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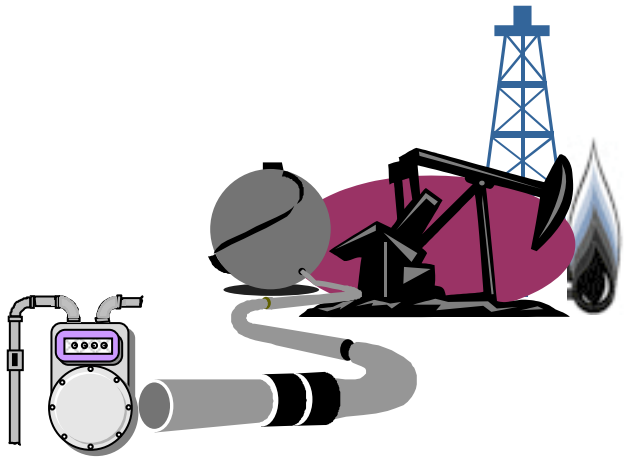
Natural Gas❖: Fuel for the Future or Future Folly?



By
Merwin Brown
Evergreen, CO

To: Department of Mechanical Engineering Seminar
University of Washington
May 19, 2004

❖ Thanks to the National Renewable Energy Laboratory in Golden, CO, for its support while composing some of this material.

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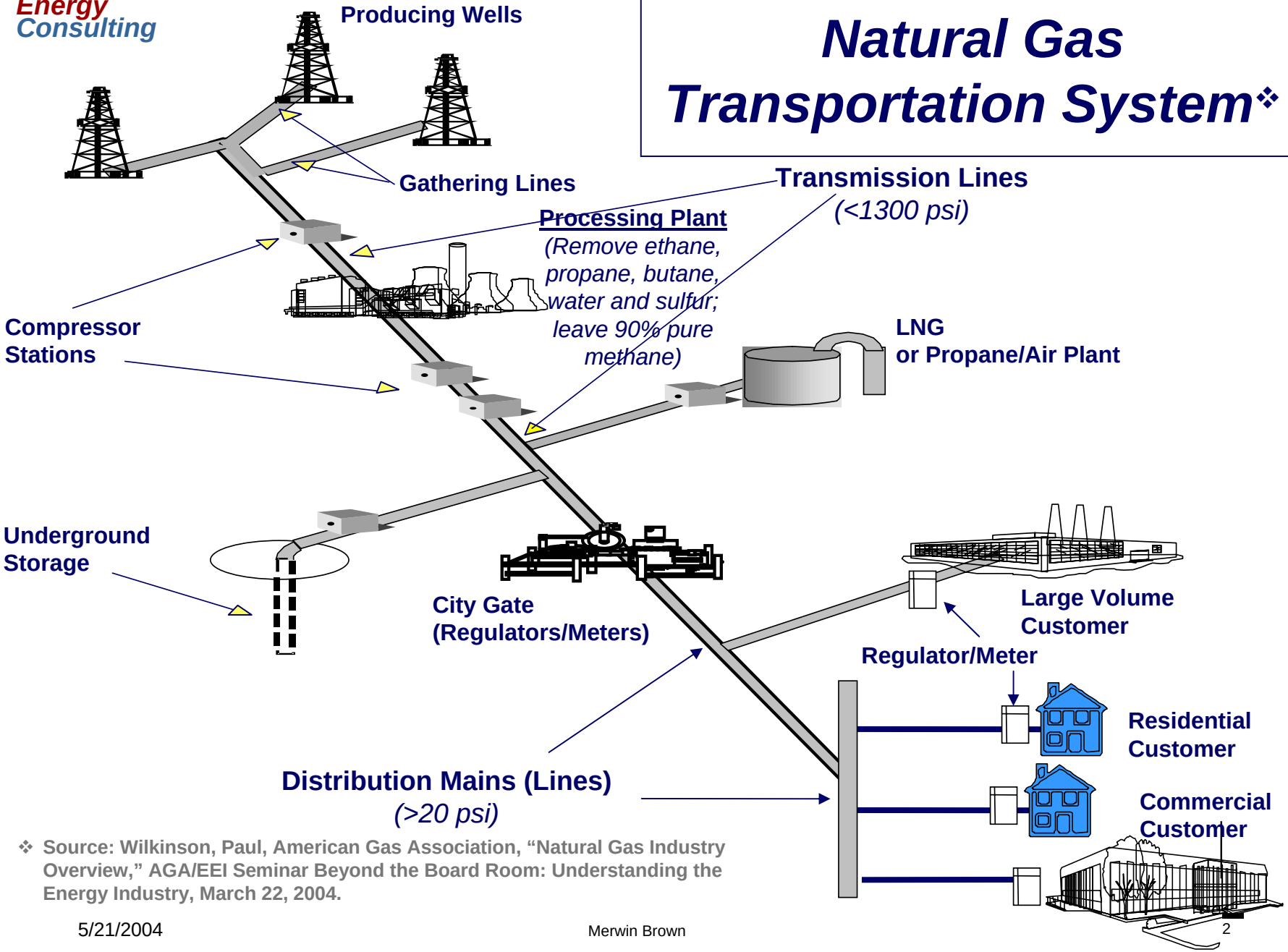
Natural Gas Transportation System❖



❖ Source: Wilkinson, Paul, American Gas Association, "Natural Gas Industry Overview," AGA/EEI Seminar Beyond the Board Room: Understanding the Energy Industry, March 22, 2004.

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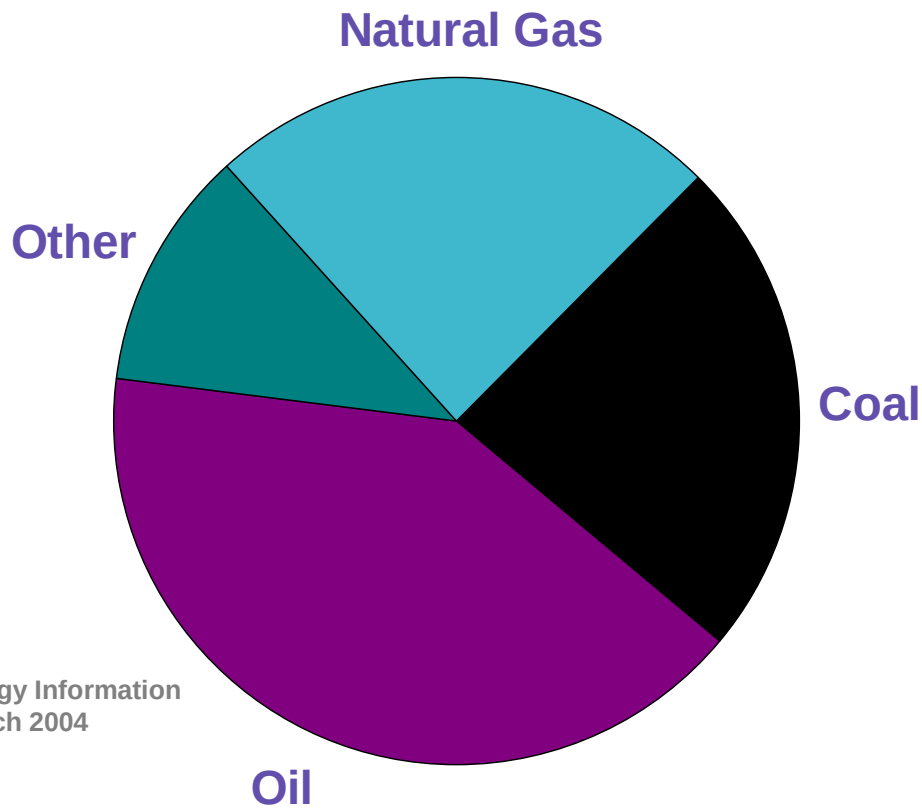
Natural gas accounts for 25% of the U.S. primary energy consumption.



Source: Dept. of Energy, Energy Information Administration, and AGA, March 2004

Although coal and oil provide the lion's share, because natural gas is the environmentally cleanest of the fossil fuels, it makes the most desirable fuel for electric power.

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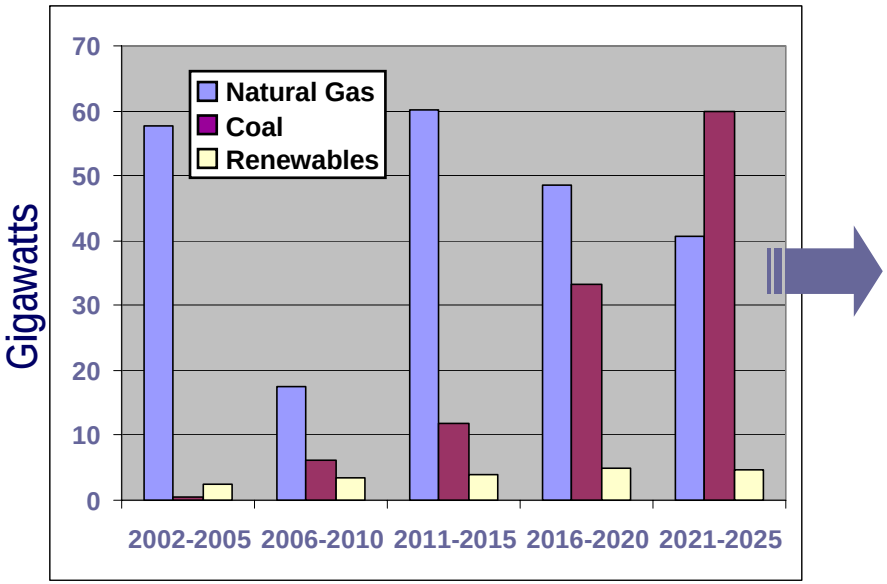
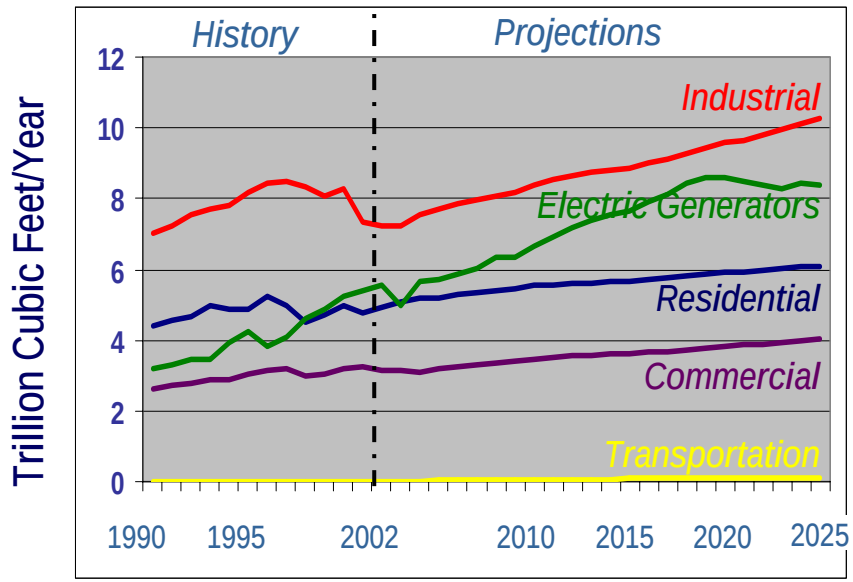
While most electricity is still fueled by coal, most new capacity is expected be fueled by natural gas well into the next two decades...

Additions to Electricity Generation Capacity



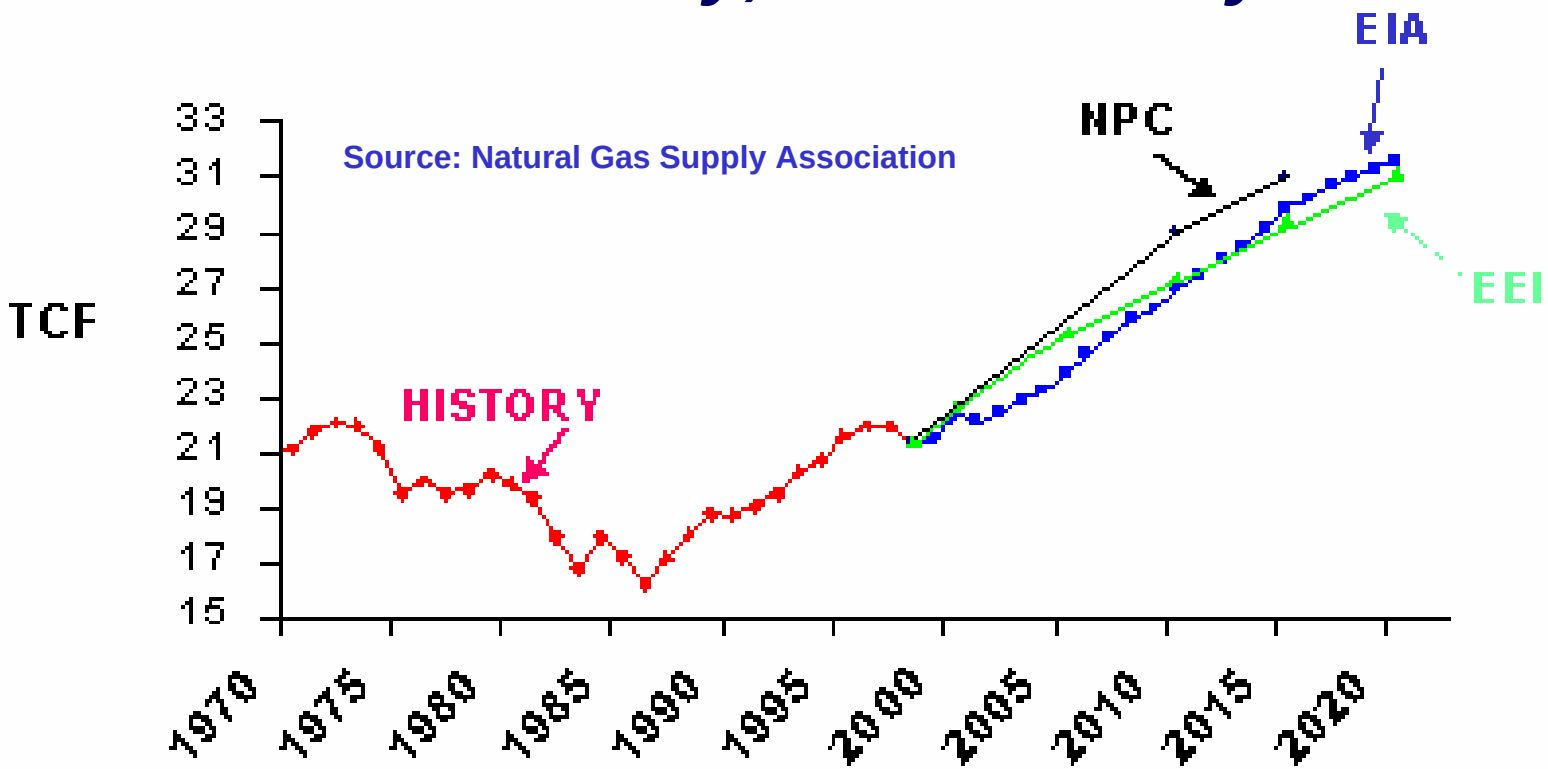
Natural Gas Consumption by Sector



Source: DOE/EIA, Annual Energy Outlook 2004 with Projections to 2025

…Resulting in substantial growth in natural gas use in electric generation, and placing strains on the industry to meet this demand.

Natural gas annual consumption is expected to increase dramatically, about 50% by 2020.



Can this much gas be found, produced and delivered, and at what cost?

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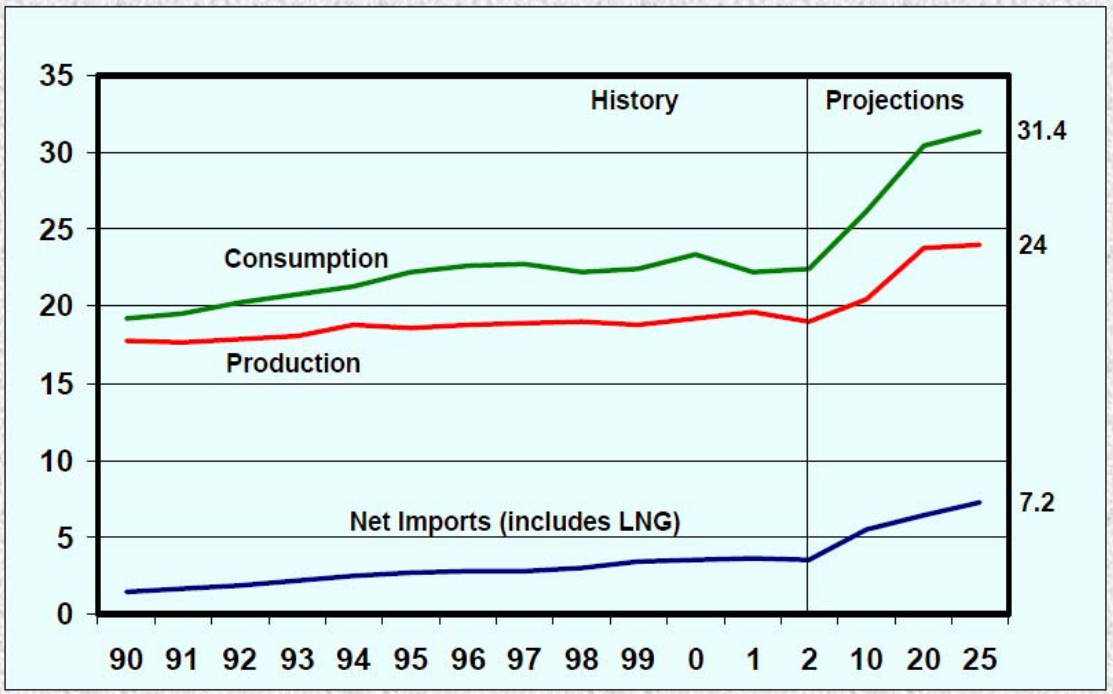
The U.S. had large natural-gas reserves and was essentially self-sufficient until late 1980s, when consumption began to significantly outpace production, and the U.S. began to import, mostly from Canada.



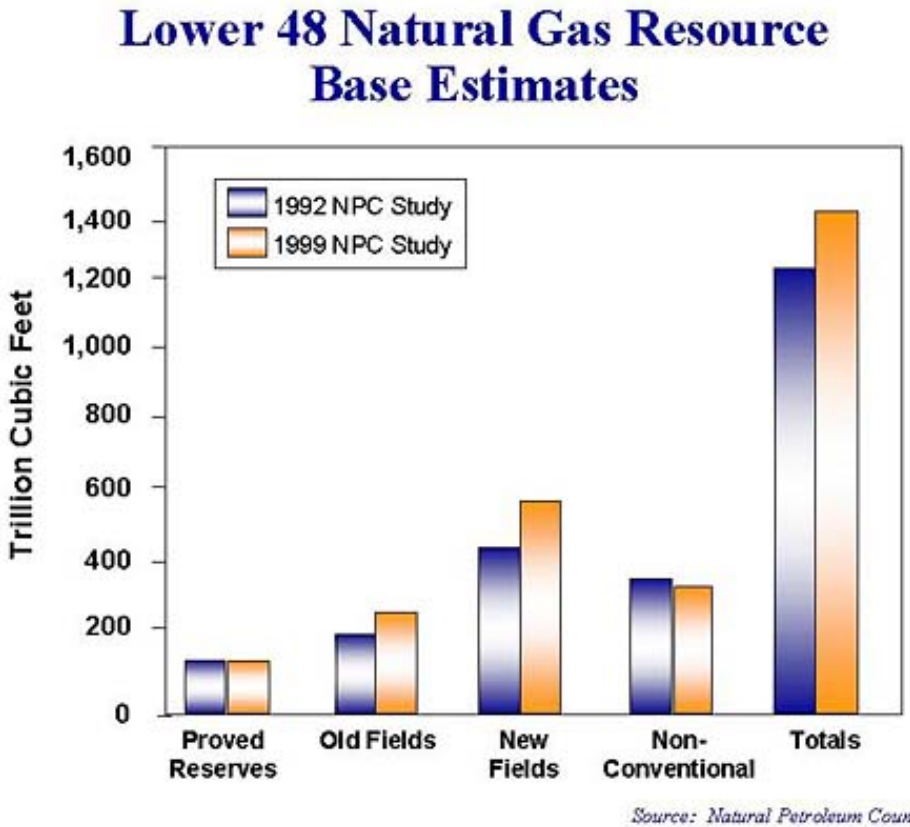
Source: Energy Information Administration, 2004

Three States (Texas, Louisiana, and Oklahoma) account for over half of the natural gas produced in the United States.

Source: Slutz, James, Deputy Assistant Secretary, Office of Natural Gas & Petroleum Technology, DOE, "Perspectives on Natural Gas," Natural Gas Technologies II Conference Phoenix, AZ, February 10, 2004

DOE projects an increasing reliance on imports. What impact will that have on the price and stability of supply of natural gas? Is natural gas destined to be the "oil" of the future, or can we develop enough domestic gas to avoid heavy reliance on imports?

National Petroleum Council estimates U.S. natural gas resources at more than 1,400 tcf,…



Source: Strategic Planning & Policy Support, Policy Support, U.S. Energy Security, National Energy Technology Laboratory, 9/17/01

… but a significant portion is not readily exploitable, nor necessarily translatable into timely, affordable supplies.

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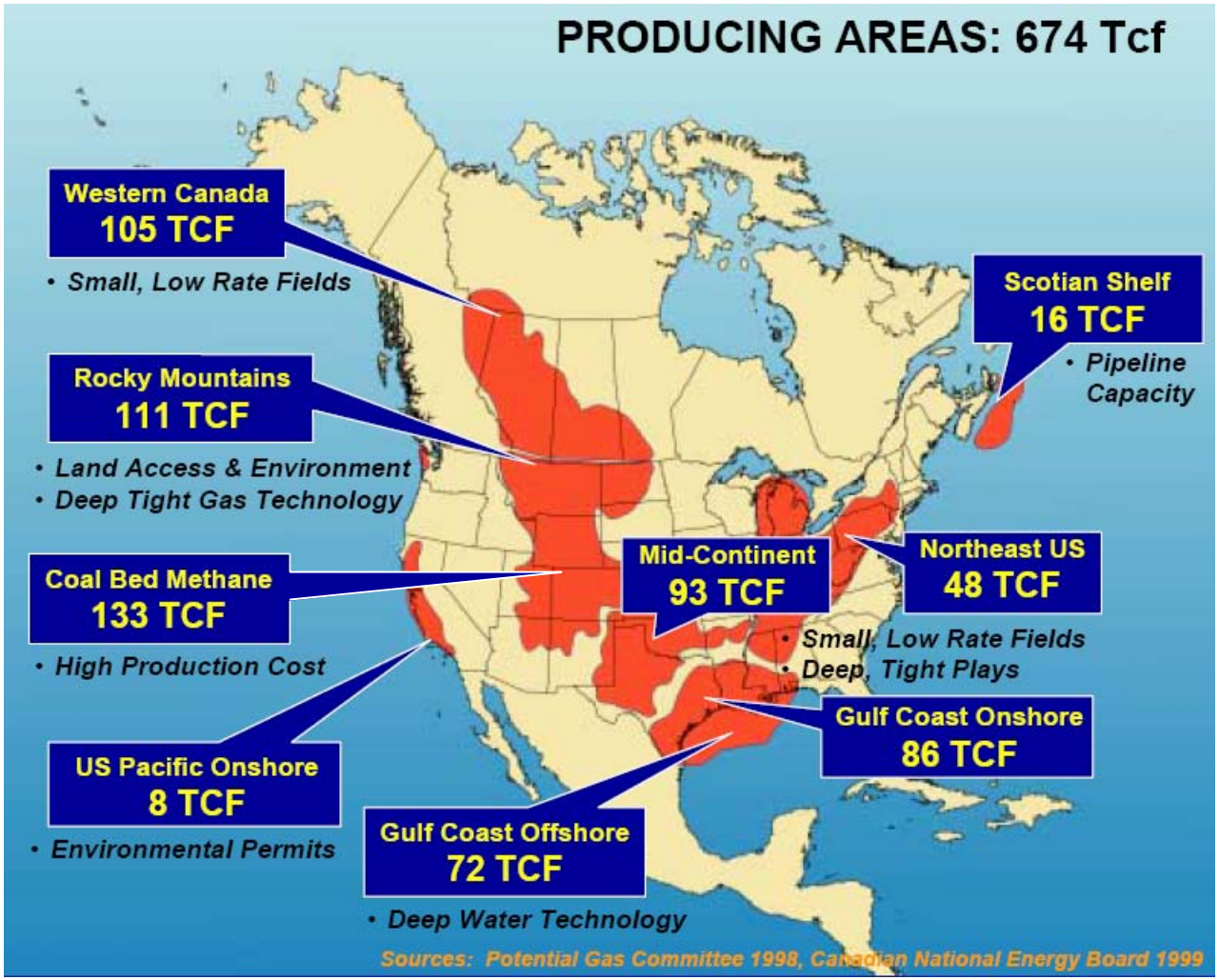
A number of physical, environmental, economic, and technological issues restrict adequate supplies of natural gas.



Source: Anadarko Petroleum Corporation, "Gas Supply Issues," May 14. 2002

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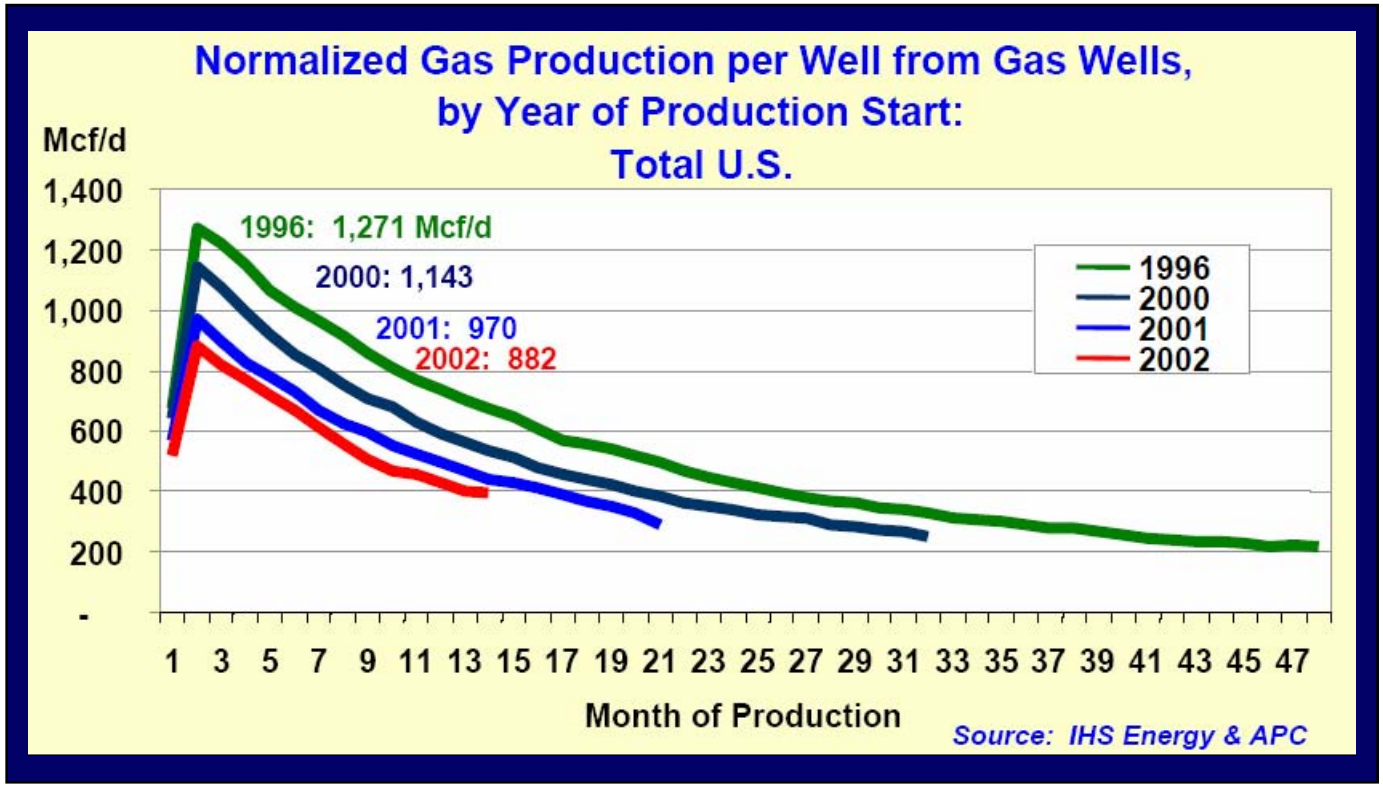
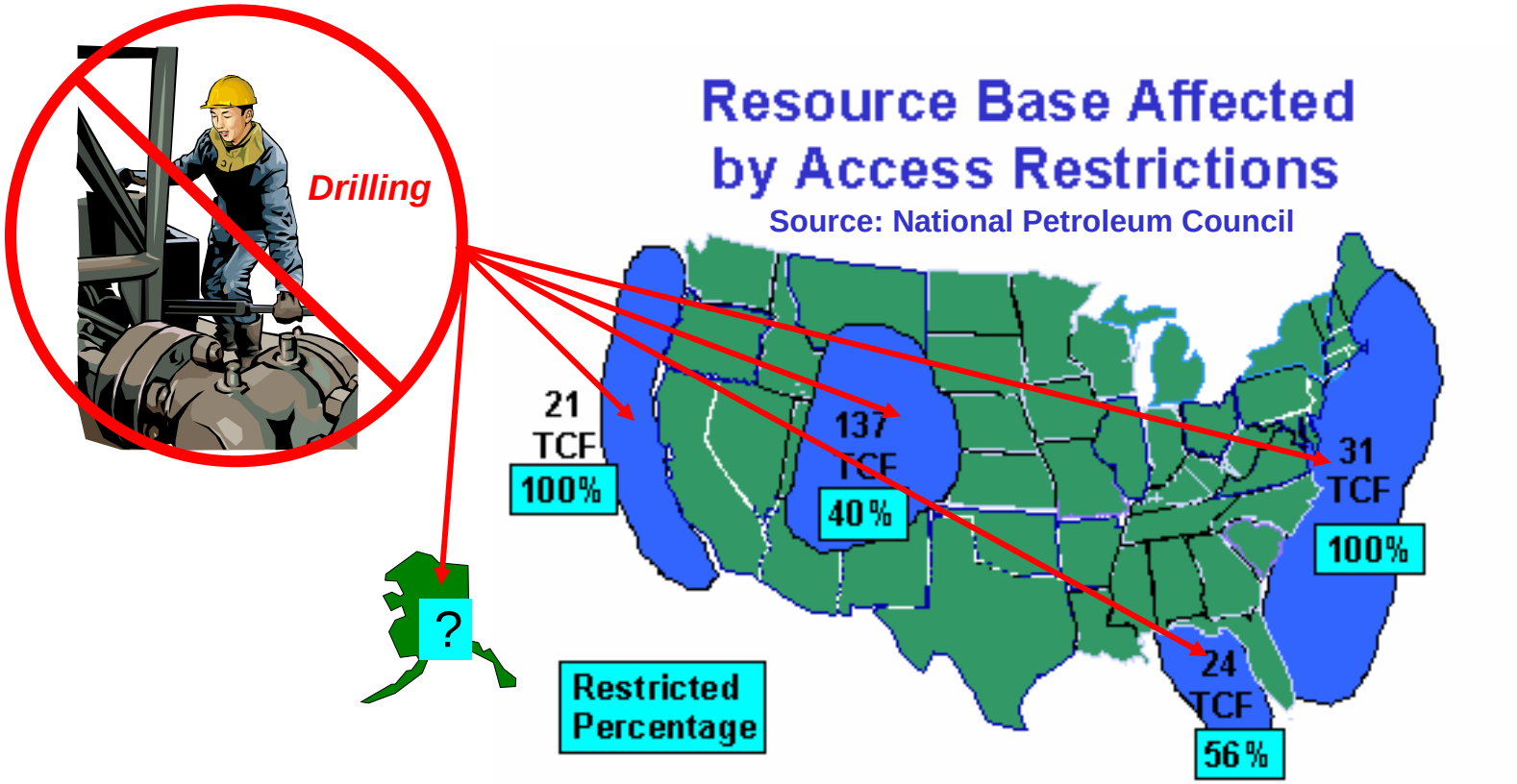
Each new well drilled in conventional natural gas fields has been less productive.



Source: Sharples, Dick, Sr VP, Strategic Planning & Marketing, Anadarko, "Gas Market Expectations for 2004 Structural Constraints and Market Reality," CBI's Gas Outlook 2004, 12/4/03, and NYMEX

Initial production is less and rate of production decline is steeper, thus less total production per new well. New fields must be found.

Some domestic natural gas supplies have been declared off-limits because of environmental concerns.



Thus, declines in well production and restricted access are creating a supply-demand mismatch.

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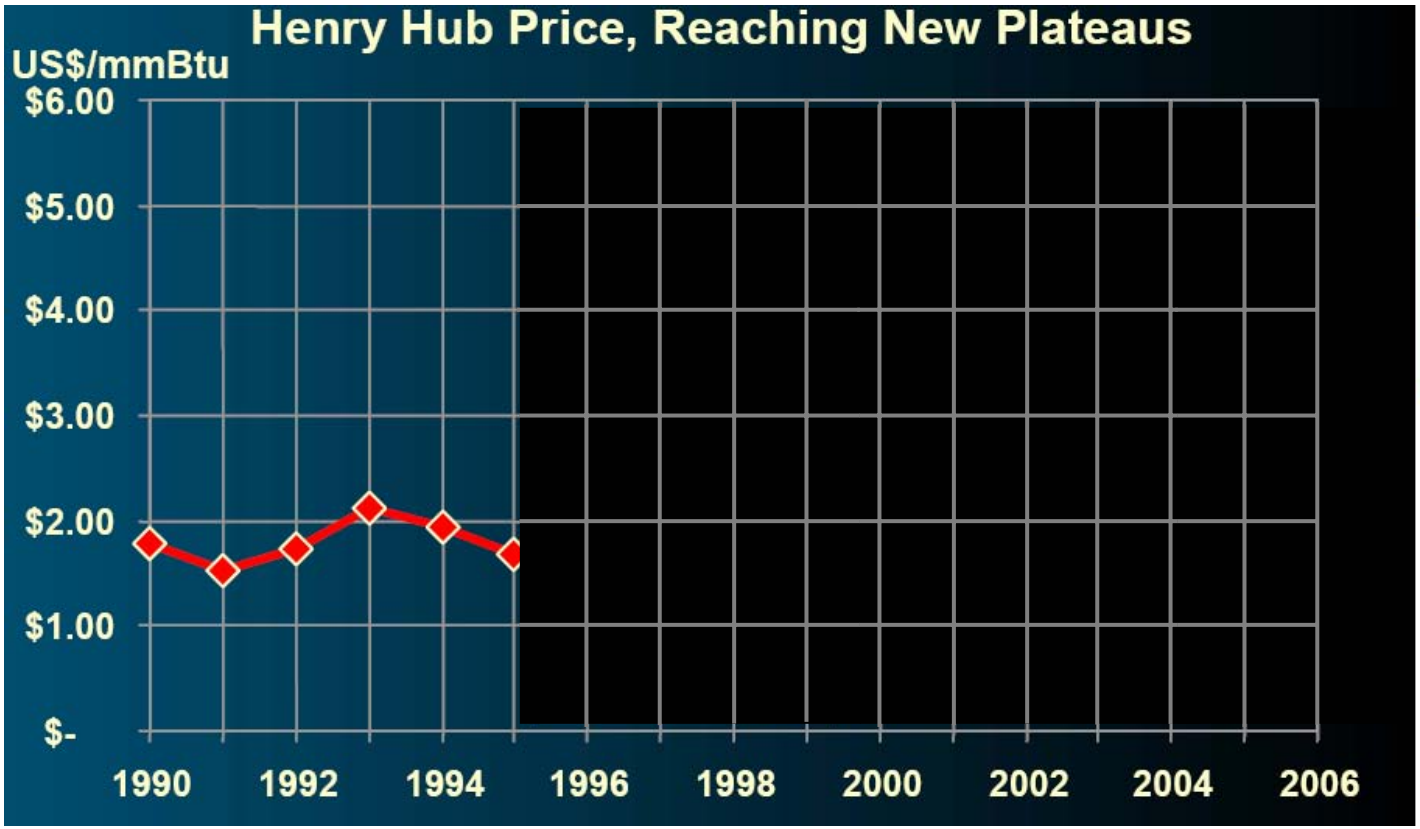
Tight supplies have created increasing price cycles to bring more expensive resources on stream & reduce demand pressure.



Source: Sharples, Dick, Sr VP, Strategic Planning & Marketing, Anadarko, "Gas Market Expectations for 2004 Structural Constraints and Market Reality," CBI's Gas Outlook 2004, 12/4/03, and NYMEX

Historically, more gas has always been found, and prices dropped. These data and DOE projections suggest, however, that history won't repeat itself this time, and the trend will be ever increasing prices from now on.

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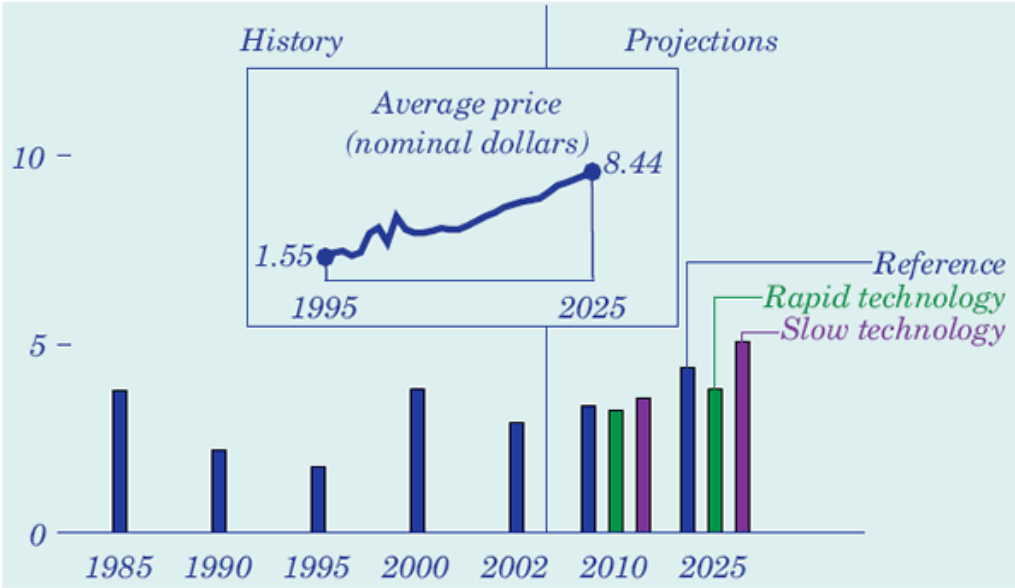
Natural gas prices are projected to increase, with new technologies assumed to be moderating factor.

Figure 90. Lower 48 natural gas wellhead prices in three cases, 1985-2025 (2002 dollars per thousand cubic feet)



Source: DOE/EIA, Annual Energy Outlook 2004 with Projections to 2025

NYMEX Natural Gas Futures Traded 5/13/04

Month	$/MMBtu
June	6.480
July	6.553
Aug	6.576
Sept	6.540
Oct	6.551
Nov	6.703
Dec	6.875
Jan	6.990
Feb	6.931
Mar	6.721
Apr	5.881
May	5.701

Source: Enerfax Daily – Section 8 – May 14, 2004

But currently prices are higher than projected. Until new investments are made and technologies developed to tap new resources, prices are likely to remain especially high and volatile for many years.

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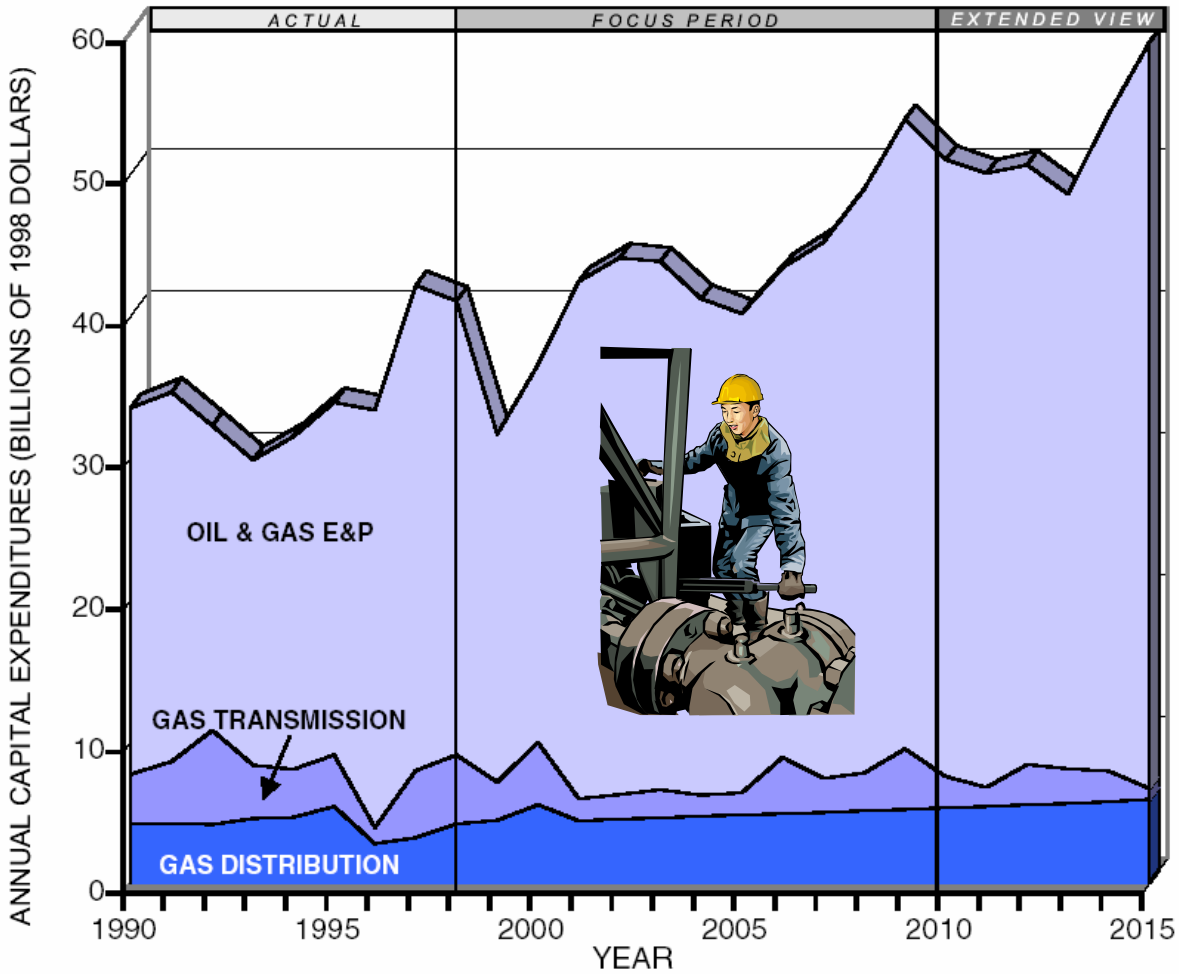
Under "business as usual," $785B ($150B in delivery) capital investment needed by the natural gas industry between 1999 and 2015.



* Because "associated" natural gas is produced with oil, expenditures for oil and gas have not been separated.

Given high market volatility in natural gas, can the gas industry compete for sizable investment capital against financially average and high performing investment alternatives? And is there enough gas?

Source of graphic: NPC Natural Gas Study DRAFT, December 15, 1999

Source of historical data: AGA Gas Facts–1998, and estimates from EEA, Inc.

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There are two different ways of characterizing future natural gas supplies in the U.S.:

- **Explore for, and analyze, natural gas resources. This approach yields:**
  - **The relative large estimates for untapped resources: more than 1400 tcf,**
  - **But in general has the implied assumption that technologies, markets and policies will make these huge resources available for a long time to come.**
- **Analyze historical trends in growth in natural gas wells, and production from them. These data:**
  - **Show a trend of declining production in North America despite more wells being drilled.**
  - **Add increasing demand, including from Mexico, and a "crisis" seems in inevitable.**

Both may be right. The U.S. will face an imbalance between demand and supply from conventional resources, until capital can be invested to tap new, unconventional natural gas resources.

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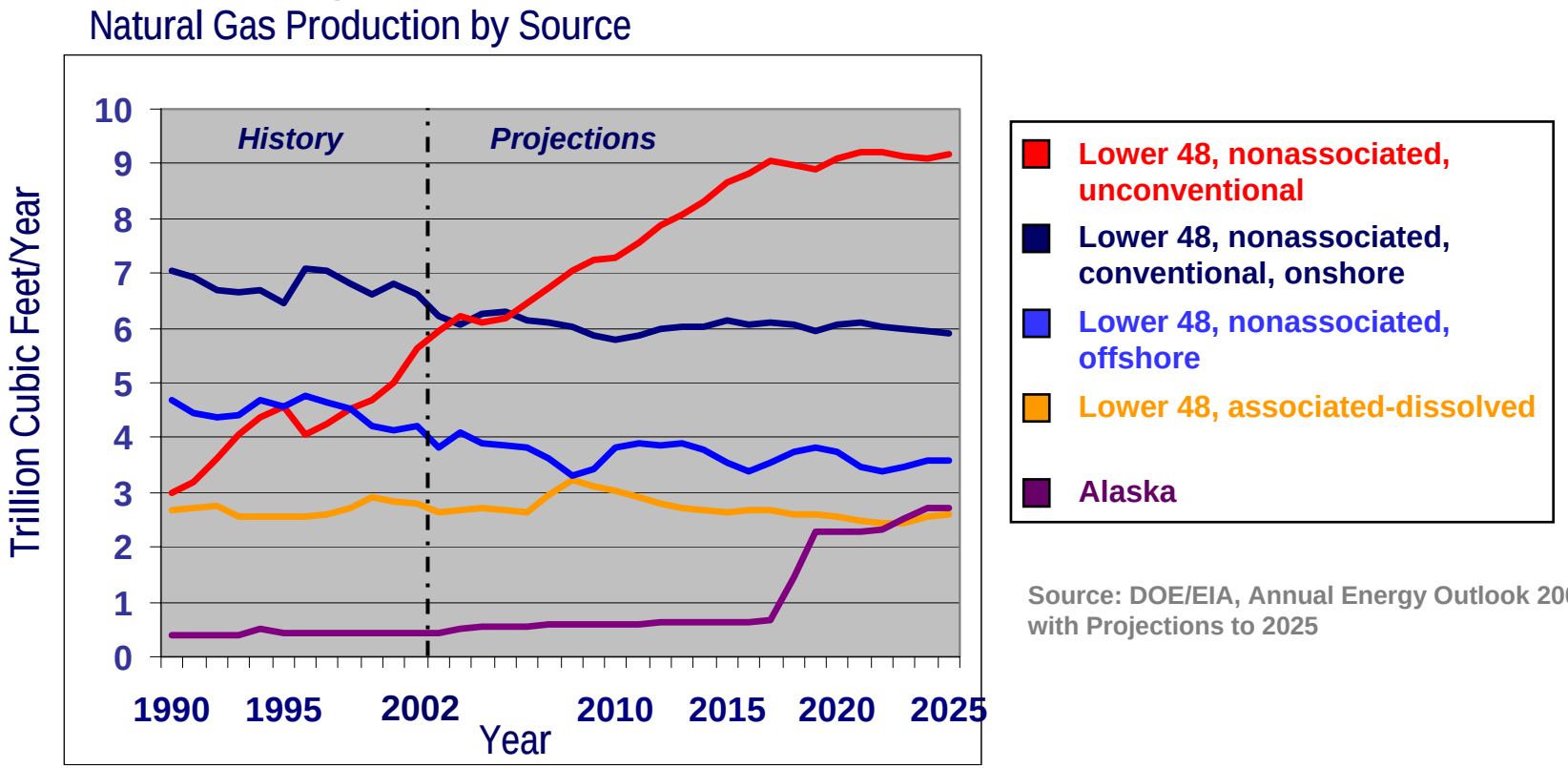
If we are to enjoy adequate supplies of natural gas, unconventional production must become the largest source of U.S. supply.



Source: DOE/EIA, Annual Energy Outlook 2004 with Projections to 2025

Access to unconventional sources and Alaskan gas, the other potential domestic resource, will require significant additional new investments and long lead times, and more.

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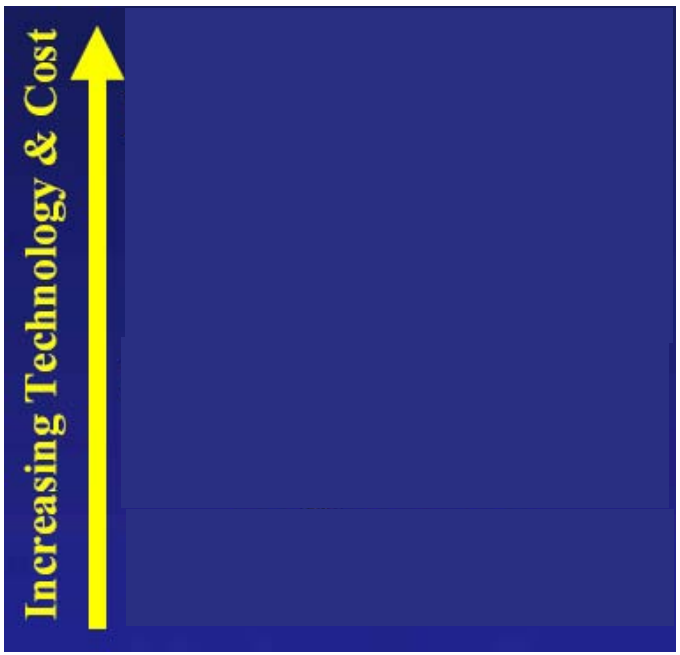
Good news, there are many, large unconventional resources of natural gas; bad news, they are expensive.



- Economics so far have allowed development of mostly conventional resources.
- Technological innovations have recently opened tight gas and coal bed methane for development.

Source: Anadarko Petroleum Corporation, "Gas Supply Issues," May 14. 2002

But most of the unconventional resources remain uneconomic with current technology.

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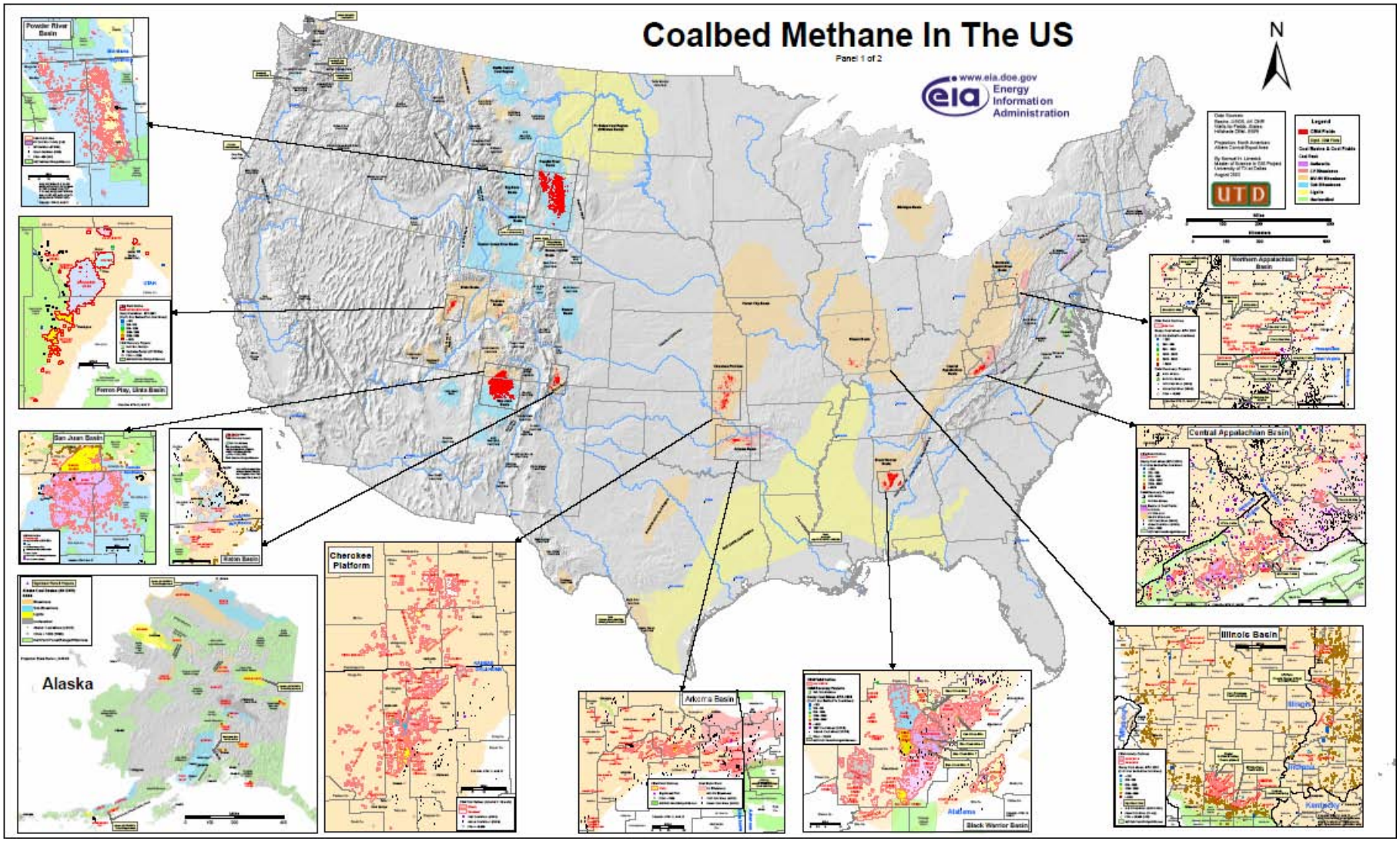
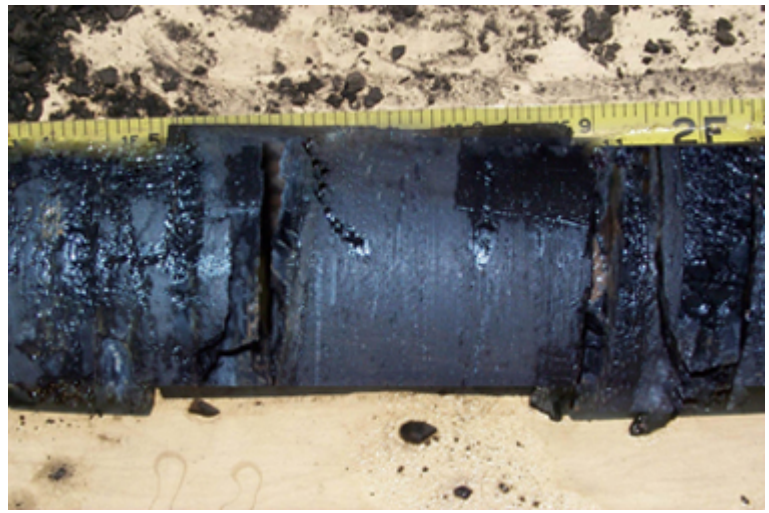
Coalbed methane is an unconventional natural gas source in production today.



Estimates place coalbed methane at 9% of total U.S. natural gas production.

- Originally, coalbed methane was of interest because it was a hazard to coal miners, but now it is an important new source of good quality natural gas.
- Coal stores 6 to 7 times more gas than the equivalent rock volume of a conventional gas reservoir.
- Water traps the methane in the coalbed; it must be removed to release the methane for collection. It might become a valuable byproduct, or an environmental hazard.
- The coalbed methane resources of the United States are estimated to be more than 700 trillion cubic feet (Tcf), but less than 100 Tcf may be economically recoverable.



Hydraulic fracturing is necessary in order to extract natural gas from coalbeds. (Photo courtesy of USGS.)

Sources: Pinsker, Lisa M., "Coalbed Methane: The Future of U.S. Natural Gas?" GeoTimes, Nov. 2002; and U.S. Geological Survey, Energy Resource Surveys Program, USGS Fact Sheet FS-019-97

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The Alaskan North Slope (ANS) natural gas, long considered a stranded asset – because no one knew how to deliver it – is now being viewed as a valuable potential resource.

- Recoverable gas resources estimated at 32-38 TCF.
- Estimates of undiscovered gas result in an ultimate recoverable resource exceeding 100 TCF.
- Industry is considering three options for delivering ANS gas to market:
  - Liquefied Natural Gas (LNG) – Natural gas is liquefied and exported by tanker to Asia.
  - Gas-to-Liquids (GTL) – Natural gas is chemically converted to a liquid fuel.
  - Pipeline to Lower-48 – Natural gas is transported by pipeline through Canada to the lower-48 states.

Source: Policy Facts, US DOE, National Energy Technology Laboratory, Strategic Center for Natural Gas, March 2002

Of the three options, a pipeline is probably the most popular.

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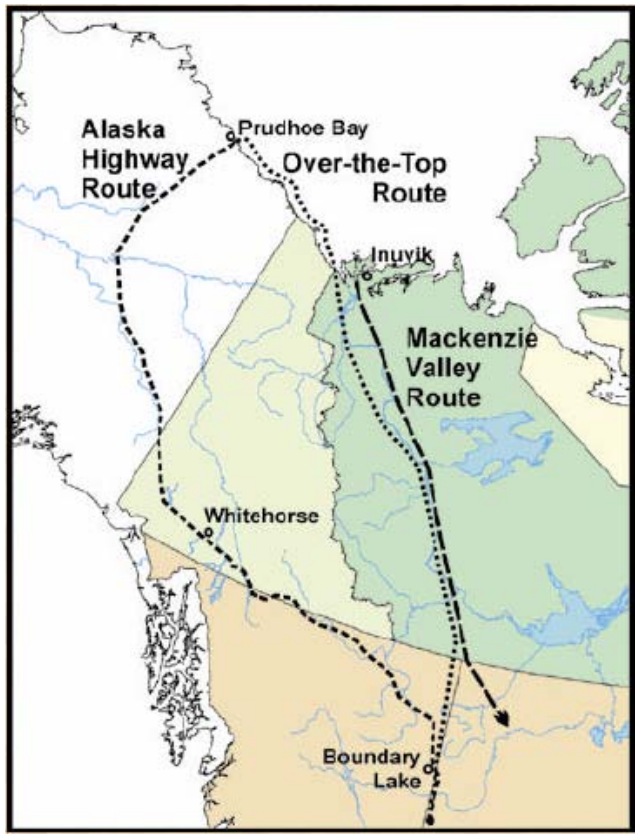
There are three general pipeline routes being considered for getting Alaskan gas to market.

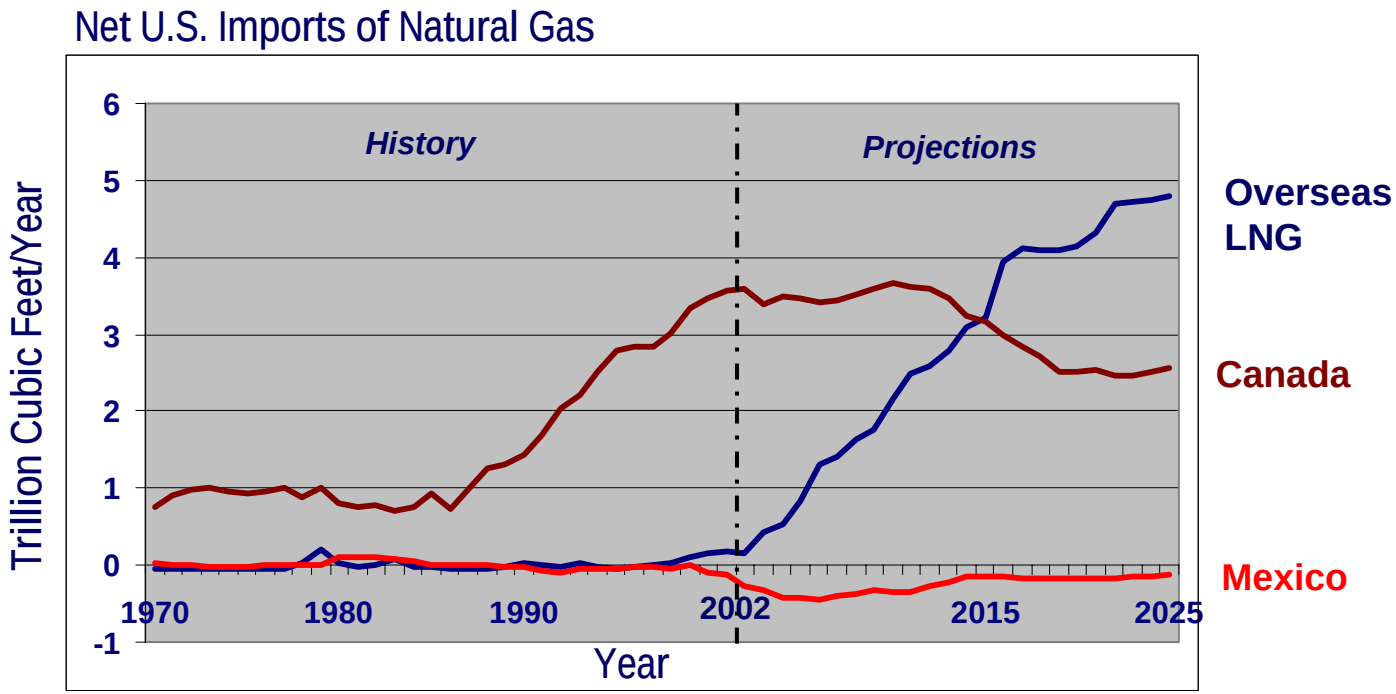
- An Alaska Hwy route
- An over-the-top "route",
- A stand-alone project to bring Canadian gas from the Mackenzie Delta south to market.
- Cost estimates are ~$20M and would require gas prices above $3/MMBtu.
- In-service date would likely be after 2010.

But investor fear of price volatility plus political issues, e.g., guaranteed price floor, and national interests, will probably lead to longer delays.



Source: Quarshie, Elizabeth, National Energy Board, "An Outlook for Canadian Gas Supply," Canadian Gas Association Annual General Meeting 11 June 2002, Vancouver, B.C.

To meet expected demand, U.S. will also increasingly rely on imported natural gas, and LNG is expected to provide the lion's share, including replacing declining imports from Canada.



Source: DOE/EIA, Annual Energy Outlook 2004 with Projections to 2025

LNG supplies might be delayed by safety, terrorist, or financial risk concerns, or international competition and political problems, jeopardizing a major future expected source of natural gas.

Liquefied natural gas (LNG) is natural gas stored and transported as liquid at atmospheric pressure and temperature of –260º F.

Transported

Source: DOE/EIA-0637 (2003): LNG Tanker

Liquefied

Source: Bechtel Briefs: Atlantic LNG Production Plant on the island of Trinidad

Stored and Regasified

Source: CH-IV International: Lake Charles Import Terminal, Louisiana

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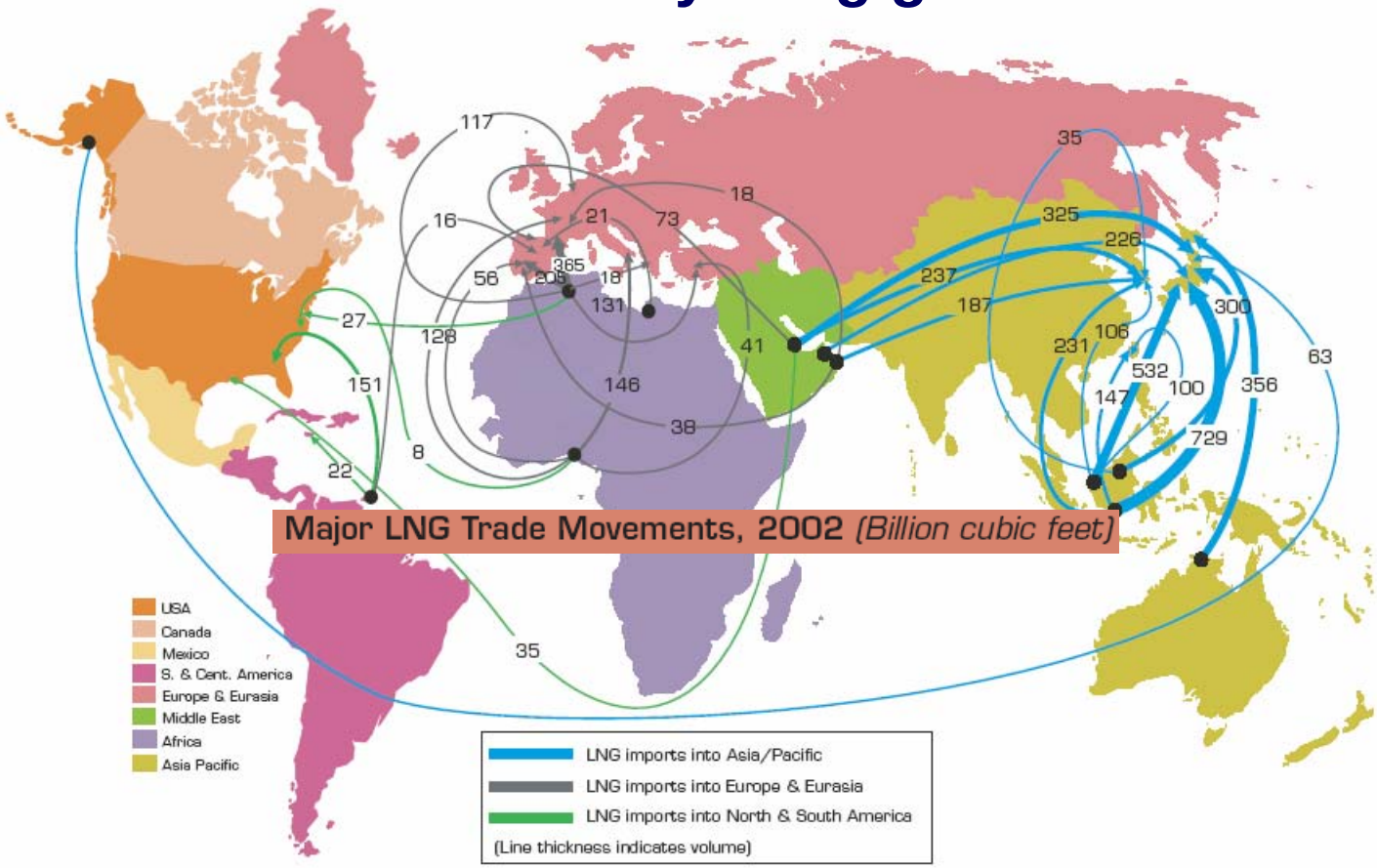
Major LNG Trade Movements, 2002 (Bcf)
LNG is already a big global business.



Note: The map includes flows greater than 5 Bcf for imports into the United States, and flows greater than 15 Bcf for imports into all other Countries.

Source: **Imports to the United States and Imports to Japan and Mexico from the United States:** Energy Information Administration, *Natural Gas Monthly* (May 2003). **All Other Countries:** Organization for Economic Cooperation and Development, International Energy Agency, Natural Gas Information 2003 (with 2002 data).

Source: "The Global Liquefied Natural Gas Market: Status & Outlook," Energy Information Administration, U.S. Department of Energy, DOE/EIA-0637 (2003), Washington, DC 20585, December 2003

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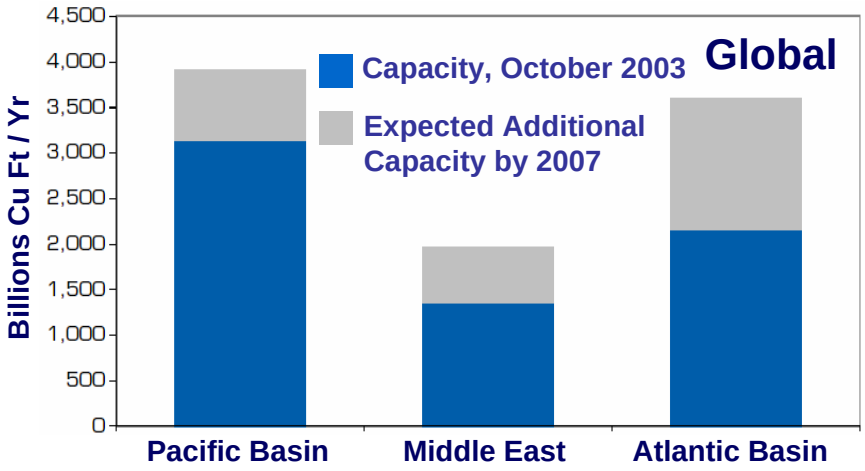
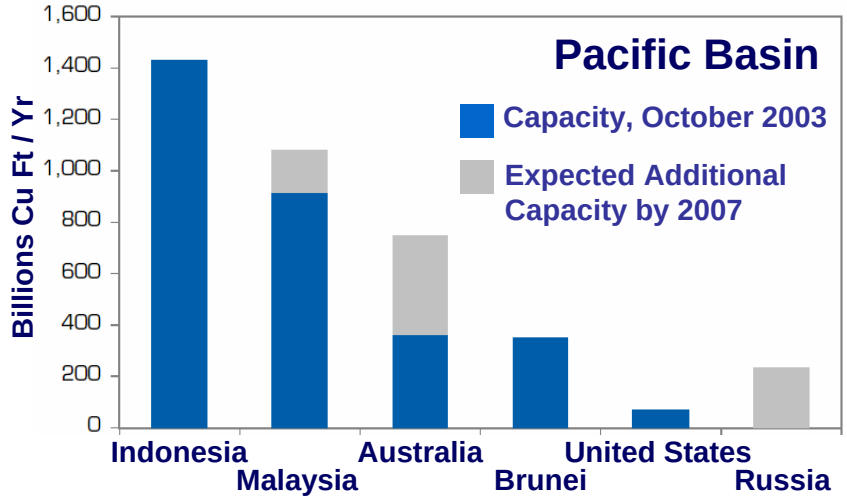
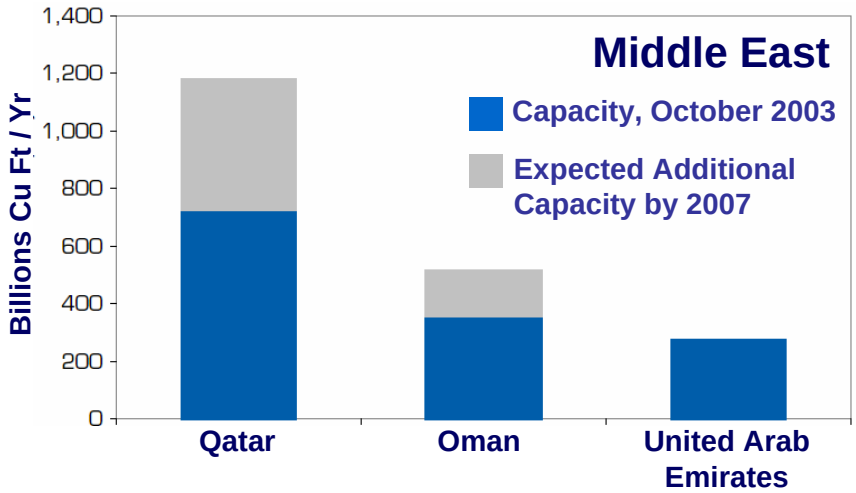
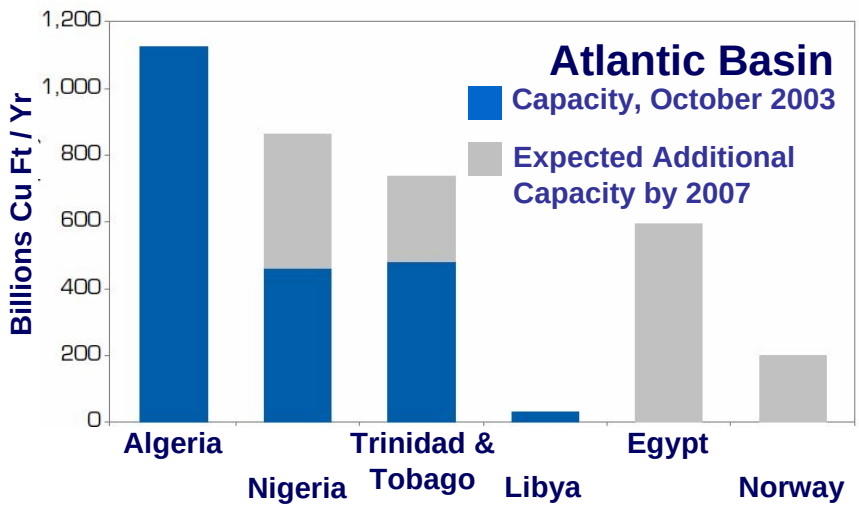
LNG Liquefaction Capacity, Global and by Region









Source: "The Global Liquefied Natural Gas Market: Status & Outlook," Energy Information Administration, U.S. Department of Energy, DOE/EIA-0637 (2003), Washington, DC 20585, December 2003

Data from IEA 2003 Natural Gas Information, and updated based on trade press reports as assembled by the Gas Technology Institute.

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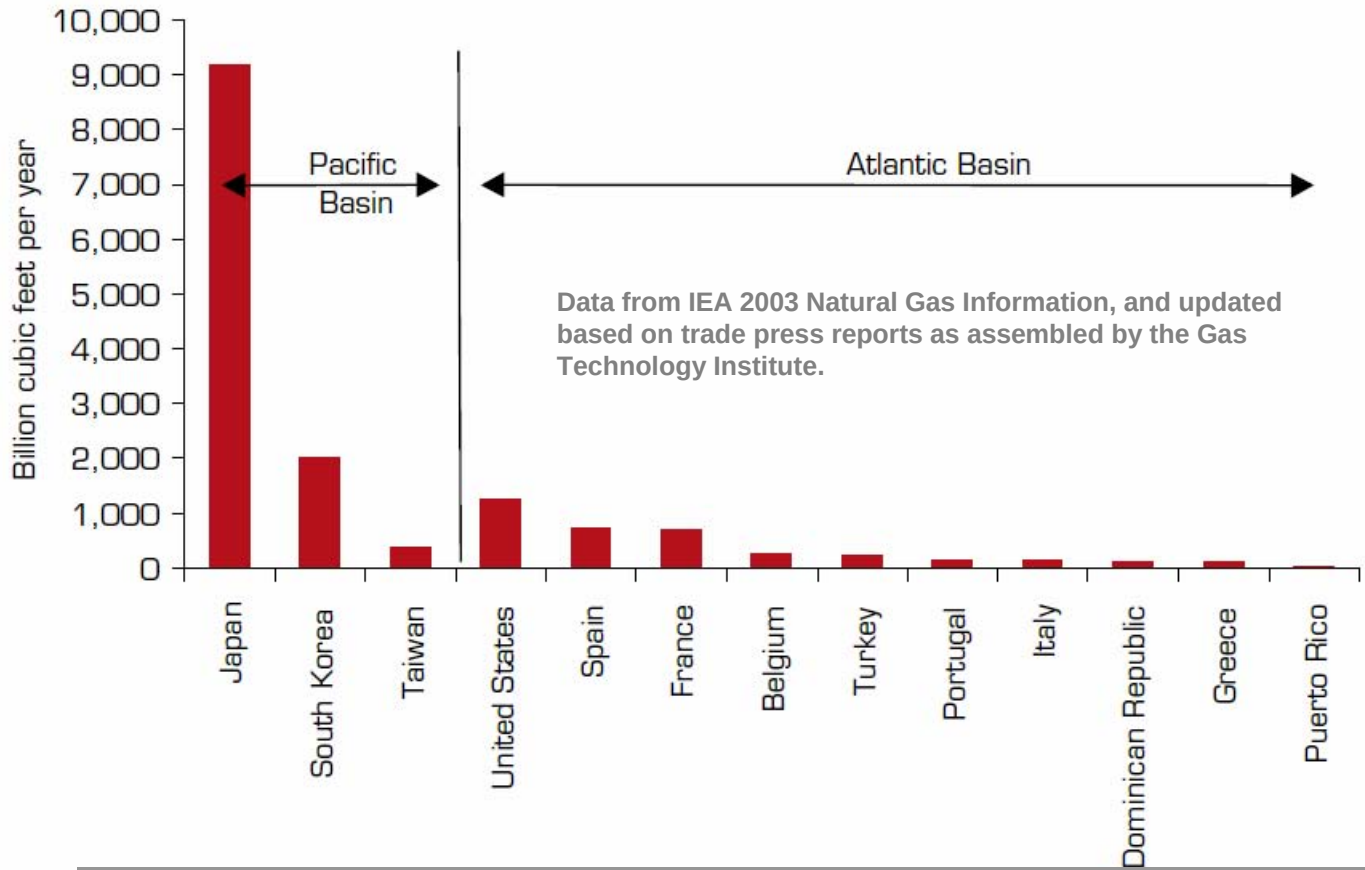
Global LNG Regasification Capacity, October 2003



Data from IEA 2003 Natural Gas Information, and updated based on trade press reports as assembled by the Gas Technology Institute.

Source: "The Global Liquefied Natural Gas Market: Status & Outlook," Energy Information Administration, U.S. Department of Energy, DOE/EIA-0637 (2003), Washington, DC 20585, December 2003

Far East countries are by far the heaviest importers of LNG, and probably most adept at it.

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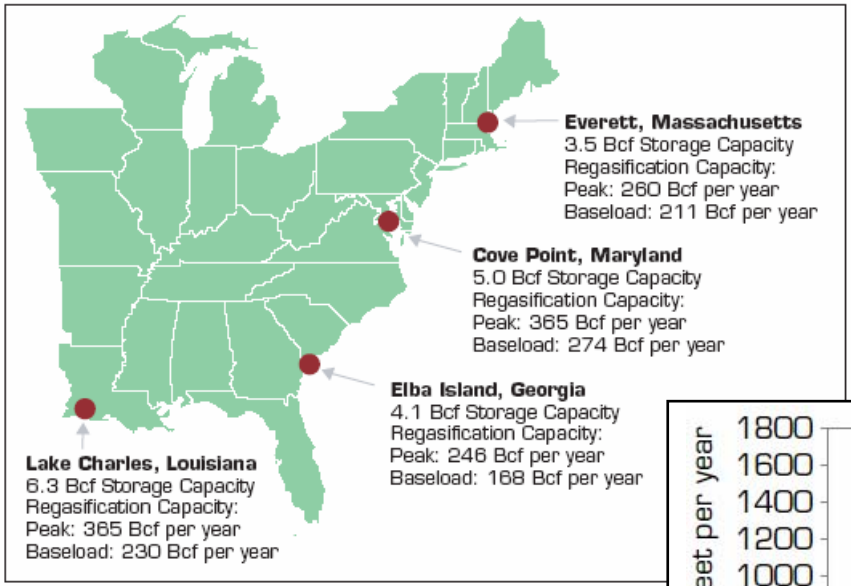
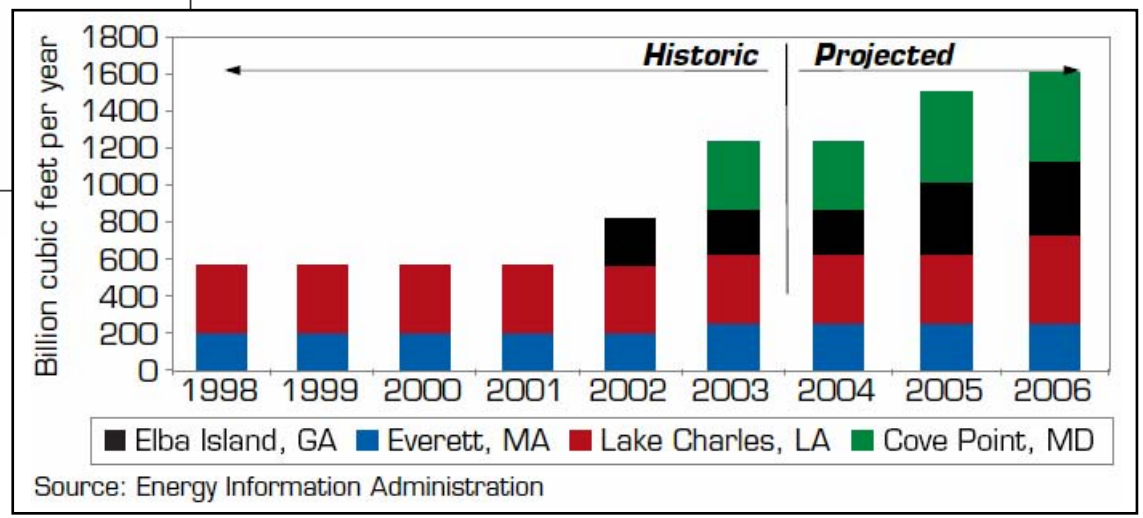
There are four LNG regasification terminals in the U.S.



Source: Energy Information Administration

Source: "The Global Liquefied Natural Gas Market: Status & Outlook," Energy Information Administration, U.S. Department of Energy, DOE/EIA-0637 (2003), Washington, DC 20585, December 2003



Source: Energy Information Administration

LNG imports almost doubled from 2001 to 2003, and considerable expansion in import capacity is planned.

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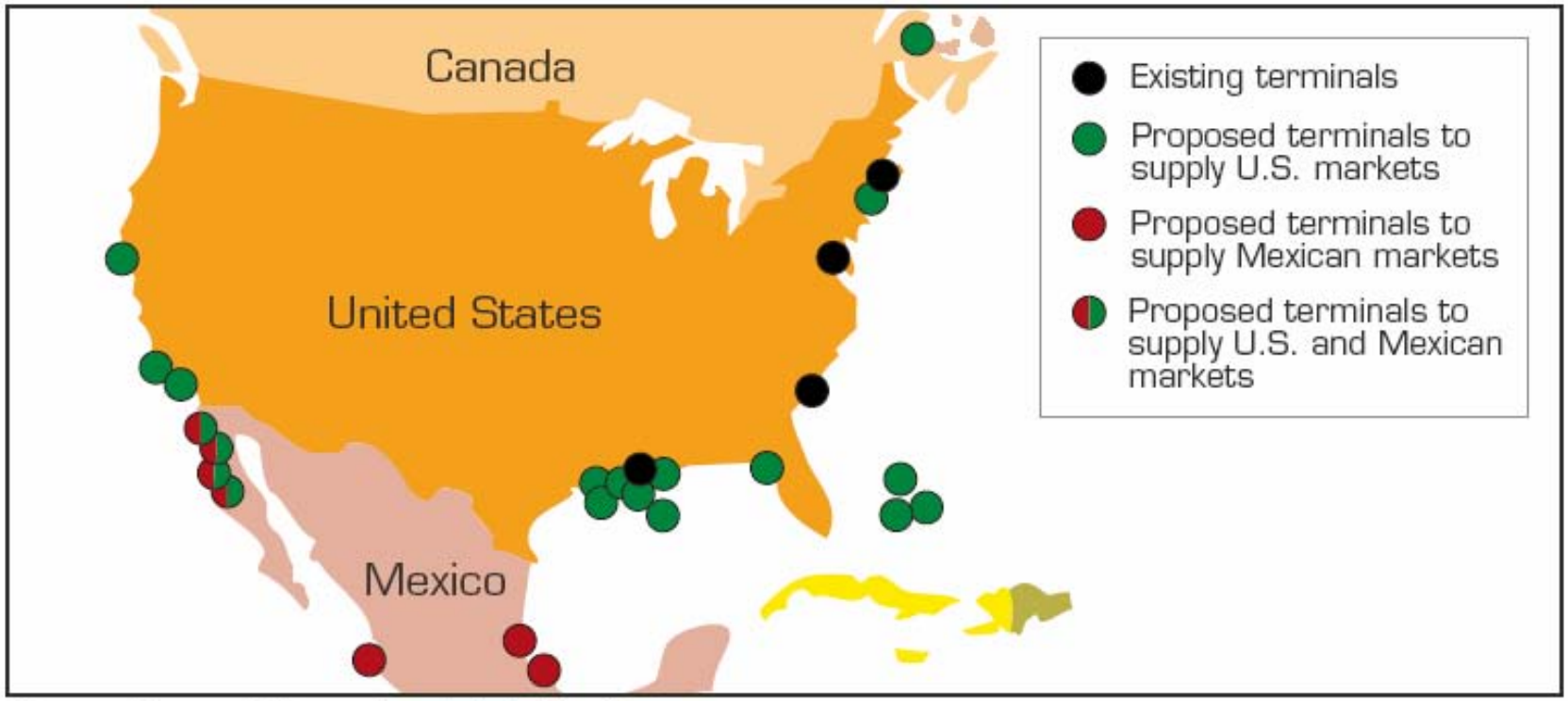
Potential Locations for LNG Regasification Terminals in North America.



Source: "The Global Liquefied Natural Gas Market: Status & Outlook," Energy Information Administration, U.S. Department of Energy, DOE/EIA-0637 (2003), Washington, DC 20585, December 2003

At least 2 dozen new terminals are proposed to be built over the next several years, if they can be permitted to be sited and built.

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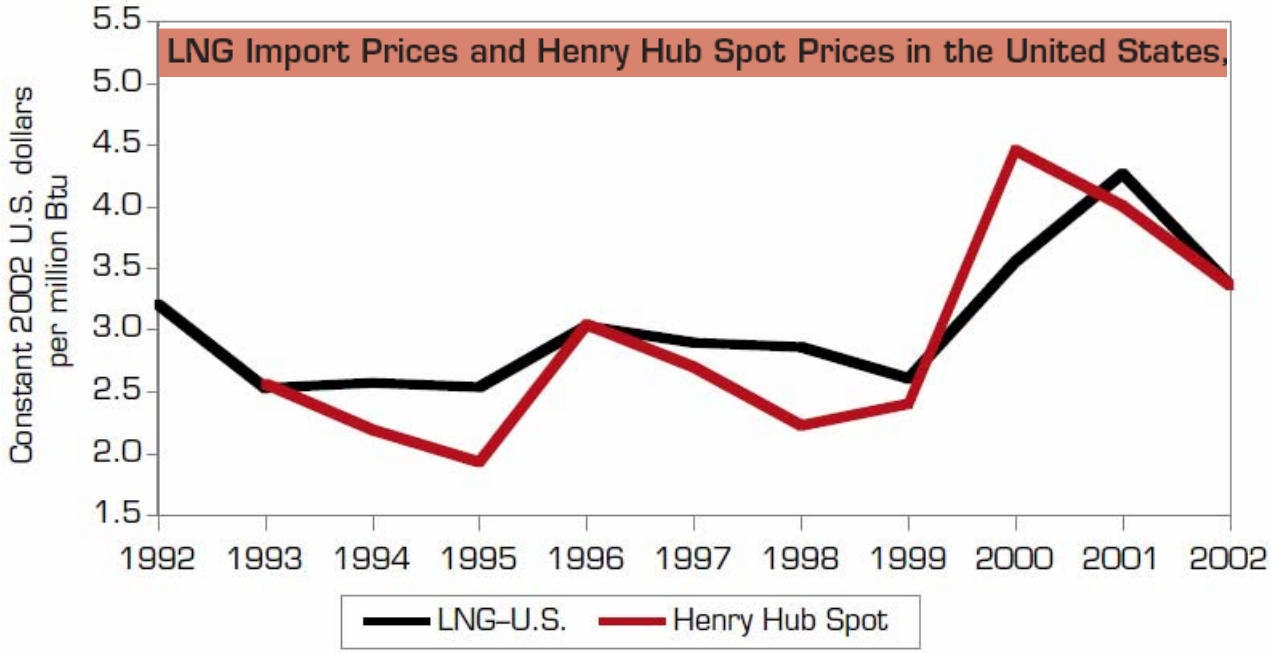
Costs of LNG becoming more competitive as domestic natural gas prices rise, and LNG costs drop.



Source: Natural Gas Intelligence; International Energy Agency, Energy Prices and Taxes, third Quarter 2003, online data services.

Source: "The Global Liquefied Natural Gas Market: Status & Outlook," Energy Information Administration, U.S. Department of Energy, DOE/EIA-0637 (2003), Washington, DC 20585, December 2003

Per LNG consultant, Andy Flower, President, Andy Flower LNG Associates, there are four main price components of an LNG project, from the gas field to the receiving terminal:

- **–*Gas production*: from the reservoir to the LNG plant, (15 to 20% of costs);**
- **–*LNG plant*: gas treating, liquefaction, LPG and condensate recovery, LNG loading & storage (30 to 45% of costs);**
- **–*LNG shipping* (10 to 30% of costs); and**
- **–*Receiving terminal*: unloading, storage, regasification & distribution (15 to 25% of costs).**

Some LNG facts

- LNG has ~ 1/600th the volume of natural gas at a stove burner tip.
- LNG weighs less than one-half that of water, ~ 45% as much.
- LNG is odorless, colorless, non-corrosive, and non-toxic.
- When vaporized it burns only in concentrations of 5% to 15% when mixed with air. Neither LNG, nor its vapor, can explode in an unconfined environment.
- LNG can be purified to almost 100% methane, causing problems for burners in existing appliances designed for pipeline quality natural gas.
- LNG is stored as a "boiling cryogen" – think very cold "boiling water" – at pressures around 5 psig (in large tanks). As long as vapor is allowed to leave container, temperature will stay constant around -260°F.
- The U.S. has substantial experience operating and regulating LNG facilities:
  - The four marine regasification terminals
  - ~ 55 local utilities own and operate LNG plants as part of their natural gas distribution networks for storing LNG to help meet peak demands.
  - The liquefaction plant in Alaska that converts natural gas into LNG.

Sources: "LNG Fact Sheet," CH-IV International, Millersville, MD, November 19, 2003; and "LNG Facility Safety," The Center for Liquefied Natural Gas, http://www.lngfacts.org/facilities/fac_safety.html

But is there enough natural gas in world to support a world LNG market?

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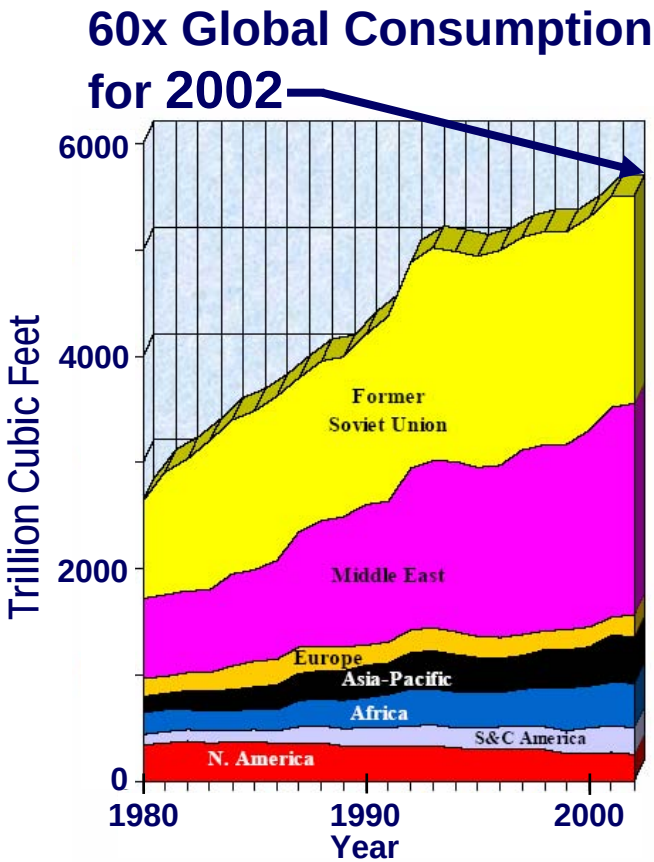
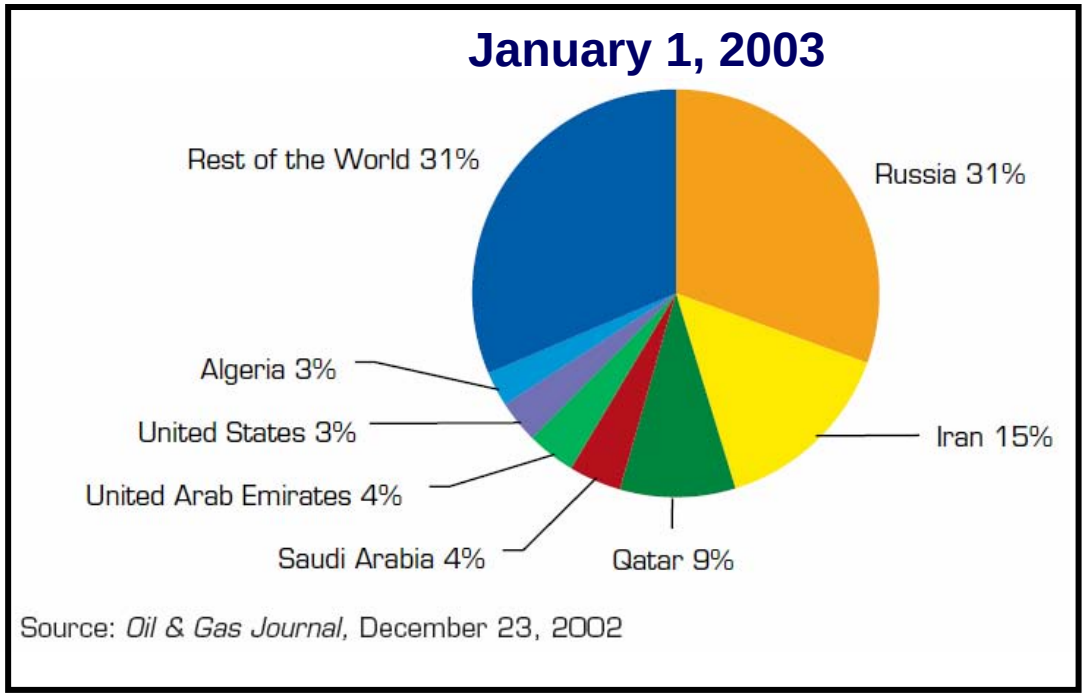
Proved World Natural Gas Reserves





Source: "The Global Liquefied Natural Gas Market: Status & Outlook," Energy Information Administration, U.S. Department of Energy, DOE/EIA-0637 (2003), Washington, DC 20585, December 2003

Source: Hughes, David, Geological Survey of Canada, "The International Outlook: Natural Gas Supply from a Canadian Perspective," *Natural Gas Technologies II, Perspectives on Natural Gas Supply*, Phoenix, Arizona, February 10, 2004 (data from BP Statistical Review of World Energy, 2003)

There's a lot of natural gas in the world, and 2/3 is in the Middle East and Russia. Sound familiar?

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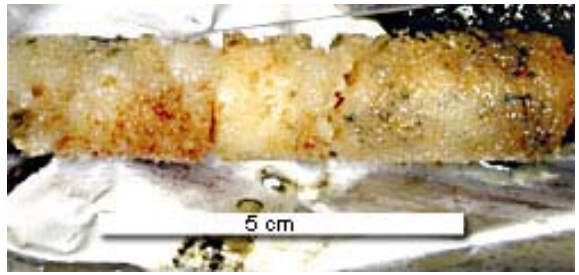
Are methane hydrates our fuel of the future?

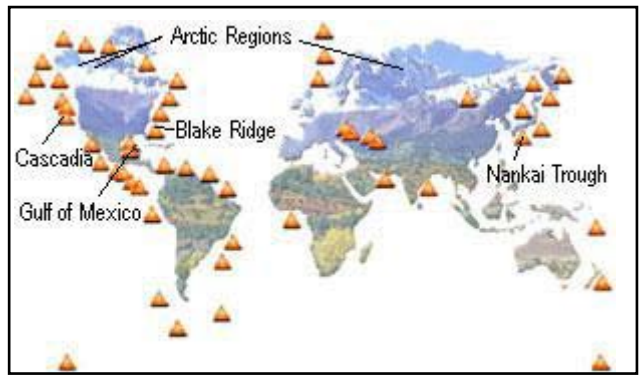
- Methane hydrate is a cage-like lattice of ice, trapping molecules of methane
  - Class of compounds, "clathrates," Latin word for "to enclose with bars."
  - Can form @ temperatures above freeze point for water.
  - One volume unit of hydrate, heated and depressurized, can yield 160 units of methane.
- Methane hydrates mainly found:
  - On land in permafrost regions where cold temperatures persist in shallow sediments,
  - Beneath the ocean floor at water depths greater than ~ 500 meters where high pressures dominate.
- The amounts of methane hydrates are staggering:
  - An estimated 200,000 TCF in U.S.; contrasted to 1400 TCF of conventional resources and reserves.
  - 1% recovery of methane hydrates in U.S., would double supplies of "natural gas."
  - An estimated 400,000,000 TCF in world; contrast to 5000 TCF known reserves.

Source: Kripowicz, Robert S., Principal Deputy Assistant Secretary for Fossil Energy, U.S. Department of Energy, Statement on Gas Hydrates before Subcommittee on Energy, Research, Development, Production, and Regulation, Committee on Energy and Natural Resources, United States Senate, May 21, 1998



Methane hydrate core recovered from the Johnson Sealink cruise in the Gulf of Mexico in July 2001.

Photo courtesy Ian McDonald Texas A&M



Locations of methane hydrates.

Source of Photos: "All About Hydrates," U.S. Department of Energy, National Energy Technology Laboratory, 2004

As much as there is, methane hydrates are more of a problem than a solution, until we develop the technology to economically extract it.

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Methane hydrates, first a curiosity, next a nuisance, then a promise, followed by a source of concerns and issues.

- In the 1800s hydrates were a curiosity of chemistry.
- In the 1930s, methane hydrates were discovered to be plugging natural gas lines in cold climates, and for decades to follow, scientists looked for ways to prevent their formation.
- In the 1960s, scientific evidence of naturally occurring methane hydrates was found, followed by the recovery of a sample in Russia in 1974.
- In the 1990s, R&D on methane hydrates hoped to find resources and a means of extraction.
  - Raise the temperature of the reservoir, e.g., hot water or steam
  - Reduce the pressure of the reservoir
  - Inject a destabilization chemical
- Today, R&D is focused on 2 critical issues:
  - The role that methane hydrate plays in the natural environment - including its interaction with sea-bottom life forms, ocean-floor stability, the global carbon cycle, and long-term climate change.
  - The hazards that hydrated-sediments pose to conventional oil and gas drilling operations as they expand into ever-deeper water.

Source: "All About Hydrates," U.S. Department of Energy, National Energy Technology Laboratory, 2004

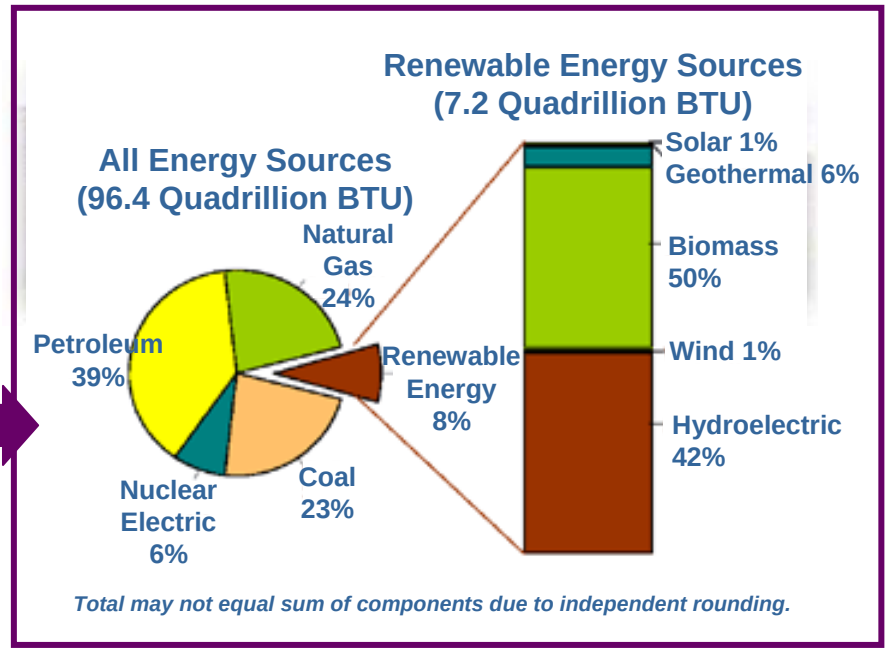
So, why we wait for answers to methane hydrates, what <u>is</u> the outlook for natural gas?

A number of scenarios are possible for the outcome of the natural gas supply crisis:

- The Glut: Tight supplies, prices high with anticipated low volatility.
  - *Actions*: Investors rush to invest in new natural gas projects, e.g., LNG, deepwater drilling, Coalbed methane, and natural gas from Alaska;
  - *Results*: Glut in 5 - 10 years, leading to dramatically falling prices.
  - *Implications*: Alternative options, such as renewables and coal, taking advantage of high prices, rush to capture market from natural gas, become stranded at the end of this 5-10 year period, unless they can recover their capital in the period of high prices.
- Skittish Investors: Tight supplies, prices high with anticipated high volatility.
  - *Actions*: Fear of volatility discourages investments in new natural gas projects.
  - *Results*: The natural gas shortages drag on along with high prices.
  - *Implications*: Alternative options deployed during this time would likely become well established and effectively take market share from natural gas for many years into the future. A wild card would be government subsidies to the gas industry to encourage the needed investments to rebuild natural gas supplies.
- Confusion and Indecision: Tight supplies, prices high with uncertain volatility.
  - *Actions*: Spurts of investments in natural gas projects, followed by “dry” periods.
  - *Results*: Natural gas continues to play a significant role during this shortage period, but never a secure one because things are just too uncertain.
  - *Implications*: Good one for investments in natural gas/renewable hybrids?

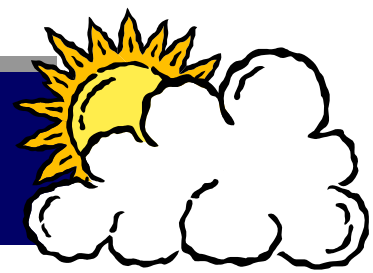
We posed renewables as a solution to the energy crisis in the 1970s.

- **We even created a national solar energy research institute, SERI, (now NREL) dedicated to renewables.**
- **Today, renewables are still less than 10% of U.S. energy mix.**

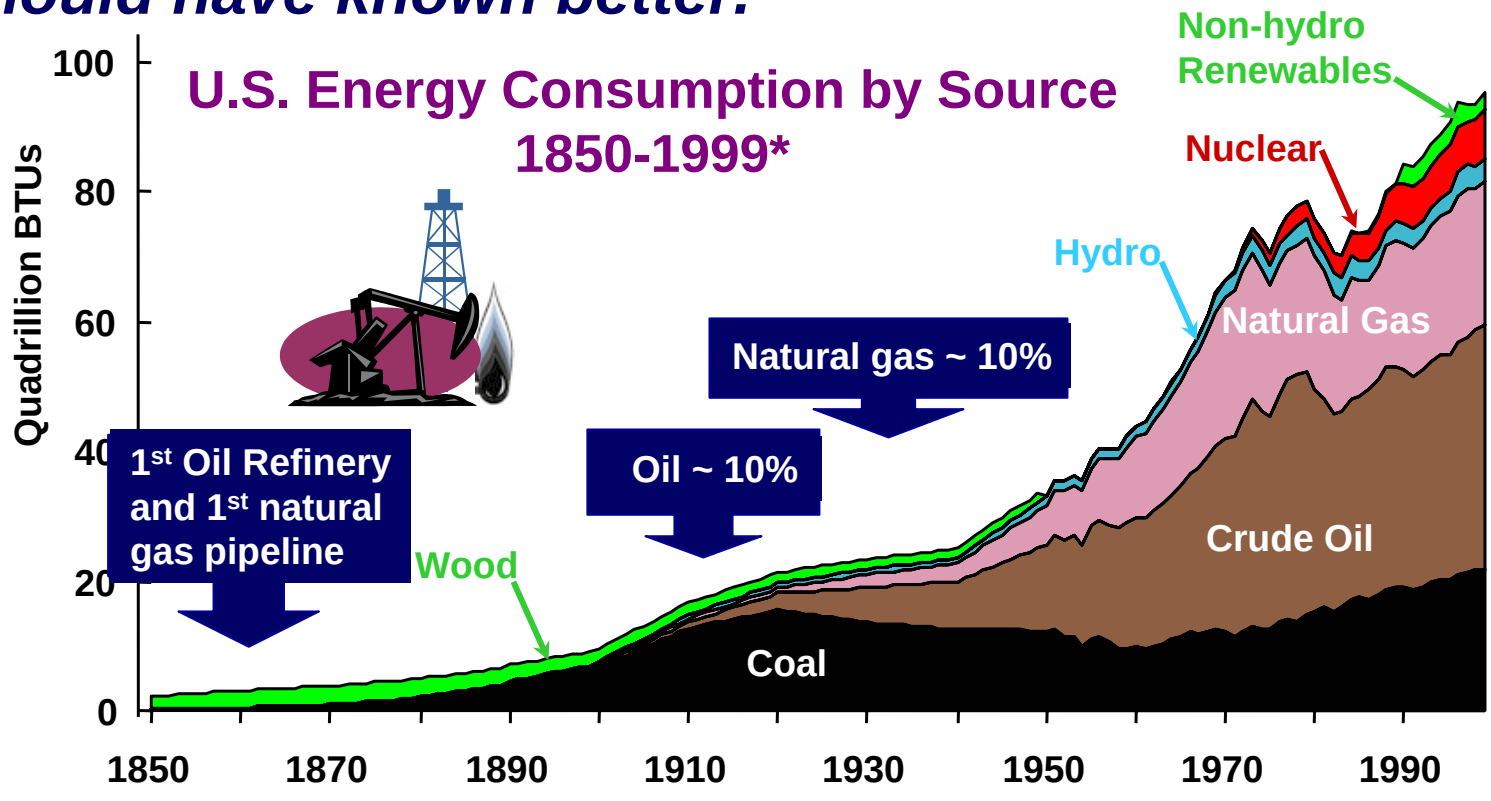


Source: DOE EIA Annual Energy Review 2001
http://www.eia.doe.gov/emeu/aer/contents.html

What happened to the promise of renewables in the U.S.?



Expectations for renewables were optimistic – We should have known better.



*Source: 1850-1949, Energy Perspectives: A Presentation of Major Energy and Energy-Related Data, U.S. Department of the Interior, 1975; 1950-1996, Annual Energy Review 1996, Table 1.3. Note: Between 1950 and 1990, there was no reporting of non-utility use of renewables. 1997-1999, Annual Energy Review 1999, Table F1b.

It typically has taken many decades for an energy source to become a substantial part of our energy mix. But some energy market trends are improving the prospects for renewables.

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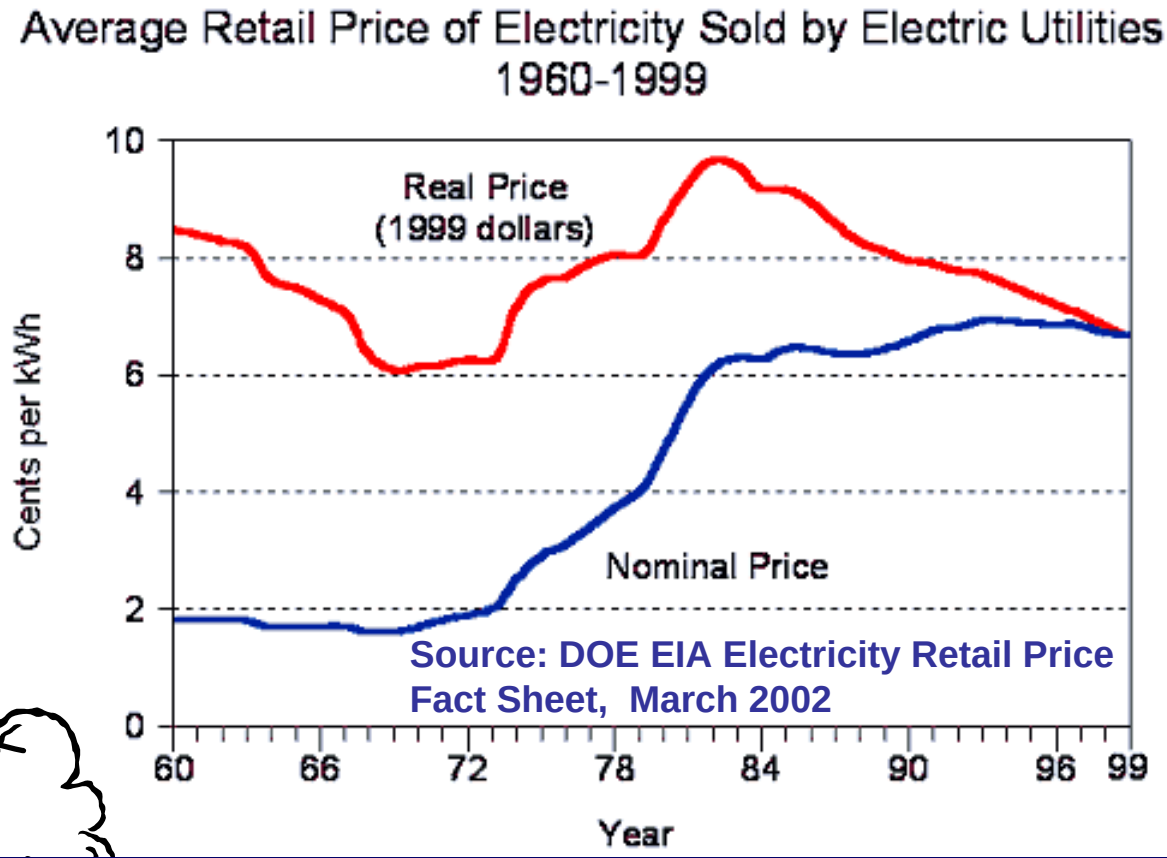
In real terms, electricity prices have declined in the last two decades.



Today, grid-connected renewables struggle to compete with bulk power produced by fossil-fueled central station generators at relatively low commodity wholesale prices. But, because of some consumer trends, renewables might not need to compete as a commodity.

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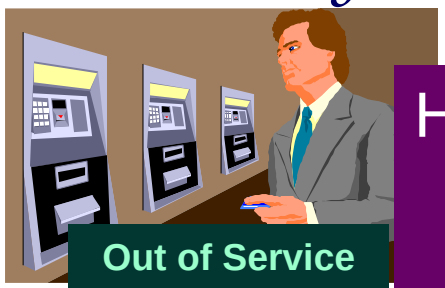
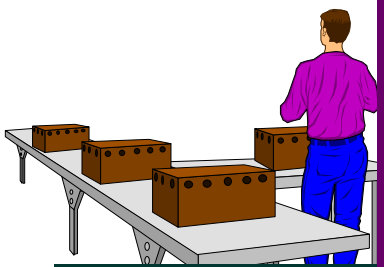
*"It is not the cost of electricity that drives our decision-making process, rather it is the cost of NOT having electricity."**



Out of Service



Production Line Down

High-Value Situations

- Reliability
- Power Quality

****

Stock Brokerage = $5M - $7M/hr
Credit Card Srvcs = $2M - $3M/hr
Phone 800 # Srvcs = $150K - $225K/hr
Nationwide = Over $120 B in losses per year

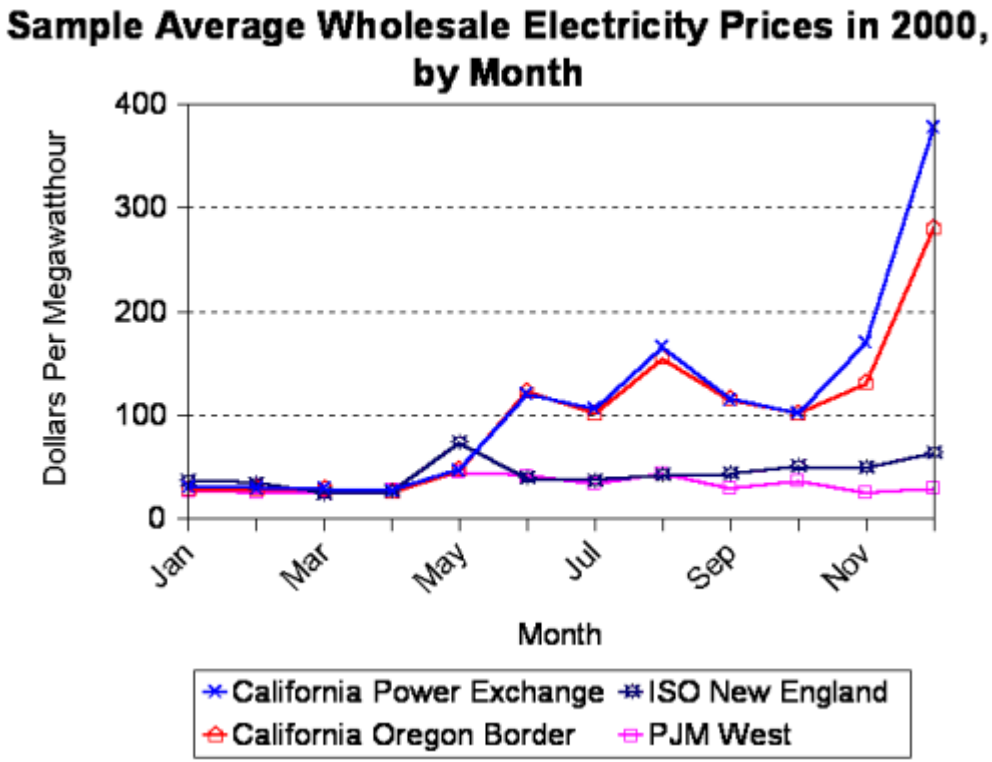
Remote & Village Power

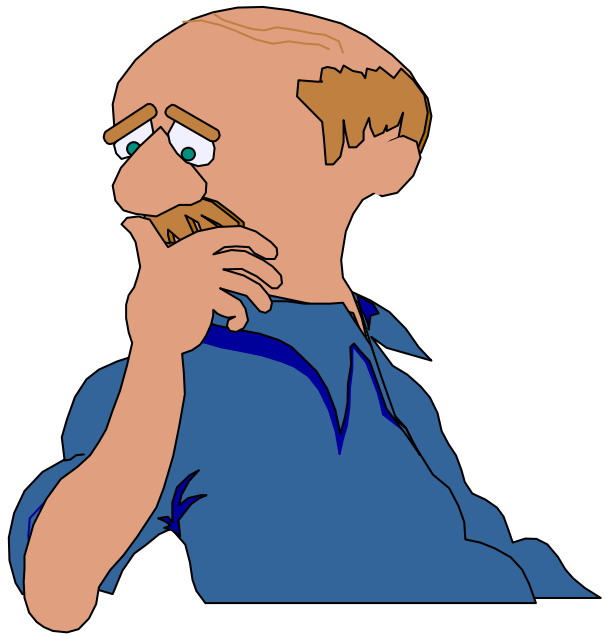
2-3 billion people w/o adequate electricity

The costs of no electricity can be quite high to human and financial health.

*Jeff Byron, Energy Director, Oracle Corp., at the E Source Distributed Energy Summit 2000

U.S. energy consumers experiencing increased energy price volatility.





What premium will consumers pay for stable prices or bills?

Source: EIA, Wholesale Competition in the U.S. Electric Power Industry Fact Sheet

Growing numbers of energy consumers are buying "green power" at premium prices, 2.54/kWh (median).

How is green power bought:

- **Green Pricing**
  - To date, more than 300 investor-owned and municipal utilities, and cooperatives, in 30 states have implemented or announced a green pricing option.
- **Green Power Marketing**
  - Competitive marketers have offered green power to retail or wholesale customers in CA, Il, MD/DC, NJ, NY, PA, TX, VA, and several New England states.
- **Green Energy Certificates**
  - Currently, about a dozen organizations market green energy certificates nationally.

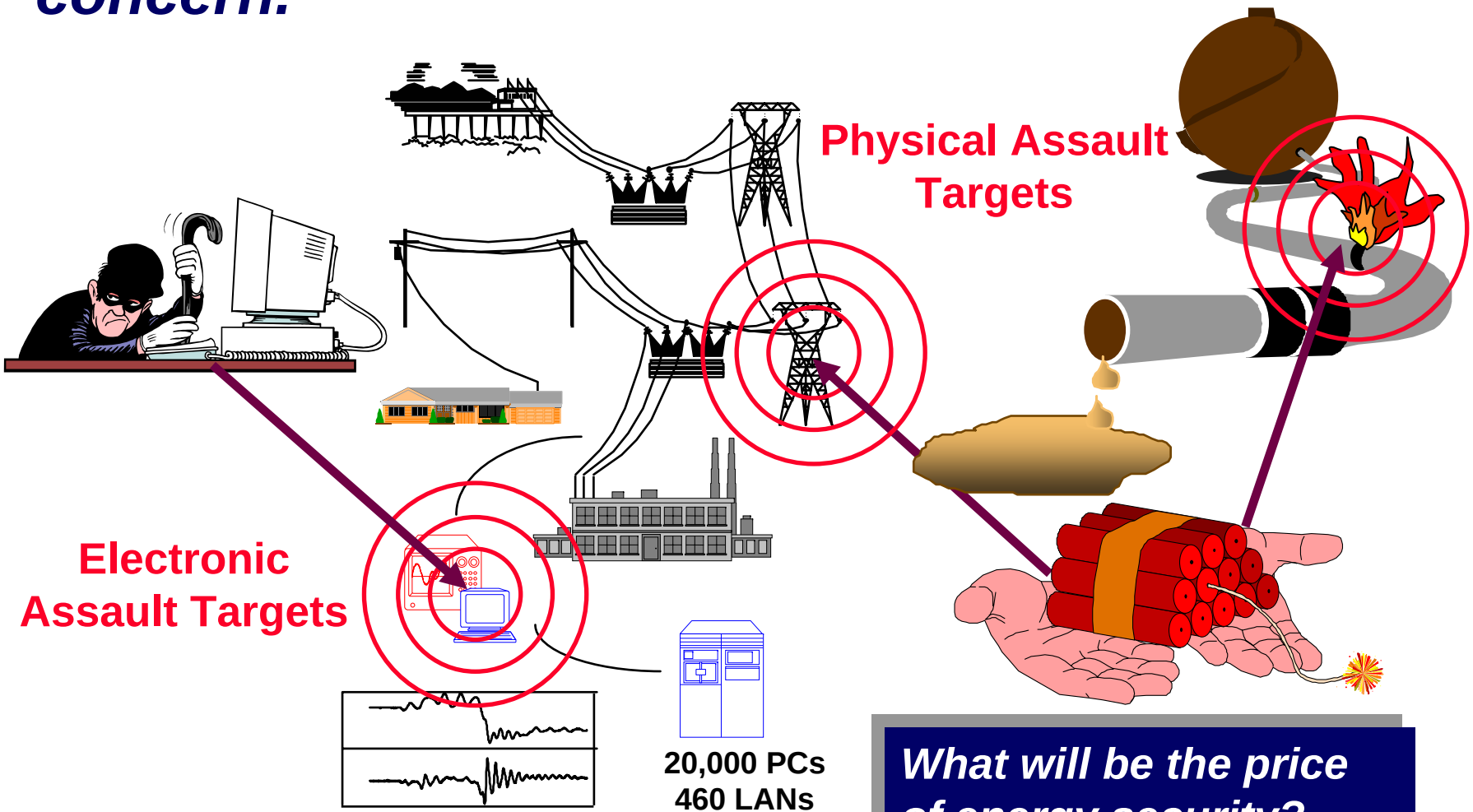
Who is buying green power?

- Households
- Small, medium, and large businesses
- Business "chains"
- Business organizations
- Health organizations
- Faith-based groups
- Colleges and universities
- State and municipal governments
- Federal agencies

http://www.eren.doe.gov/greenpower/home.shtml

Why: Civic pride, education, environment, fuel prices, image, independence, reliability, remote power, taxes, etc.

Energy security recently has become a larger concern.



A modern energy consumer is emerging who is...

- **Encountering global competition, so energy cost matters,**

But, is becoming increasingly…

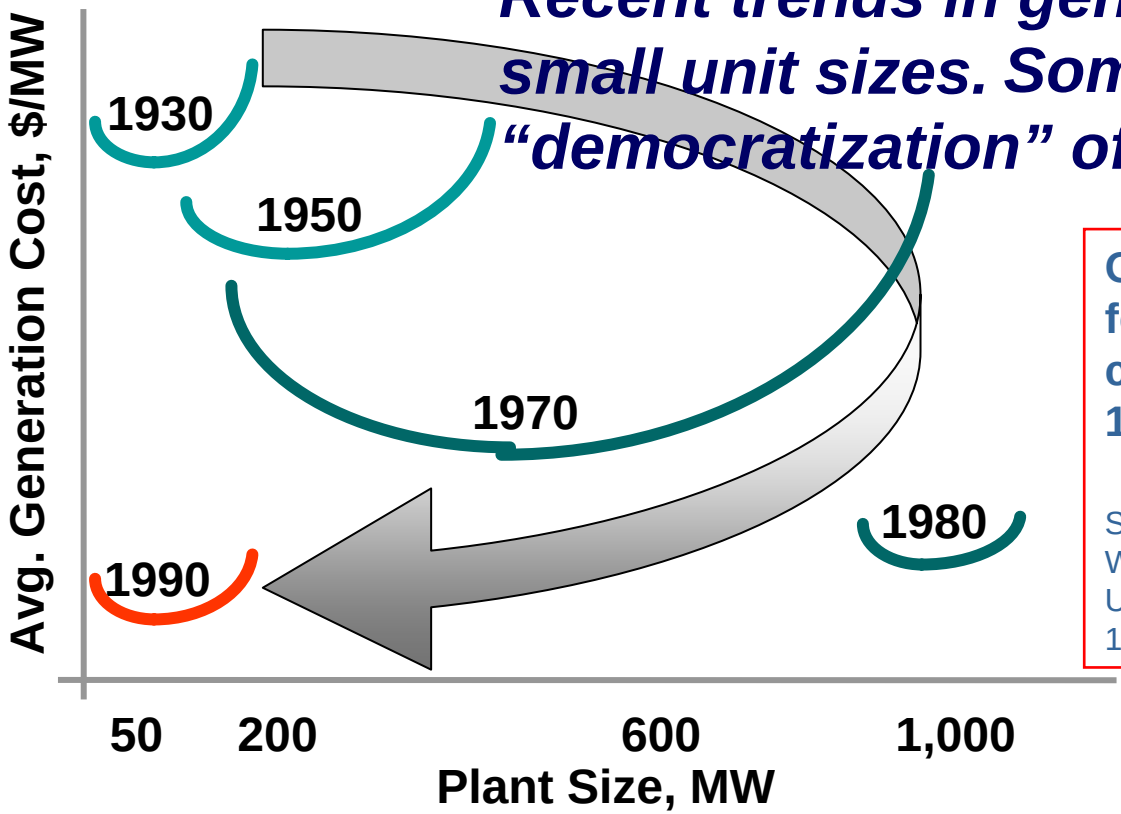
- **Digitized and round-the-clock, requiring greater energy reliability**
- **Concerned about energy price volatility**
- **Caring about health and environment issues**
- **Worried about energy security…**

These factors will:

- ***Complicate consumer decision-making, and***
- ***Create demands for new customized, high-value energy products and services, which will command premiums, where lowest cost per KWh isn't everything.***

How will these needs be met?

Recent trends in generation costs favor small unit sizes. Sometimes called the "democratization" of power because…

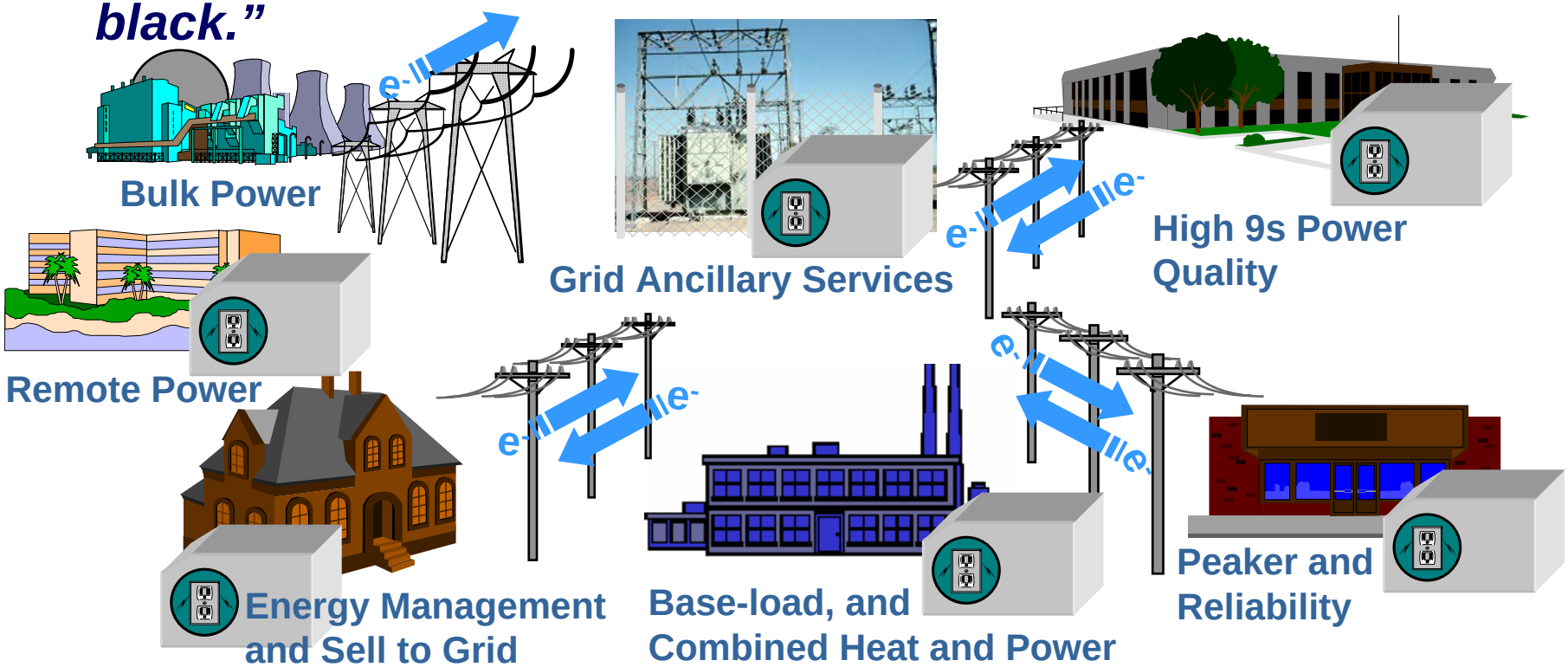


Optimal generation plant size for a single plant based on cost per megawatt [MW], 1930-1990

Source: Charles E. Bayless, "Less is More: Why Gas Turbines Will Transform Electric Utilities." Public Utilities Fortnightly 12/1/94

… now, power plant financing and siting, typically done by large companies, like public utilities, are more feasible for smaller companies and energy consumers, enabling a new generation market paradigm: **Distributed Generation**

Today's central station power production & delivery system is a "one-way street" for electricity, where "one size fits all," and "comes in any color as long as it's black."

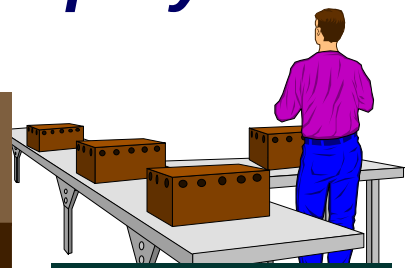


Distributed generation is enabling new emerging energy products/services customized to meet many energy consumer high-value needs not readily met by the traditional power grid.

Today, distributed generation is being deployed in a few high-value niche markets.

Remote & Village Power

- Basic Electric Service
- Improved Health
- Communications



High-Value Situations

- Reliability/Power Quality
- Peak Shaving
- High Energy Efficiency
- Independence

But these applications tap very little of the "full-value" potential of distributed generation.

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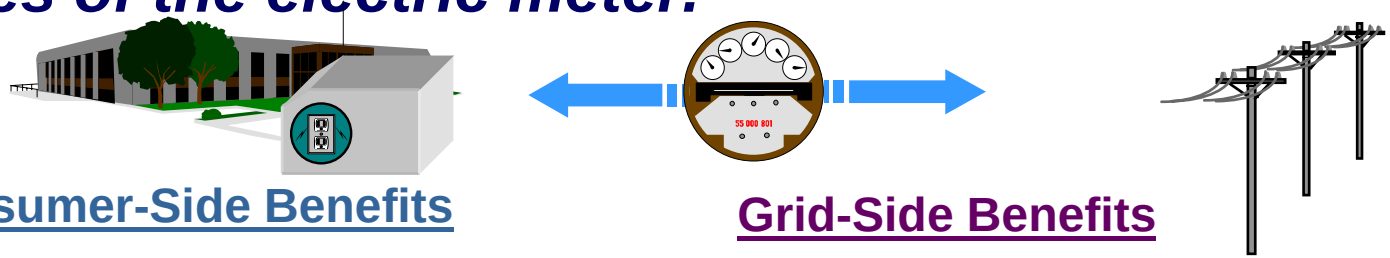
"Full-value" deployment of distributed generation would maximize the many potential benefits and values on both sides of the electric meter.



Consumer-Side Benefits

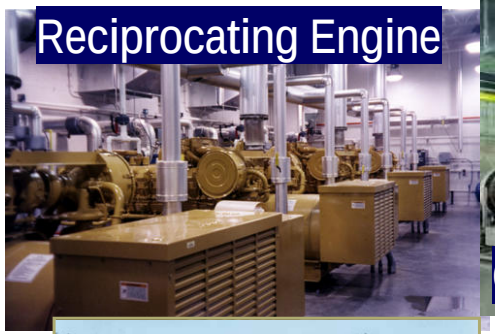
- Lower cost electricity
- Greater price volatility protection
- Greater security, reliability and power quality
- Energy and demand load management
- Cogeneration capability
- Cleaner energy

Grid-Side Benefits

- Reduced electric line loss
- Reduced upstream congestion
- Grid investment deferment
- Improved grid asset utilization
- Improved grid reliability and security
- Ancillary services, such as voltage support or stability, VARs, contingency reserves, and black start capability

The closer markets grow toward "full-value" deployment, the greater the contributions distributed generation could make.

Distributed generation prime movers don't have to be small, but most are, and being close to load centers, they must be clean.

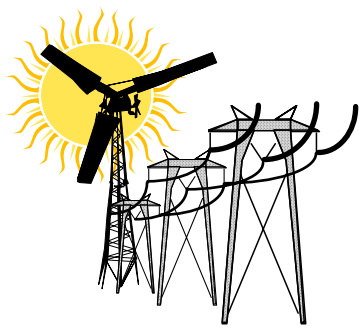


Accordingly, natural gas and renewables are prime candidate "fuels' for distributed generation.

What is the U.S. market competitiveness of natural gas and renewable electricity generation?

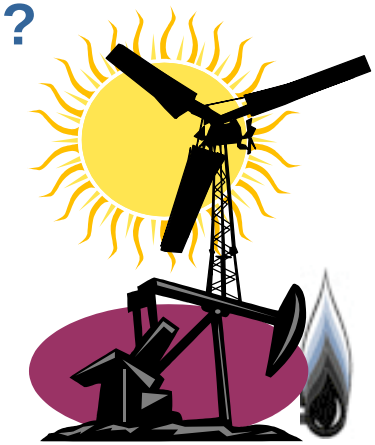
Natural gas is expected to produce the lowest cost, relatively clean and reliable electricity in the foreseeable future, but uncertain short and long term supply with price volatility create competitive weaknesses. In long run, it might face environmental constraints, and most likely increasingly higher prices.

Renewables often suffer from intermittency, relatively high costs, and weak market distribution channels, but offer relatively clean, secure, price-stable electricity, and continuously falling costs.



Can natural gas and renewables work together to:

- **Compensate for the intermittency of renewables?**
- **Bring a more "green" and "sustainable" image/reality to natural gas generation?**
- **Provide robust market distribution channels for renewables?**
- **Provide risk mitigation against natural gas price volatility?**
- **Soften the impacts of high first costs for renewables?**
- **Reduce investment burden for expanded natural gas supply and delivery infrastructure, and need for imports?**



… Offer the energy industries new hybrid energy products and services for the modern energy consumer that are superior to either alone?

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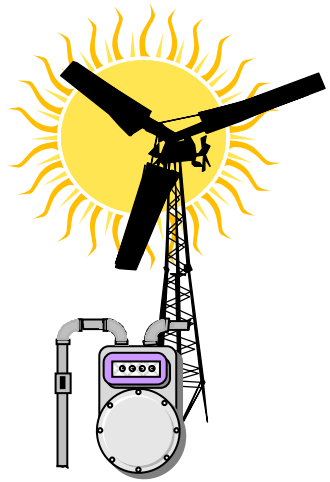
Renewable/fossil hybrids are being deployed now in emerging economies around the world.

Hybrids, like this wind/diesel system, used for village power, have been around for some time…

But can hybrids be moved from the villages to the cities?

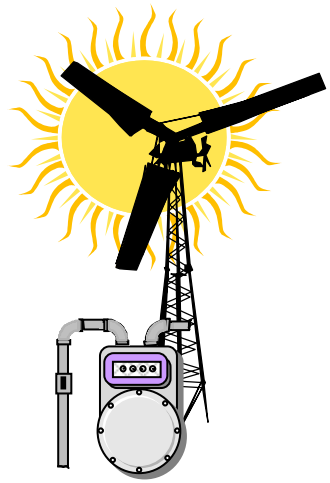
More short term understanding and long term assessments of natural gas and renewable hybrids are needed to answer these questions:

- **Which combinations of natural gas and renewable technologies work best for which application?**
- **Which combinations of natural gas and renewable technologies enhance weaknesses?**
- **Do hybrids face any special technical, policy or market barriers?**
- **In which markets are hybrids the most competitive?**



The high-value markets of distributed generation would seem to provide a good place to start for renewable/natural gas hybrids.

The future of natural gas is important to the future of renewables in the U.S.:



- **As the fuel of choice for new electric generation, natural gas will likely set the wholesale commodities benchmark price for new renewable electric generators, such as wind farms, to beat.**
- **The availability and price of natural gas will likely "make or break" distributed generation as a significant market opportunity for renewable distributed generation.**
- **Natural gas/renewable hybrids show potential for yielding superior generation technologies by combining the advantages of both energy resources.**
- **Natural gas is the likely bridging fuel for establishing a viable transition hydrogen energy economy, as a precursor to a sustainable hydrogen energy economy fueled, for example, by renewables.**

The End

A few questions before I rush to catch a plane?