Suppliers with Market Power Respond to Higher Prices



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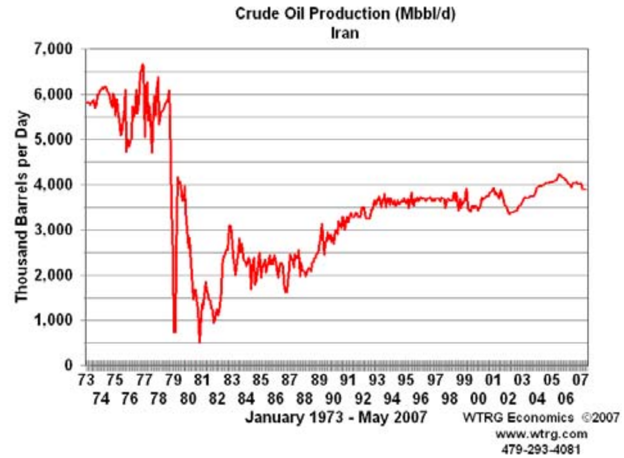
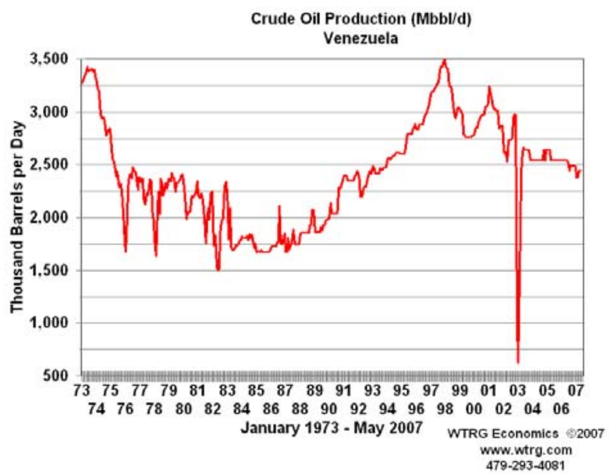


How Suppliers with Market Power Respond to Higher Prices



Exploration by Suppliers with Market Power

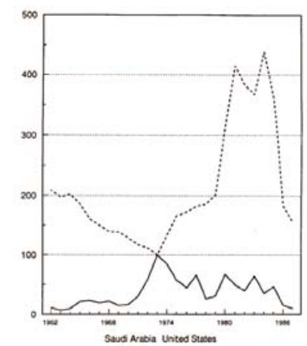
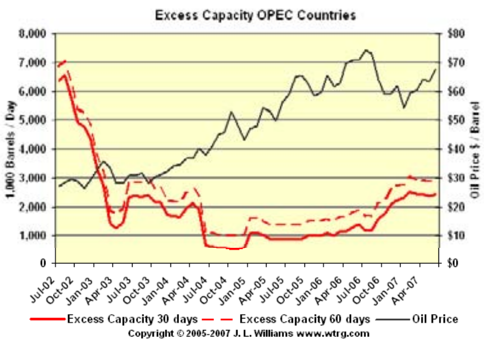


Figure 2 Number of oil wells drilled in the United States and in Saudi Arabia, using 1973 = 100. Source: Ref. 30, and previous August issues for respective years (annual international review).

Output Withholding to Increase Price

How Market Power is Exercised



Explaining Oil Price Fluctuations

- Nominal oil price increases have little to do with true scarcity
  - More to do with ability of members of OPEC to withhold output to drive prices up
- To maintain higher prices, cartels must pass up unilaterally profit-maximizing sales at very high prices to maintain jointly profitable prices
  - Given all other members of cartel produce at reduced cartel output, it is unilateral profit-maximizing for each cartel member to produce more
  - Cartel members find resisting this urge to deviate difficult because the governments of these countries need oil revenues
- Saudia Arabia, as largest producer, attempts to maintain coordinated output levels

Explaining Oil Price Fluctuations

- Fortunately for OPEC countries, world demand for oil had been growing rapidly (until recent recession) because of China and India
  - Industrialized country rate of demand growth slower
- Much easier for cartel to maintain higher prices if demand growth is unexpectedly high
- Fortunately for oil-consuming world, most OPEC countries are extremely dependent on oil revenues
  - Result: Defections from cartel output levels frequent when demand growth slows

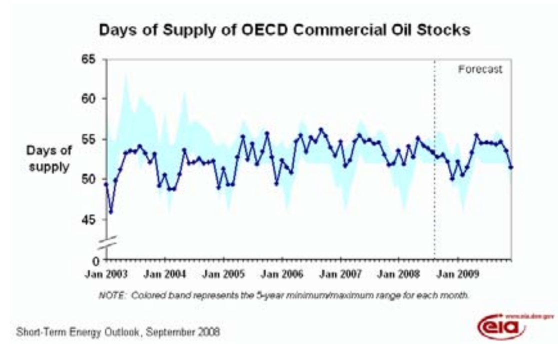
Are Speculators To Blame?

- What is a speculator?
  - Buys something it has no intention of consuming
  - Sells something it does not produce
  - Make money by buying low and selling high
- Implication--Unless speculators take a net position in short-term market, speculative supply equals speculative demand—no change in physical demand
- Conclusion--Speculators can only influence spot price by accumulating inventories of oil
- Question—How much oil would speculators have to put in inventory to raise price by $25/bbl relative to $100/bbl baseline

Are Speculators To Blame?

- Summer 2008 world oil demand = 82 million bbl/day
- Reduction in world demand necessary to raise price by \$25/bbl relative to baseline of \$100/bbl is 2.5 percent of world demand (using recent elasticity estimate)
  - Demand reduction of 2.125 million/bbl per day
- Over course of year this is 775 million barrels which is roughly capacity of US Strategic Petroleum Reserve (SPR)
- Conclusions
  - If speculators are influencing world oil prices on order of magnitude claimed, they would need to be storing lots of oil
  - Releasing 100 million bbls from SPR has was recommended by Speaker Pelosi and others would have no discernable impact on world oil prices

OECD Inventories are Large and Relatively Constant

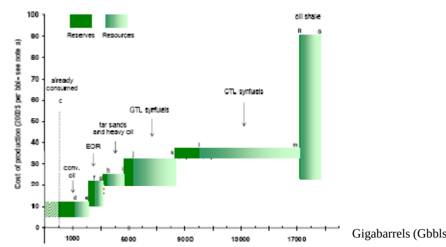


Are We Running Out of Fossil Fuels?

- People with money on the line don't think so
  - New York Mercantile Exchange runs a futures market for oil
  - Futures contract—Purchase right to delivery of oil at a future date
    - May 2012 contract—Right to one barrel of oil in May 2012
  - Deliveries in December 2015 are selling for \$87 per barrel
  - Delivery of oil in March 2010 are selling for \$82 per barrel
- If owner of oil thinks prices in the future will be extremely high, there is a profitable intertemporal arbitrage opportunity
  - Expects \$200/bbl in 2011 versus \$82/bbl right now
  - Resources owners keeps oil in ground instead of producing now
- If everyone does this, price rises now and falls in future
  - Owners of oil reserves always have this option
- Futures and forward market provide price signals for
  - Existing suppliers to produce more or less in current period
  - New suppliers to enter market to sell in future periods
  - Powerful force to ensure that we do not run out oil unexpectedly

Are We Running Out of Fossil Fuel?

Many fossil fuel SCPs (substitutes for conventional oil) are economic at the current price of oil



Taken from: "Scraping the bottom of the barrel: Greenhouse gas emission consequences of a transition to low-quality and synthetic petroleum resources" by Adam R. Brandt and Alexander E. Farrell

EOR= enhanced oil recovery
GTL = gas-to-liquid synfuels
CTL = coal-to-liquid synfuels

Dealing with OPEC's Destabilizing Actions

- OPEC harms pricing process by creating periodic artificial scarcities of oil when they are able to coordinate on output levels
- Dealing with OPEC is no different from how consumers should deal with any other supplier or group of suppliers with market power
  - Consumers must have the ability to say no to higher oil prices by OPEC
  - Modern society needs energy to prosper
  - Flexibility in demand needed to limit OPEC's market power

Limiting OPEC's Market Power

- Increase number of substitutes for OPEC oil
  - Natural gas and oil sands, EOR, GTL, CTL
  - Fuel switching capability in oil-using capital stock
    - Brazil's solution to high fossil fuel prices is cars that can burn ethanol (from sugar cane), gasoline and natural gas
  - Increase use of natural gas in non-traditional sectors
    - Transportation
- Increase extent of integration of world natural gas market

US Natural Gas Market

- Current market for natural gas is a North American market
  - Canada is major source of natural gas imports
  - New technology for horizontal drilling has made it feasible to exploit many new sources of natural gas in US
    - Marcellus shale in Appalachia
    - *Technical change wins again over depletion at existing technology*
- US is a very limited participant in world natural gas market
  - Liquified natural gas (LNG) is major source of natural gas to Asia and Western Europe
- Besides being the most environmentally friendly fossil fuel (very clean burning), natural gas availability increases alternatives to OPEC oil
  - Limits OPEC's market power over price of oil
- Natural gas in US currently sells at substantial $/BTU discount relative to oil roughly $15/MMBTU for oil versus $4/MMBTU for natural gas

US Unconventional Gas Market

The first category of unconventional gas contains resources that are currently contributing significantly to U.S. gas production, although development methods and technologies continue to evolve. These resources are described as follows:

Unconventional Natural Gas in Low-Quality Reservoirs

Definition: *Quantities of natural gas that occur in continuous, widespread accumulations in low quality reservoir rocks (including low permeability or tight gas, coalbed methane, and shale gas), that are produced through wellbores but require advanced technologies or procedures for economic production.*

Tight Gas is defined as natural gas from gas-bearing sandstones or carbonates with an *in situ* permeability (flow rate capability) to gas of less than 0.1 millidarcy. Many tight gas sands have *in situ* permeability as low as 0.001 millidarcy. Wells are typically vertical or directional and require artificial stimulation.

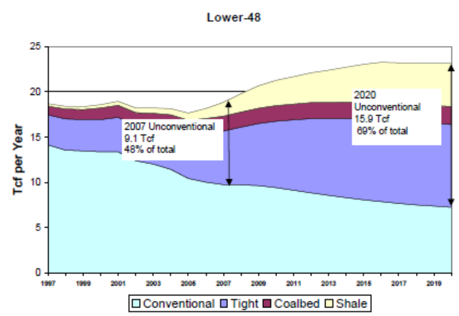
Coalbed Methane is defined as natural gas produced from coal seams. The coal acts as both the source and reservoir for the methane. Wells are typically vertical but can be horizontal. Some coals are wet and require water removal to produce the gas, while others are dry.

Shale Gas is defined as natural gas from shale formations. The shale acts as both the source and reservoir for the methane. Older shale gas wells were vertical while more recent wells are primarily horizontal with artificial stimulation. Only shale formations with certain characteristics will produce gas.

Shale Oil with Associated Gas is defined as associated gas from oil shale in horizontal drilling plays such as the Bakken in the Williston Basin. The gas is produced through boreholes along with the oil.

US Unconventional Gas Market

Figure 1 Lower-48 Natural Gas Production Forecast



US Unconventional Gas Market

Figure 4 Shale Gas Basins of the Lower-48.

Source: Modified from Schlumberger presentation, 2005 [7]

US LNG Market

- Four operating LNG terminals on east coast and gulf coast
- No operating LNG terminal on entire Pacific coast
  - From Canada down to Baja California in Mexico
- Since 2000, over 12,000 MW of new gas-fired generation capacity has been brought on line in California, roughly 25 percent increase in California's total installed capacity
  - Neighboring western states are also constructing substantial amounts of natural gas-fired generation facilities—Arizona, Nevada, and Colorado
  - Virtually all new generation capacity build in US is natural gas-fired
- Current US natural gas prices are $4/MMBTU
  - NYMEX estimates prices in $7/MMBTU to $8/MMBTU range until 2016
    - Last contract delivery data with open interest
  - LNG likely to be economic at these prices

Benefits of Greater Share of LNG in US Energy Mix

- Natural gas can be burned in Combined Cycle Gas Turbine (CCGT) at much greater efficiency than in conventional steam turbine generation facility
  - Roughly 7000 BTU/Kwh heat rate versus 10,000 BTU/Kwh for steam turbine
  - State-of-the art pulverized coal facility has roughly 10,000 BTU/Kwh heat rate
  - Less CO_2 emissions per Kwh of energy produced from using natural gas in CCGT relative to steam turbine with any fossil fuel
- Fewer emissions from burning natural gas relative to oil and coal
  - Significantly less NOx than oil or coal
  - Virtual no SOx emissions from gas relative to oil and particularly coal
  - Fewer particulates from natural gas relative to oil and particularly coal

Barriers to Increased Natural Gas Use

- Difficult to see how future natural gas demand will be met at close to world price of LNG without significant expansion of LNG facilities on West Coast
- Post-2000 natural gas prices make a LNG facility very profitable in California
  - Breakeven prices for LNG are between $4/MMBTU to $5/MMBTU
  - Prices are currently in the range of $8/MMBTU to $9/MMBTU
- Declining costs for liquefaction plant construction, LNG tankers, and re-gasification facilities over past ten years
- Efficient LNG re-gasification plant scale would entail roughly 800,000 MMBTU per day capacity
  - Slightly more than 10 percent of California's daily demand

Global Warming Benefits of World Natural Gas Market

- Roughly 5 percent of rest-of-world natural gas flared off versus 1 percent of US natural gas production in 1999
  - Some of flaring off of natural gas due to inability to transport natural gas to market where it can be sold
- Flared-off natural gas still produces CO_2, NOx without producing any useful energy
- Greater world demand for LNG would likely reduce amoutn flaring off of natural gas and amount of emissions produced without useful energy being produced
- Amount natural gas flared off in 1999 outside of US was roughly equal to California's annual demand for natural gas
  - Significant global environmental benefits are possible from greater world demand for natural gas

Canada's Role in US Fossil Fuel Future

- Major supplier of oil and natural gas to US
- Alberta has a massive oil sands desposits
  - Canadian Energy Research Institute (CERI) claims they are second only to Saudi Arabia
    - Currently producing 1 million barrels per day
    - Potential to increase to 5 million barrels per day
  - Technology beats scarcity again
- Oil sands are financially viable because of higher oil prices
  - $25/bbl to $30/bbl is estimated to be long-run breakeven price
- Many other "synthetic oils" become viable if oil prices remain at current levels

Other Important Factor

- National Oil Companies (NOCs)
  - A major change in world oil market over past 10 years is dominance of NOCs, oil companies owned by government
- Roughly 80 percent of proven oil reserves held by NOCs
  - NOCs do not have clear objective function
- Shareholder-owned firms have strong incentive to maximize discounted present value of resources in ground
  - Strong incentive to explore for more oil if this is profitable
- One model for NOCs is Target Revenue Model
  - Achieve revenues from sales of oil to carry out government activities

National Oil Companies

Table A7-1. NOC's in PIW ranking of the world's 50 largest oil companies.

Rank 2005	Rank 2004	PIW Index	Company	Country	State Ownership (%)
1	1	30	Saudi Aramco	Saudi Arabia	100
3	4	39	NIOC	Iran	100
4	3	44	PDV	Venezuela	100
7	9	68	PetroChina	China	90
10	9	83	Pemex	Mexico	100
12	12	96	Sonatrach	Algeria	100
13	13	100	KPC	Kuwait	100
14	14	106	Petrobras	Brazil	32
15	24	108	Gazprom	Russia	50
17	16	132	Adnoc	UAE	100
19	18	137	Petronas	Malaysia	100
20	21	143	NNPC	Nigeria	100
22	25	156	LibyaNOC	Libya	100
23	22	168	INOC	Iraq	100
24	23	183	EGPC	Egypt	100
24	26	183	QP	Qatar	100
26	31	185	Rosneft	Russia	75
28	28	189	Sinopec	China	55
29	30	191	Statoil	Norway	71
30	32	224	ONGC	India	74
33	15	253	Pertamina	Indonesia	100
34	37	277	SPC	Syria	100
35	34	283	PDO	Oman	60
36	38	292	Socar	Azerbaijan	100
40	35	310	Ecopetrol	Colombia	100

Source: Petroleum Intelligence Weekly (2007), on line:
http://www.energyintel.com/DocumentDetail.asp?document_id=137158

Other Contributing Factors

- Two ways for NOCs to achieve necessary revenues
  - Higher prices for existing or smaller amount of production
  - Greater production from existing reserves
- Greater production from existing reserves far more risky because it requires exploration and development
  - Considerable expense of money by NOC that could be used elsewhere in government
  - Recall reserve to production ratios shown earlier
- Conclusion--NOCs such as PDV in Venezuela may have little interest investing to supply oil in future
- NOC control of oil reserves creates challenge for future oil supply adequacy

If We Aren't Running Out then What Are the Problems?

- Managing market power of OPEC
  - Developing world market for natural gas
  - Developing economical near oils and natural gases
  - Increasing flexibility of fuel-using capital stocks
- Managing technological change in fossil fuel exploration, development and consumption
  - Make more efficient use of what we have
- Getting NOCs to develop resources to supply future demand

Environmental Concerns

- Fossil fuel consumptions results in
  - Carbon dioxide emissions
  - Coal consumption produces
    - SO_2 emissions and coal ash disposal
  - Natural gas consumption produces
    - NO_x and other particulates
- Cost to reclaim lands after resource deposit is exhausted
- Paying full cost (including environmental cost) of producing and consuming fossil fuel

Environmental Concerns

- Producing and consuming fossil fuels results in environmental costs that are not fully borne by entity that produces or consumes fuels
- Economists call these costs an "externality"
  - Private cost of producing and consuming fossil fuels less than cost to society from producing and consuming fossil fuels
- Addressing this problem requires producers and consumers of fossil fuels to pay full cost (including environmental cost) of producing and consuming fossil fuels

Environmental Concerns

- Two preferred ways to set price for environmental cost of producing and consuming fossil fuels
  - Carbon fee--$/ton fee paid for emitting greenhouse gas emissions based on CO_2-equivalents produced
  - Cap and Trade mechanism where all emitters of GHG emissions must own or purchase permit for every ton of CO_2-equivalents of GHG emissions they emit
- Either approach can achieve reductions in GHG-emissions content of energy services consumed at least cost to society

Environmental Concerns

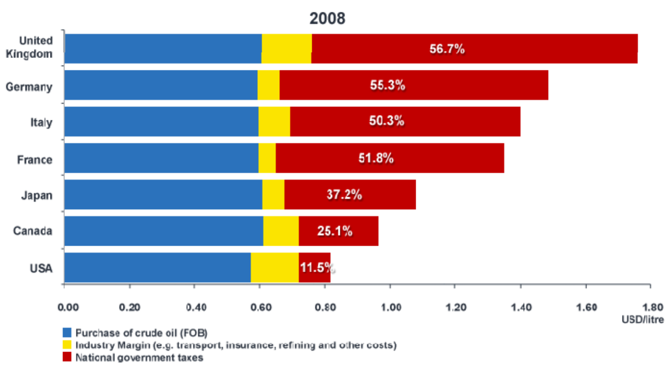
- Which approach--carbon fee or cap and trade mechanism--is preferred from economic perspective depends in large part on what is better understood
  - If cost of additional ton of CO_2-equivalents of GHG emissions to society is known then carbon fee is preferred
  - If maximum allowable total GMG emissions in CO_2-equivalents is known then cap and trade is preferred

Environmental Concerns

- In general, other policies are significantly higher cost approaches to achieving GHG emissions reductions
  - Renewable portfolio standards (RPS)
  - Corporate average fuel efficiency (CAFE)
  - Low-carbon fuel standards (LCFS)
  - Subsidies to renewable energy sources
    - Wind
    - Solar PV and Solar Thermal
- Stable and predictable price of carbon into the distant future is generally acknowledged to be least cost approach to achieving GHG emissions reductions

Pricing Carbon is Possible

Who gets what from a litre of oil in the G7?



The Growing Cost of Inaction

- Uncertainty in US climate policy makes many economic investments in near oils too risky
  - Most near oil projects or expensive conventional oil projects require massive up-front investments to produce at relatively low marginal cost
- Coal-to-liquids is economic at current price of oil
  - These investments could significantly reduce world demand and price of oil
  - A non-zero price of carbon would have very adverse consequences on the financial viability of this investment because coal-to-liquids implies roughly twice the carbon produced per unit of useful energy
    - Massive increase in variable cost of production due to carbon cost

The Growing Cost of Inaction

- Fear of a carbon price that renders up-front investment in carbon intensive energy source uneconomic prevents these investments in the first place
- Conclusion—Uncertainty in carbon policy has additional cost that high oil prices can be maintained despite existence of financially viable alternatives at current price of carbon
- Further reason to address climate policy as soon as possible

Conclusions

- Little evidence world is running out fossil fuels
  - More evidence that OPEC is currently having an easier time exercising market power because of series of fortunate (for them) events
- Integration of world fossil fuel market limiting OPEC ability to exercise market power
  - Developing LNG and near oils and natural gas
- Real problem—How to set a stable and predictable price of carbon into the distant future