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Nuclear power's competitive landscape

Amory B. Lovins, Chairman & Chief Scientist
Rocky Mountain Institute, www.rmi.org, ablovins@rmi.org
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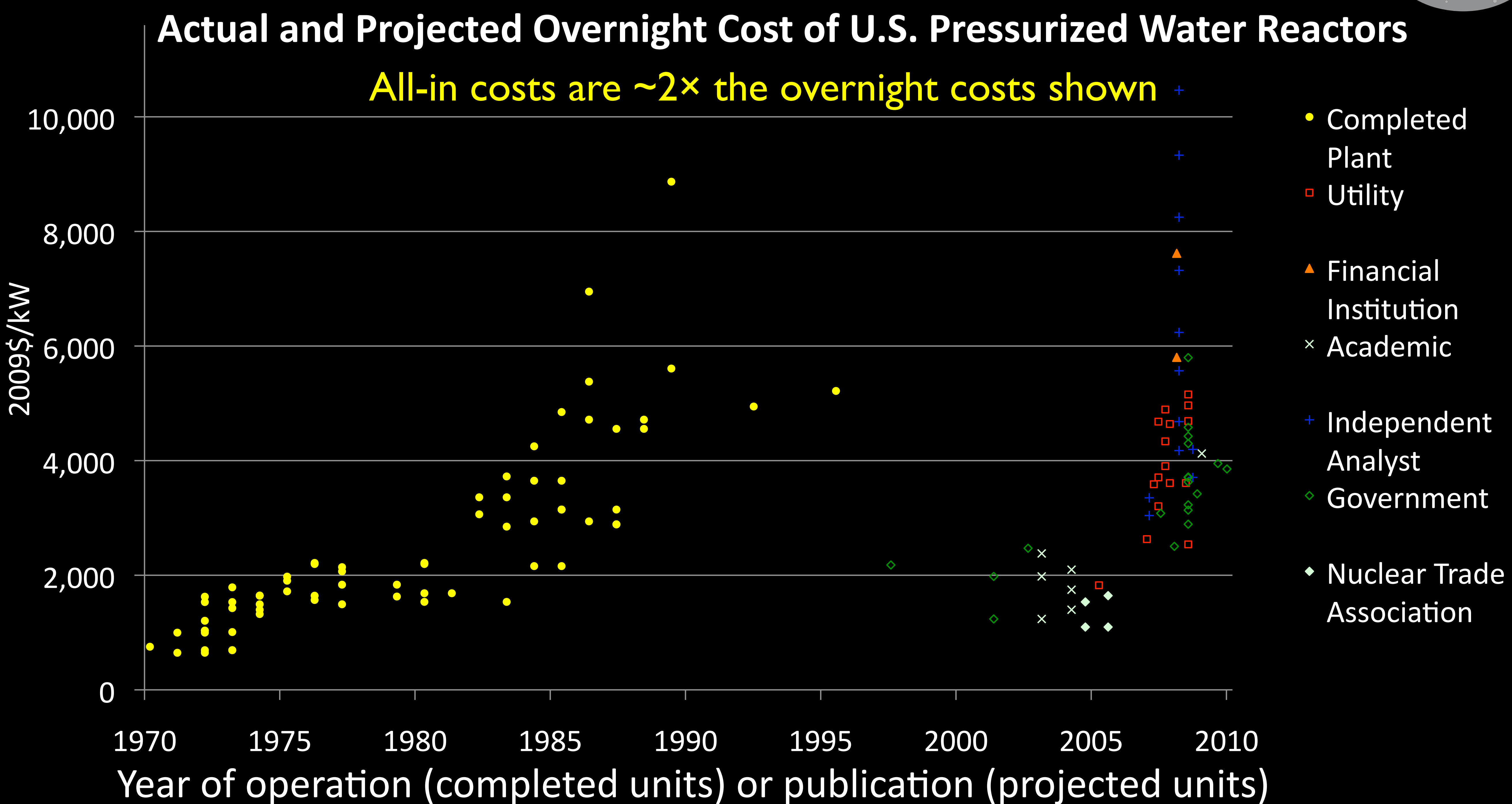
Nuclear capital costs are repeating their unhappy history



Sources: historic: Koomey & Hultman, *En. Pol.* **35**:5630–5642 (2007); projected: original sources reanalyzed by Molly M. Ward (RMI) in the graphical style of Mark Cooper (Vermont Law School), June–August 2010

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

Apparent recent escalation reflects “cost firming” as buyers move from claims to actual proposals and bids

But even more importantly, 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) are not "24/7" or "baseload" and hence cannot 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 + renewables – big hydro)

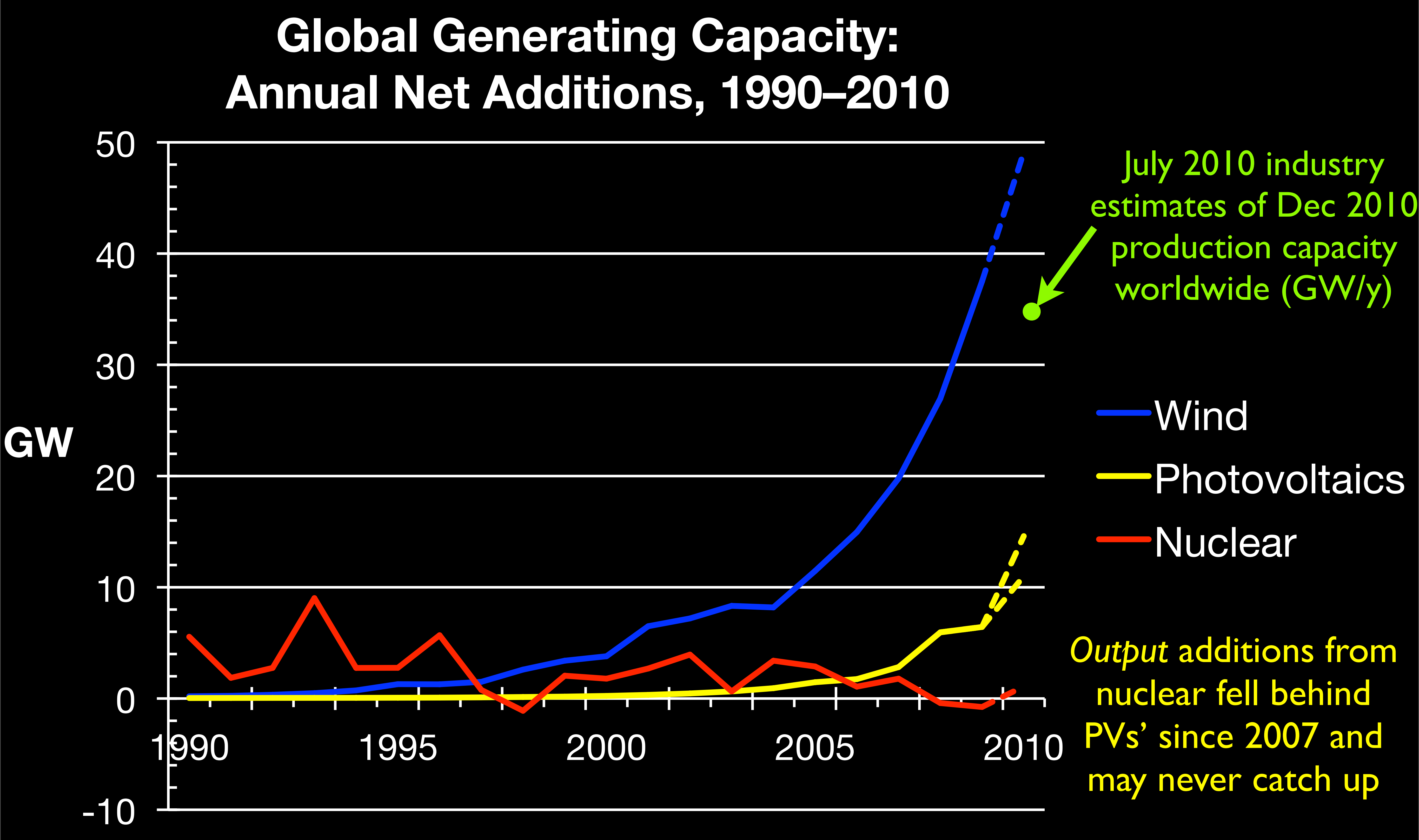
- They're cheaper, faster, more reliable, more attractive to investors, eclipsing nuclear, and winning wherever they're allowed to compete
- Variable renewables cost-effectively provide reliable power, generally without bulk storage, if properly diversified, forecasted, and integrated
- Carbon pricing benefits them and nuclear equally, fueled cogen partially

Competition from end-use efficiency

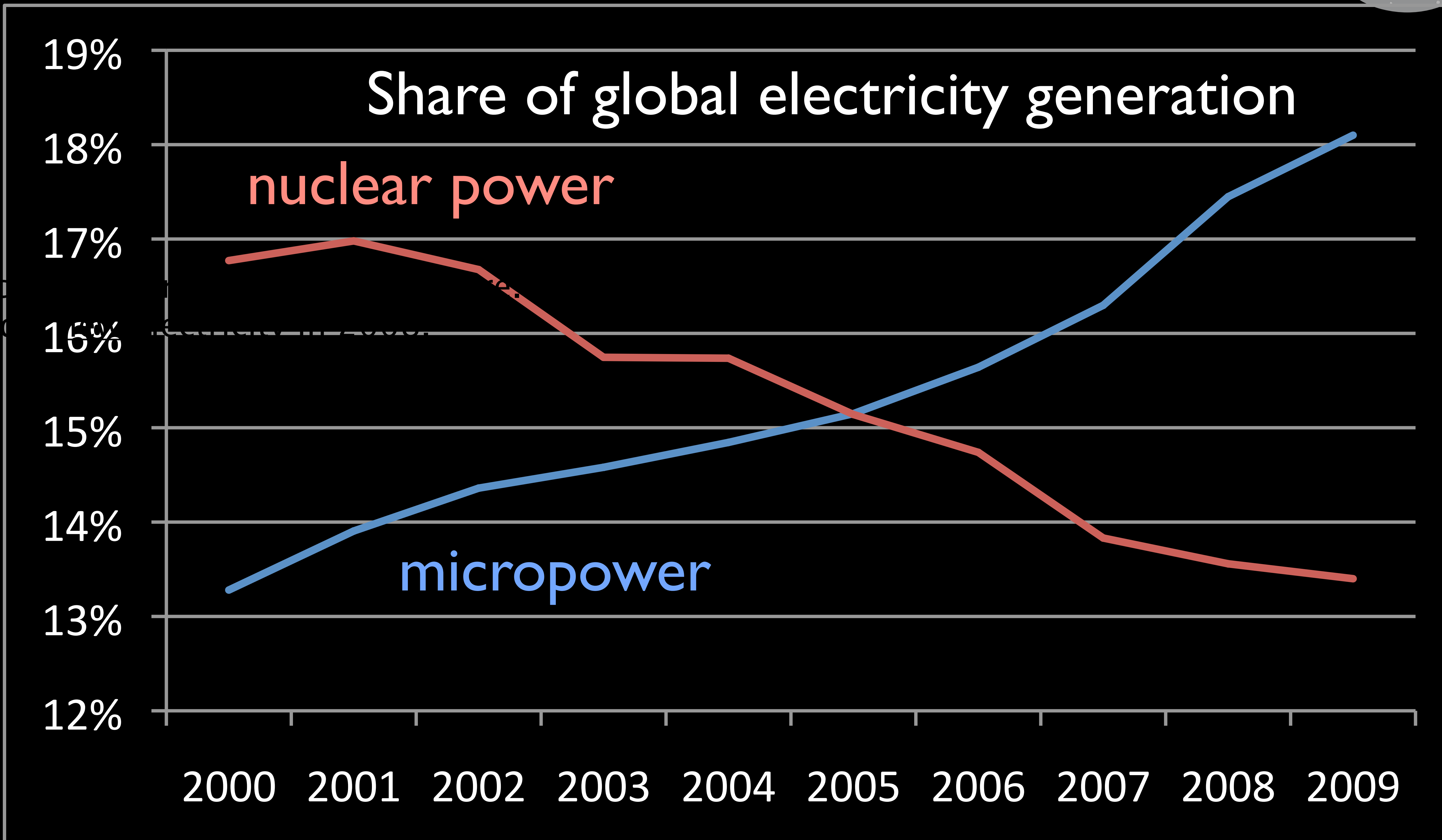
- Since 1975, California profitably held per-capita electricity use flat while per-capita real income rose 79%, saving ~US$100b of el. capex
- RMI 2008: Using electricity as productively as the top 10 US states did in 2005 (GDP/kWh adjusted for each state's economic mix & cli-mate) would save ~1,200 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
- NAS/NRC 2009: efficiency can save at least 30–34% of U.S. buildings' electricity at one-fourth its 2007 average retail price (a ~2-y payback)
- EPRI 1990: U.S. could profitably save 40–60% of 2000 electricity use at an average cost ~$0.03/kWh (2007 US$)
- RMI 1990: long-run, that's ~75% at av. cost ~$0.01/kWh (2007 US$)
- Av. utility program costs ~US$0.01–0.03/kWh; best <US$0.01/kWh

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

Global markets are rapidly shifting to distributed renewables

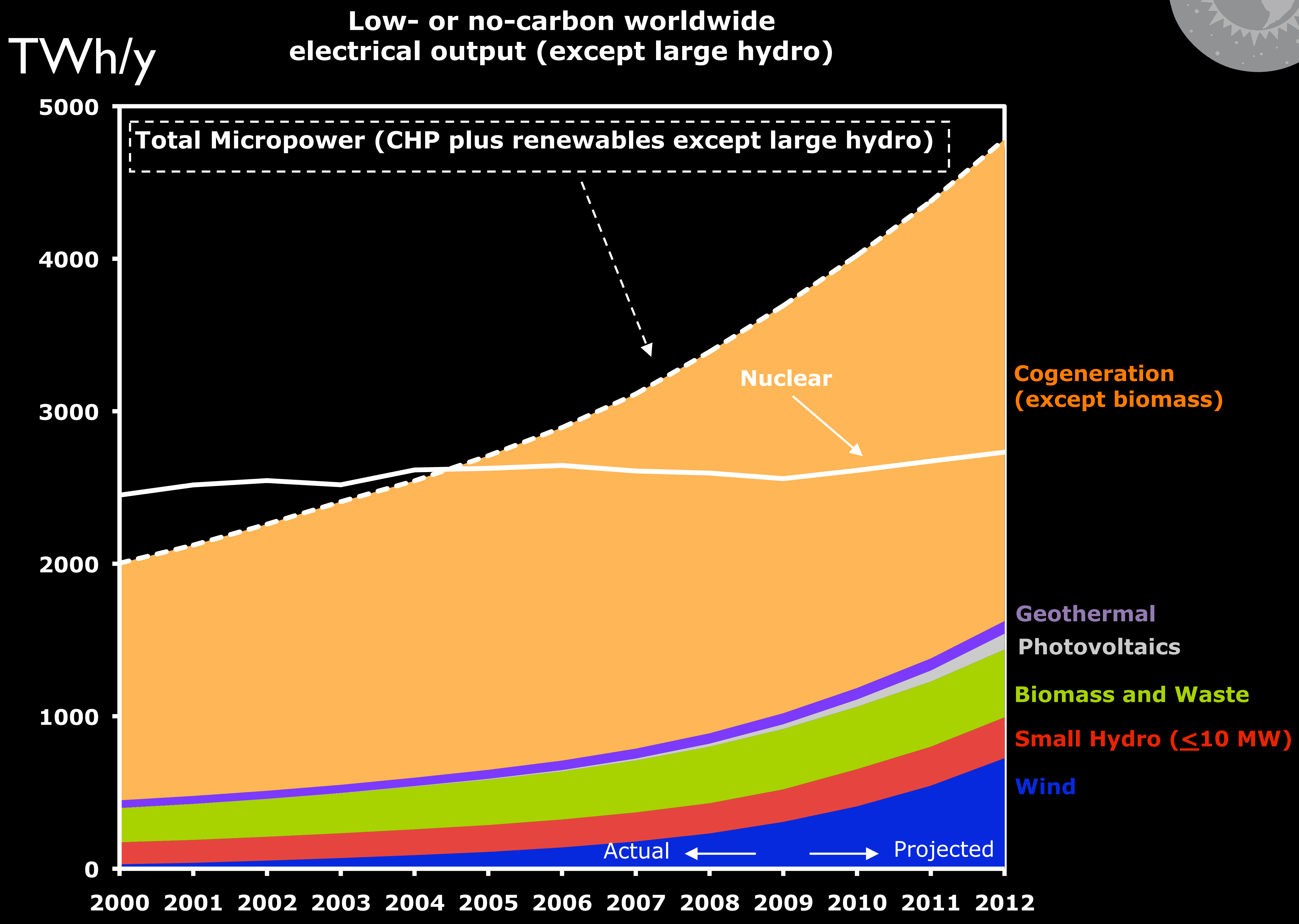


Nuclear and micropower generation have more than swapped roles, mainly due to market perceptions of their relative costs and risks

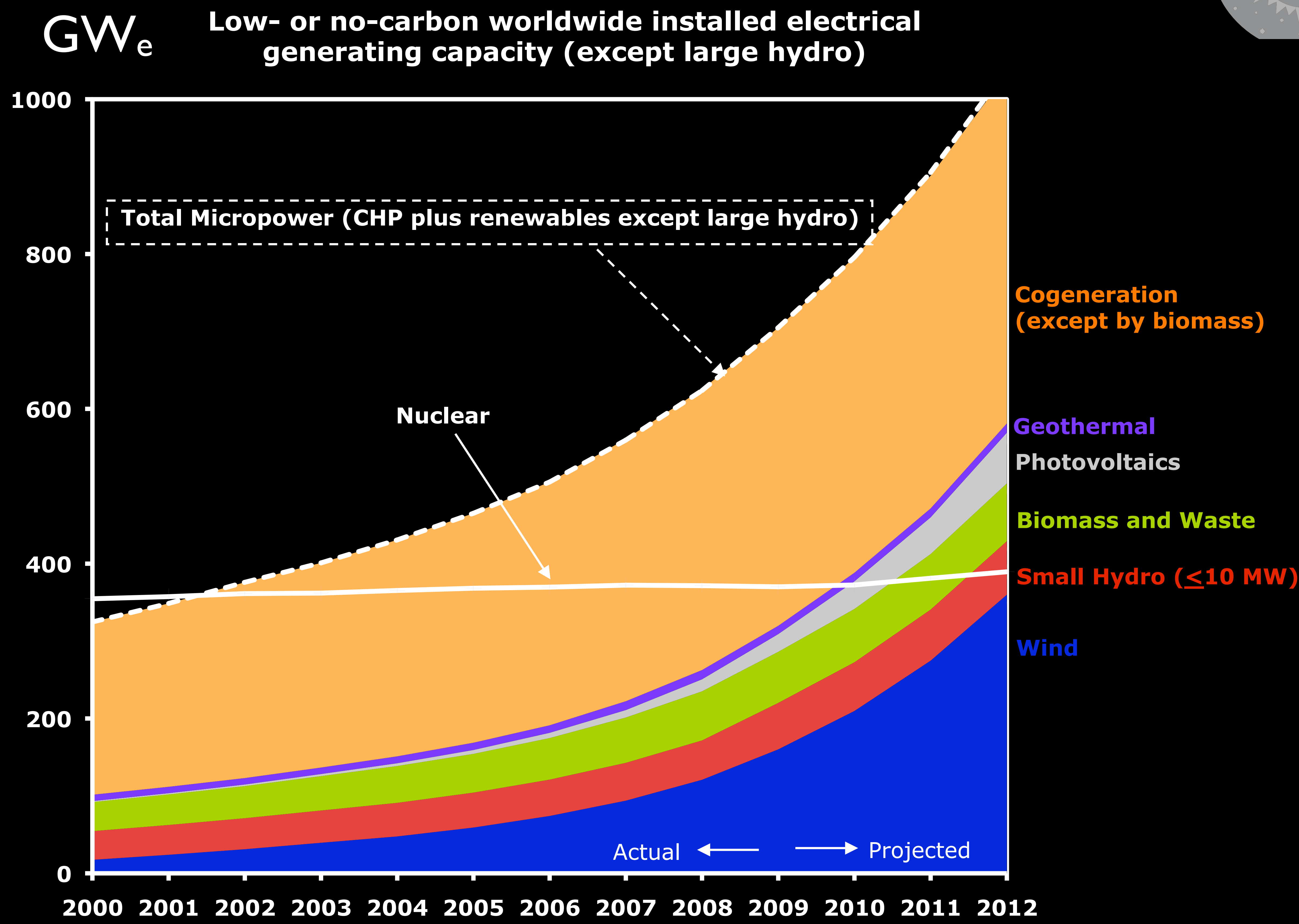


Sources: nuclear and total: *BP Statistical Review of World Energy 2010*; micropower: RMI analysis from industry sources (www.rmi.org/**rmi**/Library/2010-06_MicropowerDatabase). BP generation data are gross, renewables generally net (understating their relative share).

Low- and no-carbon distributed generation (“micropower”) is rapidly eclipsing central stations

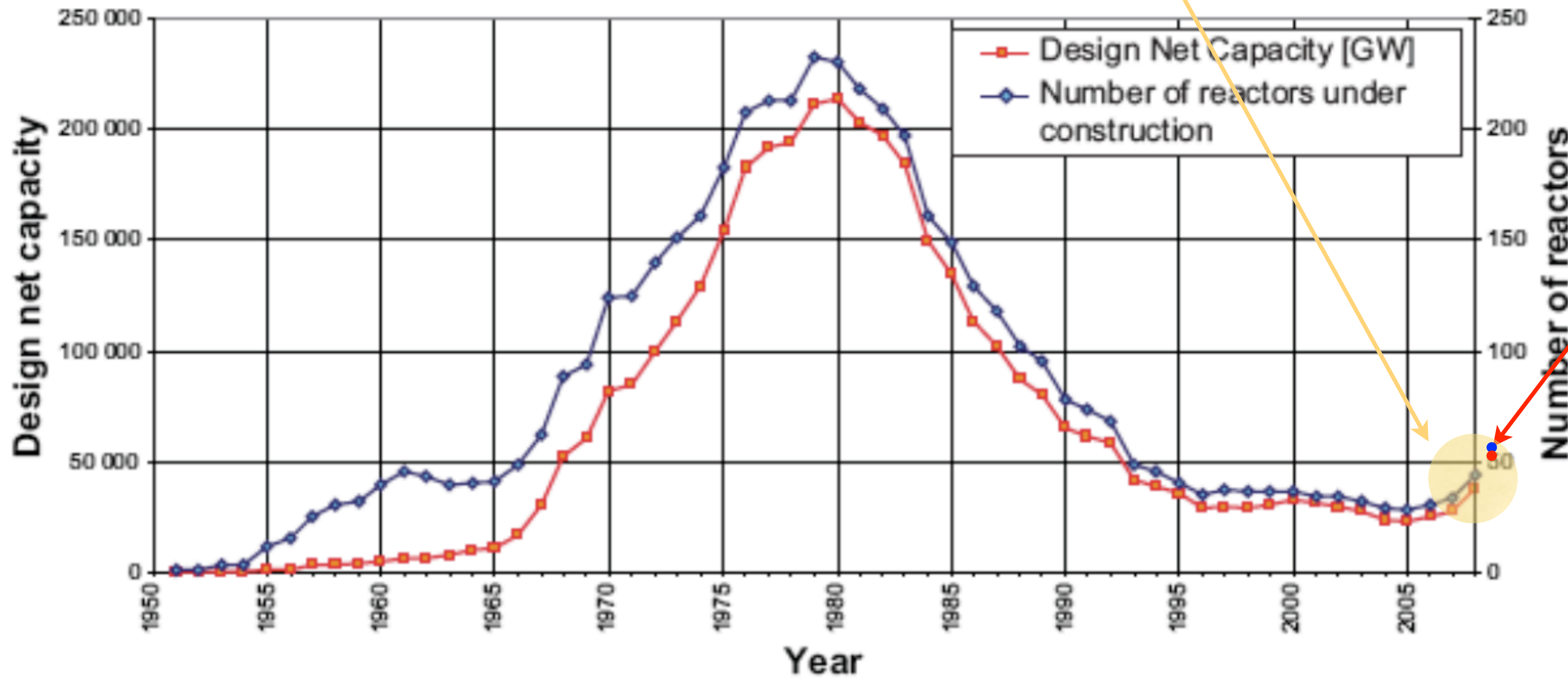


Distributed renewable generators will surpass nuclear power in capacity in 2010 and in annual output around 2014



What “nuclear renaissance”? Here it is...

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



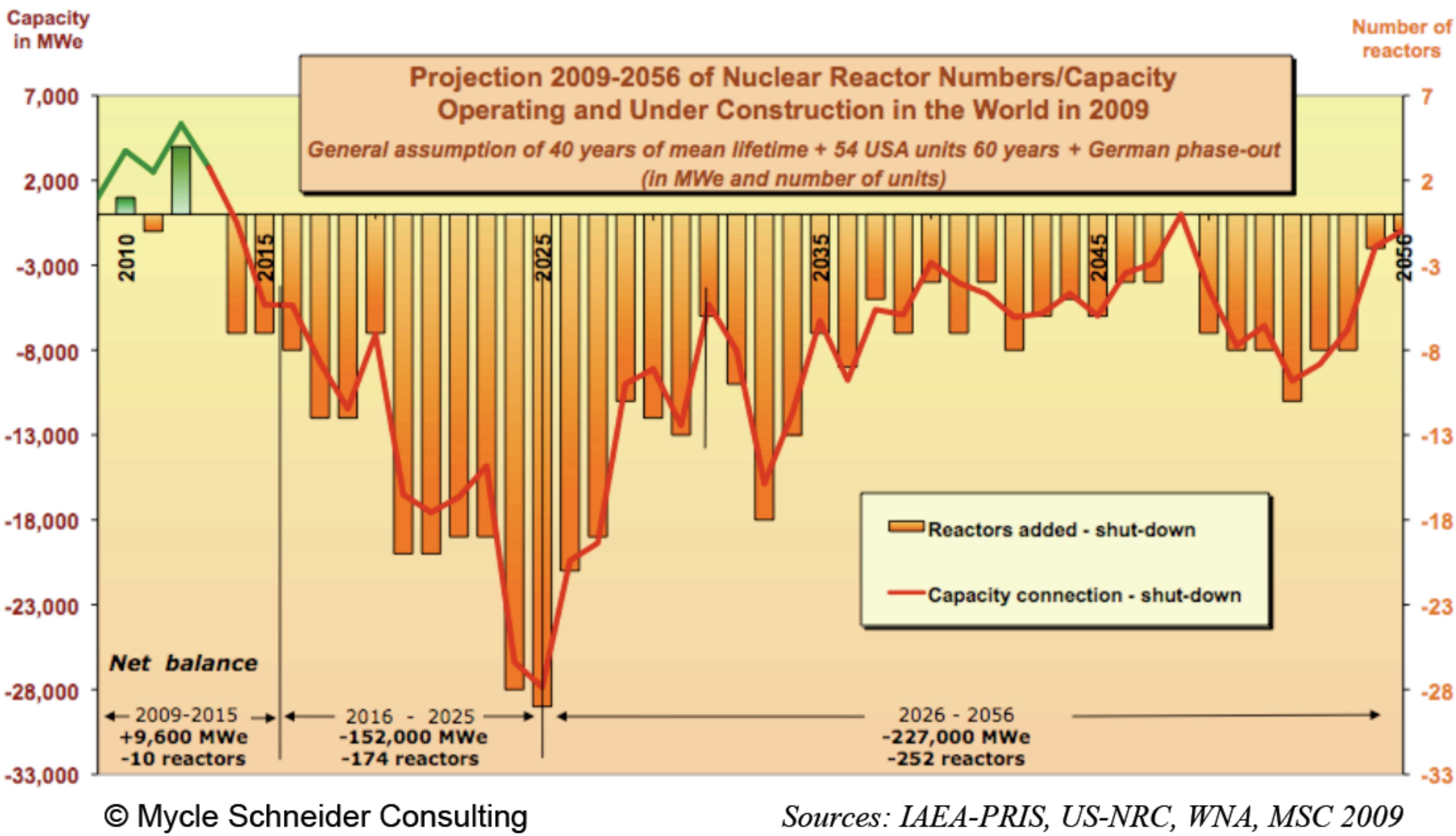
Source: IAEA, International Status and Prospects of Nuclear Power, 2008

end 2009: **56** (24% of 1979 peak), or 4.4 % of 2007 capacity under construction

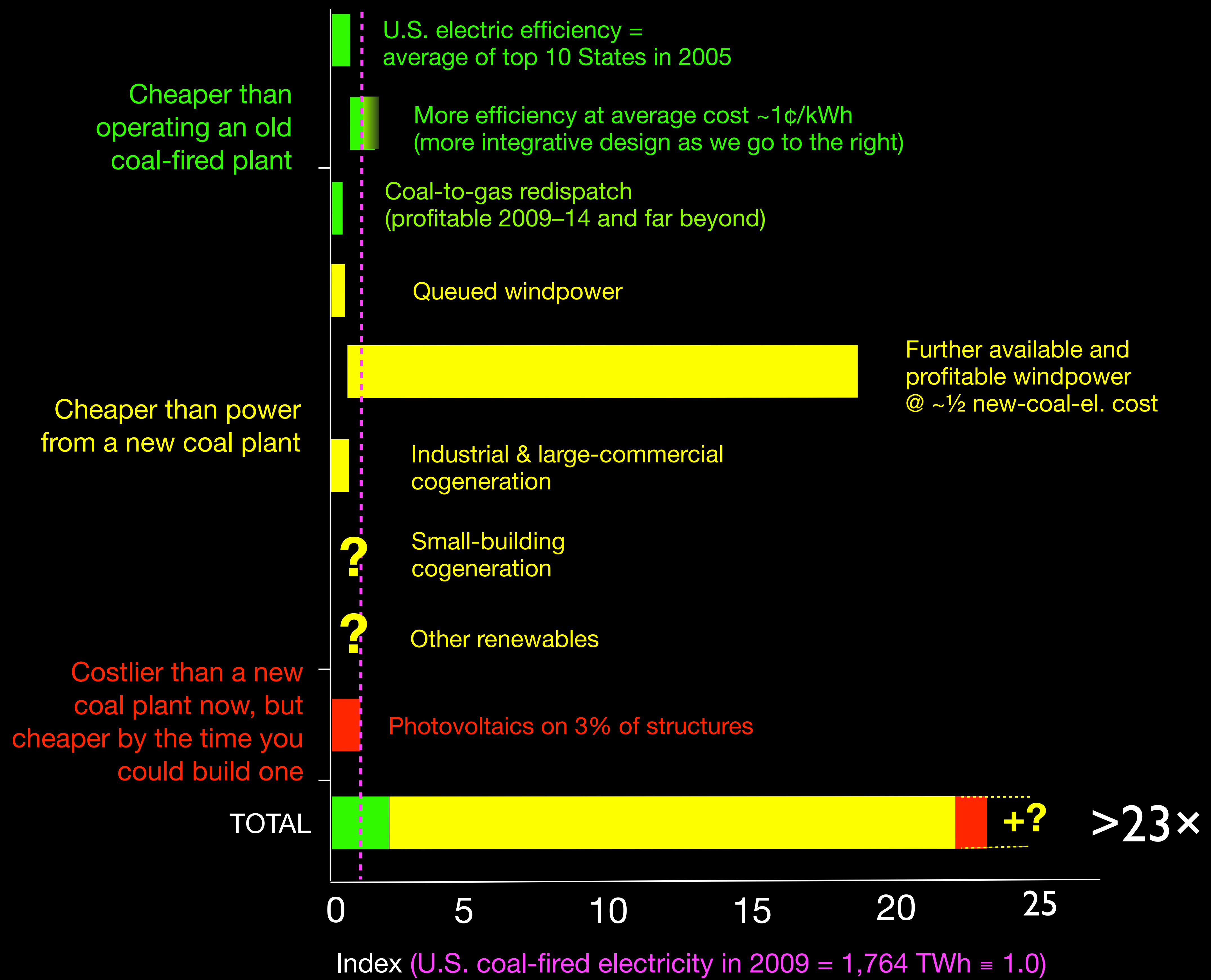
Of the 61 “under construction” reactors shown by IAEA at 26 July 2010:

- 12 have been under construction for >20 years; 39 have no official startup date; half are late
- 44 are in China, India, Russia, or S. Korea; 6 of 10 starts in ’08 and 9 of 11 in ’09 are in China
- All 61 are centrally planned, usually by authorities with a draw on the public purse
- Zero are free-market purchases fairly compared or competed against available alternatives

New nuclear plants will scarcely be able to offset old units' retirements



U.S. coal-fired electricity avoidable by...



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 (www.smallisprofitable.org)
- 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 and most renewables are getting cheaper while nuclear costs rise, but these comparisons didn’t trend *projected* costs
- Prospects for new technology breakthroughs are ubiquitous with efficiency and renewables but very hard to envisage for nuclear

What about proposed “new” types of nuclear reactors?

- Other than TerraPower’s “travelling-wave reactor” concept, they’re not new (*e.g.*, molten-salt thorium has been discussed since ~1944)
- Small prototypes say little about scaling up—especially with novel and closely coupled fuel cycles that must run continuously and often need new chemistry and engineering (*e.g.*, pyrometallurgy)
- In more than 60 years, *every* new type of reactor has proven far more costly, slow, difficult, and problematic than its advocates claimed
- Assuming a new reactor *and* a new fuel cycle *and* new political and competitive environments is a costly fantasy
- If the nuclear 1/3 of capital cost for today’s GW-scale reactors were *free*, the non-nuclear 2/3 would still be grossly uncompetitive
- For physics reasons, the systems needed to harness heat and to manage heat and radiation generally don’t scale down well
- Can new “mass-produced miniature” concepts ever catch up with competitors already ~2–20× cheaper *today*—and already decades ahead in capturing their *own* mass-production economies?

A voice of experience

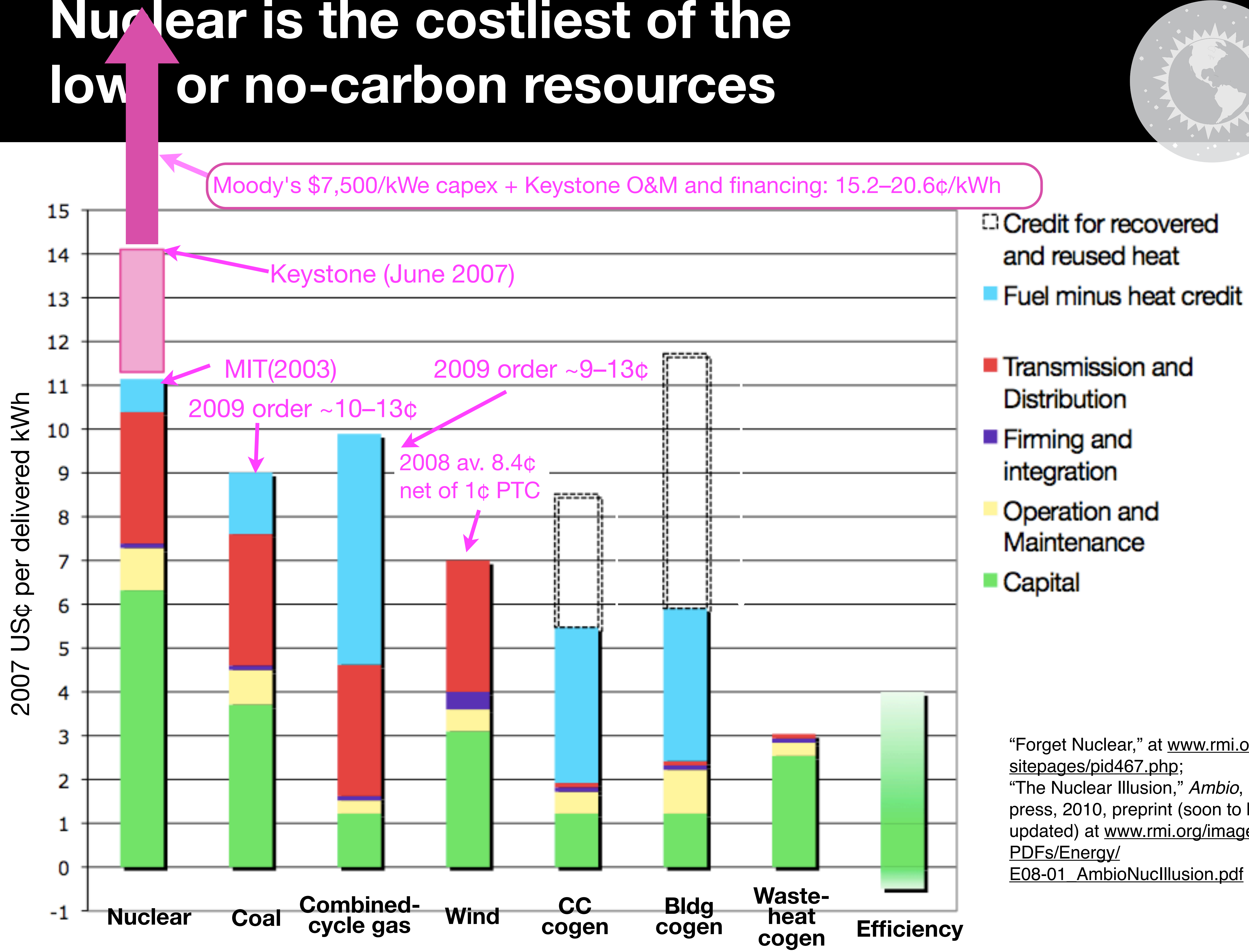
"An academic reactor or reactor plant almost always has the following basic characteristics: (1) It is simple. (2) It is small. (3) It is cheap. (4) It is light. (5) It can be built very quickly. (6) It is very flexible in purpose. (7) Very little development will be required. It will use off-the-shelf components. (8) The reactor is in the study phase. It is not being built now.

"On the other hand a practical reactor can be distinguished by the following characteristics: (1) It is being built now. (2) It is behind schedule. (3) It requires an immense amount of development on apparently trivial items. (4) It is very expensive. (5) It takes a long time to build because of its engineering development problems. (6) It is large. (7) It is heavy. (8) It is complicated."

–ADM Hyman Rickover, USN, 1953
www.ecolo.org/documents/documents_in_english/Rickover.pdf)

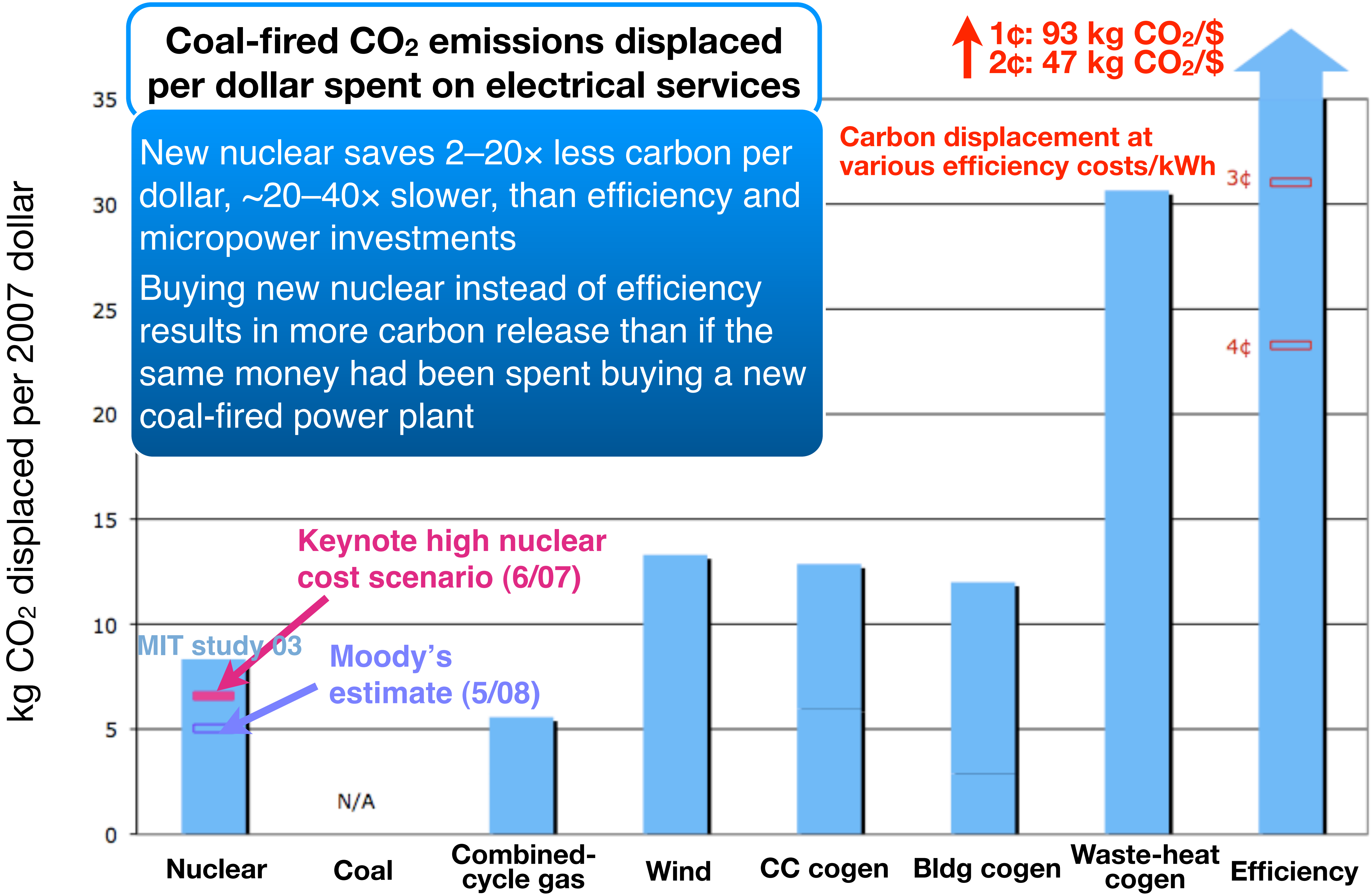
Supplementary slides

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 (soon to be updated) at www.rmi.org/images/PDFs/Energy/E08-01_AmbioNucIllusion.pdf

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

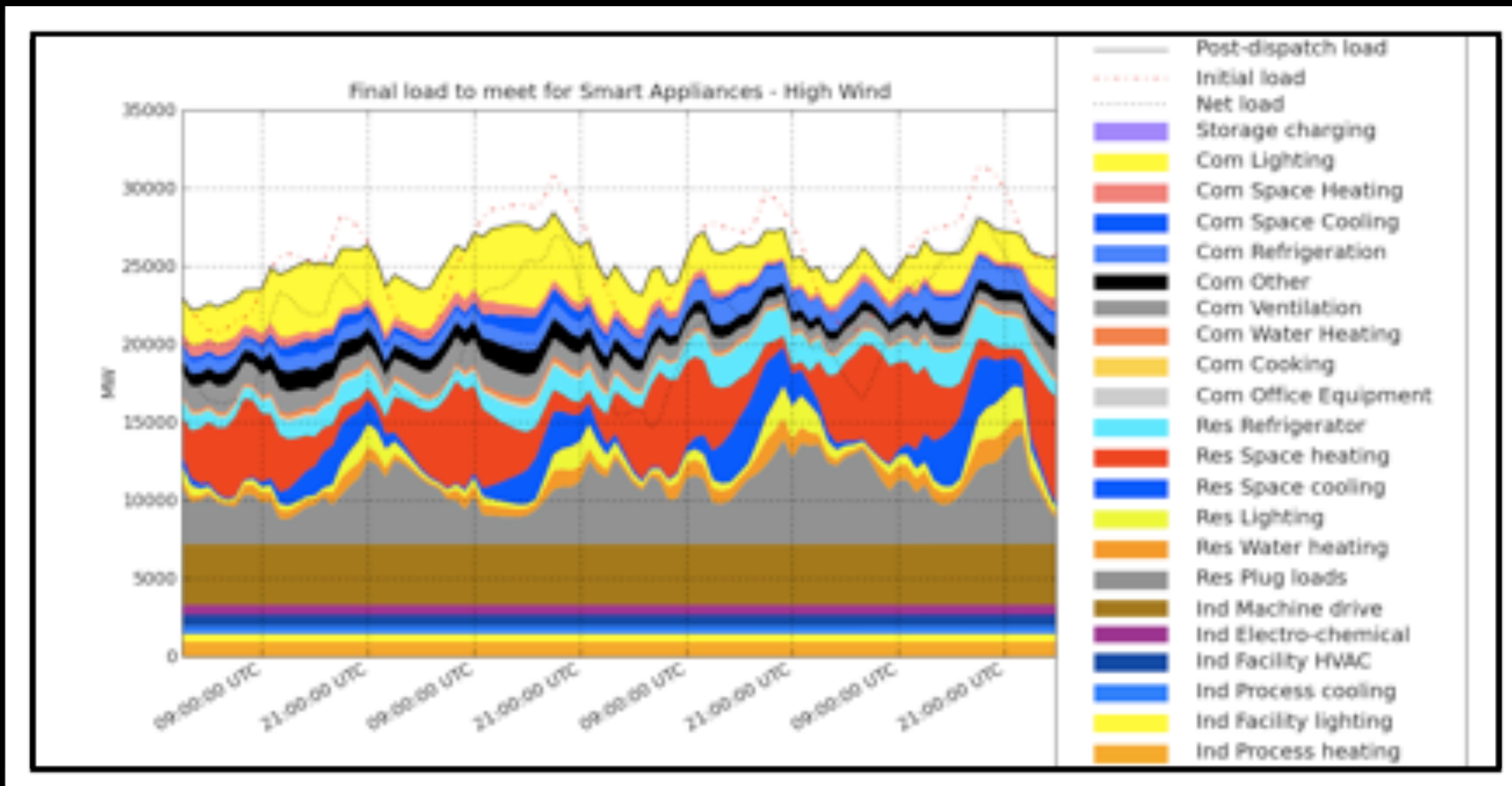


New nuclear saves 2–20× less carbon per dollar, ~20–40× slower, than efficiency and micropower investments

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

This next-generation utility shows promise of feasibility and profitability

- Extensive energy modeling and practice have demonstrated major efficiency and demand-response potential in new and retrofit buildings and factories
- Hour-by-hour utility modeling indicates that demand response technology operating on a smart grid can enable large-scale integration of variable renewables



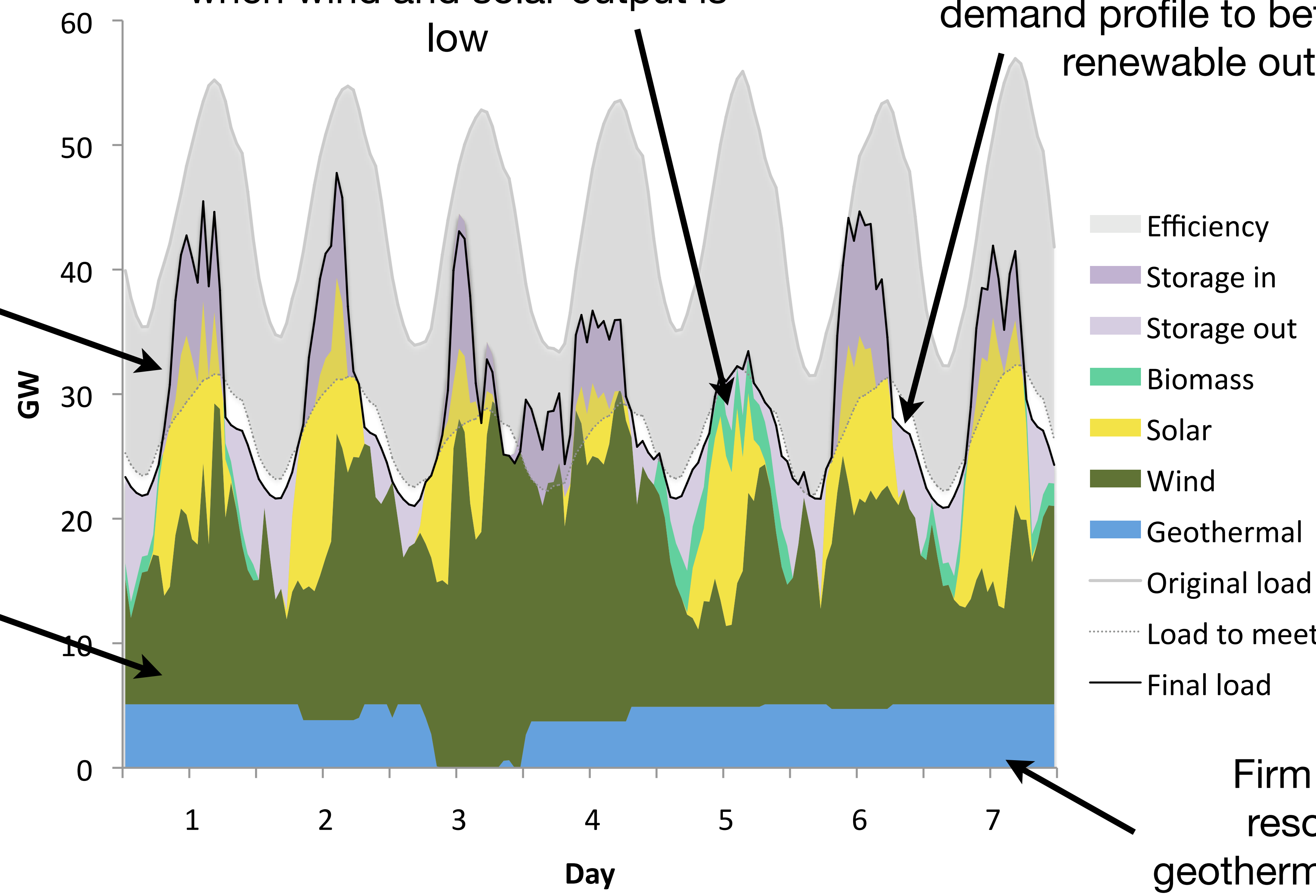
Much work remains to consolidate, test, and implement the concept...but Ireland already plans 40% renewable electricity by 2020, 100% by 2035

Storage discharge and flexible biomass can meet peak demand when wind and solar output is low

PHEV charging (or other storage) and demand response can re-shape the demand profile to better match renewable output

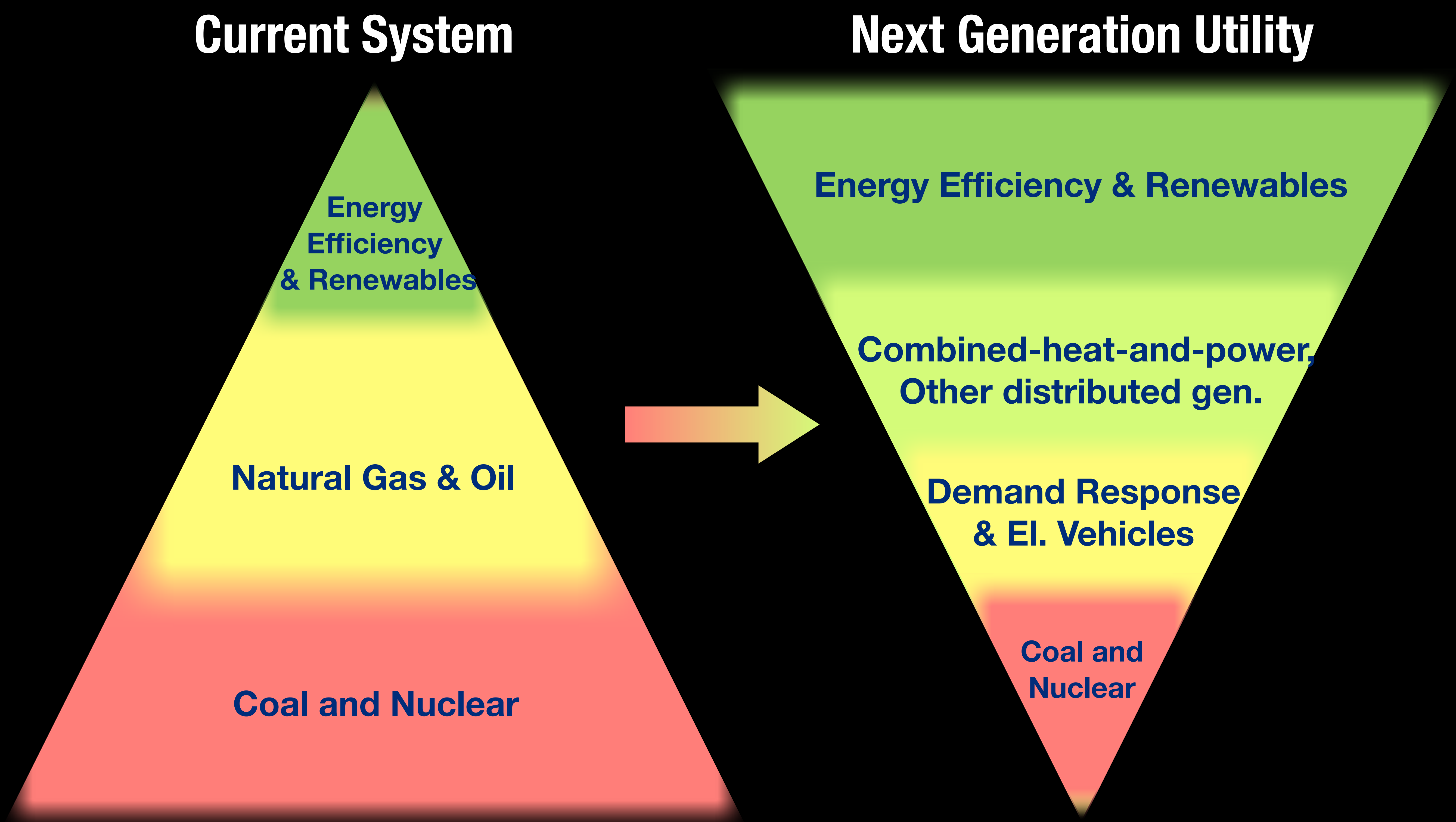
Energy efficiency can reverse peak demand growth

Renewables like wind and solar are not always correlated to demand



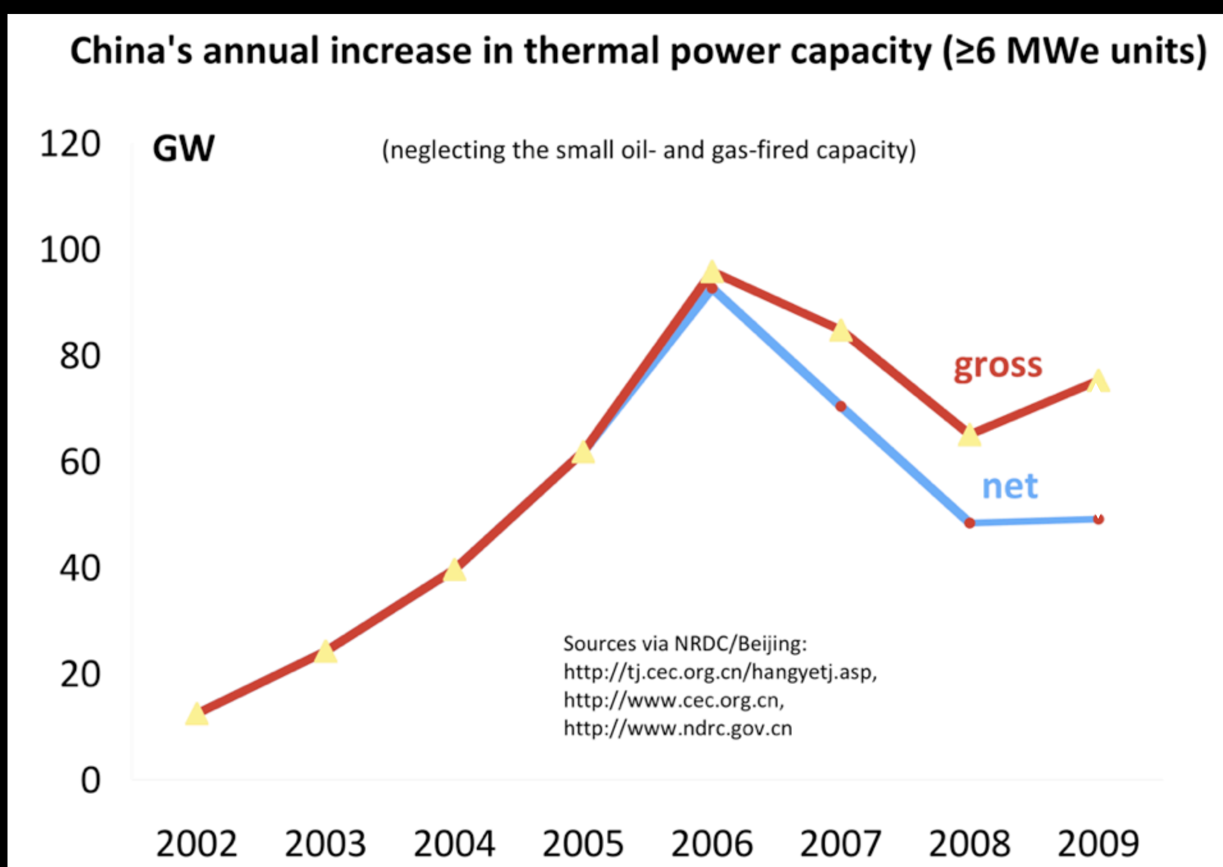
Firm renewable resources like geothermal can be used to balance wind and solar

Transforming the electricity sector



China's nuclear construction starts are >3× rest-of-the-world's: what is the internal competition?

- **Nuclear (**9 GW op, 23 GW constr'n, ?40–70 by 2020)**:** novel construction methods, low but untransparent reported costs, too early to judge
  - Nearest analog, France, had 3.5× real cost/kW escalation 1970–2000
  - Clear signs of overheating, safety & possibly corruption concerns (Kang)



- ~2/3 of 2005–7 plants were illicit
- 62 GW of dirtiest, least efficient units closed 2005–09; 31 GW more planned to close by 2011
- *Net* additions halved 2006–09
- Fleet efficiency better than U.S.
- '09 thermal share –1.45% points
- '10 add'ns planned: 55 GW coal, 15 hydro, 13 wind, 1 nuclear

- **Big hydro:** 14% of China's electricity (nuclear 2%); end-2009 hydro total 197 GW, planned for 270 GW by 2020; economic potent'l ~395 GW

Big China story is the less-reported competitors

- **Efficiency:** 70% of growth in energy services 1980–2001 and now (energy intensity fell ~5% in 2009, ≥4%/y in 2005–10; stronger laws)
  - Causes of 2001–06 binge on basic-materials industries now corrected
  - Efficiency is #1 strategic priority in 11th FYP, even stronger in 12th FYP
- **Cogeneration** and distributed engines: ~28 GW 2005, fast-growing, statistics unclear; increasingly gas-fired, very large gas resource base
- **Wind**: beat 2010 target in 2007, 25 GW ’09 (will far exceed 30-GW 2020 target 20*10*; new 2020 target 100–150 GW (5–8× Three Gorges Dam), including 6× 10–30 GW; grid will soon catch up; 70 firms; 2008 installed cost 21–47% below U.S. 2007–08 av.; available cost-effective sites @ 80m hub height can make *1 TW = 2× 2008 total electricity use*
- **Small hydro**: consistently adding several GW/y
- **PV**: 2020 target just raised from 10 to 20 GW, may be raised to 30; 400 firms; price dropped ≥40% during 2009; $\$1.30/W_p$ 2010?
- Now world #1 maker of PV, wind, small hydro, solar thermal, & biogas
- China’s distributed renewables in 2006 were 6.5× nuclear capacity and grew 7× faster; in 2009, the gap widened to 7.3× and ∞ (23 GW *vs* 0)

Four pillars of nonproliferation logic

Lovins, Lovins, & Ross, *Foreign Affairs*, Summer 1980; Lovins, *Foreign Policy, 21 Jan 2010*

1. **We can have proliferation with nuclear power**, via either end of any fuel cycle: "*every* form of *every* fissionable material in *every* nuclear fuel cycle can be used to make...bombs, either on its own or in combination with other ingredients made widely available by nuclear power."
2. **We can't have nuclear power without proliferation**, because its vast flows of materials, equipment, skills, knowledge, and skilled people create do-it-yourself bomb kits wrapped in innocent-looking civilian disguise.
3. **We can have proliferation without nuclear power—but needn't if we do it right**: with unimportant exceptions, "*every* known civilian route to bombs involves *either* nuclear power *or* materials and technologies whose possession, indeed whose existence in commerce, is a direct and essential consequence of nuclear fission power."
4. Crucially, in a world without nuclear power, the ingredients needed to make bombs by *any* known method would no longer be ordinary items of commerce. They'd become harder to get, more conspicuous to try to get, and politically costlier to be caught trying to get (or supply), because their purpose would be *unambiguously military*. This disambiguation would make proliferation not impossible but far harder—and easier to detect timely, because intelligence resources could focus on needles, not haystacks. Thus **phasing out nuclear power is a necessary and nearly sufficient condition for nonproliferation.**

How fortunate, then, that buying cheaper (and inherently nonviolent) alternatives to nuclear power is also the most effective course for climate protection—and to obtain reliable and affordable energy for global development! Time to reframe NPT Article IV around that goal.