Paper #3-5

WHAT ARE THE "BIG" THINGS THAT PAST STUDIES MISSED?

Prepared for the Demand Task Group

On September 15, 2011, The National Petroleum Council (NPC) in approving its report, *Prudent Development: Realizing the Potential of North America's Abundant Natural Gas and Oil Resources*, also approved the making available of certain materials used in the study process, including detailed, specific subject matter papers prepared or used by the study's Task Groups and/or Subgroups. These Topic and White Papers were working documents that were part of the analyses that led to development of the summary results presented in the report's Executive Summary and Chapters.

These Topic and White Papers represent the views and conclusions of the authors. The National Petroleum Council has not endorsed or approved the statements and conclusions contained in these documents, but approved the publication of these materials as part of the study process.

The NPC believes that these papers will be of interest to the readers of the report and will help them better understand the results. These materials are being made available in the interest of transparency.

The attached paper is one of 57 such working documents used in the study analyses. Also included is a roster of the Task Group that developed or submitted this paper. Appendix C of the final NPC report provides a complete list of the 57 Topic and White Papers and an abstract for each. The full papers can be viewed and downloaded from the report section of the NPC website (www.npc.org).

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I. INTRODUCTION: BACK TO THE FUTURE: TWO DECADES OF NATURAL GAS STUDIES

In 1992, 1999 and 2003 the National Petroleum Council (NPC) conducted three major studies of natural gas supply and demand.[1] The purpose of these previous NPC studies were to identify measures to promote efficient natural gas markets and to propose a menu of policy choices focused upon advancing the environment, energy security and economic well being. An evaluation of these studies of the NPC provides some lessons learned and the "big" things that past studies have missed. Key observations on the outcomes from prior NPC studies of the natural gas market include:

- Past projections of the demand fairway (or range of projections) for natural gas were generally accurate enough to be useful for testing policies and indicating necessary increments to supply (see Figure 1). Though increasing reliance upon unconventional gas was featured in each NPC study, the focus was on coal bed methane and tight sands formations while the potential role of shale gas was limited.
- While the models employed to prepare the studies worked reasonably well, assumptions about price of oil and gas, GDP growth rates and trends in energy intensity (or energy efficiency) were not borne out by actual trends in later years. There are often future surprises that change the landscape from what a study assumed. Examples of this include the swift rise of China within global industrial and energy markets, which has had strong effect on the energy landscape.
- The inherent uncertainty of a single reference case was recognized from the start and led to preparing multiple scenarios in the 1992 and subsequent NPC natural gas studies resulting in a demand fairway bounded by a maximum and minimum case useful for stress testing the industry's ability to meet demand and identifying policy recommendation commensurate with the challenges facing the industry.

[1] For description of cases, see Description of Projection Cases at the end of the NPC North American Resource development, Demand Task Group, Demand Chapter

- For the 2007 NPC study,[2] a survey of existing forecasts or "a study of studies" was used to broaden coverage and bring a wider array of assumptions and results into consideration.
- Energy and environmental policy assumptions of "Business as Usual" have been the major underpinning of the previous NPC reports. Since 1990 business as usual studies have fared well since we have not had a major shift in energy or climate policy since the Clean Air Act Amendments passed in 1990, rather a succession of incremental changes.

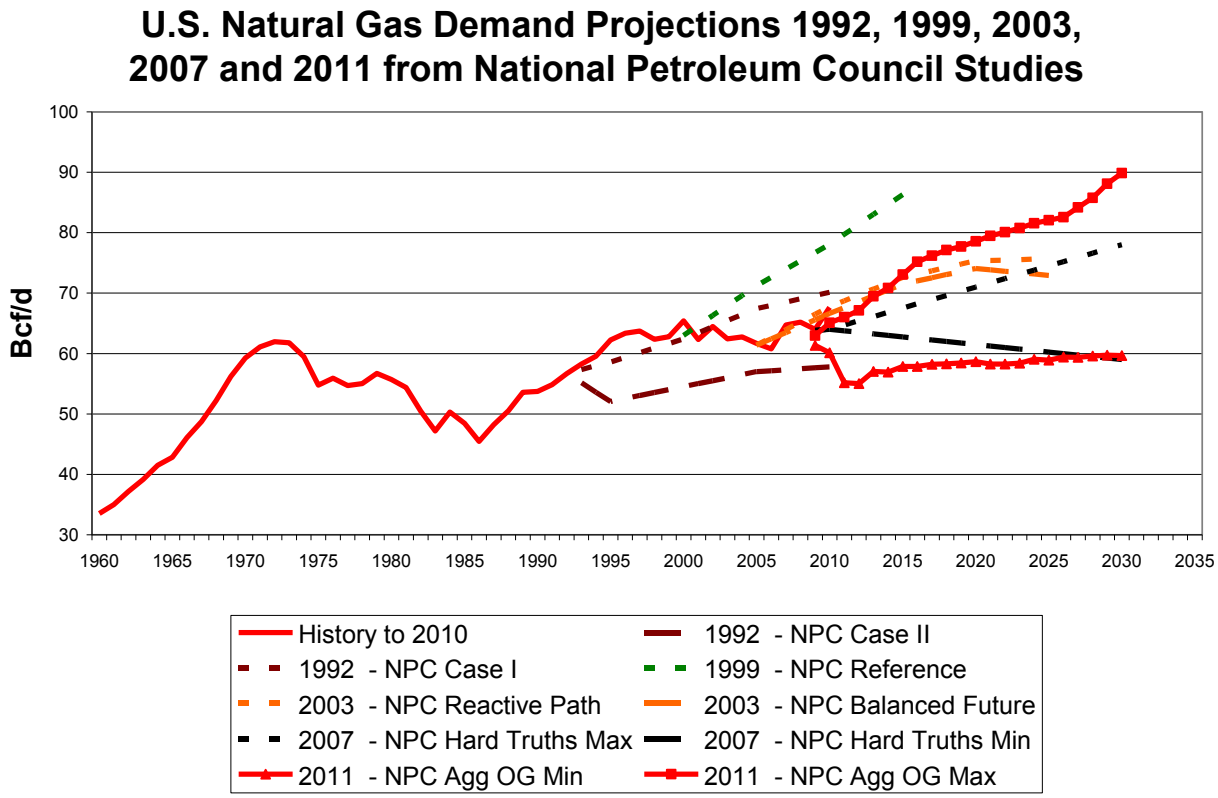
The National Petroleum Council conducted studies of the natural gas industry in 1992, 1999, 2003 and as part of the 2007 "Hard Truths" report to evaluate the contribution that natural gas could make to enhancing energy security and achieving economic and environmental goals and to identify measures to promote an efficient industry made up of producers, gatherers, processers, transporters and end-use markets. Previous studies have utilized industry experts and modern technologies, such as models and engineering studies, to deal with the most fundamental of questions for energy policymakers:

- Is there a sufficient volume of economically available natural gas resource to continue to rely upon natural gas; and
- Is natural gas demand going to grow?

More recently the supply question has expanded to include the cost to develop unconventional gas with the additional query asking if the more robust supply growth should be used to substitute for less environmentally desirable fuels in power generation.[3]

[2] For a retrospective review of past EIA Annual Energy Outlooks see:
http://www.eia.gove.oiaf/analysispaper/retrospective_review.html

Figure 1. Retrospective on Natural Gas Demand: Twenty Years of National Petroleum Council Studies



The answers to the supply adequacy question has always been answered with a qualified "yes, if accommodated by leasing of federal lands combined with development of unconventional resources." The outlook for demand growth has been a little less certain, pointing to expansion of natural gas combined cycle generation linked with policies to promote supply availability and maintain natural gas prices competitive with other fuels and other regions. Not surprisingly, the

[3] See the report of the NARD Operations and Environment Task Group for a discussion of the regulation of drilling operations and the environmental issues which have been raised

two biggest misses of the future portrayed in these earlier NPC studies have been the growth in unconventional gas and the volume of gas penetration in power generation.

Shale gas was either not included or given only a minor role in the first three studies (1992, 1999 and 2003) while limited to the known Barnett play development in the 2007 study. Shale was noted as a potential resource, but not even mentioned as a producible source of unconventional gas in the 1992 study, which stated. "Traditionally natural gas is either produced in association with oil or from reservoirs where the geology made it readily recoverable. With advances in production techniques, gas that was not considered to be economically producible many years ago is available to meet demand today. Due to the different nature of these resources, and knowledge about their extent, these resources are considered to be "nonconventional."[4] Two examples of natural gas from nonconventional sources, which are becoming more significant contributors to the domestic supply mix, are "tight" gas and "coal bed methane."[5]

The second big miss was natural gas demand in the power sector. Power generation demand for natural gas has been the only significant growth area since 1992. Though prior studies indicated some potential for growth in the industrial sector, recessions, volatile prices and strengthening international competition have contradicted these earlier projections.

The situation and focus for the NPC studies were:

- **In 1992, the "gas bubble" was making gas cheap** while extensive development of unconventional supplies of coal bed methane and "tight" gas was expanding the vision of future contributions of natural gas to US energy security. Independent

[4] National Petroleum Council, The Potential for Natural Gas in the United States, 1992

[5] National Petroleum Council, The Potential for Natural Gas in the United States, 1992

Power Producers were beginning to emerge as gas was plentiful, cheap and viewed as the "green" fuel.[6].

- **In 1999, the power generation sector was fully embracing the natural gas combined cycle** as the least expensive and most readily implemented source of electricity to meet growing demands**.** [7] Natural gas demand growth was running 1 Tcf above the moderate growth case of the 1992 study and a "30 Tcf market" was widely expected by 2010.

- **In 2003, a very cold winter had diminished storage inventories to bare minimums by March and raised gas prices to record levels.**[8] The growth in demand to a "30 Tcf" market was stymied by the high natural gas prices and this study endeavored to find a "Balanced Path" to expanded use of natural gas including renewed emphasis upon efficiency and well working markets.

- **In 2007, the "Hard Truths" study surveyed the International Energy Agency and many other sources to find that the future of world energy demand included a continued reliance upon fossil fuels with continuous improvement in energy efficiency a necessary requirement for market balance.** Since then, many of the policy recommendations of this study have been addressed by the U.S. Congress including automobile CAFÉ standards and other efficiency measures. [9]

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[6] ibid

[7] National Petroleum Council, Meeting the Challenges of the Nation's Natural Gas Demand, 1999

[8] National Petroleum Council, Balancing Natural Gas Policy, 2003

[9] National Petroleum Council, Hard Truths – Facing the Hard Truths about Energy: A comprehensive view to 2030 of global oil and natural gas, 2007

II. NATURAL GAS DEMAND OVER THE YEARS

The NPC studies of natural gas demand were designed to represent a plausible future from which to measure the magnitude of challenges facing the United States and the role of proposed policy in meeting those challenges. In this sense, the outlook for future activity levels as set forth by the NPC studies represent distinct scenarios and not expected forecasts. Nevertheless, the demand levels as presented in the NPC studies have in a broad sense, bounded the actual levels of natural gas demand for the 1992 to 2010 period and thus worked well as a tool for evaluating prospective policies within a reasonable framework for volumes. In the 1999 study, it was felt that the models used in 1992 worked well but that the assumptions used in the projections fell short.[10] Projections can and will differ from actual results for many reasons – recessions, price variability, technological change, geopolitics, energy policy and many other causes. By 2010, the 1992 projections were tracking closer to actual than were the 1999 projections.

Models based upon a market clearing mechanism such as the EIA's NEMS model and the models used by prior NPC studies, have fared relatively well over the 1990 to 2010 period in projecting demand. Models anticipated a rapid build up of natural gas generating capacity based upon realistic assumptions concerning low construction costs, ease of environmental compliance and at least for the 1990's modest fuel costs.

Circular Reasoning: Assumptions drive Conclusions

The NPC in both 2007 and 2011 uses a study of studies to help identify and analyze a broad range of possible future policy paths without reliance upon one set of assumptions or

[10] National Petroleum Council, Meeting the Challenges of the Nation's Natural Gas Demand, 1999

conclusions. A major source of studies is the EIA Annual Energy Outlook and its associated policy and sensitivity cases, which deliberately explore a wide range of assumptions through sensitivity cases.

Assumptions are the crux of forecasting and one of the biggest errors is the circularity in reasoning where the assumption drives the conclusion. The assumption that shale gas was too expensive to develop and so excluded from the resource base necessarily resulted in little or no shale gas development, a feature of all prior projections. Similarly, assumptions concerning the technology choices available to power developers necessarily restrict the projections of capacity additions. Excluding Carbon Capture and Sequestration (CCS) from the technology choices available to power generators necessarily leads to no build of CCS, including CCS along with historical carbon prices of zero can also lead to no build of CCS while including CCS at a reduced cost reflecting experience from multiple installations along with a hypothetical high carbon price could lead to substantial build of CCS. In each of these cases, the assumption drives the conclusion and it is the assumption that should be evaluated.

Implicit assumptions are also important. In policy neutral cases, there is no price placed upon carbon and hence CO_2 emissions are relatively unconstrained. Many utility planners, however, assume a hypothetical carbon price in their resource plans to advert part of the potential high cost of future carbon policy.

A. 1992 NPC Study, "The Potential for Natural Gas in the United States."

In June 1990, Secretary of Energy Watkins asked the NPC to undertake a gas study that would be "a comprehensive analysis of the potential for natural gas to make a larger contribution, not only to our national energy supply, but also to the President's environmental goals." The NPC had recently been expanded by adding 35 members from the natural gas industry to enhance its ability to analyze natural gas issues, not least of which was the enduring "gas bubble" and the enactment of the Clean Air Act Amendments of 1990 that imposed targets on SO2 emissions. [11]

The 1999 NPC study committee reviewed the 1992 study and identified several big misses that had appeared in the 6 years since the 1992 study was completed, including:

- Natural gas demand was 1 Tcf above the moderate growth case projected in 1992 in part because natural gas prices were lower but also reflecting a 4% growth rate in GDP that had eclipsed the 2.4% trend growth assumed in 1992.
- Energy intensity was not tracking as low as had been projected as efficiency measures were not reducing demand.

In 1992, the definition of the industrial sector included significant use of natural gas to generate electricity under the categories of cogeneration or Central Heat and Power (CHP), Independent Power Producers (IPPS), and Non Utility Generators (NUGs). The redefinition of the power sector to include these subsectors did not result in a significant change in total demand however. Since the mid 1990's, the natural gas used by merchant generators is

[11] Joseph A, Pratt, William H, Becker, William M, McClenahan, Jr., Voice of the Marketplace A history of the National Petroleum Council, 2002

counted within the Power Generation sector. The 1992 expectation of a combined industrial and power sector demand of 14.0 Trillion Cubic Feet (Tcf) in 2010 for the moderate growth Case I, is identical to the 14.0 Tcf preliminary estimate for 2010.[12] Natural gas demand in the four consuming sectors was expected to reach 22.2 Tcf by 2010 in Case I which is only 0.1 Tcf different from the 22.1 Tcf of demand reported for 2010 in the March 2011 EIA Short Term Energy Outlook.

Table 1. Retrospective on Natural Gas Demand from the 1992 National Petroleum Council Report

1992 NPC Demand Cases
(Trillion Cubic Feet)

	Reported Demand		NPC 1992 Demand		Difference	
			Case I	Case II	Case I	Case II
	1990	2010	2010	2010	2010	2010
Residential	4.4	4.9	4.8	4.6	-0.1	-0.3
Commercial	2.6	3.2	3.4	3.0	0.2	-0.2
	7.0	8.1	8.2	7.6	0.1	-0.5
Industrial	6.9	6.6	8.7	6.0	2.1	-0.6
Power Generati	2.9	7.4	5.3	4.8	-2.1	-2.6
	9.8	14.0	14.0	10.8	0.0	-3.2
Four Sector Total	16.8	22.1	22.2	18.4	0.1	-3.7

Note: 2010 from EIA Short Term Energy Outlook, March 2011

The demographic assumptions have changed dramatically though without much effect on population related variables. Population in 2010 was about 20 million higher than assumed in the 1992 study though households and employment projections turned out much closer to

[12] Preliminary estimates for 2010 are sourced from the Energy Information Agency, Short Term Energy Outlook.

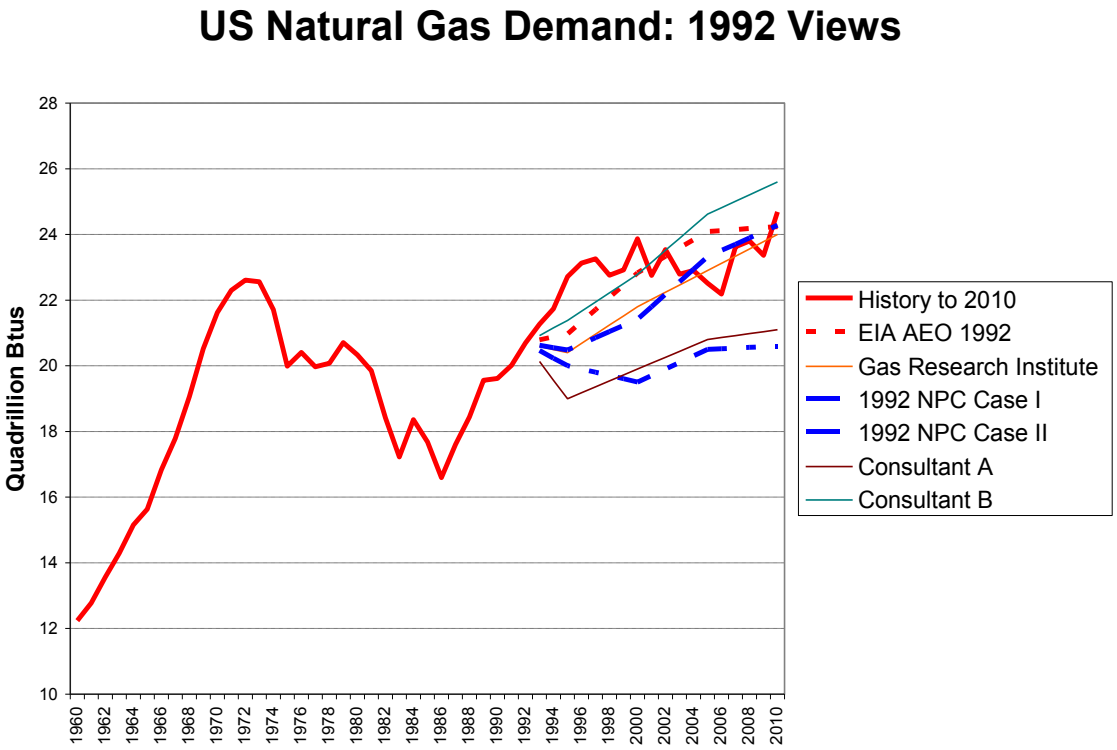
actual. The change in population levels for 2010 is related to increases in immigration levels and to revisions in census methodology for counting population. Residential and Commercial natural gas demand projections resulted in levels remarkably close to preliminary estimates for 2010 at 8.2 Tcf compared to preliminary 2010 demand of 8.1 Tcf.

Table 2. Retrospective on Economic and Demographic Outlook From 1992

Measurement of the 2010 Economy

	1992 View of 2010	2010	Difference
GNP/GDP growth rate for 1990-2010 (percent)	2.3%	2.6%	0.3%
Inflation 1990-2010 (percent)	4.6%	2.3%	-2.3%
Population in 2010 (millions)	291	310.8	19.8
Households in 2010 (millions)	115.9	119.2	3.3
Emplyoment in 2010 (millions)	134.5	130.5	-4.0

Figure 2. Retrospective on 1992 Natural Gas Demand Outlooks



Gas Research Institute, 1993 study prepared in 1992

The Gas Research Institute prepared annual natural gas supply and demand studies using the same models as did the NPC and thus provides a second set of observations on how the world of natural gas looked in 1992.

- The GRI study assumed that LNG imports would increase with all four of the existing LNG terminals expanded to their maximum capacity by 2010 reaching a total of about 5 Bcf per day. For 2010, LNG import capacity has reached 15 Bcf per day including expansion of all four existing terminals as projected but also 7 new terminals. Actual LNG imports totaled 431 Bcf in 2010 or less than one half the 1.0 Tcf of projected LNG imports.

- Oil and gas generation capacity would be increased by 114 gigawatts from 233 gigawatts in 1992 to 347 gigawatts by 2010 with 20 gigawatts of independent power producers and 50 gigawatts of cogeneration. For 2010, the EIA Annual Energy Outlook 2011 indicates that the US oil and gas generating capacity had expanded by 235 gigawatts since 1992 to 468.3 gigawatts including 35.7 gigawatts of Central Hearing and Power (CHP), 166 gigawatts of combined cycle, 135.5 gigawatts of combustion turbine and 113.2 gigawatts of oil and gas steam.
- Natural gas production would be maintained by increasing drilling to 18,400 wells per year with production of 20.7 Tcf by 2010. Preliminary EIA natural gas wells for 2010 total 19,242, while production reached 21.6 Tcf, similar to the 1992 projections despite the productivity of the new shale developments. Also, natural gas reserves, which were projected, to hold relatively flat from 153 Tcf in 1992, actually reached 283.9 Tcf as reported for 2009.

B. 1999 NPC Study, "Meeting the Challenge of the Nation's Growing Energy Needs,"

The **1999 NPC Study, "Meeting the Challenge of the Nation's Growing Energy Needs,"** was designed to "test the North American supply and delivery systems against significantly increased demand." The methodology included the use of econometric models to develop a "bottom-up" reference case for both demand and supply. However, a 30 Tcf U.S. market was a commonly assumed achievement for the 2010-2015 timeframe. The result was a reference case that included assumptions that represented a "plausible" view of the future by the task groups. No

new technologies were assumed for either the demand or supply; neither were additional environmental regulations (Kyoto Protocol, etc.) The task groups also developed various sensitivity cases including resource base changes, different oil prices, different GDP growth rates; land access changes; and technology changes.

Between the period covered by the previous NPC natural gas study (1992) and the completion of the 1999 report the natural gas industry was buffeted by a variety of forces, which had an impact on the study's assumptions and structure including:

- Large demand increase during 1990s with a 16 percent increase between 1990 and 1998 in contrast to a decline during the 1980s.
- Electric industry restructuring—independent generators and the rapid growth of gas-fired capacity.
- EPACT (92) -- legislation that effected future energy efficiency standards
- Oil prices hit a 25 year low in 1998 ($14.39/B)
- Gas prices fell below $2.00 in early 1999, the lowest since 1995.
- Historical low rig count in 1998—gas reserves did not replace production
- Three-decade decline in conventional gas production
- Doubling of imports over the decade—1999 LNG imports rose to the highest level in 20 years as Atlantic LNG was completed in Trinidad.
- Unconventional gas in the form of Coal bed methane and tight gas were the big focus for exploration and production as well as for pipeline expansions.
- New technologies included 3D Seismic

- Deepwater Royalty Relief Act of 1997 extended incentives to offshore development.

The conclusions reached in the 1999 report reflected the conditions that were seen during the period leading up to the study. Continuing the demand growth trends of the 1990s resulted in a projection of 29 TCF of demand by 2010, followed by an increase beyond 31 TCF by 2015. All sectors were expected to grow, with electricity accounting for almost 50 percent of the increase to 2010. Note that the aggressive gas-fired generating capacity assumptions turned out to be correct.

On the supply side the 1999 Study concluded that an additional 7 TCF per year of gas supply would be needed by 2010 and that supply growth was expected primarily from new deepwater fields in the Gulf and from tight gas in the Rockies. The gap between demand and production would be met primarily from Canadian imports— an increase from 3 TCF in 1998 to almost 4 TCF by 2010. LNG imports were from existing terminals--0.9 TCF in 2010, based on a 75 percent average capacity utilization rate for existing facilities.

What did the 1999 study miss?

- Assumed that the growth rate in gas demand during the 1990s was structural rather than a rebound from the demand constraining policies in the 1980s (NGPA-1978 and Fuel Use Act) and low gas prices.
- Overestimated GDP and Industrial Production growth.
- Did not foresee the downward shift in energy-intensive manufacturing post 1997.

- Forecast based on the 1990s history of low gas prices.
- Low oil price assumption (about $25.00 real in 2010).
- Solid growth in Gulf of Mexico production; instead it declines.
- Assumed that larger new homes would offset efficiency gains in the residential sector. May have not accounted for the prices effects (residential and commercial prices are higher than forecast).

C. 2003 NPC Study, "Balancing Natural Gas Policy"

The **2003 NPC study**, **Balancing Natural Gas Policy,** took a bottom-up approach to assess natural gas demand and supply in North America. Rather than developing forecasts, the study focused on two primary scenarios. A status quo scenario, the "Reactive Path," that reflected a continuation of recent history which consisted of uncoordinated policies that affected various industry segments. To illustrate the national benefits of coordinating natural gas policy the group developed a "Balanced Future" scenario. Nonetheless, all of Task Groups employed econometric models and computer simulations to test a variety of assumptions and outcomes covering natural gas demand, supply, transmission and distribution.

Between the period covered by the previous NPC natural gas study (1999) and the completion of the 2003 report the natural gas industry was buffeted by a variety of forces, which had an impact on the study's assumptions and structure including:

- Gas prices that spiked to a record $10 in 2000 and to $8 in 2003 versus $1.50-$3.00 during the 1990s

- Burner tip gas prices that were generally bumping up against oil products—distillate and residual fuel oil.
- An economic recession in 2001 and the effects of high gas prices post 2000 reduced gas demand in the residential, commercial and industrial sectors
- Announcements of process plant closures in the U.S. and Canada (mainly ammonia)
- The California power crises in 2000-01
- Rapid growth in gas-fired generation capacity
- A downward revision in the North American gas resource base.
- A limited production response to the surge in drilling in 2001
- Rapidly increasing finding and development costs
- The belief that non conventional gas production growth would just offset declines in conventional output
- Forecasts and analysis that showed that LNG import terminals and arctic gas must be developed to meet demand growth.

The conclusions reached in the 2003 report reflected the above history, so that demand growth was constrained for several years due to flat domestic natural gas production and limited import infrastructure (pipeline and LNG terminals). US gas demand-projected growth towards the end of the 2000 decade when domestic production was augmented by large-scale LNG imports and the completion of arctic gas pipeline projects. Demand and production projections were similar in both scenarios. However, the public policies recommended in the Balanced Future scenario

resulted in an improved economic picture including lower gas prices, higher output and reduced unemployment.

Policy recommendations to segue to a Balanced Future path were necessary in all industry segments.

- On the gas demand side the recommendations included (1) the encouragement of increased efficiency and conservation through market initiatives and consumer education; and (2) improve demand flexibility by increased alternate fuel utilization by power generation and industry.
- On the supply side the 2003 study suggested (1) increased access and reduced permitting impediments; (2) enacting enabling legislation in 2003 for an Alaska gas pipeline; and (3) quickly processing LNG project applications.
- Recommended policies from the infrastructure task group included (1) providing regulatory certainty by maintaining a consistent cost-recovery and contracting environment; and (2) permit projects within a one-year period utilizing a Joint Agency Review Process.
- Market efficiency proposals included (1) improving price reporting transparency and (2) the expansion and enhancement of natural gas market data collection and reporting.

Since the 2003 Study posited two "bookend" scenarios, the outlooks were not meant to be forecasts. Most of the policies assumed in the Study were not enacted, actual economic conditions differed from the assumptions and both producers and consumers made investments and process changes that were unanticipated. Further, the way in which the EIA collected

industrial and electric power gas use changed, making some of the data inconsistent (portions of CHP gas use was moved from industry to electric generation). Nonetheless, the scenarios provided a relatively accurate view of some sectors of the gas industry at the end of the 2000-decade. In particular:

- Overall gas demand in 2009 ranged from 23.8 to 24.1 Tcf in the two scenarios, versus the 22.8 Tcf reported by the EIA
- US gas production in 2009 ranged from 18.2 to 19.0 Tcf in the two scenarios, versus 20.9 Tcf reported by the EIA;
- U.S. Gas prices (Henry Hub) ranged from $4.00 to $5.22 in the two scenarios, versus $4.00 reported by the EIA; and
- However, net gas imports ranged from 5.1 to 5.3 Tcf in the two scenarios, versus 2.7 Tcf reported by the EIA.

There were a host of other things that the 2003 study missed, from underestimates of consumer and producer responses to existing technologies and price changes. On the demand side, the actual price trajectory was more volatile and included much higher prices. Consumers--primarily residential, commercial and industrial-- reacted to these higher prices via increased conservation. Further, periods of very low natural gas prices backed-out both oil and coal from electric power generation, resulting in higher gas use. On the supply side, improved technology and increasing productivity in shale gas production resulted in an explosion in output that far exceeded even optimistic estimates. With higher production, the need for LNG imports was significantly lower than expected.

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D. 2007 NPC Study, "Hard Truths – Facing the Hard Truths about Energy: A comprehensive view to 2030 of global oil and natural gas"

The 2007 NPC Study, "Hard Truths – Facing the Hard Truths about Energy," attempted to answer the following questions:

- What does the future hold for global oil and natural gas supply?
- Can incremental oil and gas supplies be brought on-line, on-time, and at a reasonable price to meet future demand without jeopardizing economic growth?
- What oil and gas supply strategies and / or demand-side strategies does the Council recommend the U.S. pursue to ensure greater economic stability and prosperity?

A survey approach was used by the participants. This process focused on an analysis of existing projections; identifying underlying assumptions, understanding why they differ, and thereby identifying important factors governing the future of oil and gas. The group gathered public data (from government, academia, and others) and aggregated proprietary data (from international oil companies and consultants). Further, they solicited input from a broad range of interested parties including non-governmental organizations and foreign countries. Emphasis was given upon long-term conditions to 2030 and beyond. Their goal was to make recommendations supported by data and science, and develop policy options and recommendations only after completing the study analyses, interpretation, and findings phase to guard against predetermined conclusions.

The energy and environmental factors that occurred post the 2003 NPC Study and likely contributed to the 2007 Study results included:

- The Energy Policy Act of 2005 that substantially increased the use of ethanol and renewable fuels.
- Growth of Hybrid vehicles.
- High oil and gas prices over the 2003-07 period; even higher than the aggressive cases in the 2003 Study.
- LNG terminal explosion and an all-time high in LNG imports in 2007 of over 600 Bcf.
- Overall marketed production rose by 3.1 percent in 2007, the highest volume since 2001. The gains were largely boosted by a 10 percent gain in Texas output, predominantly caused by production increases in unconventional formations, mainly the Barnett Shale.
- Total gas consumption in 2007 grew for the first time since 2004–up 6.3 percent. All end-use sectors contributed to the increase in consumption, with the most significant growth occurring in the electric power sector.
- 2007 Energy Independence and Security Act that raised CAFE and promotes improved building, industrial, and appliance efficiency.

The primary conclusions from the 2007 study were 1) that the demand for fuel and power will grow significantly to 2030 and beyond, requiring increases in efficiency, and expansion of all economic energy sources; 2) coal, oil, and natural gas will remain indispensable to meeting total projected energy demand growth; and, 3) the world is not running out of energy resources.

It has been 4 years since the 2007 Study, so the range of forecasts to 2030 and beyond is not likely to be significantly different from views in the 2010 studies. Nonetheless, there are lessons to be learned from the 2007 Study.

- Oil and gas prices are driven by geopolitical and financial forces as well as by the physical fundamentals of supply and demand-witness the oil and gas price spike of June 2008 with $147/B oil and $13/MMBtu gas.
- The 2008-09 recession might permanently alter the structure of the U.S. economy; thereby affecting both the growth in energy consumption and the fuel mix.
- Others? Technology and experience in the economic development of shale gas greatly expanded the US natural gas resource base; a technology that is also being applied to oil shale production.

E. Natural Gas Forecasts from the EIA Annual Energy Outlook

Every year the EIA evaluates their forecasts for recent years, looking at those from 1982 to 2009, and also those made with the NEMS model. EIA's own analysis of their forecasts indicates the range of accuracy of the policy neutral Reference cases over the 1982 to 2009 period. While energy policy is a major driver of energy supply and demand, all of the EIA forecasts are policy neutral though specific policy measures are analyzed upon request by Congress. For example, EIA Annual Energy Outlooks (AEO) made prior to or immediately after the 1987 repeal of the 1978 Fuel Use Act had considerably larger underestimation of natural gas consumption in 2000 than AEO90 and all subsequent AEOs that allowed expansion of natural gas use in boilers.

EIA stated in 2004 that "Natural gas generally has been the fuel with the least accurate forecasts. As regulatory reforms that increased the role of competitive markets were implemented beginning in the mid-1980s, the behavior of natural gas in competitive markets was especially difficult to predict. In the earlier forecasts, EIA's technology improvement expectations proved conservative, as technological advances made petroleum and natural gas less costly to produce. After natural gas curtailments were eased in the mid – 1980s, environmental pressures made natural gas an increasingly attractive fuel source, particularly for electricity generation. Historically, natural gas price instability was strongly influenced by natural gas resource estimates, which steadily rose, and by the world oil price, which was subject to its own error. More recently, natural gas consumption has been overestimated (to 2004) due to natural gas price projections that proved to be significantly lower than what occurred. "[13]

Table 3: Track Record for the Annual Energy Outlook, National Energy Modeling System

Summary of Differences Between AEO Reference Cases and Realized Outcomes

	Percent of Projections Over Estimated	Average Absolute Percent Difference
GDP	51%	1.0%
World Oil Prices	26%	30.6%
Natural Gas Prices	18%	32.7%
Natural Gas		
Consumption	68%	7.0%
Production	74%	7.0%

[13] Energy Information Agency, Annual Energy Outlook Forecast Evaluation 2004, website, http://www.eia.doe.gov

Net Imports	60%	12.9%
Consumption		
Electricity	35%	3.4%
Energy Intensity	65%	3.3%
Energy Intensity	93%	5.8%
Carbon Dioxide Emissions	38%	3.5%

Source: Annual Energy Outlook Retrospective Review: Evaluation of Projections in Past Editions (1982-2009), Report # DOE/EIA-0640(2009), March, 2010

EIA provides statistical tables that show the proportion of projections that are over estimated and the average absolute percent error. For the period that the NEMS model was used, natural gas prices were over estimated only 18 percent of the time but underestimated 82 percent of the time while the projections were an average of 32.7 percent different from actual. Natural gas consumption varied by 7 percent from actual while electricity consumption varied by 3.4 percent. Energy intensity was overestimated 93 percent of the time with an average variation of 5.8 percent. GDP assumptions were overestimated 51 percent of the time (50 percent would be the best value) with an average variation of 1 percent from actual. Assumptions underestimating price are a large source of the overestimation of natural gas demand.

III. WHAT LESSONS CAN THE NORTH AMERICAN RESOURCE DEVELOPMENT DEMAND TASK GROUP LEARN?

Key lessons from the past:

- The Market acts to negate credible forecasts. For example, the Reactive or status quo scenario in 2003 projected high gas prices. In turn, those who used this outlook to increase gas drilling and invest in new technologies contributed to higher supply growth, which had a price depressing effect.
- Similarly, the gas industry consensus in 2003-04 resulted in too many LNG terminals.
- Historic price averages are generally a poor assumption (Oil price assumption of $20 per barrel in earlier studies versus the actual 2004-2010 average of $48 per barrel in real $2002)
- The future does not often look like the past as the severe recession of 2008-09 exceeded the depth and impact of most prior recessions in the United States.
- Energy consumers and producers react to prices signals (reopening of ammonia plants in 2009 – rig count declines in 2008-09)
- Upstream technological progress is lumpy (2003 study did not see the rapid growth in shale drilling and production growth).
- U.S. gas prices can differ significantly from worldwide LNG prices for long periods.
- Recommendations typically reflect the constituencies that conducted the study, though these constituencies are deliberately large and diverse.

Other observations include:

- The demand forecasts were remarkably close to actual until the severe 2008-09 recession.
- The projections assumed the start up arctic gas projects would temporarily depress gas prices. Also, lower oil and coal price assumptions impacted the price track, as did the expectation that US gas prices would correlate with oil and world LNG.
- Pessimism about shale technology and development costs has subsequently been reversed.
- Expected that high US gas prices would result in the migration of energy intensive industries to low energy cost regions. US manufacturing establishments fell from 360,000 in 1998 to 320,000 by 2009 with a reduction of manufacturing employment from 18 million workers to below 12 million workers.
- Assumed a continuing shift of population to the Sunbelt, larger new construction, and higher efficiency appliances. Note that actual demand was affected by the 2004 and 2007 gas price spikes. Most studies underestimated the effect of efficiency measures and conservation trends.

The View to 2050

Given 20 years of history of prior projections of natural gas demand, can we extrapolate with any assurance on what will likely transpire over the next 40 years?

- The demand for natural gas to 2050 would most likely be bounded by the high and low cases and if past trends hold, demand would for much of the future be closer to the middle of the High/Low range than to either side. A study of studies includes a very wide range of outcomes.
- We do know that some of the Business as Usual (BAU) assumptions used in the various studies that were considered are going to be wrong, we just don't know which ones. But if past trends hold true, many of the BAU assumptions will prove to be reasonable, if not to 2050 then perhaps to 2030.
- The trend in the resource base has been upwards for the past two centuries as new resources and new regions were added to the inventory and this despite growing production. The NARD Supply Task Group has added "tight oil" as a new category of supply.
- The cost of producing natural gas is likely to be capped by new technologies in developing existing supply sources while the cost of using natural gas will be moderated by new end use technologies that raise the efficiency of natural gas use.
- Energy production from renewable sources continues to grow with wind power likely to surpass hydroelectric generation as a source of electricity within the next two decades. Solar, geothermal and tidal power are other sources of renewable generation that are projected to expand. Electric generation from natural gas or other dispatchable power sources are likely to be required to compensate for non-dispatchable power sources until electricity storage technologies become economic.

Conclusions on assumptions that have changed or may change since the 2007 "Hard Truths" NPC study:

Energy intensity, energy efficiency and End Use demand technologies were missed in the past studies but will continue to make major contributions in the future.[14]

- The contribution of the natural gas combined cycle to efficient use of natural gas in power generation can be followed by progression in the NGCC technology, more extensive CHP, and advances in other generation technologies.
- Industrial natural gas use has declined by 1.9 percent per year relative to the value of industrial output. Some of the new technologies and products that manufactures may produce could require more rather than less energy.
- Natural gas furnace efficiency is approaching 98 percent, presenting a physical limit to future gains in energy efficiency from furnaces.

Emergent technologies to reduce emissions are expected.[15]

- Carbon capture and sequestration (CCS) is heavily relied upon in some studies while initially substituting gas for higher carbon fuel holds the potential to greatly reduce CO_2 emissions. However, using natural gas with carbon removal before combustion is an alternative approach to reducing CO_2 emissions.
- An inexpensive oxygen supply would reduce emissions. The use of oxygen for combustion rather than air would save energy, reduce NOx emissions and perhaps enable

[14] See the working papers for the Demand Task Group Residential and Commercial, Industrial and Power subgroups. Also, see the Demand Chapter of the North American Resource Development report, NPC 2011.

[15] Ibid

cheaper carbon capture. Since nitrogen makes up 79 percent of air, combustion of fossil fuels with air requires heating the nitrogen and producing nitrous oxides. The flue gas from combustion with pure oxygen would be carbon dioxide and water vapor.

- Low temperature heat transfer could save substantial energy if a noncorrosive material could be developed for such devices. At low temperatures, water vapor in flue gases condenses and forms acids with the carbon and sulfur in the exhaust. Thus a non-corrosive heat transfer material is required for low temperature heat transfer.

Economic Outlook[16]

- Economic growth is assumed but trend growth is not assured as the economy has exhibited highly cyclical components in the housing, automotive and trade sectors amidst a deep recession in 2008 and 2009. Several of the mainstays of economic growth will be challenged by carbon reduction strategies including energy intensive manufacturing and the production of fossil fuels.

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[16] See the EIA cases evaluating carbon reduction strategies in the Demand chapter and the working paper of the Industrial subgroup of the Demand Task Group, North American Resource Development, NPC 2011

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