The Current View of the US Energy Strategy and How Fusion May Contribute

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Socio-Economic Aspects of Fusion Power
At UCSD, San Diego, CA
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Purpose

- **Convey an understanding of the US forecasts of energy supply, demand, and prices through 2025**
- **Consider national issues related to energy production and usage**
- **Examine how fusion may contribute to easing energy supply and reduce CO_2 levels**

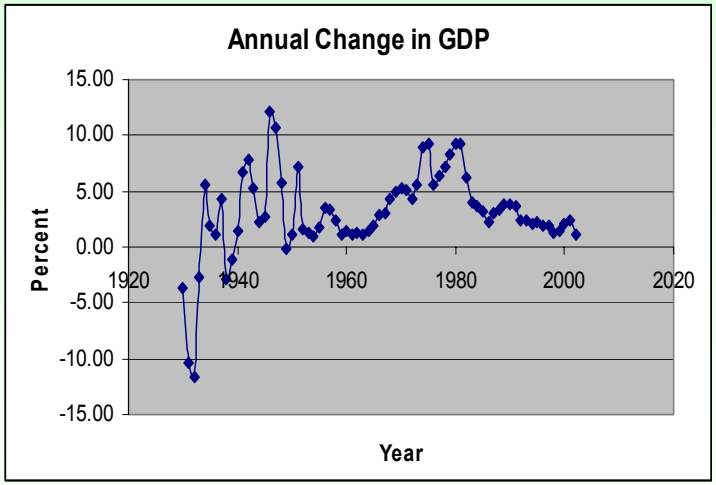
Data Source

The historical and projected energy data was obtained from "The Annual Energy Outlook 2003". This was prepared and published in January 2003 by the Energy Information Administration (EIA), Office of Integrated Analysis and Forecasting, DOE, and is based on the National Energy Modeling System.

There is a companion publication, "International Energy Outlook - 2003" that was not reviewed that would offer a more global perspective.

Underlying Influencing Factors

- Availability of energy resources
- Developments in US electricity markets
- Technology improvements
- Impact of economic growth
  - The economic growth, as measured by Gross Domestic Product (GDP), is projected to be 3.0 % per year to 2025 for base case (inflation adjusted).

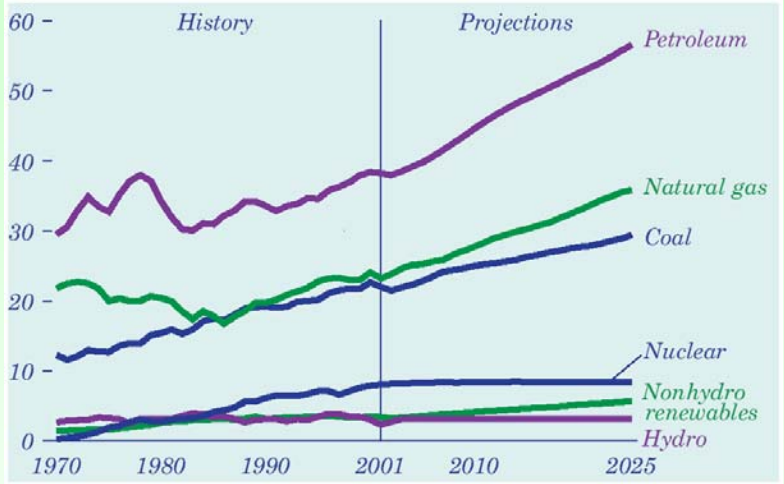


All of these are important to the introduction of fusion

Energy Consumption Will Continue to Increase

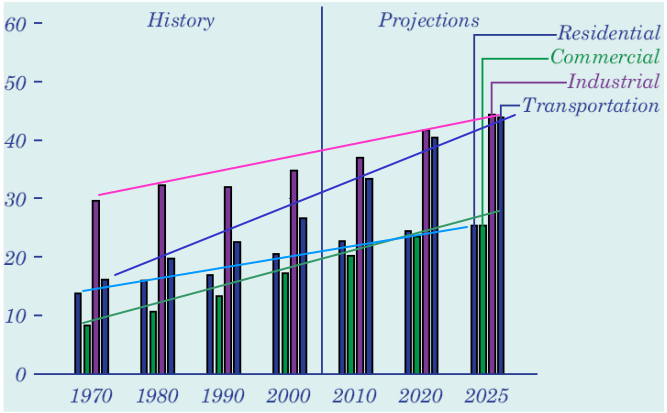
- **Total energy demand is expected to grow at 1.8%/y with petroleum, natural gas, and coal showing steady consumption increases**
  - **Nuclear, non-hydro renewables, and hydro remain nearly constant**

Figure 2. Energy consumption by fuel, 1970-2025 (quadrillion Btu)



- **The large user sectors are transportation and industrial with commercial and residential being smaller**
  - **Transportation and commercial are expected to increase faster than others**

Figure 41. Primary energy consumption by sector, 1970-2025 (quadrillion Btu)



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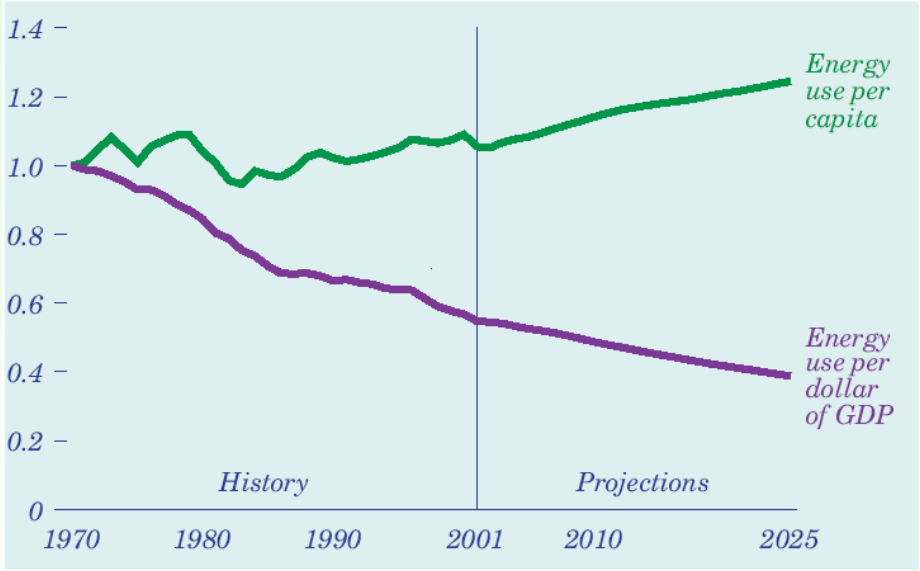
We Use More Energy But It Costs Us Less of GDP

Figure 3. Energy use per capita and per dollar of gross domestic product, 1970-2025 (index, 1970 = 1)



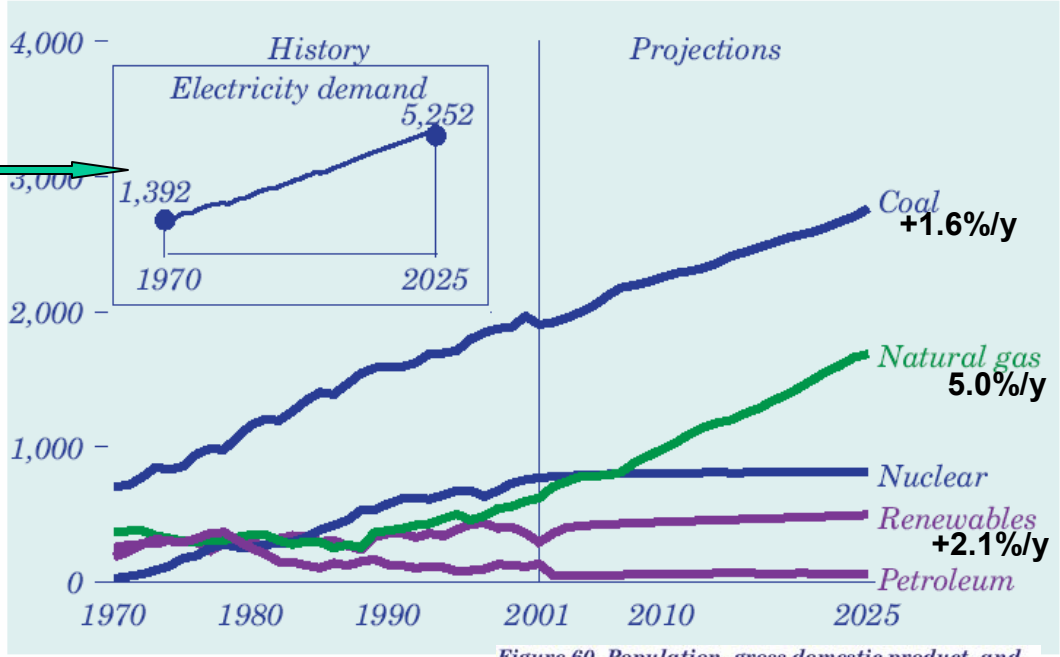
- **The trend for increased energy use per capita will continue, while cost per dollar of GDP will continue to decrease due to technology improvements and efficiency gains**

This trend will probably be more pronounced in developing regions

NG and Coal Meet Increasing Demand

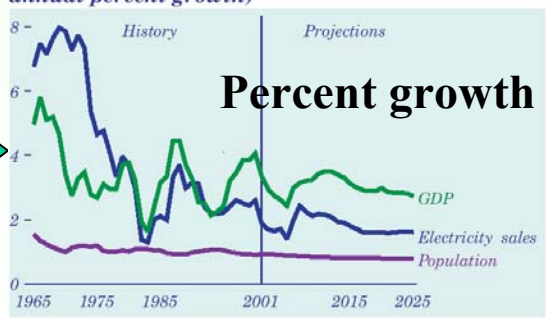
- **Electricity demand is projected to continue at a steady 2.4%/y**
- **Coal and natural gas will be the main sources of electricity**
  - **Forecast for NG has been reduced due to higher prices, but it has low capital costs**
  - **Nuclear is still forecast as flat in base scenario**
  - **State and Federal subsidies help increase renewables**

Figure 4. Electricity generation by fuel, 1970-2025 (billion kilowatthours)



However, Electricity Sales Will Grow Slower Than GDP

Figure 60. Population, gross domestic product, and electricity sales, 1965-2025 (5-year moving average annual percent growth)



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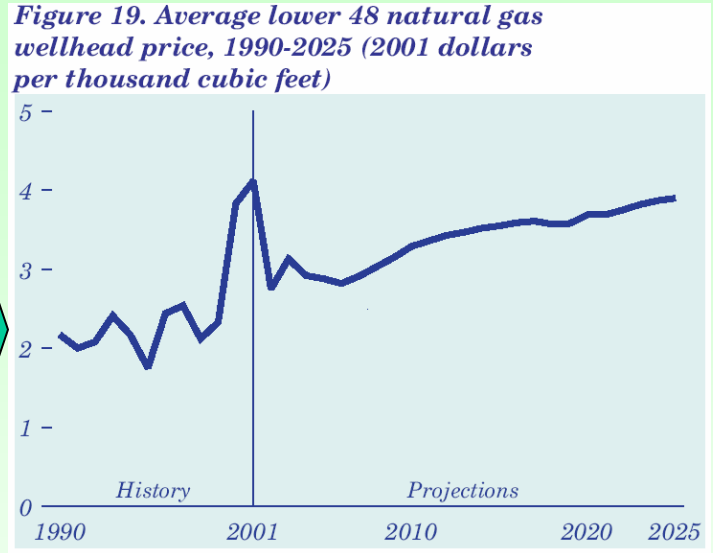
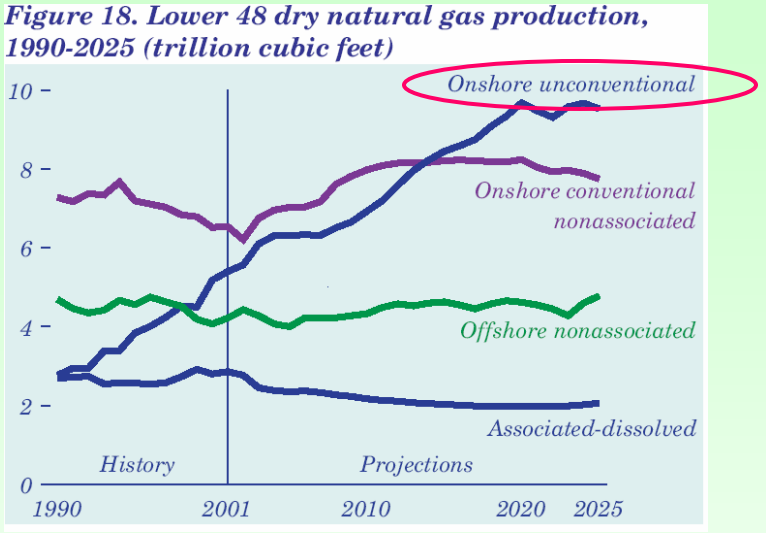
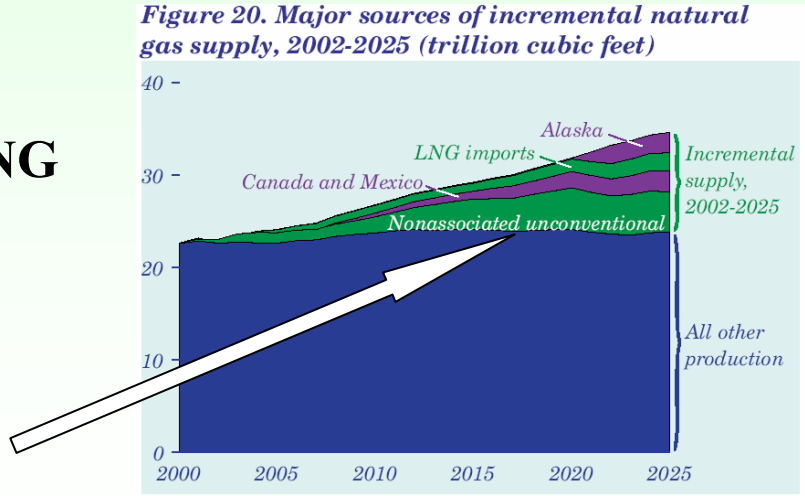
NG Demand Influences Cost and Production





- **The price of NG is expected to climb over time**
- **The biggest new source of lower 48 NG is expected to be Onshore Unconventional (low permeability sandstone)**
- **Incremental supply will be non-associated (not with known fields) unconventional plus imported supplies**



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It Is Difficult to Keep Capacity and Demand in Balance

Figure 25. Electricity sales growth, 1955-1999 (5-year moving average annual percent growth)

Slow electricity sales in 70's and 80's resulted in large capacity margins

Figure 24. Electricity sales and generating capacity, 1950-2005 (index, 1950 =1)

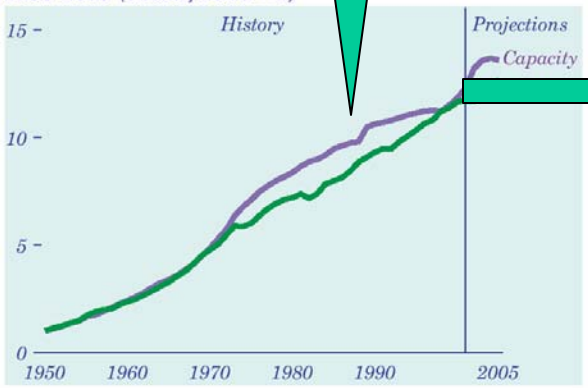
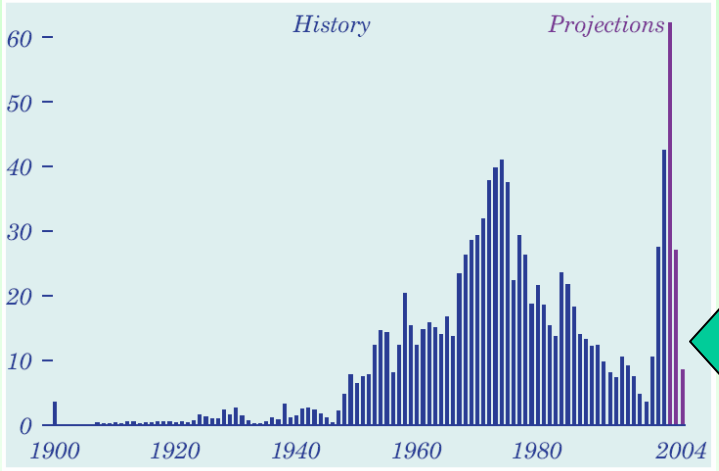


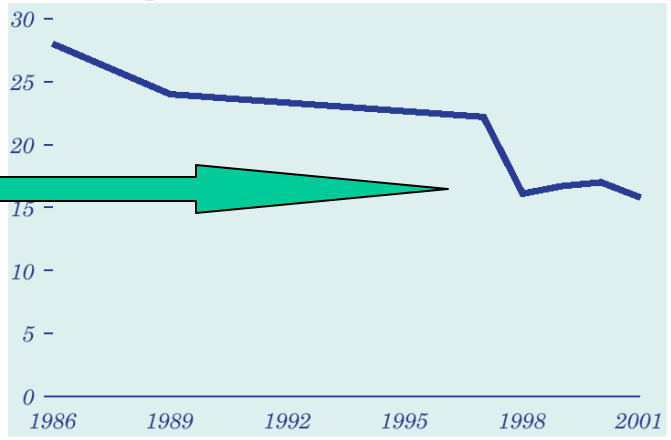
Figure 26. Generating capacity added by year, 1900-2004 (gigawatts)



Now capacity is being ramped up to meet demand and sufficient capacity factor

62 GWe added in 2002

Figure 27. Average U.S. summer capacity margin, 1986-2001 (percent)



The lack of new capacity with continued sales in 90s reduced capacity margins

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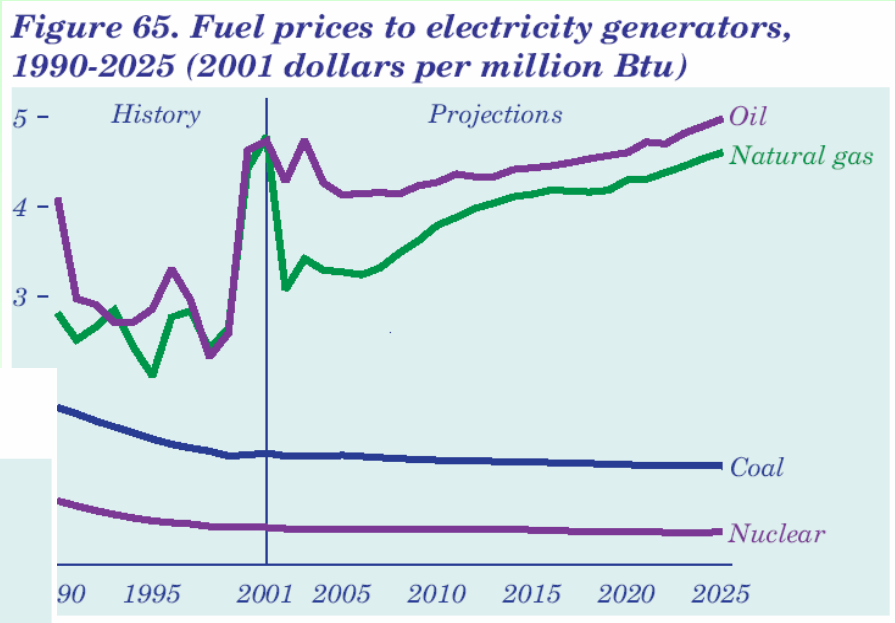
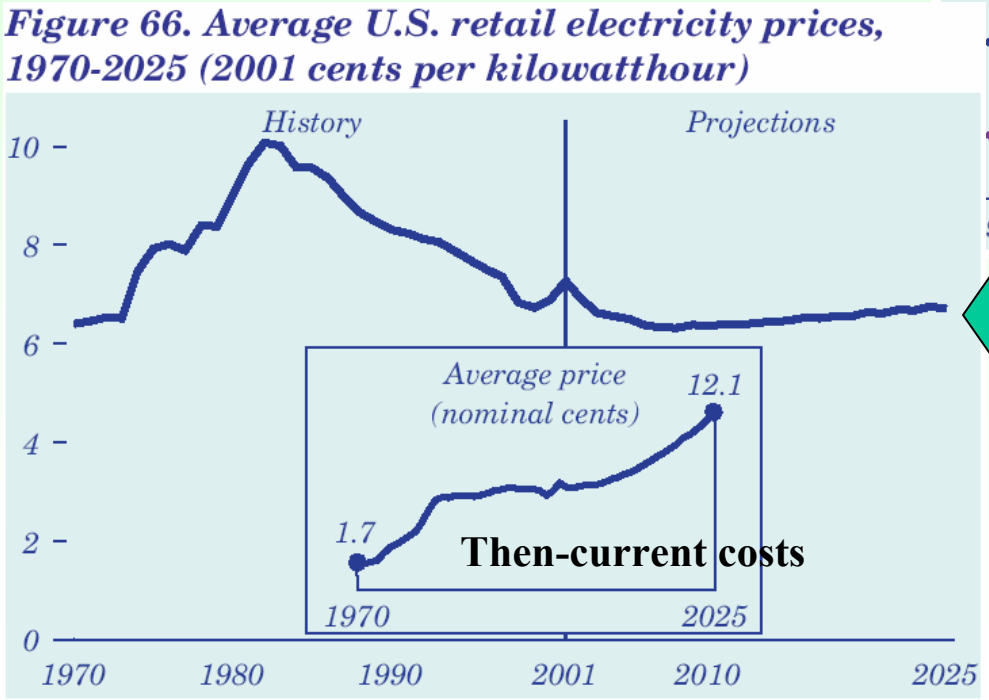
Although NG Prices Increase, the Price of Electricity Remains Nearly Fixed

Natural gas (and oil) prices continue to climb, but the cost of coal and nuclear fuels for electricity production decline





Price of electricity is expected to decline in real 2001$ by 1.6%/y in 2001-2008 and then slowly increase at 0.3%/y to 2025.

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Capital Costs Influence Plant Choice

- **Minimal capital cost NG plants have lowest generation costs through 2025**

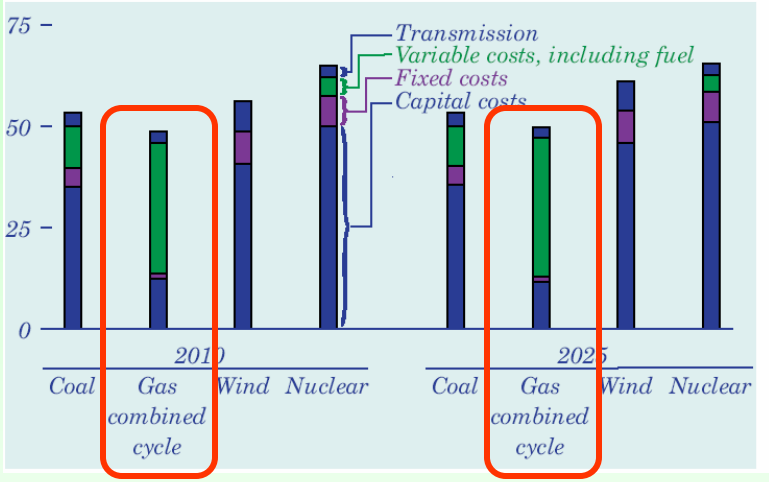
Table 8. Costs of producing electricity from new plants, 2010 and 2025

Costs	2010 Advanced coal	2010 Advanced combined cycle	2025 Advanced coal	2025 Advanced combined cycle
	2001 mills per kilowatthour			
Capital	35.08	12.33	35.62	11.55
Fixed	4.53	1.34	4.53	1.34
Variable	10.37	32.21	9.85	34.14
Transmission	3.28	2.82	3.23	2.77
Total	**53.26**	**48.70**	**53.23**	**49.80**

ARIES-AT

Cap Factor	0.85	0.90
	52.54	49.67
	9.93	9.46
	5.30	5.30
	3.00	3.00 (Assumed)
	70.77	**67.43**

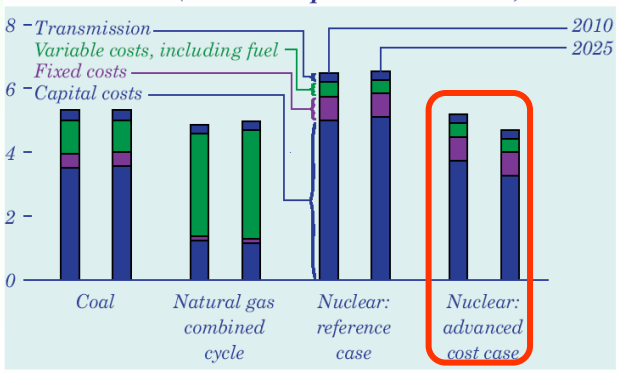
Figure 67. Projected levelized electricity generation costs, 2010 and 2025 (2001 mills per kilowatthour)



ARIES-AT is still too high

- **Present nuclear plants have higher costs than adv coal or CCNG, but Advanced Nuclear (with aggressive overnight costs) would be competitive**

Figure 70. Projected levelized electricity costs by fuel type in the advanced nuclear cost case, 2010 and 2025 (2001 cents per kilowatthour)



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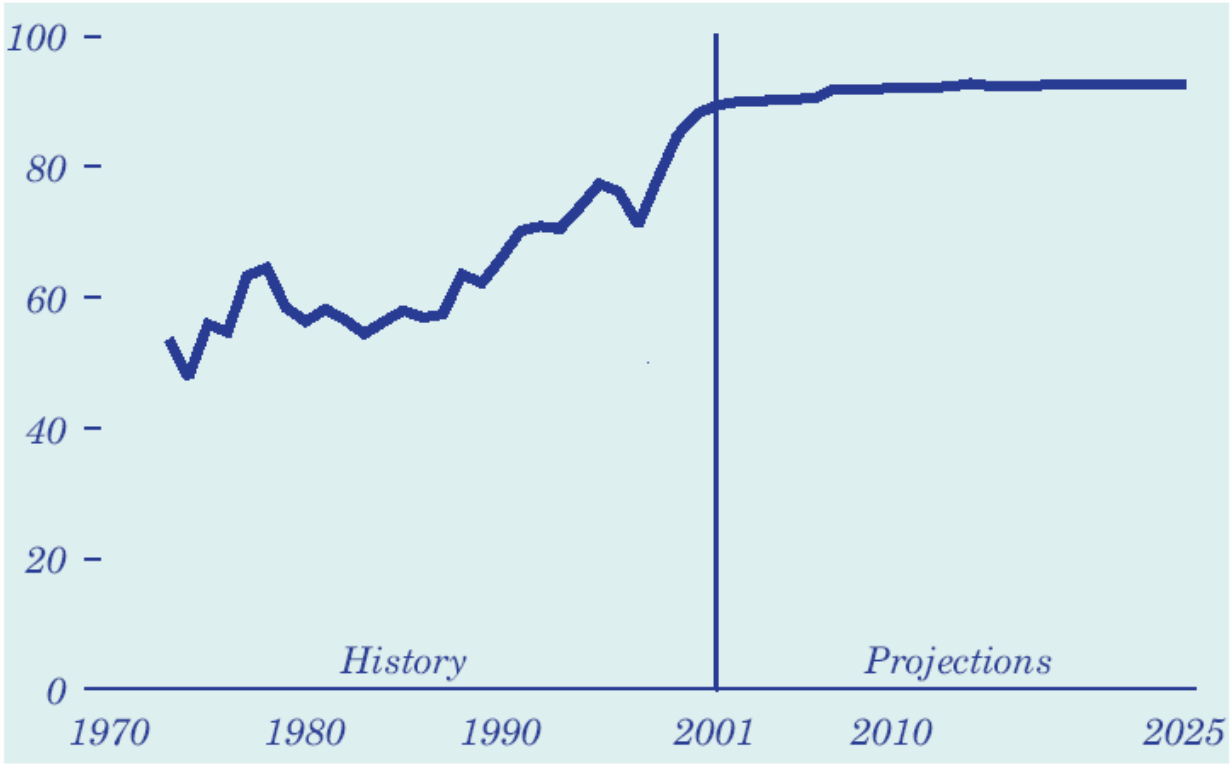
Capital Intensive Nuclear Plants Compete By Increasing Plant Capacity Factor to the Maximum

Figure 69. Nuclear power plant capacity factors, 1973-2025 (percent)



104 US nuclear plants provided 20% of the electricity in 2001 with a capacity factor of 89%. This CF is expected to increase to 92%, average by 2010.

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Expected Nuclear Contributions
- 2002 to 2025 -

- 3% of nuclear capacity will be retired
- This is offset by increased capacity of existing units
  - US NRC has approved 22 applications for power uprates in 2001 and 22 approved/pending for 2002 resulting in 4.2 GW increase in capacity
- No new nuclear units are expected to be operational between 2002 and 2025 as NG and coal are cheaper
- By 2025 the majority of US nuclear units will be beyond their original licensing lifetimes
  - As of 10/2002, 10 nuclear renewal of licenses had been approved, 16 pending, and 23 announced

What About The Environment?

- Congress passed the Air Pollution Control Act of 1955, the first national legislation to identify air pollution, fund research, and identify additional steps to be taken
- The Clean Air Act of 1963 dealt with reducing air pollution by setting standards for stationary power sources. Amendments dealt with standards for autos, compliance deadlines for stationary sources, and more research
- The prior acts proved to be inadequate and The Clean Air Act (CAA) of 1970 was a major revision and set more demanding standards on stationary and mobile sources. The initial standards proved to be too aggressive and amendments extended the deadlines.
- No changes were forthcoming during the 1980s due to the emphasis on economic growth over environmental concerns

What About The Environment? (Cont.)

- Congress addressed growing environmental concerns by enacting the Clean Air Act of 1990 that addressed air-quality standards, motor vehicle emissions and alternative fuels (low-sulfur), toxic air pollutants, acid rain, and stratospheric ozone depletion by strengthening and improving existing regulations.
- The CAA of 1990 mandated the installment of the Best Available Control Technology (BACT) to reduce the amount of air toxins
- The Government called for a reduction in the amount of chlorofluorocarbons (CFCs) to reduce/prevent ozone depletion

Recent Environmental Initiatives

On 14 Feb 2002, President Bush announced two initiatives to cut power plant emissions and address climate change

- **The Clear Skies Initiative cuts power plant emissions**
  - **Cuts 2001 SO_2 emissions by 73%, with caps in 2010 and 2018**
  - **Cuts 2001 NOx emissions by 67%, with caps in 2008 and 2018**
  - **Cuts 2001 mercury emissions by 69%, with caps in 2010 and 2018**
  - **Uses market based approach, ala, Clean Air Act**

- **Global Climate Change Initiative**
  - **Cut Green House Gas Intensity (grams carbon equiv/GDP 1996$) by 18% by 2012**
  - **Applies to CO_2, methane, nitrous oxide, and other GHGs**
  - **Applies to all economic sectors**

Clear Skies Initiative Establishes Aggressive Goals

Figure 118. Projected sulfur dioxide emissions from electricity generation, 2005-2025 (million tons)

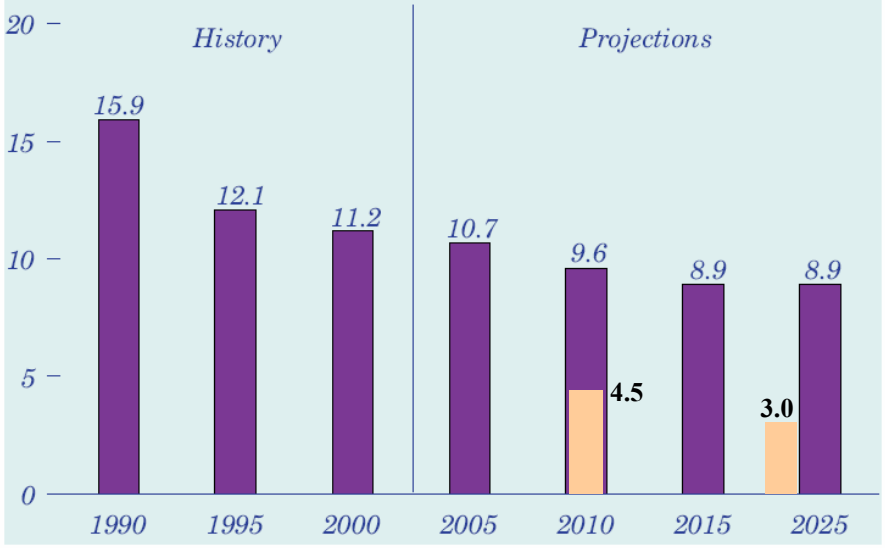
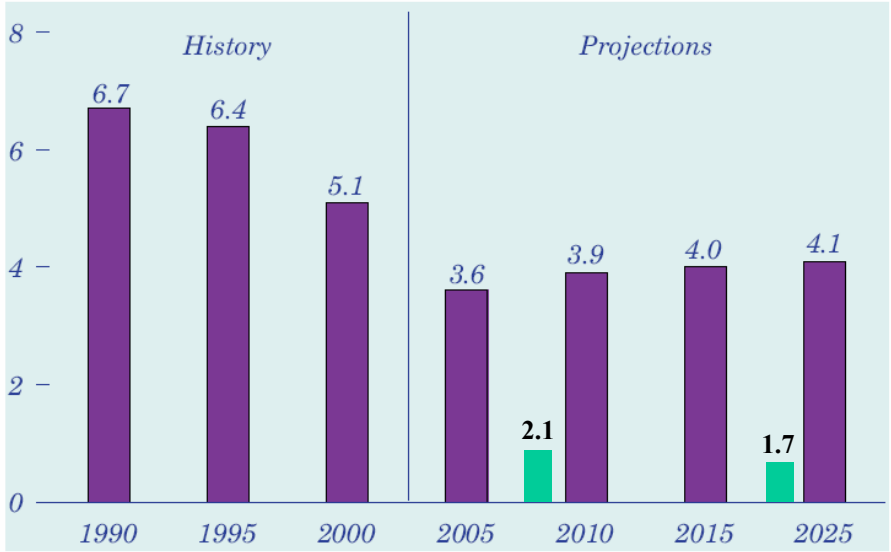


Figure 119. Projected nitrogen oxide emissions from electricity generation, 2005-2025 (million tons)



- **The Annual Energy Outlook 2003 predicted reductions from technology improvements and regulatory actions**
- **SO_2 and NOx need to be actively controlled to meet the Clear Skies Initiative goals**

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Global Climate Change Initiative Links Goals to GDP Levels

Table 6. Projected changes in U.S. greenhouse gas emissions, gross domestic product, and greenhouse gas intensity, 2002-2012

Projection	2002	2012	Percent change, 2002-2012
Greenhouse gas emissions (million metric tons carbon equivalent)			
Energy-related carbon dioxide	1,536	1,862	21.2
Non-energy-related carbon dioxide	37	40	10.3
Methane	171	171	0.2
Nitrous oxide	120	129	7.5
Gases with high global warming potential	39	66	69.1
Adjustments for bunker fuel and military use	-16	-16	-0.7
Total	**1,886**	**2,252**	**19.4**
Gross domestic product (billion 1996 dollars)	9,440	13,082	38.6
Greenhouse gas intensity (grams carbon equivalent per 1996 dollar)	**200**	**172**	**-13.8**

-18 GGI Goal

- **All GHGs increase in absolute value by 2012 (+19.4%), but GDP increases at a greater rate (+38.6)**
- **Therefore, the Greenhouse Gas Intensity (GHG/GDP) is predicted to be lower by 13.8%**
- **Global Climate Change goal is 18% reduction**

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Energy-Related Carbon Dioxide Is the Major GHG Contributor

Projection	2002	2012	Percent change, 2002-2012
Greenhouse gas emissions (million metric tons carbon equivalent)			
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Adjustments for bunker fuel and military use	-16	-16	-0.7
Total	**1,886**	**2,252**	**19.4**

- **On February 2003, President Bush announced the $1B, 10-year "FutureGen" initiative to build the world's first coal-based, integrated sequestration, and hydrogen production research power plant with zero-emissions**
- **The EPA ruled on 8/28/2003 that carbon dioxide cannot be regulated as a pollutant. *"Congress must provide us with clear legal authority before we can take regulatory action to address a fundamental issue such as climate change," added Jeff Holmstead, an EPA assistant administrator***

A Troubling Rule Change

- Enacted in 1977, the New Source Review (NSR) section of the Clean Air Act (CAA) required that coal fired power plants and other major industrial sources of air pollution install up-to-date pollution control technology if the power plants are rebuilt and air pollution levels are increased (but not required for routine maintenance).

- On August 27, 2003 the United States Environmental Protection Agency (EPA) approved an administrative rule change of the CAA that will essentially allow coal burning power plants to incrementally rebuild or upgrade their facilities without having to install modern air pollution control devices, providing the annual cost does not exceed 20% of the production unit.
- This rule change may derail the Clear Skies Initiative
- Several environmental groups and many states are preparing to file lawsuits against plant operators to limit pollution and challenge this rule change

A Commentary on the Authors of the Energy Bill

How Can Fusion Help?

- **USDOE FESAC endorses the assumption that fusion-generated electricity can be on the grid by 2038 (i.e., an operational Demo plant)**
  - **This would imply significant fusion electricity capacity would not be forthcoming until ~ 2050**
- **However, fusion can offer an unlimited, long-term energy resource that will be non-polluting**
  - **Large scale production of electricity and/or hydrogen**
  - **Reduces dependence on imports**
  - **No emission of polluting and greenhouse gases**
  - **Relinquishes petroleum for more valuable uses**
  - **Alternate applications are possible**
    - **Transmutation of nuclear waste**
    - **Isotope generation**