Climate Change and Nuclear Power

Summary of *World Nuclear Industry Status Report 2019 chapter* (worldnuclearreport.org), pp. 218–256, 24 Sep 2019

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Conference: Climate Crisis—Why nuclear is not helping
Vienna, 07 Oct 2019, by videoconference

Criteria for comparing nuclear power with other options

- Building coal-fired power stations paid attention to *cost but not carbon*
- Defending nuclear plants paid attention to *carbon but not cost*
- Protecting climate requires avoiding the most carbon at the least cost in the least time, paying attention to *carbon, cost, and time—not just carbon*
- **Costly or slow options will avoid less carbon per € or per year than cheaper or faster options could have done, making climate change worse than it could have been.** A low-carbon but costly or slow choice thus *reduces and retards* climate protection

A simple analytic framework for comparing the climate-effectiveness of different ways to save or make electricity is at www.rmi.org/decarb

Mind the logical gap

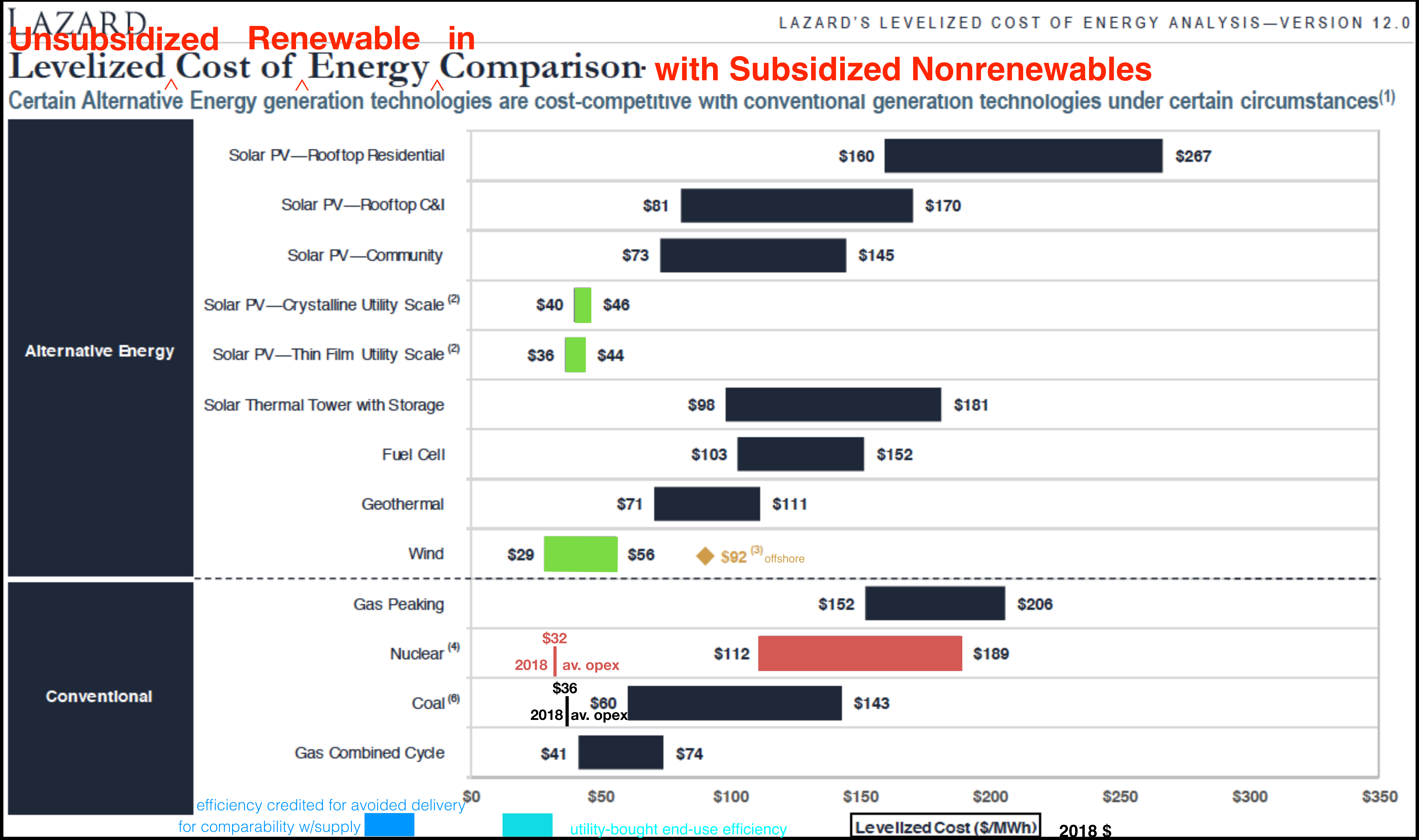
- People are hungry
- Hunger is urgent
- Caviar and rice are both food
- Therefore caviar and rice are both vital to reducing hunger

When solving a problem needs money and time, both finite, we must understand *relative cost and speed* to choose effective solutions.

Climate opportunity cost

- You can buy only one thing with the same money at the same time.
- Nuclear and fossil-fueled generation compete with renewables and efficiency to meet the same finite demand for electrical services, so each kWh met by one resource is lost to its competitors.
- Since new or often even existing nuclear plants can no longer win in the marketplace, their owners often seek and get from politicians major new subsidies or preferences—misdescribed as “not forcing nuclear out of the market,” “not taking nuclear off the table,” or “keeping the nuclear option open.” Success displaces renewables and efficiency.
- Every kWh of nuclear output forced into walled-garden markets in which renewables (and efficiency) are forbidden to compete slows the growth, hence the cost reductions, of those zero-carbon competitors.

Lazard's November 2018 view of new US electricity resources' costs



Small **M**odular **R**eactors (let alone other non-LWR or non-U types) cannot materially change these conclusions

- Because reactors don't scale down well, advocates generally expect SMRs will initially cost (per kWh) ~2× LWRs, hoped to be offset by mass production
- LWRs now cost ~3–6× renewables and ~5–10× efficiency
- That gap will widen by another ~2× by the time SMRs can be proven and start to scale
- The required ~12–24× cost reduction is not economically or physically plausible
- Yet Small Modular *Renewables do* scale down well and are already decades ahead in exploiting their own formidable economies of mass production, so SMRs can't catch up
- Other reactor types, especially with new fuel cycles, lack the magical properties often claimed by enthusiasts and are even less promising: even if the nuclear part (~13–22% of LWR capex) were *free*, the other ~78–87% would cost too much
- SMRs are also far too late/slow to address their advocates' rightly claimed climate urgency

Choreographing Variable Renewable Generation

Europe, 2015–18 renewable % of total electricity consumed

74%

Scotland 2018

71%

Denmark 2017 (2013 windpower peak 136%—55% for all December)

38%

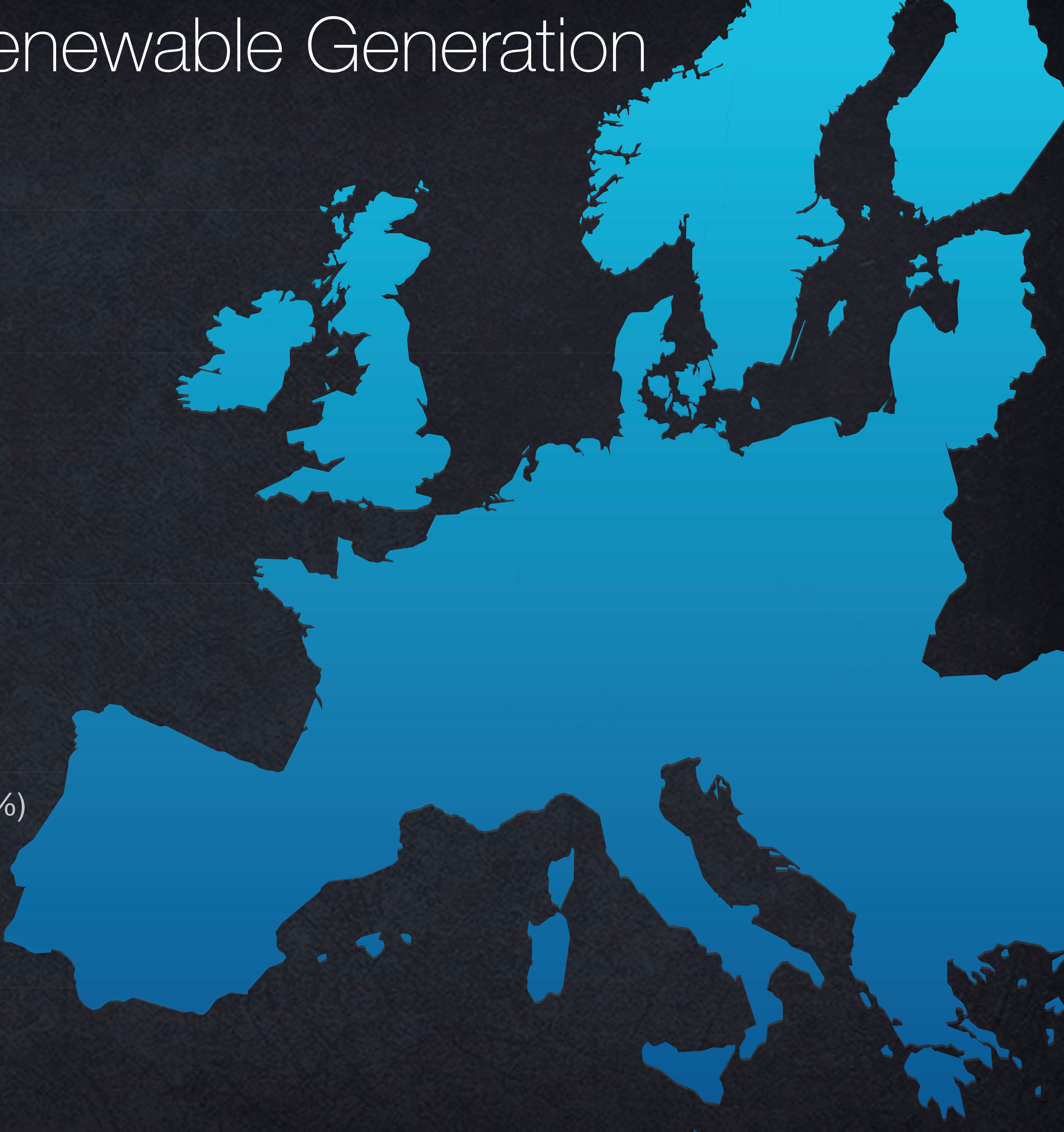
Germany 2018 (2016 peak 88%, 2018 ~100%)

66%

Portugal (2018, 42% without hydro) (2011 & 2016 peak 100%)

46%

Peninsular Spain (2016, 27% without hydro)

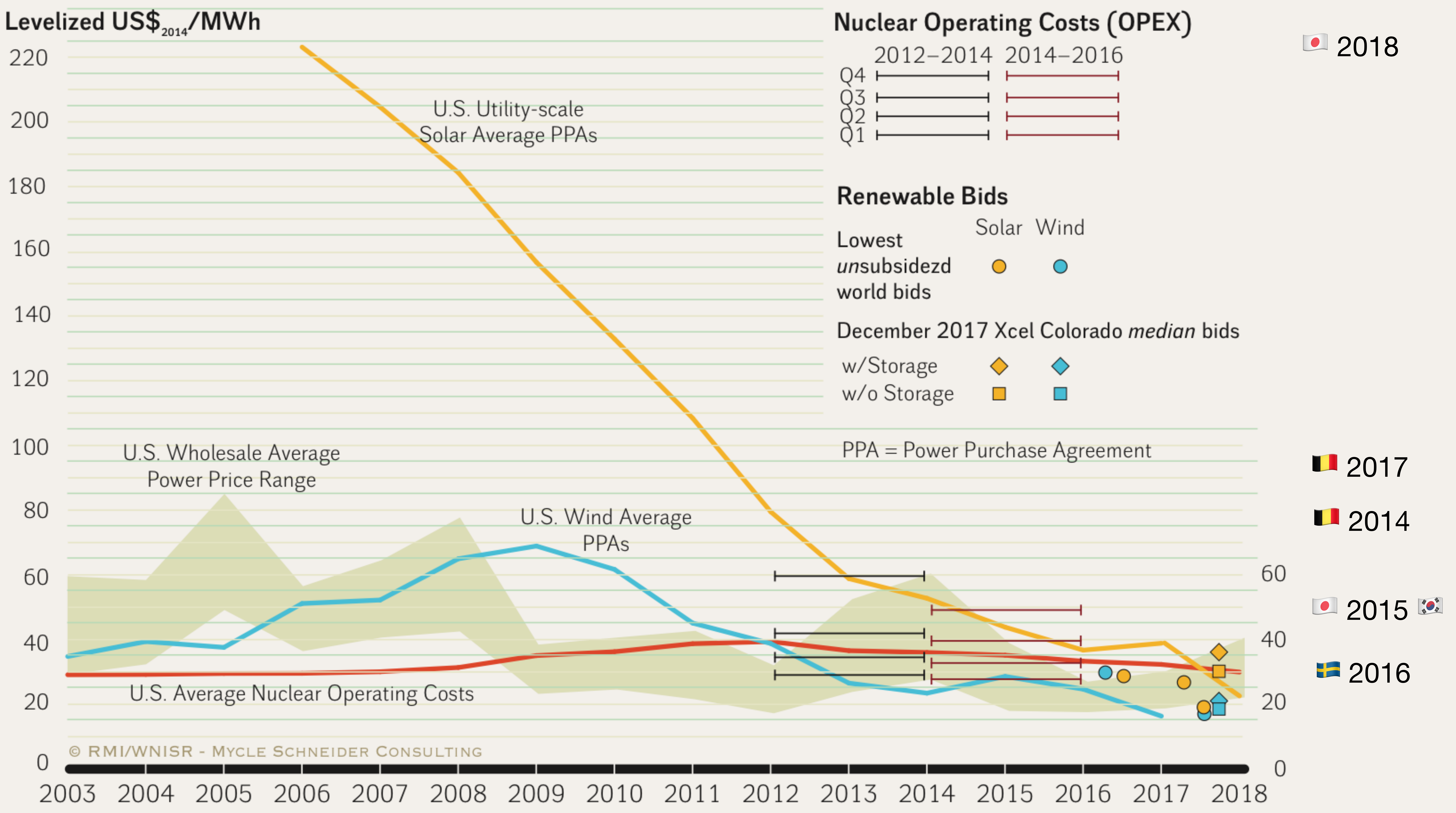


“…[M]ost nuclear plants in advanced economies are at risk of closing prematurely.”

—International Energy Agency
Nuclear Power in a Clean Energy System
May 2019, p. 4

Renewable Electricity vs. Nuclear Operating Costs U.S./World

in US$/MWh *World Nuclear Industry Status Report 2019*, www.worldnuclearreport.org, Fig. 49. PPAs; LBNL. Nuclear opex: NEI.



Closing distressed reactors can generally save money *and* carbon

- US nuclear opex in 2014–16 (latest NEI data) averaged >5¢$_{2014}$/kWh for the top 25 units, >4¢/kWh for the next 25; closing the plant saves that opex + any new subsidy
- Utilities buy efficiency at average (not lowest) costs ~2–3¢/kWh—can be <1¢/kWh
- So closing a top-quartile-cost reactor *and* reinvesting its saved opex (as could be required) can buy ~*2–3+* kWh of carbon-free substitutes—1 kWh to replace the nuclear electricity, the rest to displace fossil-fueled generation, saving *more* CO_2
- Thus coal plants should be closed to save CO_2—*and* high-opex (most) nuclear plants should also be closed to save money whose reinvestment can save even more CO_2
- US evidence shows efficiency and renewables can scale up to replace closed reactors within 1–3 years, then save even more carbon for longer
- PG&E, FOE, NRDC, unions, et al. agreed that orderly closure of Diablo Canyon would save money *and* carbon while improving grid operation; it will be replaced by zero-carbon resources acquired by competitive auction, saving the most carbon per dollar
- *We must track not just the carbon but also the money…and the years*

A B Lovins, "Closing Diablo Canyon Nuclear Plant Will Save Money and Carbon," *Forbes*, 22 Jun 2016, www.forbes.com/sites/amorylovins/2016/06/22/close-a-nuclear-plant-save-money-and-carbon-improve-the-grid-says-pge; —, "Do Coal and Nuclear Generation Deserve Above-Market Prices?," *El. J.* **30**(6):22–30 (Jul 2017), http://dx.doi.org/10.1016/j.tej.2017.06.002 (see also Oct & Dec *El. J.* issues' exchanges with two Exelon-funded critics), preprint at https://d231jw5ce53gcq.cloudfront.net/wp-content/uploads/2017/07/ElJ6May2017_preprint.pdf

Nuclear *vs.* modern-renewable per-capita deployment speed (–2015)

This misleading graph (Science, 5 Aug 2016) implies nuclear is"much faster"…

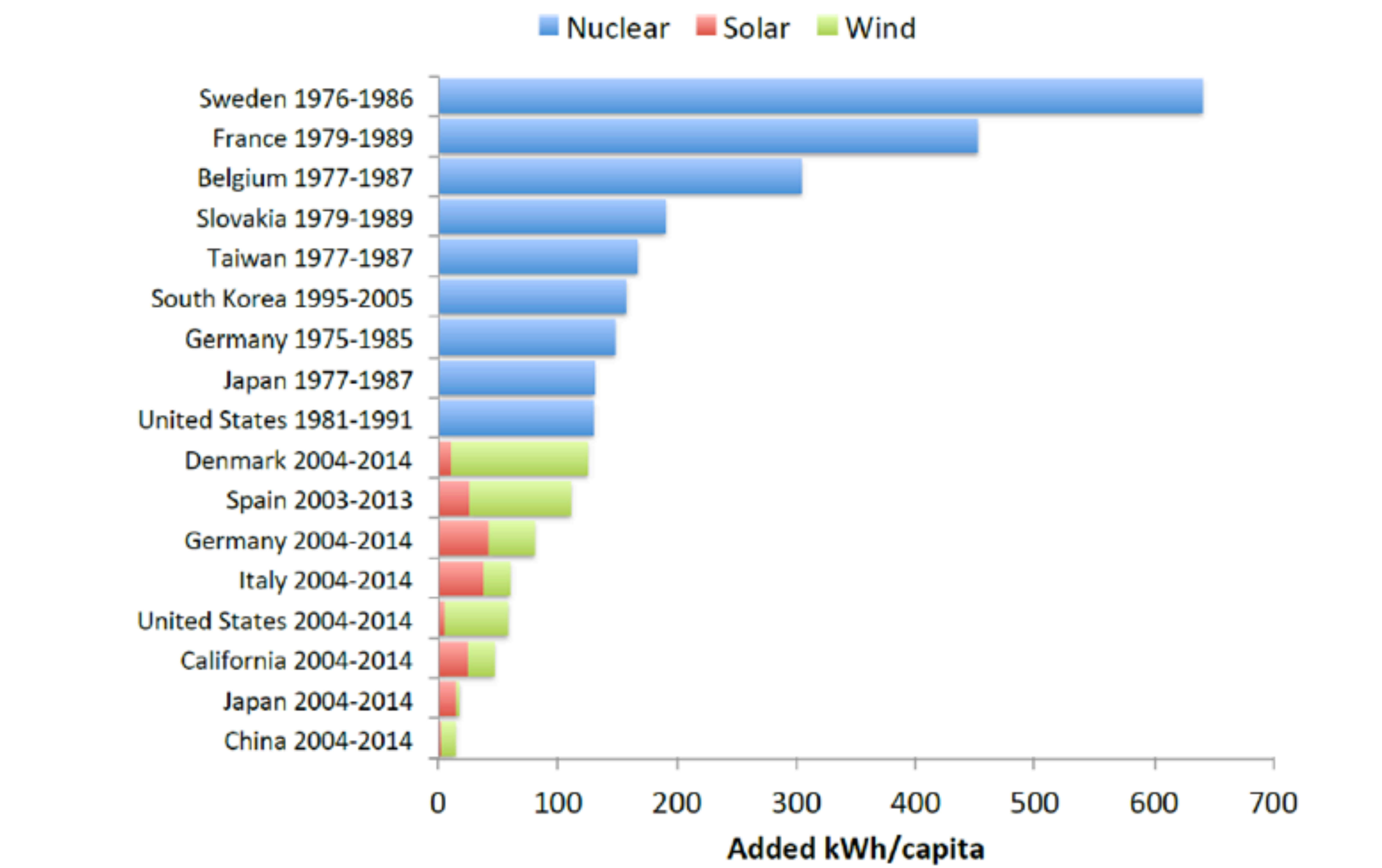
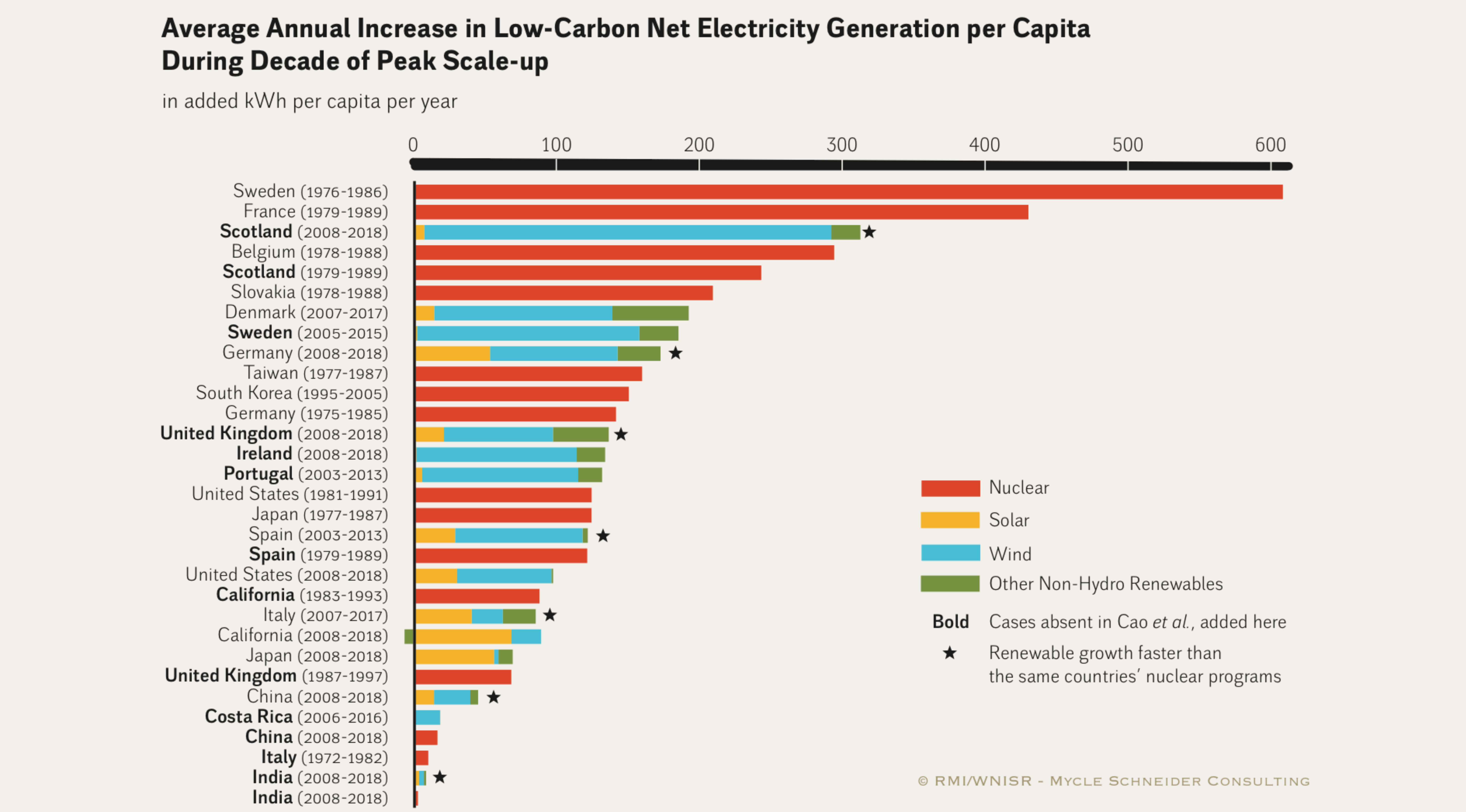


Fig. S2. Average annual increase of carbon-free electricity generation in kilowatt-hours per capita during decade of peak scale-up. Same graph as Fig. 2 in the main text. All generation data from (*S4*), except California renewables generation from (*S1*). All population data from (*S5*). See Tables S1 and S2.

Source: Junji Cao *et al.*, "China-U.S. cooperation to advance nuclear power," *Science* **353**:547–8, 5 Aug 2016, doi: 10.1126/science.aaf7131, from Supplementary Materials at www.sciencemag.org/content/353/6299/547/suppl/DC1; see also A. Lovins, "Nuclear power: deployment speed," *Science* **354**:1112–1113 (2 Dec 2016), https://doi.org/10.1126/science.aal1777, and sources on the following slide.

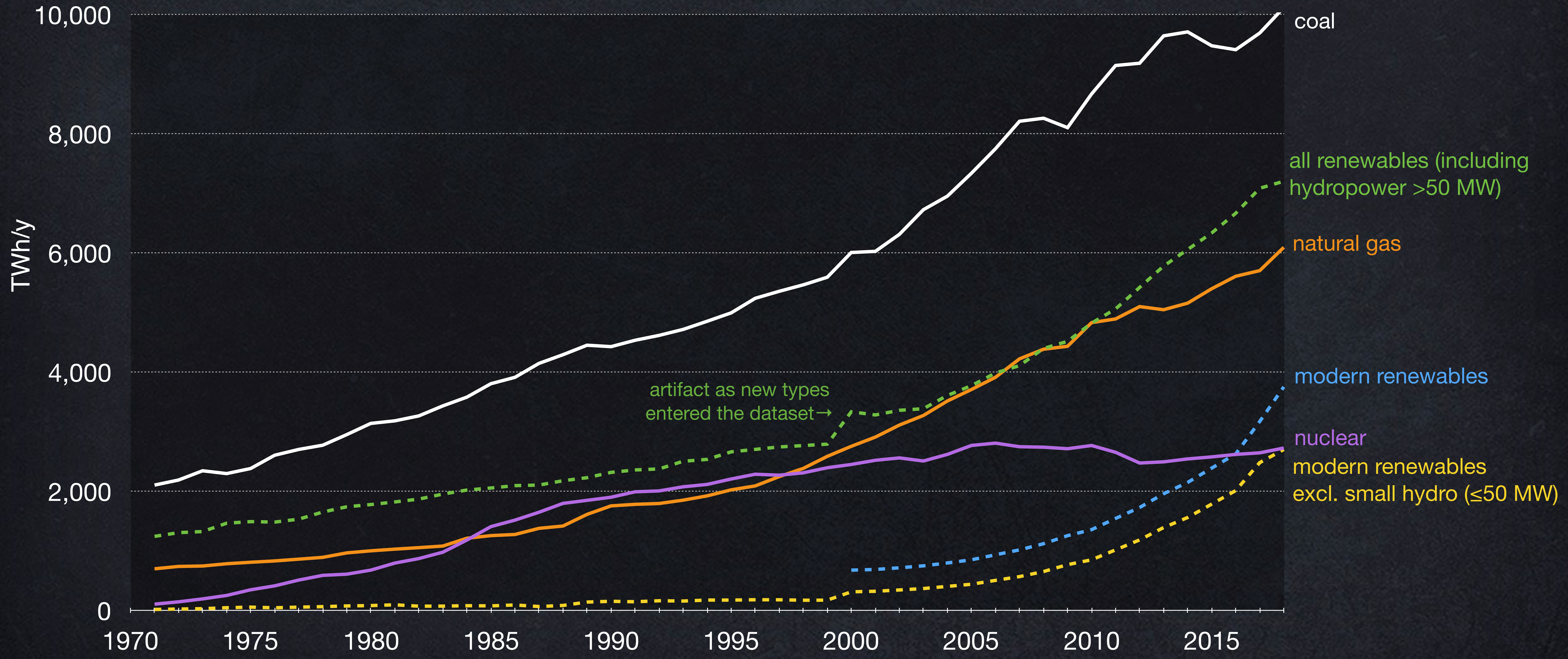
Nuclear *vs.* modern-renewable per-capita deployment speed (–2018)

…but even using the same deeply flawed methodology and the same data source yields a very different answer when omitted cases are included and errors corrected.



Redrawn from A. Lovins, Corrigendum to "Relative deployment rates of renewable and nuclear Redrawn from Lovins, Corrigendum to "Relative deployment rates of renewable and nuclear power: a cautionary tale of two metrics," *Energy Res. Soc. Sci.* **38** (2018) 188–192], https://doi.org/10.1016/j.erss.2018.08.001; see also original analysis in A. Lovins *et al.*, "Relative deployment rates…," *Energy Res. Soc. Sci.* **38:**188–192, 22 Feb 2018, https://doi.org/10.1016/j.erss.2018.01.005.

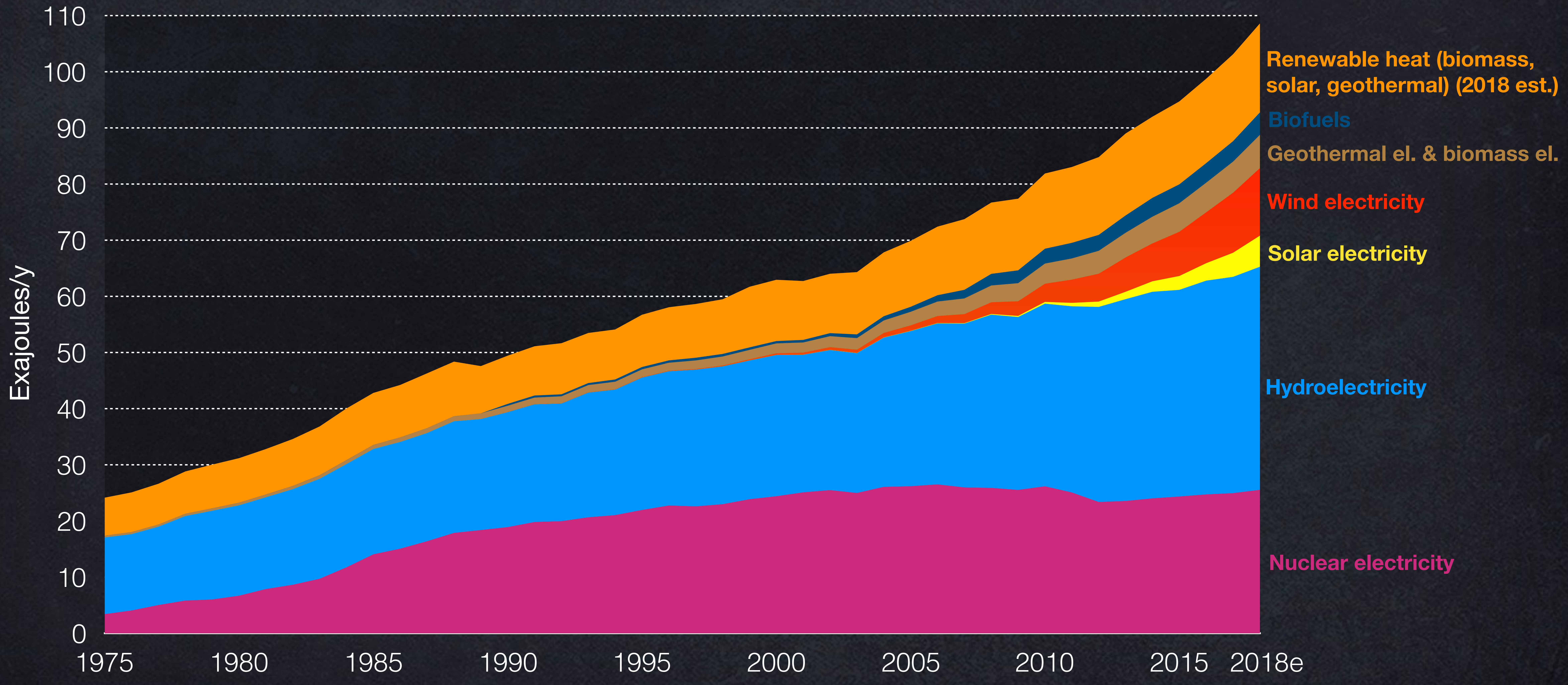
Worldwide electricity generation by source, 1971–2018



A B Lovins *et al.*, "Relative deployment rates of renewable and nuclear power: a cautionary tale of two metrics," *El. Res. & Soc. Sci.* **38**:188–192 (2018), doi:10.1016/j.erss.2018.01.05.
Preliminary 2018 from same source (BP) except coal- and gas-fired data from IEA, "Global Energy & CO_2 Status Report 2018", estimating small hydro share of hydro from prior BNEF data.

Carbon-free global final energy is 28% and accelerating

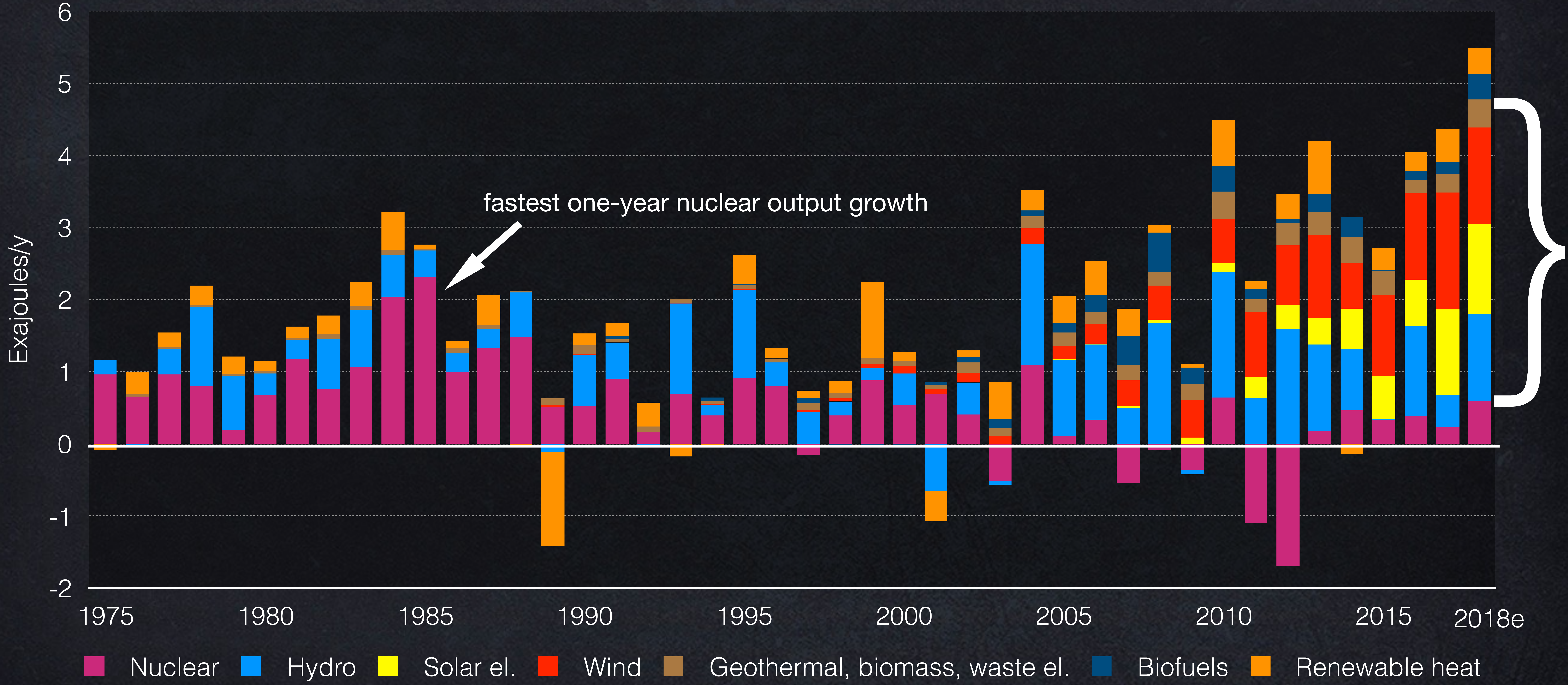
Global total final commercial energy consumption from non-fossil-fuel sources, 1975–2018e



Sources: BP *Statistical Review of World Energy 2019* for all resources, except renewable heat (excluding traditional biomass) from IEA online database, verified within ~1% from IEA *WEO 2018* Figure 6.6 by subtracting BP "biofuels" from IEA "other renewables." (BP does not appear to show renewable heat, while IEA aggregates biofuels with biomass. BP's biofuels data begin in 1990.) REN21 *Global Status Report 2019* draws very similar renewable heat data from IEA and reports its total as 4.2% of 2017 TFEC, comprising 89% biomass, 9% solar, and 2% geothermal. We extrapolate renewable heat total from 2017 to 2018 by using its average annual growth rate during 2014–17.

Modern renewables: the new engine of carbon-free growth

Modern renewables are conventionally all renewables less hydro >50 MW; this graph doesn't distinguish small hydro



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Clean watts are obvious; negawatts are invisible but bigger