Seven Myths of the Nuclear Renaissance

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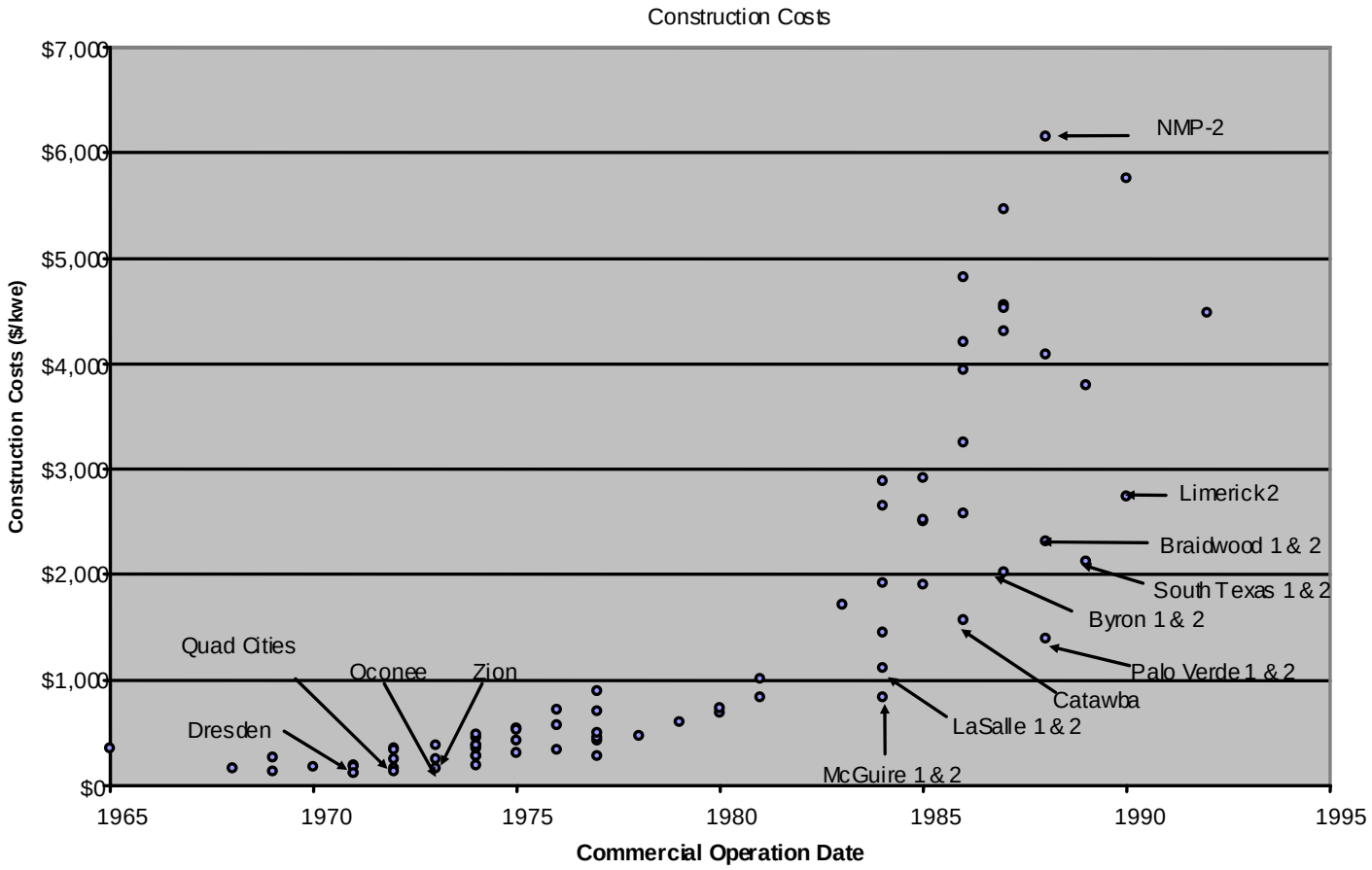
Myth One: Nuclear Power is Cheap

- Existing nuclear reactors are cheap; new ones are not
- Some studies estimate very low costs for new plants (various year dollars)
  - GE/Westinghouse ($1000-1500/kW)
  - French Ministry of Economics, Finance, and Industry ($1664/kW)
  - University of Chicago ($1500/kW)
  - World Nuclear Association ($1000-1500/kW) – 2-3 cents/kWh
  - MIT Nuclear Study ($2000/kW)
  - US Energy Information Administration ($2083/kW)

What's Wrong With This Picture?

- Studies assume:
  - Rapid construction, no delays
  - Easy financing
  - No escalation during construction
  - Cheap uranium
  - Vendor estimates with no owner's costs
  - No transmission interconnection costs
  - Easy importation of Asian learning (crews and contractors)
  - "Learning curves"

Background – Industry Experience "Last Time"

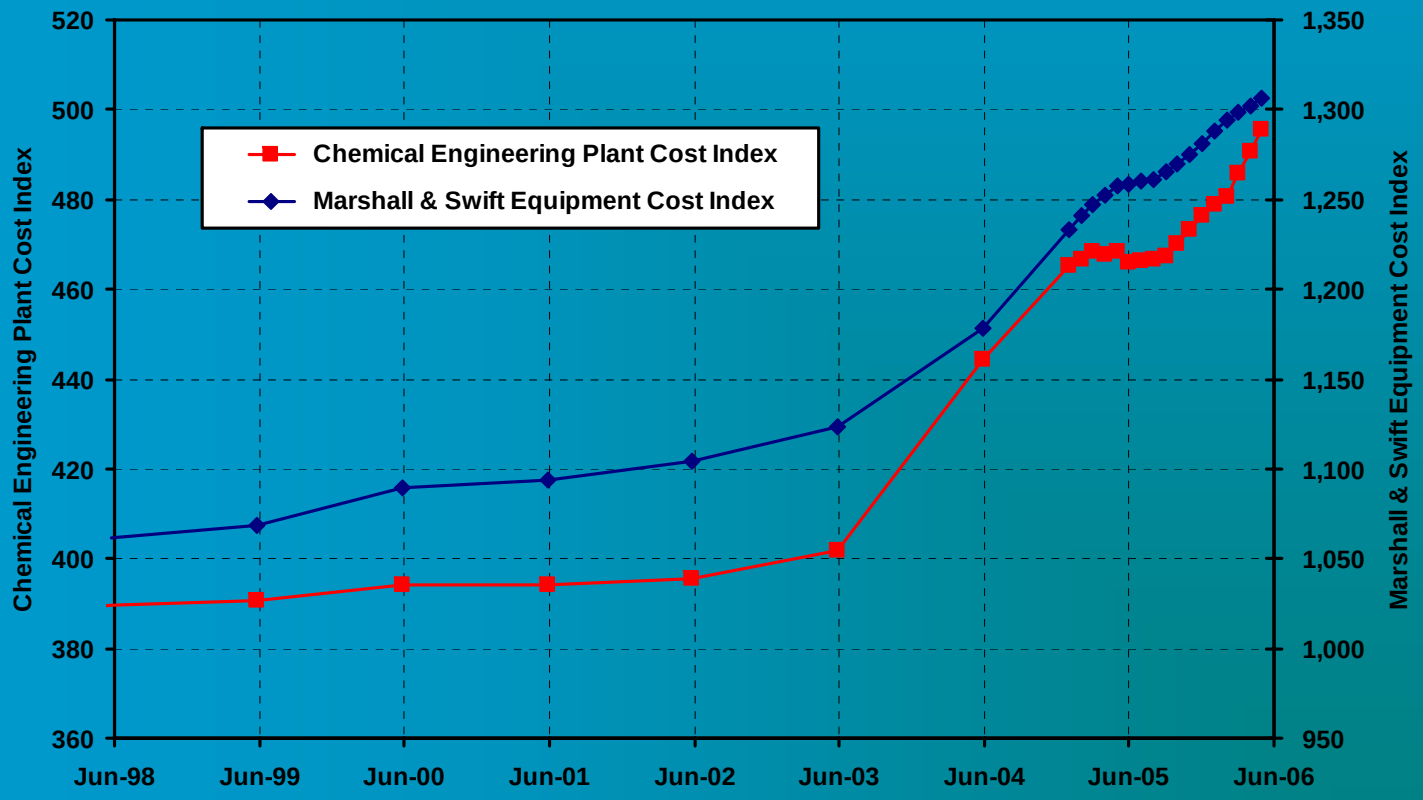


Historical US Construction Cost Experience
75 (pre-TMI-2 plants operating in 1986; $2002)

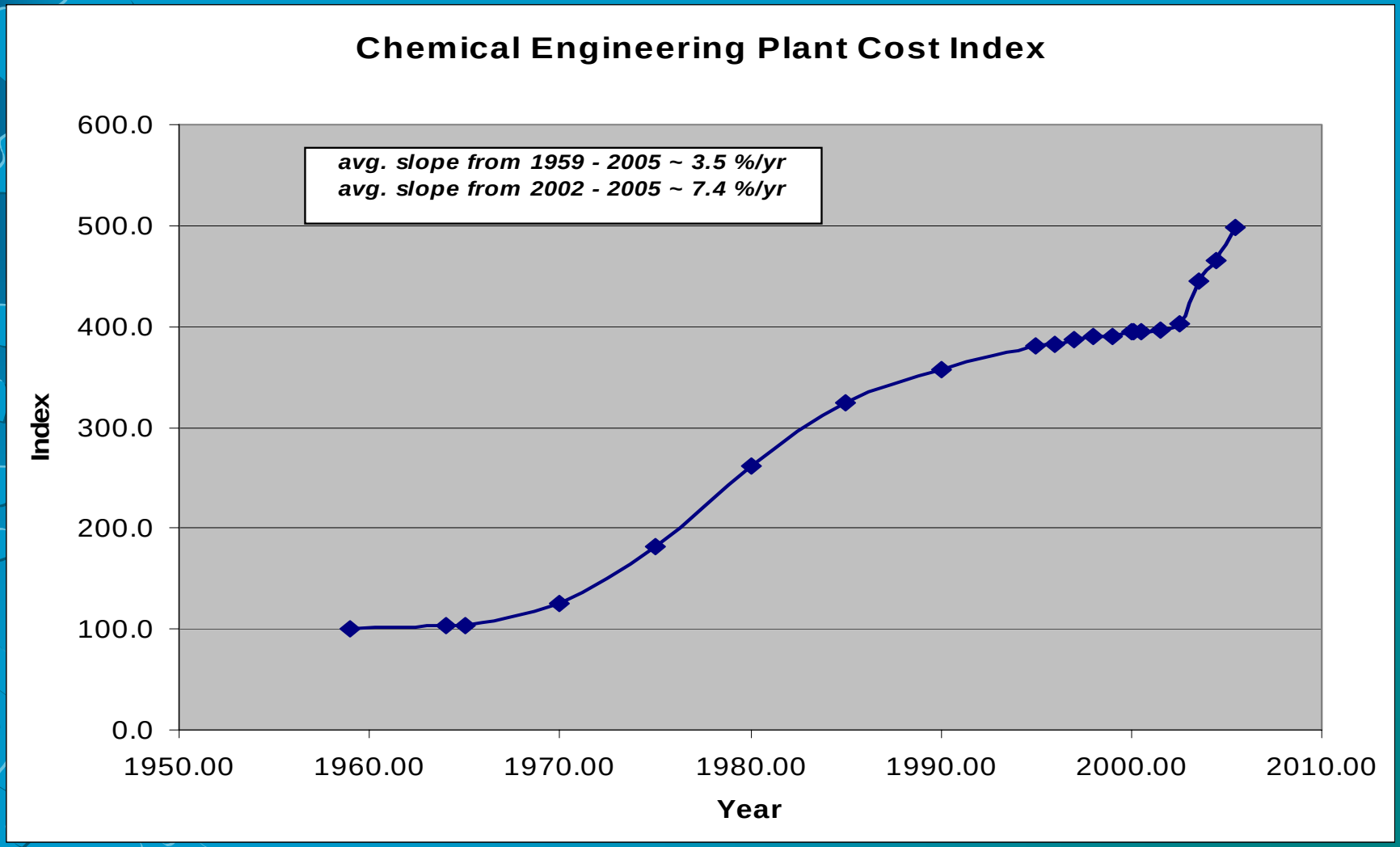
Construction start	Estimated Overnight	Actual Overnight	% Over
1966-1967	$560/kW	$1170/kW	209%
1968-1969	$679/kW	$2000/kW	294%
1970-1971	$760/kW	$2650/kW	348%
1972-1973	$1117/kW	$3555/kW	318%
1974-1975	$1156/kW	$4410/kW	381%
1976-1977	$1493/kW	$4008/kW	269%

Mark Gielecki and James Hewlett, Commercial Nuclear Power in the United States: Problems and Prospects, US Energy Information Administration, August 1994.

That Was Yesterday – This Is Today's Picture



A Steeper Curve Today Than in the Mid 1980s



Start by Getting Real

- Use data from eight recent Asian plants
  - Assume 4% real escalation from 2002-2007 and through 6-yr completion
  - 50/50 debt equity, with 3% equity premium
  - 75 percent lifetime capacity factor
  - Higher fuel cycle costs (2-4x current levels)
  - Capital cost - $4540/kW ($4000/kW in 2007 dollars)
  - Real discounted costs – 11 cents/kWh versus 5-7 cents/kWh for wind and 0-4 cents/kWh for conservation
- WNA study? 2-3 cents/kWh

Myth Two: Learning is Easy

- More standardized design and better construction practices
- But, “learning curves” can go in reverse, driven by:
  - Skilled labor and materials shortages
    - GE/Toshiba study for TVA Bellefonte found insufficient skilled labor within 400 mile radius to support rapid construction schedule
    - Only one steel mill – in Japan – currently available for pressure vessel forgings
    - Other pinch points throughout the supply chain, with potential for monopoly pricing
  - Fragmented market structure – different utilities; different contractors
  - Questionable public acceptance of additional repositories
  - Growing concern and opposition, regulatory delays, and possible loss of investor and utility confidence

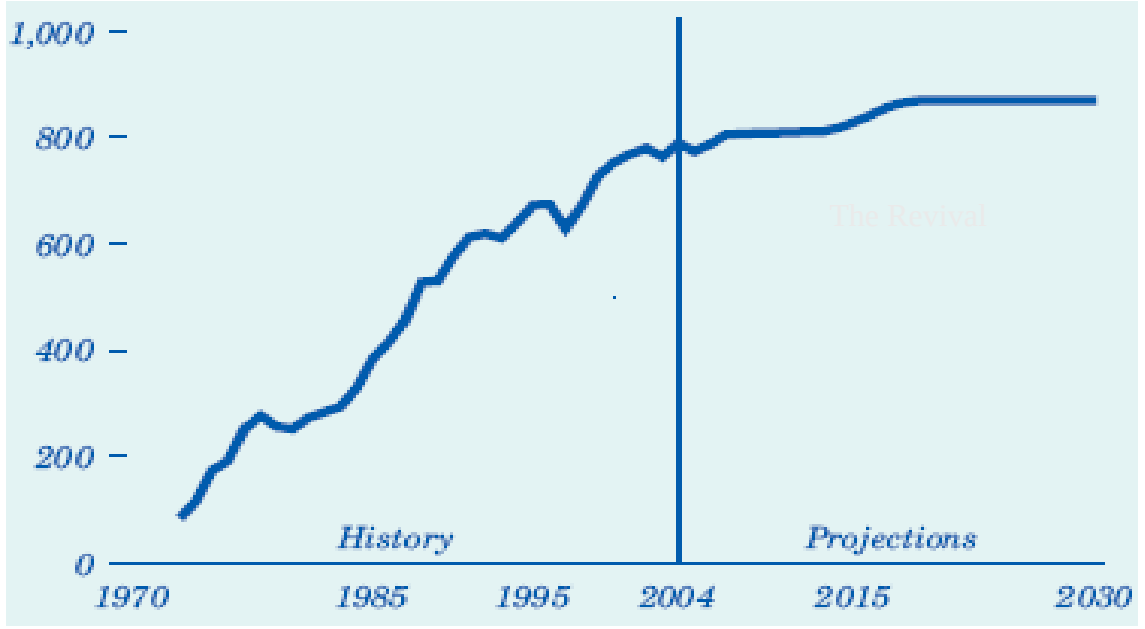
Myth Three: This Industry Can Scale Up Rapidly

- Shortages of skilled contractors, labor, and key parts inevitably lead to cost escalation and delay
- Fuel supply – not uranium in the ground – but mines, mills, and enrichment capacity are a huge problem
- Huge job simply to keep pace with retirements – need 8 new plants per year for the next ten years and 20 per year for the following decade vs. 1 per year globally since 2000

US Government (EIA) Projections of New Nuclear Power

EPACT2005 Tax Credits Are Expected To Stimulate New Nuclear Builds

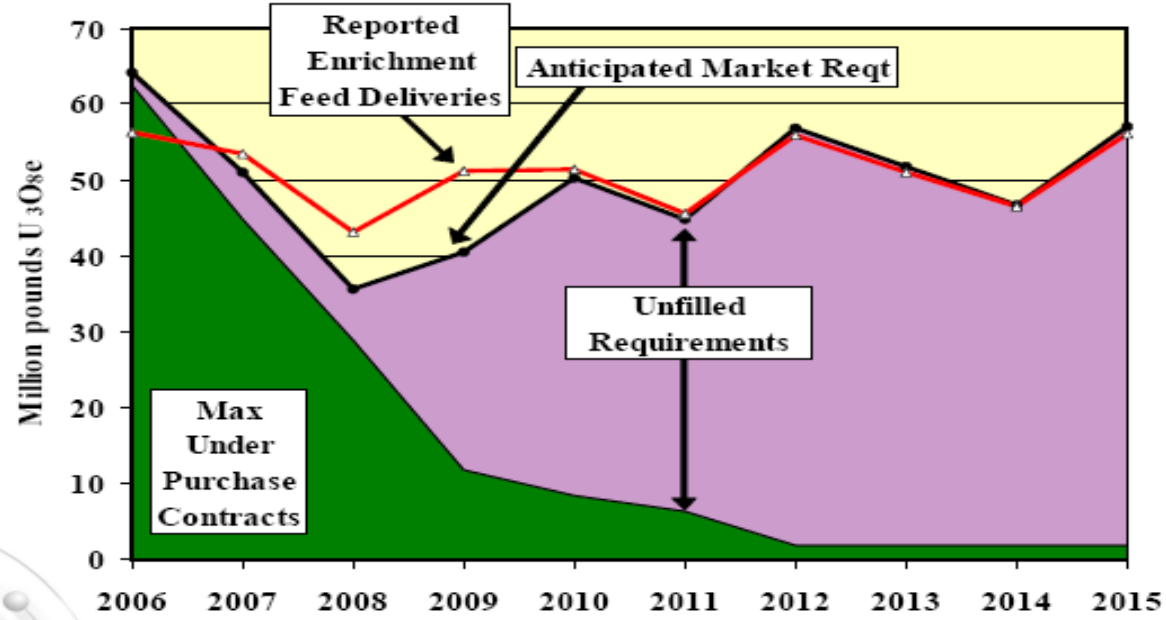
Figure 59. Electricity generation from nuclear power, 1973-2030 (billion kilowatthours)



Fuel Supply Issues

- **Western uranium production (37 kTU) is about half current consumption (62 kTU)!**
  - Excess utility and Russian inventories from cancelled and shutdown plants (1980-1990s, and after Chernobyl)
  - US enrichment privatized (1998-2006)
  - Surplus Russian weapons uranium (1999-2013)
  - So – prices well below cost, short term contracts with price ceilings, no new development
- **Enrichment capacity is also priced below marginal cost**
  - New plants would lose money at current price
  - Low uranium prices led to 25% higher output with more uranium wasted
- **Long lead times for expanding both - worse than California's failed electricity market experiment**

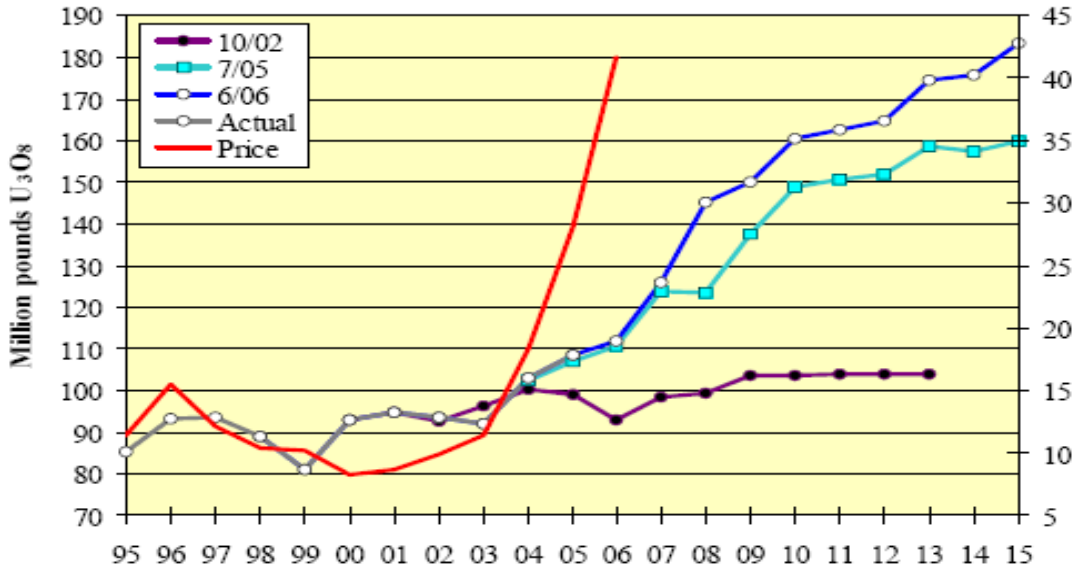
EIA Anticipated U.S. Uranium Market Requirements



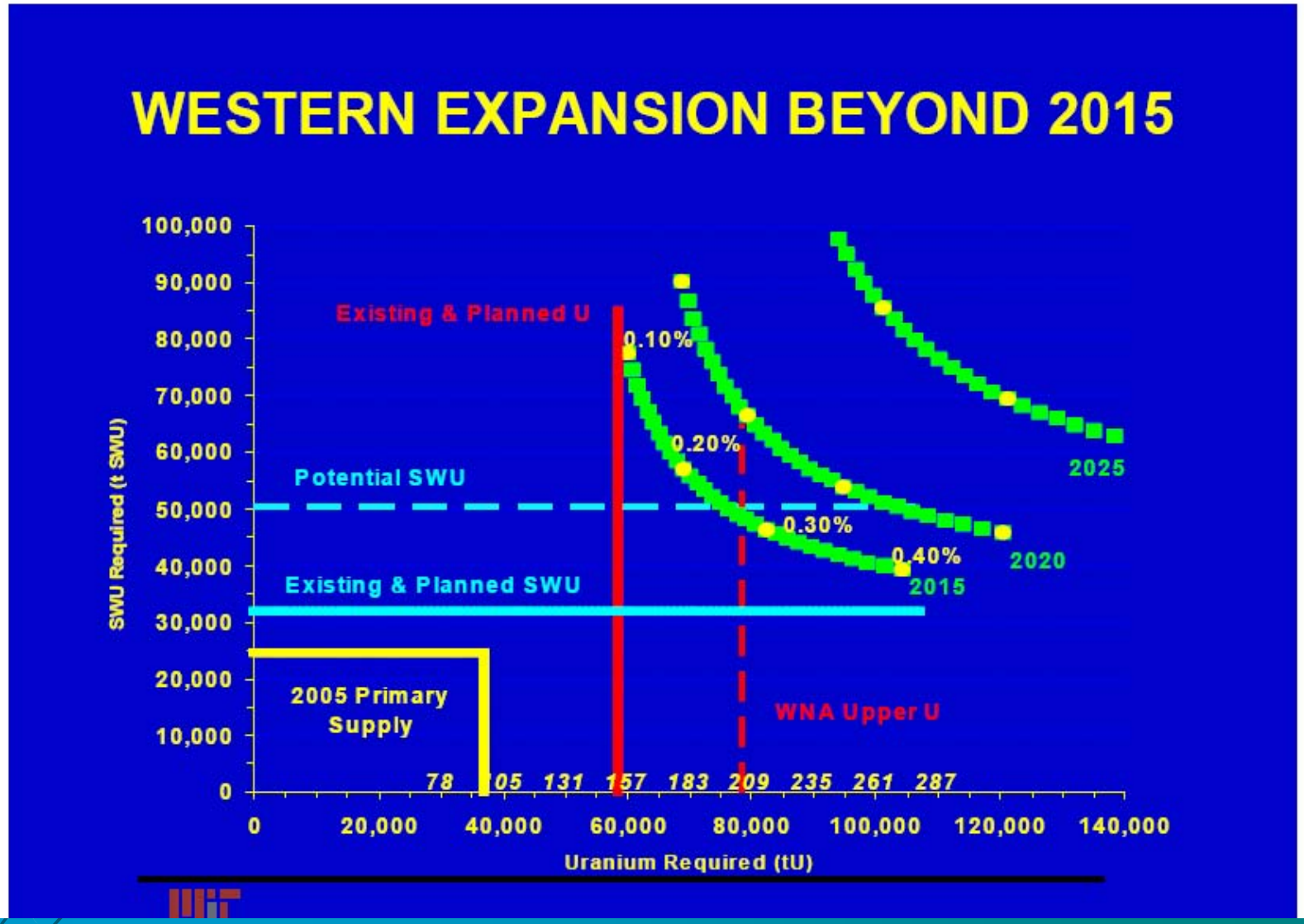
Source: EIA *Uranium Marketing Annual Report*, May 2006

Jeff Combs, President, Ux Consulting Company, Price Expectations and Price Formation, presentation to Nuclear Energy Institute International Uranium Fuel Seminar 2006

Changes in U Production Plans



Combs, October 2006. **Prices in mid February 2007 were $85/lb – off the chart.**



Tom Neff (MIT), Uranium and Enrichment: Enough Fuel for the Nuclear Renaissance?, December 2006.

FUELING THE NUCLEAR RENAISSANCE

- Substantial new orders for reactors will require heroic efforts to expand primary uranium & enrichment supply
- Secondary supply is highly problematic (MOX, Russian exports, HEU, government sales)
- Utilities will start seeking fuel when they order reactors, likely before new supply is available—problems arise sooner than charts show
- Prices will rise for U and SWU, perhaps above historical levels ($120/lb U3O8 ($315/kgU), $250/SWU in 2006 USD)

Myth Four: Reprocessing Solves the Supply Problem

- Reprocessing is expensive – probably 3x once-through nuclear fuel cost – and very capital intensive
  - Rokkasho (Japan) ~ $20 billion/800 MTHM/yr
  - More than $2400/kg just for capital return
- Limited capacity to use mixed oxide fuel in current reactors (about ¼ core without modifications)
- The U and SWU bubbles will burst some time; new reprocessing is extremely risky

Fuel cycle steps	MIT	This analysis
Uranium	$30/kg	$160-265/kg
Enrichment	$100/SWU	$200-250/SWU
Fabrication	$275/kg	$275/kg
Disposal	$400/kg	$400/kg
Reprocessing	$1000/kg	$1250-2000/kg
Fuel cycle cost		
Open	5 mills/kWh	12-17 mills/kWh
Closed	20 mills/kWh	21-35 mills/kWh
Differential	4x	1.3-3x

Myth Five: Waste is No Big Deal

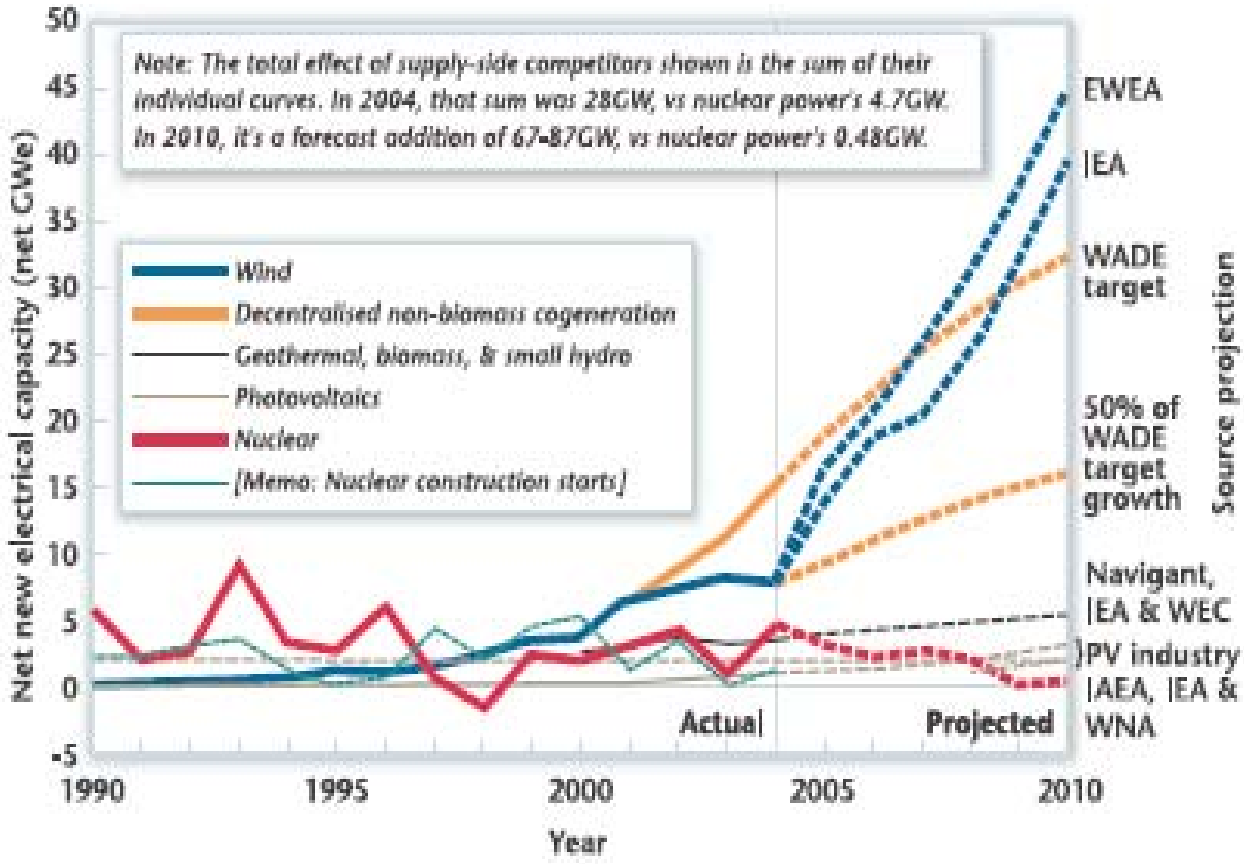
- Uranium mill tailings contain 85% of the radioactivity in the original ore, often left on the surface to contaminate building materials and water supplies – effects often limited to indigenous peoples in US, Australia, Canada, etc
- Yucca is in serious trouble
  - **It has reached its statutory volume limit**
  - **US NRC Commissioner McGaffigan** – "We've so ruined politics with the state of Nevada that we've never recovered. We're unlikely to recover. You cannot impose things on sovereign states." (February 16, 2007)
  - **Former US DOE project manager Lake Barrett** – "I think the program is in jeopardy." (February 19, 2007)

Myth Six: Reprocessing Solves the Radioactive Waste Problem

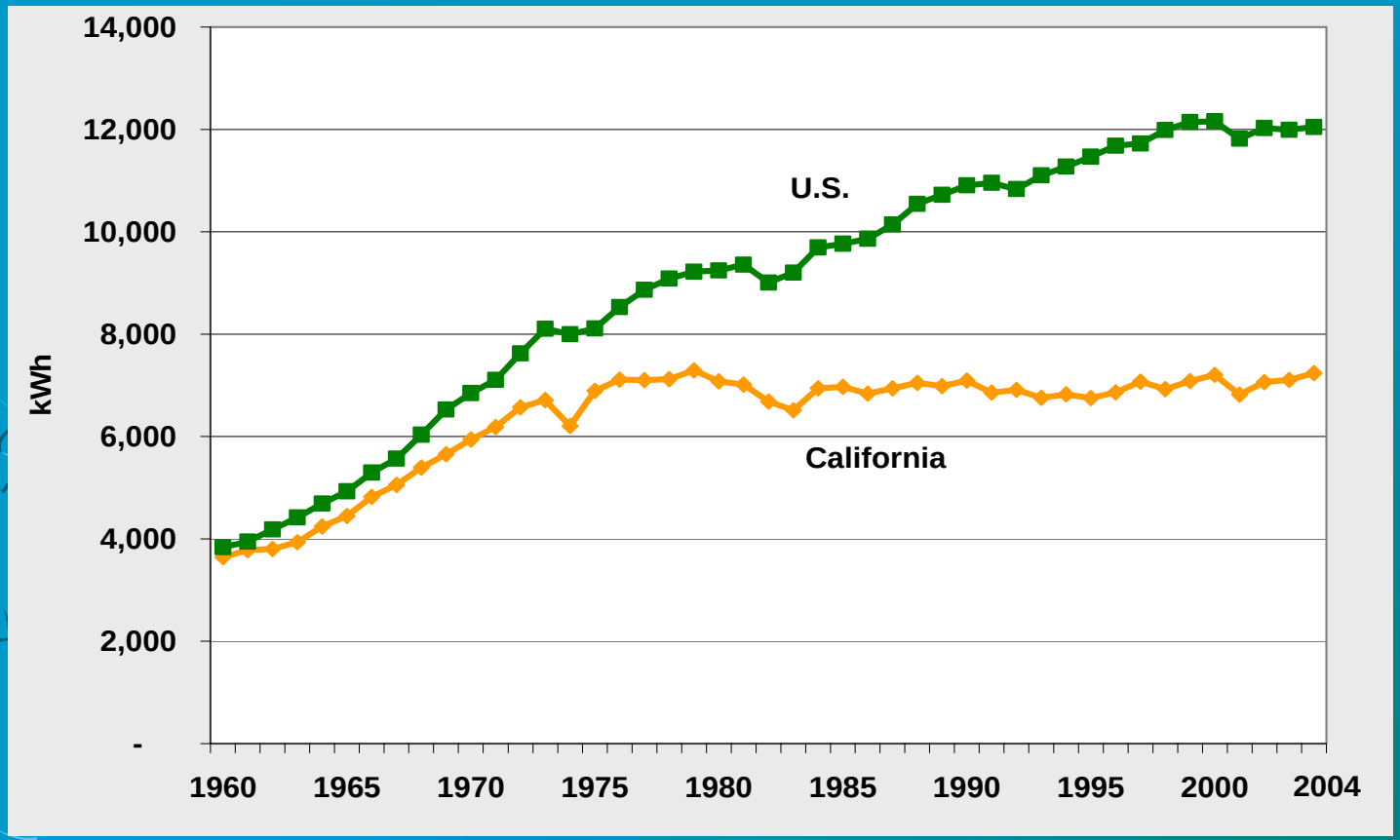
- GNEP – at the very least a $50 billion mistake
  - Trebles (at least) nuclear fuel cost
  - Expands Yucca capacity, primarily by leaving Sr-90 and Cs-137 above ground for hundreds of years
  - Relies on untested and unproven technologies for both actinide separation and advanced reactor operation
  - Accelerates near term proliferation risks
  - It will not happen

Myth Seven: The Alternatives Cannot Compete – They Already Do

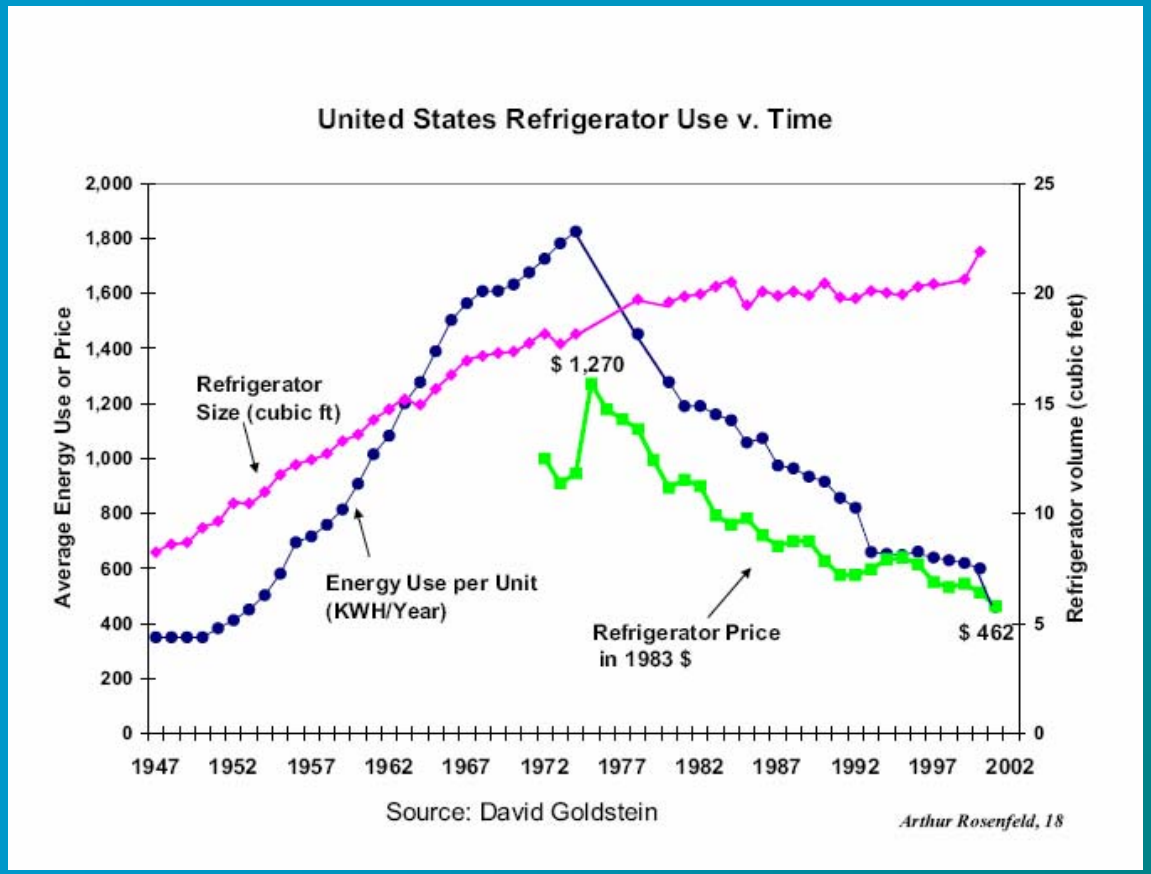
Figure 2:
Global additions of electrical generating capacity by year and technology



An Efficiency Success Story = 22 Fewer Reactors since 1970



The Fridge – size up 10%, cost down 60%, and efficiency up 75%



Finally – Rapid Technological Change in Renewables

- Larger more efficient wind turbines with offshore siting
- Extremely rapid progress in photovoltaic technology
- Take one example --- Nanosolar
  - started by the Google founders, backed also by Swiss Re
  - Building two 430 MW/yr thin film PV production facilities this year in Germany and California, using a technology they equate to printing newspapers
  - Non silicon CIGS technology (copper indium gallium diselenide)
  - **Target price is $0.50/peak watt --- cheaper than delivered electricity price in most parts of the world**
  - Will it work? Will they last? Perhaps – we will know soon.
- Twenty years from now light water reactor technology will be roughly the same as it is today