

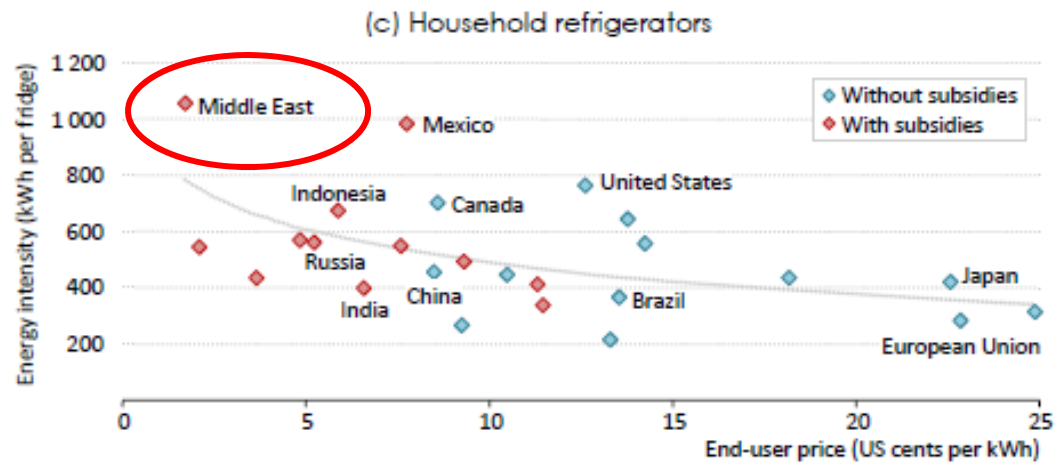
# The Nuclear Solution? The Role of Subsidies and Market Distortions

***NPEC Public Policy Fellowship Retreat***  
**Nonproliferation Policy Education Center**

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# How Much To Push Nuclear if Non-Nuclear Cheaper to Meet Energy Needs?



IEA, World Energy Outlook 2016.

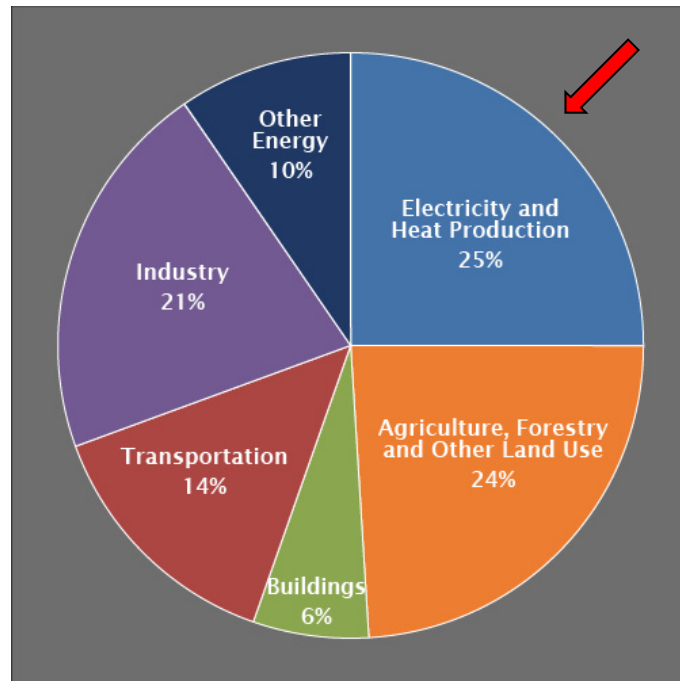
- Subsidies to conventional energy drive inefficient demand.
- Subsidies to nuclear overstate its viability as a building block energy technology.

# Vetting the Nuclear Solution

- Recurring claims:
  - Nuclear is the only viable solution to address climate change.
  - Nuclear will soon be cost-competitive.
  - Subsidies to competitors are the reason nukes aren't thriving.
- How viable an energy solution is nuclear?
  - System, not just reactors, matter: enrichment, waste, regulatory oversight.
  - Long-tail costs (accidents, waste, decommissioning); state ownership; and capital subsidies are much more important for nuclear than other power sources.
  - Proliferation risks are an oft-ignored externality of the nuclear fuel cycle.
  - Yeah, it's low carbon, BUT: cost and delivery matter.

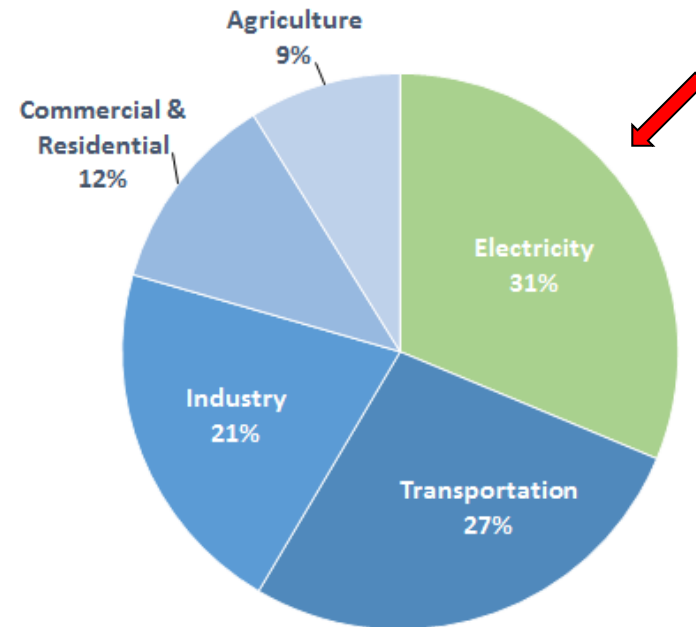
# Efficient Abatement ghg Reductions Not Just about Electricity

## Global ghg Emissions



*IPCC 2014, based on 2010 emissions data.*

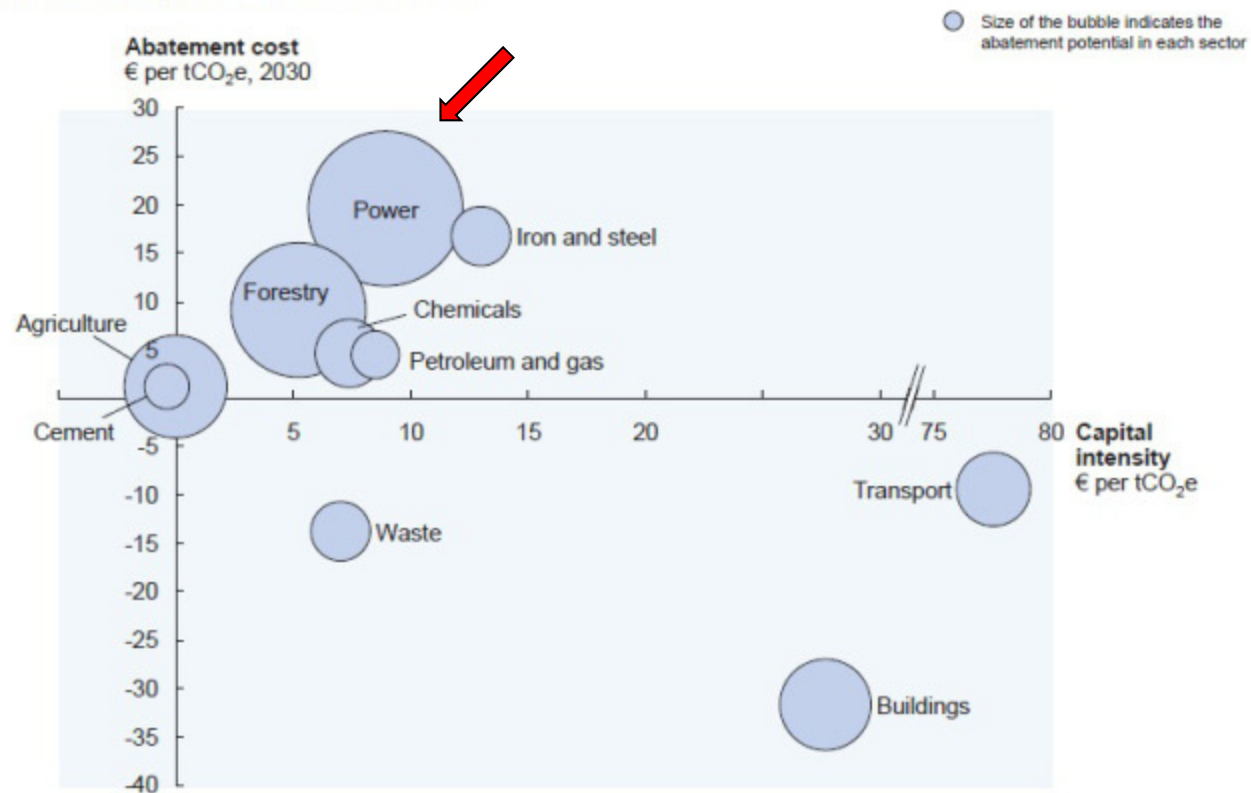
## US ghg Emissions



*US EPA inventory, 2014 emissions data*

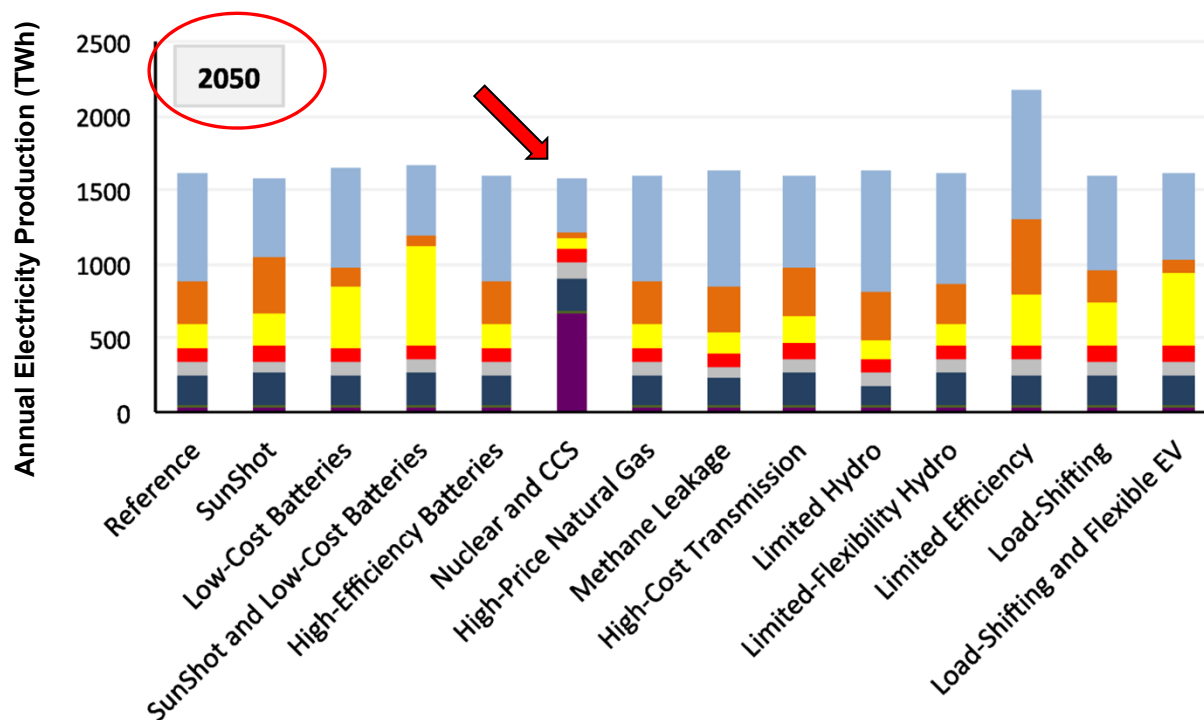
# Efficient Abatement But Power is High Cost Sector

Capital intensity and abatement cost



Source: Global GHG Abatement Cost Curve v2.0

# Efficient Abatement Modeling: Late Arrival under Constrained Competition

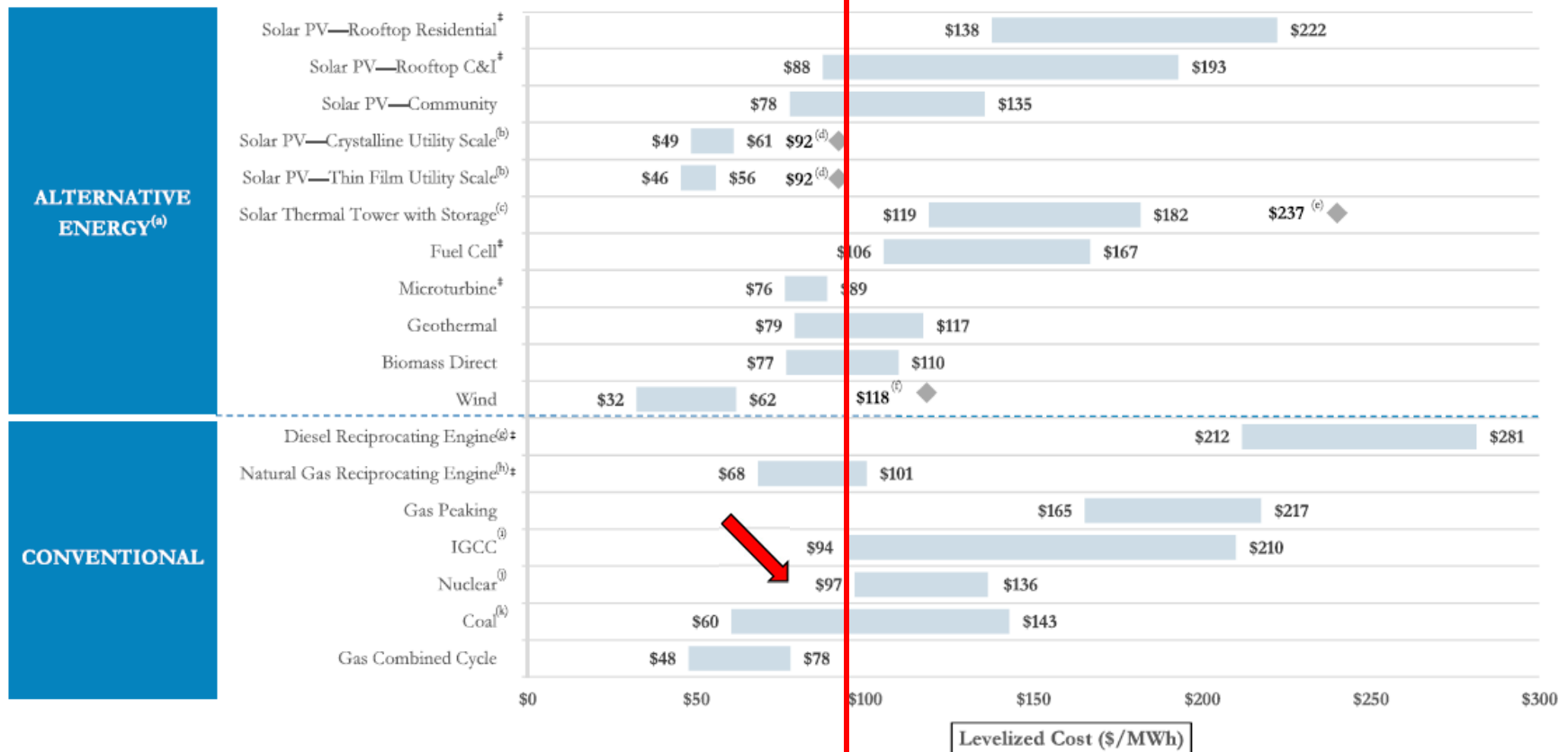


Source: Mileva et al., *Applied Energy*, Jan. 2016.

\*Western Electric Coordinating Council includes part or all of 14 Western states, the provinces of Alberta and British Columbia, and northern Baja California in Mexico.

- ~No nuclear prior to 2050.
- Only in 2050 if freeze innovation in other power sources.
- Late and expensive abatement has high opportunity cost.

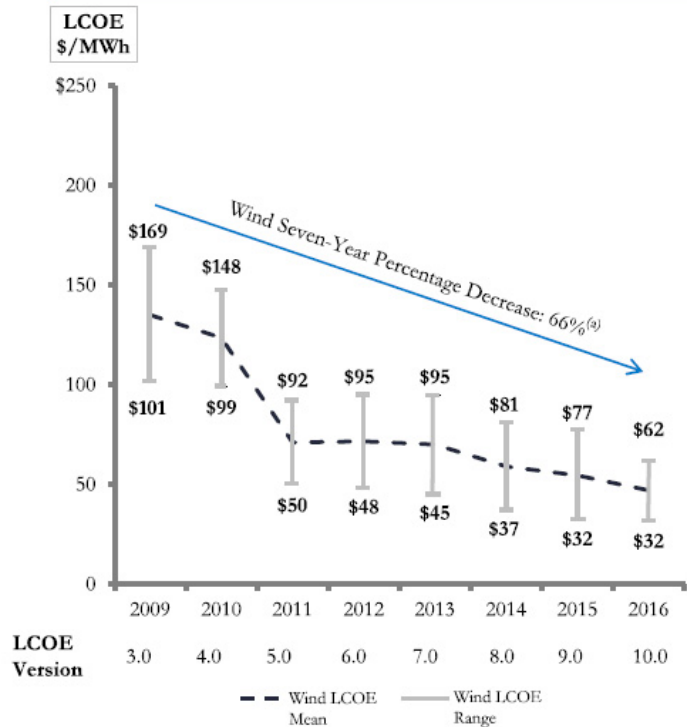
# Market Testing Nuclear Wind, Centralized Solar, Gas Cheaper than Nuclear



© 2016, Lazard.

# Market Testing Nuclear Costs Falling Steadily for Wind and PV

WIND LCOE



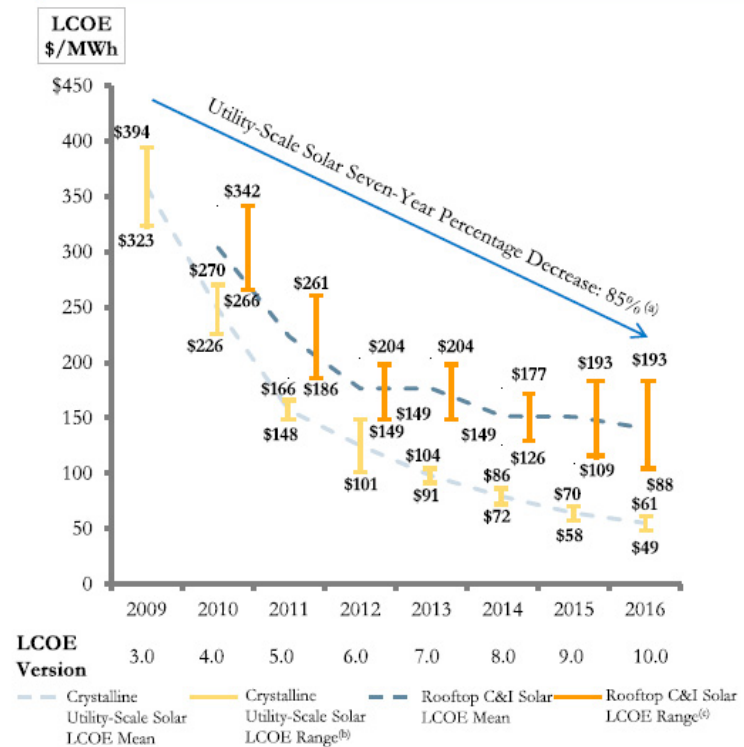
Source: Lazard estimates.

(a) Represents average percentage decrease of high end and low end of LCOE range.

(b) Low end represents crystalline utility-scale solar with single-axis tracking in high insolation jurisdictions (e.g., Southwest U.S.), while high end represents crystalline utility-scale solar with fixed-tilt design.

(c) Lazard's LCOE initiated reporting of rooftop C&I solar in 2010.

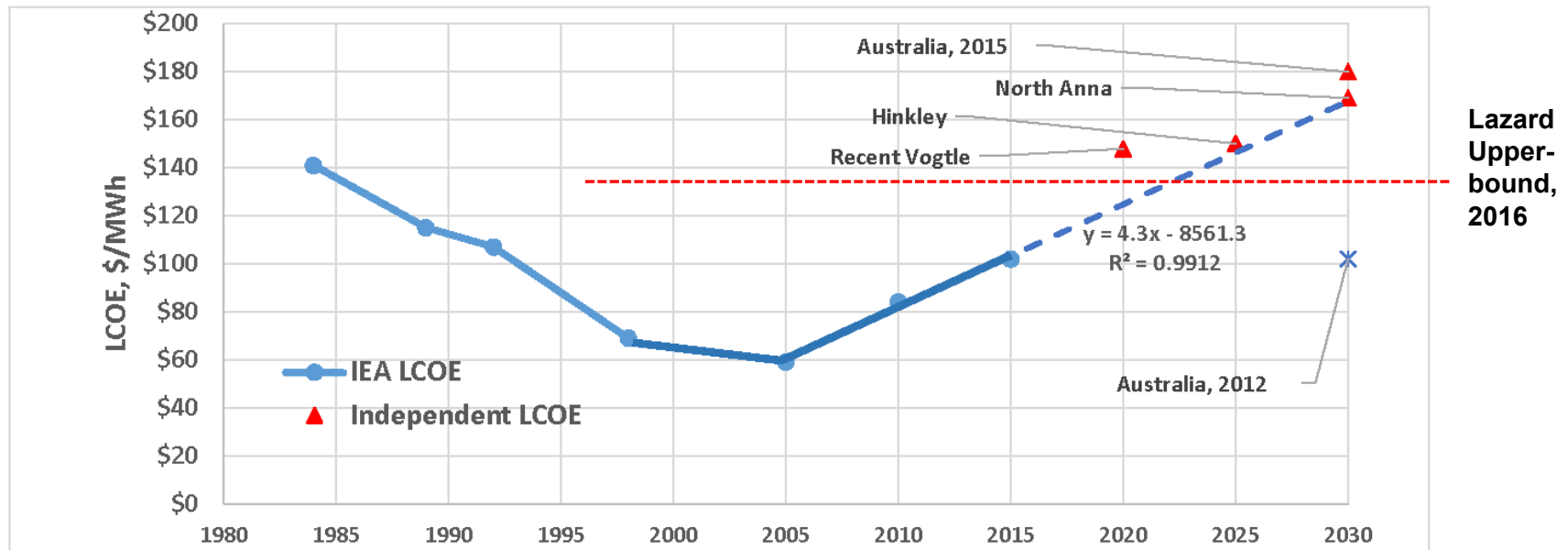
SOLAR PV LCOE





# Market Testing Nuclear Off-Cited Cost Reductions from Learning in Nuclear Sector Remain Stuck in Reverse

## Levelized Cost Estimates



Source: "The Economic and Institutional Foundations of the Paris Agreement on Climate Change: The Political Economy of Roadmaps to a Sustainable Electricity Future," working paper by Mark Cooper, Vermont Law School, Jan. 2016.

# Nuclear's Subsidy Problem

## Energy Prices are *not* Market-Based

Global Energy Subsidies are Massive, **But Nobody is Tracking Support to Nuclear**

Fuel type	IEA	OECD	IMF (pre-tax)	IMF (post-tax)
<i>Measurement approach/billions of 2015 US\$</i>				
	Price gap	Total support estimate	IEA plus OECD, less tax breaks	IMF pre-tax plus tax breaks plus externalities
<b>Fossil fuels</b>	506	170	333	5,302
<b>Nuclear electric</b>	NE	NE	NE	NE
<b>Renewables electric</b>	112	NE	NE	NE
<b>Biofuels, transport</b>	23	NE	NE	NE
<b>Total all fuels</b>	641	170	333	5,302
<b>% of world GDP</b>	0.8	0.2	0.4	6.8

**Source:** Earth Track tabulation from IEA (2014, 2015); OECD (2015); Coady et al. (2015). GDP data from World Bank (2017a).

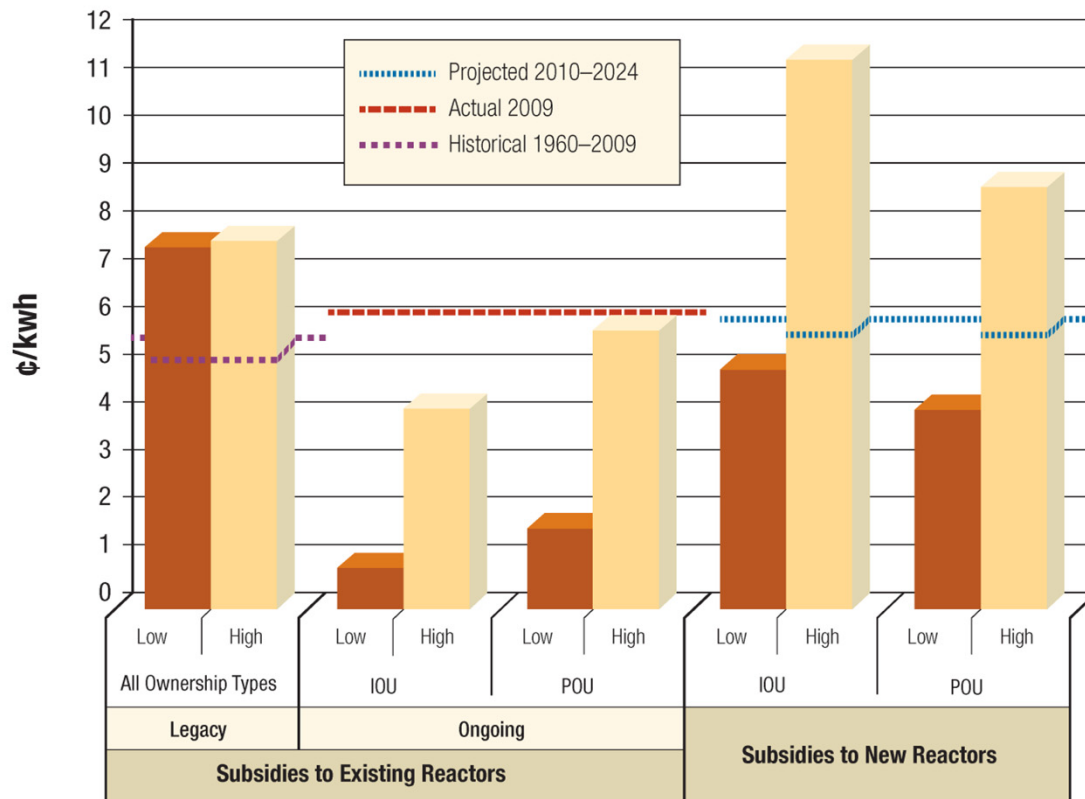
**Notes:**

NE = not estimated

Data year: 2014 for IEA and OECD; mixed input years for IMF.

# Nuclear's Subsidy Problem

## Global Data or No, Nuclear *is* Heavily Subsidized



Note: Legacy subsidies are compared to the Energy Information Administration (EIA) average 1960–2009 industrial power price (5.4 ¢/kWh). Ongoing subsidies are compared to EIA 2009 actual power prices for comparable busbar plant generation costs (5.9 ¢/kWh). Subsidies to new reactors are compared to EIA 2009 reference-case power prices for comparable busbar plant generation costs (5.7 ¢/kWh).

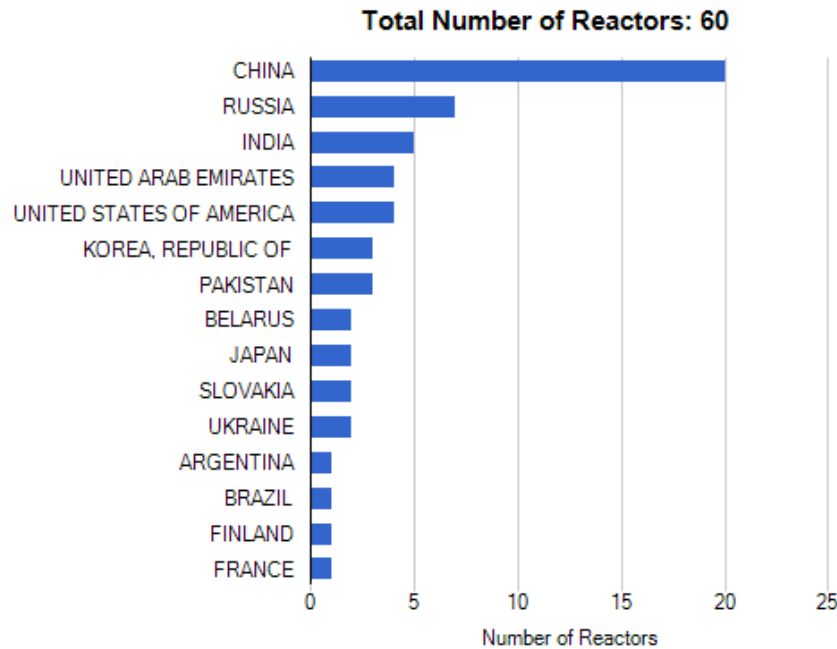
- Financing (LG, CWIP, tax exempt debt for POUs)
- Accident risk
- Waste management
- Decommissioning
- PPAs (mostly abroad)
- R&D
- Enrichment (remains mostly state-owned)

Source: Koplou, *Nuclear Power Still Not Viable Without Subsidies*, 2011

# Nuclear's Subsidy Problem

## "Go Big" Nuclear Countries also Have Large FF Subsidies

**New reactor projects by country**



Source: IAEA Power Reactor Information System database, 22 Feb 2017

**Consumer subsidies to fossil fuels, by country**

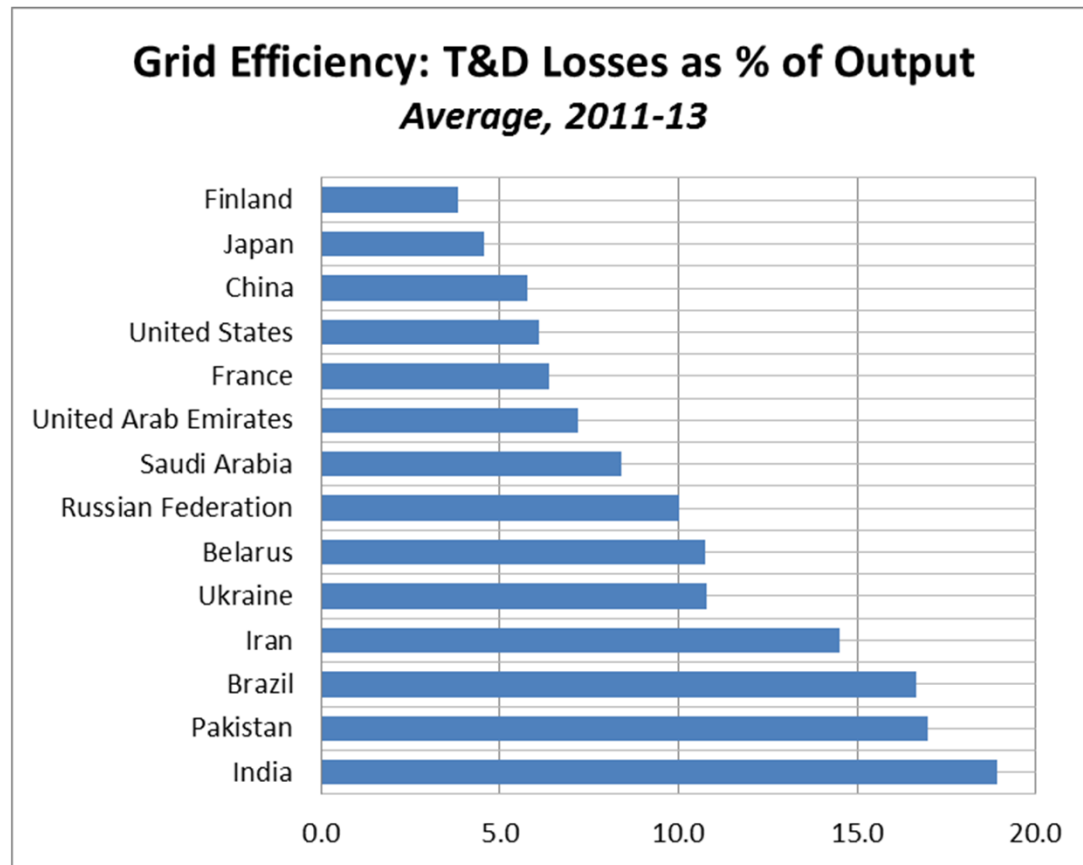
(Average, 2012-14)

Country	Bils USD	Rank by Subsidy Amout	Country share of Global Total
China	23.4	8	4.5%
Russia	40.4	4	7.7%
India	43.6	3	8.3%
UAE	20.9	9	4.0%
Ukraine	11.0	15	2.1%
Saudi Arabia	72.7	1	13.9%
Iran	64.2	2	12.2%
Pakistan	8.9	18	1.7%
Taiwan	0.7	33	0.1%
	285.7		54.5%
IEA World Estimate	524.2		100.0%

Source: IEA subsidy database, accessed Feb. 2017.

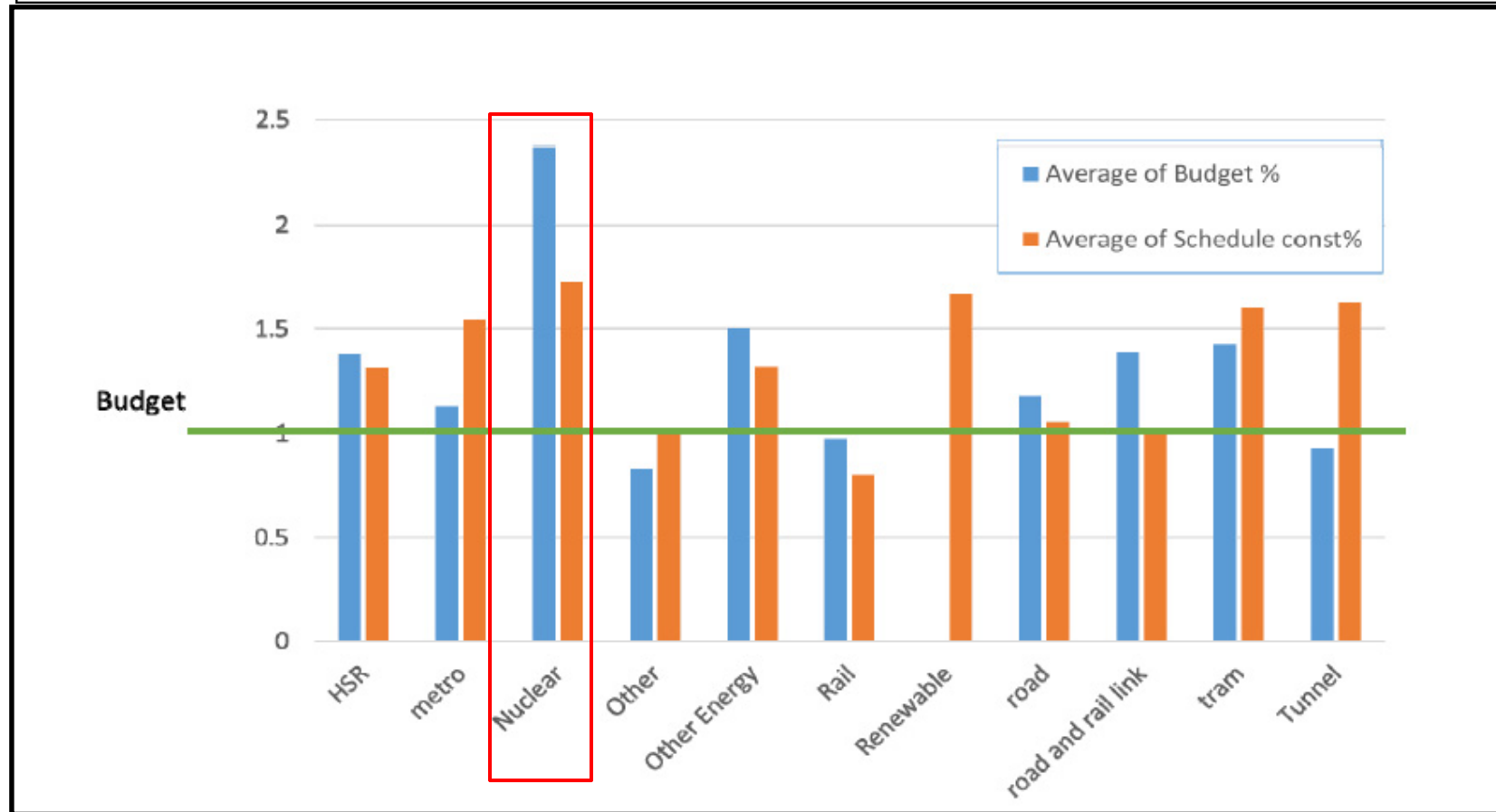
# Nuclear's Subsidy Problem

## Line Losses Equal to Quite a Few Reactors



Source: World Bank Data Bank, World Development Indicators, accessed 23 Feb 2017.  
Includes technical losses and pilferage.

# State salvation Megaprojects: Nuclear is “Winning”



Source: Locatelli, University of Leeds, 2015.

## State Salvation

# Because when you can't compete...

- **Enrichment:** nearly 90% of SWU capacity state-owned in 2015.
- **Nuclear waste:** mostly state responsibility, sometime in 2030, 2040, or 2050...
- **Accident liability:** US has largest pool in the world, yet equal to less than 11% of the *already incurred* costs of Fukushima.
- **Capital risks:** state ownership, guarantees, CWIP, or above-market price floors.
  - Top two reactor builders (Russia, China) have heavy state-ownership; financing packages for sales abroad.
  - Military overlap: keeping supply chains alive.
  - Most LCOE calculations use the same discount rate for nuclear as for other options.

## Long-tail risks

# Nuclear Waste is Somebody Else's Problem

Country	Percentage of global nuclear megawatt electric, 2015	Earliest high level waste repository open date	Location chosen	Accrued funding held outside firm	Ownership
United States	25.6	2048	Chosen site terminated	Yes	State
France	16.2	2025	Yes, although opposition remains	No	State
Japan	10.4	>2035	No	Yes	Utility
China	7.8	>2050	'First priority' area selected	Yes <sup>1</sup>	State
Russia	7	No target date	No	Yes	State
South Korea	5.9	No target date	No	Yes	State
Canada	3.5	2035	No	Yes	State <sup>2</sup>
Germany	2.7	>2025	Opposition to target site	No	State
United Kingdom	2.3	No target date	No	Yes	State
Sweden	2.3	2028	Yes	Yes	Utility
Spain	1.8	No target date	No	Yes	State
India	1.6	No target date	No	Publicly funded <sup>3</sup>	State
Belgium	1.5	>2035	No	No	State
Switzerland	0.9	No target date	No	Yes	State
Finland	0.7	2023	Yes	Yes	Utility

Source: Koplou in Van Ness and Gurtov, eds., (ANU Press, forthcoming).