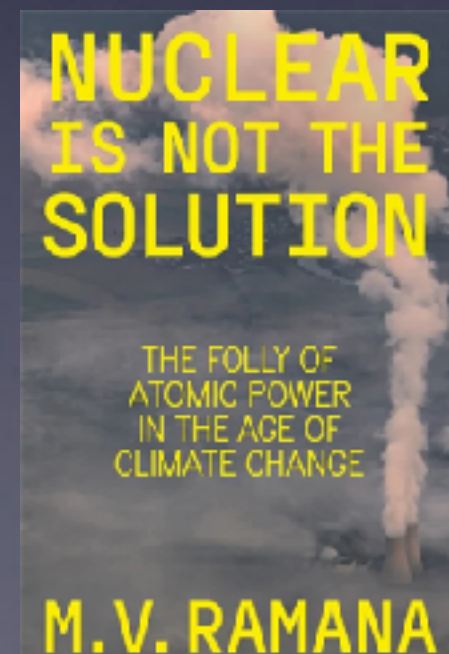
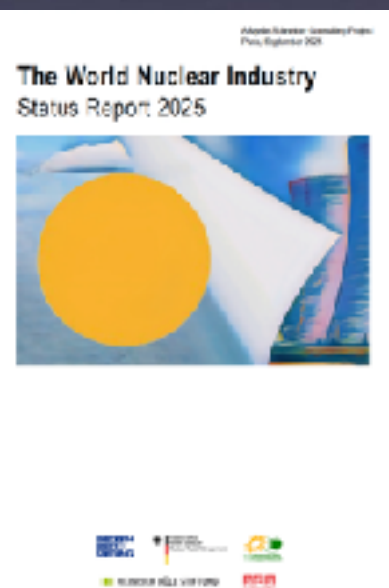


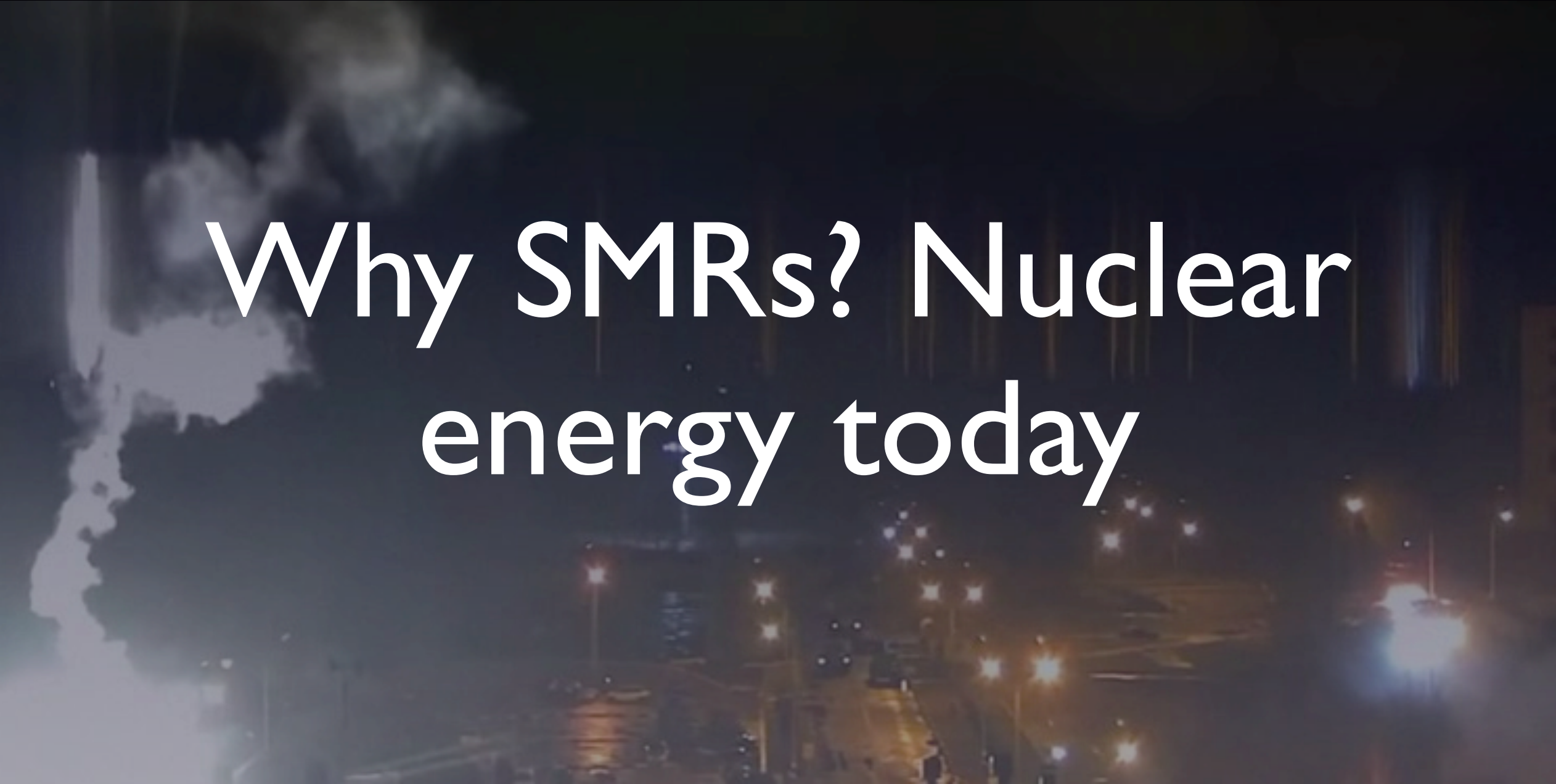
Small Modular Reactors: Current Status, Open Issues

M.V. Ramana

School of Public Policy and Global Affairs
University of British Columbia

Kyoto Club, Roma
2 February 2026





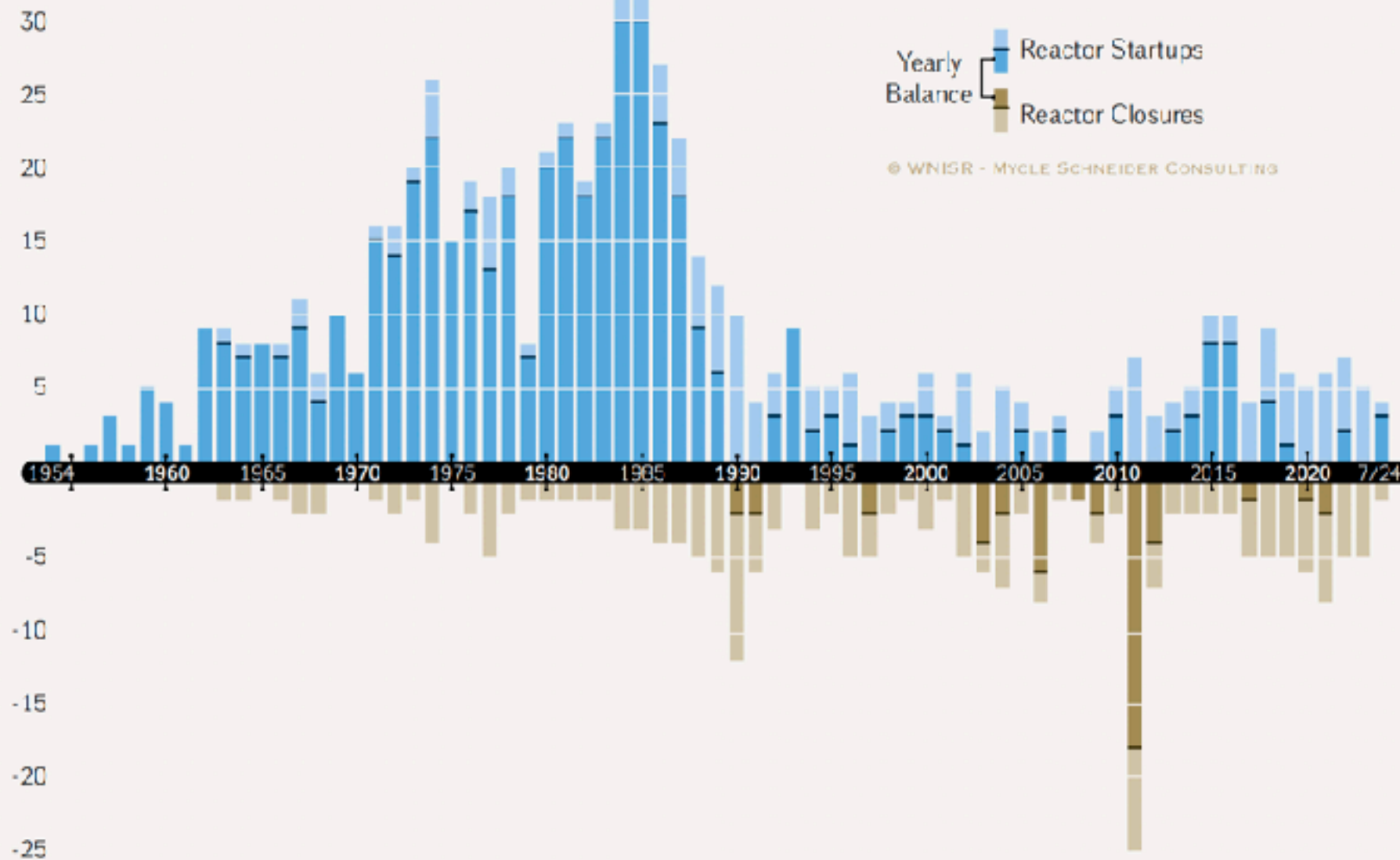
Why SMRs? Nuclear energy today

Source: https://media.farsnews.ir/Uploaded/Files/Images/1400/12/16/14001216000113_Test_PhotoN.jpg

The best days of nuclear construction ended three decades ago

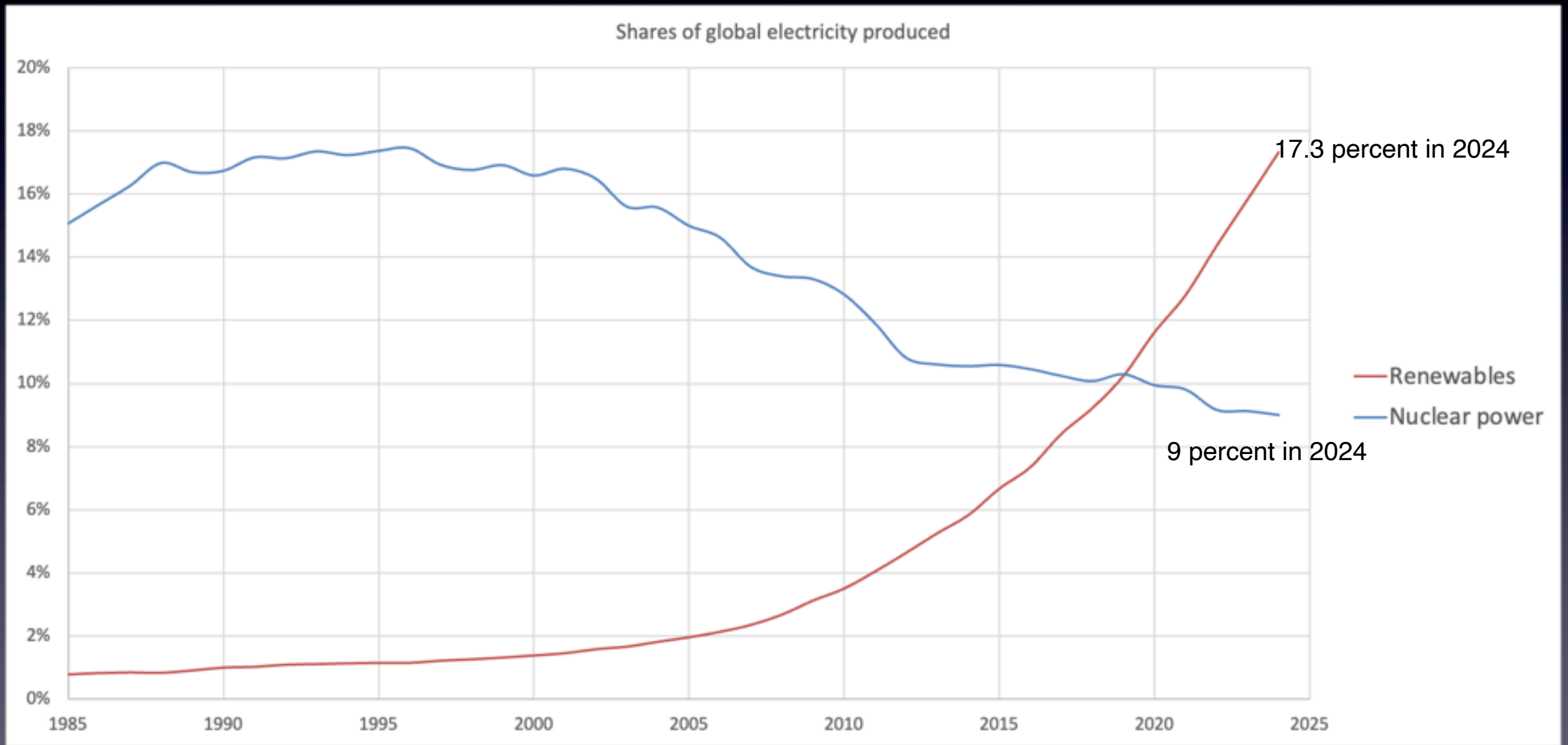
Reactor Startups and Closures in the World

in Units, from 1954 to 1 July 2024



Sources: WNISR, with IAEA-PRIS, 2024

Share of nuclear electricity is 48.5 percent below historical maximum of 17.5 percent in 1996



Source: Calculations using data from Energy Institute. "Statistical Review of World Energy 2025," June 2025

Why this trend?

Nuclear reactors cost too much to build



Construction costs

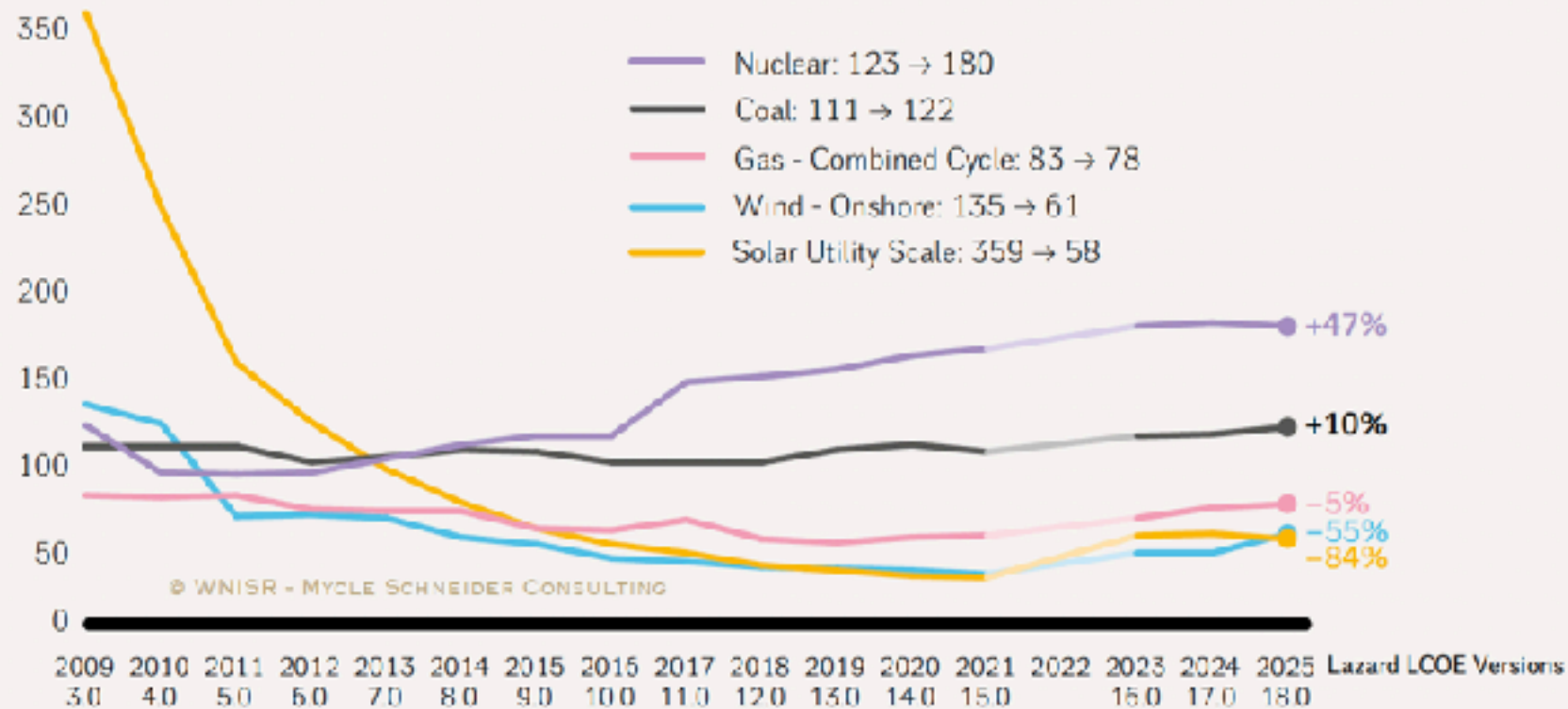
Reactor Name	Reactor Type	Current Estimate	Generation Capacity	Implied Cost/ Unit Capacity
Flamanville	1 X EPR	\$17 billion	1630 MW	\$10,400/kW
Hinkley Point	2 X EPR	\$54 billion	3260 MW	\$16,600/kW
Vogtle (USA)	2 X AP1000	\$37 billion	2234 MW	\$16,560/kW

UK costs originally in 2015 GBP; inflated using <https://www.gov.uk/government/statistics/gdp-deflators-at-market-prices-and-money-gdp-october-2024-autumn-budget-2024>

Nuclear power is expensive; other sources of electricity are cheaper

Selected Historical Mean Costs by Technology

LCOE values in US\$/MWh *



* Reflects total decrease in mean LCOE since Lazard's LCOE VERSION 3.0 in 2009

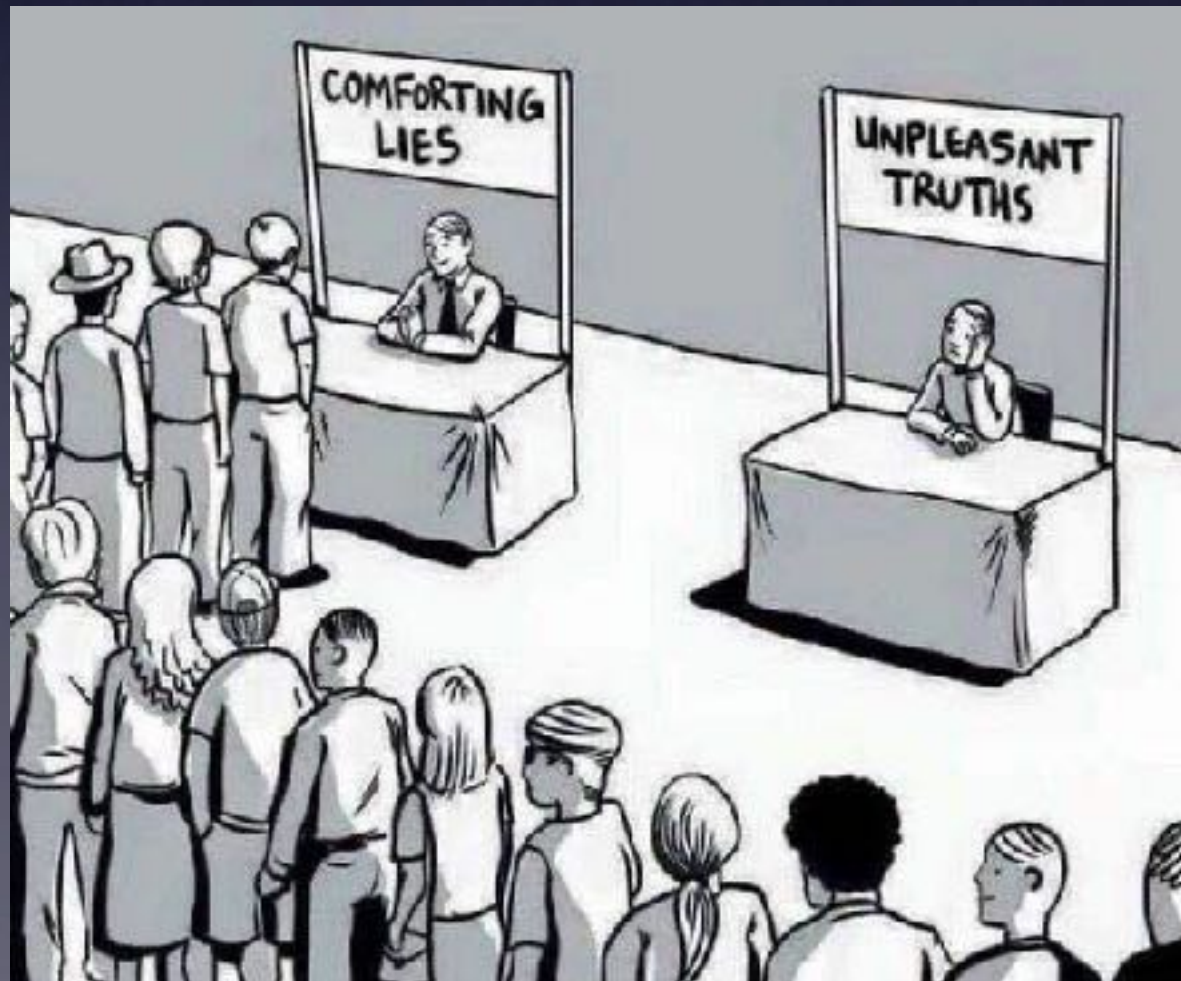
Source: Lazard Estimates, 2025

Notes: **LCOE**: Levelized Cost of Energy

*This graph reflects the average unsubsidized LCOE values in current dollars (not adjusted for inflation) for a given version of LCOE study. It primarily relates to the North American energy landscape but reflects broader, global cost developments.

Source: data from Lazard, as plotted in World Nuclear Industry Status Report 2025

Can new nuclear
reactor designs change
this picture?



Cheap game changer!

NuScale Changed the Game

NuScale was the first to offer the market a commercially viable modular, scalable light water design

- Modular – factory manufacturing of major components and systems lowers costs, improves quality, shortens construction
- Scalable – incremental addition of nuclear generating capacity produces cash flow sooner, places plant in rate base earlier
- Commercially viable – light water technology provides clear path to licensing

Source: Ross Snuggerud, NuScale Power at U.S. Win 2011 Conference

Reality: No single design can have all desirable properties

Energy Research & Social Science 2 (2014) 115–124



Contents lists available at ScienceDirect

Energy Research & Social Science

journal homepage: www.elsevier.com/locate/erss



Original research article

One size doesn't fit all: Social priorities and technical conflicts for small modular reactors

M.V. Ramana*, Zia Mian

Nuclear Futures Laboratory and Program on Science and Global Security, Princeton University, United States



Small also means...

More cost

$$\frac{K_1}{K_2} = \left(\frac{S_1}{S_2} \right)^{0.6}$$

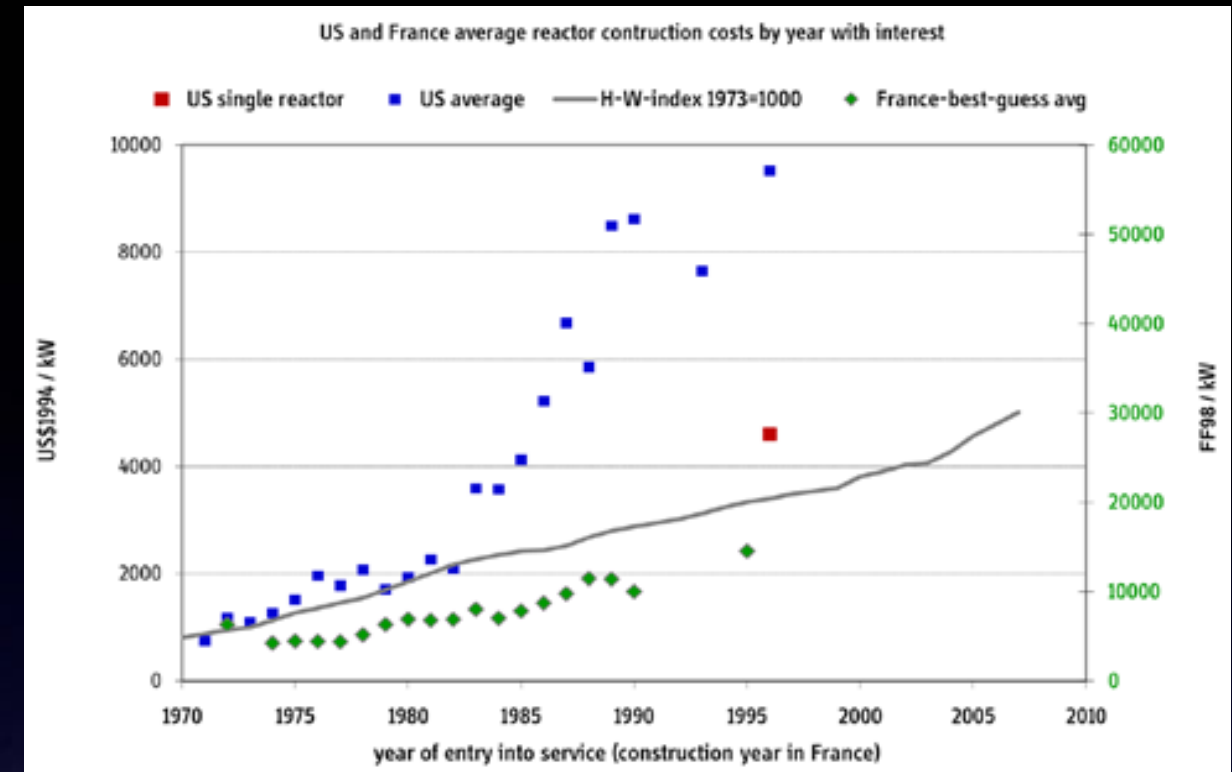
More spent fuel/waste

RESOURCE REQUIREMENTS AND
PROLIFERATION RISKS ASSOCIATED
WITH SMALL MODULAR REACTORS

ALEXANDER GLASER,* LAURA BERZAK HOPKINS, and M. V. RAMANA

NUCLEAR TECHNOLOGY VOL. 184 OCT. 2013

“Learning” might make plants more expensive



Grubler, Arnulf. 2010. “The Costs of the French Nuclear Scale-up: A Case of Negative Learning by Doing.” *Energy Policy* 38 (9): 5174–88.

Even if there was learning, too many “loss leaders” have to be built

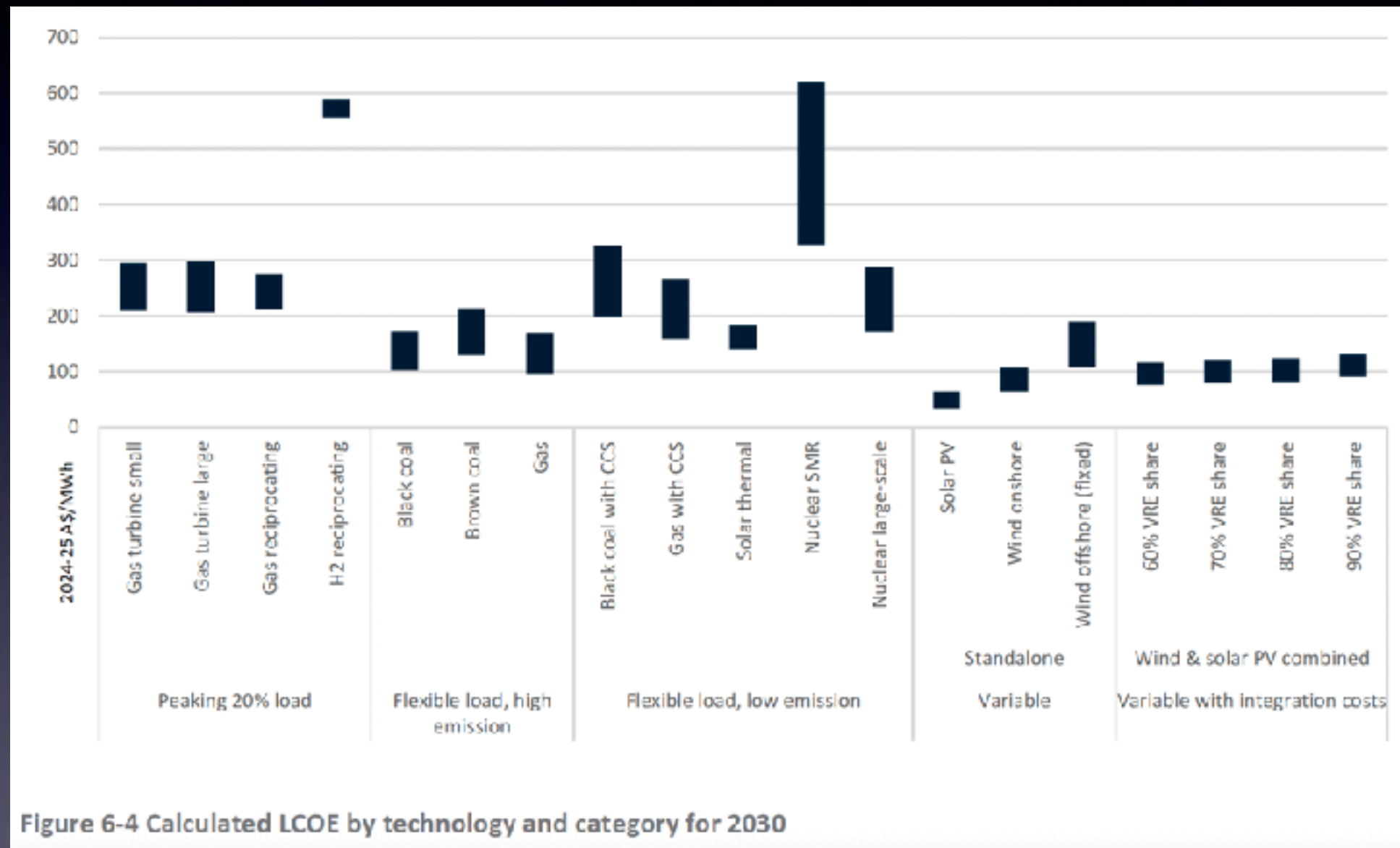
Diseconomies of Scale Exponent		
	0.6	0.8
Learning Rate 10%	700	80
Learning Rate 5%	60,000	780

Glaser, Alexander, M.V. Ramana, Ali Ahmad, and Robert Socolow. 2015. “Small Modular Reactors: A Window on Nuclear Energy.” *An Energy Technology Distillate*. Princeton, N.J.: Andlinger Center for Energy and the Environment at Princeton University. <http://acee.princeton.edu/distillates/distillates/small-modular-reactors/>.

Diseconomies of scale

Design	Cost Estimate (\$/kW)
CAREM (Argentina)	\$32,000/kW
NuScale (462 MWe, USA)	>\$20,000/kW (250% more than Vogtle estimate as of 2014)
BWRX-300 (280 MWe, USA/Canada)	\$12,471-\$17,949/kW (range from TVA 2025 Integrated Resource Plan)

Cost of electricity from SMRs is much higher, even taking into account variability of renewables



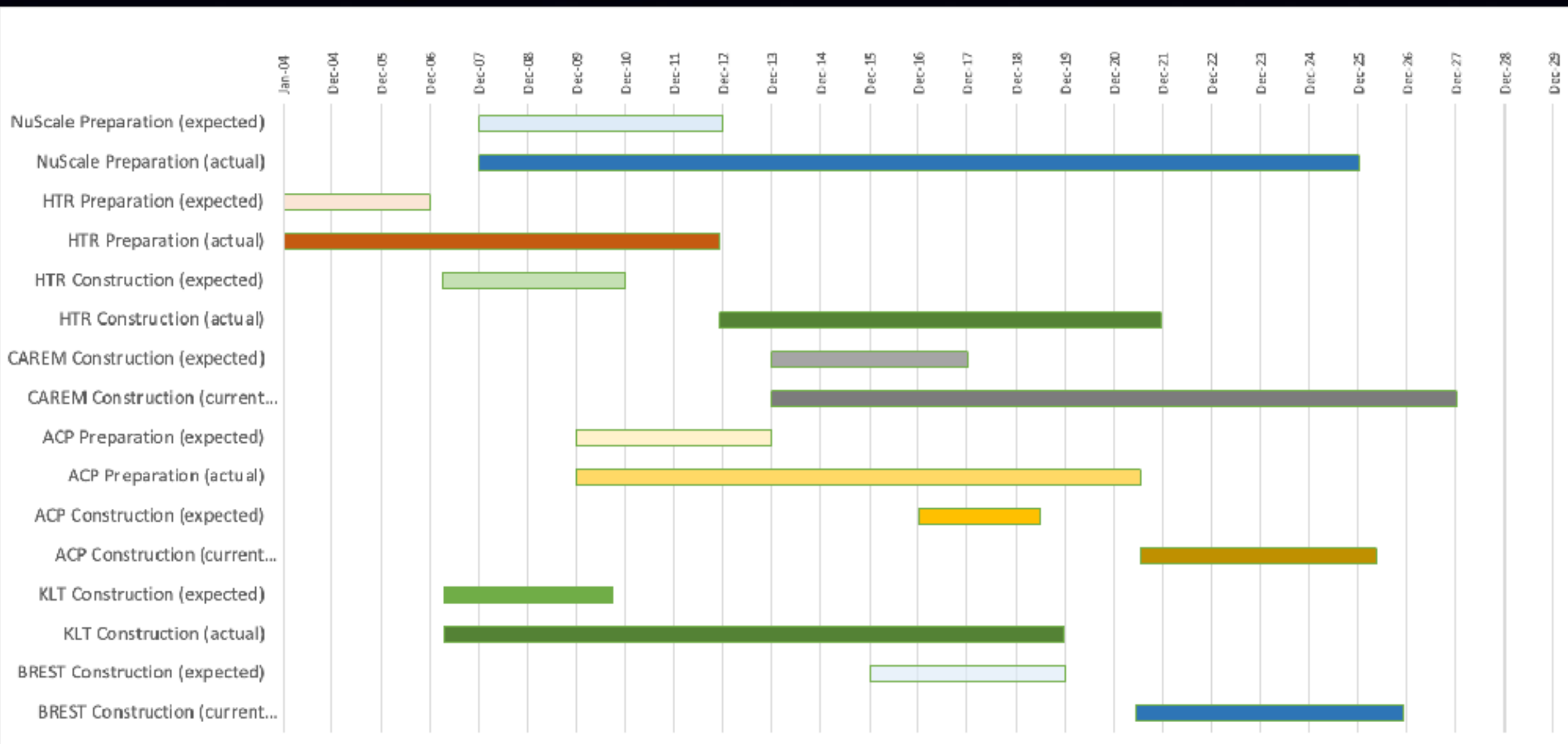
Source:CSIRO. 2025. GenCost: Cost of Building Australia's Future Electricity Needs. December. <https://www.csiro.au/en/research/technology-space/energy/Electricity-transition/GenCost>.

Small Reactors aren't new—a long history of economic failures

REACTORS						
Name	Type	Status	Location	Reference Unit Power [MW]	Gross Electrical Capacity [MW]	First Grid Connection
SAXTON	PWR	Permanent Shutdown		3	3	1967-03-01
PIQUA	X	Permanent Shutdown	Piqua	12	12	1963-07-01
BONUS	BWR	Permanent Shutdown	Rincon	17	18	1964-08-14
CVTR	PHWR	Permanent Shutdown	Parr	17	19	1963-12-18
ELK RIVER	BWR	Permanent Shutdown		22	24	1963-08-24
GE VALLECITOS	BWR	Permanent Shutdown	Pleasanton, Sanol	24	24	1957-10-19
PEACH BOTTOM-1	HTGR	Permanent Shutdown	YORK COUNTY	40	42	1967-01-27
LACROSSE	BWR	Permanent Shutdown	GENOA	48	55	1968-04-26
PATHFINDER	BWR	Permanent Shutdown		59	63	1966-07-25
FERMI-1	FBR	Permanent Shutdown	LAGOONA BEACH	61	65	1966-06-05
HUMBOLDT BAY	BWR	Permanent Shutdown	EUREKA	63	65	1963-04-18
SHIPPINGPORT	PWR	Permanent Shutdown		60	68	1957-12-02
BIG ROCK POINT	BWR	Permanent Shutdown	CHARLEVOIX	67	71	1962-12-08
HALLAM	X	Permanent Shutdown	Lincoln	75	84	1963-09-01
YANKEE NPS	PWR	Permanent Shutdown	ROWE	167	180	1960-11-10
DRESDEN-1	BWR	Permanent Shutdown	MORRIS	197	207	1960-04-15
INDIAN POINT-1	PWR	Permanent Shutdown	BUCHANAN	257	277	1962-09-16

Source: <https://pris.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=US>

Current Delays

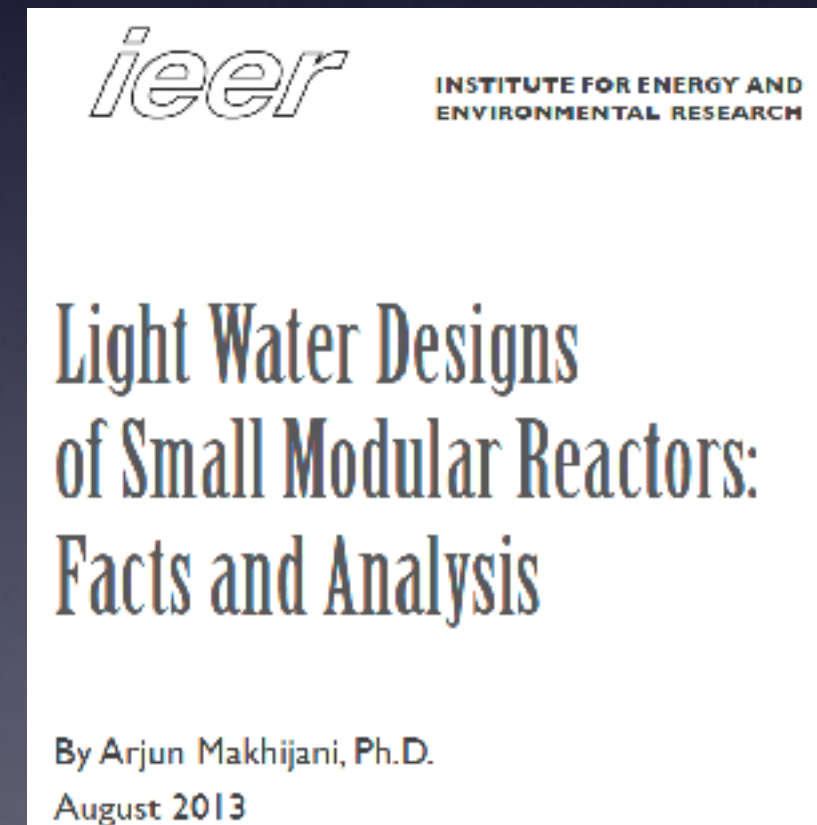


Underbelly of Mass Manufacture

Generic safety problems and recalls



Source: https://upload.wikimedia.org/wikipedia/commons/thumb/3/39/Boeing_737-8_MAX_N8704Q_rotated.jpg/1200px-Boeing_737-8_MAX_N8704Q_rotated.jpg



Problem 1: Nuclear energy is capable of severe accidents



Cannot envision all possible accident pathways
Impossible to reliably assess probability of accident
Japan Center for Economic Research 2019
estimate for Fukushima cleanup: \$750 billion

Regulation & Governance
Regulation & Governance (2020) doi:10.1111/rego.12300

Empires built on sand: On the fundamental implausibility of reactor safety assessments and the implications for nuclear regulation

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M. V. Ramana 
Elu Institute for Global Issues, School of Public Policy and Global Affairs, University of British Columbia, Vancouver, British Columbia, Canada

Bulletin of the Atomic Scientists

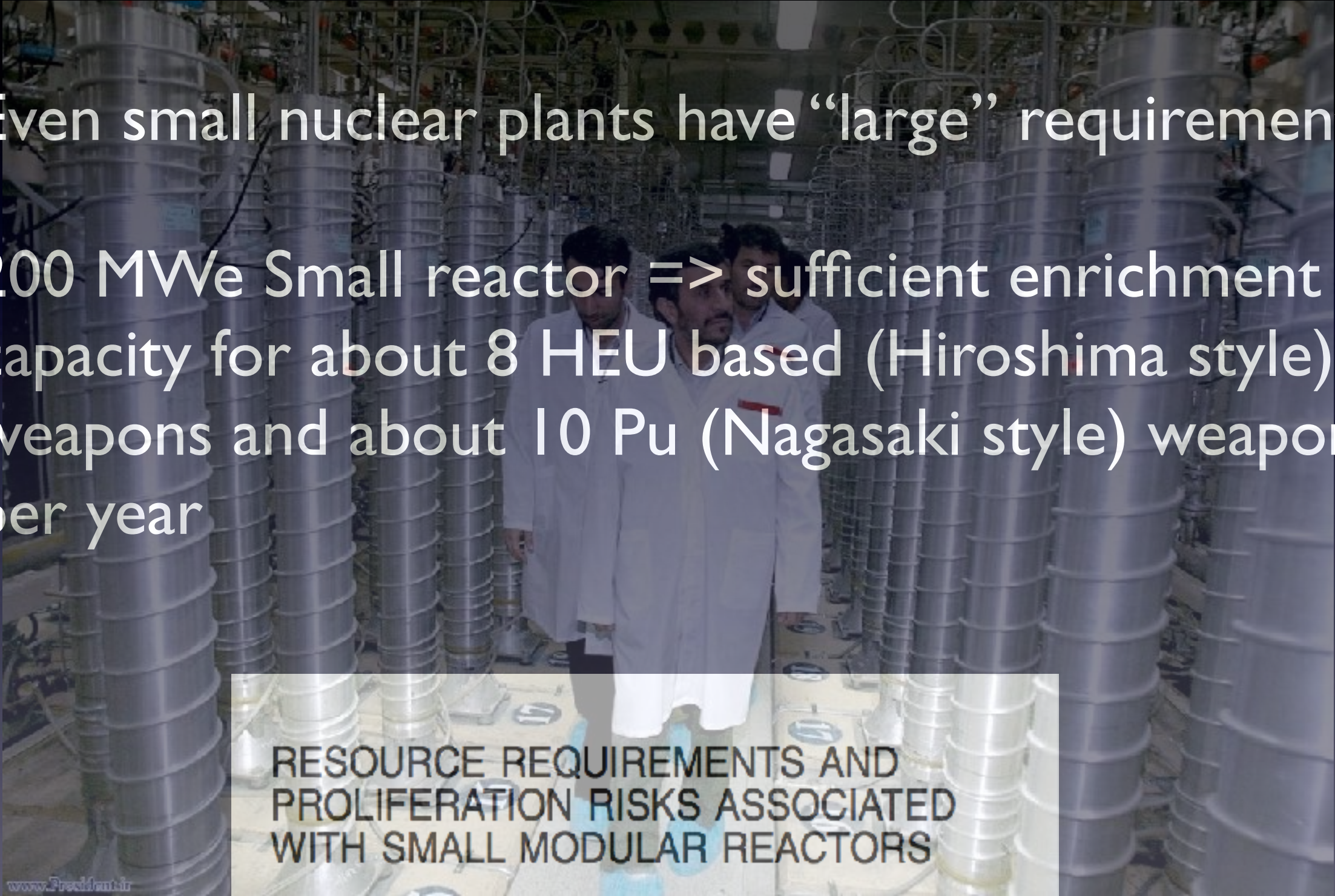
Beyond our imagination: Fukushima and the problem of assessing risk

BY M. V. RAMANA | 19 APRIL 2011

Problem 2: Nuclear energy is closely linked to nuclear weapons

Even small nuclear plants have “large” requirements

200 MWe Small reactor => sufficient enrichment capacity for about 8 HEU based (Hiroshima style) weapons and about 10 Pu (Nagasaki style) weapons per year



RESOURCE REQUIREMENTS AND
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ALEXANDER GLASER,* LAURA BERZAK HOPKINS, and M. V. RAMANA

Problem 3: Nuclear power produces radioactive wastes that remain hazardous for millennia

Technical challenges coupled with social concerns => No demonstrated solution

An Enduring Problem: Radioactive Waste From Nuclear Energy

BY M. V. RAMANA

Program on Science and Global Security, Princeton University, Princeton, NJ, USA



Photograph of a waste container at the Waste Isolation Pilot Plant, USA, with its lid removed and apparent heat discoloration taken by the U.S. Department of Energy on May 28, 2015. Source: https://www.doe.gov/sites/default/files/2015/05/28/20150528_001.jpg

1. GEOLOGICAL DISPOSAL: THE PROMISE AND THE REALITY

Some of the radioactive elements produced during the operation of nuclear reactors have extremely long half-lives, and have to be isolated from human contact for hundreds of thousands of years (see Fig. 1). This requirement for stewardship is unprecedented in human history. Since the 1950s, nuclear establishments have advocated dealing with these radioactive wastes by constructing an underground repository in a suitable geological medium and placing the waste there, within special containers. Much attention from the technical community has been focused on finding a suitable location because the choice of geological media (e.g., granite, volcanic tuff, or clay) will influence the behavior of radionuclides when they escape from the containers [2]. The question is one of "when," not "if," because of our status; radionuclides will migrate into the biosphere over the long periods of time it would take for them to decay. As Allison Macfarlane, former Chair of the U.S. Nuclear Regulatory Commission put it, no "site will...contain nuclear waste indefinitely. The goal is to select a site and engineered features, such as the waste container, which maximize the amount of time the waste is isolated" [3, p. 24].

Nevertheless, confidence in the idea of a repository remains high. The U.S. National Academy of Sciences'

Decades after the idea was first proposed, it appears that underground repositories to manage radioactive spent fuel from commercial reactors are finally going to be constructed. In November 2015, the ruling center-right party in Finland became the first government to grant a construction license for such a repository [1]. The U.S. Department of Energy is pursuing a consent-based process to set up a similar repository. Do these developments mean that a long-sought solution to the problem of nuclear waste is imminent?

As this article will argue, there are many fundamental reasons why dealing with radioactive waste is a special and enduring challenge. Even if a repository is constructed in one or two countries, those examples are by no means generalizable. The confusing problem of radioactive waste disposal, in turn, is another reason to be wary of a large scale expansion of nuclear power.

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DOI: 10.1002/wene.289

ADVANCED REVIEW

Technical and social problems of nuclear waste

M. V. Ramana

WILEY

