



ANALYSIS GROUP
ECONOMIC, FINANCIAL and STRATEGY CONSULTANTS

US Energy Infrastructure Vulnerability

Lessons From the Gulf Coast Hurricanes

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EXECUTIVE SUMMARY

OVERVIEW – ASSAULT ON THE GULF’S ENERGY INFRASTRUCTURE

On August 29, 2005, Hurricane Katrina carved a path through the Gulf of Mexico, hitting the coasts of Mississippi and Louisiana with devastating impact. Less than a month later, Hurricane Rita followed a similarly destructive path through the Gulf. The magnitude of the hurricanes’ impacts are still being felt – with severe loss of life, displacements of coastal populations, damage to coastal ecosystems and public and private property, and crippling of local economies and commercial activity.

Perhaps no economic sector was more affected than the energy sector by the hurricanes, which wiped out coastal electricity generation and transmission infrastructure across the region. Outages are estimated to have affected 2.5 million customers, with full recovery not expected until months after the hurricanes struck. The extent of the damage in New Orleans forced the local utility – Entergy New Orleans – into bankruptcy, and the cost of full recovery for all utility systems affected is estimated in the billions. But the impacts on energy supply and prices have been far from local.

This hit to the Gulf Coast energy infrastructure resembles scenarios that analysts have worried about for decades, out of fear for what our dependence on imported oil and concentrated supply infrastructure means to our security, our health and welfare, our mobility. The paths of Katrina and Rita sliced right through the heart of the Gulf Coast’s fossil fuel infrastructure. Hundreds of petroleum and natural gas production wells and import facilities were destroyed, set adrift, or damaged, as was the extensive web of pipelines that carry oil and gas to processing facilities or ultimate customers. Processing capacity – both petroleum refineries and natural gas processing centers – suffered hurricane damage or were otherwise disrupted through interruptions of the workforce, electricity needed for operations, or processing inputs. At this time, a significant portion of this capacity remains out of service. Full recovery of Gulf energy infrastructure is not expected until later this year, and in the wake of the hurricanes the rest of the country braced itself for an extremely difficult and costly winter heating season. Is it a worst-case scenario? Maybe. It is hard to imagine a more forceful hit, and it is hard to imagine it coming at a worse time – a period when global supply and demand conditions for crude oil are at their tightest in three decades; when global and national spare refining capacity are similarly stretched thin; when North American supplies of natural gas are in decline while demand is growing strong, and prices are already at all-time peaks; and when some suggest we are reaching the limits of the ability of existing infrastructure to meet our growing, insatiable appetite for fossil fuels.

Why did the hurricanes produce such an impact, and what does it tell us about our energy infrastructure needs? The Gulf Coast is the undisputed heart of the U.S. energy industry. In the Gulf, we produce or import three-fifths of the country’s supply of crude oil and a third of U.S. natural gas supplies; we generate half of the country’s refined product, supplying nearly all of the requirements for the Gulf region, the East Coast, and most of

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the Midwest. The vast majority of the petroleum and natural gas products consumed in the eastern half of the country find their origin in markets, storage, processing, and pipeline capacity concentrated in Gulf states. The sheer magnitude of fossil fuel operations in the Gulf make them the centerpiece of U.S. natural gas and refined petroleum product supply and pricing.

The combined effect of the two hurricanes took out virtually all of this capacity for a short period of time, and an unprecedented level of capacity for a more extended period of time. It did so, as mentioned, against a backdrop of historically thin supply and high prices, and the results were predictably severe. What are our options to address the weaknesses that the hurricanes revealed: to try to prevent such a disproportionate impact in the future, whether it is the result of hurricanes or other natural forces, or the result of an intentional terrorist act?

If there is a silver lining, it is in the potential that the aftermath of the hurricanes on energy markets will serve as a wakeup call – that they will remind us of some basic facts related to energy security and infrastructure vulnerability. In particular, they have demonstrated the magnitude of the influence of energy costs and availability on personal wealth and national and local economies. And they have revealed both how sensitive energy supply and pricing is to relatively small disruptions, and how concentrations and weaknesses in our energy infrastructure leave us vulnerable to such supply disruptions.

This paper reviews the vulnerabilities in our nation's energy infrastructure, as revealed in part by the havoc wreaked by the Gulf hurricanes. The focus is primarily on petroleum and natural gas. First, it describes the sources of supply for each fuel, along with the capacity to process raw fuels and distribute the resulting products to U.S. markets. Next it describes industry conditions following the hurricanes, and the actual and expected supply and price impacts of these disruptions. Finally, it examines in particular the supply and price impacts on energy markets in the Northeast, which is excessively dependent on Gulf supplies of oil for heating, and on natural gas for heating, commercial activity, and electricity generation.

This review underscores the consequences of existing vulnerabilities in our energy infrastructure, and in our national and regional pattern of dependencies on tightening global and national markets for petroleum and natural gas. Concern over energy supply and price vulnerability is not new – indeed, understanding the role of energy supply and cost in national security and economic health has been the primary focus of numerous government and privately-funded studies spanning decades. The impacts of the Gulf hurricanes have reinforced certain fundamental concerns prevalent in these studies – namely our dependence on fossil fuels and the concentration of our energy infrastructure. But they also have revealed important near-term vulnerabilities associated with recent growth in demand and current infrastructure conditions.

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FINDINGS ON VULNERABILITIES

Certain themes arise from the review of the impacts of the Gulf Coast hurricanes for the development of energy policy in their wake. These are summarized here and presented in more detail in the final section of the paper:

- Hurricanes' Impact

The havoc wrecked on U.S. energy markets in the wake of the two hurricanes was unprecedented. They took out virtually all of the Gulf region's capacity for a short period of time, with sustained outages for a much more extended period of time. On top of historically thin supply margins and high prices, the results were predictably severe. The supply and price impacts that followed revealed or reinforced what we already knew: U.S. oil and gas industries are concentrated geographically, with extraordinarily thin reserve capacity in other parts of the country. U.S. energy supply, energy markets, and (by extension) economic activity are all heavily dependent on energy supply and infrastructure concentrated in the Gulf region.

- Dependence

Reducing our demand for oil – through increasing vehicle fuel efficiency, reducing residential, commercial and industrial demand, and developing alternative liquid fuel options – is the single most effective option available to relieve the stresses that currently exist at every stage of the energy supply cycle. A concerted attempt to address this dependency now can buy needed time in the near term to address critical infrastructure deficiencies, and a sustained effort to continuously reduce this dependence over time will help maintain an important degree of flexibility and resiliency in our energy supply systems in the Gulf and across the country.

- Geographically Concentrated Refining and Reprocessing Infrastructure

The hurricanes exposed a certain frailty in our domestic refinery capacity, which is currently operating near maximum output. The industry has evolved so that refinery ownership and production rests in fewer and fewer refineries, with most of it in the Gulf region. This concentration of refinery capacity, ownership, and location may have resulted from market economics, but it nonetheless has introduced supply and price vulnerabilities associated with disruptions in domestic refinery output. The situation is similar for natural gas. It is estimated that three quarters of the marketed dry natural gas consumed in the country has needed to be processed at natural gas processing plants before injection into inter- and intra-state pipelines. Most of the natural gas processing capacity is located in the Gulf region.

Following the hurricanes, many refineries and gas reprocessing plants were shut down or faced reduced operation for a short period of time simply because the input fuel was not available due to disruption in supply from Gulf production and import capacity. Ironically, much of the shut-down capacity resulted from storm-related damage to the electric grid. While many refineries have a substantial amount of electric generating capacity on-site, this capacity was not sufficient for refinery operations, or may also have been inoperable due to the need for synchronous operation with the surrounding grid.

Summary

- Pipelines

The Midwest and East Coast are heavily dependent on deliveries of natural gas, crude oil and refined products via a few major pipelines emanating in the Gulf region. Loss of these pipelines meant the nearly full disruption of pipeline supply of gas, crude oil, and refined product to the consuming regions. Shut-in supply and refining/processing capacity, combined with the loss of electric power to key pipeline operation and support systems (such as compressor stations), dramatically reduced the flow of product out of the region.

- Natural Gas

The hurricanes highlight a unique and timely infrastructure challenge relating to natural gas supply. This industry is on the brink of moving from a largely continental supply resource dominated by supplies from the Gulf, to one increasingly reliant upon imports of liquefied natural gas (LNG). On the one hand, this technology will provide flexibility and opportunities for diversification that do not exist with continental sources of gas. But unfortunately, existing proposals to site LNG imports are dominated by sites in the Gulf region. To some extent, this makes sense because the Gulf is a location of major natural gas processing, storage, and transportation infrastructure, as well as a region where domestic supply productivity is decreasing. The siting of LNG import capability in the Gulf can thus prolong the utilization of existing gas system infrastructure in that region. But if we end up siting most LNG regasification and storage capacity in the Gulf, we risk remaining in the kind of geographic dependency we have experienced for years.

- Prices

With the hurricanes coming on the heels of already tight oil and gas markets and refining capacity, prices shot up dramatically with the news of the storms in the Gulf. Prices stayed high, dropping gradually as capacity came back on line. More severe price impacts were avoided in part by lower-than-expected demand as the major gas-consuming regions experienced extraordinarily warm winter conditions.

SUMMARY OF RECOMMENDATIONS

In light of these circumstances, the following recommendations flow from this analysis:

- It may be possible to increase imports of refined products, but it is worth considering domestic-based alternatives to foreign supplies of refined product. Specifically, we should consider the feasibility and cost of diversifying the geographic distribution of U.S. refinery capacity, and the benefits (such as reduced risk of supply disruption) that would come from doing so.
- Mechanisms to support or reinforce refinery and reprocessing operations under conditions of extended outage of the surrounding electric system in the Gulf region should be reviewed.
- As with the impact on refinery operations, the recent experience calls for enhanced efforts to reduce dependence on supplied products, as well as an evaluation of the

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feasibility and costs of diversifying supply methods. In addition, the risk of disruptions associated with pipeline outages could be reduced by increasing permanent placement of backup electric generation capacity at pipeline compression/operation locations, and fortification of such locations against flooding/damage associated with storms of the magnitude just experienced, as well as against other plausible natural, accidental, or intentional impacts.

- If we end up siting most LNG regasification and storage capacity in the Gulf, we will remain in our current geographic dependency. The nation has the option to site LNG in a manner that better reflects patterns of expected demand growth, maximum utilization of existing pipeline capacity (e.g., through backfill from the end of interstate systems, through the filling of under-utilized capacity, and through maintaining pipeline flow from regions where existing supplies are in decline). However, it would be a mistake to continue to increase the vulnerability of the major consuming regions in the country through a further concentration of natural gas supply and transportation in the Gulf. A national review should be undertaken to support review of LNG proposals that identifies the optimum locations from among existing proposals for siting LNG import infrastructure, in light of demand projections, existing patterns of supply, risks of supply concentration, and transportation infrastructure capacity and utilization trends.

EXISTING INFRASTRUCTURE

PETROLEUM

Our dependence on the refined products of crude oil is pervasive – geographically, economically, socially, historically, culturally, and militarily. Oil goes into nearly everything we come into contact with in our daily lives – the production and distribution of food; the building, furnishing and heating of our homes; the wheels of commerce; the building and maintenance of roads and other public infrastructure and services; and work and leisure transportation. We are completely dependent on oil for work and play, health and security. The affordability of oil-based transportation fuels drives economic activity and provides the freedom of motion that is so important to Americans. This pervasive *demand* for oil – along with its relative inflexibility to price changes in the short run, and the lack of significant alternatives – remains our most important energy vulnerability.

On the *supply* side, crude oil is a global commodity. The U.S. is increasingly dependent on the production of oil in foreign countries, and is therefore increasingly subject to the price changes that result from the dynamics of global supply and demand. Because oil is a global commodity, we will be subject to global swings in the price of crude oil regardless of how much we import. In other words, the level of U.S. imports contributes to, but is not the source of crude oil price volatility; instead, it is the interplay of supply and demand in global crude oil markets; current price conditions reflect the current tightness of global supplies. The dynamics of global supply, in turn, are strongly tied to the decisions of the OPEC cartel and the effects of political and social instability in other producing nations.

But the global market in crude oil is only the first link of the supply stranglehold. Crude must be converted into gasoline, jet and home-heating fuel, and other products at refineries, then shipped to market via pipeline, boat, truck, and train. While the global market in crude historically has been the most important determinant of the availability and price of refined products, refining and transport are significant contributors as well. Constraints or vulnerabilities at any of these stages add to the risks of shortages and price spikes in downstream refined-product markets.

Pinpointing our key petroleum infrastructure vulnerabilities thus begins with an overview of our demand for oil products, and a review of the concentration and weaknesses of each step in the sequence of activities that move crude from geologic reservoirs to gas pumps and furnaces.

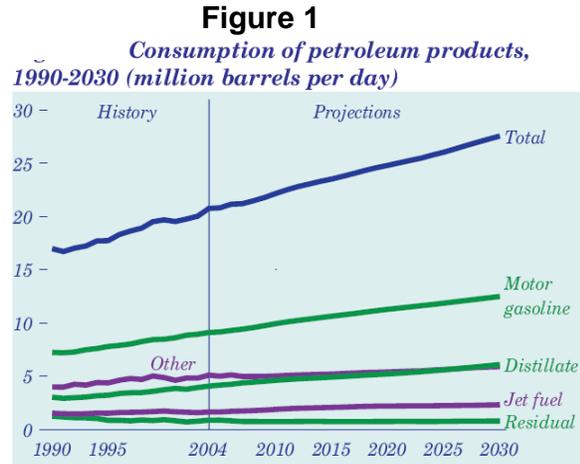
Petroleum Demand and Supply

In 2004 the U.S. consumed roughly an average 20.7 million barrels per day (MBD). This

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level represents a new high for U.S. consumption, a growth of 3.5 percent over 2003 levels, and 24 percent over 1991 consumption.¹ The U.S. Energy Information Administration (EIA) projects U.S. petroleum product consumption to grow at an annual average growth rate of 1.1 percent, increasing to 28 MBD in 2030.² See Figure 1.

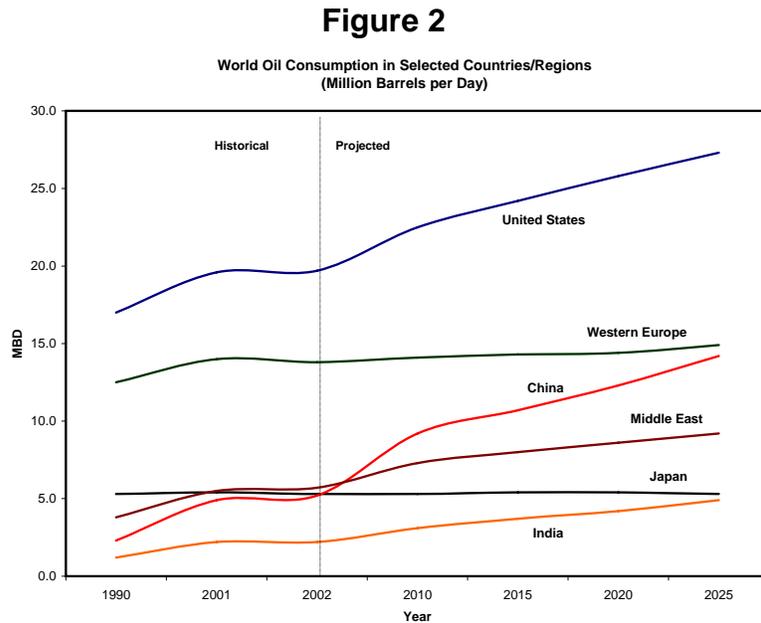
The United States remains by far the world's biggest oil consumer. At over 20 MBD in 2004, it represented one quarter of global crude oil consumption in that year (80 MBD). Moreover, the U.S. consumed over three times more than China (6.5 MBD), which in 2004 overtook Japan as the world's second largest consumer of crude oil.



EIA AEO 2006, Figure 91

EIA projects world oil consumption to increase to nearly 120 MBD by 2025, driven by growth in all economies, with particularly strong average annual growth rates over that period in China and India – 4.5 and 3.5 percent respectively. The increasing importance of China and India in world oil demand is evident in Figure 2, which presents world oil consumption in selected major consuming countries/regions through 2025.³

The remarkable growth rate of crude oil consumption in China and India is most often cited as the driver of recent tightening of global crude supply and demand conditions, leading to sustained higher price levels. For example, the Federal Trade Commission (FTC) suggests that in 2004 crude



Data source: EIA, International Energy Outlook 2005, June 2005, Table A4

¹ U.S. Energy Information Administration (EIA), *Petroleum Supply Annual 2004, Volume I (PSA 04)*, June 2005, Table S1.

² EIA, *Annual Energy Outlook 2006 (AEO 06)*, February 2006, Table A11.

³ EIA, *International Energy Outlook 2005*, June 2005, Table A4.

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producers were not prepared for larger-than-expected increases in world demand, noting “[l]arge demand increases from rapidly industrializing countries, particularly China and India, made supplies much tighter than expected.” Notably, the unexpectedly high demand was not limited to these countries; it was across the board (See Figure 3).⁴

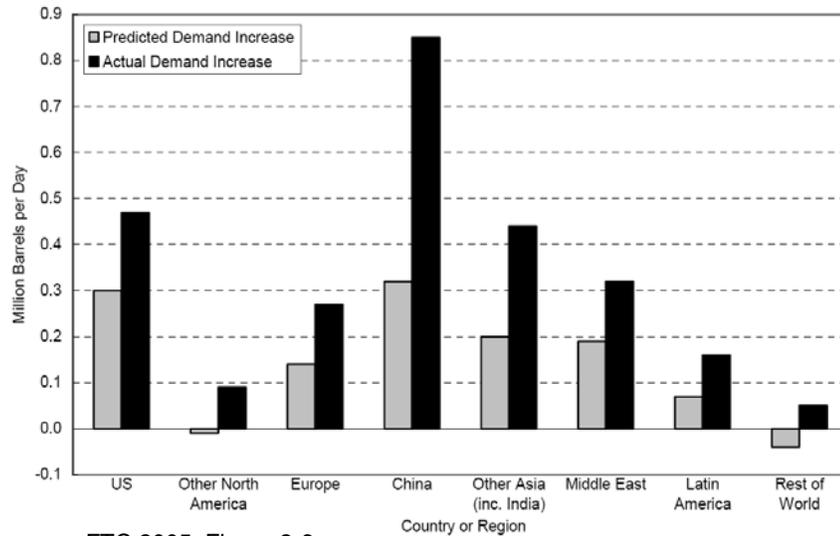
Thus, supply and demand conditions in the global crude oil market were already stretched thin at the time that the hurricanes struck the Gulf Coast. Such conditions would be expected to exacerbate the short-term impact of any additional disruptions in this market (such as disruption of crude production in the Gulf).

Crude oil supply is only the first piece of the domestic oil infrastructure chain, which also includes critical refinery, storage, pipeline, and other transportation/delivery infrastructure. Each of these can have an important influence on delivered product supply and price conditions across U.S. regions.

While the U.S. has long been a net importer of crude oil (a trend that is expected to continue and grow in importance in the coming decades), domestic refinery capacity has been the source of nearly all of the refined products consumed within the country. In 2004, the U.S. imported roughly two thirds, or 10 MBD, of the crude inputs to refineries in the U.S. Domestic refineries combined these imports with 5.5 MBD of domestic crude production to generate 16.5 MBD or 91 percent of refinery product consumed in the U.S. Net imports of refined products equaled approximately 1 MBD, or 9 percent of U.S. consumption.⁵ Figure 4 represents graphically the relative contributions in the U.S. of domestic and imported crude and refined products, and the relationship between them.

Figure 3

Figure 2-6: 2004 Predicted vs. Actual Crude Oil Demand Increase, Million Barrels per Day



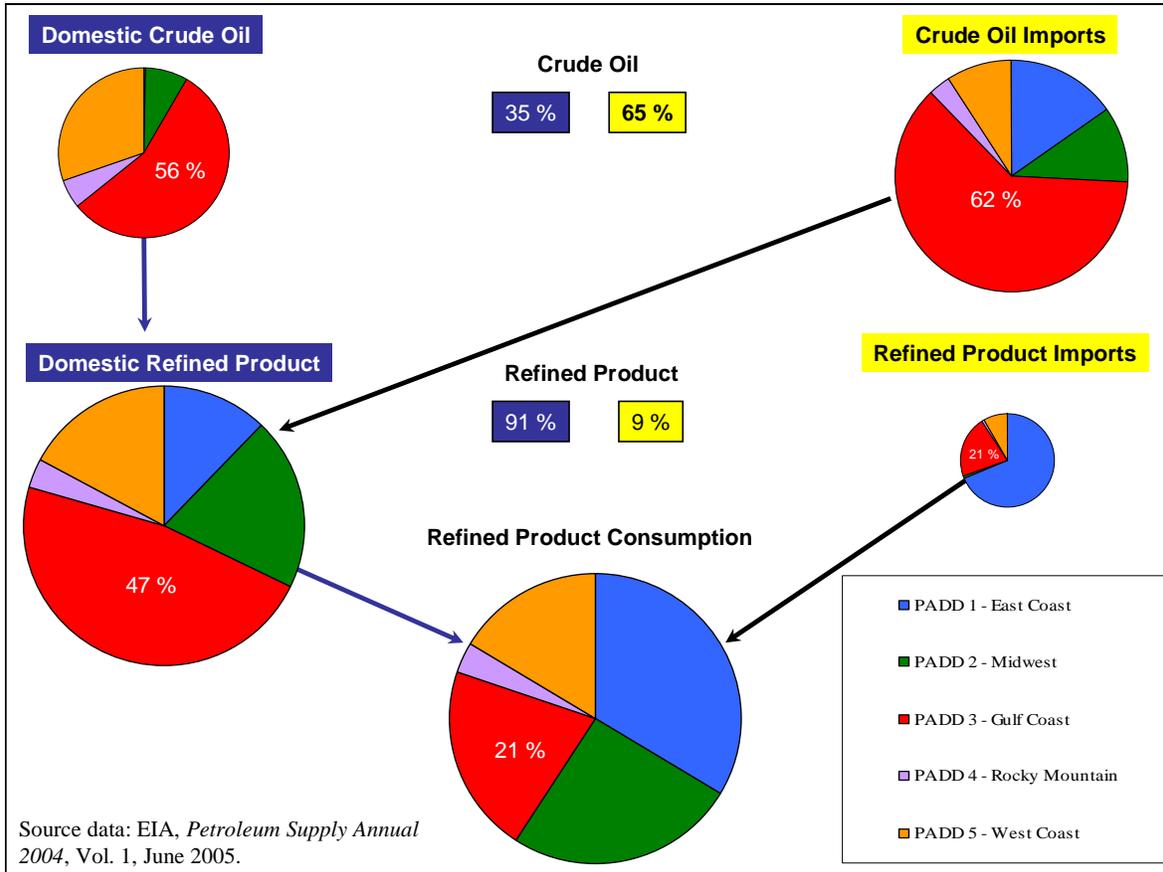
FTC 2005, Figure 2-6

⁴ Federal Trade Commission, *Gasoline Price Changes: The Dynamic of Supply, Demand, and Competition*, June 2005 (“FTC 05”), page vi.

⁵ Most of the remaining 2.5 MBD of petroleum products consumed in the U.S. in 2004 was associated with domestic production of natural gas liquids.

Figure 4

Import and Domestic Production of Crude Oil and Refined Products for U.S. Consumption



The final major piece of the national petroleum infrastructure puzzle is transportation – transportation of crude from producing wells and import terminals to refineries and crude storage; and transportation of refined products to refined product storage and local markets. Three quarters of crude oil moved domestically occurs via pipeline, as do roughly three fifths of refined products.⁶ Most of the remainder is moved by water carriers.⁷

Infrastructure Considerations

The ability to turn crude oil into energy products for consumers involves a web of oil infrastructure facilities: terminals, production facilities, refineries, pipelines, and so

⁶ Association of Oil Pipe Lines, *Pipelines and Water Carriers Continue to Lead All Other Modes of Transport in Ton-Miles Movement of Oil in 2003*, May 16, 2005, Tables 2 and 3.

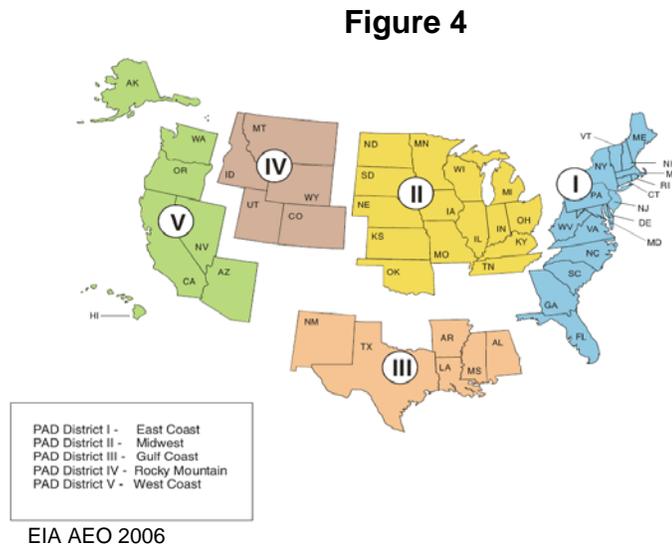
⁷ Less than one percent of crude, and ten percent of refined products, are shipped domestically via motor carriers and railroads. Id.

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forth. These facilities are necessary to transform a raw energy resource into useable forms, but they are also important because the geographic configuration of the facilities can influence the distribution and local severity of impacts associated with events that strike a single region – such as the hurricanes did this summer. These features involve:

Crude Oil

- The U.S. is strongly dependent on Gulf of Mexico petroleum infrastructure for crude oil supplies, both from the standpoint of domestic production, and from the standpoint of crude oil imports. The major consuming regions of the Midwest and East Coast import smaller but significant quantities of crude. Most of the crude oil input to refineries in the Rocky Mountain and West Coast regions was produced in those regions.
- 56 percent of daily average domestic crude oil production in 2004 was from the Gulf of Mexico region (PADD III – see Figure 4).⁸
- 62 percent of crude oil imports into the U.S. in 2004 was received at import terminals in the Gulf region. Approximately 15 percent of imported crude was received on the East Coast (PADD I), and 10 percent in the Midwest (PADD II).⁹
- Combined, approximately 60 percent of the crude oil input to domestic refineries in 2004 was either produced or imported via petroleum supply and delivery infrastructure located in the Gulf region (PADD III).



Refining

- While the U.S. is heavily dependent on imports for crude oil consumption, it has historically produced nearly all finished petroleum products at domestic refineries. In 2004, net imports of refined products averaged only 1 MBD, or about 5 percent of the total petroleum products supplied for U.S. consumption. But as with crude oil

⁸ PSA 04, Tables 3 and 9. During World War II, the Petroleum Administration for Defense divided the 50 U.S. states into “Petroleum Administration for Defense” Districts (PADD), for the purpose of administering oil allocations. These designations are still used today by EIA for the reporting of petroleum demand, supply, and disposition data. The Gulf of Mexico region is included in PADD III.

⁹ PSA 04, Tables 3, 5, 7, and 9.

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production and import, much of our refinery capacity, particularly for supplying the East Coast and Midwest, is located in the Gulf region.

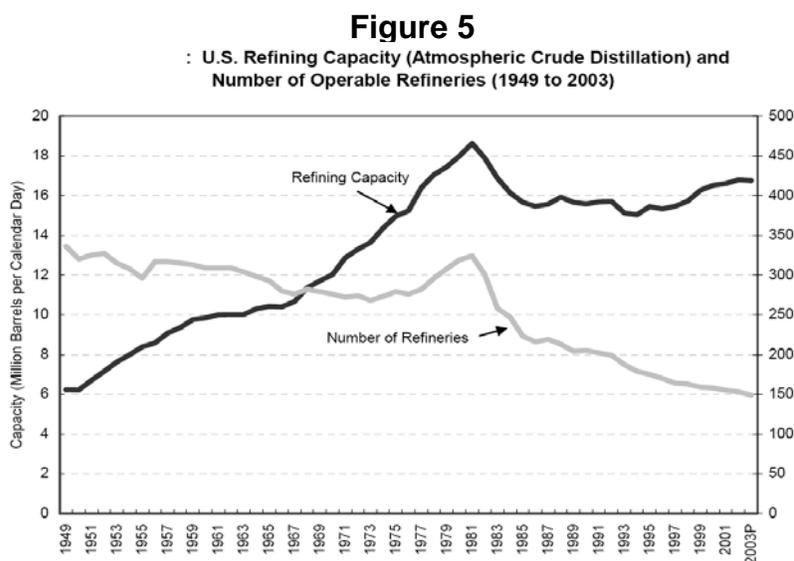
- Nearly half the U.S. operable refinery capacity, and most of the operable capacity added in the past 6 years, is located in the Gulf Coast region (PADD III), with most of that located on the Texas and Louisiana coasts. See Table 1.

Table 1
U.S. Operable Refinery Capacity By Region
(Thousand Barrels per Day)

	1999	2000	2001	2002	2003	2004	2004
U.S.	16,105	16,251	16,320	16,457	16,667	16,891	100%
Region							
PADD 1	1,598	1,608	1,601	1,596	1,681	1,730	10%
PADD 2	3,612	3,620	3,508	3,480	3,518	3,526	21%
PADD 3	7,370	7,476	7,621	7,716	7,784	7,947	47%
Texas Inland	572	574	584	588	603	615	
Texas Gulf Coast	3,583	3,653	3,768	3,822	3,808	3,912	
La. Gulf Coast	2,923	2,956	3,004	3,012	3,073	3,109	
N. La., Ark	198	197	169	198	205	202	
New Mexico	95	96	96	96	96	110	
PADD 4	528	533	553	573	578	582	3%
PADD 5	2,997	3,014	3,037	3,093	3,106	3,107	18%

Data Source: EIA Petroleum Navigator, Accessed 11/30/05.

- U.S. refinery production has generally kept pace with increases in U.S. demand for refined products over the past several decades not through construction of new refineries, but rather through increasing the average size and capacity of refineries (see Figure 5), increasing the efficiency of refineries (in order to get more product per unit of crude input), and increasing the capacity utilization of existing refineries (see Figure 6).¹⁰

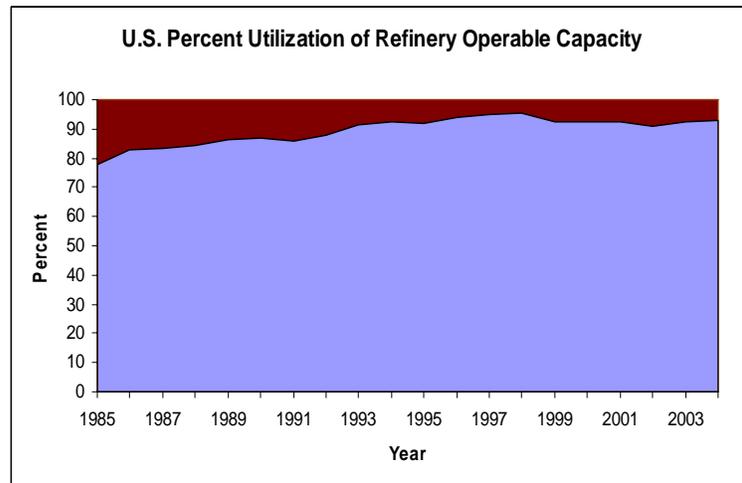


¹⁰ FTC, pages 49-57.

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- The last new refinery built in the U.S. was in 1976. Since that time the number of operable refineries has decreased substantially. Possible explanations for these trends include the existence of economies of scale in the industry, encouraging increasing the capacity of existing refineries (rather than building new ones); the decline in U.S. crude production (reducing the value of collocating production and refinery capacity); relatively low profit margins on refinery operations; and extensive permitting and licensing requirements related to the environmental and public health risks of refinery construction and operation.

Figure 6

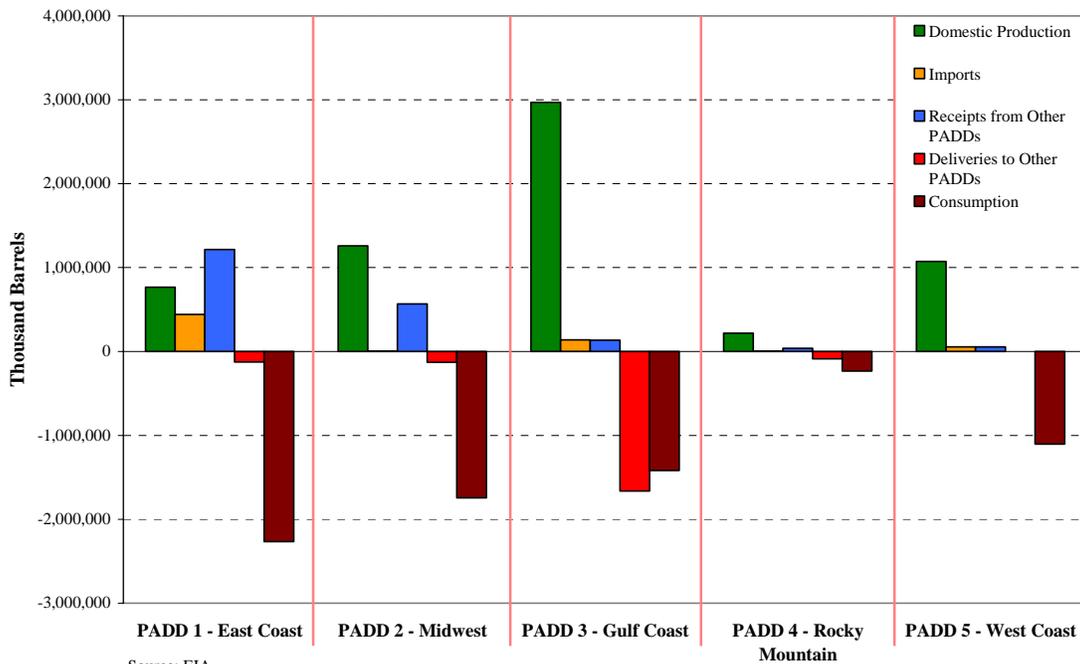


Data Source: EIA Petroleum Navigator, Accessed 11-3--2005

- The changing circumstances of domestic refining infrastructure in the past few decades has increased the country's vulnerability to events that can disrupt refinery operations. Our vulnerability stems from the combination of (a) the industry running extremely close to its production margins (having reached historic lows with respect to excess available operating capacity), and (b) the higher geographical concentration of domestic refinery capacity.
- Figure 7 breaks down production, consumption and shipments of refined gasoline products by region for 2004. A number of conditions emerge from this data. First, the Rocky Mountain and West Coast regions' (PADDs IV and V) refinery gasoline production is sufficient to supply in-region demand. Similarly, much of the Midwest demand is met through in-region refinery capacity; however, the Midwest is still significantly dependent on refined product shipped from other regions. On the other hand, the East Coast has the highest amount of refined product consumption, but the second-lowest refined product production. It is heavily dependent on product from other regions, which comes mostly from the Gulf, but also includes the largest share of refined product imports to the U.S. The Gulf has by far the largest quantity of refinery output, exceeding consumption by a wide margin, with the remainder exported mostly to the East Coast and Midwest.

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Figure 7
Consumption, Production, Imports, and Flows of Refined Petroleum Product
by PADD2004



- Historic crude production, efficiency, and economic considerations have led to this concentration of a significant portion of refinery capacity in the Gulf region, and are likely to continue to encourage this trend. However, the dependence of the East Coast and Midwest on Gulf refinery capacity means that disruptions to Gulf supply will be felt heavily in those regions, and can not be easily or cheaply replaced.

Transport

- The high concentration of crude and refined product production and import in the Gulf region, combined with significantly lower consumption levels, means that a huge amount of crude and refined product must be moved from the Gulf to other regions in the U.S. via liquid pipelines, barge, truck and train. Two thirds of crude oil and three fifths of domestic refined products moves over the U.S. petroleum product pipeline network. Most of the rest involves barge shipments from the gulf, or along the coasts.
- This domestic pipeline infrastructure is an extensive network of large- and small-diameter pipelines designed to move liquid petroleum from the Gulf to other regions, and to a lesser extent to move petroleum between other regions, within each region,

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and from Canada to the U.S..¹¹ See Figures 8 and 9. Figure 8 shows the major trunkline systems that move crude oil imports from Canada and overseas to U.S. refineries; and crude oil from domestic Gulf production to refineries in the Gulf and in the Midwest. Figure 9 shows the major refined petroleum product trunkline systems in black, primarily moving product from the Gulf Coast refineries to markets on the East Coast and in the Midwest. Blue lines reflect the smaller diameter pipelines that move refined products shorter distances within and across regions.¹²

- In short, the Midwest and East Coast are heavily dependent on crude and refined product shipments from the Gulf Coast through just a handful of major pipelines and, to a lesser extent, crude and refined product barge shipments. The time it takes to move product from the gulf to downstream markets can take days or weeks, as can the arrangement for alternative supplies through imports, barge, truck, or rail transport. Disruptions to pipeline flows across these pipes – through lack of petroleum supplies, outage of electrical power needed to run pipeline compressors, or damage to the pipelines themselves – can severely affect supply and price conditions in the Midwest and East Coast.
- In addition to these interregional distribution systems, there is an extensive network of short-haul supply pipes that bring crude oil product from on-shore and off-shore wells in the Gulf region to central hubs for collection and transport, or for delivery to refineries for processing. The supply of domestic crude from the Gulf region relies on this network of short-haul supply lines.

¹¹ Data on shipments from: Association of Oil Pipe Lines, *Pipelines and Water Carriers Continue to Lead All Other Modes of Transport in Ton-Miles Movement of Oil in 2003*, May 16, 2005, Tables 2 and 3. Figures 8 and 9 from: Allegro Energy Group, *How Pipelines Make the Oil Market Work – Their Networks, Operation and Regulation* (Allegro), December 2001.

¹² Allegro, pages 9-10.

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Figure 8
Selected Crude Oil Trunkline Systems

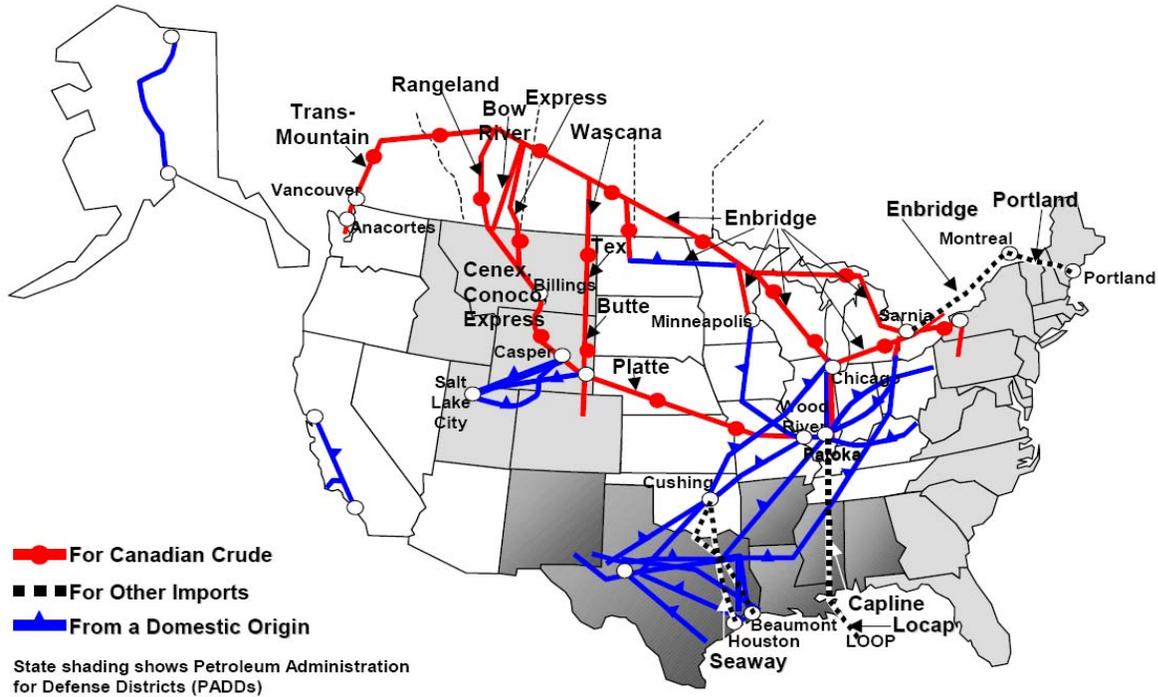
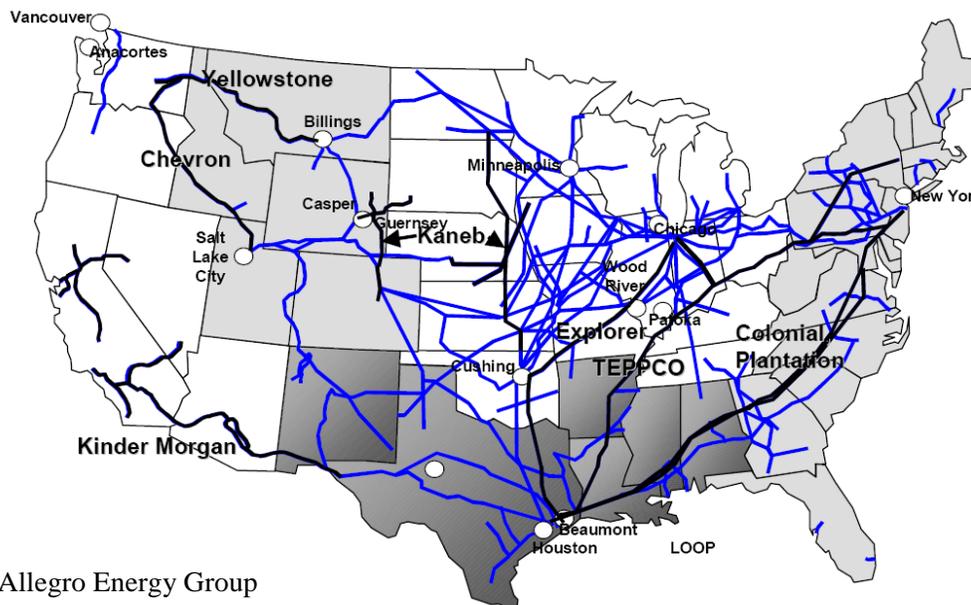


Figure 9
Major Refined Product Pipelines



From Allegro Energy Group

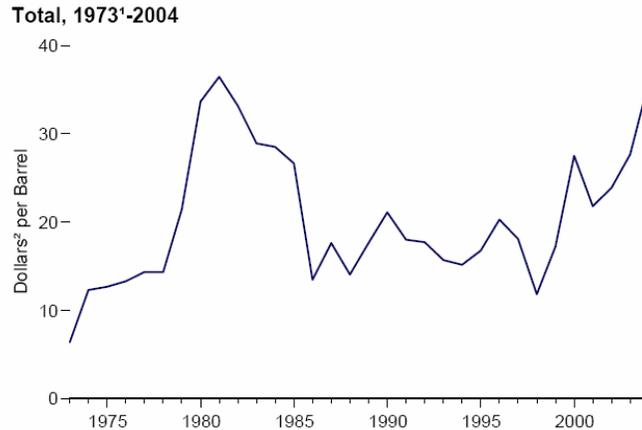
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Prices

- After a period of relatively flat, low prices, in recent years, oil prices have begun to rise slowly and steady. See Figure 10, which shows nominal prices for crude oil imports to the U.S. in the past three decades. From 1985 through around 2000, prices remained between approximately \$10 and \$30 per barrel. Starting around 2000, the situation began to change, and prices have risen relatively steadily since then. This reflects the global oil market fundamentals described above.

Figure 10

Landed Costs of Crude Oil Imports to the U.S.

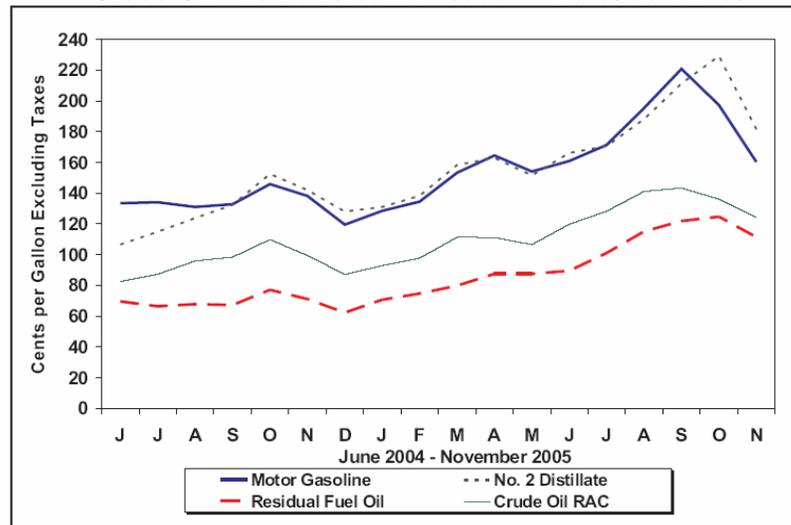


EIA, Annual Review of Energy, 2004, Figure 5.19

- Prices in the period immediately leading up to the hurricanes of Fall 2005 show this continuing pressure. Figure 11 shows price increases (on a cent per gallon equivalent basis) of crude oil and refined products (including gasoline, distillate and residual fuel oil).

Figure 11

Crude Oil and Petroleum Product Wholesale Prices



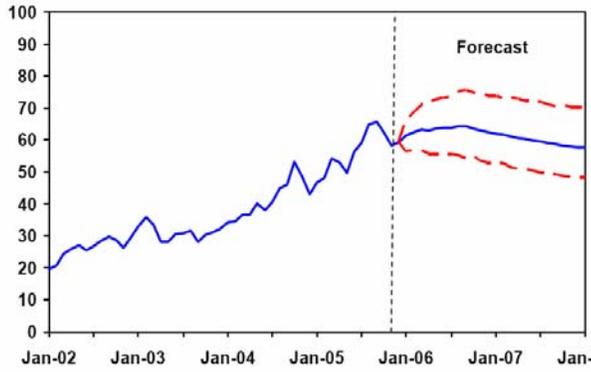
EIA, Petroleum Marketing Monthly, February 2006, Figure HL1

- Most recently, projections of short-term oil prices reveal expectations for sustained high prices for the next few years, even though the immediate effects of the hurricanes on prices have diminished. Figure 12 shows EIA's short-term price outlook from January 2006, indicating a base case as well as higher and lower projections reflecting a 95% confidence interval. Figure 13 indicates the same crude oil price forecast in cents per gallon, along with the price outlook for refined products.

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Figure 12

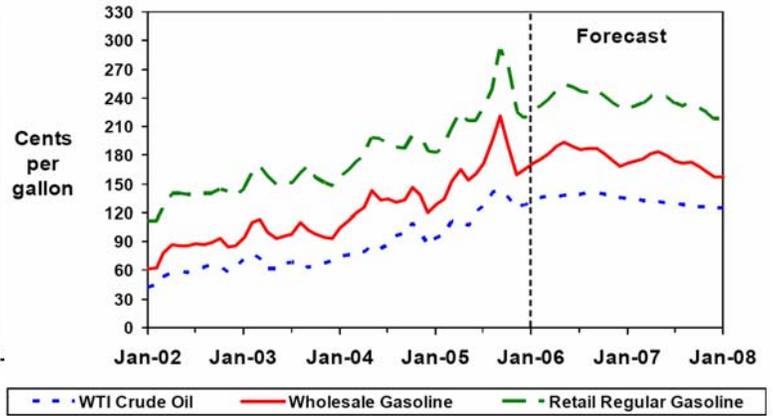
WTI Crude Oil Prices (\$/barrel)



EIA Short-term energy outlook (January 2006)

Figure 13

Gasoline and Crude Oil Prices (¢/gallon)



Existing Infrastructure

NATURAL GAS

The natural gas picture looks similar to the oil scene, in many ways. The U.S. is increasingly dependent on natural gas for residential and commercial heating, commercial/industrial process needs and electric power generation. Our reliance is projected to grow in importance over the next 20 years. The Gulf region is the primary location of domestic supply, processing, and transportation infrastructure, and its role in natural gas supply is expected to increase in significance over time. While historically most of our supply of natural gas has come from domestic and Canadian sources, the productivity of this supply base is in decline, and the U.S. will become more and more dependent over time on the global market for gas to meet growing demand.

But there are key differences in infrastructure vulnerabilities and challenges between oil and gas. Once gas is injected into the national or regional gas pipeline networks, it exits at the point of consumption. There is little or no opportunity for alternative transportation or delivery mechanisms in the event of major pipeline disruptions. This also means that as demand grows, pipeline infrastructure must also grow, and it must do so in a way that makes sense in the context of the sources of new demand and supply. Also, the level of reliance upon international markets for gas – through the addition of liquefied natural gas (LNG) import terminals in the U.S. – will be a new reality for our country. How (or *where*) infrastructure is developed to accommodate the needed increase in LNG to meet growing demand in the coming decades will significantly influence the vulnerability of natural gas consumers to supply disruptions and price spikes.

Natural Gas Demand and Supply

Historically, gas customers have been added when new sources of domestic supply and other sources from within North America became available at attractive prices. Thus, the nation's natural gas demand was relatively in balance with supply. This picture changed somewhat in recent years, as low gas prices in North America led to unprecedented new demand for natural gas in power plants built in various regions around the U.S. Increasingly, the U.S. is looking outside the traditional supply basins to meet this need. It is widely expected that in the future, increasing imports will provide the swing supplies to meet growing demand in the face of decreasing domestic productivity.

In 2004 the U.S. consumed roughly 22.4 trillion cubic feet (TCF) of natural gas – 7.8 TCF (35 percent) in the residential and commercial sectors, 7.4 TCF (33 percent) in the industrial sector, and 5.4 TCF (24 percent) for electricity generation.¹³ U.S. production nearly matched that amount, totaling roughly 18.9 TCF – or 84% of U.S. demand – for the year. Most of the remainder needed to meet demand in 2004 was imported via pipeline from Canada.¹⁴ In recent years, the U.S. has met nearly all of its demand in this

¹³ The remainder – approximately 1.8 TCF – was used in gas processing, distribution, and vehicle consumption. EIA, *Natural Gas Monthly October 2005* (NGM), Table 3.

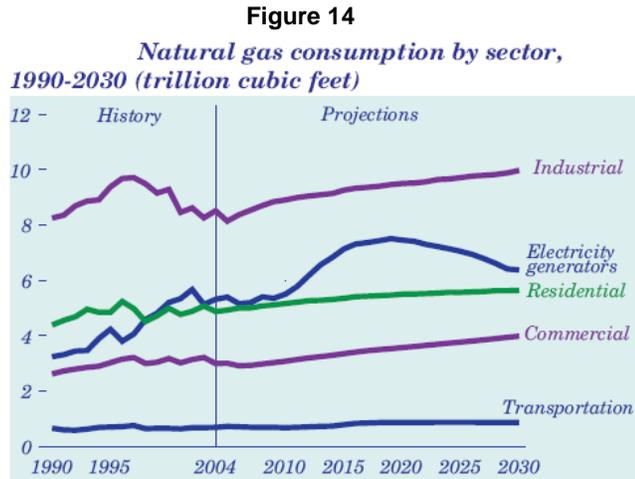
¹⁴ EIA NGM, Tables 3 and 5.

Existing Infrastructure

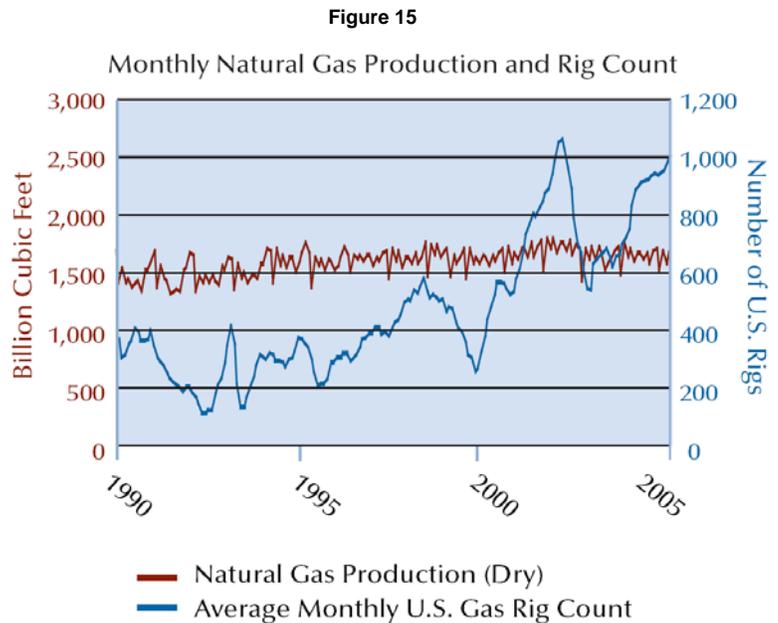
way via pipeline from continental sources of gas in the U.S. and Canada, with small (but important, particularly during winter peak seasons) contributions from existing LNG import facilities.

For the future, EIA projects natural gas demand in the U.S. to grow to 26.9 TCF in 2030, with demand growth initially dominated by the electric generation sector, followed by a decline in the contribution of the electric sector towards the end of the forecast period. See Figure 14.

This projected strong growth in demand for natural gas comes at a time of declining productivity for the conventional continental sources of natural gas supply. While recent drilling activity has increased substantially, the productivity of rigs drilled continues to decline on average. See Figure 15. EIA projects that in order to meet increasing demand for natural gas in the U.S., we will thus rely more and more upon non-conventional sources of gas, primarily from the Rocky Mountain region, and on imports of LNG. See Figure 16.



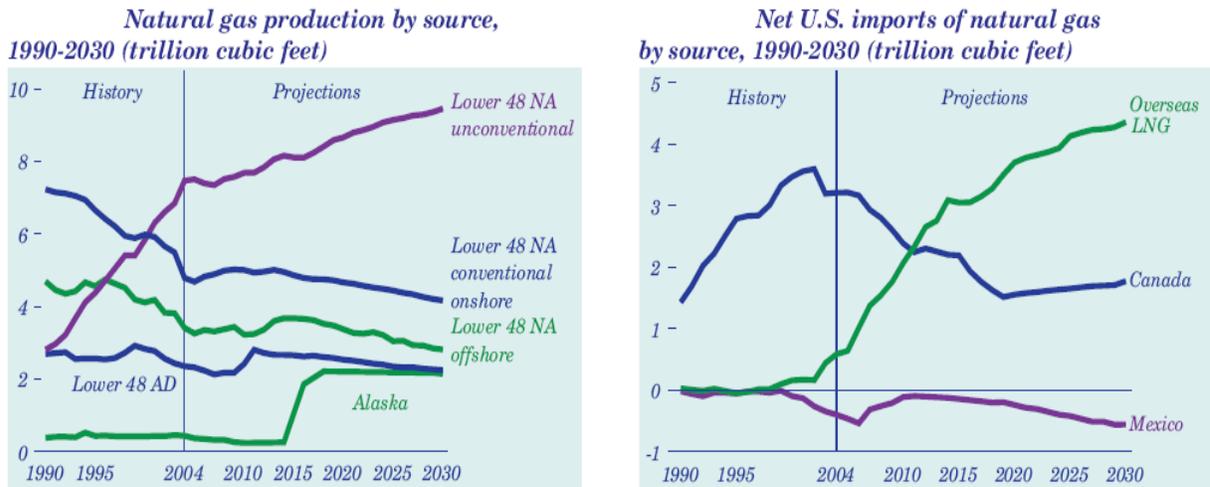
EIA AEO 2006, Figure 71



NCEP, Figure 4-4

Existing Infrastructure

Figure 16



EIA AEO 2006, Figures 73 and 74

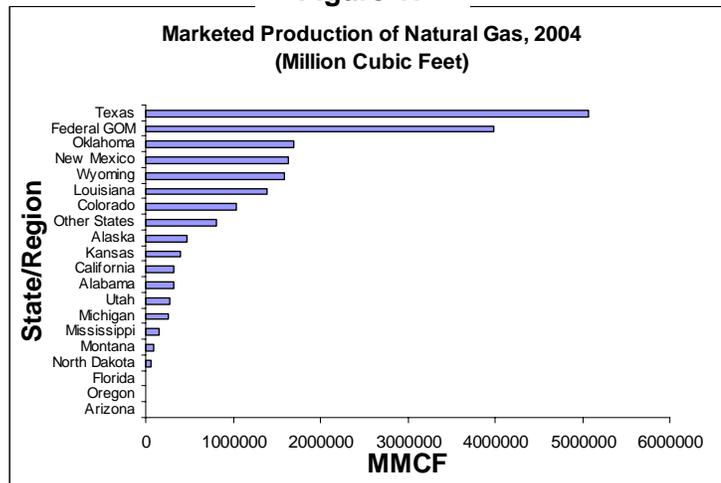
Infrastructure Considerations

For natural gas, there are important considerations associated with the distribution of key supply and delivery infrastructure across the U.S. These considerations can influence the location and severity of impacts associated with events that strike a single region. Important considerations are summarized below:

Production and Import

- The Gulf Coast region has been the most significant source of domestic natural gas production, a situation likely to continue for some time. In 2004, the offshore Gulf of Mexico region, Louisiana and Texas combined accounted for over 10 TCF, or approximately 53 percent of domestic marketed natural gas supplies. See Figure 17.
- Imports from Canada are projected to decline, in light of declining productivity of gas supplies in Western Canada, less-than-expected productivity from Eastern Canadian sources, and growing demand in Canada for natural gas (particularly from the electric sector). This effect could be partially offset by the potential location of new LNG import

Figure 17



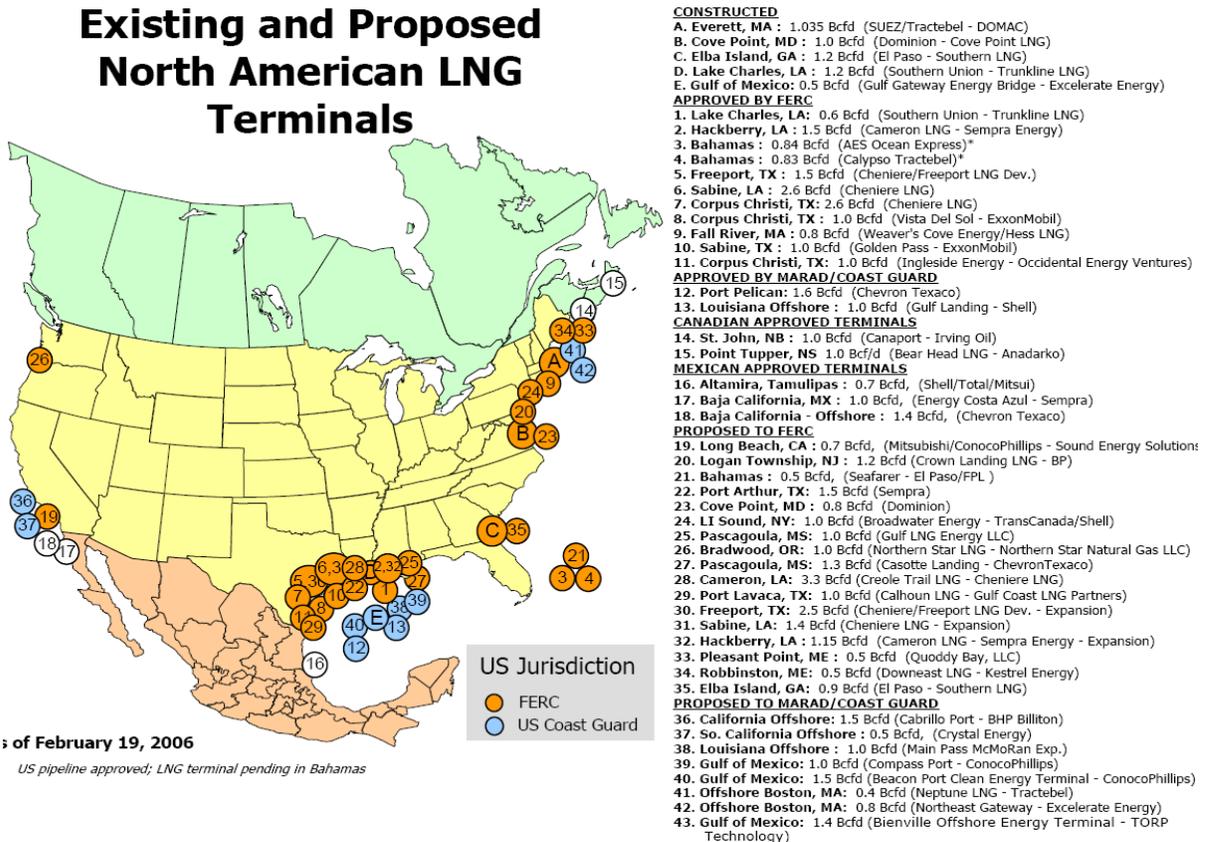
Source data from EIA.

Existing Infrastructure

facilities proposed for Eastern Canada.

- EIA projects that unconventional sources, largely from the Rocky Mountain Region, will continue to grow in importance relative to the offshore Gulf and other U.S. sources as the leading lower-48 supply region for natural gas in the U.S. in the coming decade (see Figure 16). But taking off-shore and on-shore production into account, the Gulf states are expected to remain a dominant source of domestic natural gas supplies over the forecast period.
- Most industry observers expect LNG imports to be the fastest growing source of natural gas supply to the U.S. in the coming decades. There are roughly 38 applications for new LNG terminals and expansions before or recently approved by the FERC or U.S. Coast Guard, representing a potential additional supply of well over 40 Bcf/d for the U.S. See Figure 18. While no one expects that all of current proposals will be developed, it is reasonable to anticipate approval and development of enough LNG import capacity to meet EIA's projected increase in LNG-based supply in the coming decades (an increase on the order of 4 Tcf/year by 2030 – see Figure 16).

Figure 18



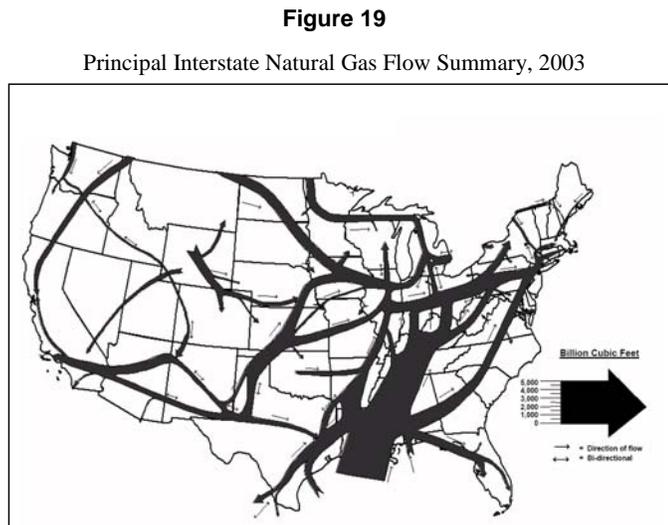
FERC, Office of Energy Projects, accessed 3/3/06
<http://www.ferc.gov/industries/lng/indus->

Existing Infrastructure

- From the perspective of infrastructure vulnerability, a critical question is the location of the new LNG import facilities that are ultimately developed. Already there are indications that the Gulf region may get the lion's share of new LNG development, which would result in even further concentration of critical U.S. natural gas infrastructure. The Gulf region benefits from the availability of significant existing natural gas processing and blending capabilities (to address any issues associated with delivered gas quality), and an extensive network of supply line and interstate carrier pipeline capacity, opening up new supplies to a wider range of downstream markets. The Gulf is also a shorter haul for shipments from several potential sources of LNG supply (e.g., from Nigeria, Trinidad, and Venezuela). In addition, many have pointed to the historical, cultural, and political factors that create a more comfortable climate for permitting and siting large infrastructure development in the Gulf and Gulf States region as an added incentive for location of most new LNG import capability there. Already, significant opposition to new LNG development has arisen in the context of proposal on both coasts – in California, Maine, Massachusetts and Rhode Island.
- In light of the continued development of Gulf sources (especially in deep offshore waters) and the likely location of a significant portion of LNG import capacity in the Gulf, it is unlikely that in the coming decade the significance of the natural gas infrastructure in the Gulf region will diminish. It is more likely to grow in importance.

Transportation

- Natural gas is moved throughout the U.S. over a comprehensive network of long-haul mainline systems.¹⁵ At the close of 2004, this network included over 200 mainline inter- and intra-state systems, totaling almost 300,000 miles of pipeline, with a capacity of approximately 178 billion cubic feet per day (Bcf/d).¹⁶
- Functionally, the pipeline network moves gas for consumption within regions, but more significantly from the producing areas to the major consuming areas, for example from the Gulf region to the Midwest and Northeast. See Figures 19 and 20.



EIA, Natural Gas Annual 2003, Figure 7

¹⁵ Locally, gas pulled off mainline systems is moved to customers over smaller-diameter pipeline networks of the local distribution companies.

¹⁶ EIA, *Changes in U.S. Natural Gas Transportation Infrastructure in 2004*, June 2005 (NGTI), page 4.

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- Expansion of the pipeline network has been significant in recent years, particularly in 2002. In 2004 a total incremental capacity of 7.7 MMcf/d was added across the U.S., roughly a third of which represent additions in the Gulf region, where twice as much was added than any other region.¹⁷ The current inventory of proposals for new pipeline projects suggests there will be major growth in the pipeline network over the next few years, particularly in support of proposed new LNG facilities.¹⁸ See Figure 21.

Figure 20

State Dependence on Interstate Pipeline Network

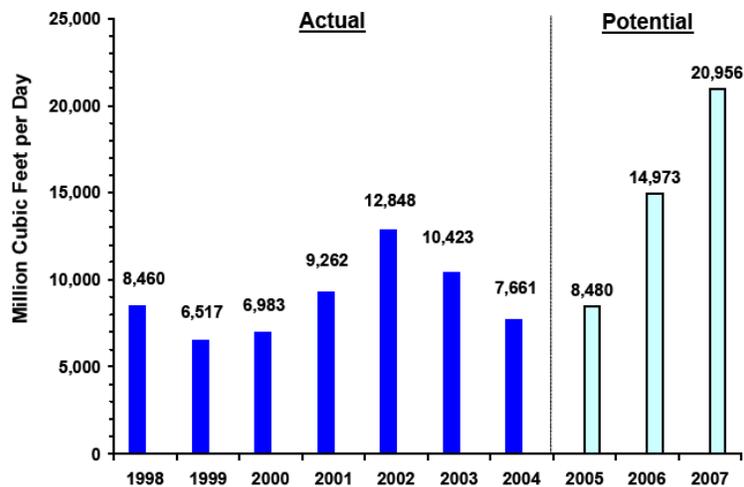


EIA, Natural Gas Annual 2003, Figure 10

- Ultimately, the number, capacity and location of pipeline projects added over the next few years will be tied closely to the success of new LNG facility proposals. However, a significant amount of additional capacity will also be added to support movement of gas from production fields in Wyoming, Colorado and Utah to consuming regions in the Midwest and West.¹⁹

Figure 21

Figure 2. Natural Gas Pipeline Capacity Additions, 1998-2007



EIA NGTI, Figure 2

¹⁷ Id., Table 2.

¹⁸ Id., page 12.

¹⁹ Id.

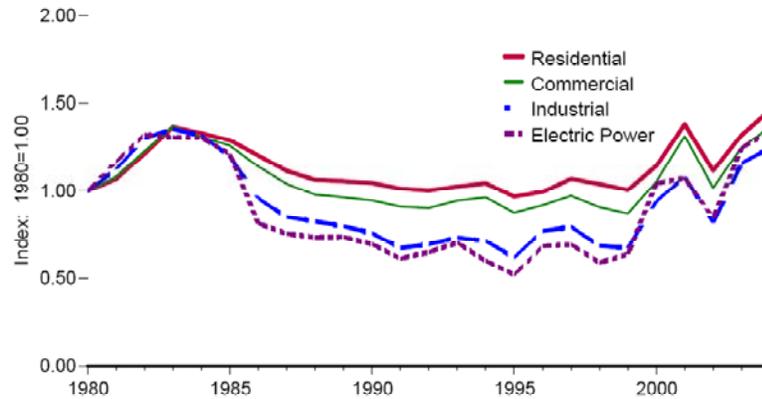
Existing Infrastructure

Prices

Ultimately, natural gas prices trends are the most important influence on both the demand for new gas and the type and location of new gas infrastructure. There are several important features in this respect concerning recent trends in natural gas prices.

- As shown in Figure 22, U.S. natural gas markets experienced a period of relatively low prices (in real terms) during an approximately 15-year period from the mid-1980s through around 2000. This is the same period which witnessed significant growth in demand for natural gas, in particular in the electric sector. These low prices made natural-gas-fired combined cycle the “fuel of choice” in new power projects through much of the 1990s, thus fueling that sector’s continued demand for gas supplies.

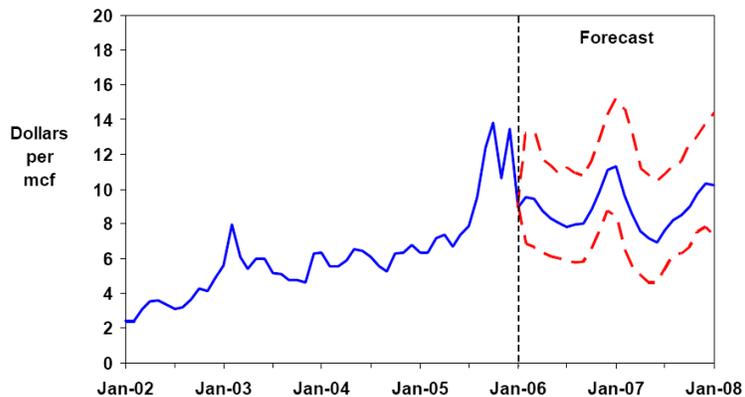
Figure 22
Real Natural Gas Prices, Indexed
1980 - 2004



EIA, Annual Review of Energy 2004, Figure 6.8.

- The tightening gas supply situation, both in the U.S. and internationally, as described above, then put pressure on gas prices starting around 2000, as shown in Figure 22. Prices continued to rise well above the levels that were expected during much of the robust period of development, permitting, and financing of natural-gas plants that occurred through the 1990s. Those price increases reflected the tightening of resources due to changes in market fundamentals. These increasing price trends continued in the past couple years leading up to last summer’s hurricane season. See Figure 23.

Figure 23
Natural Gas Henry Hub Spot Prices
(Base Case and 95% Confidence Interval*)

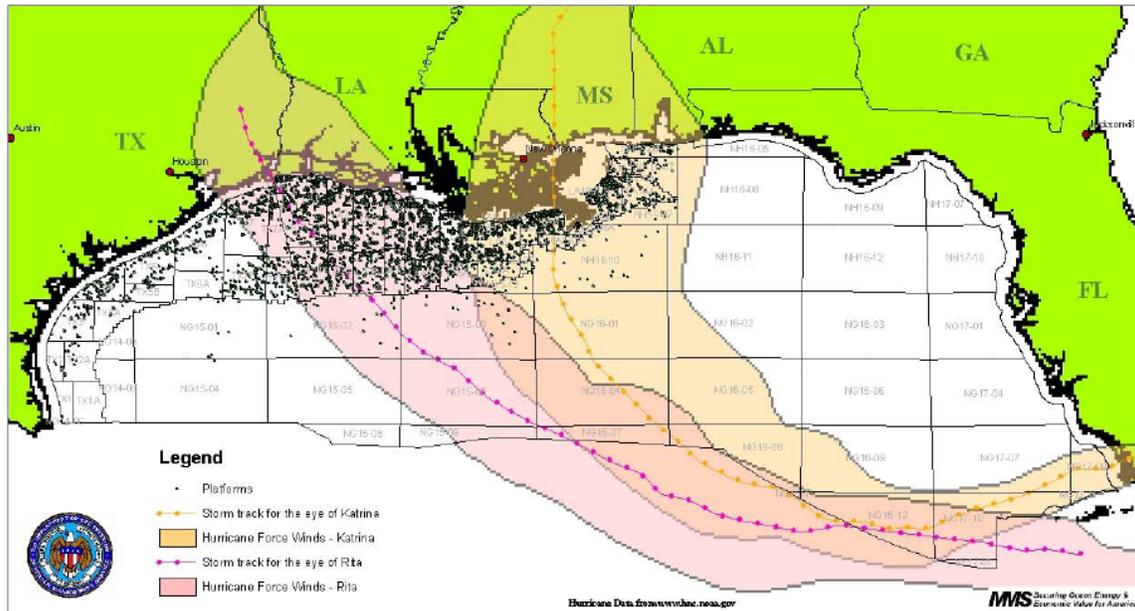


*The confidence intervals show +/- 2 standard errors based on the properties of the model.

EIA, Short-Term Energy Outlook, February 2006

THE HURRICANES

Hurricanes Rita and Katrina, August - September 2005



INFRASTRUCTURE DAMAGE

On August 29, 2005, Hurricane Katrina made landfall near the Louisiana/Mississippi border with maximum sustained winds near 135 miles per hour (mph), and hurricane force winds extending 125 miles from the center. Just weeks later, on September 24, Hurricane Rita followed nearly the same track, striking near the Texas/Louisiana border with sustained winds of 120 mph. The storms' damage is well-reported: the two hurricanes together caused more than a thousand deaths, widespread flooding of New Orleans, massive displacement of coastal communities, and economic damages that are likely to be on the order of a hundred billion dollars.

The impact on electric industry generation and transmission infrastructure in the region was unprecedented. As of August 30, 2005, a day after Katrina struck, 2.6 million customers were without power, including primarily customers in Louisiana (64% of electricity customers in the state), Mississippi (42% of customers), and Alabama (27% of customers).²⁰

Utilities in all three states reported extensive damage to their transmission systems. They expected – and indeed, experienced – extended outages given the difficulty of major

²⁰ U.S. DOE, Office of Electricity Delivery and Energy Reliability, *Hurricane Katrina Situation Report* (“DOE Katrina Situation Report”) #11 and #12, August 30 and 31, 2005. Additional customers in Florida and Georgia were reported to be without power due to the hurricane.

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restoration efforts. Linemen crews from as far away as Massachusetts were called in to help restore the utilities' systems. All of Mississippi Power Company's customers lost electric service.²¹ The company estimated that 70 percent of its transmission and distribution system would need to be replaced.²² Similarly extensive damage was reported by other utilities in Mississippi and Louisiana, where Entergy reported losing as many as 181 lines and 263 substations following Katrina's hit. 100 percent of Entergy New Orleans' customers lost power, and restoration was severely hampered by access and flooding. The Waterford III nuclear unit was shut down prior to Katrina's landfall for precautionary reasons. As of September 23, 2005, when Entergy New Orleans filed for bankruptcy protection, nearly a quarter million customers remained without power in Mississippi and Louisiana.²³ By mid-October, Mississippi Power estimated its restoration costs to be between \$245-295 million. Even two months after the hurricane, 10% of that company's pre-Katrina customer lacked electricity primarily because they "could not take power."²⁴

In many ways, the impact on the Gulf region's power systems from Hurricane Rita may have been even worse. Following landfall, outages in the region spiked back up to 1.6 million, including customers in Texas and Arkansas in addition to Louisiana and Mississippi.²⁵ Entergy reported that damage from Hurricane Rita to transmission and distribution systems, as well as power plants, was worse than that from Hurricane Katrina. At its peak, Rita took out 82 percent of Entergy's transmission lines in Texas and 38 percent of its lines in southwest Louisiana – nearly 4,000 miles of lines – and over 400 substations. Rita also took offline 12 of the 14 Entergy-owned fossil units in the area affected by the hurricane. The onset of high temperatures following the hurricane, combined with Rita-induced transmission system limitations led to rolling outages in several counties in Texas, affecting approximately 142,000 homes and businesses.²⁶

The concentration of oil and gas infrastructure in the Gulf region meant that the hurricanes took out not only power facilities, but also the oil and gas facilities that depended upon them. This loss of electricity to the region's refineries, natural gas reprocessing facilities, and liquid and gas pipelines immediately following the hurricanes adversely affected the pace of recovery of production and transportation of refined products and natural gas to the rest of the country. This complicated the implications of the direct physical damage to Gulf infrastructure – including production platforms, import terminals, and refineries.

²¹ <http://newsinfo.southernco.com/article.asp?mnuType=sub&mnuItem=ni&id=1900&mnuOpco=mpc&category=000>.

²² U.S. DOE, Office of Electricity Delivery and Energy Reliability, *Hurricane Katrina Situation Report* ("DOE Katrina Situation Report") #11 and #12, August 30 and 31, 2005. Also, for Mississippi Power: "More than 1,000 miles of line and nearly 9,000 distribution poles and 300 transmission poles and towers had to be replaced in the effort." <http://newsinfo.southernco.com/article.asp?mnuType=sub&mnuItem=ni&id=1900&mnuOpco=mpc&category=000>.

²³ DOE *Katrina Situation Reports* #11, #12, and #42 (September 23, 2005).

²⁴ <http://newsinfo.southernco.com/article.asp?mnuType=sub&mnuItem=ni&id=1868&mnuOpco=mpc&category=0>

²⁵ U.S. DOE, Office of Electricity Delivery and Energy Reliability, *Gulf Coast Hurricanes Situation Report* ("DOE GCH Situation Report") #4, September 27, 2005.

²⁶ DOE *GCH Situation Reports* #4, #7 (September 30, 2005), and #12 (October 7, 2005).

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Taken together, the hurricanes carved a vast destructive path through the heart of the Gulf region's energy infrastructure. It's been called a "perfect storm," as if it were designed to do maximum combined damage. Three quarters of the 4,000 offshore oil and gas platforms overseen by the Minerals Management Service of the U.S. Department of the Interior were directly in the combined paths of the two hurricanes.²⁷ Leading up to each hurricane, virtually all Gulf coast production and import facilities, and many of the region's refining/processing facilities, were evacuated or operations were otherwise suspended. The hurricanes interrupted operations at all platforms, and either damaged, set adrift, or sunk nearly 200 of them. The storms damaged supply pipelines in the Gulf and interrupted operation of the major pipelines that carry crude and refined products from the Gulf to consuming regions. They significantly disrupted nearly half of the U.S. refining industry (much of which is centered in the Gulf) and dozens of natural gas reprocessing plants. And they temporarily interrupted the flow of imported crude and refined products to the Gulf.

The impacts on supply and prices associated with these losses and disruptions were noticed immediately in both petroleum and natural gas markets (as well as, by extension, electricity markets), affected consumers not just locally, but across the country, and have continued to be felt for months. Prices rose quickly and sharply with the onset of the storms. The level and duration of supply concerns and elevated prices were in part due to the tight supply and demand conditions that existed prior to the hurricanes (and which continue to persist). But they spiked precipitously with the storms. With so many parts of the U.S. energy markets depending on but not getting supplies of oil and gas from the Gulf region, prices for gasoline, natural gas and oil petroleum products rose everywhere around the country. The patterns are described further below.

Petroleum

Virtually all GOM oil platforms were evacuated as each of the hurricanes approached, as was the Louisiana Offshore Oil Port (LOOP). The LOOP is responsible for receiving about a million barrels per day of imported crude. Both hurricanes caused significant direct damage to rigs and platforms, as well as supply pipelines, and cut off LOOP, refineries, and pipelines from needed electrical power supplies. Together these extended the duration of significant production capacity shut-ins and processing/transport disruptions.

Katrina initially reduced oil supplies by an estimated 1.4 MBD.²⁸ Restoration of production capacity proceeded shortly after the hurricane, reducing shut-in capacity to just over 0.8 MBD by the end of the first week in September. Rita initially caused an even higher level of shut-in crude production capacity – over 1.5 MBD (equivalent to 100% of normal daily production in the Gulf), and recovery after the hurricane proceeded more slowly. See Figure 24. As of the beginning of November more than 50% of GOM

²⁷ Minerals Management Service, *Interior Secretary Gale Norton Reports on Gulf of Mexico Energy Status*, October 4, 2005.

²⁸ U.S. EIA, *Special Report - Hurricane Katrina's Impact on U.S. Energy*, August 30, 2005.

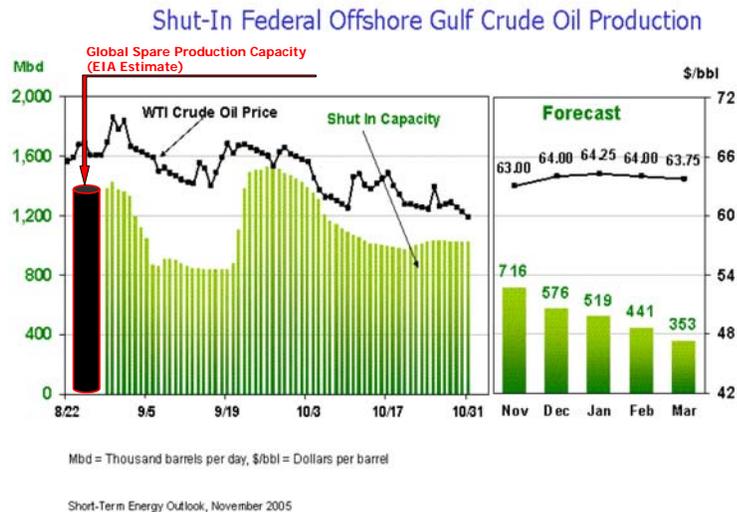
Hurricanes

crude production capacity remained shut in, with EIA projecting full recovery to take several months. Toward the end of 2005, production capacity returned a little faster than expected in the months after the Hurricanes, but prices ended up being slightly higher than expected.²⁹

The prices for crude oil delivered to the nation’s refineries are determined in a global market based on the balance between the global demand for crude and available supply, or production capacity. Prices can vary significantly as a function of this relationship, where relatively minor changes in either demand or supply can lead to large shifts in prices, due in part to the fact that the levels of both demand and supply are (in the short-term) relatively insensitive to, or slow to respond to price changes. Crude oil prices prior to Katrina were already very high in response to tight global supply/demand conditions. The magnitude of the disruptions (or shut-in production capacity) in global supply of crude oil associated with the hurricanes – which was on the order of worldwide spare production capacity – were easily enough to generate and sustain a significant response in global crude oil prices on top of these elevated levels, and they did.³⁰ See Figure 24, which shows the levels of shut-in GOM crude oil production capacity, and the contemporaneous WTI price of crude. The chart also includes for comparison purposes EIA’s estimate of the

level of worldwide spare production capacity. The bumps associated with the hurricane impacts are evident. Interestingly, the effects of the hurricanes on crude oil production were partly offset by a reduction in refinery demand due to the shut down refinery capacity in the Gulf; this likely had a moderating effect on crude oil price impacts.

Figure 24



The impacts of damage to crude production and import capacity in the Gulf on supply and prices of finished petroleum products were amplified by damage to and loss of service of GOM refinery capacity. See Figure 25. Nearly 2 MBD of Gulf coast refining capacity was shutdown as Katrina approached. As of September 22, 4 refineries remained shut down with a capacity of approximately 1 MBD, due to damage or loss of

²⁹ EIA, Short Term Energy Outlook, Jan 2006.

³⁰ Worldwide spare production capacity is at its lowest level in three decades. EIA STEO October 2005, page 4.

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electricity due to Katrina, and 16 other refineries were shutting down in preparation for Hurricane Rita. At this point in time, the total amount of shutdown capacity amounted to roughly 6 MBD of refined products. Reduction of shut down capacity to 3 MBD took over two weeks, and additional reductions took another couple weeks.³¹ The average crude oil input to refineries in the Gulf during September and October, 2005 was significantly lower (by over 1 MBD) than the same months for 2004, despite being roughly the same as 2004 for the 8 months prior to the hurricanes. Similarly, refinery capacity also came back through the Fall and early winter, along the schedule that was projected in the weeks after the hurricanes.³² Gasoline prices declined more quickly than expected, although they remain slightly higher than originally expected soon after the hurricanes.

Figure 25
Shut-In Gulf Crude Oil Refinery Capacity

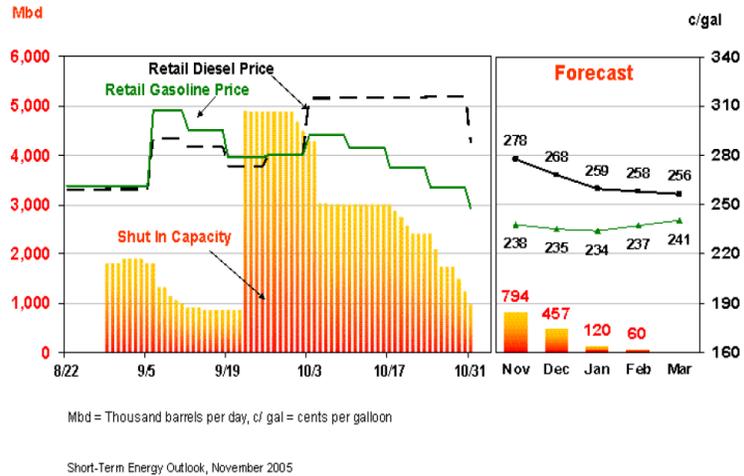
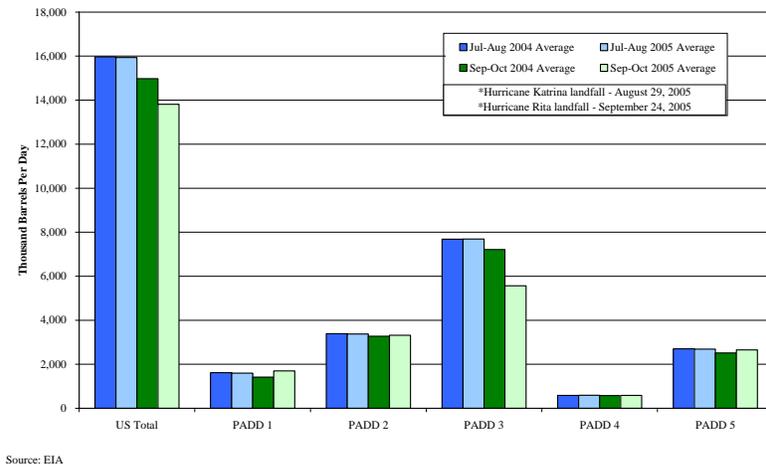


Figure 26 shows that in these months at least a small portion of the difference was made up through increased inputs to refineries in the Midwest and East Coast regions. Retail prices for refined products sustained very high levels during this period – high enough to generate public outcry and lead to the calling before Congress of the executives of major oil companies. With the return of Gulf production and refinery capacity, gasoline prices declined significantly, but

Figure 26

U.S. Crude Oil Inputs into Refineries:
Comparison of 2004 and 2005



³¹ EIA Daily Report on Hurricane Impacts on U.S. Energy, September 23, 2005.

³² Id, Figure 6.

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the focus on gasoline production with the return of refinery capacity (at the expense of other refined products) left diesel and home heating oil prices higher for a longer period.

Both crude oil and refined product pipelines were also affected by the storms. As noted earlier, several major pipeline systems move crude oil to refineries in the Midwest, and finished product to markets in the Midwest and on the East Coast. All of these pipelines are critically dependent on both product to ship, and on electricity for compression/pumping. After Hurricane Katrina, the Colonial and Plantation pipelines – which provide most of the refined products to markets on the East coast – were out of service due to the loss of power at key pump stations in Louisiana and Mississippi. The Capline, which is the major pipeline providing crude oil to Midwest refineries, was also shut down. By September 1, all pipelines were back operating at partial capacity, and returned to full capacity shortly thereafter.³³ In preparation for Hurricane Rita, at least 2 crude oil pipelines and 6 finished product pipelines that carry supplies to other regions from Texas and Louisiana were shutdown, operating at reduced capacity, or expecting reduced shipments.³⁴ In addition, many of the shorter-haul on- and off-shore pipeline systems implemented force majeure, were damaged, or were operating at reduced volumes due to lack of product following the hurricanes.³⁵ By the end of the first week in September, the major on-shore crude and refined product pipelines, and other pipeline transportation systems, were operating near capacity, with some of the unused capacity a function of the fact that so much production and refinery capacity was shut in for an even longer period.³⁶

In short, virtually every aspect of the chain of functions that ultimately delivers refined gas, heating oil, jet fuel, and other refined products to consumers across the country was significantly damaged or reduced as a result of the hurricanes. The combined level of production and import shut-in, refinery outage, and pipeline capacity loss shook crude oil and refined product markets across the country. This raised some challenging supply and price issues, which were particularly of concern at the start of the winter heating season before it was known that the winter would be relatively mild. To be sure, actions taken by industry participants, government and consumers ended up mitigating some of the worst supply and price issues – including temporary draw-downs of private inventories, limited use of the Strategic Petroleum Reserve,³⁷ increased imports of crude and refined

³³ DOE *Katrina Situation Reports* #13 (August 31, 2005) and #15 (September 1, 2005).

³⁴ DOE *Hurricane Rita Situation Report* #3, September 23, 2005.

³⁵ DOE *GCH Situation Report* #7 (September 30, 2005).

³⁶ Association of Oil Pipelines, *Oil Pipeline Status Report*, In the Pipe, September 9, 2005.

³⁷ DOE offered 30 million barrels from the Strategic Petroleum Reserve between September 6-9, 2005, following President Bush's finding of a "severe energy supply interruption," resulting from Hurricane Katrina. The sale resulted in award of 11 million barrels of crude oil to five companies who submitted favorable bids. The reserve is capable of beginning deliveries as soon as 13 days from a Presidential directive to sell oil, with delivery schedules and crude oil transportation arrangements the responsibility of the purchaser. Deliveries began on September 26 and were originally expected to be completed during October. However, the arrival of Hurricane Rita along the Gulf coasts of Louisiana and Texas on September 24, caused significant damage to several refineries, terminals, and distribution systems that reduced the rate at which purchasers were able to take delivery of crude oil and process it into products. That resulted in changes to the original schedules. Deliveries were completed on January 4, 2006.
http://www.fossil.energy.gov/news/techlines/2006/06002-SPR_Deliveries_Complete.html

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products from non-Gulf regions, release of inventory and increased export from Europe and other trading partners, consumer price responsiveness, and government demand reduction efforts. But the importance of the Gulf in U.S. energy supply is too large for a disruption of this magnitude to not hit hard; short-term price impacts were severe in petroleum markets immediately following the hurricanes, and the impacts have continued to be felt throughout the winter heating season (though with significantly less impact than expected due to how mild the U.S. winter has been for most).

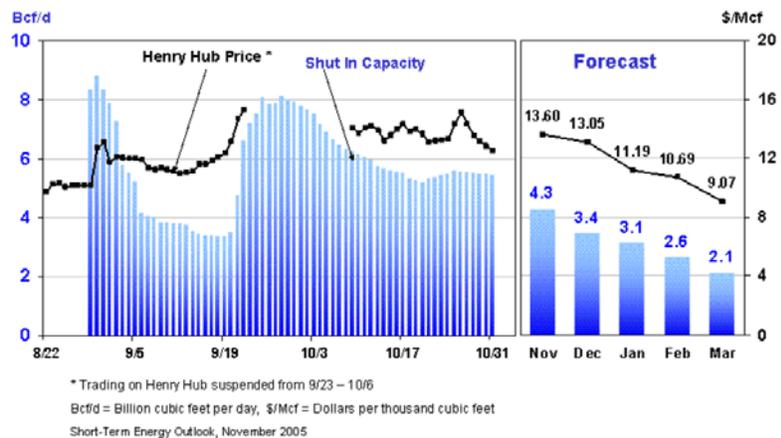
Natural Gas

The natural gas industry did not fare much better than the oil industry. The GOM natural gas production platforms were similarly evacuated as each of the hurricanes approached. On August 30, shut-in natural gas production in the Gulf region totaled roughly 8.8 billion cubic feet per day (Bcf/d). Recovery reduced the shut-in capacity to about 3.4 Bcf/d by September 19, just prior to the onset of Hurricane Rita. On September 28, shut-in natural gas capacity had again risen, to 8 Bcf/d; and as with petroleum, the recovery of capacity has been less and slower than following Hurricane Katrina.³⁸

As of the end of October, less than 3 Bcf/d of capacity had been recovered. By November 23, natural gas production shut-ins were down to 3.2 Bcf/d which, while down an additional 2.4 Bcf/d since the end of October, still represented roughly 32 percent of offshore production at that time.³⁹ See Figure 27. By early 2006, overall natural gas production capacity ended up returning to service more quickly than expected soon after the hurricanes.⁴⁰ Finally, while the Gulf is a major source of imported LNG for the U.S., the impact of the hurricanes on receipt of LNG may have been partially mitigated by the fact that the Lake Charles LNG terminal had been shut down at the time in any event for maintenance.⁴¹

Figure 27

Shut-In Federal Offshore Gulf Natural Gas Production



³⁸ American Gas Association, *Gulf of Mexico Natural Gas Shut-In Report*, November 23, 2005.

³⁹ Id.

⁴⁰ EIA, Short Term Energy Outlook, January 2006, Figure 5.

⁴¹ EIA, *Special Report*, August 30, 2005.

Hurricanes

Approximately three-fourths of marketed natural gas production is processed before being shipped to consumers in the U.S.⁴² The Gulf region is home to the majority of the U.S.'s natural gas processing capacity, and the hurricanes damaged or reduced/suspended operation (for example, due to a lack of electricity or product) at several of the major processing facilities. As of September 26, over a dozen natural gas processing facilities, with a combined capacity of more than 10 Bcf/d (though lower pre-hurricane average daily flow volume) had confirmed that they were offline due to damage, flooding, lack of supplies, or an inability to move product.⁴³ As of December 1, a number of processing plants in Louisiana and Texas, with an aggregate pre-hurricane flow volume of 3.26 Bcf/d, remained inactive.⁴⁴

On- and off-shore natural gas pipelines appear to have sustained significant damage and flooding from the hurricanes, and reductions in capacity due to lack of power at compressors. In addition, following the hurricanes, natural gas pipeline throughput and operations were also significantly affected by a lack of upstream supply due to the damage and reductions in Gulf region natural gas production and processing capacity.⁴⁵ Following the hurricanes, the Sabine Pipeline, operator of the Henry Hub, and several other pipelines were forced to implement force majeure due to reductions in capacity or availability of supply.

Natural gas supply and price conditions leading up to and following the hurricanes have been very difficult. In general, natural gas consumption and prices are heavily dependent on weather conditions, as loads increase significantly with the use of gas for heating across the country, as well as the level and use of working gas in storage during winter months. In October of this year, the Henry Hub natural gas spot price averaged \$13.82 per mcf, and EIA had projected that average spot prices would remain very high throughout the winter heating season, based on average seasonal weather conditions – well above \$10 per mcf. See Figure 27. While prices dropped since then, in part due to a milder than expected early winter, natural gas prices remained high (and higher than expected in the month immediately after the hurricane) into early 2006.⁴⁶

In short, as with petroleum, virtually every aspect of the chain of functions that ultimately delivers dry natural gas to residences, businesses and power plants across the country was significantly damaged or reduced as a result of the hurricanes. The combined level of production shut-in, processing outage, and pipeline capacity loss lead to a major short-term price increase in natural gas spot and future markets; and the impact on gas markets has, and is expected to continue to remain very high throughout the duration of the winter

⁴² EIA, *Special Report*, September 6, 2005.

⁴³ EIA, *Special Report*, September 26, 2005.

⁴⁴ EIA, *Special Report*, December 1, 2005.

⁴⁵ DOE, *GCH Situation Report #7*, September 30, 2005

⁴⁶ EIA, *Short Term Energy Outlook*, January 2006, Figure 6. As compared to the outlook published in November 2005, prices for January, February and March were expected to be \$11.24, \$11.53 and \$11.03, respectively, as compared to \$11.39, \$10.69, and \$9.07, as projected in November's *Short Term Energy Outlook*.

Hurricanes

heating season, as the existing tight supply conditions shake out, and the production capacity in the Gulf recovers.

REGIONAL INFRASTRUCTURE VULNERABILITY CASE STUDY: NEW ENGLAND

The impact on energy consumers across the country of the potential supply and price impacts associated with disruptions to national energy infrastructure can vary significantly by region, depending on the type and status of infrastructure to and used within the region. In this sense, New England's status is unique, and the impacts of events such as the recent hurricanes are amplified by the unique energy infrastructure conditions in the region.

New England shares the over-dependence of all other regions of the country on refined petroleum products for transportation fuel, and on fossil fuel consumption in general to meet heating, cooling, commercial, industrial and transportation needs. However, New England is unique in the following ways:

- New England has no appreciable indigenous supplies of crude oil, natural gas, or coal.
- New England has no suitable geologic capacity for the storage of any meaningful quantities of oil, petroleum products, or natural gas.
- New England has no refinery capacity.
- New England has no major interstate pipelines for the transportation of crude oil, or refined petroleum products that deposit supplies in the region.
- New England is at the very end of the interstate natural gas pipeline delivery network, and is thus in a difficult position from the perspective of paying additional gas transportation charges and competing with upstream regions for supply of gas.
- New England is extremely dependent on natural gas and refined petroleum products (primarily home heating fuel) for winter heating needs.
- No other U.S. region depends upon home heating oil as much as New England.
- New England recently emerged from a power plant construction boom that featured almost exclusively natural-gas fired capacity additions, and is now excessively dependent on natural gas for electricity generation. To make matters worse, much of this new capacity was not constructed with the capability to switch fuels (e.g., if gas is not available or too expensive relative to oil), and most of it operates under interruptible contracts, and thus will be the first to be curtailed in short-supply peak winter conditions.
- New England's high-voltage electricity transmission network contains important transmission capacity constraints between sub-regions, at times constraining the import of power to high-load regions in Connecticut and Massachusetts, and at times constraining the export of low-cost power from other regions.
- New England is extremely dependent upon the Gulf region for supplies of natural gas and refined petroleum products (the region imports more refined petroleum product from overseas than any other "consuming" region of the country, and receives gas from Canada; however, these amounts are very small compared with supplies from the Gulf via pipeline (natural gas) or via barge (gas and other refined products)). New England is home of one of the nation's few LNG terminals, located in Everett, Massachusetts.
- Part of New England is very populous, and all of New England is strongly focused on minimizing the health and environmental impacts and risks of major energy infrastructure, creating challenges for proposed infrastructure development proposals.

As a result of these dependencies and infrastructure issues, New England starts with very high energy costs relative to the rest of the country. And the region is particularly susceptible to significant disruptions associated with (a) our economy's dependence on fossil fuels; (2) our concentration of energy supplies and infrastructure in the Gulf; and (3) our dependence on a relatively limited number of major pipelines distributing product to the Northeast. In short, the lack of diversity in New England's energy infrastructure, and its unique reliance on production, processing and long-haul transportation infrastructure from primarily the Gulf, have left it particularly vulnerable to supply and price disruptions in that region. Only an extraordinarily warm early winter season spared the region from what many thought would be severe price and reliability impacts this winter associated with supply and price affects of the hurricanes' damage to Gulf infrastructure. The degree of concern present in the region late last year was evidenced by the filing of emergency rules with the Federal Energy Regulatory Commission by the ISO, coordinating meetings between the ISO and regional and state governmental officials, and public appeals for energy conservation, all in an attempt to reduce winter electric demand and otherwise prepare for what could have been a uniquely challenging gas and electric supply situation.

In short, New England represents in the extreme the price and supply vulnerabilities associated with our dependence on oil and gas, with the vulnerabilities and concentration of our energy infrastructure, and with our need to reduce these weaknesses through reducing demand and seeking supply diversity.

LESSONS LEARNED

The hit the combined destruction of Hurricanes Katrina and Rita delivered to the Gulf Coast energy infrastructure resembles scenarios that energy security analysts have worried about for decades. Is it a worst-cast scenario? Maybe. It is hard to imagine a more forceful hit, and it is hard to imagine it coming at a worse time – a period when global supply and demand conditions for crude oil are at their tightest in three decades; when global and national spare refining capacity are similarly stretched thin; when North American supplies of natural gas are in decline while demand is growing strong, and prices are already at all-time peaks; when some suggest we are reaching the limits of the ability of existing infrastructure to meet our growing, insatiable appetite for fossil fuels; and all at the start of a winter heating season.

The call for a fundamental review of long-term energy policy in light of current conditions is hardly new. Experts and analysis have raised concerns about it for decades, and continue to do so today.⁴⁷ In August, 2005, Congress and the President finally agreed upon energy legislation that included a number of provisions to address energy security and infrastructure issues, including provisions to provide tax breaks and other financial incentives for development of needed infrastructure, and to clarify or streamline regulatory jurisdiction and procedures for the siting review of major energy infrastructure development proposals. The Energy Policy Act of 2005 did not, however, address the nation's over-dependence on oil.

A large amount of energy literature reviews the vulnerable position we leave ourselves in with our excessive dependence on oil (and the other fossil fuels) for health, safety, security, economic strength, and overall quality of life. Arguably, hearings, discussions and legislative proposals in recent months suggest that the issue is finally getting the serious attention it deserves in national energy policy contexts. Even President Bush took the step of mentioning “Americans’ addiction to oil” in his 2006 State of the Union Address. The hurricanes and the high energy prices that followed them have a lot to do with that, as our vulnerability to concentration of our resources in the Gulf caused prices for gasoline and natural gas to skyrocket following the disasters, and nothing grabs the attention of the public and policymakers like \$3 gas at the pump and the specter of doubling winter heating costs.

⁴⁷ For example, studies from a wide range of groups include: John E. Gray, *Energy Policy: Industry Perspectives – A Report to the Energy Policy Project of the Ford Foundation*, 1975; David A. Deese and Joseph S. Nye, eds., *Energy and Security* (Cambridge, Mass.: Ballinger Publishing Company, 1981); Charli Coon, and James Phillips, “Strengthening National Energy Security by Reducing Dependence on Imported Oil,” *The Heritage Foundation, Backgrounder #1540*, April 24, 2002; William Martin, Ryukichi Imai, Helga Steeg, “Maintaining Energy Security in a Global Context, Task Force Report #48, *The Trilateral Commission* (1998); Joel Darmstadter, “U.S. Oil-Import Dependence: A Sufficient Guide to Energy Security Policy?” *Resources for the Future*, December 5, 2005; Heather Ross, “Producing Oil or Reducing Oil: Which is Better for U.S. Energy Security?” *Resources for the Future*, Spring 2003; Amory Lovins and Hunter Lovins, *Brittle Power: Energy Strategy for National Security*, Brick House Press, 1982 (and Rocky Mountain Institute, 2001 Edition); *America’s Energy Choices*, 1996, Union of Concerned Scientists, Natural Resources Defense Council, et al.; National Commission on Energy Policy, “Ending the Energy Stalemate,” December 2004.

Lessons Learned

Why did the hurricanes produce such an impact, and what does it tell us about our energy infrastructure needs? The Gulf Coast is the undisputed heart of U.S. energy infrastructure. In the Gulf, we produce or import three-fifths of the country's supply of crude oil and half of U.S. natural gas supplies; and we generate half of the country's refined product, supplying nearly all of the requirements for the Gulf region, the East Coast, and most of the Midwest. The vast majority of the petroleum and natural gas products consumed in the eastern half of the country find their origin in markets, storage, processing, and pipeline capacity concentrated in Gulf states. The sheer magnitude of fossil fuel operations in the Gulf make them the most important piece of U.S. natural gas and refined petroleum product supply adequacy and pricing.

The combined effect of the two hurricanes did indeed take out virtually all of this capacity for a short period of time, and an unprecedented level of capacity for a more extended period of time. It did so, as mentioned, against a backdrop of historically thin supply and high prices, and the results were predictably severe. What are our options to address the weaknesses that the hurricanes revealed; to try to prevent such a disproportionate impact in the future, whether it is the result of hurricanes or other natural forces, or the result of an intentional terrorist act?

Some of the observations and lessons learned include the following:

- Dependence

While not strictly an infrastructure issue, any discussion of our vulnerability to disruptions in energy supply must begin with a review of our dependence on oil. Reducing our demand for oil – through increasing vehicle fuel efficiency, reducing residential, commercial and industrial demand, and developing alternative liquid fuel options – is the single most effective mid- and long-term option available to relieve the stresses that currently exist at every stage of the energy supply cycle. A concerted attempt to address this dependency now through aggressive near-term energy efficiency policies may buy us some time to address critical infrastructure deficiencies (discussed below); a sustained effort to continuously reduce this dependence over time will help maintain an important degree of flexibility and resiliency in our energy supply systems. Increasing and strengthening CAFÉ standards, and recent proposals in Congress to implement specific targeted reductions in oil dependence represent the most effective potential responses.

- Refining and Reprocessing

The U.S. has historically produced most of its refined product domestically, and domestic refinery capacity is currently operating near maximum output. In addition, economies of scale and the proliferation of prescriptive fuel specification standards have tended to push refinery ownership and production into fewer and fewer refineries, and fewer and fewer hands. This concentration of refinery capacity, ownership, and location may be appropriate from the perspective of economic efficiency and the cost to produce a gallon of gas. It does, however, increase the vulnerability of the country, or of specific regions, to supply and price impacts associated with disruptions in domestic refinery output. Similarly, it is estimated that three quarters of the marketed dry natural gas consumed in the country has needed to

Lessons Learned

be processed at natural gas processing plants before injection into inter- and intra-state pipelines. As with refineries, the majority of the country's natural gas processing capacity is located in the Gulf region. The recent experience with the hurricanes in the Gulf showed just how vulnerable we are to our concentrations of refinery and reprocessing capacity in that region.

There are, of course, alternatives to domestic refinery production – other countries have shown a willingness to construct refinery capacity with the technical capability to produce refined product blends that meet U.S. specifications, and have priced such products competitively. Certain regions of the U.S. – notably the Northeast – have in the past imported a substantial quantity of refined products from overseas. Indeed, refined product imports increased in response to the reduction in refinery capacity following the Gulf Coast hurricanes. Yet it is worth considering domestic-based alternatives to assuming the U.S. will be able to, or should, increase our dependence on foreign supplies of refined product. Specifically, we should consider the feasibility and cost of diversifying the geographic distribution of U.S. refinery capacity, and the benefits (such as reduced risk of supply disruption) that would come from doing so.

Following the hurricanes, many refineries and gas reprocessing plants were shut down or faced reduced operation for a short period of time simply because the crude input or natural gas was not available due to disruption in supply from Gulf production and import capacity. But much of the shut-down capacity was the result of damage from the storms themselves, most importantly the lack of electric power given the widespread destruction of the regional systems that provide electricity to, or are interconnected with, refineries and reprocessing plants. While many refineries have a substantial amount of electric generating capacity on-site, this capacity was not sufficient for refinery operations, or may also have been inoperable due to the need for synchronous operation with the surrounding grid. Consequently it would be useful to consider, at least in the region of the Gulf potentially susceptible to future hurricanes, what the opportunities are for additional on-site, back-up generating capacity, or alternative regional electric grid connections and configurations, for supporting refinery and reprocessing operations under conditions of extended outage of the surrounding electric system. To the extent there are economic barriers to such installations, we should consider whether there are appropriate regulatory or financial mechanisms that could help achieve this result.

- Pipelines

The Midwest and East Coast are too heavily dependent on the delivery of natural gas, crude oil and refined products via only a few major pipelines emanating in the Gulf region. The hurricanes revealed that nearly full disruption of pipeline supply of gas, crude oil, and refined product to these regions need only involve the simultaneous loss of a handful of pipeline operation support systems in the Gulf. In this case, the culprit was reduced input due to shut-in supply and refining/processing capacity, and the loss of electric power to key pipeline operation and support systems (such as compressor stations). As with the impact on refinery operations, the recent experience calls for enhanced efforts to reduce dependence on supplied products, as

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well as an evaluation of the feasibility and costs of diversifying supply methods.

Unfortunately, given the length of long-haul trunkline supply pipelines, the need for supply and transportation contracts to support development, and the cost and siting challenges involved, building in redundancy/duplication of long-haul pipeline capacity is infeasible. Shortly following the hurricanes, emergency generators were brought in to support temporary operation of pipeline compression stations on some of the lines. The risk of disruptions associated with pipeline outages could likely be reduced by increasing permanent placement of backup electric generation capacity at pipeline compression/operation locations, and fortification of such locations against flooding/damage associated with storms of the magnitude just experienced, as well as against other plausible natural, accidental, or intentional impacts.

- Natural Gas

Natural gas supply represents a unique and timely infrastructure challenge. As the productivity of domestic and Canadian supplies decline, we expect to find ourselves ever-more dependent on importing LNG to meet growing demand. But the challenge of meeting future demand via LNG has built-in flexibility and opportunities for diversification that do not exist with continental sources of gas. To-date, natural gas production, pipeline, and reprocessing capacity has been tied geographically to the sources of discovered reserves. As demand grows, pipeline capacity has been sited on an as-needed basis to meet firm customer demands, originating in the regions where gas supplies were found. In the context of increased LNG imports of gas, we have the opportunity to pursue as a matter of national energy policy the siting of LNG regasification and storage capacity in a manner that reflects patterns of expected demand growth, maximum utilization of existing pipeline capacity (e.g., through backfill from the end of interstate systems, through the filling of under-utilized capacity, and through maintaining pipeline flow from regions where existing supplies are in decline). Unfortunately, existing proposals to site LNG imports are dominated by sites in the Gulf region. To some extent, this makes sense because the Gulf is a location of major natural gas processing, storage, and transportation infrastructure, as well as a region where domestic supply productivity is decreasing. However, it would be a mistake to continue to increase the vulnerability of the major consuming regions in the country through a further concentration of natural gas supply and transportation in the Gulf. A national review should be undertaken to support review of LNG proposals that identifies the optimum locations from among existing proposals for siting LNG import infrastructure, in light of demand projections, existing patterns of supply, risks of supply concentration, and transportation infrastructure capacity and utilization trends.