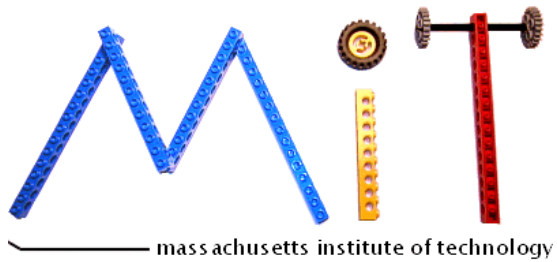
THE ECONOMICS OF INVESTMENT IN NEW NUCLEAR POWER PLANTS IN THE U.S.

Paul L. Joskow

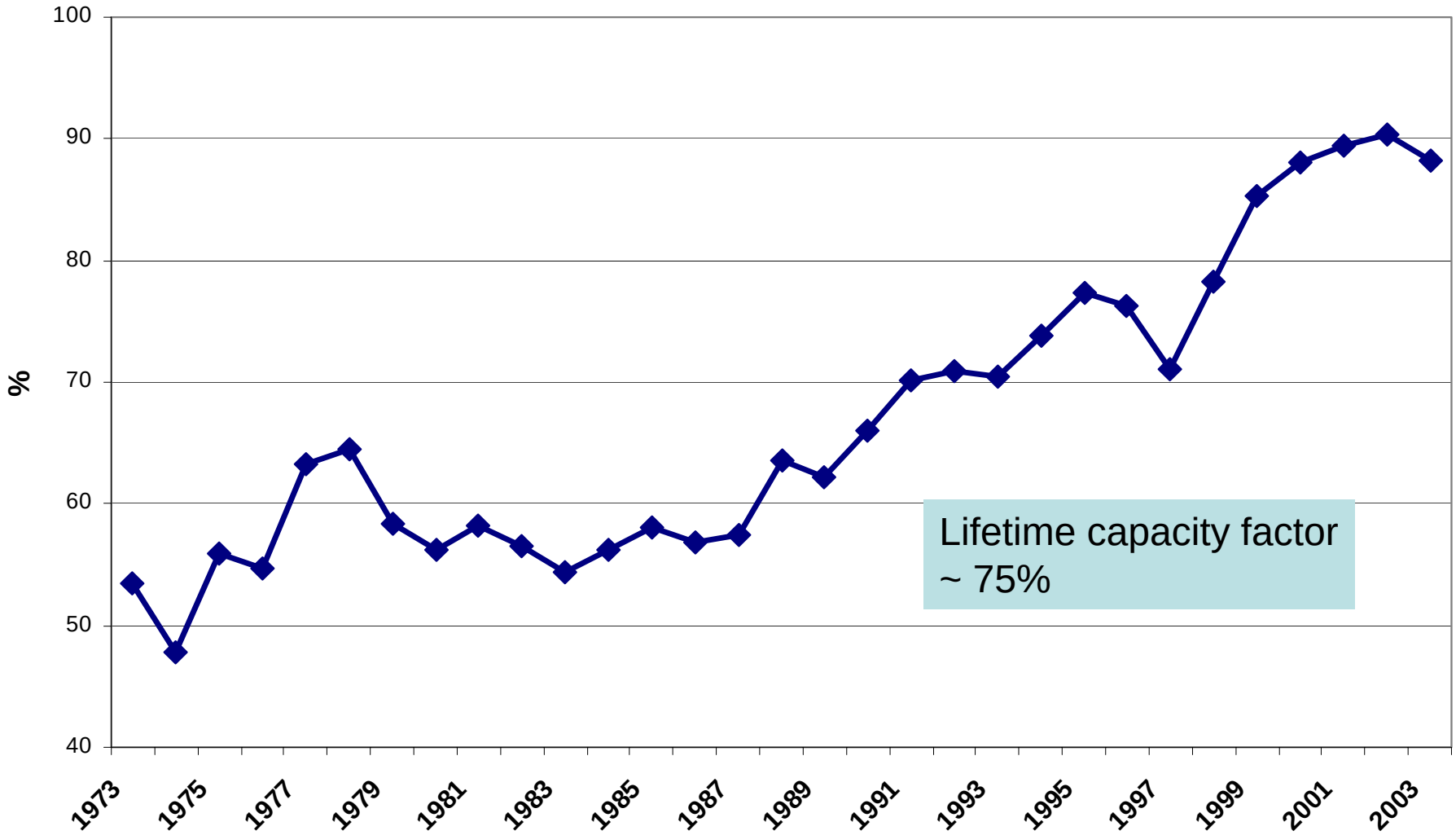


APRIL 12, 2005

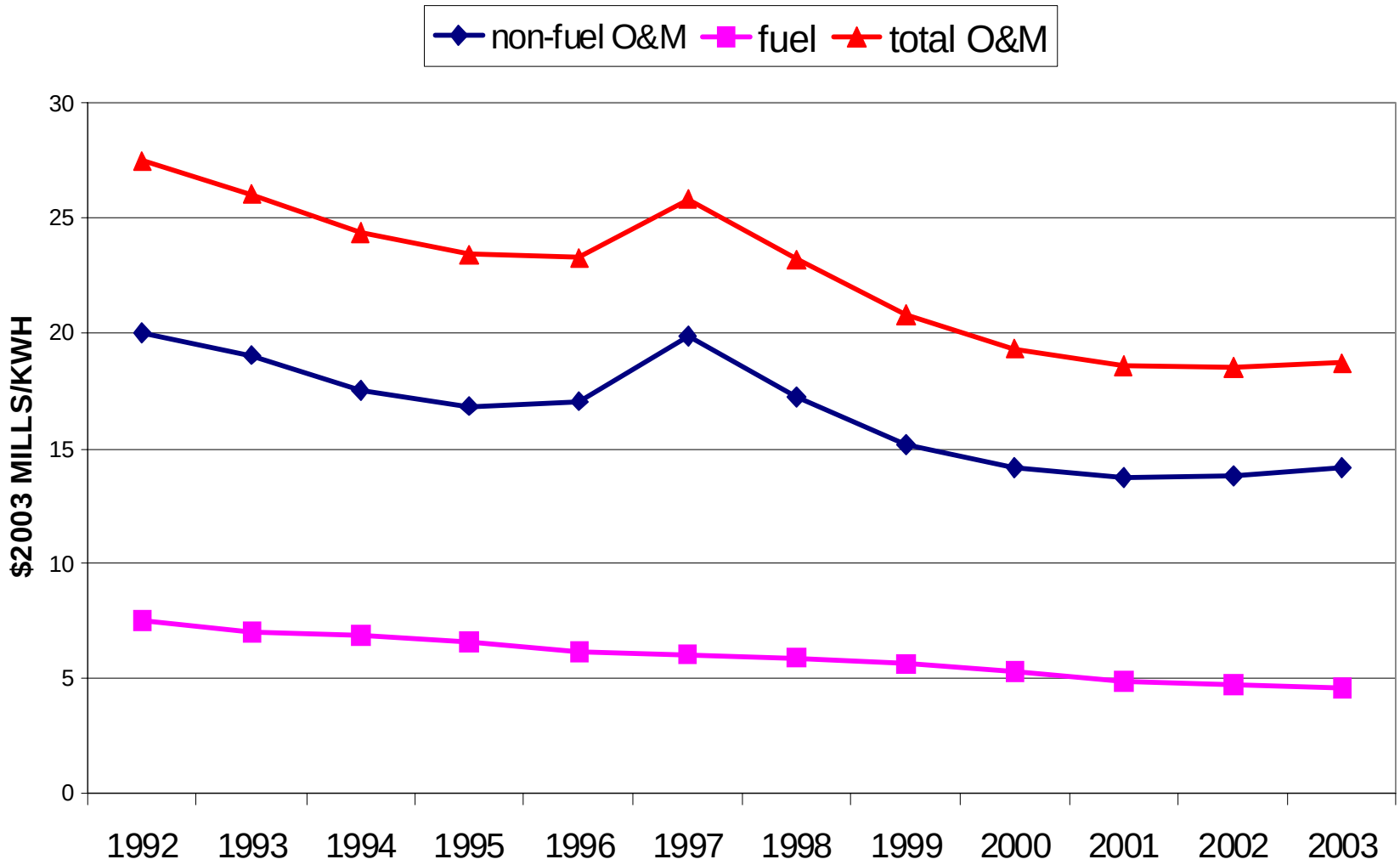
RECENT U.S. NUCLEAR PLANT EXPERIENCE

- Availability of the current stock of LWRs has improved significantly over time
- Real nuclear O&M costs have declined over time, though there is significant variance across plants
- Average nuclear O&M costs are now slightly lower than those for average PC plant O&M costs (including fuel)
- On a going forward cost basis the existing fleet is very economical compared to the market value of electricity as long as performance can be sustained
- Social costs of CO2 emissions are not (yet) reflected in the price of fossil fuels use by the generation alternatives with which nuclear must compete, though public policies favor other non-CO2 emitting technologies like wind

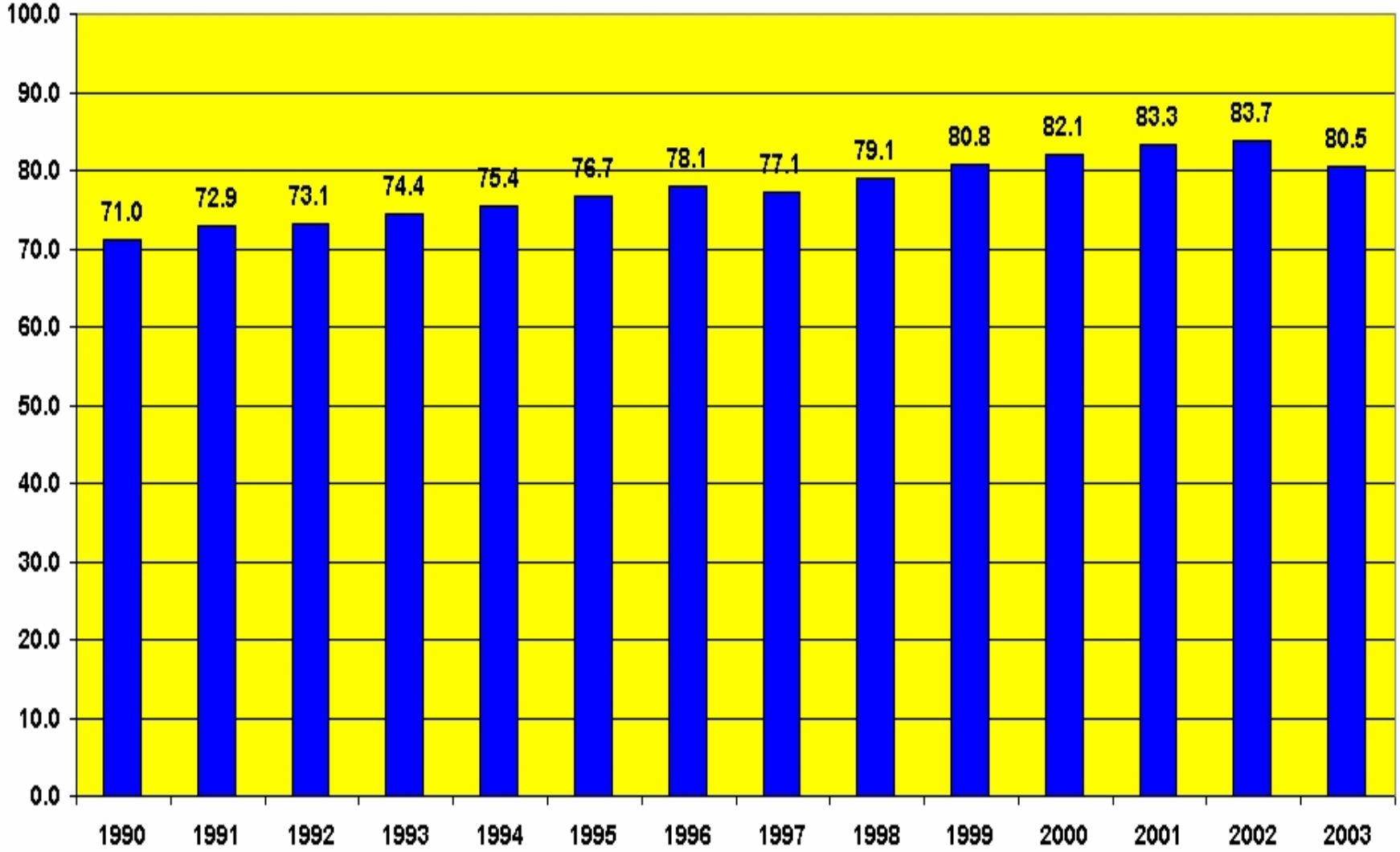
U.S. NUCLEAR PLANT CAPACITY FACTORS: 1973-2003



REAL NUCLEAR O&M COSTS ($2003 MILLS/KWH)



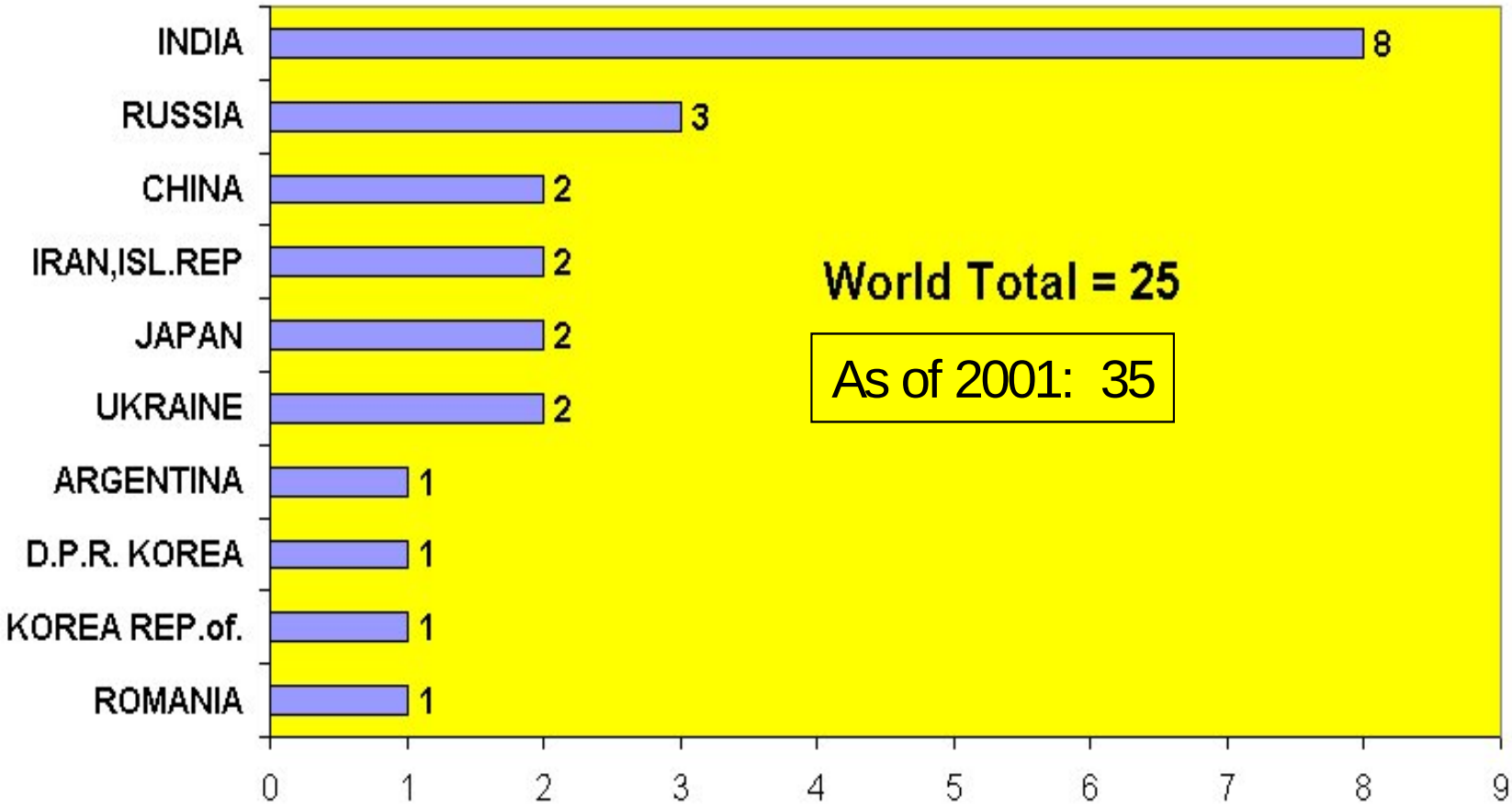
Average World Availability Factor



NEW INVESTMENT ECONOMIC CONSIDERATIONS

- Capital costs
  - Construction cost
  - Construction time
  - Financing costs
- O&M Costs: fuel and other
- Capacity Factor
- Effective prices placed on emissions from fossil-fueled competitors to internalize environmental externalities, including CO2
- Compared to base-load generation alternatives
  - Pulverized coal
  - NGCC
  - IGCC
- Direct and indirect subsidies

Number of Reactors under Construction Worldwide
(as of 10 October 2004)



Note: There were also 2 reactors under construction in Taiwan, China.

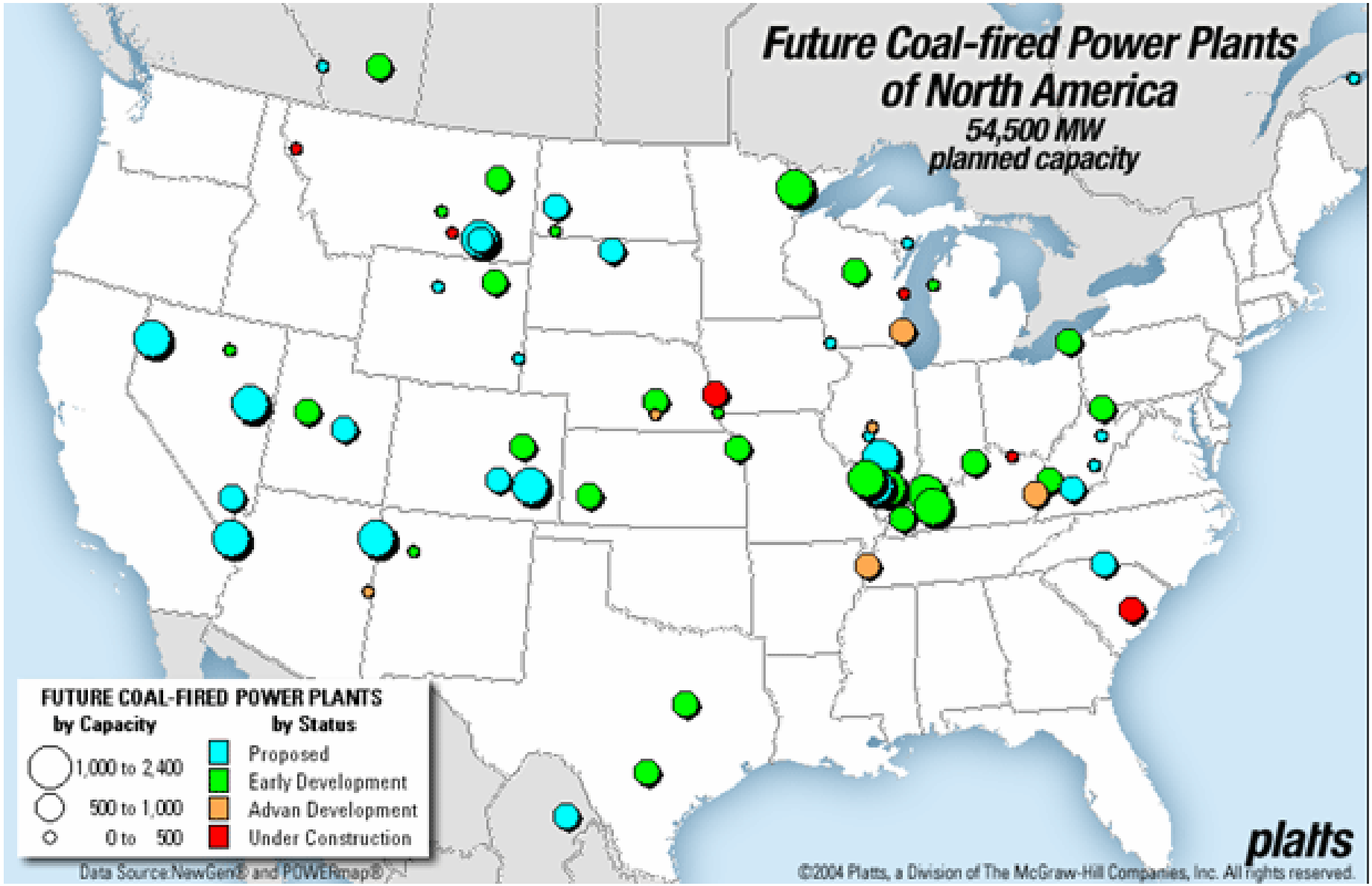
NUCLEAR CONSTRUCTION COST CONSIDERATIONS

- Nuclear industry has a poor historical record on construction cost estimation, realization and time to build
- Few recent plants built and limited information on recent actual construction cost experience
- Nuclear industry has put forward very optimistic construction cost estimates but there is no experience to verify them
- Nobody has ever underestimated the construction cost of a nuclear power plant at the pre-construction stage

HISTORICAL CONSTRUCTION COST EXPERIENCE

75 (pre-TMI) plants operating in 1986: $2002/kWe

Construction Started	Estimated Overnight Cost	Actual Overnight Cost	% OVER
1966-67	$ 560/kWe	$1,170/kWe	209%
1968-69	$ 679	$2,000	294%
1970-71	$ 760	$2,650	348%
1972-73	$1,117	$3,555	318%
1974-75	$1,156	$4,410	381%
1976-77	$1,493	$4,008	269%


Future Coal-fired Power Plants of North America
54,500 MW
planned capacity
FUTURE COAL-FIRED POWER PLANTS
by Capacity
1,000 to 2,400
500 to 1,000
0 to 500
by Status
Proposed
Early Development
Advan Development
Under Construction
Data Source:NewGen® and POWERmap®
platts
©2004 Platts, a Division of The McGraw-Hill Companies, Inc. All rights reserved.

Weston 4
Proposed 515 Mw PC Unit
(2008 in-service, dollars of the day)

Item	Estimated Costs	
Engineering Costs		**$35,602,471**
Procurement Costs:		
Civil/Structural Equipment	$45,257,123	
Mechanical Equipment	$72,811,933	
Electrical Equipment	$13,897,651	
Control Equipment	$6,086,948	
Chemical Equipment	$7,389,774	
		$145,443,429
Construction and Fabrication/Engineering Contract Costs:		
Civil/Structural Erection	$93,602,099	
Mechanical Erection	$332,623,982	
Electrical Erection	$35,869,075	
Control Erection	$2,342,214	
Chemical Erection	$616,669	
		$465,054,039
Owner Construction Costs		**$47,832,534**
Construction Management Costs		**$58,508,736**
Total Cost		**$752,441,209**

Public Service Commission of Wisconsin 2004

OVERNIGHT CONSTRUCTION COST ESTIMATES

- Construction cost estimates should include all costs, including owner's costs
- The best estimates are drawn from actual experience rather than engineering cost models
- Construction cost estimates for PC and CCGT can be verified from actual experience
- Publicly available data on recent plants completed suggest that $2000/Kw, including all owner's costs, with a 5-year construction period is a good base case cost estimate
- Competitive power markets induce truthful revelation of costs and associated uncertainties

FINANCING COST CONSIDERATONS

- Your old regulated public utility no longer exists in many developed countries and in many regions of the U.S.
- Electric power sectors have been restructured to rely on competitive wholesale markets
- These markets place high powered incentives on investors to control costs by transferring construction cost, operating performance and market risks to investors
    - project financing
    - balance sheet financing
    - contract support is important
- A merchant investment framework may significantly increase the cost of capital faced by investors and makes long lead time capital intensive generation technologies less attractive
- You don't have to convince me, but you do have to convince the Board of directors that proposed nuclear investments are the most profitable risk-adjusted options

FINANCING COSTS UNDER DIFFERENCT REGULATORY/COMMERCIAL FRAMEWORKS

$100 million transmission project:	Annual net cash flows required
(a) traditional regulated utility (BS –COS):	$ 9.4 million
(b) long term incentive contract (merchant) (PF):	$ 13.9 million
(c) no long-term contract (merchant) (PF):	$ 16.5 million

Balance sheet financing (BS)
Project financing (PF)
Cost of debt
Cost of equity
Debt/equity ratio
Debt repayment/cash flow constraints
Equity return time horizon
Income tax considerations

Source: Morgan Stanley
CMU conference 12/04

OTHER COST CONSIDERATIONS

- 90% lifetime capacity factor is very optimistic
- Non-fuel O&M cost assumptions are typically very optimistic compared to current experience
- Owner costs and relevant overheads may not be properly reflected in cost estimates

COMPARATIVE POWER COSTS
MIT REPORT

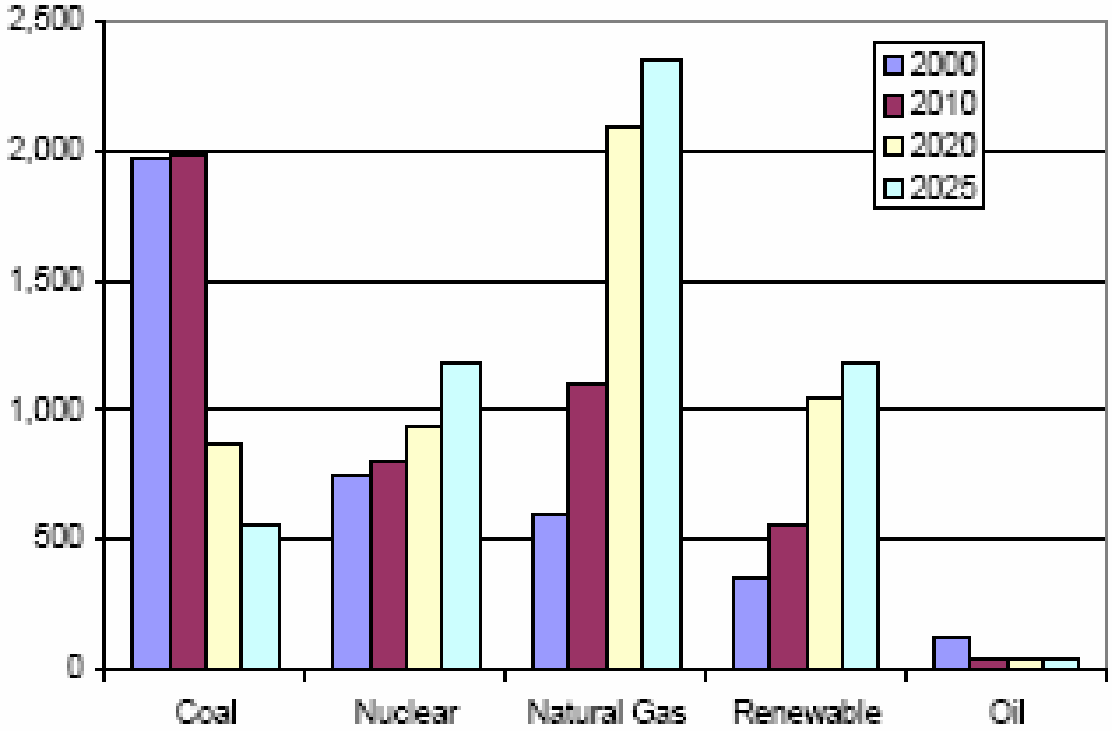
($2002 cents/kWh)

	Merchant	Traditional
Base Case ($2000/kW)	6.7	5.2
Reduce Construction Costs 25% ($1500/kW)	5.5	4.4
Reduce Construction time by 12 months	5.3	4.3
Reduce cost of capital (financing cost)	4.2	3.6
Coal-PC	4.2	3.5
Gas-Low ($3.77/MCF)	3.8	3.6
Gas-Moderate ($4.42/MCF)	4.1	4.0
Gas-High ($6.72/MCF)	5.6	5.7

FOSSIL GENERATION COSTS WITH CO_2 PRICES ($2002 levelized cents/kWh)

	$50/tonne C	$100/tonne C	$200/tonne C
Coal	5.4	6.6	9.0
Gas (low)	4.3	4.8	5.9
Gas (moderate)	4.7	5.2	6.2
Gas (High)	6.1	6.7	7.7

Figure 5.3. Electricity Generation by Fuel in the S.139 Case, 2000, 2010, 2020, and 2025 (billion kilowatthours)



Sources: History: Energy Information Administration, *Annual Energy Review 2001*, DOE/EIA-0384(2001) (Washington, DC, November 2002), Table 8.2a. Projections: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System run MLBILL.D050503A.

Source: EIA McCain-Leiberman Analysis

WHAT IS NEEDED TO RE-LAUNCH NUCLEAR INVESTMENT?

- Stable regulatory, competitive and commercial framework that will support capital intensive projects with relatively long construction expenditure cycles
- Achieve credible $1500/kW overnight cost including all relevant owner's costs and 85% life-time capacity factor
- Improve average non-fuel O&M cost experience by 25%
- Place a significant "price" on carbon emissions
- Realize credible and economic nuclear waste disposal policy