Is it Time to Embrace Nuclear Energy?

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- **Panel Detail:**
- **Monday, April 27, 2009**
  2:30 PM - 3:45 PM Is It Time to Embrace Nuclear Energy?

- **Speakers:**
  Lady Barbara Thomas Judge, Chairman, United Kingdom Atomic Energy Authority
  Amory Lovins, Co-Founder, Chairman and Chief Scientist, Rocky Mountain Institute
  David Scott, Executive Director, Economic Affairs, Executive Affairs Authority of Abu Dhabi

  Moderator:
  Peter Passell, Senior Fellow, Milken Institute; Editor, *The Milken Institute Review*

Nuclear power generation growing

Billion megawatt hours

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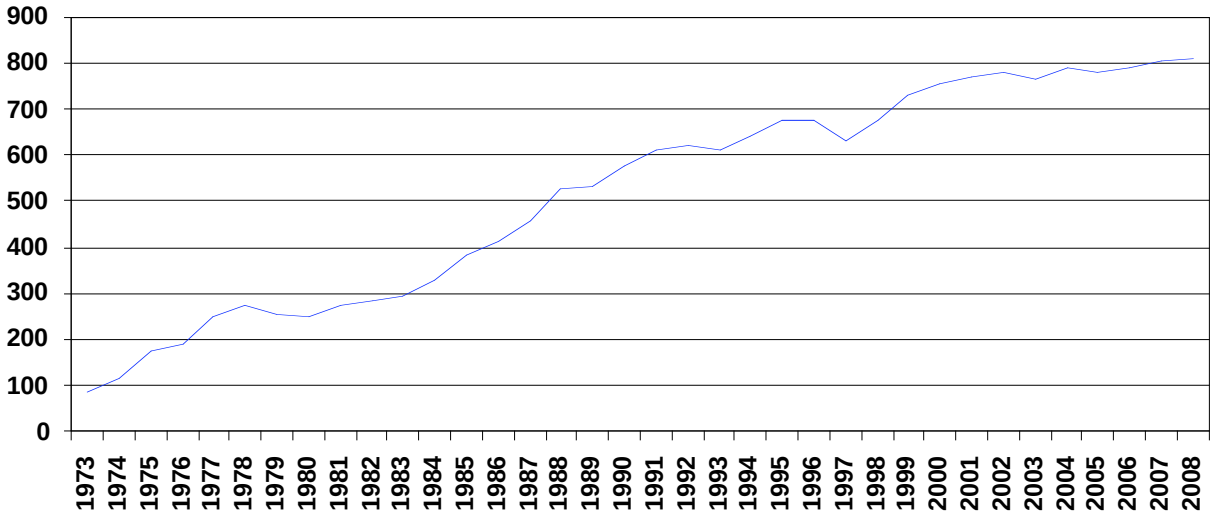

Source: Energy Information Administration.

Nuclear infrastructure flat in last ten years

Nuclear Generating Units, Total Operable Units

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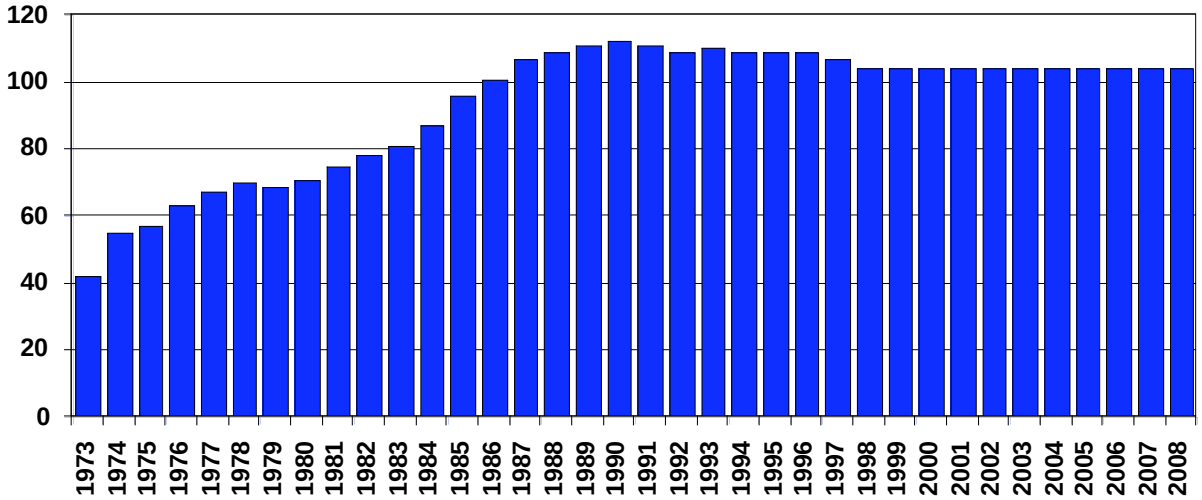
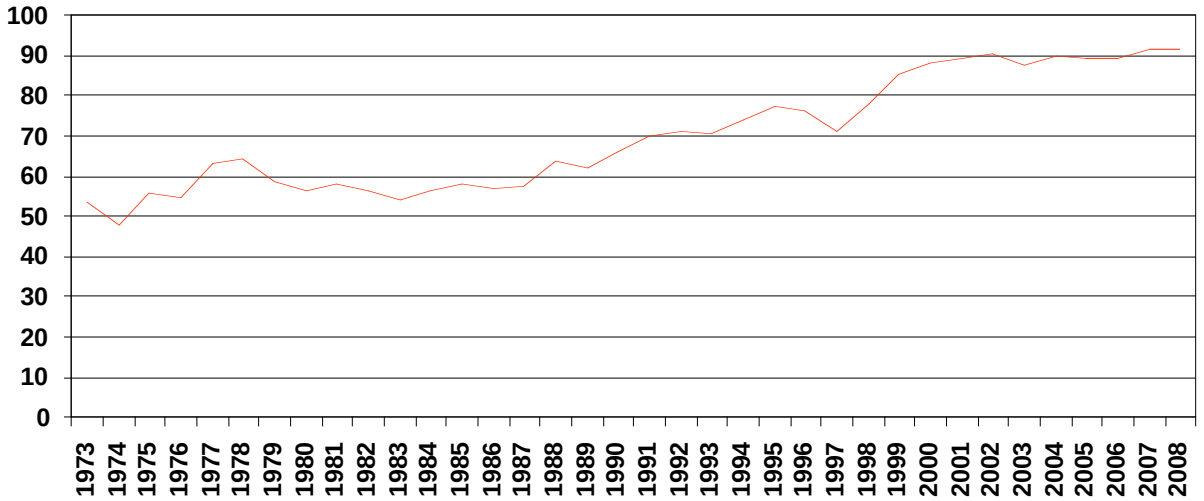


Source: Energy Information Administration.

Nuclear generating units, capacity factor

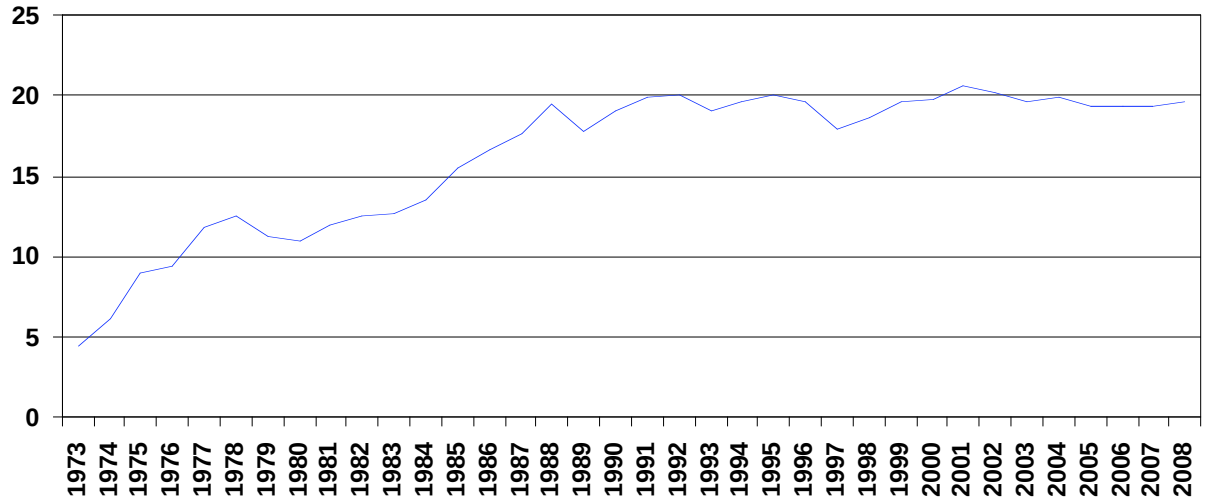
Percent



Source: Energy Information Administration.

Nuclear energy's share of net generation

Percent



Source: Energy Information Administration.

Nuclear generation, current and projected for 2030 *Terawatt hours*

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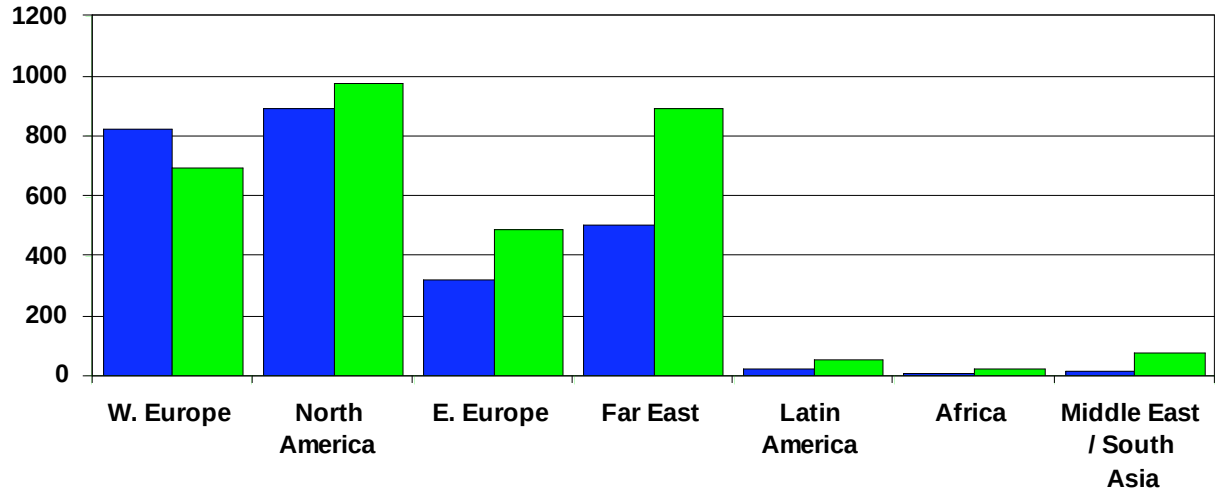

Source: Energy Information Administration.

Known recoverable resources of uranium *Tons of uranium, 2007*

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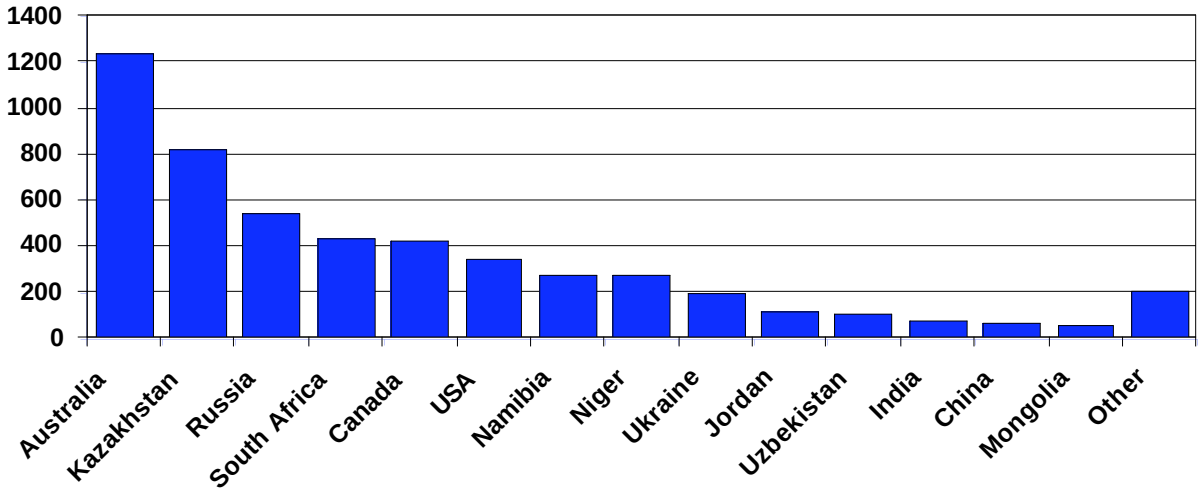

Source: World Nuclear Association.

Uranium concentrations in minerals

Parts per million

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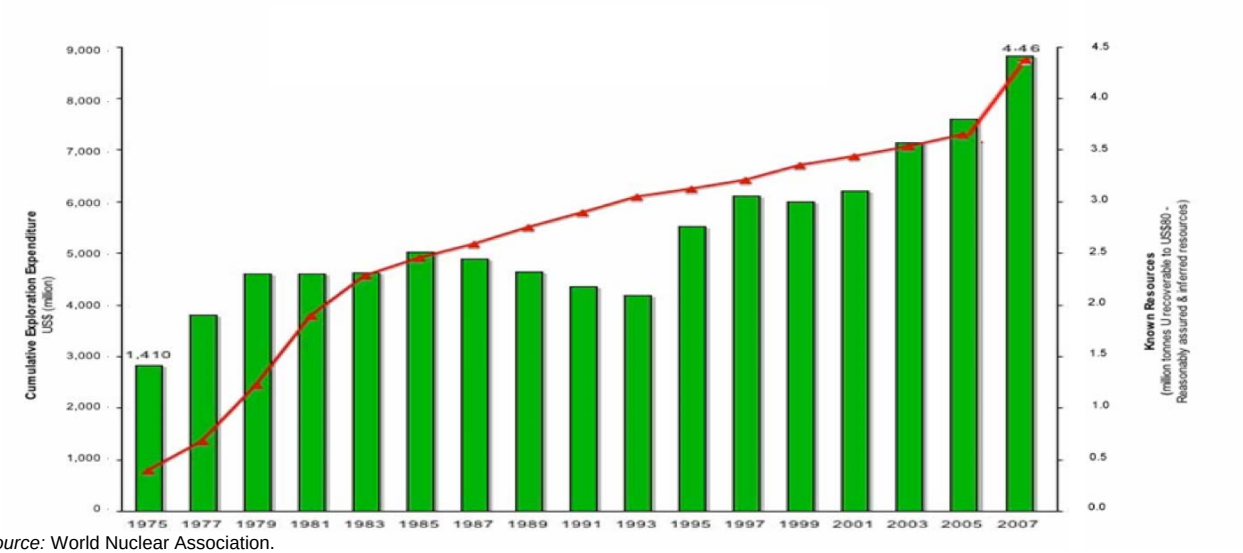
Material	Concentration
Very high-grade ore (Canada) - 20% U	200,000
High-grade ore - 2% U	20,000
Low-grade ore - 0.1% U	1,000
Very low-grade ore (Namibia) - 0.01% U	100
Granite	4-5
Sedimentary rock	2
Earth's continental crust	2.8
Seawater	0.003

Source: World Nuclear Association.

Known Uranium Resources + Exploration



Source: World Nuclear Association.

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Panelist slides

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Amory Lovins

1989 supply curve for saveable U.S. electricity (*vs.* 1986 frozen efficiency)

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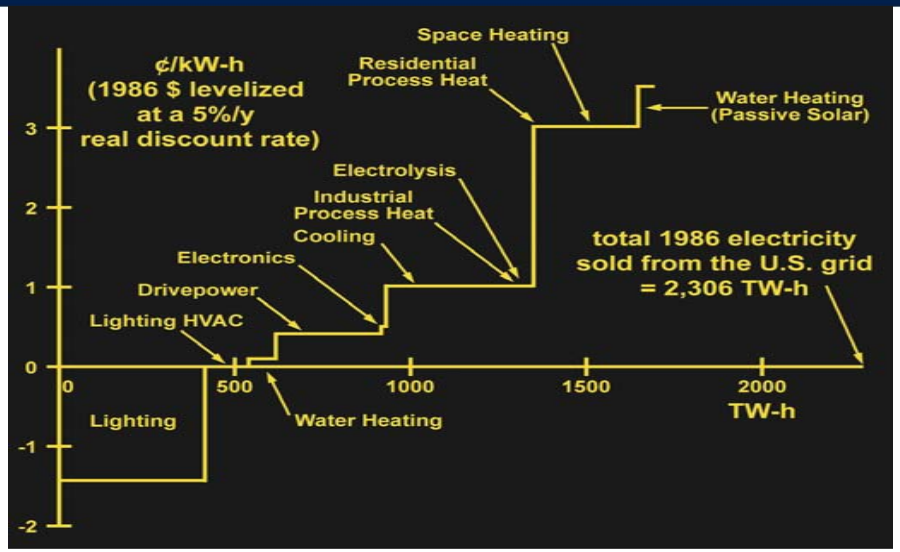

Best 1989 commercially available retrofittable technologies

Similar in S, DK, D, UK…

EPRI found 40–60% saving potential for 2000

Now conservative: savings keep getting bigger and cheaper, and integrative design makes many cost <0

Source: Lovins *et al.*, RMI, *Technology Atlases*, 1986–92, 6 vols, 2,509 pp, 5,135 notes: measured cost & performance for ~1,000 end-use efficiency technologies

Electric shock: low-/no-carbon decentralized sources are eclipsing central stations

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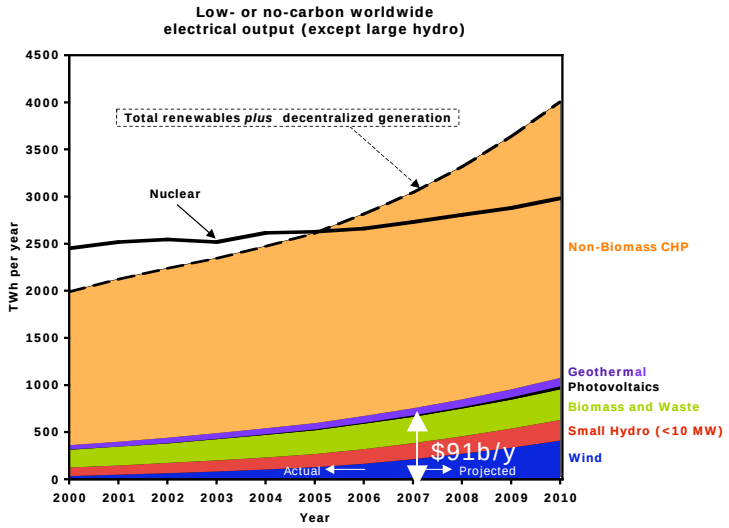

- Mostly cogeneration (CHP), mainly gas-fired, saving ≥50% of fuel, CO_2, and cost
- 1/3 renewable (hydro only if ≤10 MW_e)
- *1/6 of total and 1/3 of new electricity*
- 1/6 to >1/2 of all el. in 12 industrial nations
- Negawatts look comparable or bigger, so central plants have <1/2 of el. service market!
- Micropower is winning due to its lower costs and financial risks, so it gets private capital
- In 2006, nuclear added less capacity (1.44 GW, 100+% from upratings) than PVs added, 10× less than windpower added, 30–41× less than micropower added
- In 2007, China, Spain, & U.S. each added more windpower than the world added nuclear capacity; U.S. added more windpower than it added 2003–07 coal capacity

Source: www.rmi.org/sitepages/pid171.php#E05-04; Lovins & Sheikh, www.rmi.org/images/PDFs/Energy/E09-01_NuclPwrClimFixFolly1i09.pdf

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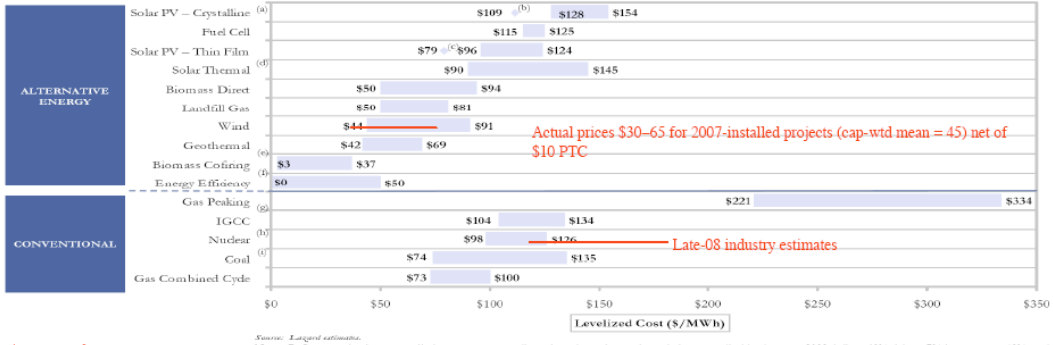
Many renewables can compete *now*

LEVELIZED COST OF ENERGY ANALYSIS

Levelized Cost of Energy Comparison At the Busbar, Not Delivered

Certain Alternative Energy generation technologies are already cost-competitive with conventional generation technologies under some scenarios, even before factoring in environmental and other externalities (e.g., RECs, potential carbon emission costs, transmission costs) as well as the fast-increasing construction and fuel costs affecting conventional generation technologies



Assuming zero carbon price

Source: Lazard estimates.

Note: Reflects production tax credit, investment tax credit, and accelerated asset depreciation as applicable. Assumes 2008 dollars, 60% debt at 7% interest rate, 40% equity at 12% cost, 20-year economic life, 40% tax rate, and 5-20 year tax life. Assumes coal price of $2.50 per MMBtu and natural gas price of $8.00 per MMBtu.

(a) Low end represents single-axis tracking crystalline. High end represents fixed installation.
(b) Represents a leading solar crystalline company's targeted implied levelized cost of energy in 2010, assuming a total system cost of $5.00 per watt. Company guidance for 2012 total system cost of $4.00 per watt would imply a levelized cost of energy of $90 per MWh.
(c) Represents the leading thin-film company's targeted implied levelized cost of energy in 2010, assuming a total system cost of $2.75 per watt. Company guidance for 2012 total system cost of $2.00 per watt would imply a levelized cost of energy of $62 per MWh.
(d) Low end represents solar tower. High end represents solar trough.
(e) Represents retrofit cost of coal plant.
(f) Estimates per National Action Plan for Energy Efficiency; actual cost for various initiatives varies widely.
(g) High end incorporates 90% carbon capture and compression.
(h) Does not reflect potential economic impact of federal loan guarantees or other subsidies.
(i) Based on advanced supercritical pulverized coal. High end incorporates 90% carbon capture and compression.

"What is clear is that it is completely impossible to produce definitive estimates for new nuclear costs at this time…."

—Steve Kidd, VP Strategy & Research, World Nuclear Association, *Nucl. Eng. Intl.*, 21 Aug 2008

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Date	*Source*	*U.S. nuclear construction cost, 2007 $/W, including interest*	*Levelized busbar '07 $/MWh*
7/03	MIT Study	2.3	77–91
6/07	Keystone Study Group	3.6–4.0	83–111
11/07	Harding	4.3–4.6	~180
5/07	Standard & Poor's	~4	
8/07	American Electric Power	~4	
10/07	Moody's	5–6	
3/08	Florida Power & Light filing	~4.2–6.1, 3.1–4.5 overnight (*i.e.*, without interest or real escalation)	
3/08	Constellation Energy	3.5–4.5 overnight	
5/08	Moody's	7.3	146
6/08	Lazard	5.6–7.4	96–123
11/08	Duke Energy	4.8 overnight	

Harding warns that *cost estimates vary widely in buyer's risk:* high estimates have more fixed or firm pricing, low estimates have more variable pricing, and the mix of risk allocation is almost always secret

Nuclear power: costliest no-/low-carbon option

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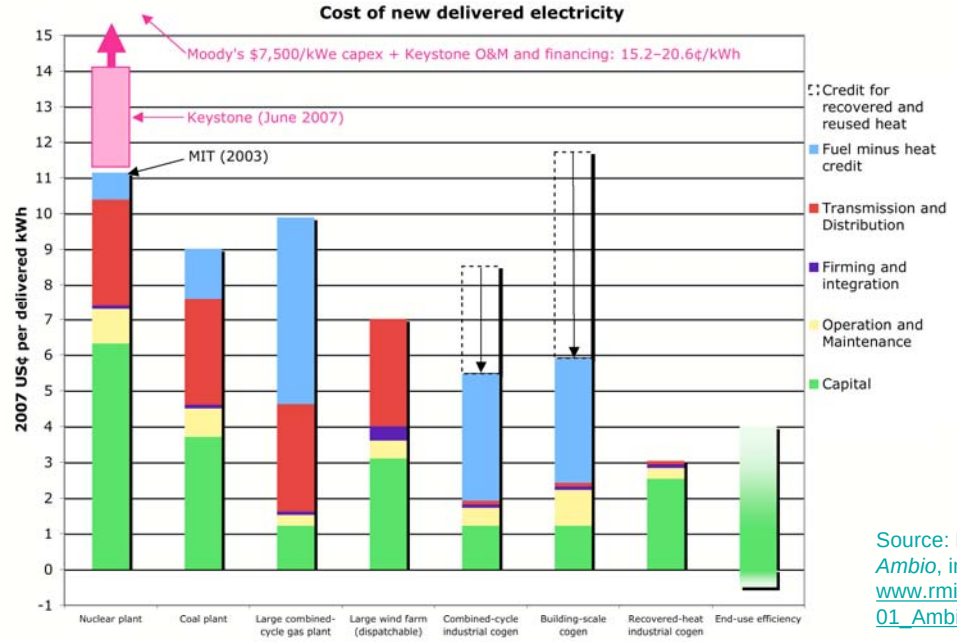
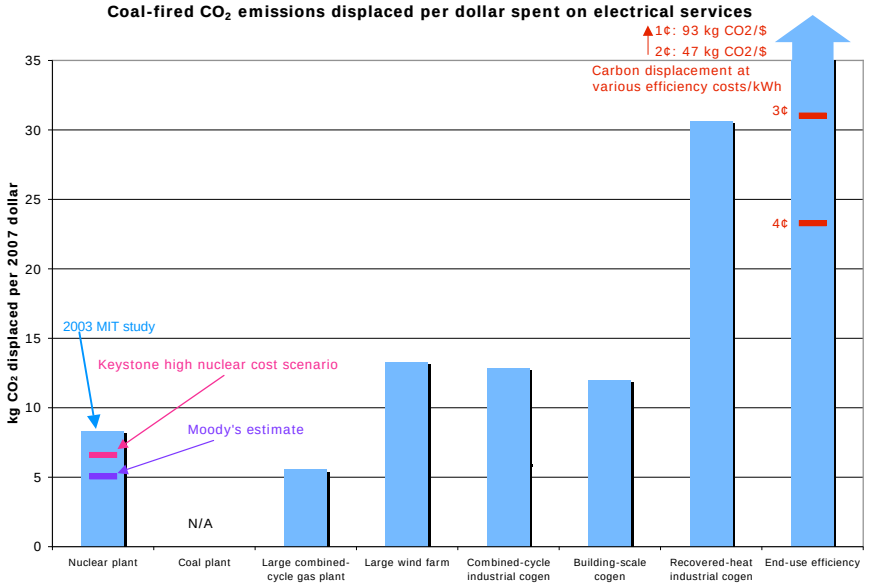


Delivered to the retail meter, electricity from a new U.S. nuclear plant will cost ~15–21¢/kWh in levelized 2007 dollars. That's ~2–3× the cost of firmed wind-power, ~3–7× that of cogeneration, and ~5–20^{+}× that of end-use efficiency. All costs shown are those *empirically observed in the marketplace* in 2007–8.

Source: Lovins & Sheikh, "The Nuclear Illusion," *Ambio*, in press, 2009, preprinted at www.rmi.org/images/PDFs/Energy/ E08-01_AmbioNuclIllusion.pdf

The cheapest *and* lowest-carbon resources save the most carbon per dollar



New nuclear saves 2–20^{+}× less carbon per dollar, ~20–40× slower, than efficiency and micropower investments

Buying new nuclear *instead of* efficiency results in more carbon release than if the same money had been spent buying a new coal-fired power plant

Source: Lovins & Sheikh, "The Nuclear Illusion," *Ambio*, in press, 2009, preprinted at www.rmi.org/images/PDFs/Energy/ E08-01_AmbioNucIllusion.pdf

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David Scott

Nuclear New Build Cost Cycle

Where are we today?

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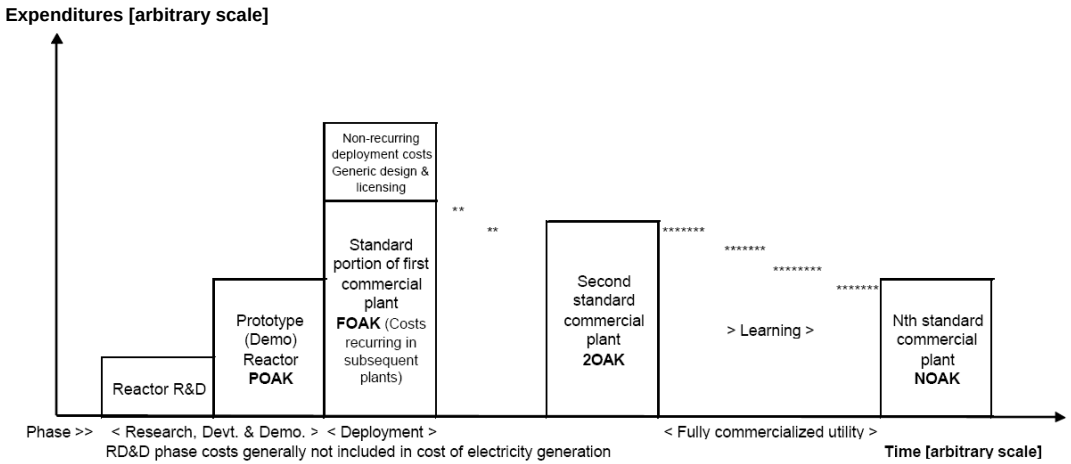
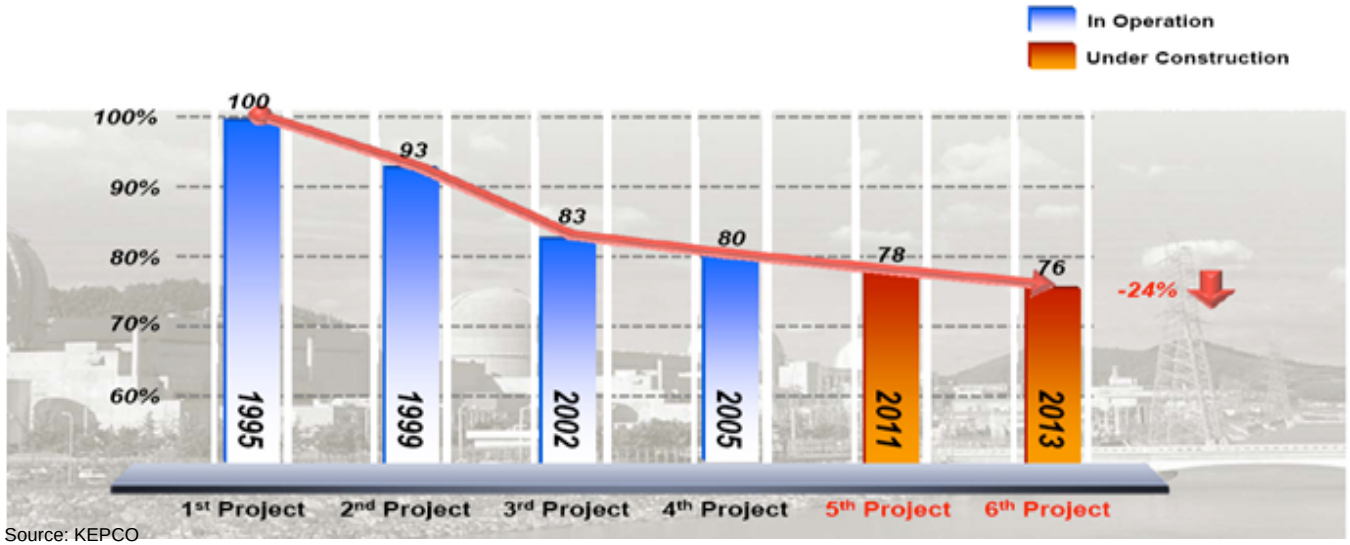
Figure 1.1 Temporal relationships of RD&D, deployment, and standard plant costs



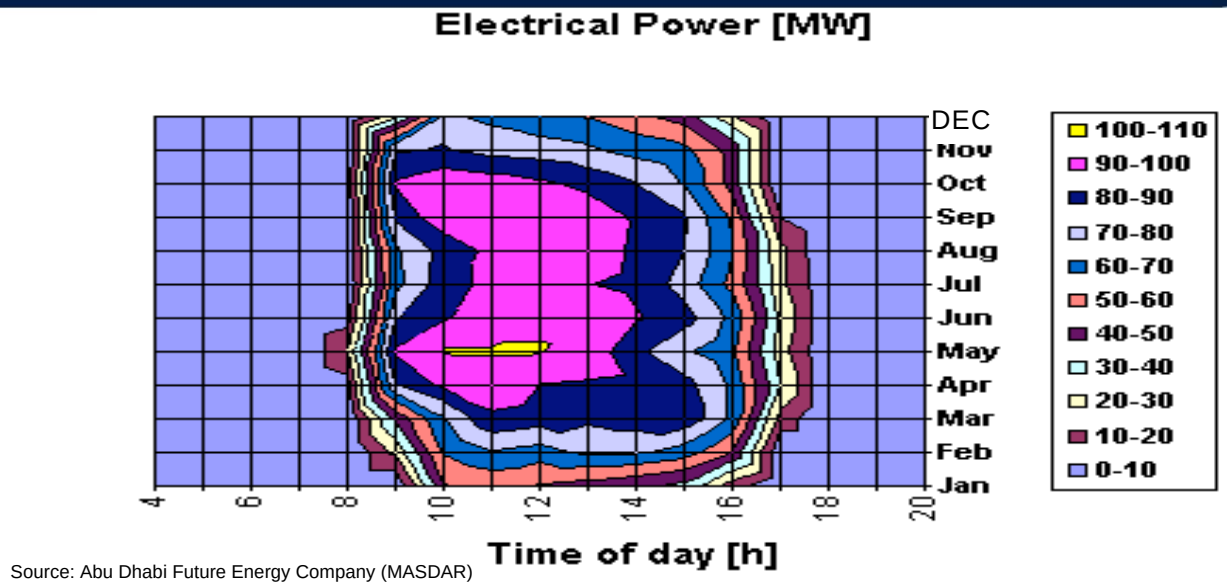
Source: *Cost Estimating Guidelines for Generation IV Nuclear Energy Systems*, US DOE

Korean OPR 1000 Cost Performance



Source: KEPCO

Abu Dhabi Solar Capacity (100 MW TSP)



Source: Abu Dhabi Future Energy Company (MASDAR)

The UAE Non-Proliferation Model

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