



Nuclear Power for the 21st Century

Mujid S. Kazimi

Director, Center for Advanced Nuclear Energy Systems
TEPCO Professor of Nuclear Engineering
Professor of Mechanical Engineering
Kazimi@mit.edu, tel 1-617-253-4206

*Introductory Remarks at
Symposium on Supercritical CO₂ Power Cycle,
MIT
March 6, 2007*



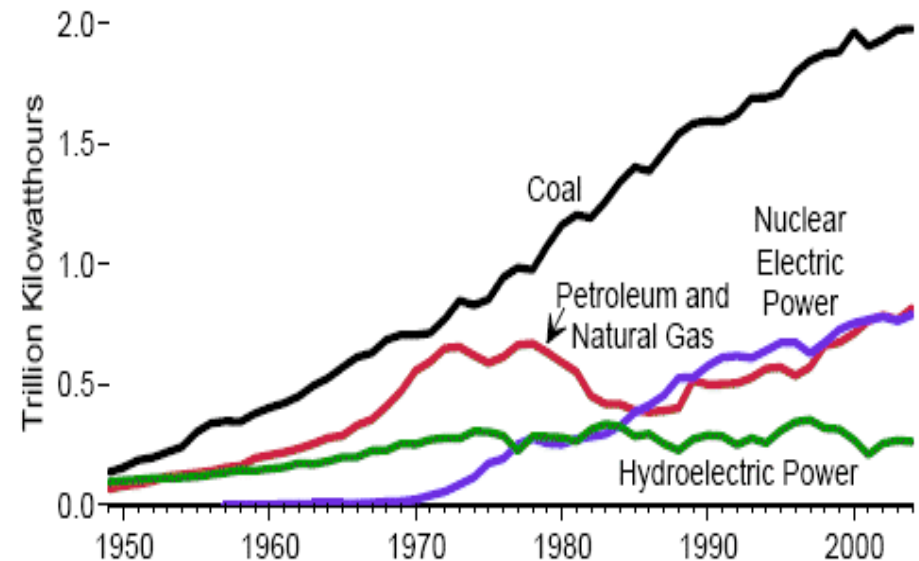
MIT Center for Advanced Nuclear Energy Systems



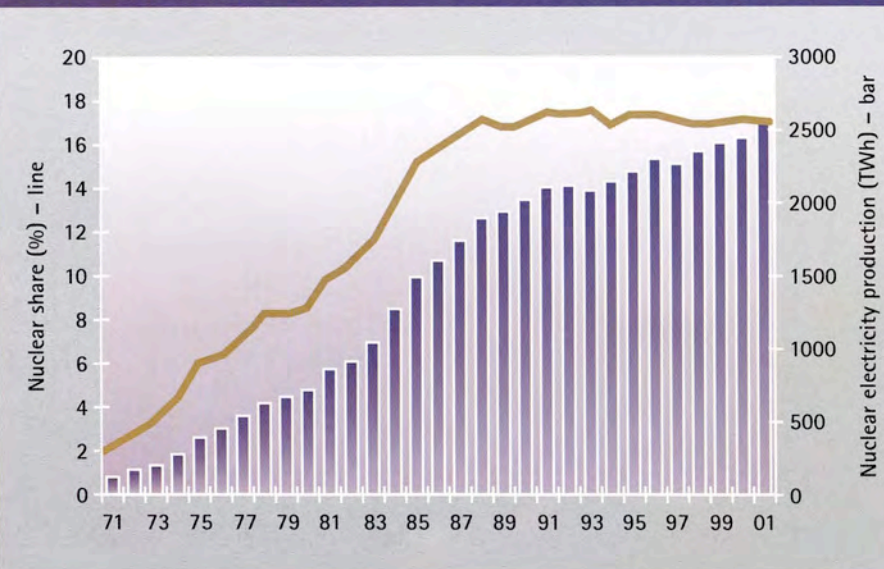
Nuclear Energy Today

- The largest non-fossil supplier of electricity in the US and worldwide
 - 103 US reactors, 442 World wide
 - US: 99.5 GWe, 20% of production
 - World: 347 GWe, 16% of production
- No order for US nuclear plants since 1975, but in 2005 nuclear production was the highest ever.
 - US plants have run at 90% capacity in 2005, up from 71% in 1990.
 - 3.0 GWe of uprates were permitted in

USA Major Sources of Total Electricity Net Generation

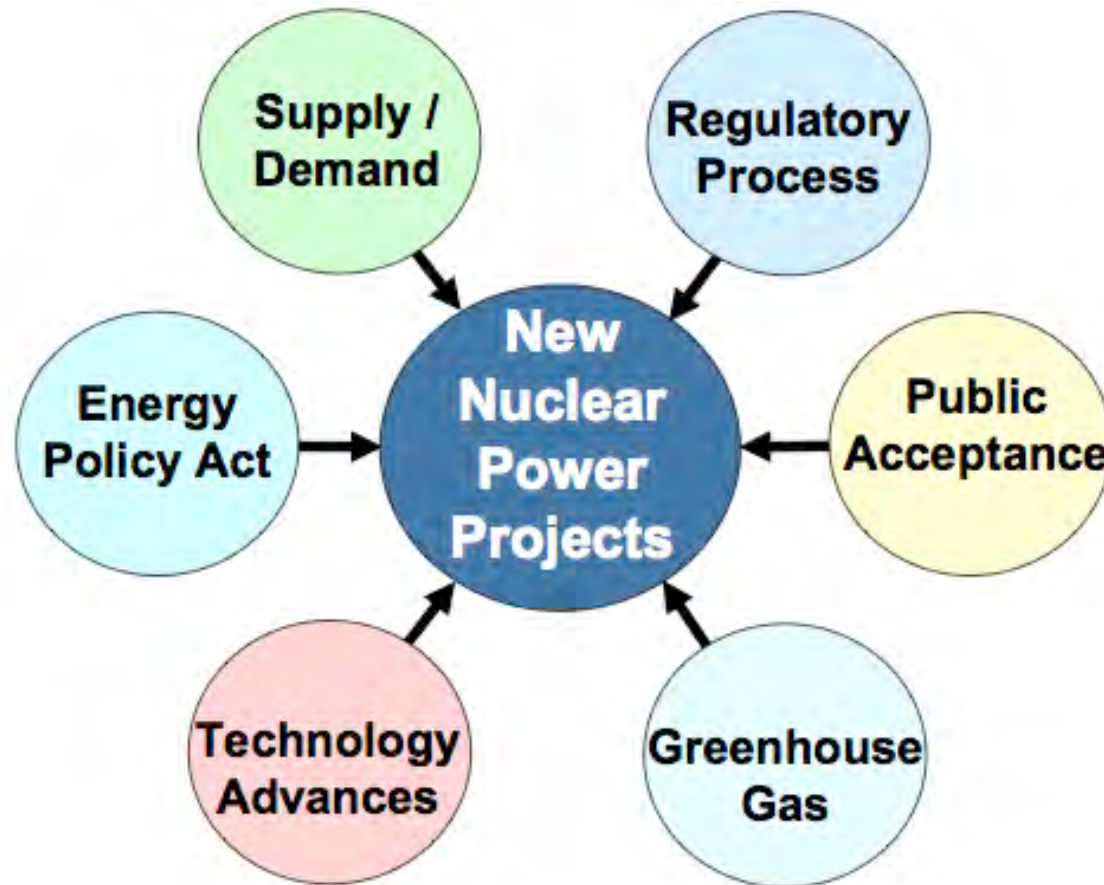


Nuclear electricity production and share of total electricity production



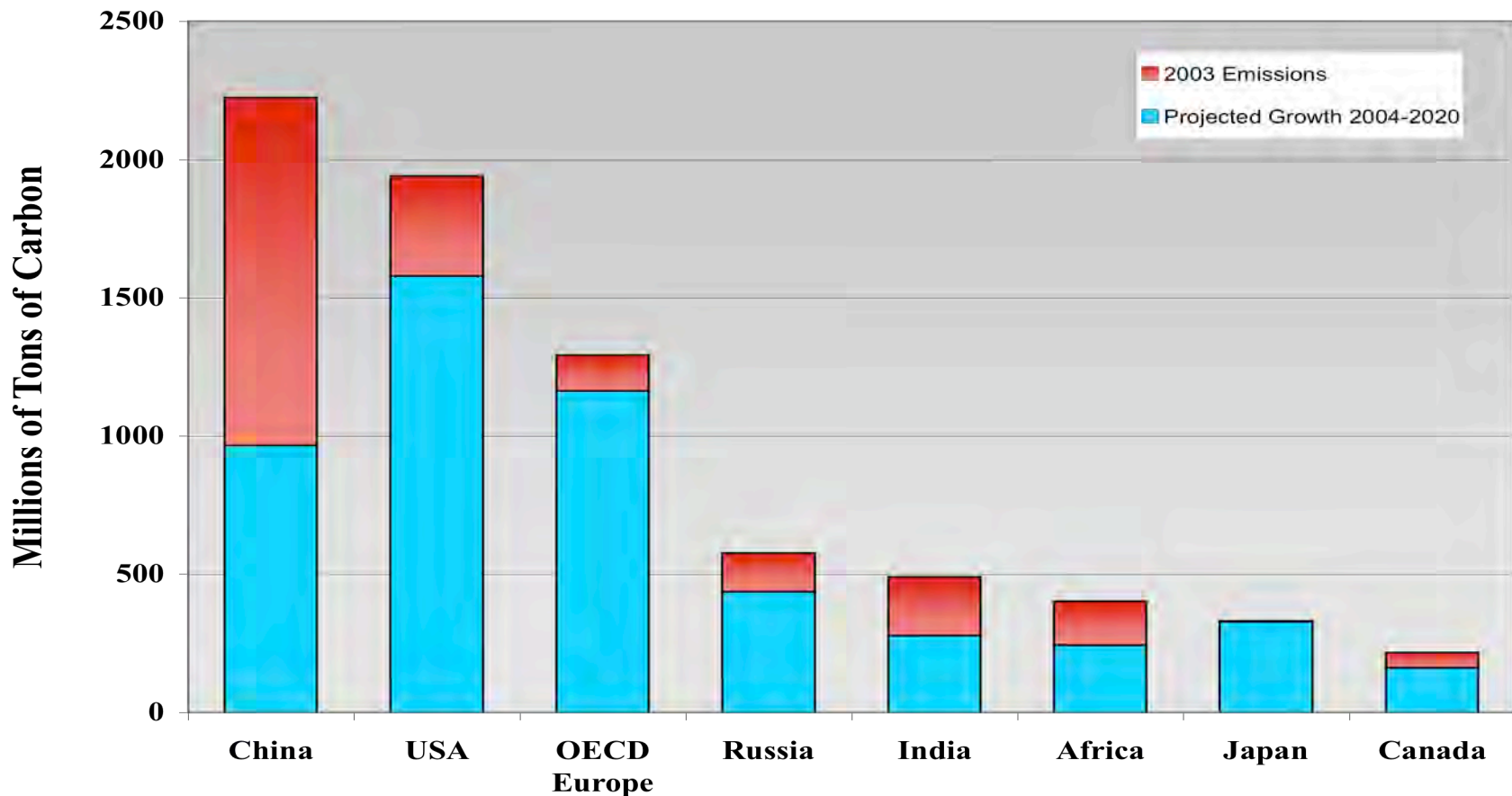
- 44 reactor licenses extended, from 40 to 60 years.
- Applications for an additional 3 GWe are pending
- US utilities recently declared plans for license applications for 30 new light water reactors (LWRs)
- China, India, Russia and South Korea have declared plans to add about 110 new reactors by 2025

Why New Nuclear Orders?



2003 Carbon Emissions

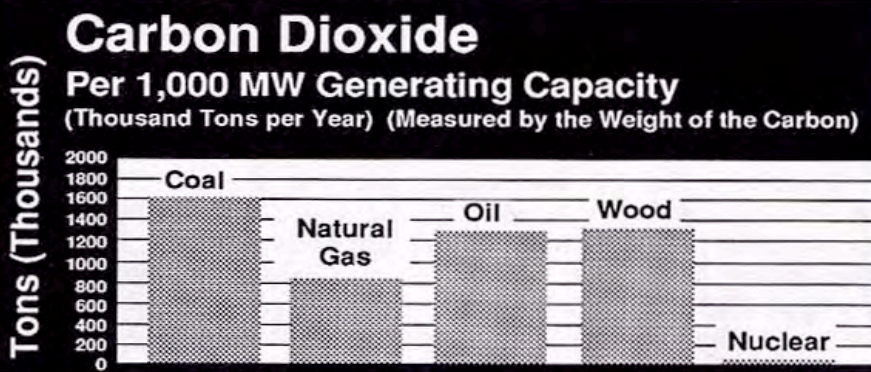
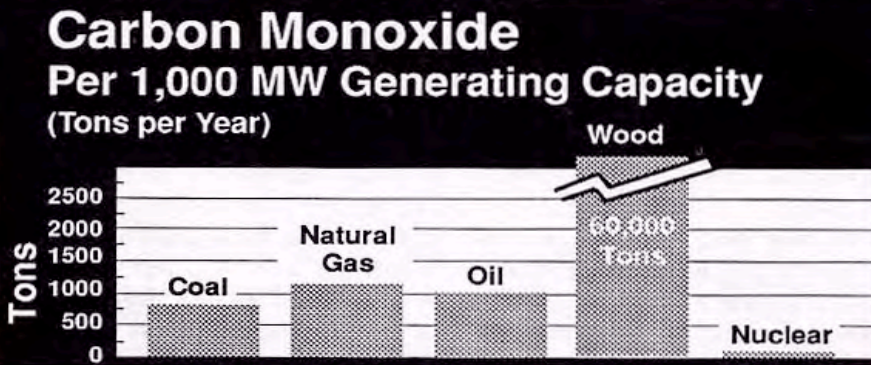
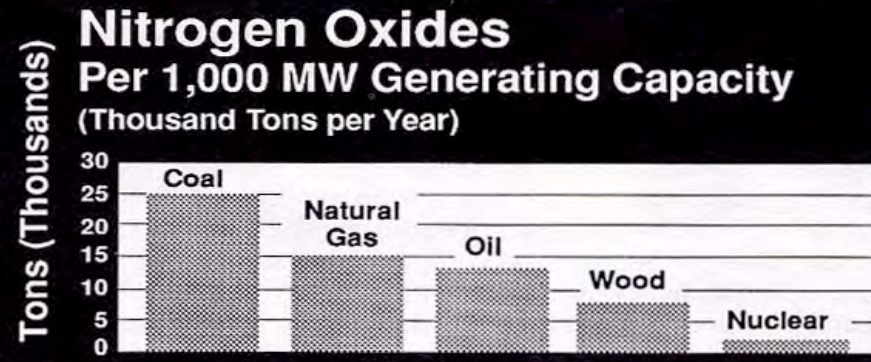
and Expected Increase by 2020



Source: Energy Information Agency

Nuclear energy emissions to environment are thousands of times less by volume or mass than fossil fuels.

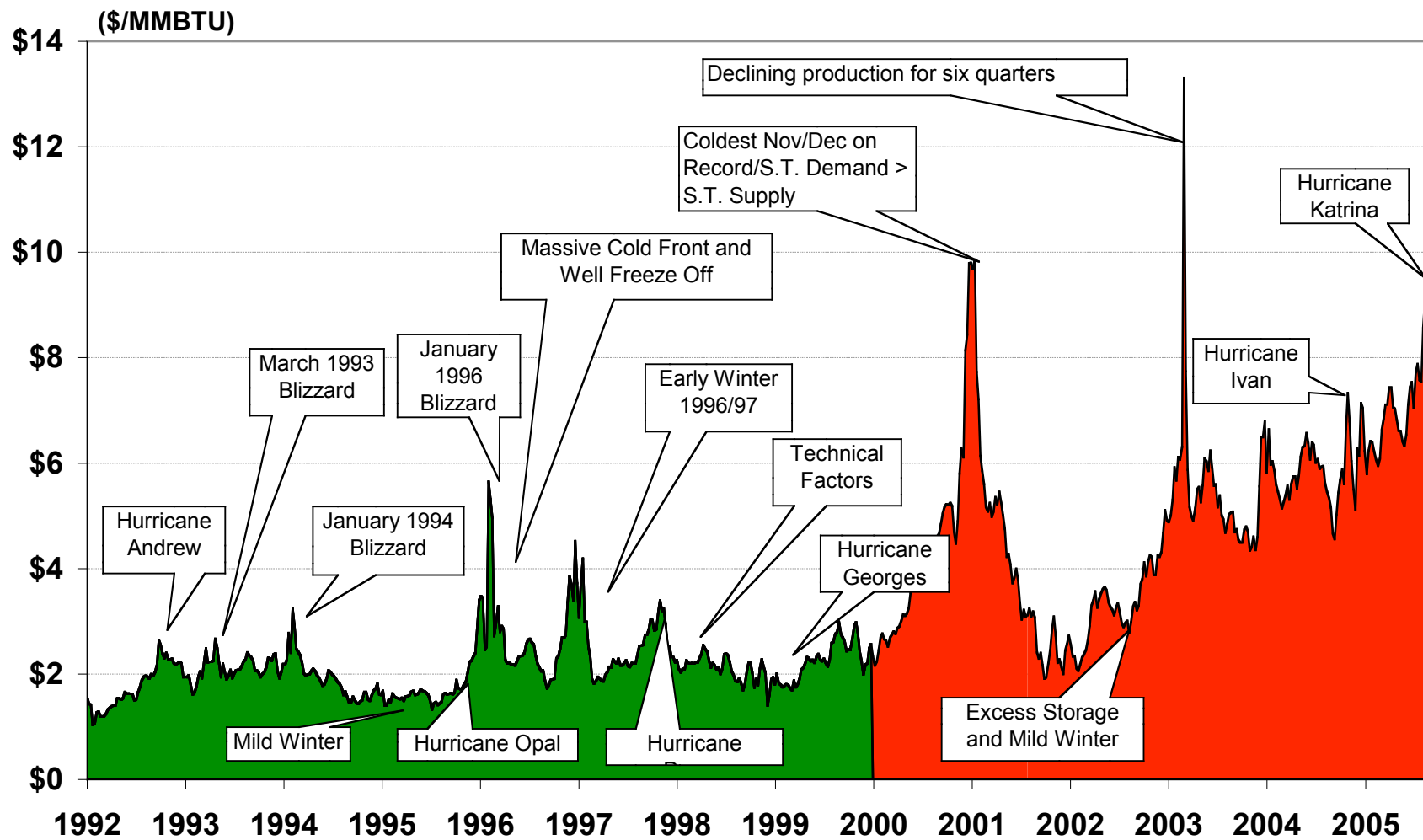
Nuclear need for land is 10,000 times less per MWhr-e than biofuel, and 100s times less than wind, or solar.



(Source: Environmental Protection Agency)

Natural Gas Price Volatility...A Huge Issue

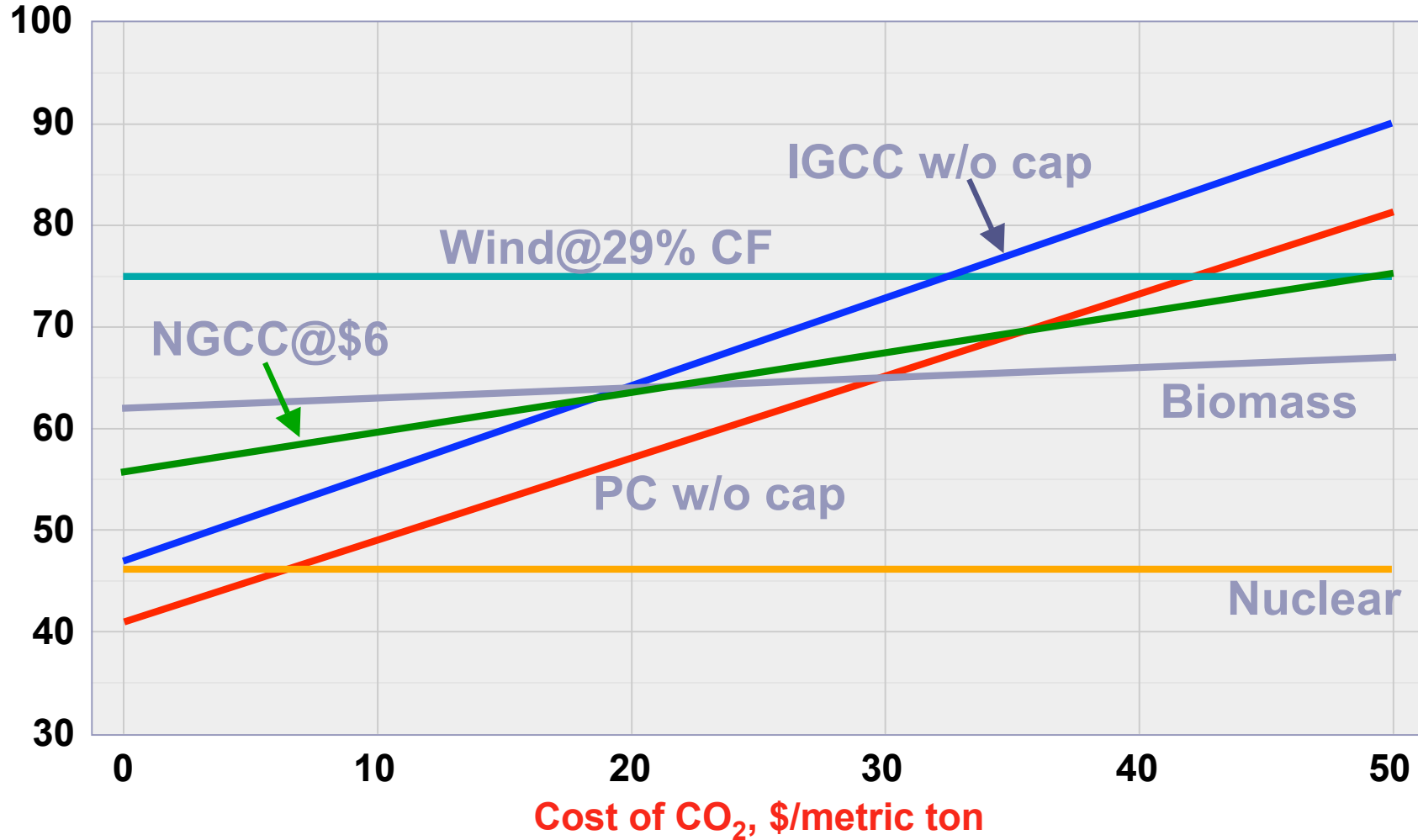
HENRY HUB NATURAL GAS PRICE WEEKLY DATA



Source: NGW and EVA, Inc.

Comparative Costs in 2010

Levelized Cost of Electricity, \$/MWh



Source: EPRI Study 2005

Nuclear Energy Economics

Key Factors

- Plant cost is about 70% of cost of electricity
- Depends on duration of construction and effective Interest rate on capital.
- Nuclear fuel is only 15% of cost of electricity

Industry Solutions

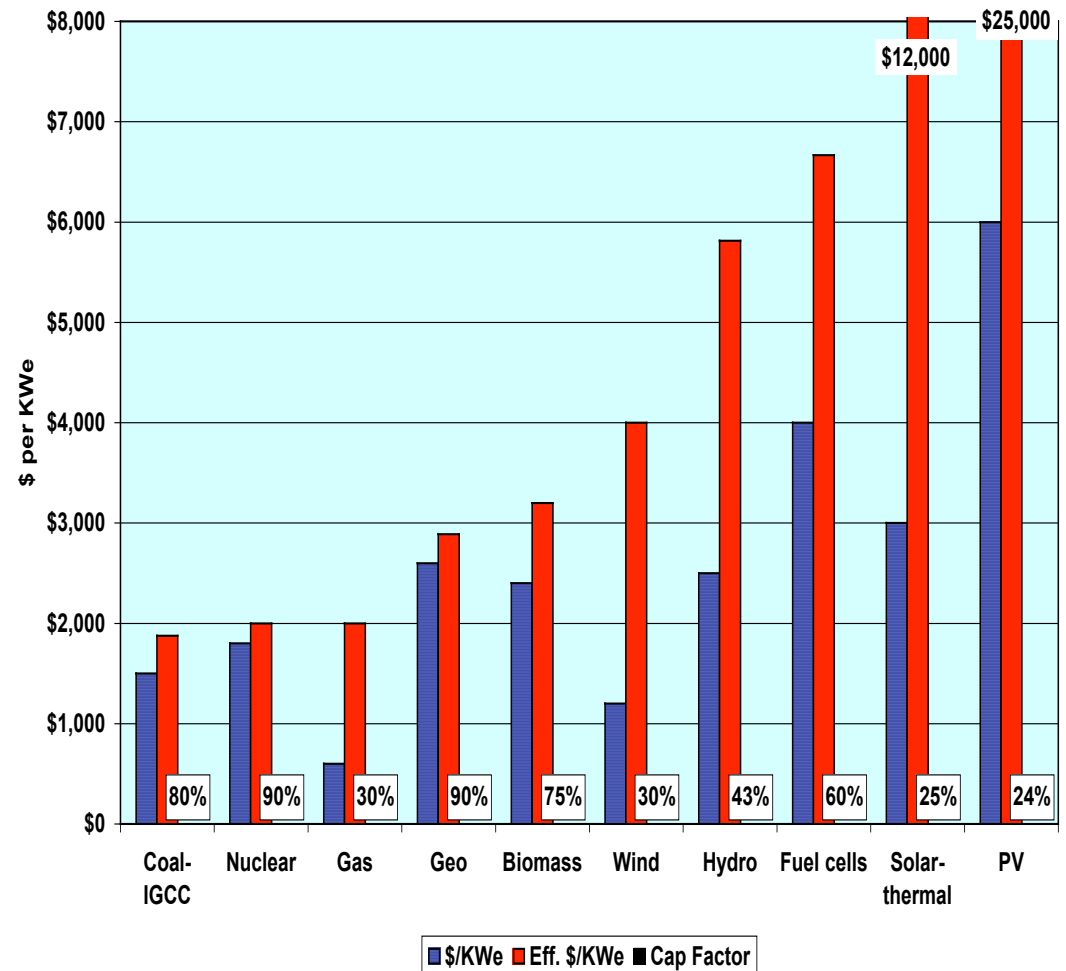
- **Simplification:** W-AP1000 uses 2 not 4 loops & GE-ESBWR eliminates pumps
- **Standardization:** fixed design for multiple units
- **Large Capacity:** Several models at 1500 MWe
- **Construction time** 5 yrs, as in Japan and France

Government Solutions - Energy Act 2005

- Production credits up to 6000 MWe
- Regulatory reform, and Insurance for delays
- Loan guarantees for non-emission

Innovative Technology Solutions

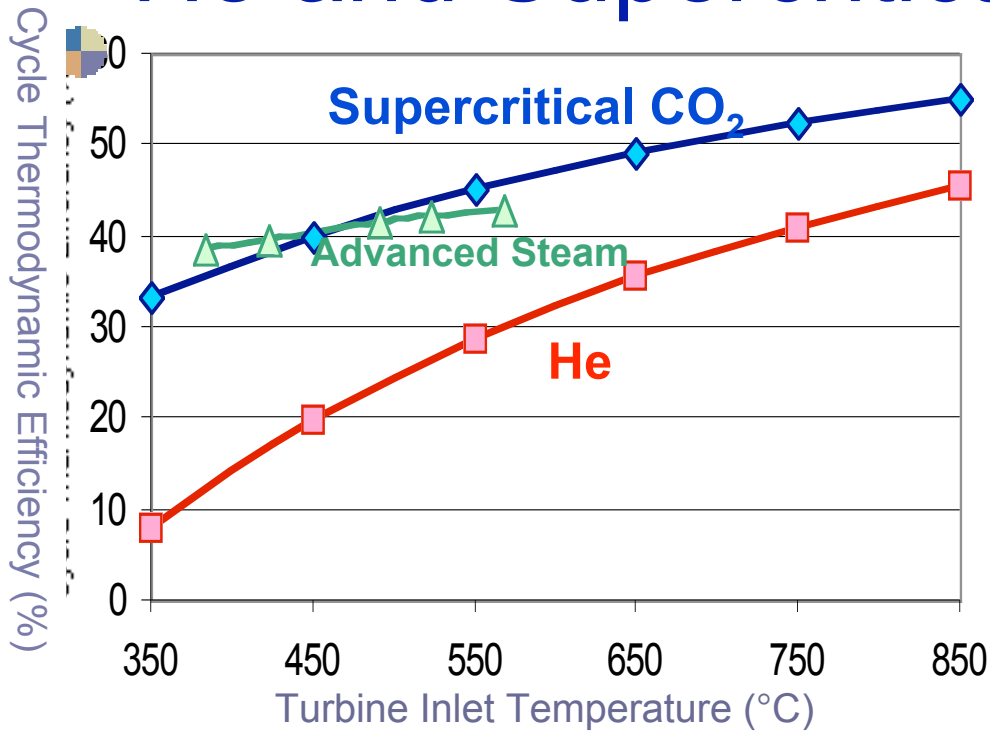
- Increase reactor power density
 - New fuel design
 - Improved coolant properties - nanofluids
- Increase power conversion efficiency
 - High Temperature Gas Cooled Reactors



Nuclear as a base loaded electricity source beats all other sources but coal.

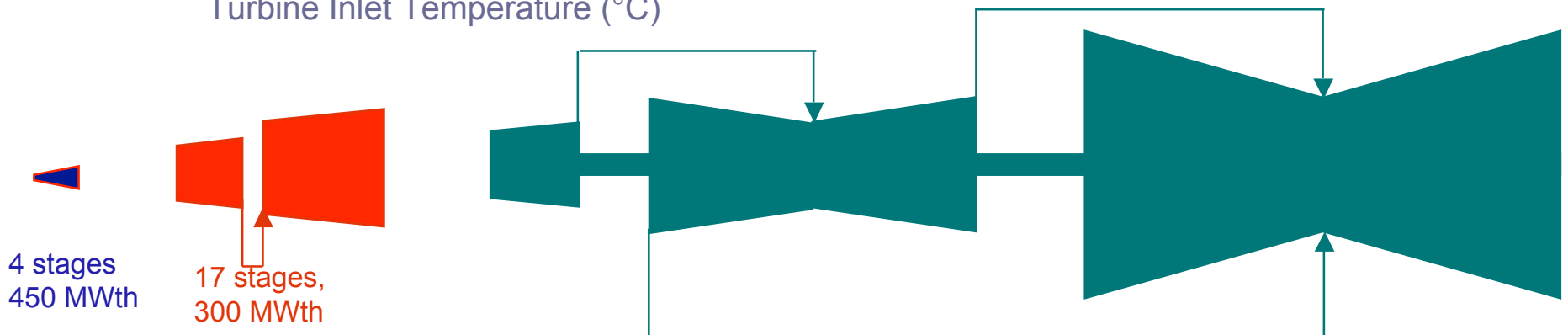
Gas is only competitive below \$5/MBTU. Question is how far off are Carbon taxes?

Advanced Power Cycles: He and Supercritical CO₂ Gas Turbines



While a He gas turbine plant is already 25 times smaller than the steam turbine equipment, a CO₂ turbine size is smaller by another factor of 8.

Steam turbine: 55 stages / 250 MWe
Mitsubishi Heavy Industries Ltd., Japan (with casing)



Source: Dostal, Hejzlar & Driscoll, MIT, 2004



Why Supercritical CO₂ Power Cycles Should be Developed

- Highly Compact Cycle
- Requires Moderate Temperatures
- Compatible with many reactor concepts
 - Advanced Gas Reactors (CO₂ Cooled)
 - Gas Fast Reactors (CO₂ cooled)
 - Sodium Cooled Reactors
 - Lead Cooled Reactors
 - High Temperature Helium Cooled Reactors
- In practice is it less challenging, and more forgiving than helium turbine machinery?
- Can it be made compatible with fossil gas fired plants?