2008 Update to the National Petroleum Council Report
Hard Truths: A Comprehensive View to 2030 of Global Oil and Natural Gas

Topic Paper

ENERGY SUPPLY

On July 18, 2007, the National Petroleum Council (NPC), in approving its report *Facing the Hard Truths about Energy,* also approved making available certain materials used in the study process, including detailed, specific subject matter papers prepared or used by the Task Groups and their Subgroups. These Topic Papers were working documents that were part of the analyses that led to development of the results presented in the report's Executive Summary and Chapters.

On September 17, 2008, the NPC approved an update that assessed the implications of recent energy outlooks and events on the *Hard Truths* Report's findings and recommendations. As with the original report, the NPC again approved making available certain materials used in the study process, consisting of a Supply Topic Paper prepared for the use of participants in the update.

This Topic Paper represents the views and conclusions of the authors. The National Petroleum Council has not endorsed or approved the statements and conclusions contained in this document, but approved publication of this material as part of the study process.

The NPC believes that this paper will be of interest to readers of the *Hard Truths* Report and its update, and will help them better understand the results. This material is being made available in the interest of transparency. The attached Topic Paper is one of 39 such working documents used in the original study analyses and its update.

NATIONAL PETROLEUM COUNCIL

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Introduction

This paper supplements the 2008 Update to the 2007 National Petroleum Council (NPC) Report, *Facing the Hard Truths about Energy: A Comprehensive View to 2030 of Global Oil and Natural Gas*.[1] The paper includes additional information that reconfirms the 2007 findings about prospective energy supplies and makes them more urgent.

1. In 2007, the NPC found that risks to energy supply were accumulating. Today, we reiterate that resources are ample on a global scale, but

   - Global liquids production growth has been slowing
   - Rising oil prices since 2002 have not created a liquids supply surplus to date.

   In a tight supply situation, small adjustments to supply will continue to have large effects.

2. The *Hard Truths* Report found that energy supply must be expanded and diversified to include all economically-viable energy sources. Today, we find that diversification has become embedded in the supply system but forecast energy requirements have grown.

   - Biofuels, for example, are embedded in energy supply, providing about 1 million barrels per day of oil equivalent. However, the projected growth of 1^{st} generation biofuels will flatten by 2015, requiring additional supply from 2^{nd} generation sources.

   Expansion and diversification of the supply system must accelerate as part of an integrated U.S. national energy policy.

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3. The 2007 Report noted that the scale and timing of energy investment and infrastructure were immense and decades-long. Today we find that rising capital costs and stressed supply chains are delaying timetables and completion of major energy projects and infrastructure.

   - Policies, regulatory uncertainty, and proposed single-source solutions compound the risk that less supply infrastructure will be built as the world needs more.

Although energy prices have been extremely volatile in 2008, we believe that the fundamental forces underlying global energy supply and the actions needed to ensure that supply are unchanged.

[1] Both the *Hard Truths* Report and the 2008 Update can be viewed and downloaded from the National Petroleum Council website, **www.*npc.org*.**

The Growing Liquids Supply Challenge

Figure 1 illustrates the challenge in filling the gap between projected demand and global liquids supply. The demand increase is based on EIA projections in which energy prices vary but fossil sources remain dominant. The potential annual production declines of 4% to 7% in existing production capacity are based on historical data.

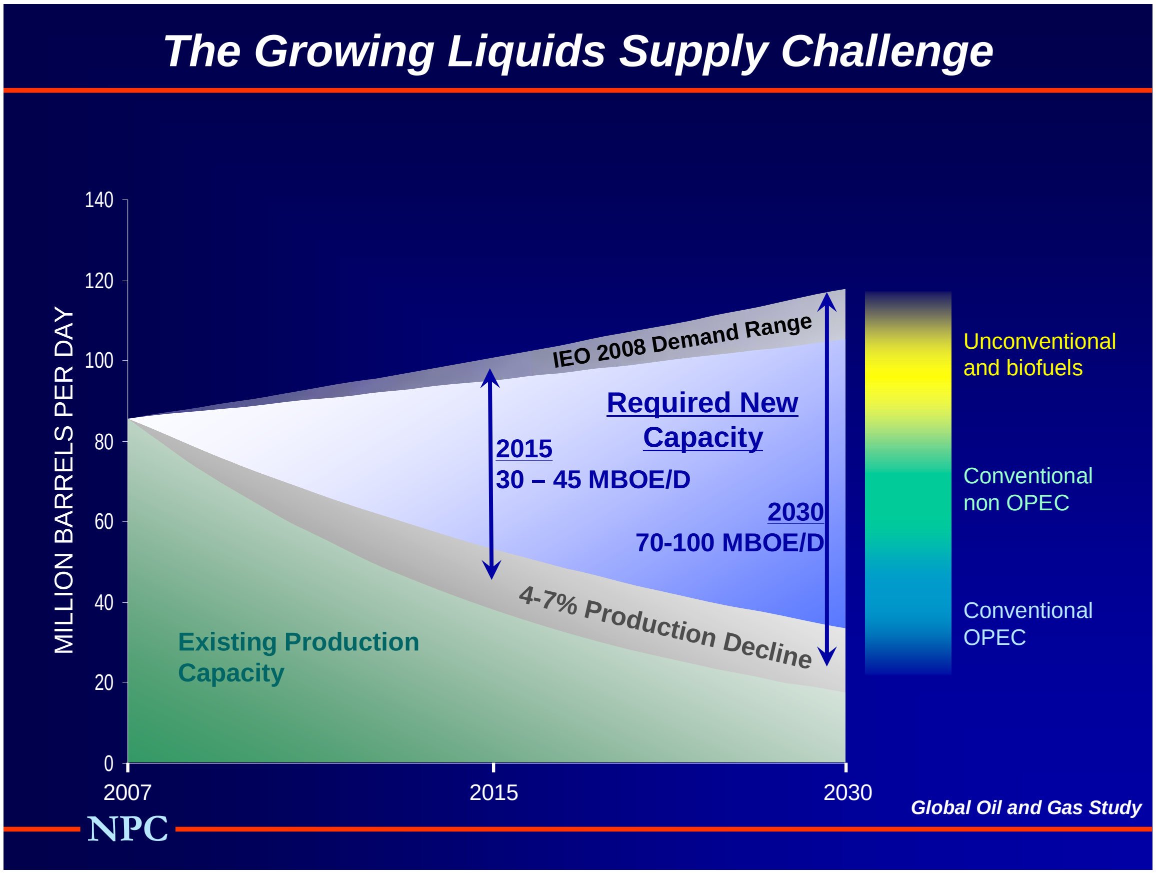

Figure 1. The Liquids Supply Challenge

Increasing demand and natural production decline create a growing need for large new production capacity. The gap between demand and supply in 2015 equals 1 to 1.5 times OPEC's current crude-oil production of about 30 million barrels per day. By 2030, the production gap could be equivalent to three OPEC's. The additional production will require increased investment, substantial contributions from conventional sources, and significant expansion of unconventional sources.

Figure 2 shows that even with dramatically increased investment, years are required to increase production. Complex developments, for example, may take 10 years to reach production from the time construction starts. The large investments required and long lead times increase the uncertainty about meeting the liquids supply challenge.

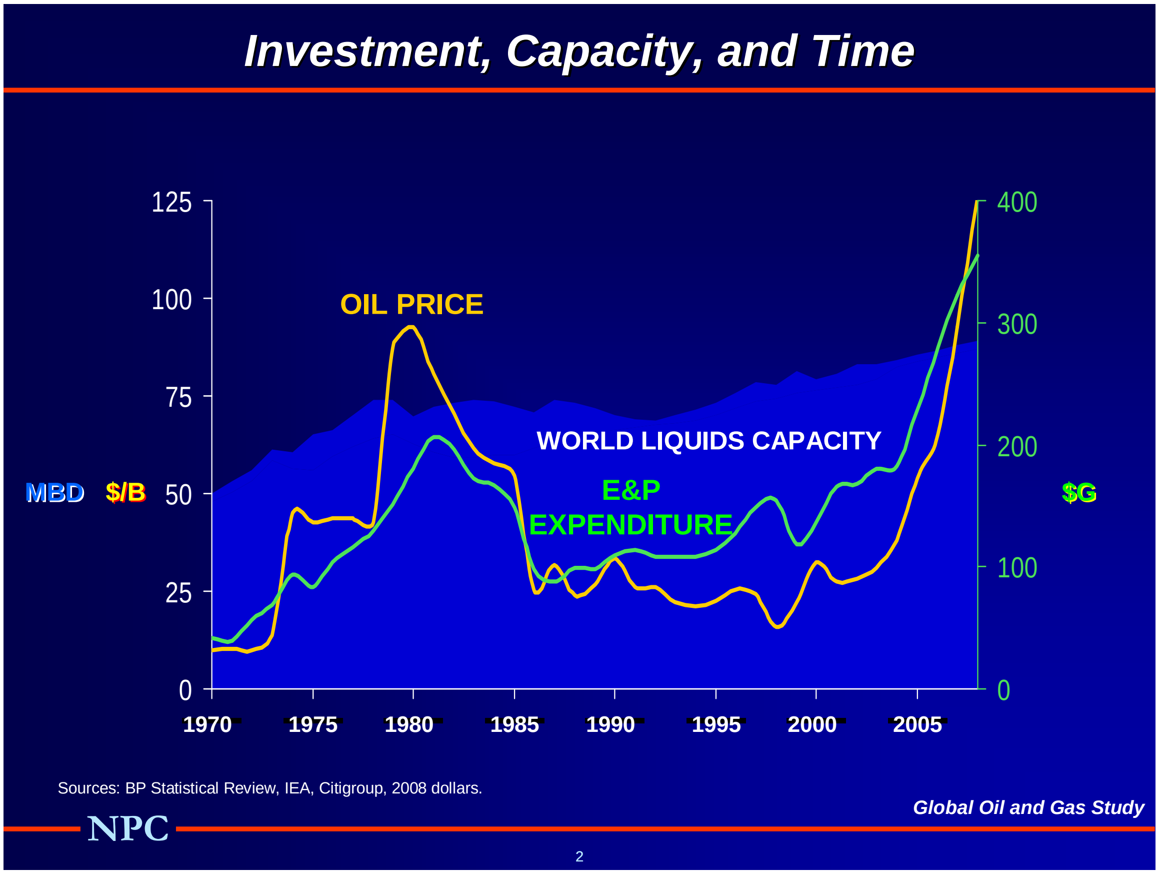

Figure 2. Interval between Investment and Production

In addition to the interval between investment and production shown in Figure 2, other indicators also suggest increasing risks to liquids production growth:

- Production is not growing commensurate with unprecedented investment levels.
- Increased costs and delays are hindering major development projects.
- Further growth of ethanol use after 2015 will require 2nd generation sources.

Hydrocarbon Resources and Endowment

The endowment of natural resources such as oil, gas, and coal is the basis of hydrocarbon supply. Figure 3 shows the United States Geological Survey (USGS) estimate of the global oil endowment in 2000. The endowment includes both conventional resources, which are found as oil and natural gas liquids (NGL), and unconventional resources such as tar sands and oil shale, which must be processed into liquids. Coal, natural gas, and biomass, which are not included in the oil endowment, represent significant additional sources of fuel and power.

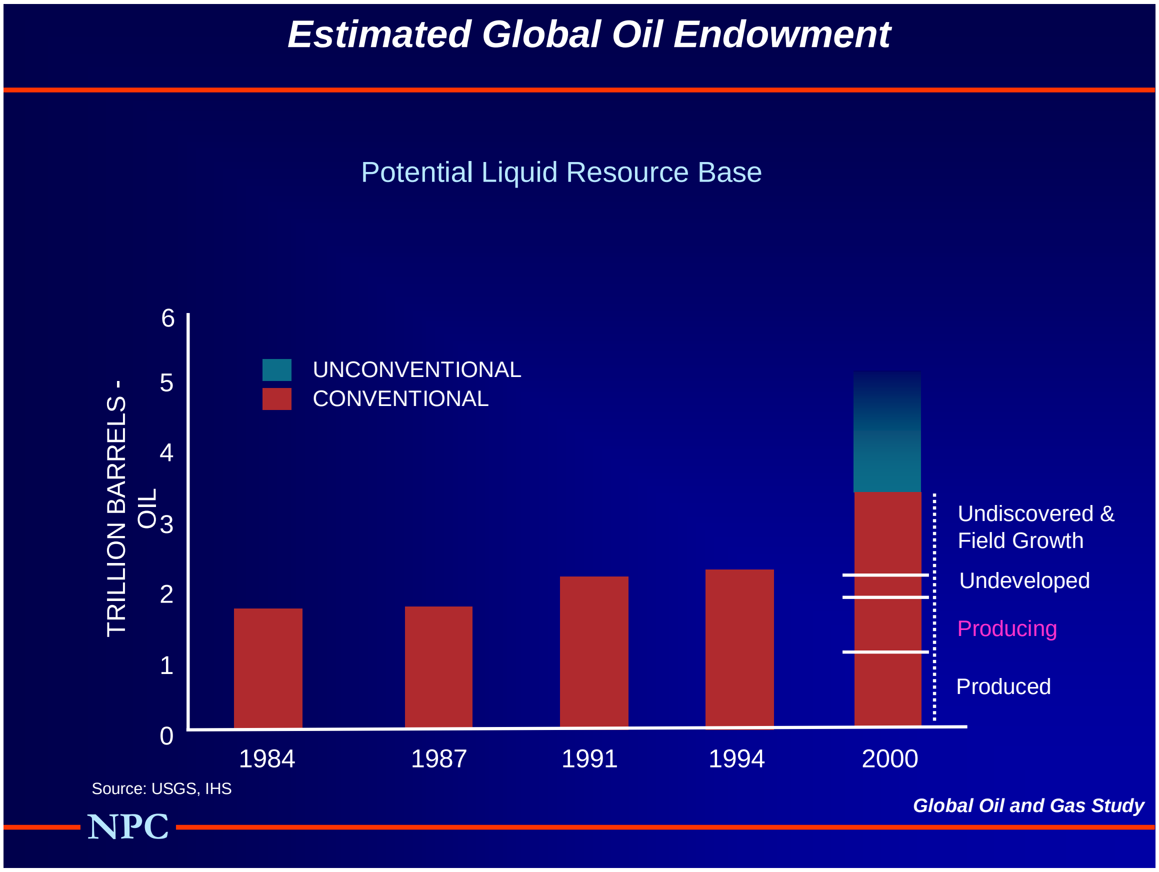

Figure 3. Estimated Global Oil Endowment

The USGS oil resource estimates shown in Figure 3 increase between 1984 and 2000, with total conventional and unconventional resources of 5 to 6 trillion barrels. Recent USGS regional assessments (2007 and 2008) indicate a larger resource endowment, while other estimates range up to about 7.5 trillion barrels. Resource estimates are essential to understanding future production, but provide no certainty about when or if resources will be available. The size and quality of the resource base provides long-term production opportunities, but only *producing* resources contribute to supply at any given time. Production is determined by the resources discovered and developed. The *rate* of resource discovery and development versus the *rate* of production is critical to understanding future supplies.

Many factors influence resource discovery, development, and production. On one hand, government restrictions, physical and geographic challenges (e.g., Arctic, Ultra-Deep Water), infrastructure constraints, and economics may adversely affect discovery and development. Conversely, technology, higher prices, and eased access can accelerate exploration, discovery, and production. These competing forces determine how much of the natural resource is developed and produced. Currently, the rate of oil discovery and development is barely sufficient to increase production volumes.

The global oil endowment shown in Figure 3 illustrates a general trend in which estimated hydrocarbon resources increase as geologic knowledge and prices increase. Figure 4 shows a large number of resource estimates through time as compiled by the USGS. The data support two observations. First, the estimates generally increase from the 1940s to the 1970s. Second, increases in both the number of estimates and quantity of resource correspond with high price environments. The correlation between high resource estimates and high price may be due to the belief that higher prices mean more resources will be found and economically produced. Figure 4 also indicates that today's estimates do not range as high as the 1970s, but have generally narrowed. For example, estimated conventional oil appears to be settling at 3 to 4 trillion barrels.

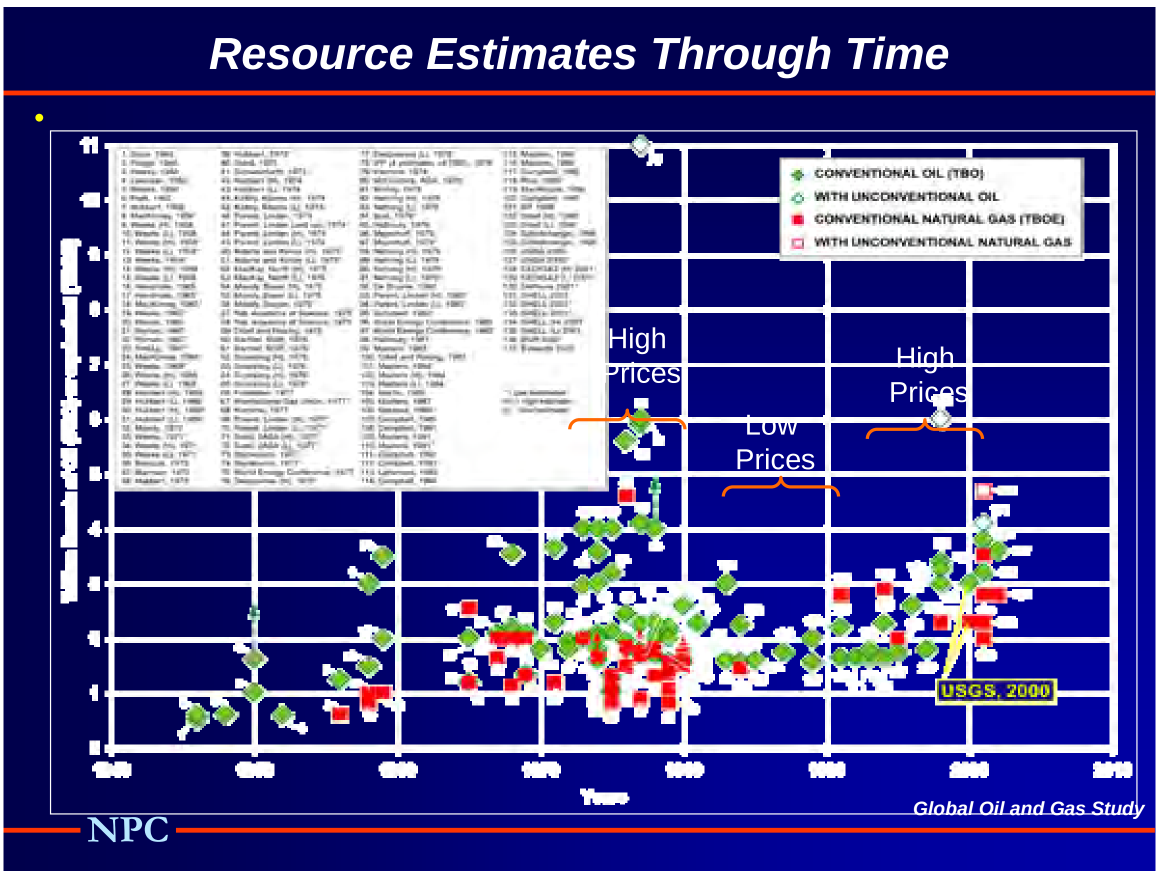

Figure 4. Oil and Natural Gas Resource Estimates 1940 - 2000

to price is limited because increasingly challenged liquid supplies can only be unlocked through expanded investment, access, technology, and infrastructure.

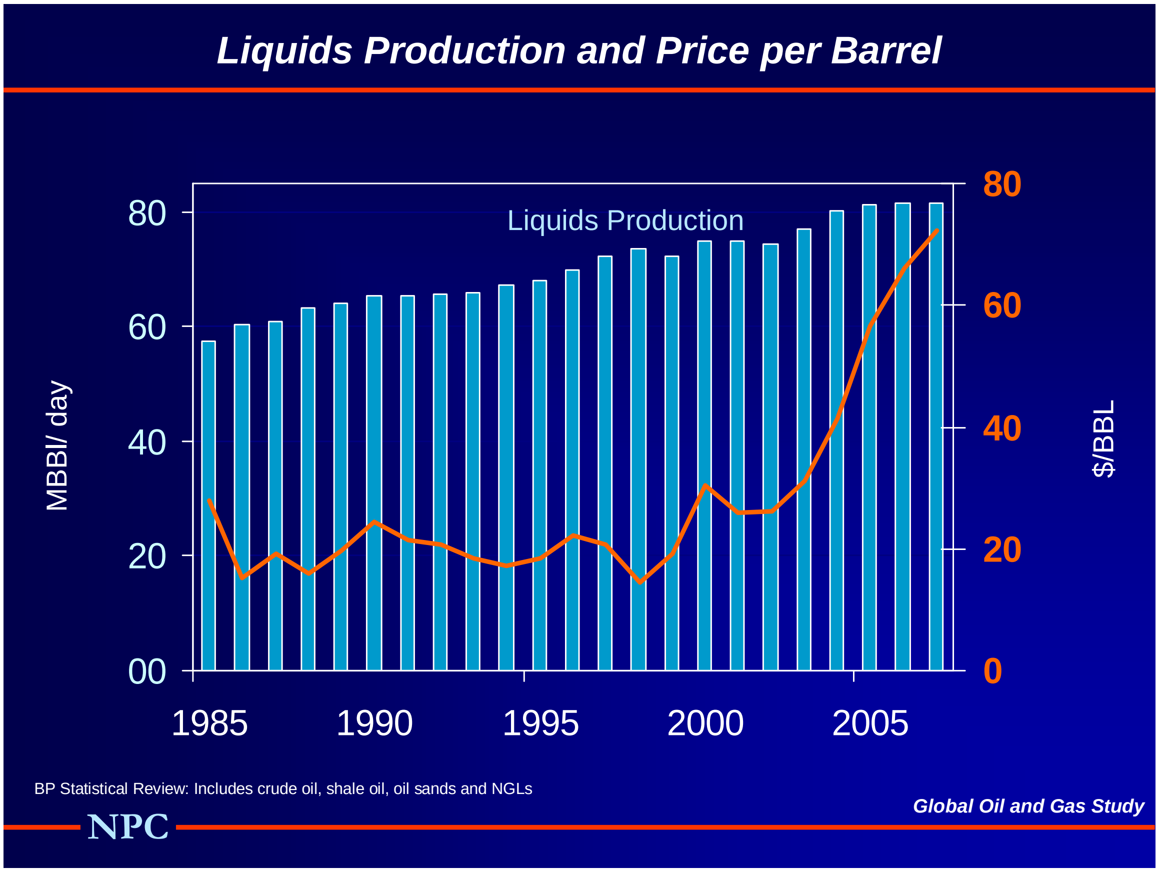

Figure 5. Oil Production and Price per Barrel 1985 - 2005

Global Supply Projections for Liquids

As noted in the *Hard Truths* Report, projected global liquids production in 2030 ranges from less than 80 million barrels per day (MMBD) to nearly 140 million barrels. The range represents a diverse set of sources, including integrated forecasts from the International Energy Agency (IEA) and Energy Information Administration (EIA); other publicly available sources such as the Association for the Study of Peak Oil (ASPO); and aggregated proprietary data from international energy companies (IOCs) and consultants.

The supply projections reflect different assumptions about:

- Decline rates in the existing production base
- Risks in current reserve estimates and their conversion to production
- The proportion of the resource actually produced (recovery factor)
- Enhanced recovery from existing fields
- The rate and timing of major investments
- The timing and scale of new discoveries

- The role of unconventional resources in overall liquid production.

Figure 6 shows representative 2008 liquids supply projections plotted against the 2007 range. The new projections are within the 2007 range and show increasing total liquids production. However, the highest projection (EIA High Economic Growth Case) is lower than the top of the 2007 range. The EIA and other lower 2008 projections may reflect reduced demand rather than supply limitations. For example, real prices in the EIA High Oil Price Case rise to approximately $120 per barrel by 2030. Even with large growth in unconventional liquids, total liquids production is projected at less than 100 MMBD.

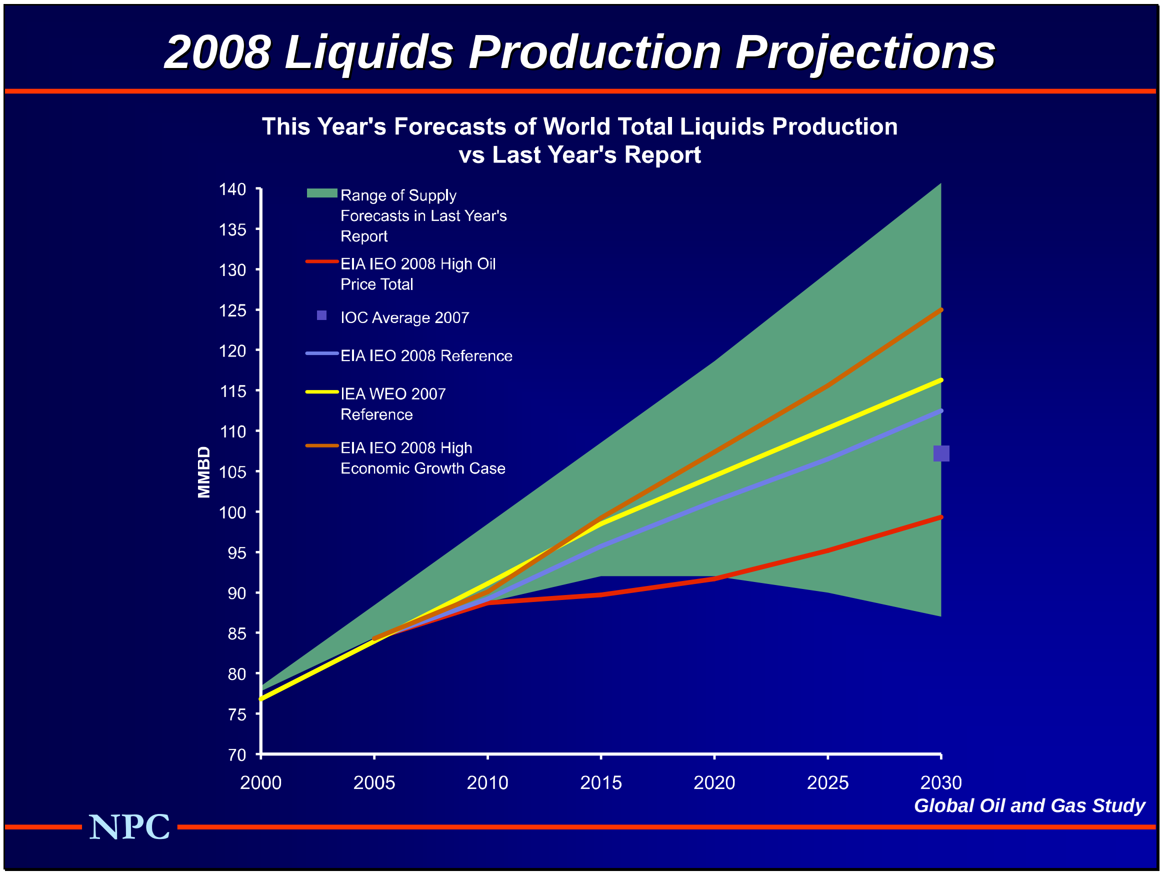

Figure 6. Projected Global Liquids Production

Projected OPEC Liquids Production

The projected OPEC share of global liquids production varies considerably, as shown in Figure 7. For example, OPEC market share in the IEA Alternative Policy Case grows from its current 42% to 46% in 2030, but is 6% and 14 MMBD lower than in the Reference Case.

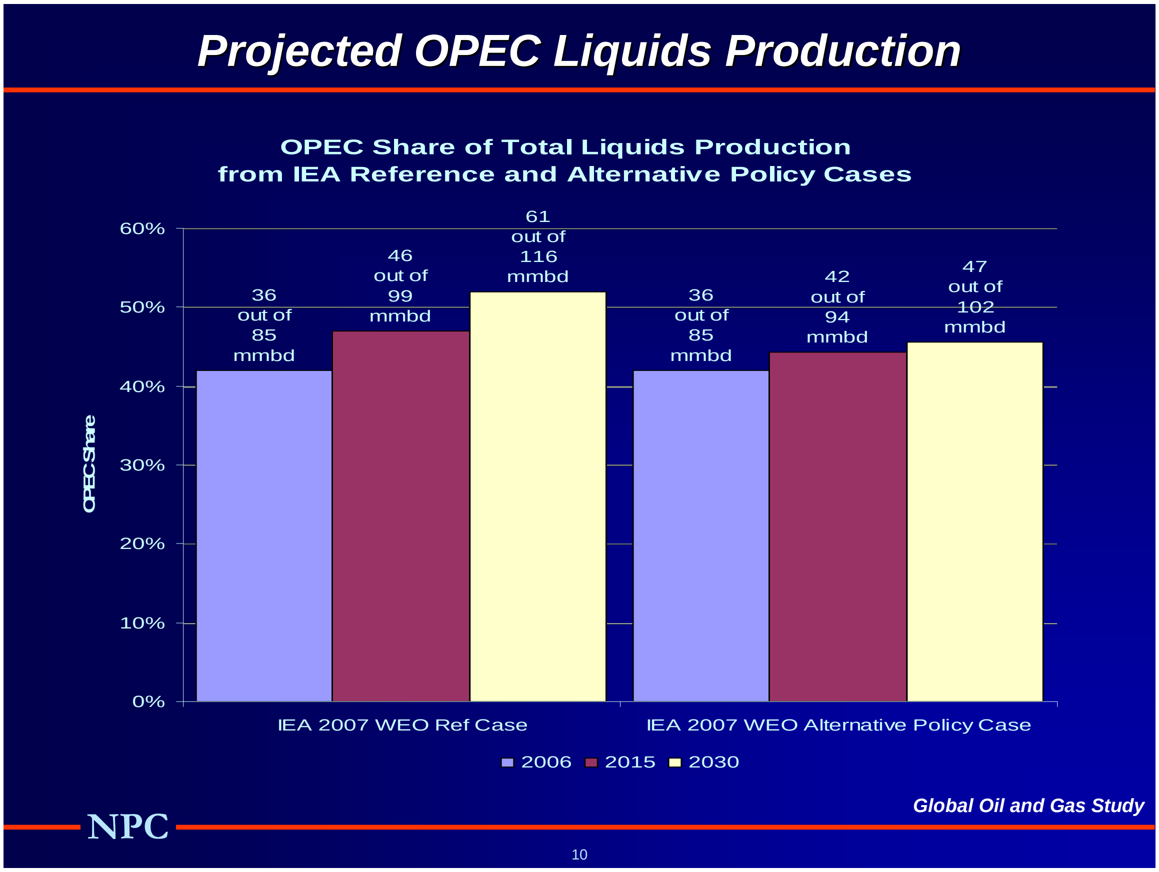

Figure 7. Projected OPEC Liquids Production

Conventional Oil Supply

Conventional oil production comprises about 85% of current total liquids production. Figure 8 shows the projected range for conventional production, updated with 2008 data. Recent projections indicate more uncertainty about the continued growth of conventional production. For example, the EIA High Oil Price case shows conventional oil production dropping 3.6 MMBD between 2010 and 2015 and remaining flat thereafter, while Shell's scenarios show a plateau after 2020. The difference in projections is largely based on assumptions about decline rates, access, OPEC investment, market requirements, technology, and other factors described above.

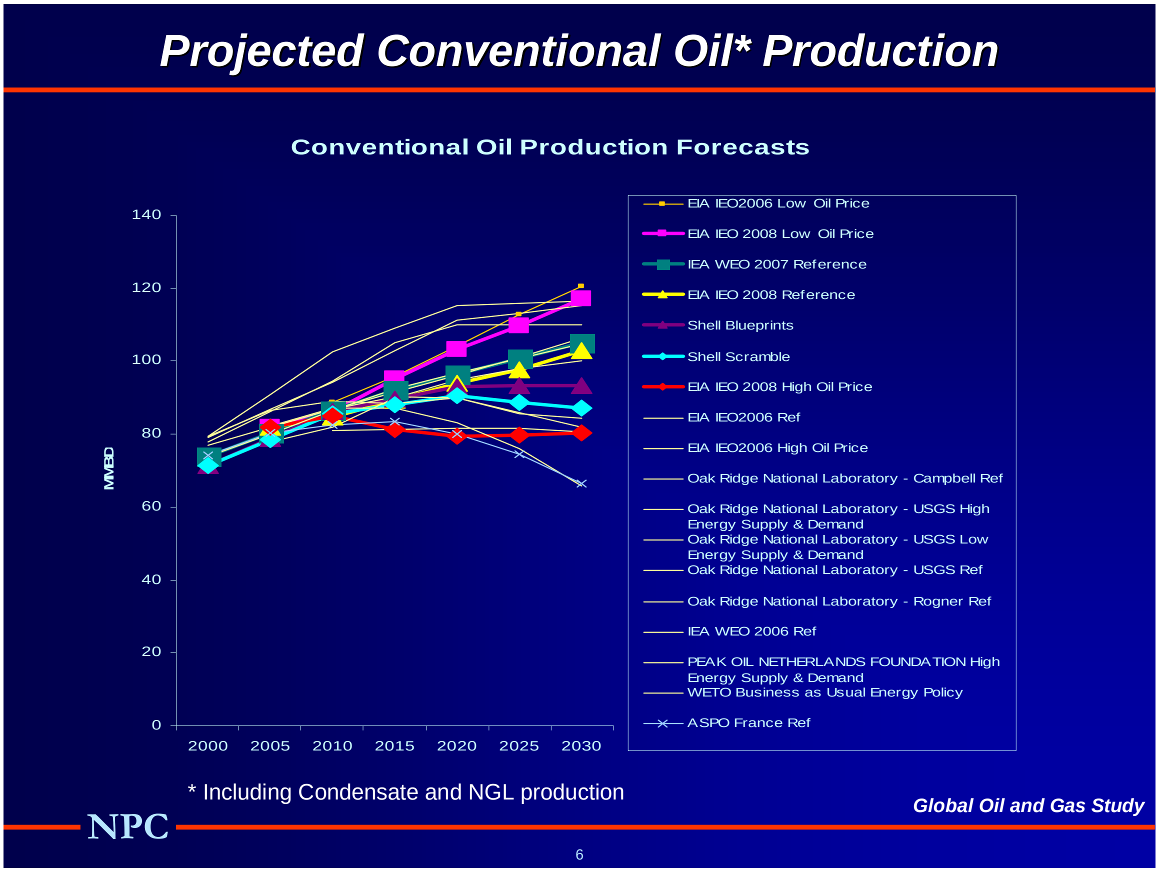

Figure 8. Projected Conventional Liquids Production

Unconventional Liquids Supply

Unconventional liquids are essential in most oil supply projections, although unconventional resources require significantly increased investment, continuing technology advances, potentially large carbon management infrastructure, and, in some cases, subsidies. Significant differences in projected unconventional supply result from the assumptions made about these requirements.

Figure 9 shows Reference and High Oil Price Cases for global unconventional liquids production. The IEO 2008 Reference Case projects approximately 9.5 MMBD from unconventional liquids, distributed as follows:

- Biofuels: 2.7 million barrels oil equivalent per day (MMBDOE)
- Oil sands: 4.2 MMBDOE
- Extra-heavy oil: 1.3 MMBDOE
- CTL: 1.0 MMBDOE
- GTL: 0.3 MMBDOE

The EIA 2008 High Oil Price Case calls for significant growth in unconventional liquids supply to 19 MMBD in 2030. In this case, total liquids production is less than 100

MMBD, but real prices of approximately $120/ barrel promote unconventional production.

Expanded production of bitumen, extra-heavy oil (XHO), gas-to-liquids (GTL), and coal-to-liquids (CTL) requires construction of very large conversion infrastructure at high capital cost. Upgrading also requires increased hydrogen production and CO2 mitigation.

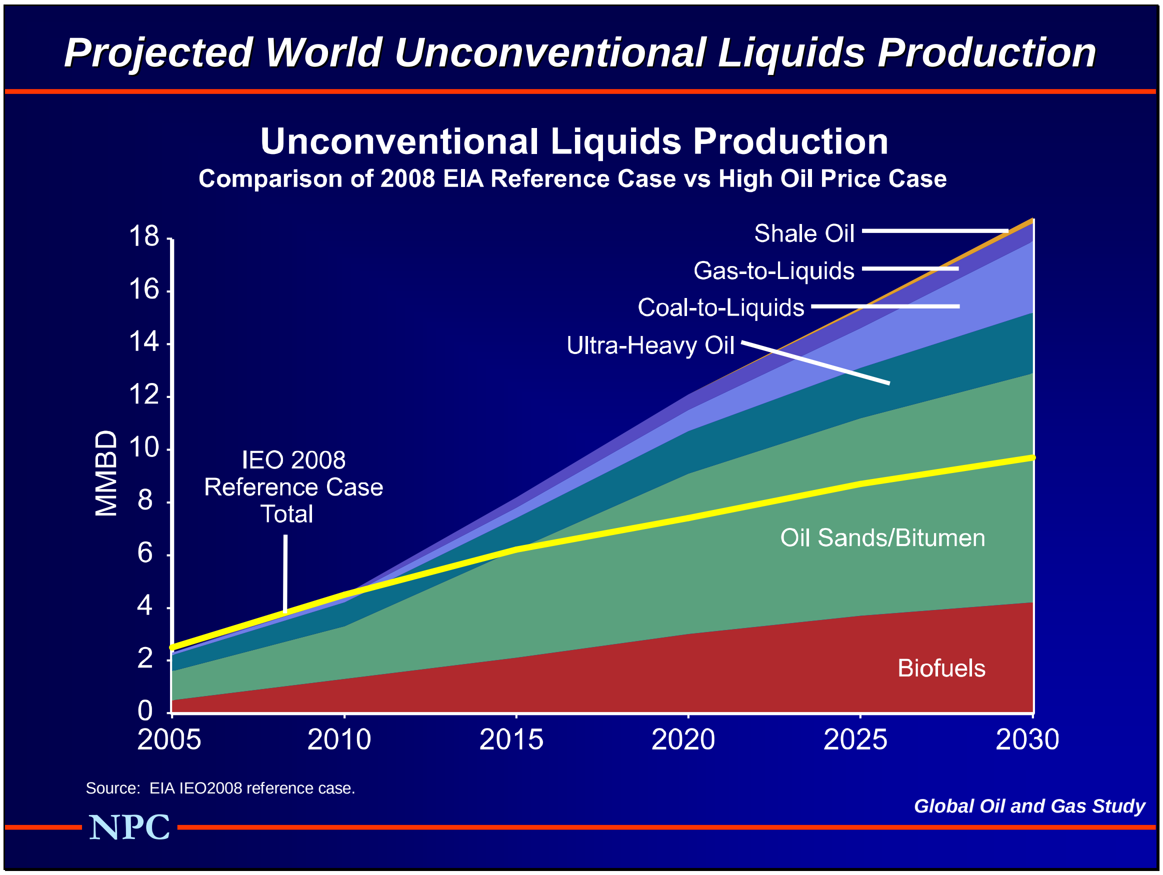

Figure 9. Projected Global Production of Unconventional Liquids

Within the global context for unconventional liquids, Figure 10 shows similar projections for the United States. In the very aggressive case shown, unconstrained assumptions yield a projected unconventional liquids supply of nearly 16 MMBD.

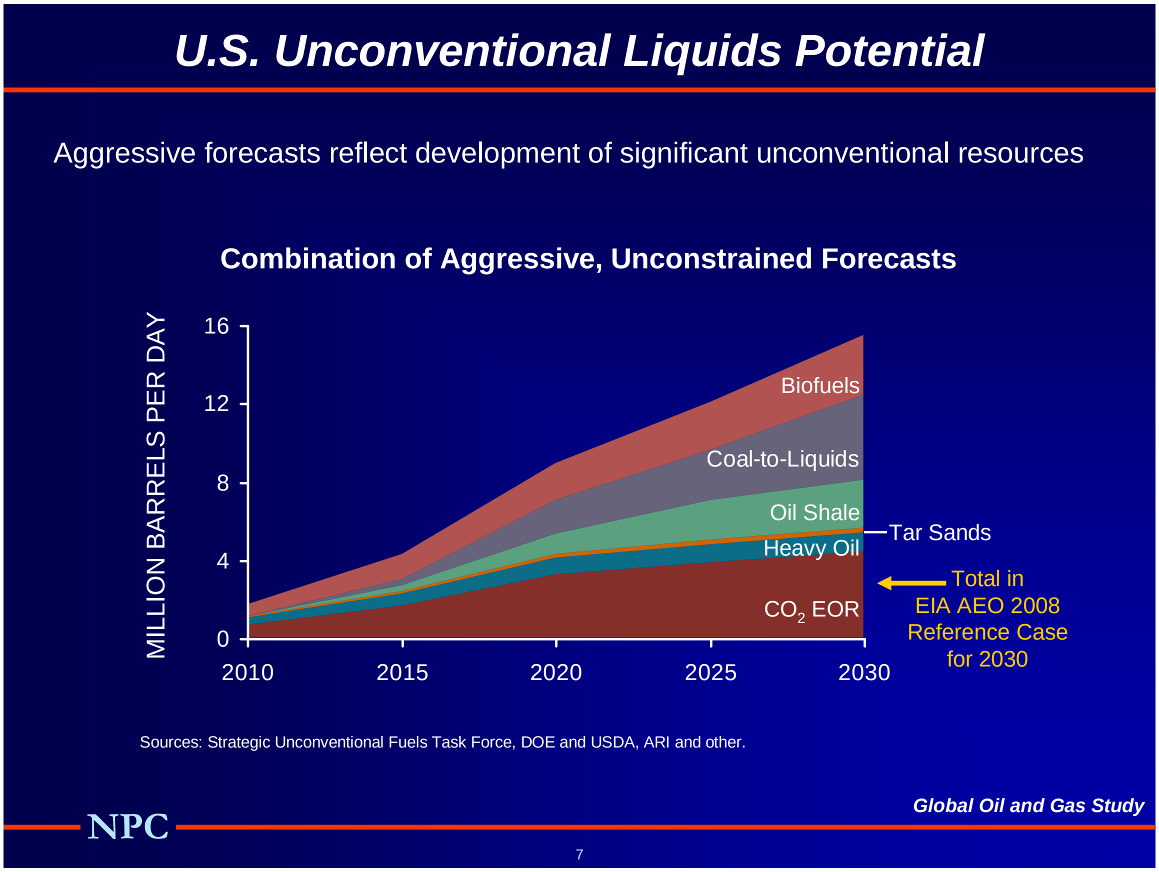

Figure 10. Projected U.S. Unconventional Liquids Production under Aggressive Assumptions

Upward Trend in U.S. Oil and Gas Production

In a notable development since publication of the *Hard Truths* Report, the annual growth rate for 2009 U.S. oil production could be positive for the first time in a decade (Figure 11). U.S. natural gas production has also increased 9% between 1st Quarter 2007 and 1st Quarter 2008. Reported future deepwater exploration and production are trending upward based on new discoveries, high production rates, technology, and a rise in oil and gas prices.[2]

The USGS has also released new estimates of technically recoverable oil, including the Bakken Formation (North Dakota and Montana) with almost 4 billion barrels.[3] This estimate is a 25-fold increase over earlier estimates and represents the largest onshore oil accumulation to date in the lower-48 United States. Activity in Barnett Shale, Bakken, Marcellus and deepwater Gulf of Mexico shows promise for future U.S. oil and natural gas production.

[2] U.S. Minerals Management Service, June 2008.
[3] United States Geological Survey, May 2008.

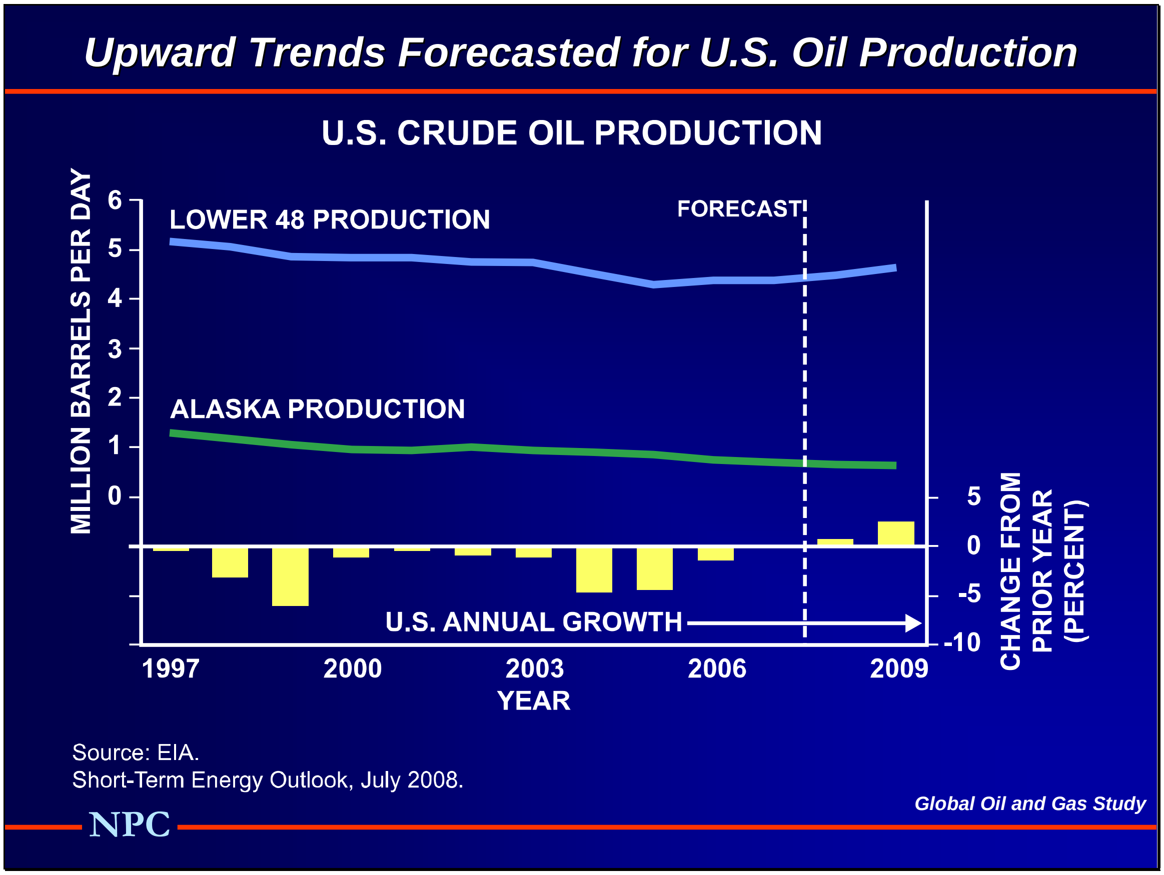

Figure 11. Uptrend in U.S. Projected Oil Production

Global Supply Projections for Gas

Natural gas has a broad range of supply projections, most of which are above the historical trend line (Figure 12). Both the 2007 projections and the 2008 updates indicate that supply can meet future natural gas demand to 2030.[4] However, the world will consume approximately 50 percent of the existing proved reserve base to meet the mid-range projections. Significant additional discovery and development will be required to replace the reserves. In addition, gas is less developed than oil. The global gas infrastructure that must be built – pipelines, terminals, processing plants – is significant and massive.

The EIA 2008 International Energy Outlook (IEO) projections for 2030 range between 394 and 476 billion cubic feet per day (BCF/D), depending on the rate of global economic growth (1.3% and 2.1%, respectively). Even the lowest projection is above the historical trend. The EIA Reference Case reduces global gas supply in 2030 by 13% from the 2007 Reference Case, from 498 to 433 BCF/D, still above the historical trend but considered feasible.

[4] This is not the case in the 2008 Shell International BV, *Shell Energy Scenarios to 2050*

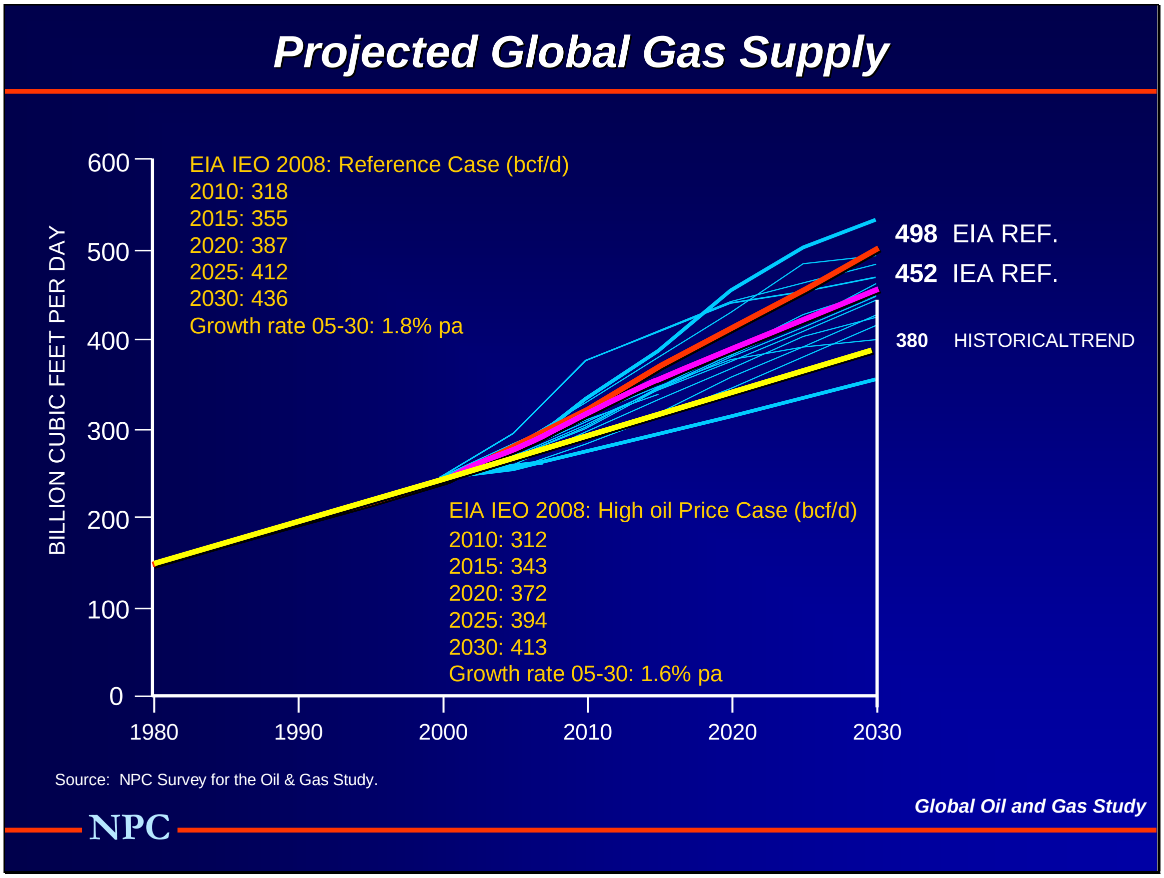

Figure 12. Projected Global Gas Supply

Regional Gas Supplies

The EIA 2008 International Energy Outlook Reference Case has reduced projected 2030 gas supply by 33% for Central and Latin America, 27% for the Middle East, and 5% for the United States (Figure 13). The reductions are based on potential risks to expanding production and export infrastructure capacity in Venezuela, Iran, and Qatar as noted in the *Hard Truths* Report, as well as potential gas restrictions in Nigeria and investment uncertainty in Russia.

The lower U.S. projection is based partly on increased use of coal rather than gas. However, recent developments in shale gas as noted below indicate potentially higher sustained U.S. gas production than shown in the projections.

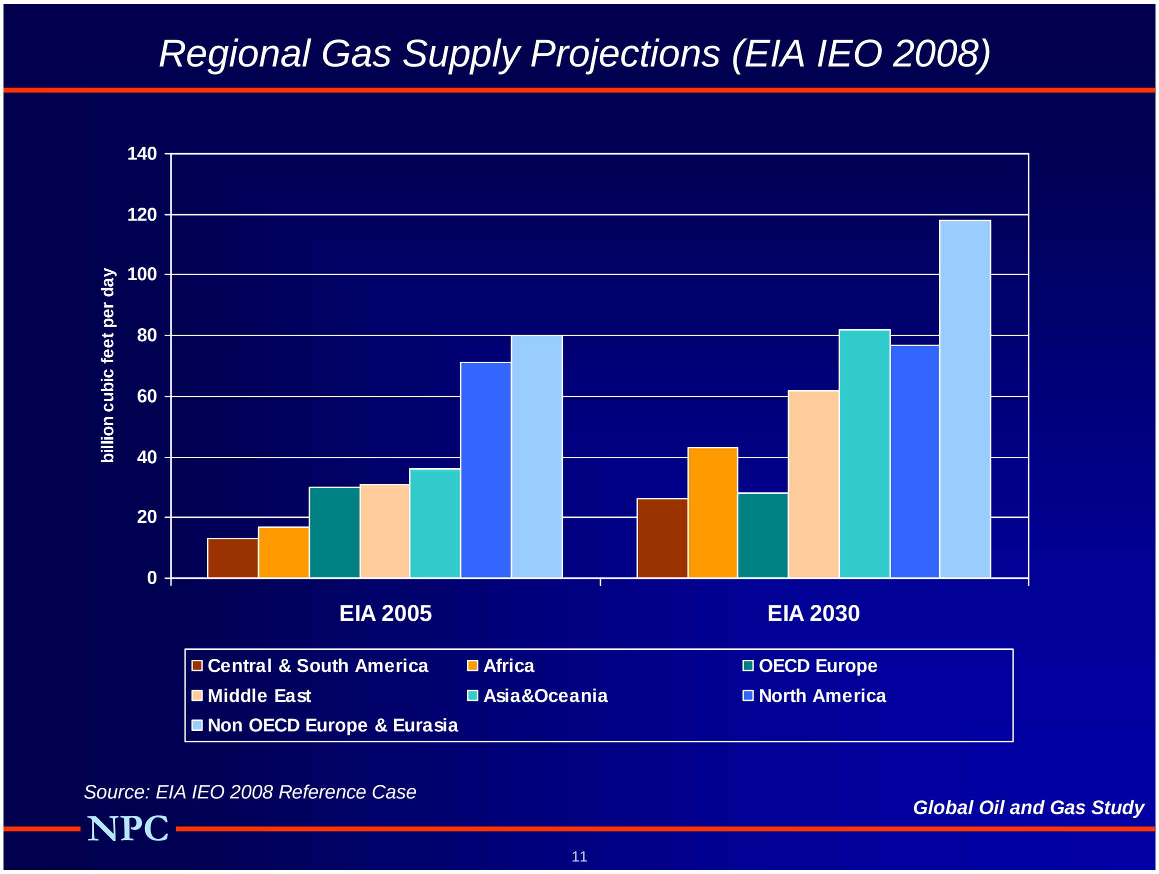

Figure 13. Projected Regional Gas Supplies

U.S. Unconventional Gas

Recent forecasts for U.S. gas production have raised the potential contribution of unconventional gas – tight gas, coal bed methane (CBM), and shale gas – at least through 2020. The 2008 projections do not include the notable success over the past year in expanding U.S. unconventional gas production and identifying new opportunities, particularly in shale gas. Recent and prospective developments such as Haynesville and Marcellus raise more optimistic prospects for indigenous U.S. gas supply. The more robust outlook for U.S. gas production potentially reduces LNG imports (Figure 14). Unconventional gas in Canada also has significant new potential as technology developed in the U.S. is adopted there. This development will further support and expand indigenous North American gas supplies.

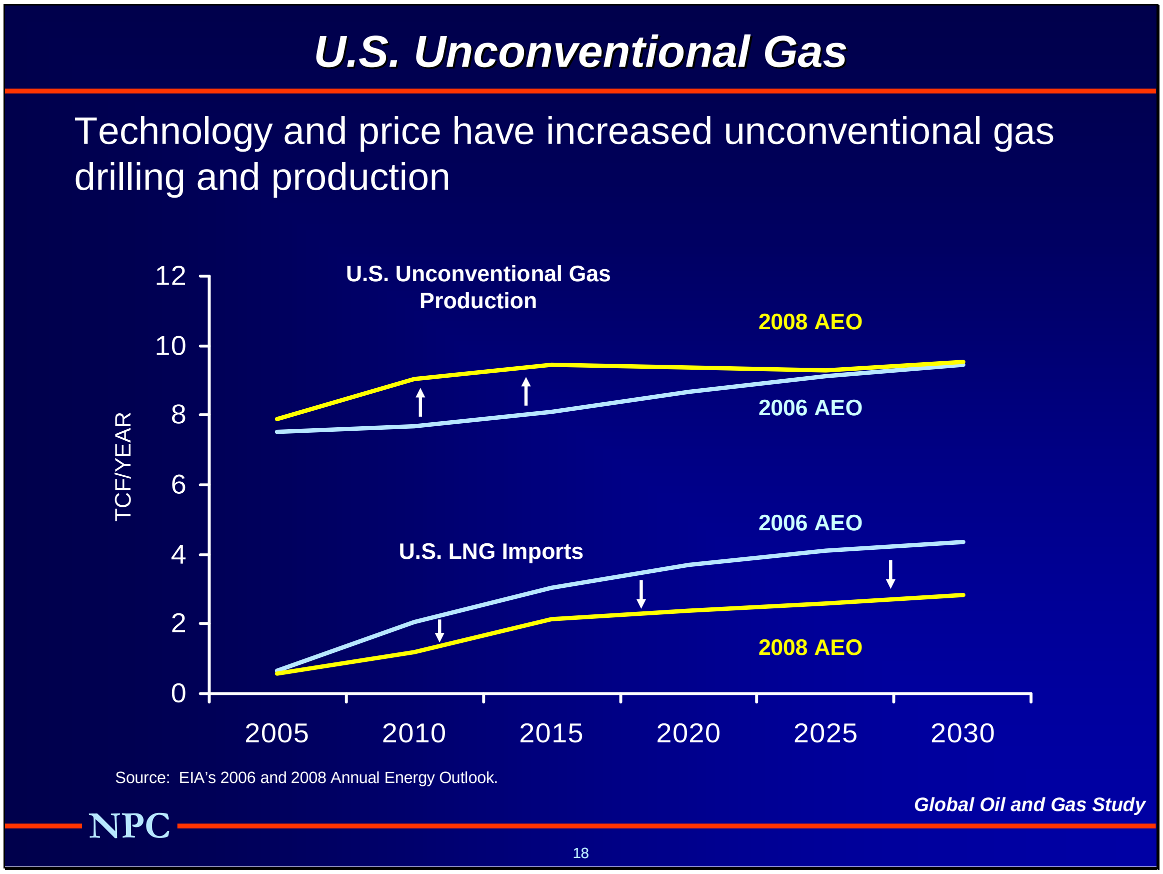

Figure 14. Projected U.S. Unconventional Gas Production

U.S. LNG Supplies

The EIA 2008 Reference Case has reduced the 2030 market share of U.S. LNG imports from 17% to 12.5% (Figure 15). The decrease represents a 37% volumetric reduction from 4.5 trillion cubic feet (tcf) to 2.8 tcf. The Reference Case is very similar to the NPC's 2003 Gas Study Low Case for LNG imports. The 2003 Low Case assumed that regulatory obstacles would prevent construction of new regasification terminal(s) in the U.S. However, U.S. regasification capacity has increased since 2003, particularly on the Gulf Coast, while bottlenecks have shifted to the international supply chain. U.S. regasification capacity has evolved from near-term choke point to enabler of long-term supply options, which contributes to energy security in the event of domestic supply disruption.

Recent developments suggest that the U.S. may be relatively less exposed to the risks of delay and shortfall in LNG development than previously thought. The basis for competition of LNG in the U.S. market has shifted from cost of supply (low cost LNG) to oil price parity (high price LNG) which promotes the growth of higher-cost domestic resources.

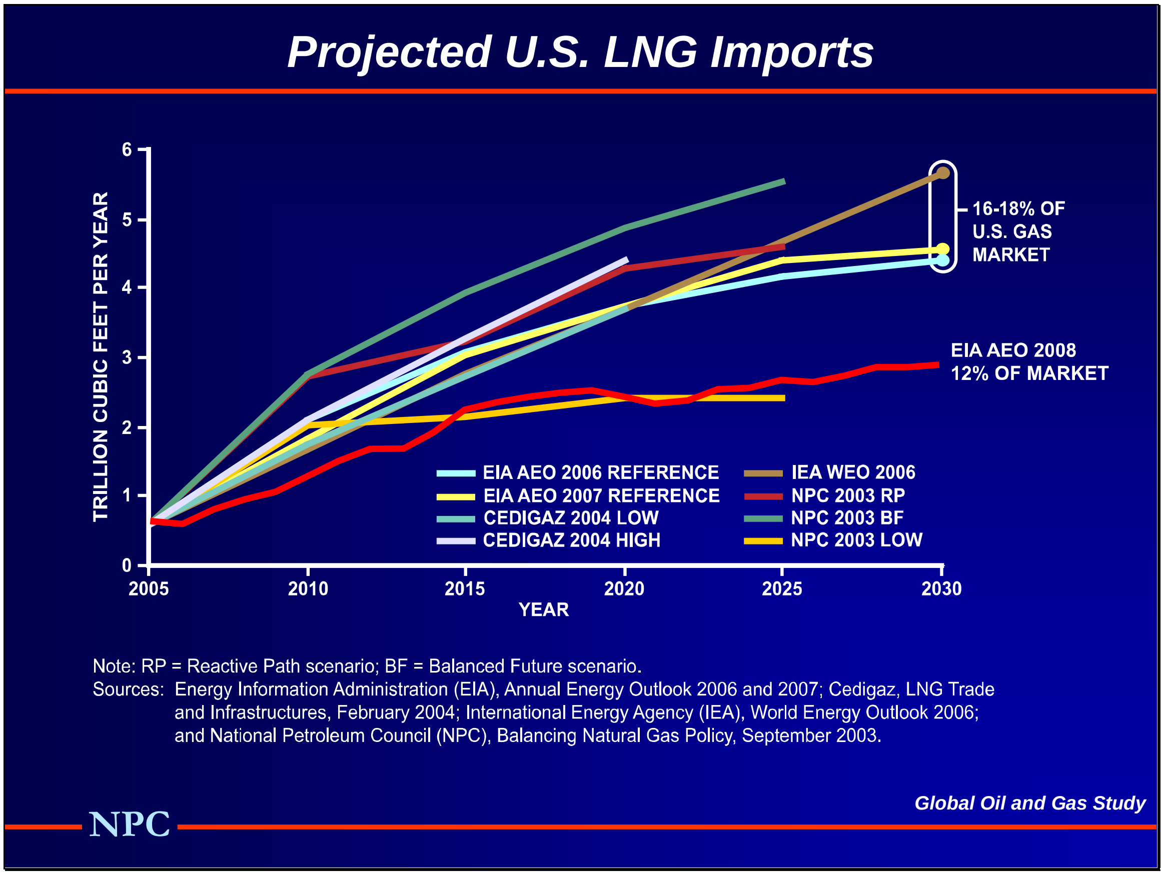

Figure 15. Projected U.S. LNG Imports

Global Supply Projections for Coal

The *Hard Truths* Report noted that estimated global and U.S. coal resources and reserves are very large relative to production requirements. In order to reduce uncertainty about these resources, the USGS is currently updating its assessments of technically and economically recoverable coal resources.

The supply projections in Figure 16 cover a range of approximately 10 billion short tons of coal per year, largely dependent on CO2 constraints, but meet projected demand in all cases. Compared to the prior year, the IEA 2007 WEO Reference Case requires 12% more coal in 2030. The Shell “Scramble” scenario anticipates that coal supply will grow fastest through 2020, then flatten through 2030.[5]

[5] Shell International BV, *Shell Energy Scenarios to 2050* (2008).

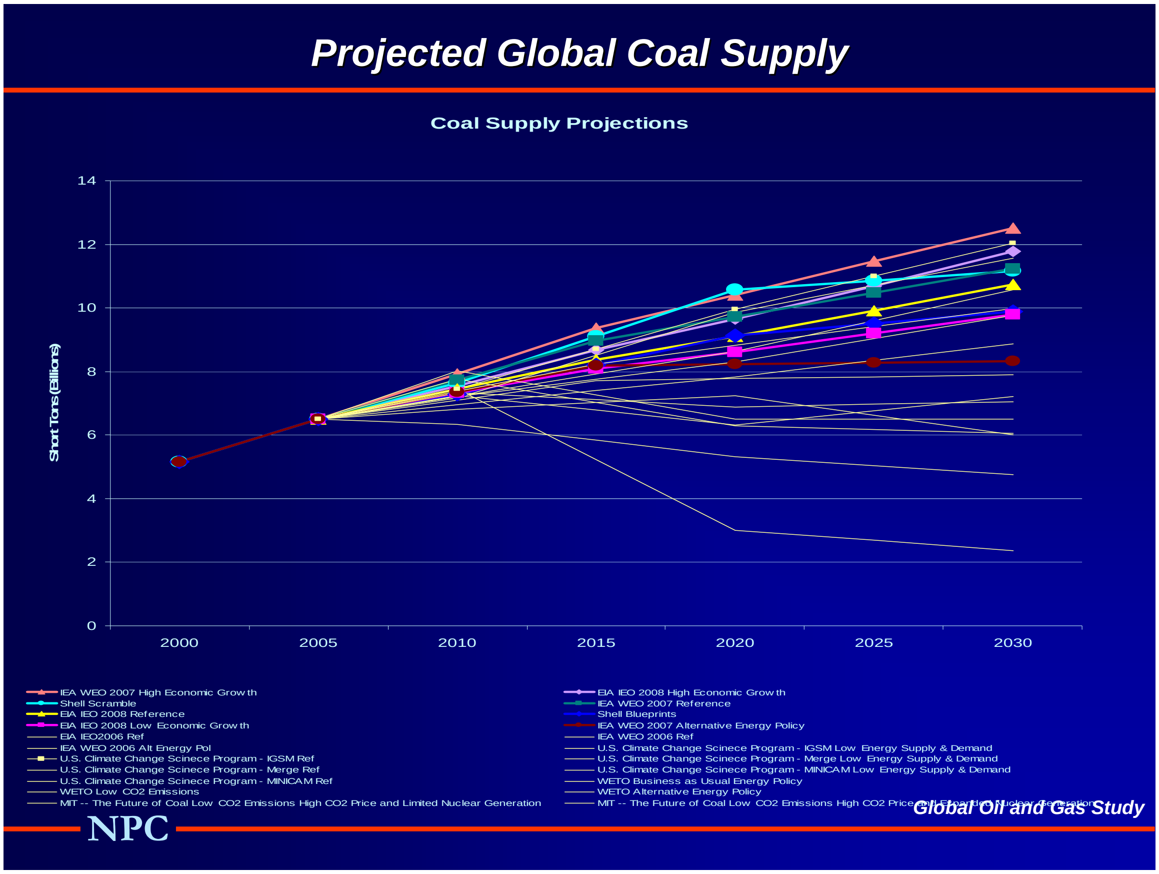

Figure 16. Projected Global Coal Supply

The EIA IEO 2008 foresees strong global growth in coal consumption (Figure 17). China, for example, will open one 400 MW – 500 MW coal-fired power plant every week to 10 days for the next decade.[6] European countries are expected to bring about 50 coal-fired plants into operation over the next 5 years.[7] The projected growth, particularly in China, is likely to strain available infrastructure and exacerbate the global CO2 challenge. The prospects for U.S. coal plants are more problematic while CO2 concerns affect plans, financing, and permits. As noted in the *Hard Truths* Report, the future of coal is closely linked to resolving carbon capture and sequestration (CCS) issues.

[6] *New York Times,* June 11, 2006.
[7] *New York Times*, April 23, 2008.

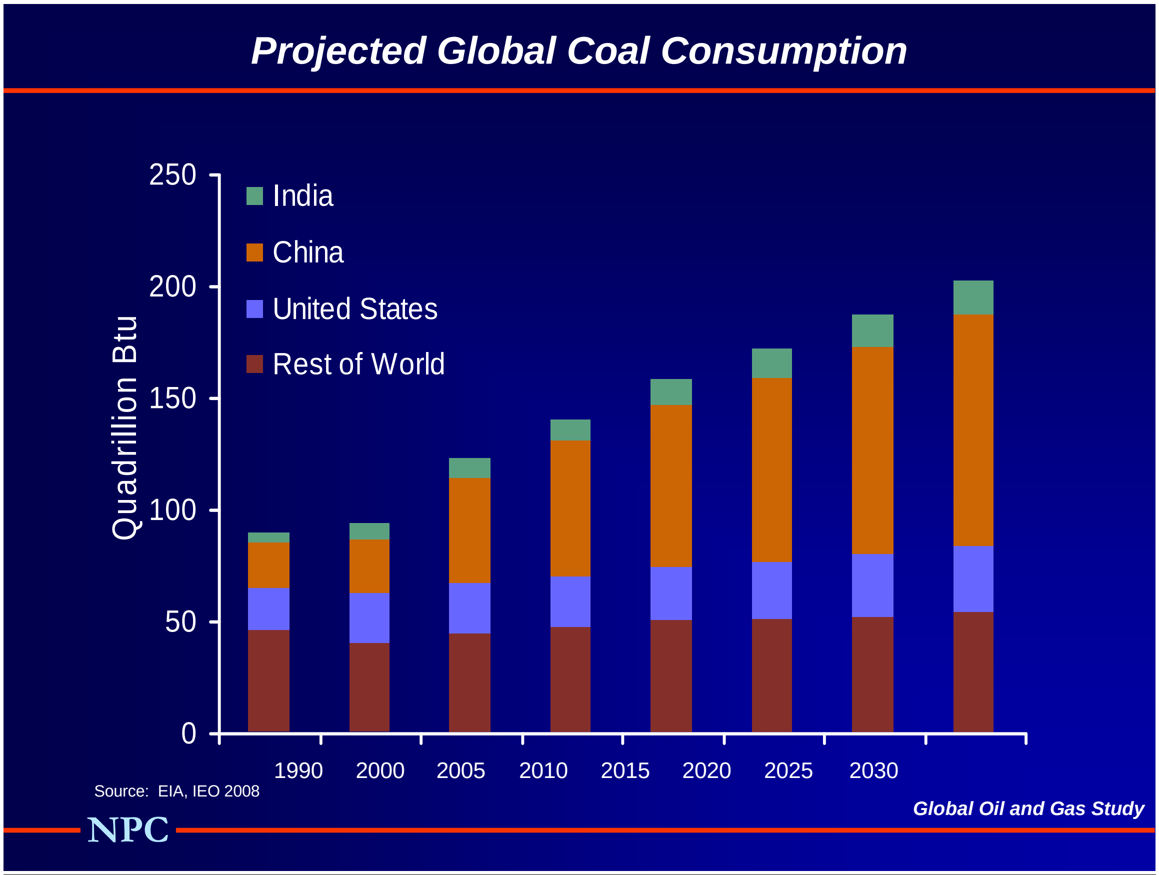

Figure 17. Projected Global Coal Consumption

Supply Projections for Biofuels

Biomass is a significant contributor to domestic U.S. energy supply. The U.S Energy Information Administration (EIA) reported that in the first six months of 2008, renewable energy accounted for 3.6 Quadrillion BTUs (Quads) or more than 10 percent of U.S. energy production. Biomass and biofuels were the largest component of renewable energy, amounting to 1.89 Quads.[8] For example, 1st generation ethanol production equivalent to 1 million barrels of oil per day (MBOE/day) is an integral part of global fuel supply.

Biofuels production has accounted for 30 percent of the growth in global grain use since 2002. At current trends for population and economic growth, production of 1st generation biofuels will be constrained unless crop yields or the land area in production increase. Figure 18 shows the 1st generation constraints appearing from 2010 onwards. Increased ethanol production after 2015, as shown in the EIA IEO 2008 Reference Case, requires 2nd generation (cellulosic) ethanol. While 2nd generation biofuels technology is moving to the demonstration stage in various parts of the world, it has not been demonstrated at scale.

[8] U.S. EIA *Monthly Energy Review* as reported in *Biodiesel Magazine*, October 1, 2008.

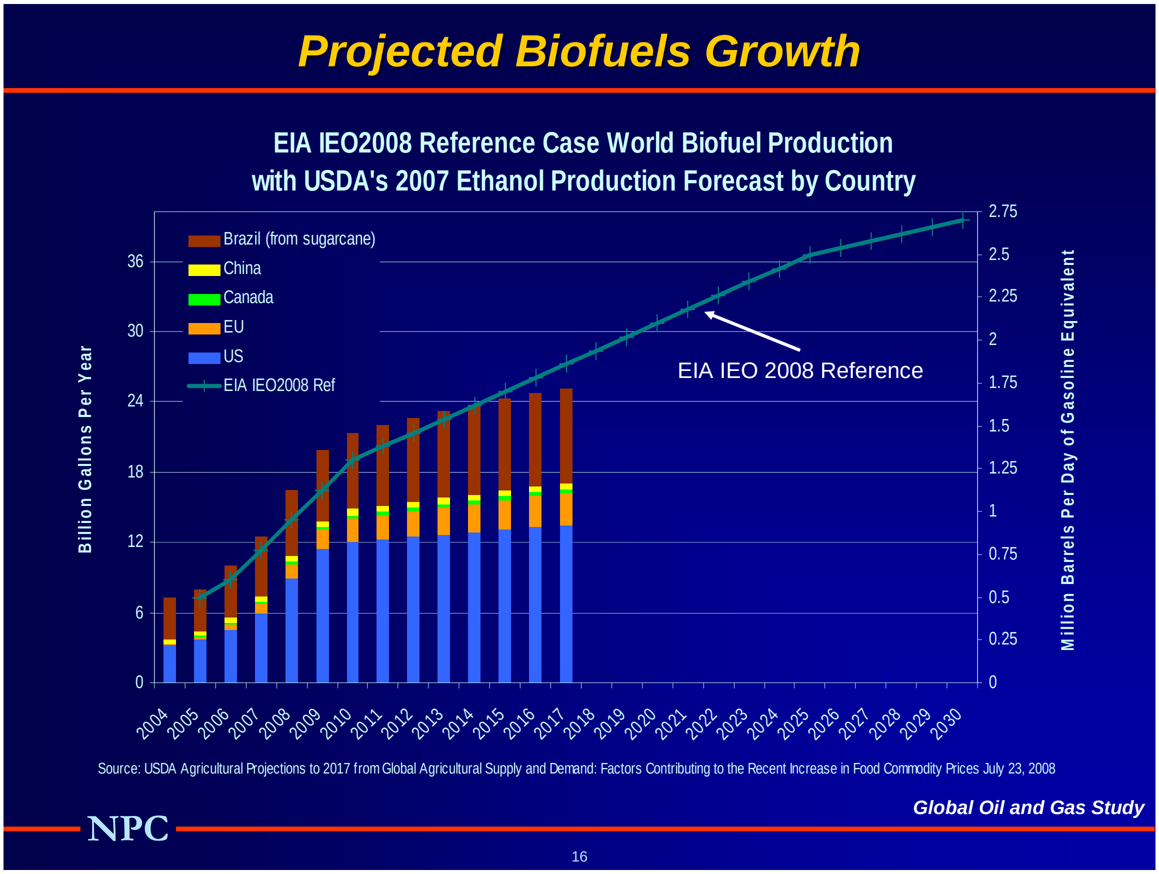

Figure 18. Projected Biofuels Growth

Three developments could relieve the constraints on biofuels production.

1. Increasing crop yields through biotechnology. Figure 19 shows potential enhancements to crop yields through molecular breeding and enhanced crop traits. The effect on the U.S. corn crop alone could be equivalent to producing an extra 9 billion bushels or 24 billion gallons of ethanol (1 million BOE/day).

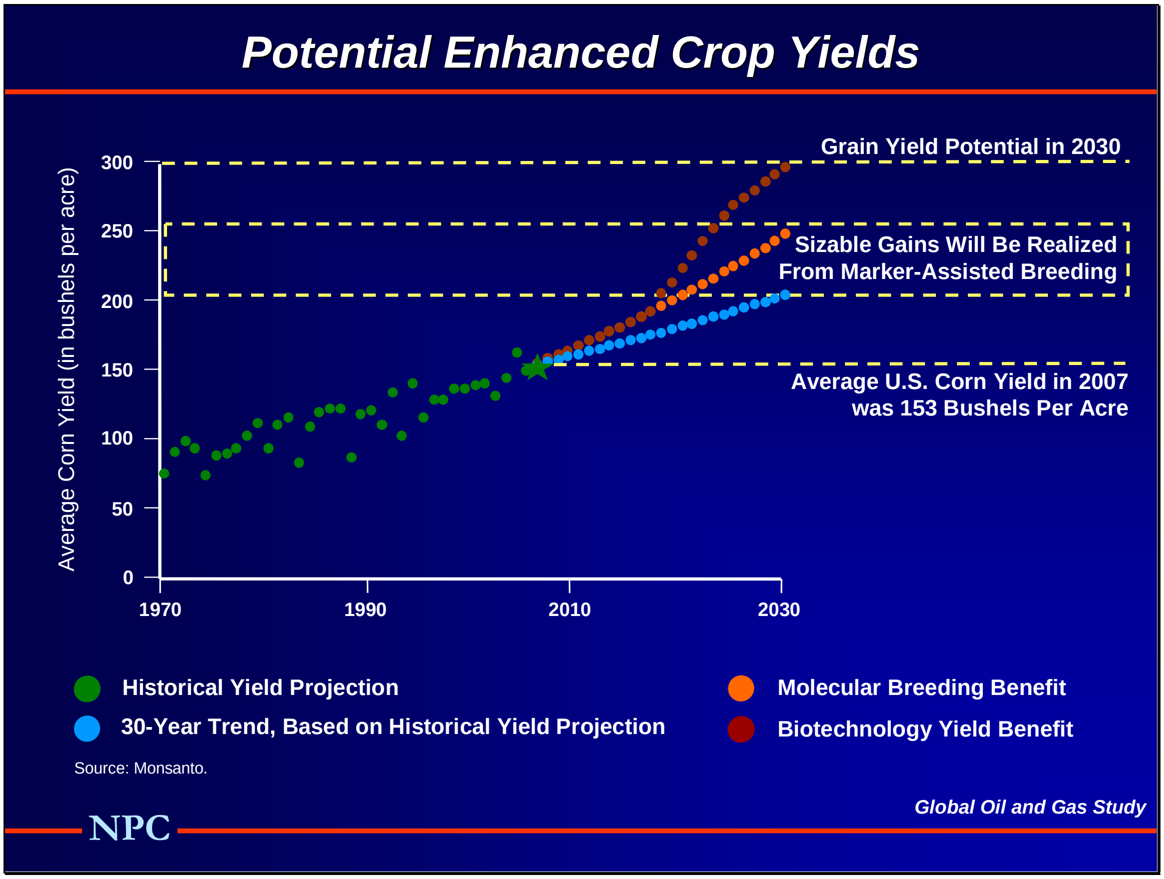

Figure 19. Potential Enhanced Crop Yields

2. Rising commodity crop prices. Price increases for commodity crops stimulate investment in production and higher productivity on current agricultural land. One projection sees the effect for wheat alone as a 193% increase in production from 302 to 596 million tons in the 19 largest wheat producing countries.[9] Figure 20 depicts the potential increase in yield if regional corn production were raised to U.S. levels.

3. Increasing acreage under production. South America and sub-Sahara Africa have large areas suitable for crop production. However, sustainable expansion raises potentially complex issues about land use, water, environmental effects, and related public policy.[10]

[9] Bruinsma J (ed): *World Agriculture: Towards 2015/2030, An FAO Perspective*, Earthscan Publications Ltd., London (2003).
[10] Sub-Saharan Africa, for example, has almost 25% of the world's arable land, but it is extremely underutilized. Crop yields are 1/4 of U.S. levels.

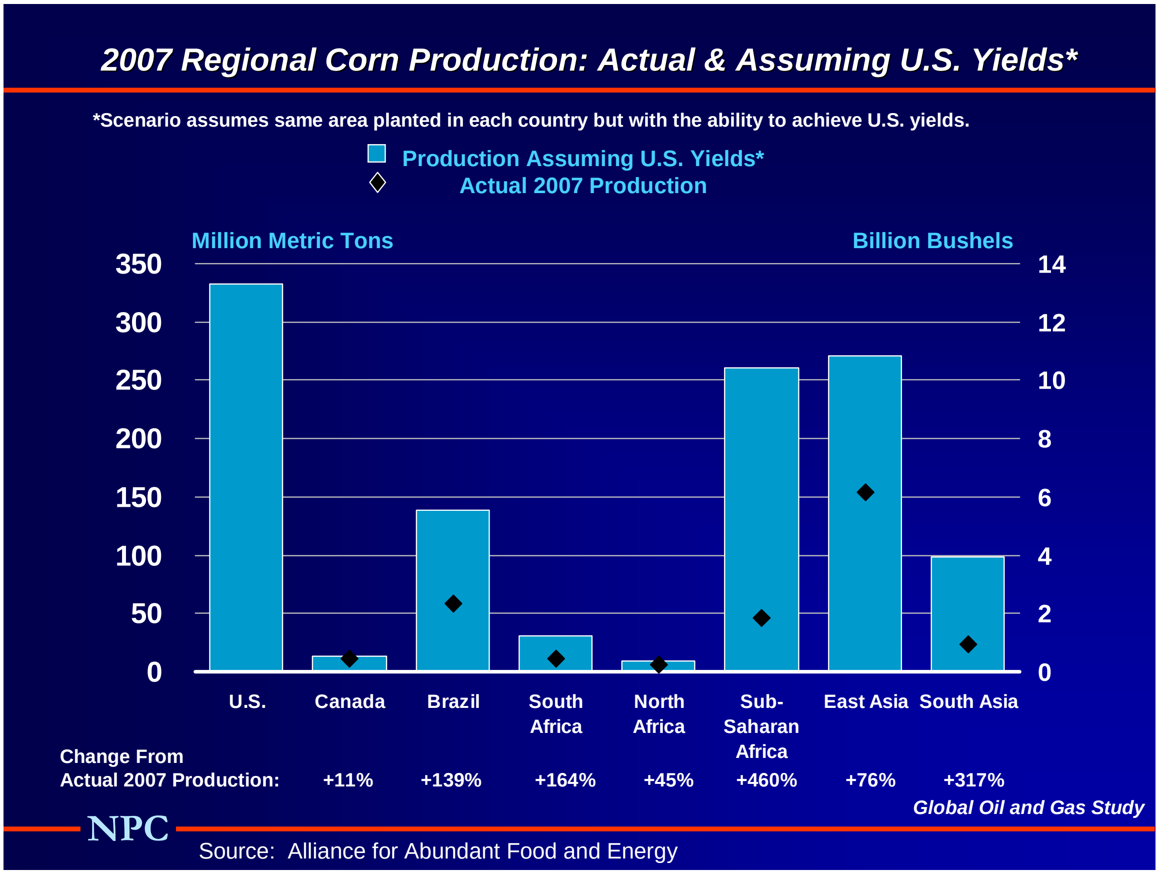

Figure 20. Potential Regional Corn Production

Feedstocks

The U.S. Department of Energy (DOE) estimates that approximately 1 billion tons of biomass are available in the U.S. to produce bioenergy (Figure 21).[11] Agricultural residues derived from food crops are the largest potential feedstock for biofuels, comprising about 31% of the resource. For example, 13% (1.43 billion bushels) of the U.S. corn crop in 2006 produced nearly 4 billion gallons of ethanol.

World production of food continues to increase, as it must keep pace with population growth. However, food prices have risen as readily available arable acreage has decreased. In order to sustain crop production, marginal acres are exploited through deforestation. As an alternative to deforestation, developing nations require massive investments in existing arable acres in order to raise crop yields.

[11] U.S. DOE and DOA "Billion Ton Study," Oak Ridge National Laboratory 2005

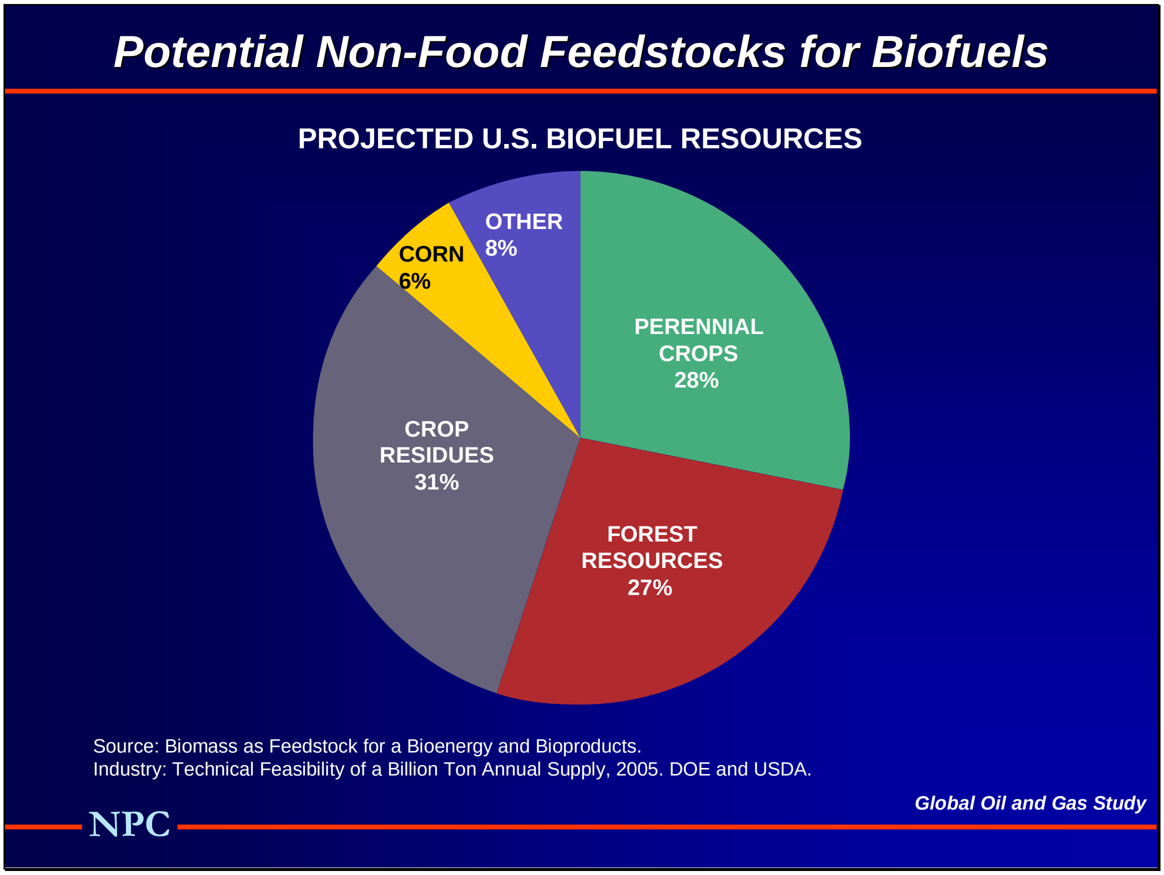

Figure 21. Potential Non-Food Feedstocks

Commodity Price Volatility

Agricultural feedstocks have experienced the same volatility in 2008 as petroleum and other commodities. Price increases in the 1st half of 2008 followed two years of lower global crop production due to weather conditions. At the same time, demand for food, feed, and fuel crops increased. Declining production and increasing demand generated upward pressure on prices. Conversely, in the 2nd half of 2008, agricultural commodities have followed a downward price trend based on global financial turbulence and economic prospects.

Wind, Solar, and Geothermal Power

Non-biomass renewable energy sources continue to grow in R&D investment, installations, and output. Proposed energy policies and plans, both governmental and private, also place increasing importance on these energy sources. Rising oil and gas prices and heightened concerns about climate change have focused attention on renewable energy as an alternative to fossil fuels and an attractive investment. In some respects, this trend has progressed faster than anticipated in the *Hard Truths* Report.

The NPC report noted an apparent disparity between the sustained growth rates of wind and solar power and their relatively small contribution to energy supply through 2030. Growth of wind and solar power has continued at large multiples of the U.S. electricity growth rate of about 2%. During 2007, wind capacity expanded by 45% in the U.S., 46% in Asia-Pacific, and by 19% on Europe's much larger installed base. Although solar photovoltaic capacity still lags wind, it grew by 28% in the U.S. in 2007 and 39% globally (Figure 22).[12]

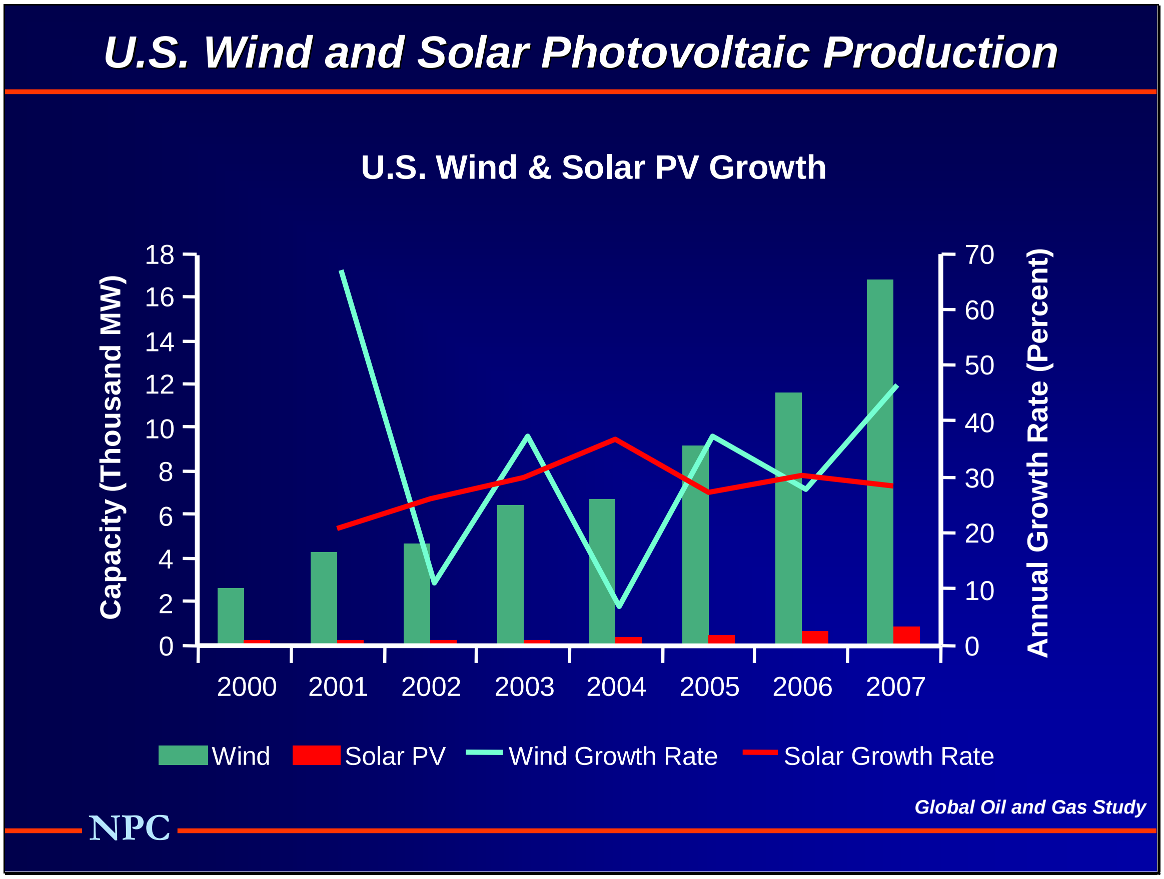

Figure 22. U.S. Wind and Solar Photovoltaic Production

Strong public support, including tax credits, as well as significant capital inflow into the renewables sector contributed to the growth rates shown in Figure 22. Investment sources include established corporations outside the energy industry, specialized wind and solar project developers partnering with energy companies and private equity firms, and venture capital. Steady technology improvements in non-bio renewable sources have also contributed to their growth.

[12] Alternative Energy eTrack, Wind Generation & Capacity Database; "Global Solar Photovoltaic Market."

Wind Energy

Wind energy has benefited from several technology trends, including increased turbine blade length and improved rotors, drivetrains, and controls that increase generation capacity. Turbines with nameplate capacities of 5 to 7 MW are being built, with capacity factors from the mid-20% to mid-30% and, in some cases, nearly 50%. These developments have important implications for wind farm profitability, even as costs per MW of nameplate capacity level out.

Solar Photovoltaic Energy

Solar photovoltaic (PV) power is developing rapidly. Global supply-chain constraints on the polysilicon used in traditional PV cells have stimulated interest in thin-film PV technology. With polysilicon output likely to double in the next two years, prices are beginning to fall. Increased competition between PV types should lower module costs and boost demand. In any case, higher raw material costs did not prevent global PV capacity from increasing at a higher rate in 2007 than in 2006.

The 64 MW Nevada Solar One concentrating solar power plant started operating in 2007, demonstrating the technology at utility scale. Later versions of the technology incorporating thermal energy storage are expected to provide dispatchable generation outside peak sunlight hours. A recent report from McKinsey & Company estimated that combined cumulative solar thermal and PV capacity would be between 200 GW and 400 GW globally by 2020.[13]

Geothermal Power

Although generators of conventional geothermal power continue to add modest amounts of new capacity, their U.S. output was only 1.8% higher in 2007 than in 2006. This trend is unlikely to change until enhanced geothermal systems tap geothermal energy without relying on natural steam reservoirs. As with wave energy, this technology has not yet advanced beyond the pilot stage.

Supply Projections

Government estimates of future energy sources have begun to reflect the growth and improved performance of wind and solar technologies. In May 2008, the DOE's Office of Energy Efficiency and Renewable Energy (EERE) released a scenario in which wind power could grow from 1% to 20% of net U.S. power generation by 2030.[14] The study concluded that achieving such growth would require an enhanced national commitment to clean energy, as well as improved technology and infrastructure. Nonetheless, the study validated the size of the resource and the potential of the wind industry to add capacity at the required rate.

Although more conservative than the EERE's 20% Wind Scenario, the Energy Information Agency's *Annual Energy Outlook 2008* foresees a significant increase in renewable energy generation compared to the 2007 AEO.[15] The 2008 AEO anticipates

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[13] McKinsey Quarterly, "The Economics of Solar Power," June 2008.
[14] EERE, "20% Wind Energy by 2030," May 2008.
[15] EIA *Annual Energy Outlook 2008.*

that renewable electricity will grow by 271 billion kWh by 2030, including conventional hydropower and end-user generation. This increment is larger than the entire 2007 contribution of conventional hydropower, which accounted for 6% of the U.S. electricity mix.

Renewable-Energy Policy

Since publication of the *Hard Truths* Report, U.S. energy policy has seen notable developments in renewable energy. Although the Energy Independence and Security Act of 2007 mainly enacted aggressive efficiency measures such as the Renewable Fuel Standard and a new CAFE standard, Congressional debate included extensive discussion of a national Renewable Portfolio Standard for electricity. The District of Columbia and 26 states already have such standards in place.

There have also been several attempts to fund the extension of the Renewable Electricity Production Tax Credit (PTC) and solar investment tax credit through new taxes on domestic oil and gas production. Although these efforts failed, the underlying concept of taxing "old" energy to support "new" energy appears likely to survive. The 2008 Presidential election has significant implications for energy policy in general, and for renewable energy in particular. The next administration is very likely to pursue aggressive actions to address climate change, with positive consequences for the growth of renewable energy.

Supply Prospects for Nuclear Power

Global projections for nuclear power (Figure 23), ranging from sharp decline to about 3 times the installed 2005 base, reflect the uncertainties affecting this energy source. Concerns about operational safety, security, proliferation, and radioactive waste disposal have retarded nuclear development. However, recent public policies and private initiatives indicate revived interest in nuclear power as a way to mitigate greenhouse gas (GHG) emissions while providing secure supplies of power. For example, the Intergovernmental Panel on Climate Change (IPCC) identified nuclear power as the electricity generation technology with the largest CO2 emission avoidance in 2030.[16]

As a result of renewed interest, "after three decades without starting a single new plant, the American nuclear power industry is getting ready to build again."[17] Applications for new nuclear power plants in the U.S. illustrate the trend (Table1).

[16] IPCC Working Group III, "Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change," Cambridge UK (2007).
[17] Matthew Wald, "Nuclear Power May Be in Early Stages of a Revival," *New York Times,* October 24, 2008.

Calendar Year	Number of Applications	Number of Units
2007	5	8
2008	13	19
2009	2	4
2010	2	4
2007 - 2010 Total	22	35

Table 1. Actual and Expected Applications for New U.S. Nuclear Power Plants[18]

Expansion of nuclear power will require new, inherently safer reactor designs, but technical advances will not be sufficient for further growth. Nuclear power also requires:

- Public acceptance
- Updated and streamlined licensing and regulatory processes
- An industrial base incorporating mining, fabrication and construction, fuel processing, and waste storage.

While signs of progress have appeared in each of these areas, a public consensus has not developed. In addition, the ability to finance and construct nuclear plants without significant delays and cost escalation remains to be demonstrated.

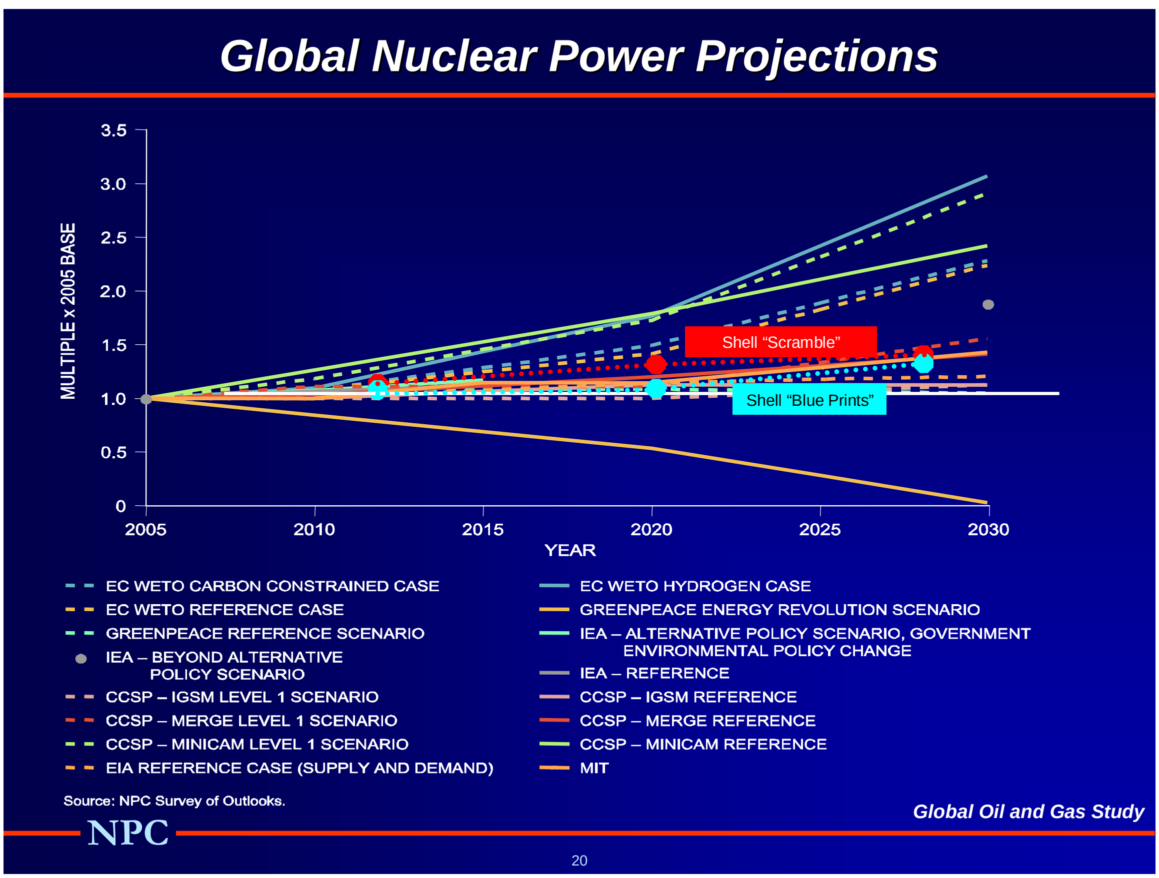

Figure 23. Global Nuclear Power Projections

[18] U.S. Nuclear Regulatory Commission, August 2008.

Supply Prospects for Hydrogen

Figure 24 shows projected use of hydrogen for transportation in the United States as noted in the *Hard Truths* Report. Even in the highest growth case, hydrogen does not displace fossil fuels as an energy source, although it could contribute to reduced gasoline consumption and CO2 emissions. The National Academy of Sciences (NAS) has since issued a report on hydrogen's viability for transportation and electric power generation.[19] While focusing on hydrogen fuel cell vehicles (HFCV), the NAS study addresses the technological, carbon management, and policy context that will influence hydrogen's role in the energy portfolio. The study concludes that a transition to HFCV's starting as early as 2015 would require strong government policies to promote HFCV use even if technical improvements are not achieved.[20]

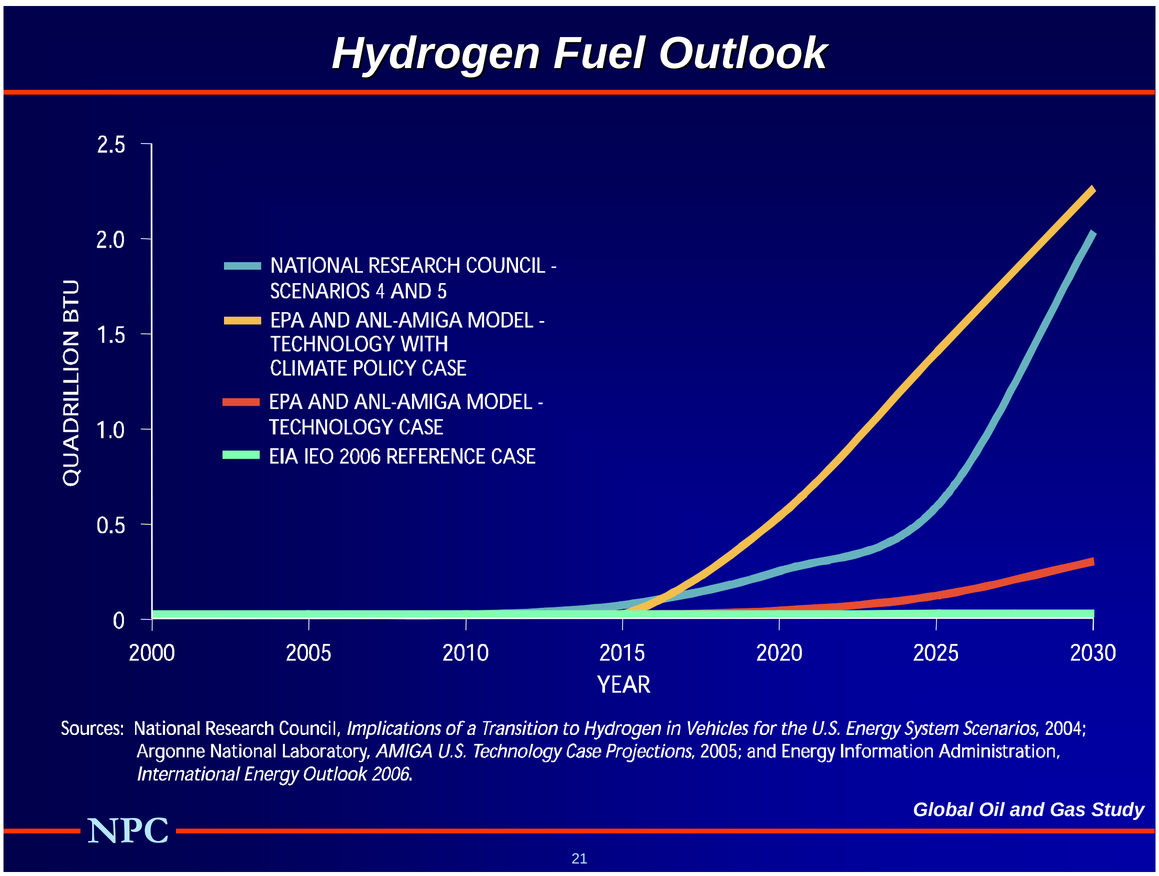

Figure 24. Projected U.S. Hydrogen Use for Transportation

Hydrogen Production

The NAS study identifies three technologies that are most likely to be commercially viable for producing hydrogen in the period 2015 – 2035:[21]

[19] National Research Council, *Transitions to Alternative Transportation Technologies: A Focus on Hydrogen* (2008).
[20] Ibid., S-4.
[21] Ibid., S-4.

1. Distributed steam methane reformation (DSMR) for on-site hydrogen production at refueling stations using natural gas feedstock

2. Centralized hydrogen production from coal gasification with carbon capture and sequestration (CCS)

3. Centralized hydrogen production from biomass gasification.

Other potential technologies for producing hydrogen such as electrolysis or using nuclear power or renewable energy to split water thermochemically face technical, economic, and policy uncertainties. Even the three most likely technologies face major hurdles involving CCS, biomass production and transportation at scale, and hydrogen infrastructure permitting and construction.

Hydrogen and Electric Power

The NAS concludes that the electric power industry could accelerate near-term production of hydrogen for fuel cells by producing electricity designated for electrolysis of water. In the longer term after 2025, hydrogen could potentially be used for stationary power generation as well as for transportation. In this case, gasification plants using biomass feedstock or coal with CCS would produce hydrogen.[22] This prospect, however, requires demonstration at scale of coal-based hydrogen with CCS within the next decade.[23]

U.S. Resource Access

The U.S. has large undeveloped oil resources that could be recovered with expanded access, investment, technology, and infrastructure (Figure 25). Moreover, the substantial resources shown in Figure 25 do not include oil shale, which is estimated at 800 billion barrels of technically recoverable oil and 1.5 to 2.1 trillion barrels of oil in-place.

Although the U.S. has a large hydrocarbon resource base, access to significant oil and gas resources is restricted. The *Hard Truths* Report noted that 39.5 billion barrels (B-BBL) of U.S. oil and 244 trillion cubic feet (tcf) of natural gas are under access restrictions (Figure 26). Federal announcements in June 2008 highlighted ANWR (10.4 B-BBL), OCS moratoria areas (18 B-BBL oil and 76 tcf gas) and longer-term, unconventional, U.S. oil shale potential (800 B-BBL technically recoverable).[24]

[22] Ibid, S-14.
[23] Ibid., S-15.
[24] Sources: 1) Onshore Lower 48: DOI BLM, *Two Year Report: Section 365 EPACT Pilot Project to Improve Federal Permit Coordination*, 2008; and IPAA, Producing Oil and Natural Gas: Not "Just a Time" Business, 2008. 2) Onshore Oil Shale: RAND, *Oil Shale Development in the United States*, 2005; 3) Offshore Moratoria Areas: MMS, *Deepwater Gulf of Mexico 2008: America's Offshore Energy Future*, MMS 20008-013, 2008; API, *OCS Moratoria Fact Sheet*, 2008; and Advanced Resources International, *Estimate of the Potential Economic Benefits From the Leasing and Development of Oil and Gas Resources in OCS Moratoria Areas*, prepared for DOE, 2006. 4) Alaska: EIA, *Analysis of Crude Oil Production in the Arctic National Wildlife Refuge*, SR-OIAF/2008-03, 2008.

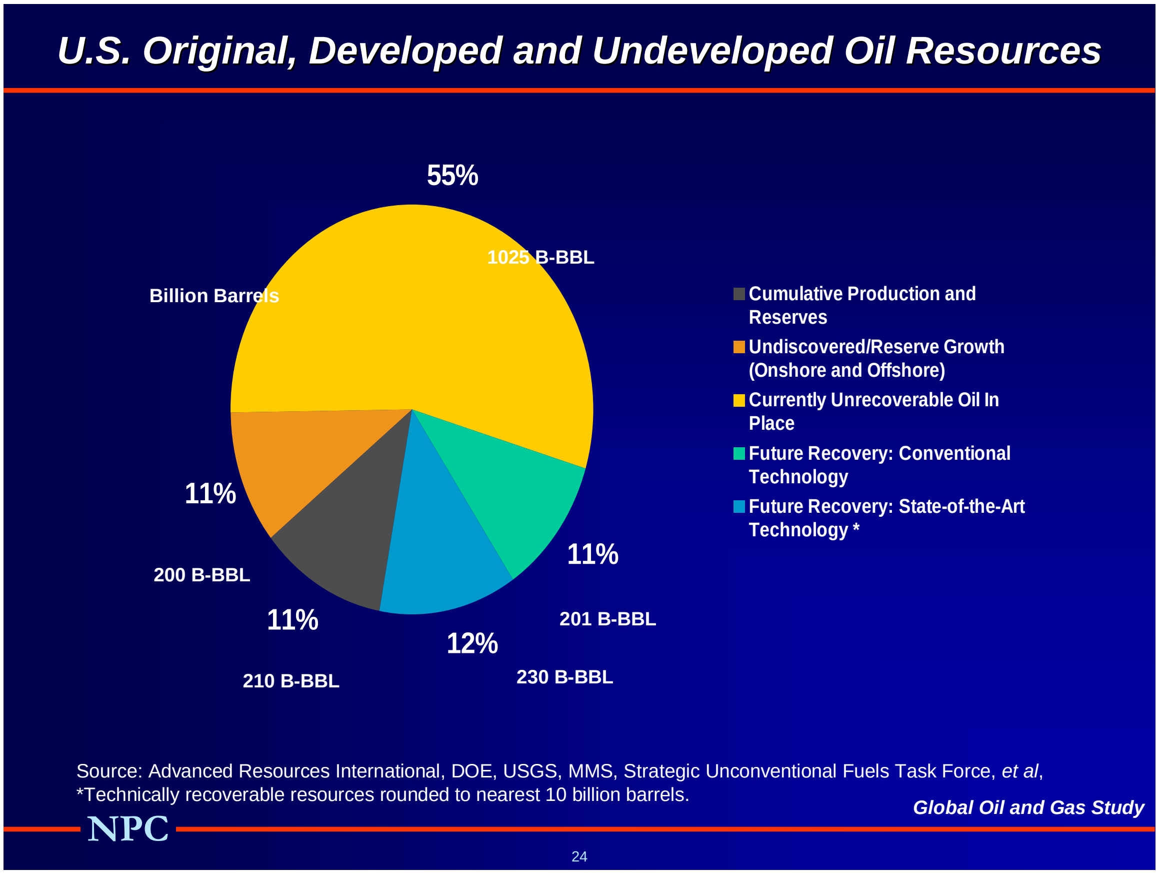

Fig 25. U.S. Oil Resources

Sharply increased energy prices contributed to the lifting in July 2008 of the Presidential moratorium on development in the Outer Continental Shelf and decisions to allow certain Congressional moratoria to expire in October 2008. However, moratoria in some portions of the Eastern and Central Gulf of Mexico established under the Gulf of Mexico Energy Security Act of 2006 remain in effect to 2022. The Department of Interior (DOI) issued regulations in May 2008 for sharing offshore oil and gas leasing revenues with states. In November 2008, the DOI issued regulations governing royalty rates and the regulatory framework for commercial oil shale leasing. Whether federal, state, and Congressional policy makers can resolve their sometimes conflicting views on access to U.S. oil and gas resources for development will determine the role of these resources in meeting the future energy needs of U.S. consumers.

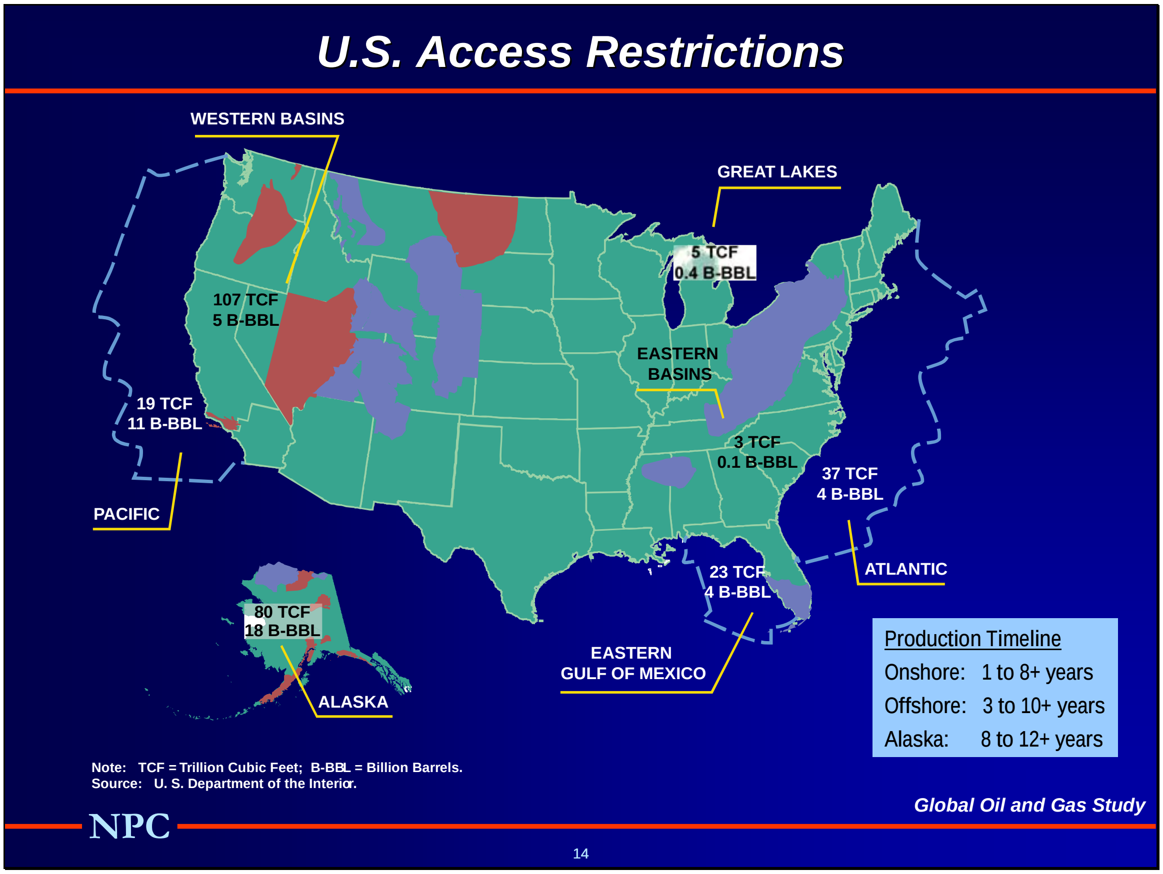

Figure 26. U.S. Oil and Gas Access Restrictions

Figure 26 illustrates that even with increased access, streamlined regulatory processes, and public acceptance, development timelines (leasing to production) remain lengthy. The timeframes range from 1 to 8 years in the onshore lower-48 states; 6 to 8 years for oil shale; 3 to 10 years in offshore moratoria areas; and 8 to 12 years in Alaska (ANWR). The timelines emphasize that access decisions are urgent, since in some cases, they may not produce results for more than a decade.