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REINVENTING FIRE

Nuclear Power's Competitive Landscape

Comparing Costs, Reliability, and Climate-Protection Potentials

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FROM IDEAS TO SOLUTIONS

What are nuclear power's competitors?

Conventional theology:

Only other central thermal plants (coal, combined-cycle gas)

- Efficiency and renewables are worthy but minor
- Variable renewables (wind and photovoltaics) aren't "24/7" or "baseload" and hence can't contribute "reliable" supply
- Carbon pricing will benefit nuclear

Heresy based on observed market behavior:

Not central plants (which are all uncompetitive) but negawatts (saved electricity) and micropower (cogeneration + distributed renewables)

- They're cheaper, faster, more reliable, more attractive to investors…and winning wherever they're allowed to compete
- Carbon pricing benefits them and nuclear equally (and fueled cogeneration partially)

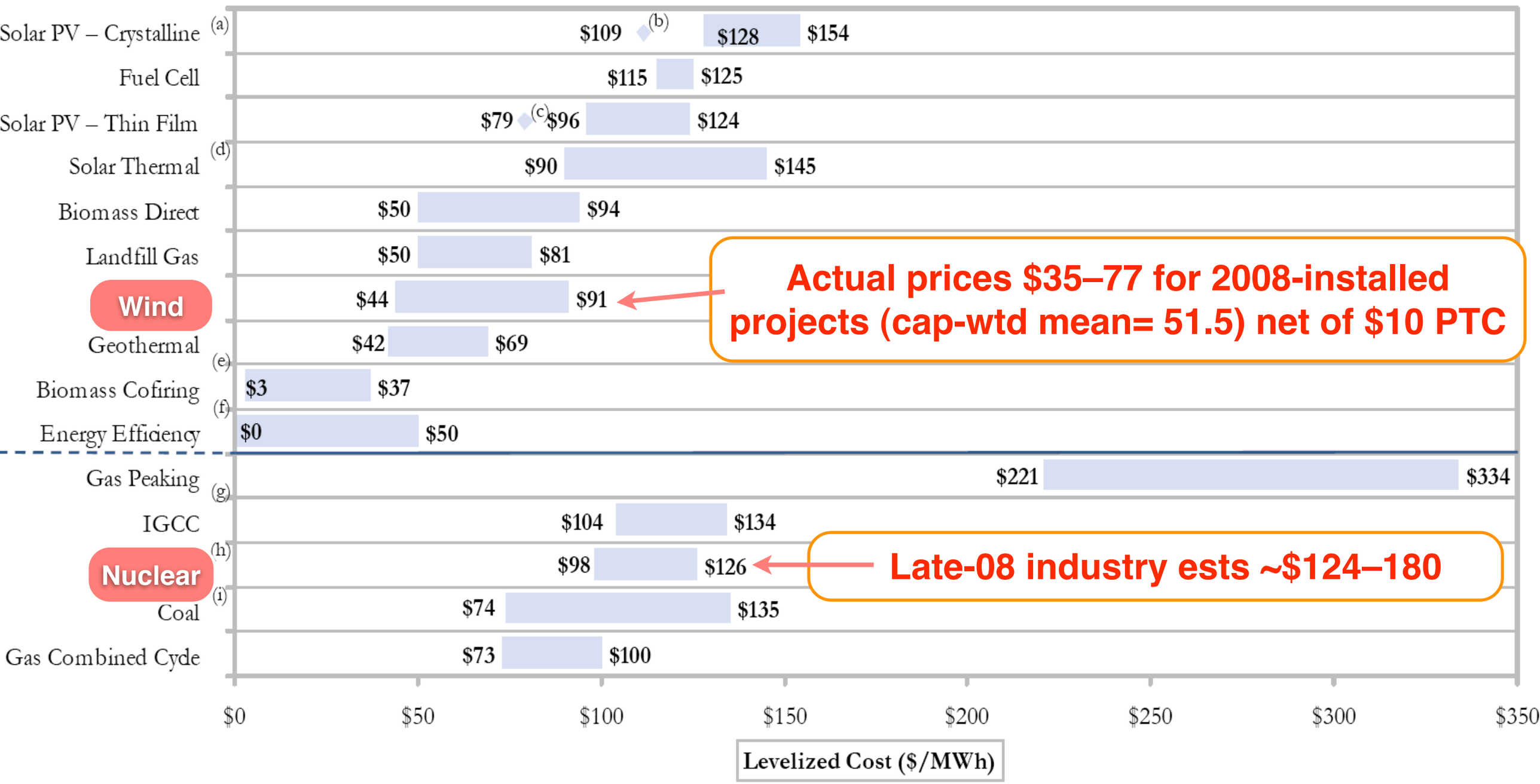
Competition from end-use efficiency

- Since 1975, California profitably held per-capita electricity use flat while per-capita real income rose 79%, saving ~$100b of el. capex
- RMI 2008: Using electricity as productively as the top 10 states did in 2005 (GSP/kWh adjusted for each state's economic mix and climate) would save ~1,200 TWh/y, or ~62% of U.S. coal-fired electricity
- McKinsey 2009: efficiency can very profitably save half of current U.S. coal-electric production by 2020
- EPRI 1990: U.S. could profitably save 40–60% of 2000 electricity use at an average cost ~3¢/kWh (2007 $)
- RMI 1990: long-run, that's ~75% at average cost ~1¢/kWh (2007 $)
- Utility program costs average ~1–2¢/kWh; the best are <1¢/kWh

Untapped savings are becoming far bigger/cheaper—radically so with integrative design, which all official studies ignore

Even without carbon pricing, many renewables can compete with new central plants today

Levelized cost of energy comparison: At the Busbar, Not Delivered



Source: Lazard, *Levelized Cost of Energy Analysis*, June 2008, v. 2.0 (2008 $, zero externalities)

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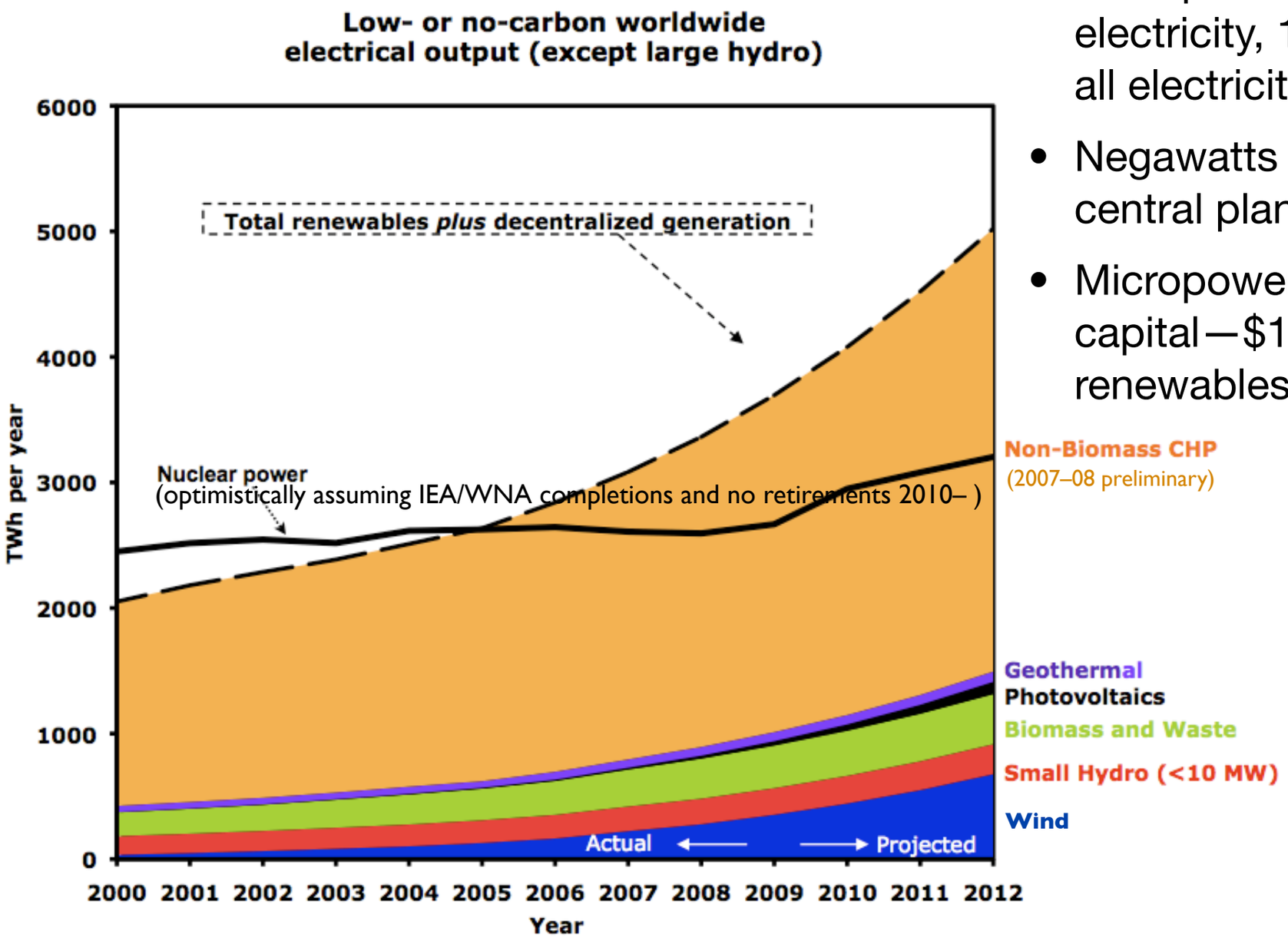
Low-/no-carbon distributed generators, too, are rapidly eclipsing central stations



- Micropower in 2006 delivered 1/6 of global electricity, 1/3 of new electricity, 1/6 to >1/2 of all electricity in a dozen industrial nations
- Negawatts look comparable or bigger, so central plants have <50% market share!
- Micropower is financed mainly by private capital—$100b/y in 2008 for distributed renewables alone, which added 40 GW

2006

2007

2008

China:
2010 ➢ 2020

Escalating U.S. nuclear construction cost estimates (including interest & real escalation unless *[overnight]*)

Date	Source	Capex, 2007 $/W	Levelized busbar 2007 $/MWh
7/03	MIT	2.3	77–91
6/07	Keystone	3.6–4.0, *[2.95]*	83–111
11/07	Harding	4.3–4.55	~180
5/07	S&P	~4	
8/07	AEP	~4	
10/07	Moody's	5–6	
3/08	FPL filing	~4.2–6.1, *[3.11–4.54]*	
3/08	Constellation	*[3.5–4.5]*	
5/08	Moody's	*7.3*	146
6/08	Lazard	5.6–7.36	96–123
11/08	Duke	*[5.0]*	
/09	ESKOM(SAfr)	*[6.0]*	

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
- The mix of risk allocation is always secret

Escalating construction cost estimates

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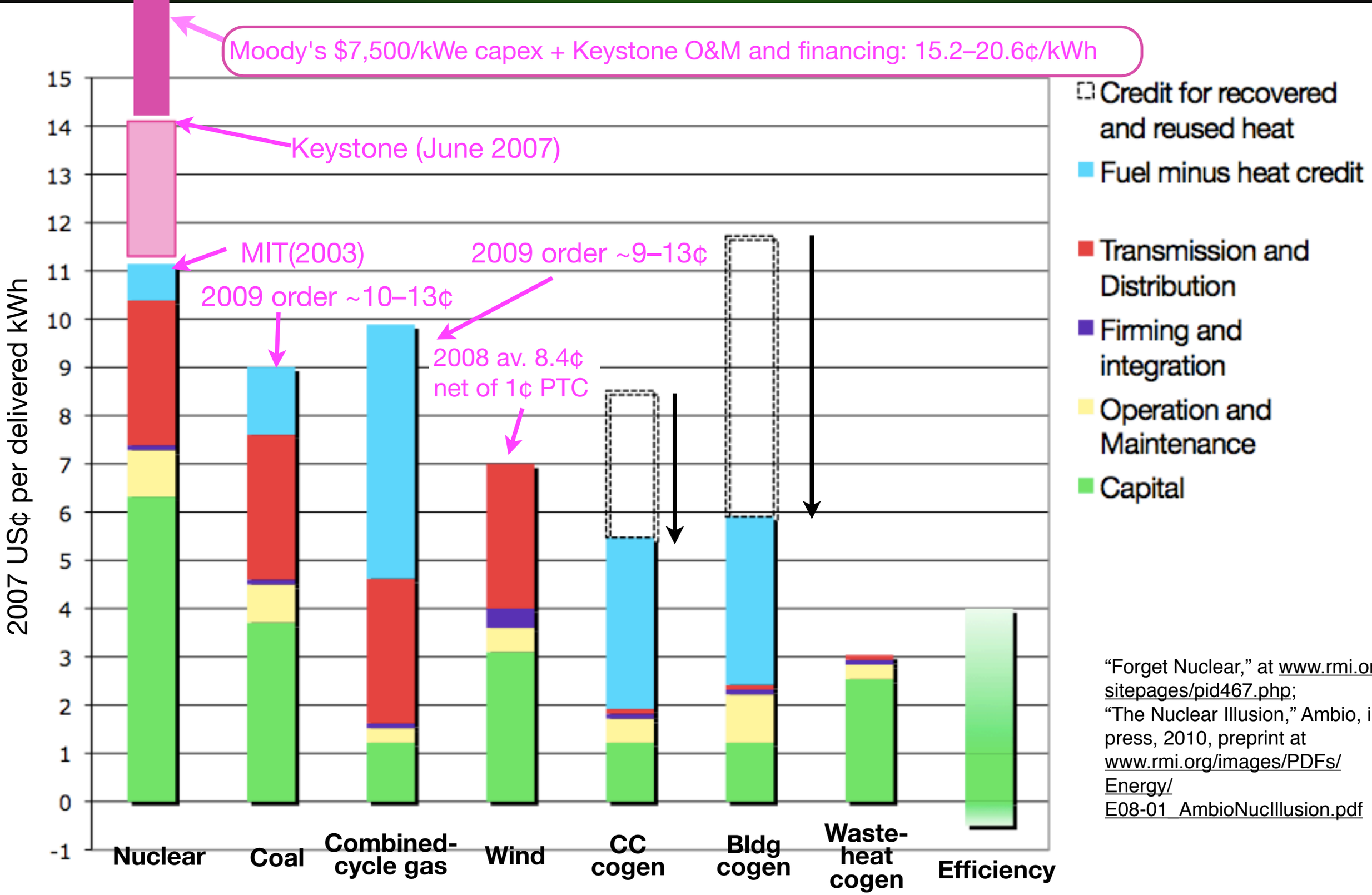
A reasonable and honest conclusion…

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

—Steve Kidd, Director of Strategy & Research, World Nuclear Association, *Nuclear Engineering International*, 22 August 2008, www.neimagazine.com/storyprint.asp?sc=2050690

New nuclear plants worldwide got zero at-risk private investments 2005–09 (only central planners bought them); then capital markets and growth in electricity demand both collapsed, making big plants unfinanceable anyhow

Nuclear is the costliest of the low- or no-carbon resources



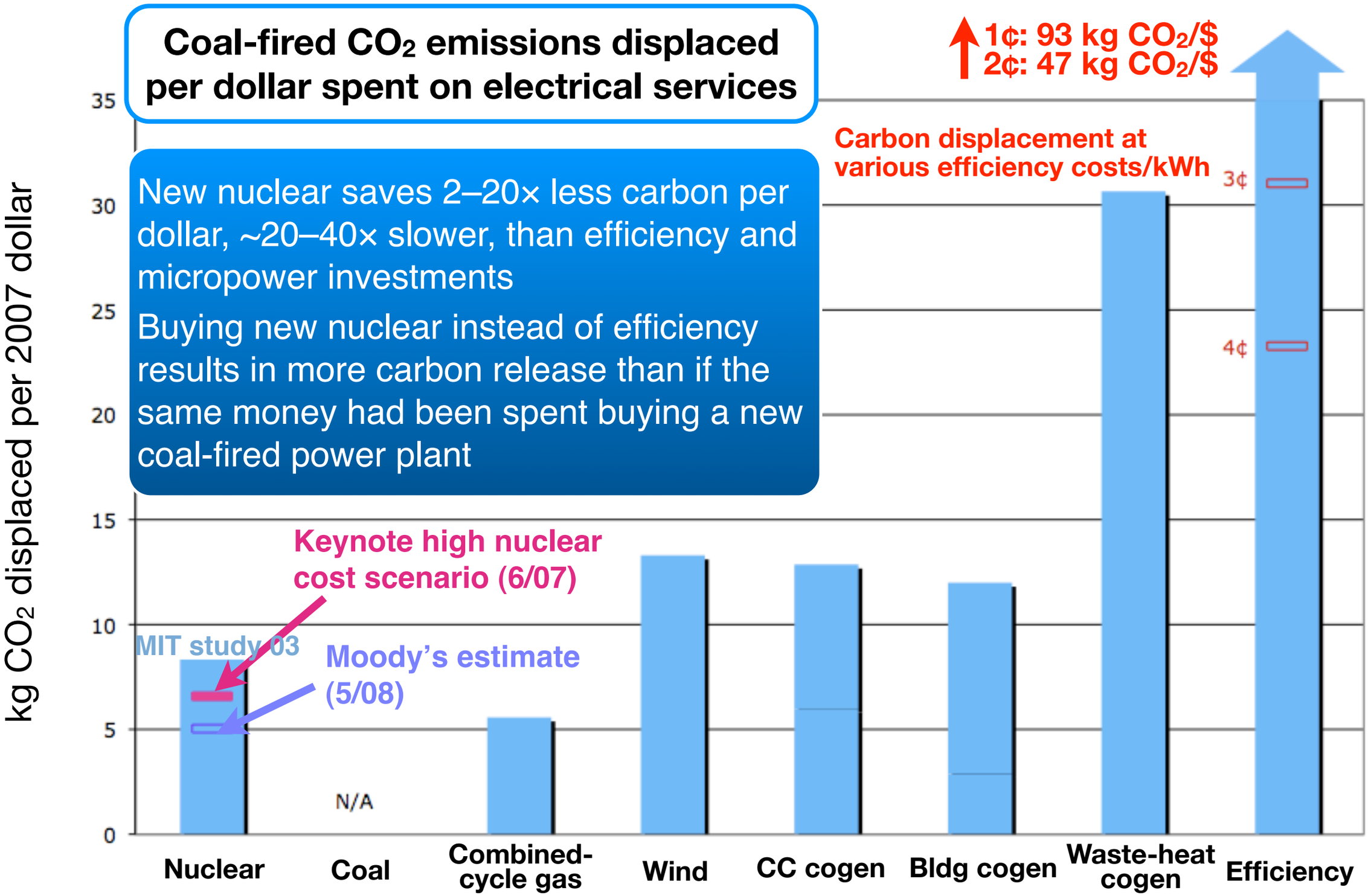
"Forget Nuclear," at www.rmi.org/sitepages/pid467.php;
"The Nuclear Illusion," Ambio, in press, 2010, preprint at www.rmi.org/images/PDFs/Energy/E08-01_AmbioNuclIllusion.pdf

The cheapest and lowest-carbon sources save the most CO_2 per dollar

Coal-fired CO_2 emissions displaced per dollar spent on electrical services

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



Major conservatisms in the foregoing comparisons

- End-use efficiency often has side-benefits worth 1– 2 orders of magnitude more than the saved energy
- End-use efficiency and distributed generators have 207 “distributed benefits” that typically increase their economic value by an order of magnitude
- Integrating renewables with each other typically saves over half their capacity for a given reliability
- Integrating strong efficiency with renewables typically makes them cheaper and more effective
- Efficiency & most renewables are getting cheaper, but our comparisons didn’t trend projected costs

Even solar power beats thermal plants within their construction lead time—at zero carbon price

Comparison: Solar PV vs 500 MW Coal Plant

For an equivalent amount of annual energy, PV generates at 10% lower cost and installs in shorter time than a coal power plant . . .

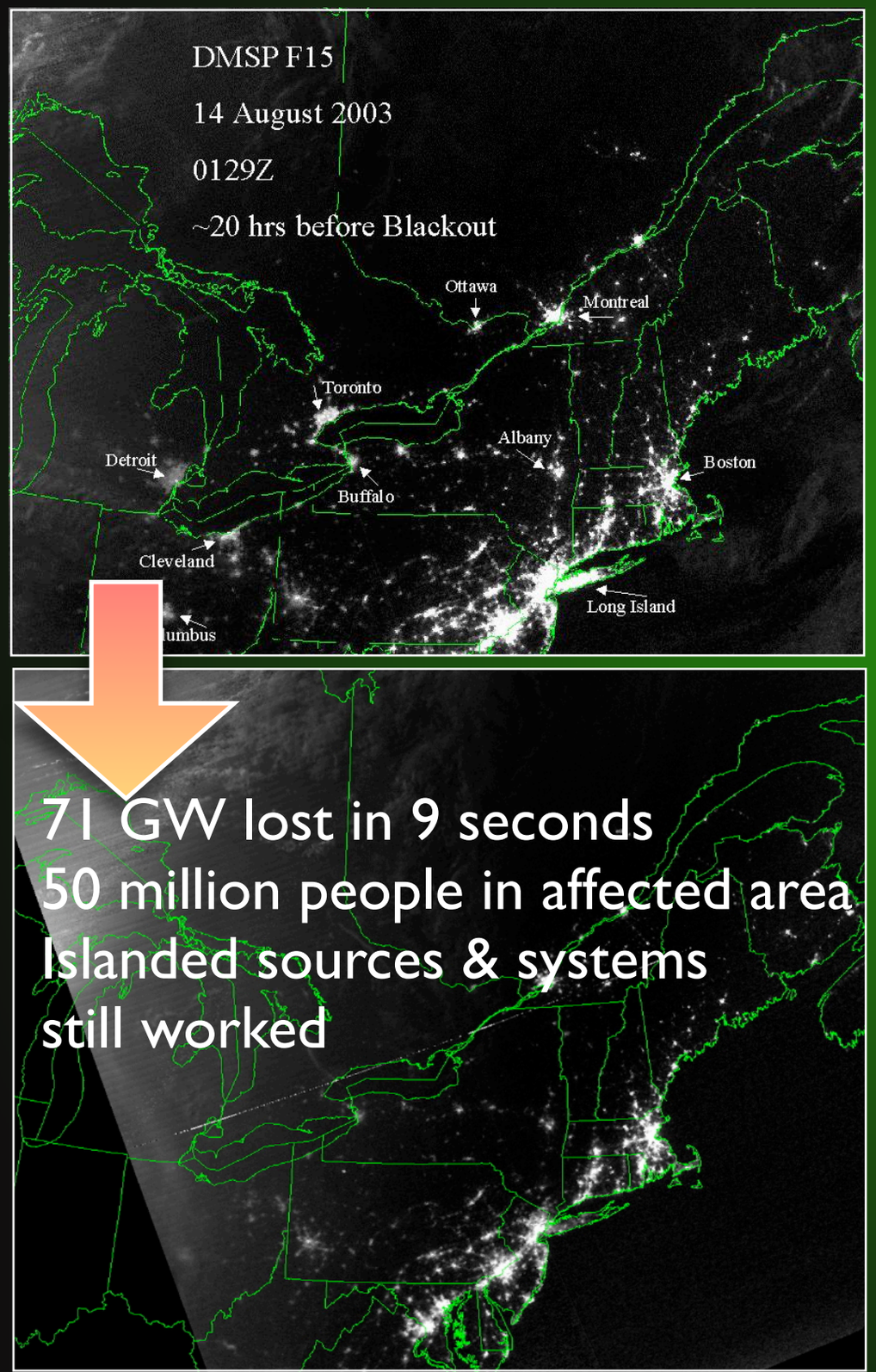
Solar PV		2010	2011	2012	2013	2014	2015	2016	2017	
	MWac Annual	20	45	80	135	210	325	500	750	
	MWac Cumulative	20	65	145	280	490	815	1,315	2,065	
	MWac Cumulative (ELCC Adjusted)	12	39	87	168	294	489	789	1,239	
	GWh Annual	37	120	267	515	901	1,499	2,419	3,799	
	LCOE (from PV plants in the year constructed)	$ 0.173	$ 0.160	$ 0.150	$ 0.143	$ 0.135	$ 0.129	$ 0.122	$ 0.116	
	LCOE Weighted (over Cumulative PV installed)	$ 0.173	$ 0.164	$ 0.156	$ 0.150	$ 0.144	$ 0.138	$ 0.132	$ 0.126	
	Weighted LCOE at full capacity (2008 Dollars)	$ 0.106								
Coal Plant - 500 MW		**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
	MWac Cumulative	-	-	-	-	-	-	-		500
	GWh Annual	-	-	-	-	-	-	-	-	3,723
	LCOE (from plants in the year constructed)	$ 0.115	$ 0.118	$ 0.121	$ 0.124	$ 0.127	$ 0.130	$ 0.133	$ 0.137	$ 0.140
	LCOE at full capacity (2008 Dollars)	$ 0.115								
Coal LCOE by Lazard; PV LCOE Forecast tracks DOE figures, adjusted for New Jersey.										
Assumes 30% ITC for Solar, no state incentives, and no Cap&Trade costs.										
Note: All figures in nominal (future) dollars, unless noted otherwise										

In addition, a PV Program:

- ***Generates power year 1***
- ***Has multiple times the peak generating capacity***
- ***Results in a program that can deliver over 750 MW/yr following Year 7***

SUNPOWER

Nuclear power's reliability



- Of the 253 ordered U.S. nuclear plants, 48% weren't built, 10% were prematurely closed, and 13% were shut down for a year or more
- Even well-designed, -built, & -run light-water reactors have reliability disadvantages
- *All* power sources are intermittent and/or variable
- There is *no* necessity for "24/7 power" or "baseload" or GW-scale units

98–99% of blackouts start in the grid —so bypass it!

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What is “baseload”? At least five meanings...

1. For someone who analyzes utility loads: the steady, 8,766-hour-per-year, portion of system load (below the load-duration curve’s shoulder)
2. For the system planner: the least-levelized-*total*-cost marginal resource that can be planned and built, regardless of unit size or type
3. For the system operator: the lowest-marginal-*operating*-cost resource, dispatched whenever available and needed for load
4. For the journalist, politician, and layperson: a gigawatt-scale thermal power plant, or maybe a big hydroelectric dam
5. For the nuclear advocate: a hypothetical power plant that runs at all times (but no such power plant exists)

- Baseload (steady) *demand* does not require a steady *generator*
- Steady output is a *statistical* attribute of the *aggregate* of generators on the grid, not a *physical requirement* for nor an actual attribute of any *single* generating unit

The misunderstanding underpinning nuclear advocates' denigration of variable renewables is disproven by theory, practice, and soon policy

"I think baseload capacity is going to become an anachronism....You don't need fossil fuel or nuclear [plants] that run all the time....We may not need any [more], ever."

—Jon Wellinghoff, Chairman
Federal Energy Regulatory Commission
22 April 2009

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The competitors are extremely large resources

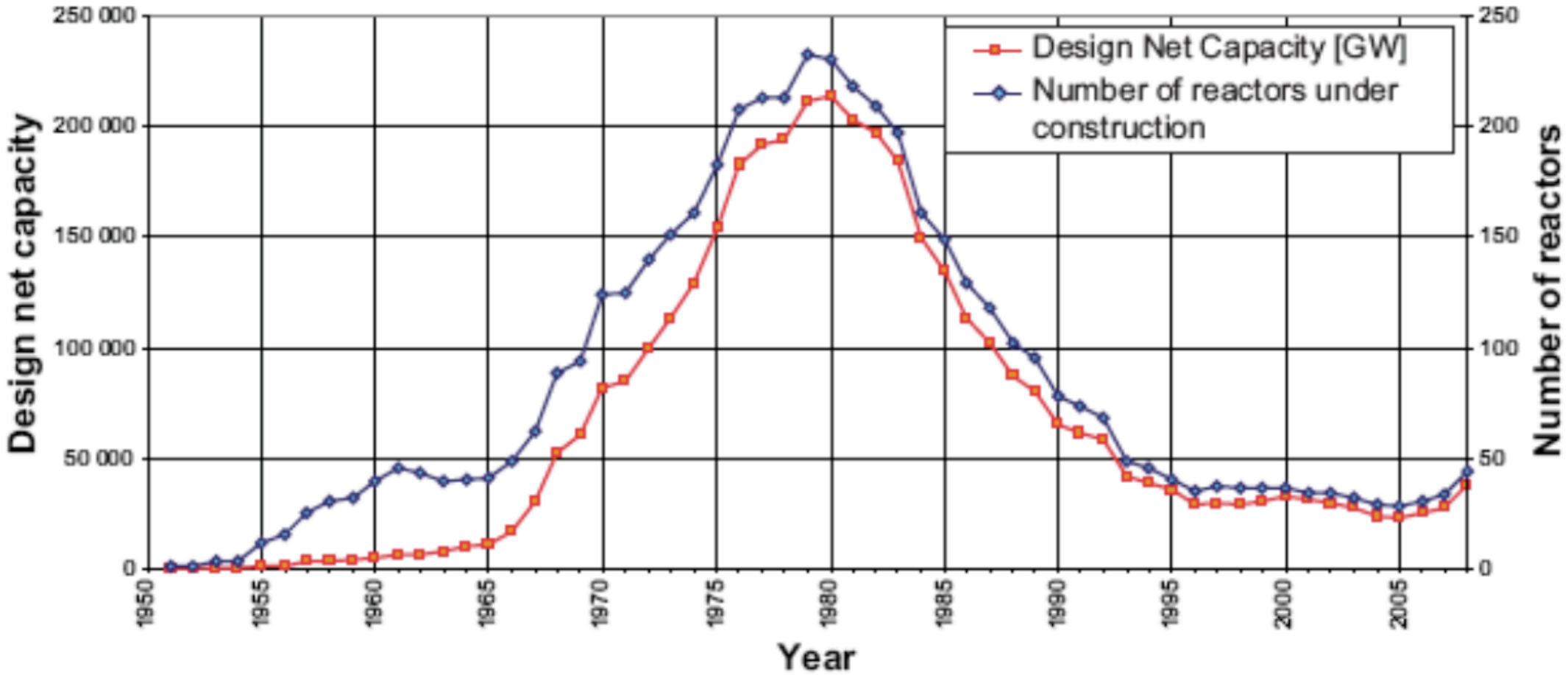
- Raising U.S. to top-ten-states' electric productivity would profitably save ~62% of U.S. coal power
- Global onshore and nearshore wind potential is 35 times global electricity use (@ 80m; turbines are now >100m)
- In the U.S. or China, available windy land (after land-use exclusions) can provide over twice today's electricity use
- The ~300 GW of windpower now stuck in the U.S. inter-connection queue could displace half of U.S. coal power
- NREL says putting solar cells on 7% of U.S. structures could provide all annual U.S. electricity, using no land
- Running existing combined-cycle gas plants more and coal plants less could *immediately* displace 1/3 of U.S. coal power, at a fraction of the cost of new nuclear build

Where's the "nuclear renaissance"?

- In Aug 05–Aug 08, with the most robust capital markets and nuclear politics in history, and new 100+% subsidies, 33 proposed new U.S. nuclear projects got zero offers of equity capital
- Of the 52 "under construction" reactors shown by IAEA at 1 Aug 09:
  - 13 have been "under construction" for >20 years
  - 24 have no official start date; half are late
  - 36 are in China, India, Russia, or South Korea
  - All 52 are centrally planned
  - Zero are normal competitive free-market purchases
- Nuclear capacity fell in 2008. Further falls are inevitable at least through 2015, and can be temporarily stabilized thereafter only by heroic building plus near-global extensions of 40-year licenses (the average operating plant is now 25 years old)

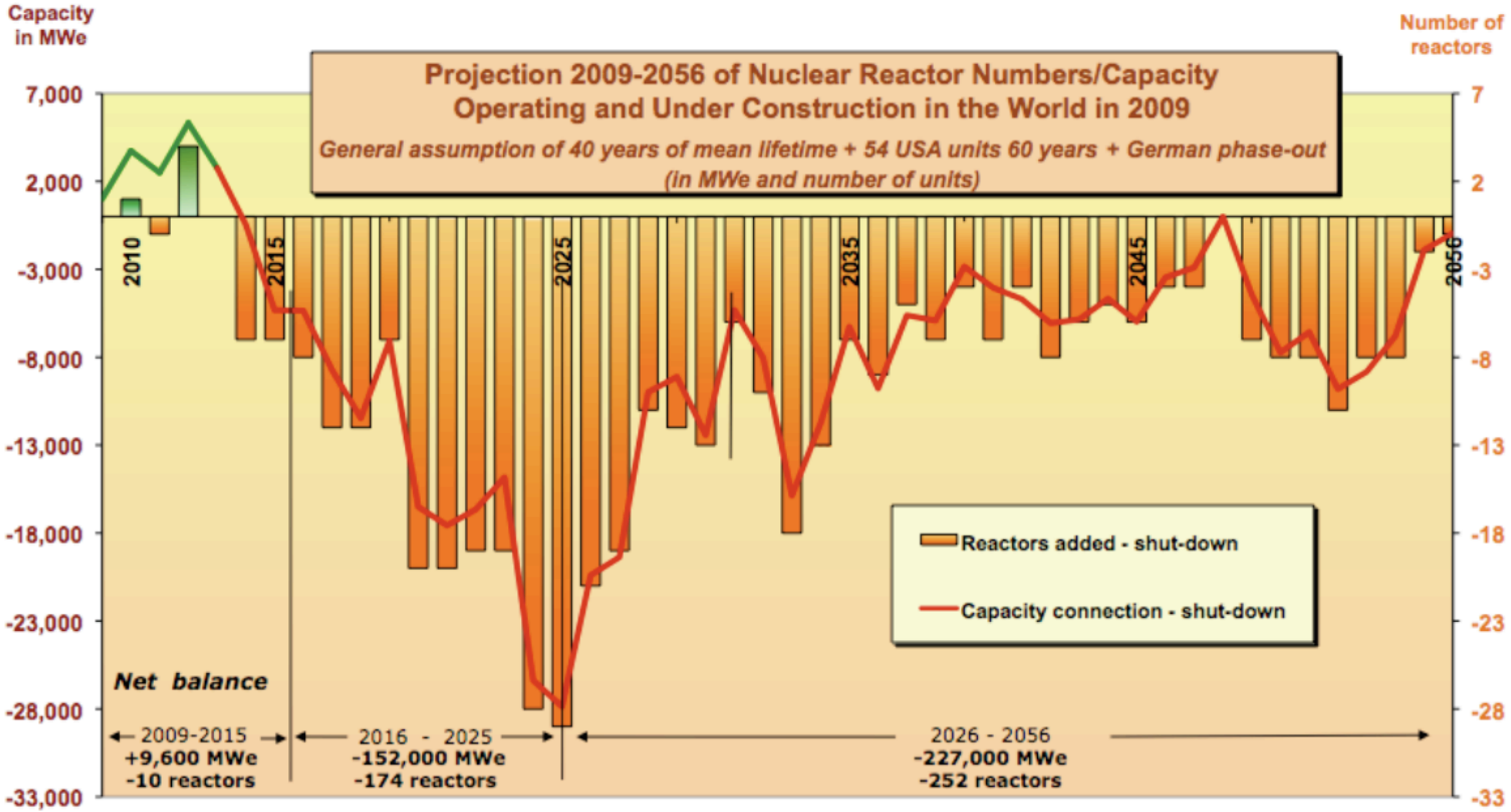
A “dead-cat bounce” revival

Graph 4: Number of units and total nominal capacity in MW[35] under construction 1951—2008



Source: IAEA, International Status and Prospects of Nuclear Power, 2008

New nuclear plants won't even be able to offset old nuclear plants' retirements



Sources: IAEA-PRIS, US-NRC, WNA, MSC 2009

Germany's Environment Minister: Sigmar Gabriel, 27 August 2009

"The renaissance of nuclear energy, much trumpeted by its supporters, is not taking place. The only thing frequently revived is the announcement. The study* shows: the number of old nuclear power plants which are decommissioned worldwide is greater than the number of new ones taking up operation. Available resources, engineering performance and funds are not even enough to stop the downward trend, let alone increase the number of reactors. All the facts are in favor of phasing out this technology while at the same time expanding the use of renewable energies and energy efficiency…."

Foto: Deutscher Bundestag/Fran[illegible]Ossenbrink

*The *World Nuclear Industry Status Report 2009*, which he published that day

The study is at www.bmu.de/english/nuclear_safety/downloads/doc/44832.php;
his remarks are at www.bmu.de/english/current_press_releases/pm/44840.php

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