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**Natural Gas as a  
Chemical Industry Fuel  
and Feedstock:  
Past, Present, Future  
(and Far Future)**

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# Fuel and Feedstock

- Natural gas is the fuel that powers most (but not quite all) US chemical and refining processes
- Natural gas methane is the feedstock for hydrogen production (for hydrocracking, hydrodesulfurization, and ammonia) and for syngas (for methanol, and its derivatives e.g. MTBE, formaldehyde, and acetic acid)
- Natural gas condensate (ethane and propane) is an advantaged raw material via ethylene and propylene to much of the organic chemicals industry (compared to crude-oil-derived naphtha)

# Feedstock Pricing Considerations

## ■ Crude Oil

- Global supply and demand
- Established oceanic transportation network
- Productive capacity and risk premium
- Impact of speculation

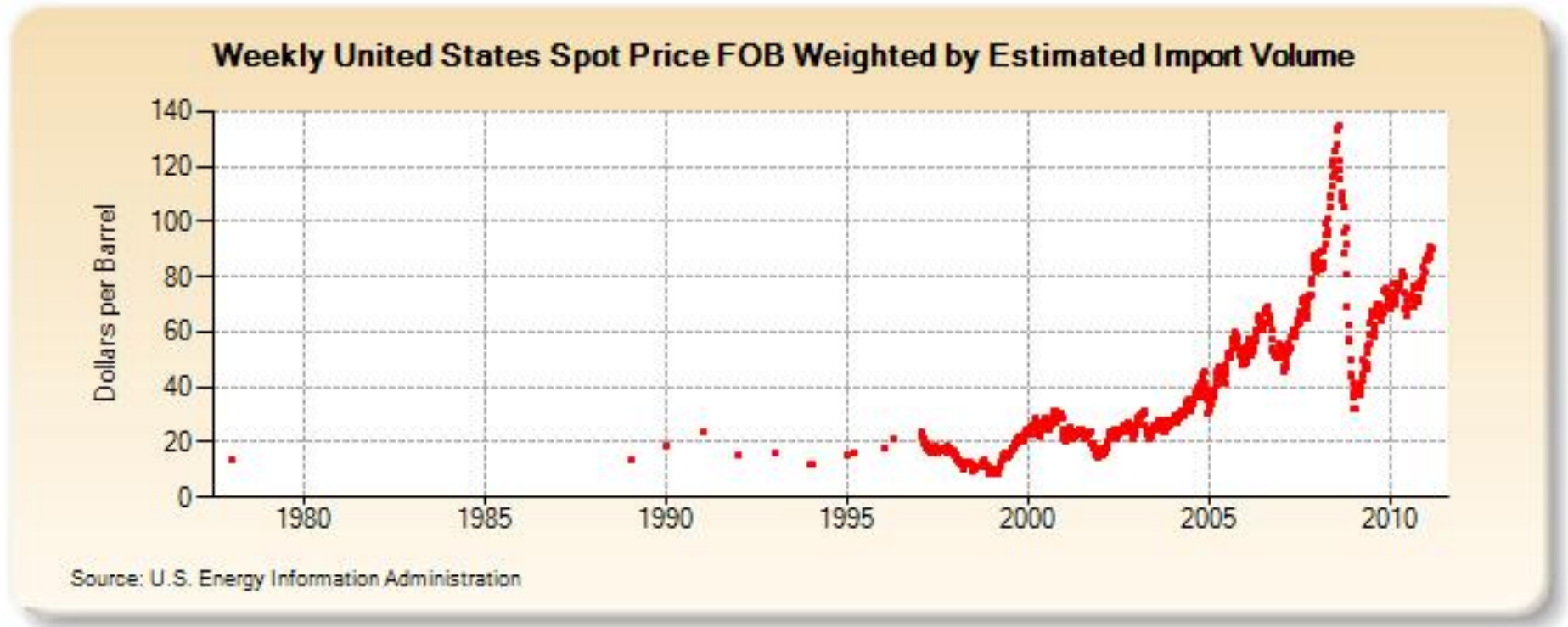
## ■ Natural Gas

- Local supply and demand
- Transportation limitations
- Limited US conventional supply
- New shale gas production technology

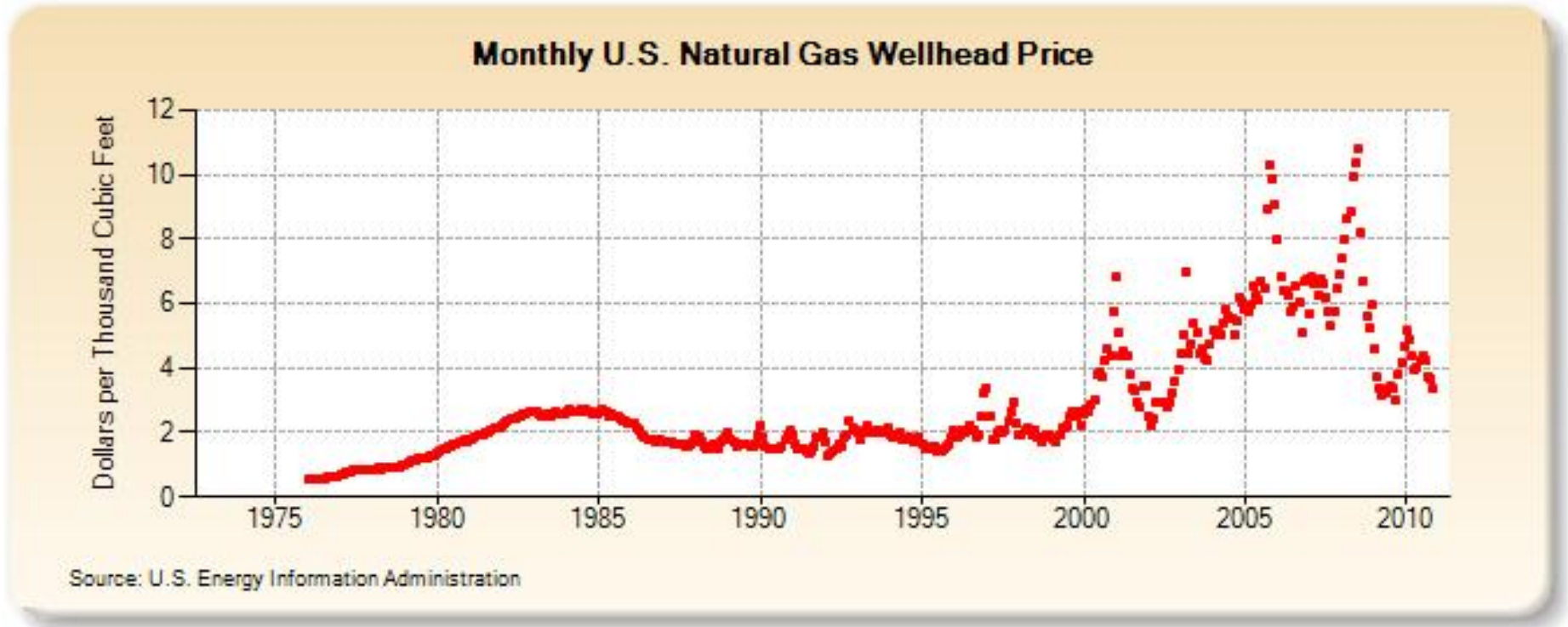
## ■ Coal

- Excess productive capacity
- Inexpensive extraction technologies
- Environmental impact issues

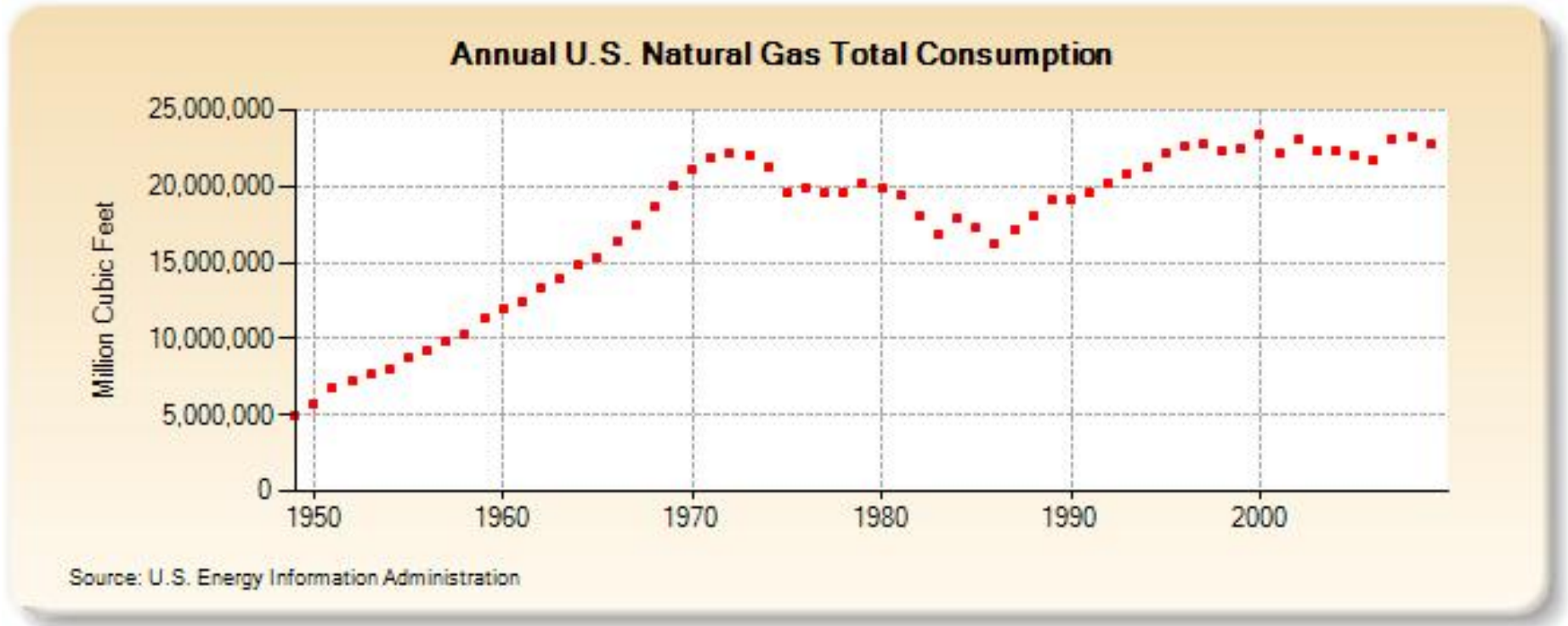
# US Crude Oil Price



# US Natural Gas Price



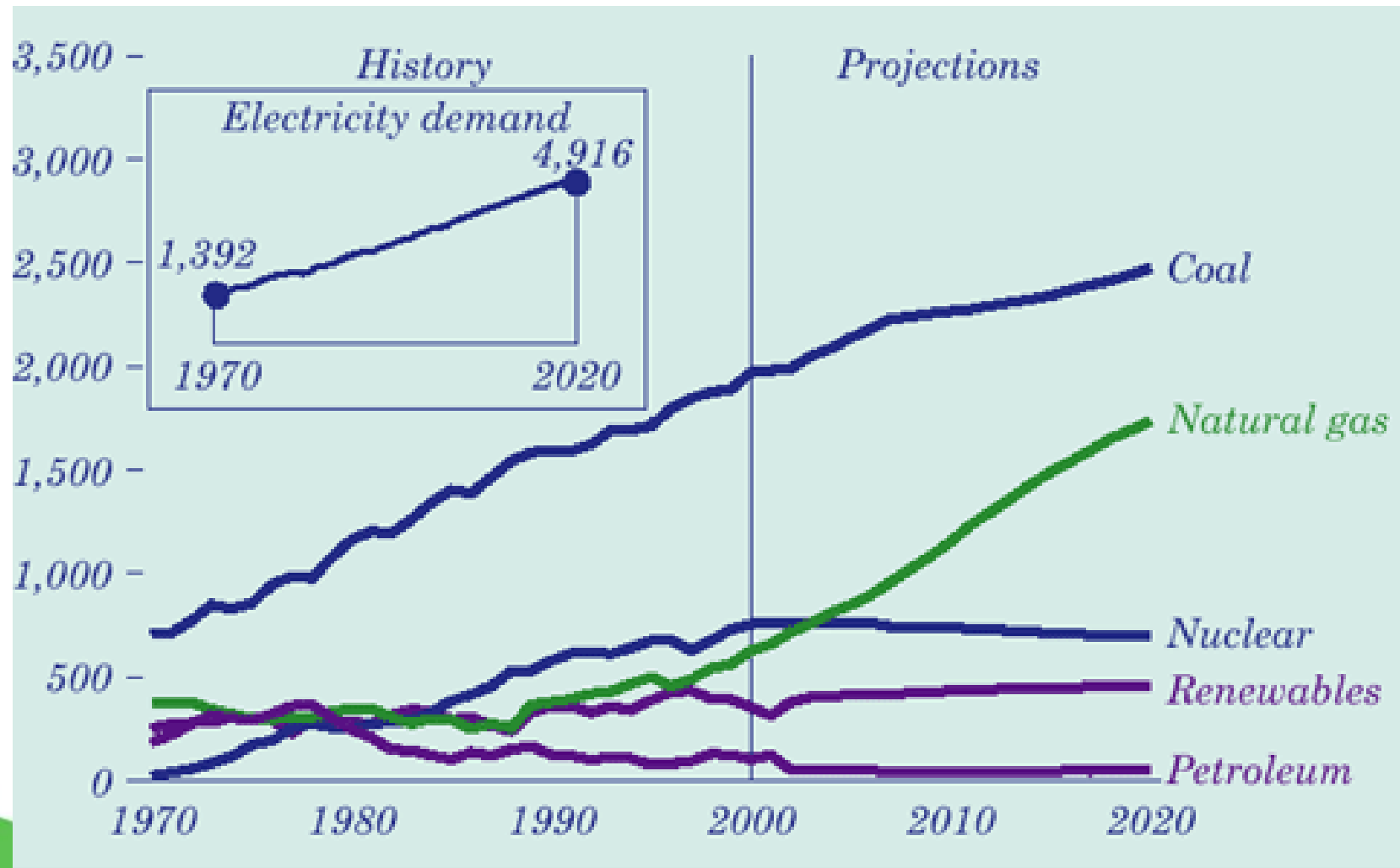
# US Natural Gas Consumption



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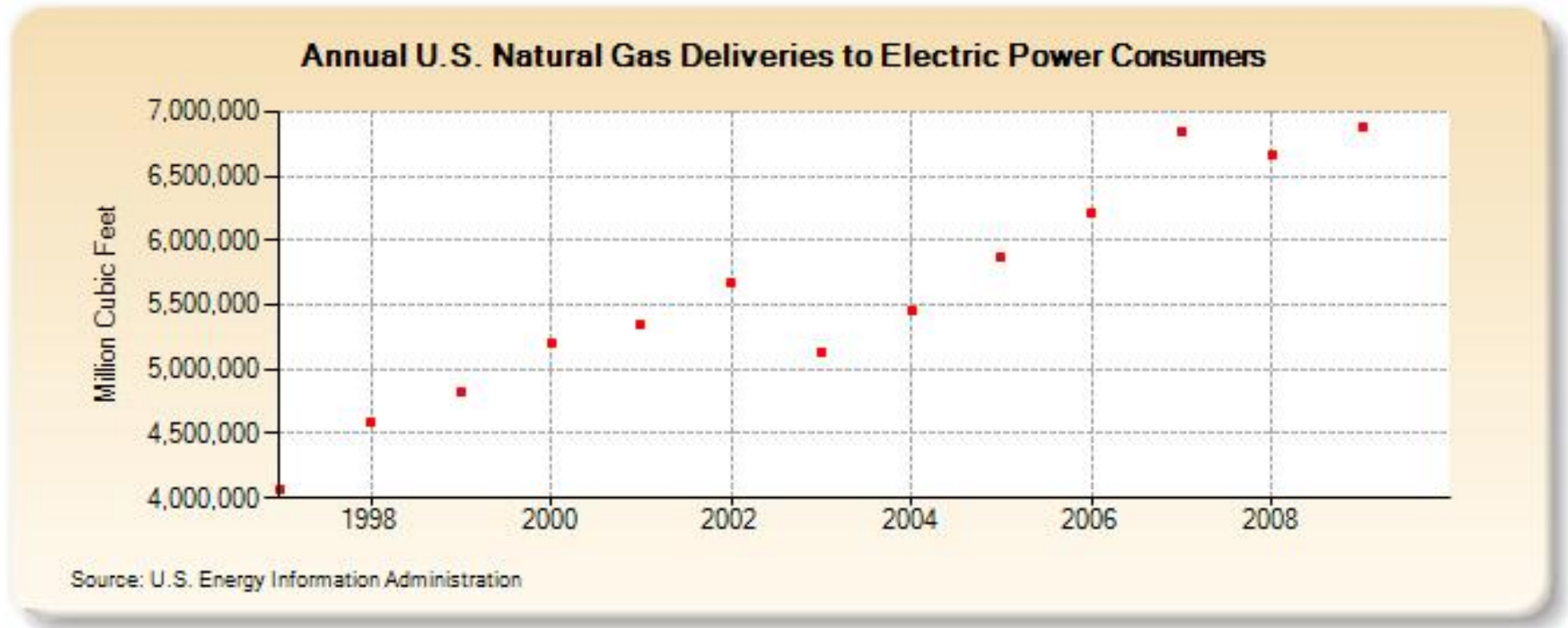
**Recent Past  
(Last Decade)**

# US Electricity Production by Fuel

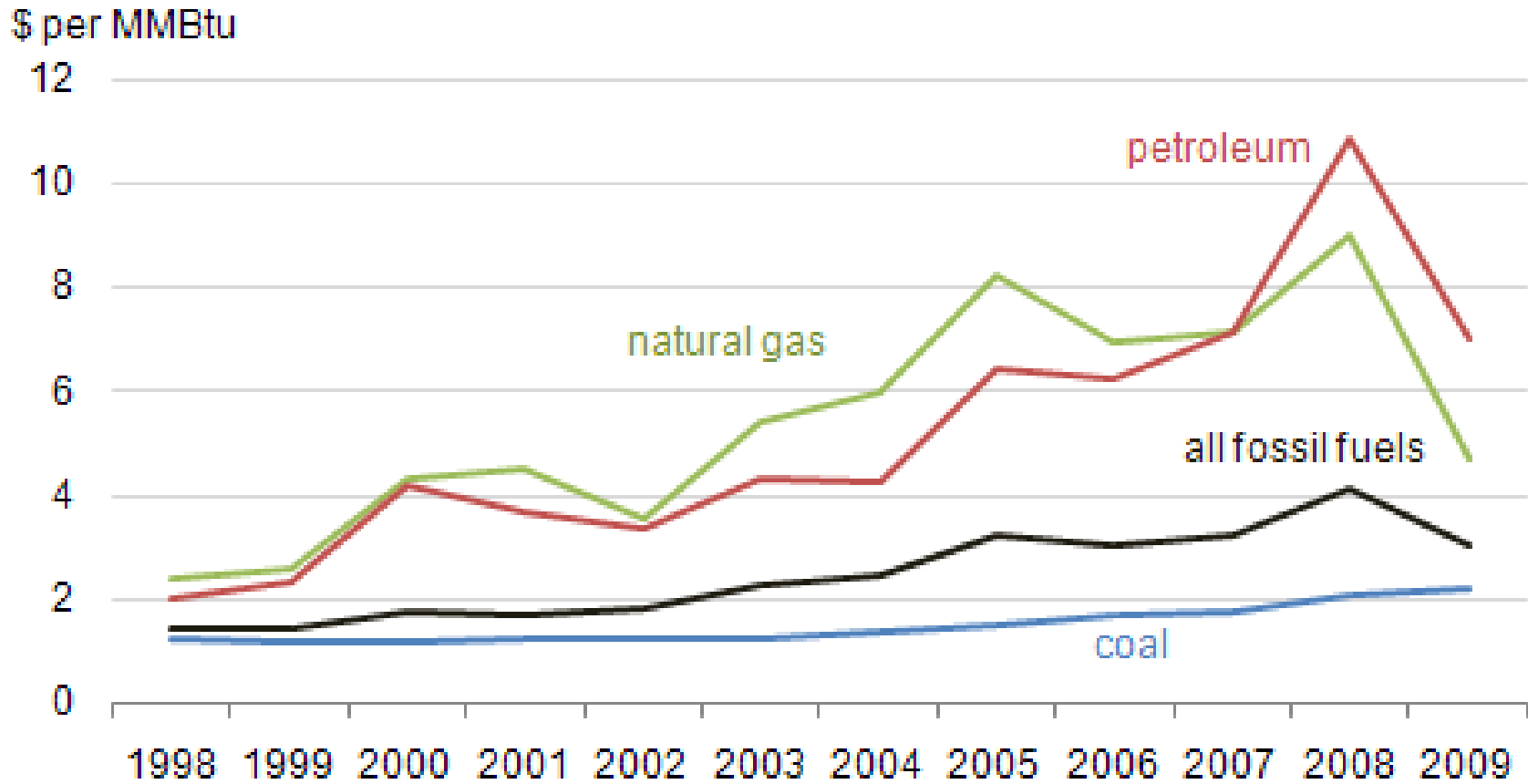




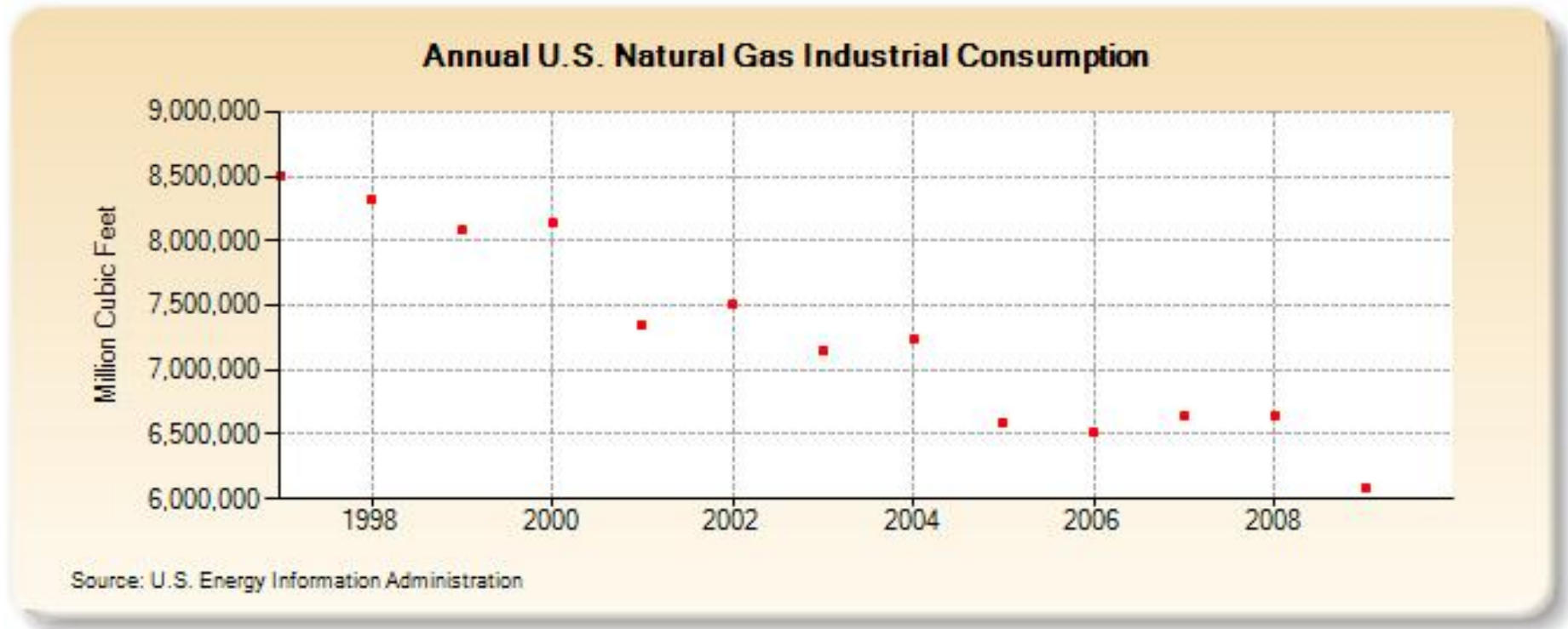
# Power Plant Natural Gas Consumption



# US Fossil Fuel Price



# Industrial Natural Gas Consumption



# Impacts of Increasing Natural Gas Prices

- Chemicals from methane
  - Methanol production moves offshore to sources of stranded gas
  - MTBE abandoned as gasoline oxygenate
  - Ammonia moves to Canada
  - Hydrogen becomes expensive (and low-sulfur diesel at the pump becomes more expensive than regular gasoline)
- Chemicals from condensate and naphtha
  - Condensate price rises with natural gas (for awhile)
  - Ethylene price spikes
  - Propylene price finally rises higher than ethylene

# Eastman Response

- Shut down older cracker capacity
- Abandon some ethylene derivatives (polyethylene) and seek C<sub>1</sub> routes to others (ethylene glycol, acetaldehyde) as previously done for acetic acid/anhydride)
- Abandon polypropylene
- Seek C<sub>1</sub> routes to propylene (MTP) for existing oxo derivatives and other intermediates currently made from propylene (acrylics, methacrylics, acetone, etc)
- Developed process for the large-scale gasification of petcoke, lignite, or coal as source of syngas for C<sub>1</sub> chemistries and refinery hydrogen

# Other Responses

- Flight to off-shore production (to sources of stranded methane and condensate – Persian Gulf)
- Bio-based feedstocks (ethylene from sugar-based bioethanol dehydration - Brazil)
- Feedstocks from coal gasification and liquefaction (China)
- Calls for increased US LNG infrastructure
- Development of directional and horizontal drilling and hydraulic fracturing technologies (Shale Gas)

# Feedstock Substitution Challenges

## Capital

- Extra steps required to employ alternate feedstocks are often very capital-intensive
  - Solids (coal and biomass) handling
  - Low bulk density solids transportation
  - Pyrolysis
  - Gasification
  - Air separation
  - Fischer-Tropsch reaction
  - Direct liquefaction
- Capital costs follow average energy prices (after a lag)

# Feedstock Substitution Challenges

## Energy

- As methane, condensate, and light crude become depleted, feedstocks for both transportation fuels and chemicals will become heavier and higher oxidation state
- Hydrogen will be required to reduce these feedstocks
  - If derived as at present from steam reforming, will result in significant additional carbon dioxide production
  - Unless derived from solar or nuclear water-splitting
- Processes will become net endothermic
- Reaction energy and separation/purification energy both to be supplied from utilities

**Process industries become much more energy-intensive**

**Greater role for heat integration, multi-effect operation, low-energy separations, process intensification technologies, etc.**

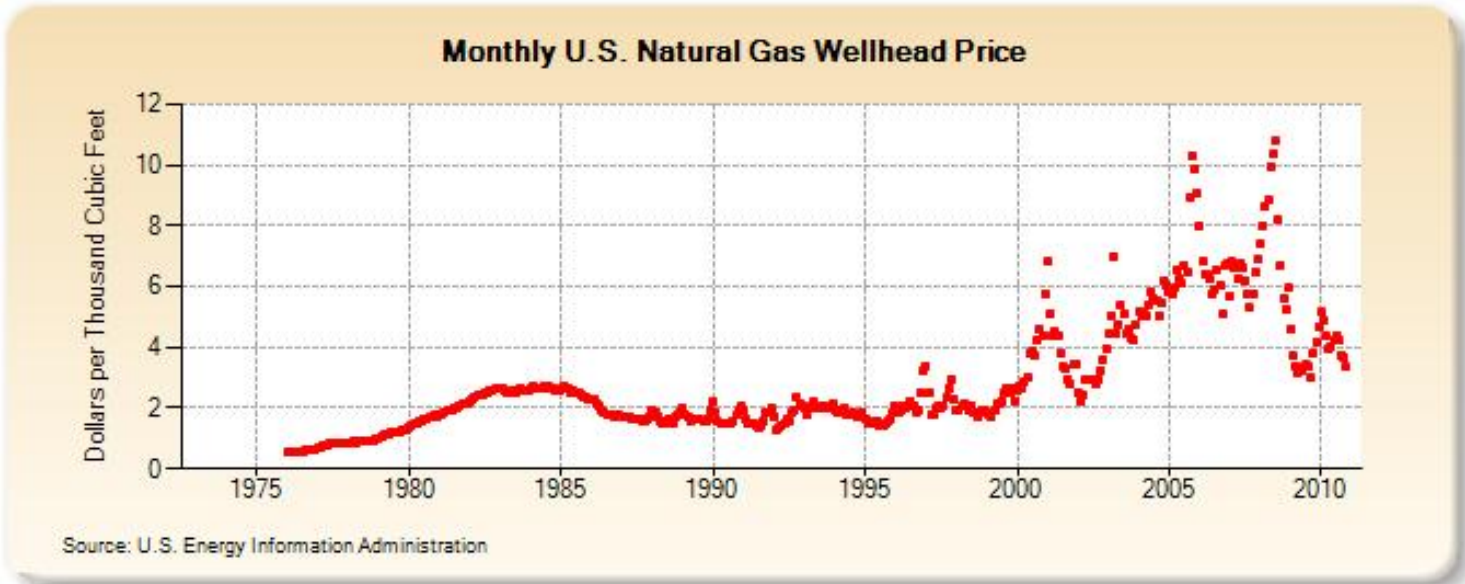
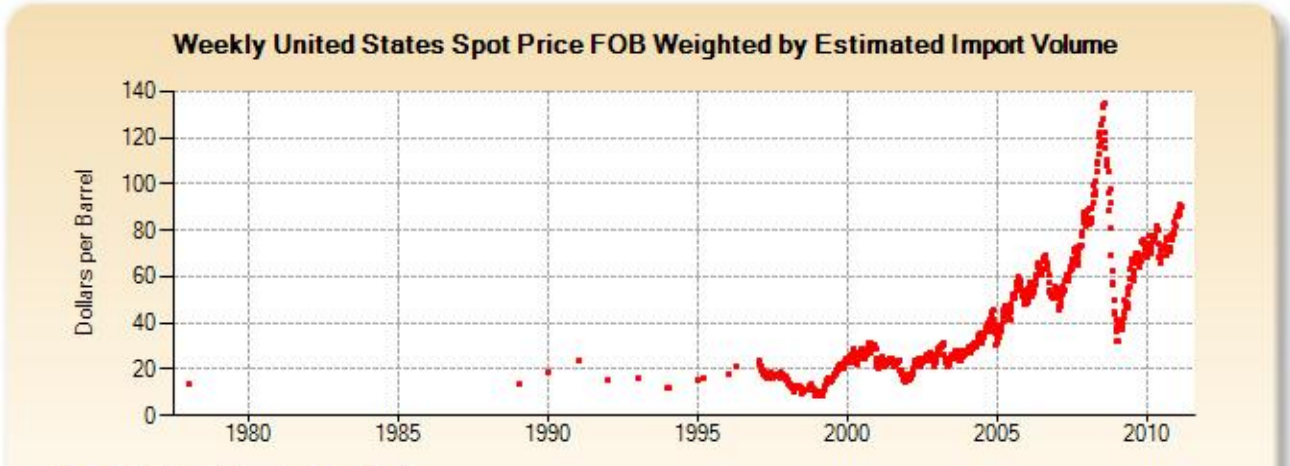


The image features a large, abstract geometric shape on the left side, composed of several overlapping planes in various shades of green and grey. The shape is oriented diagonally, with its top-left corner pointing towards the top-left of the frame. The word "EASTMAN" is printed in a bold, red, sans-serif font in the upper right quadrant of the image. The background is a plain, light grey color.

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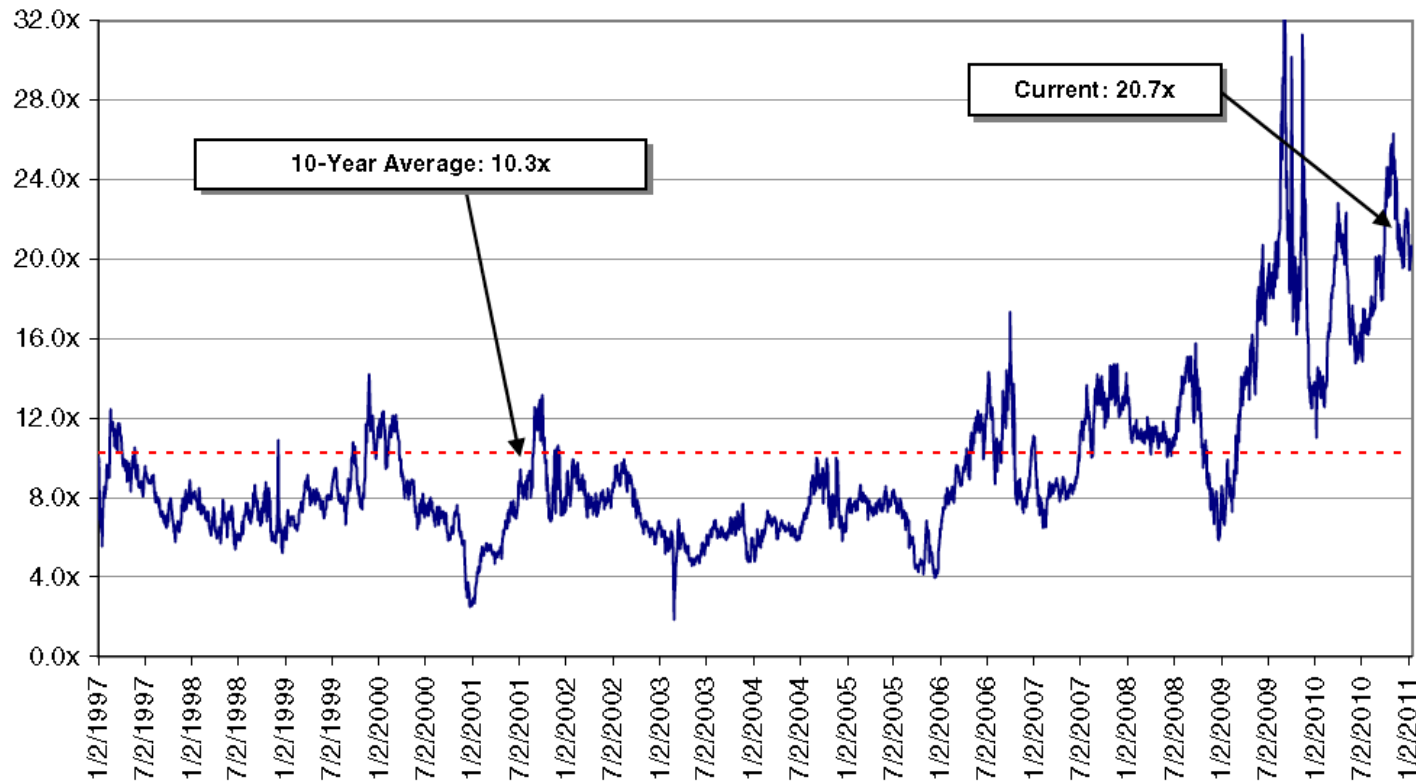
**Present  
(Last Few Years)**

# Crude Oil and Natural Gas Prices



Source: U.S. Energy Information Administration

# Ratio of Crude Oil Price (\$/bbl) to Natural Gas Price (\$/MBTU)



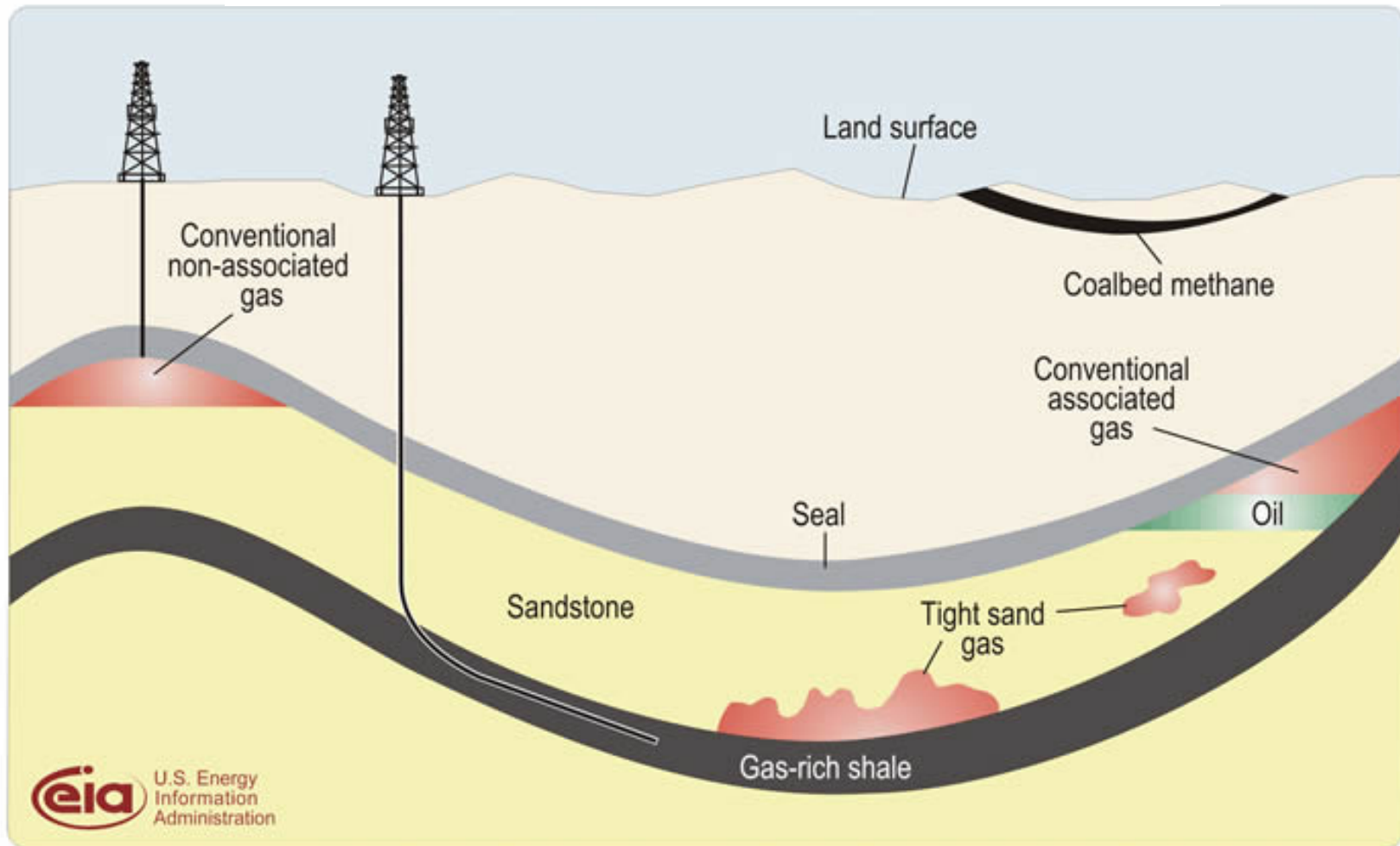
Source: Bloomberg

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# Shale Gas

- Unconventional natural gas (as is coalbed methane, tight sandstone gas, and methane hydrates)
- Found in relatively thin shale formations of very low permeability
- Economic production enabled by two technological innovations:
  - Directional drilling
  - Hydraulic fracturing
- Technology and field development encouraged by high natural gas prices

# Geology of Natural Gas Resources



# US Shale Gas Plays



# Shale Gas Impact

- Shale gas now reclassified as conventional gas
- US conventional gas reserves doubled
- Price of natural gas halved
  
- Accelerate electric power fuel switching from coal to natural gas
- Killed proposed Eastman gasification project
- Restored US production of methanol and ammonia
- Condensate crackers restarted
- Restored advantaged US feedstock position for many organic chemicals

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**Near Future**



# What is Likely to Happen

- Natural gas replacement for coal as the primary early carbon management technique (source reduction)
- Increased deployment of highly efficient Natural Gas Combined Cycle plants for electricity production and chemical plant cogeneration
- Increased US production and export of chemicals decreasing the trade deficit
- For many intermediates, interesting competition between  $C_1$  (methane) and  $C_2$  (ethane) feedstocks resulting from advances in catalysis, energy efficiency, and process design optimization

# For How Long?

- Depends on how long shale gas remains plentiful and whether it is wet or dry
- If plentiful and wet, then the existing US ethane-based chemical industry infrastructure will remain world-competitive
- If plentiful but dry, new C<sub>1</sub> chemistries will emerge, but based on methane steam reforming syngas
- If oil shale is developed using directional drilling and hydraulic fracturing gas shale technology, the role for naphtha cracking infrastructure may be extended

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**Far Future**

# What could go Wrong?

- Electricity power plant fuel switching could dominate the rate of shale gas development
- Amount of gas producible from shale formations might be less than predicted
- Additional shale formations might be more expensive to produce than first experiences suggest
- Some shale formations might be geologically inappropriate for development (e.g. shallow formations near groundwater supplies)
- Production technologies (especially hydraulic fracturing) might have unintended environmental consequences leading to political or regulatory restrictions

# Then What?

- If a great deal of infrastructure is put in place to displace coal by natural gas for electricity production and for institutional and industrial boilers and to otherwise expand the use of methane for chemical production,
- But natural gas becomes less economically advantaged compared to coal...
  
- Then coal gasification may once again return,
- But if so, most likely only to make Synthetic Natural Gas (SNG)!
  - With the corresponding carbon dioxide captured and sequestered

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**Thank You**