Nuclear technology and policy across the globe

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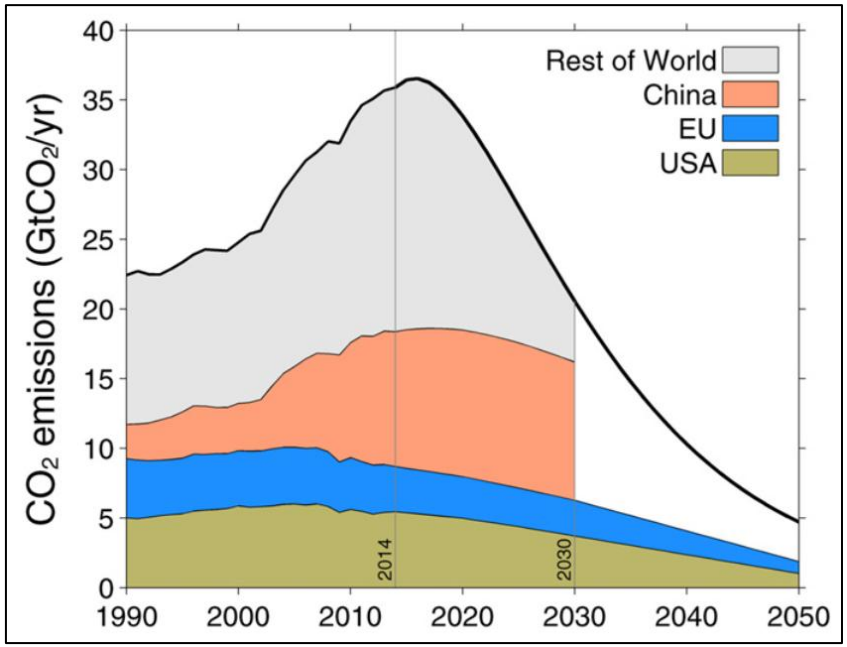
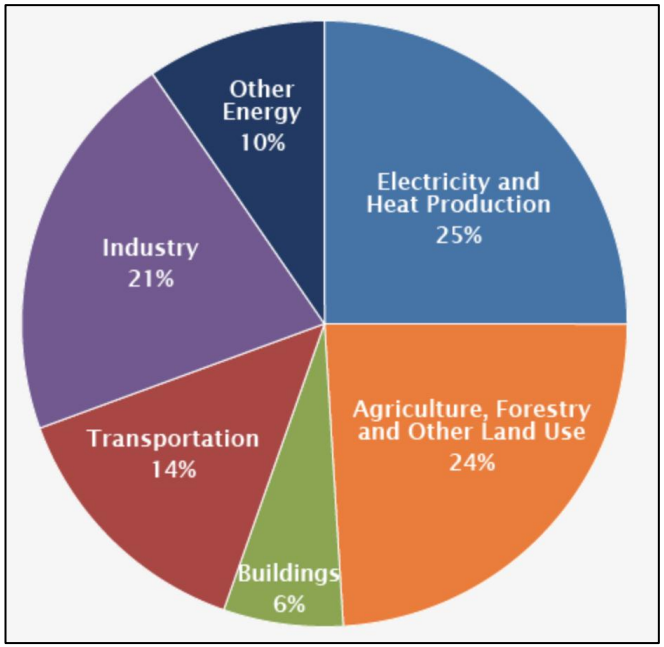
Deep decarbonization is necessary

If we want to get close to the Paris target of < 2°C, we must massively reduce emissions over next 2-3 decades.



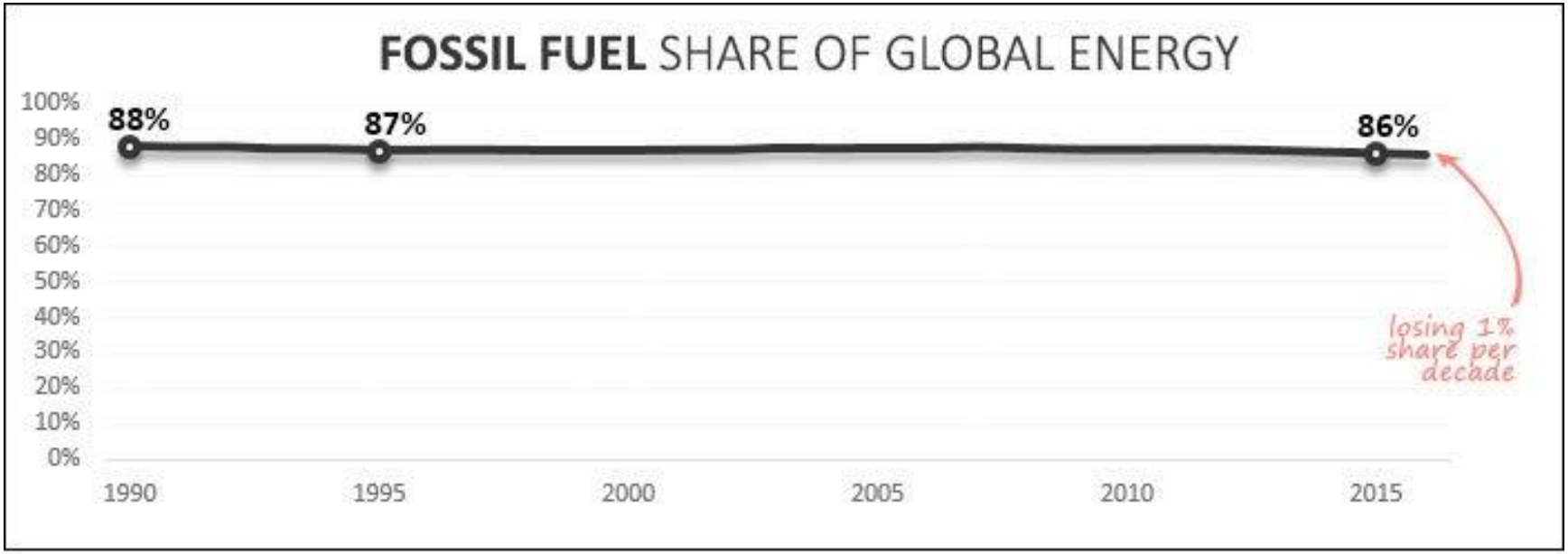
Peters et al. (2015) ERL



EPA, 2015 Global GHG Emissions

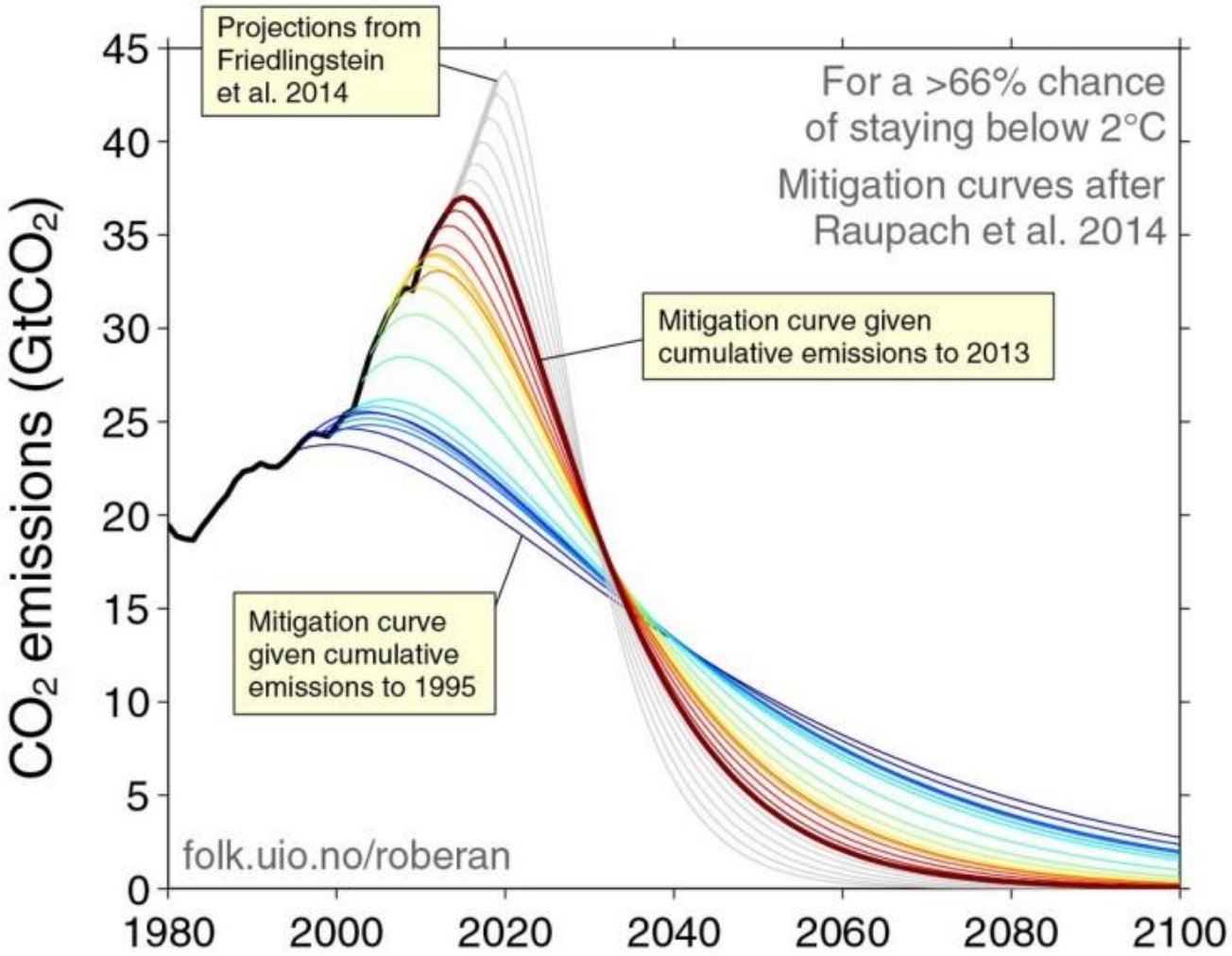
Current efforts best described as "muddling through"

Current “improvements” not enough



GLOBAL FOSSIL FUEL CONSUMPTION, 1990 - 2016. Percent of total energy consumption. SOURCE: Sum of Oil, Gas and Coal consumption vs total energy in BP Statistical Review of World Energy June 2017. CHART by Barry Saxifrage at VisualCarbon.org, June 2017

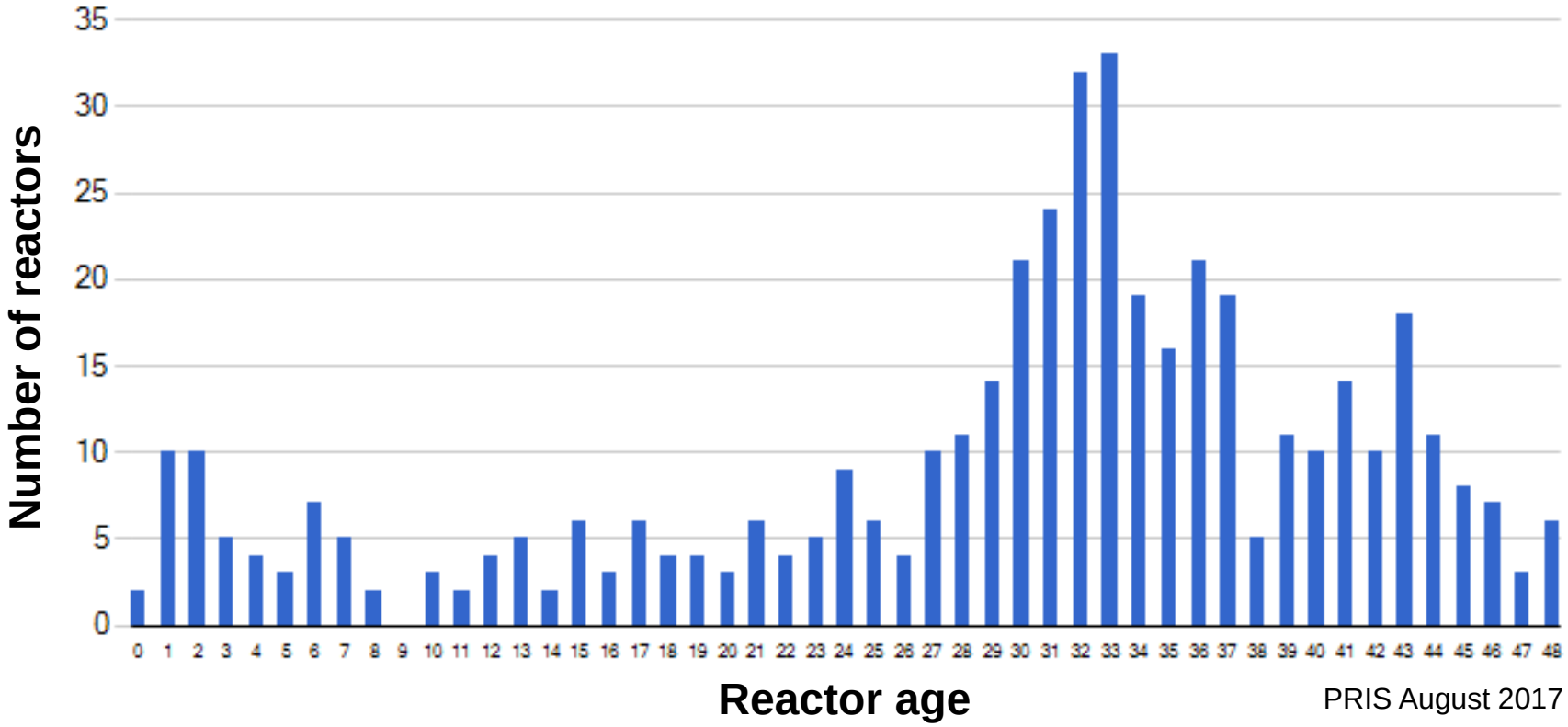
Time is profoundly of the essence



A snapshot of the nuclear enterprise

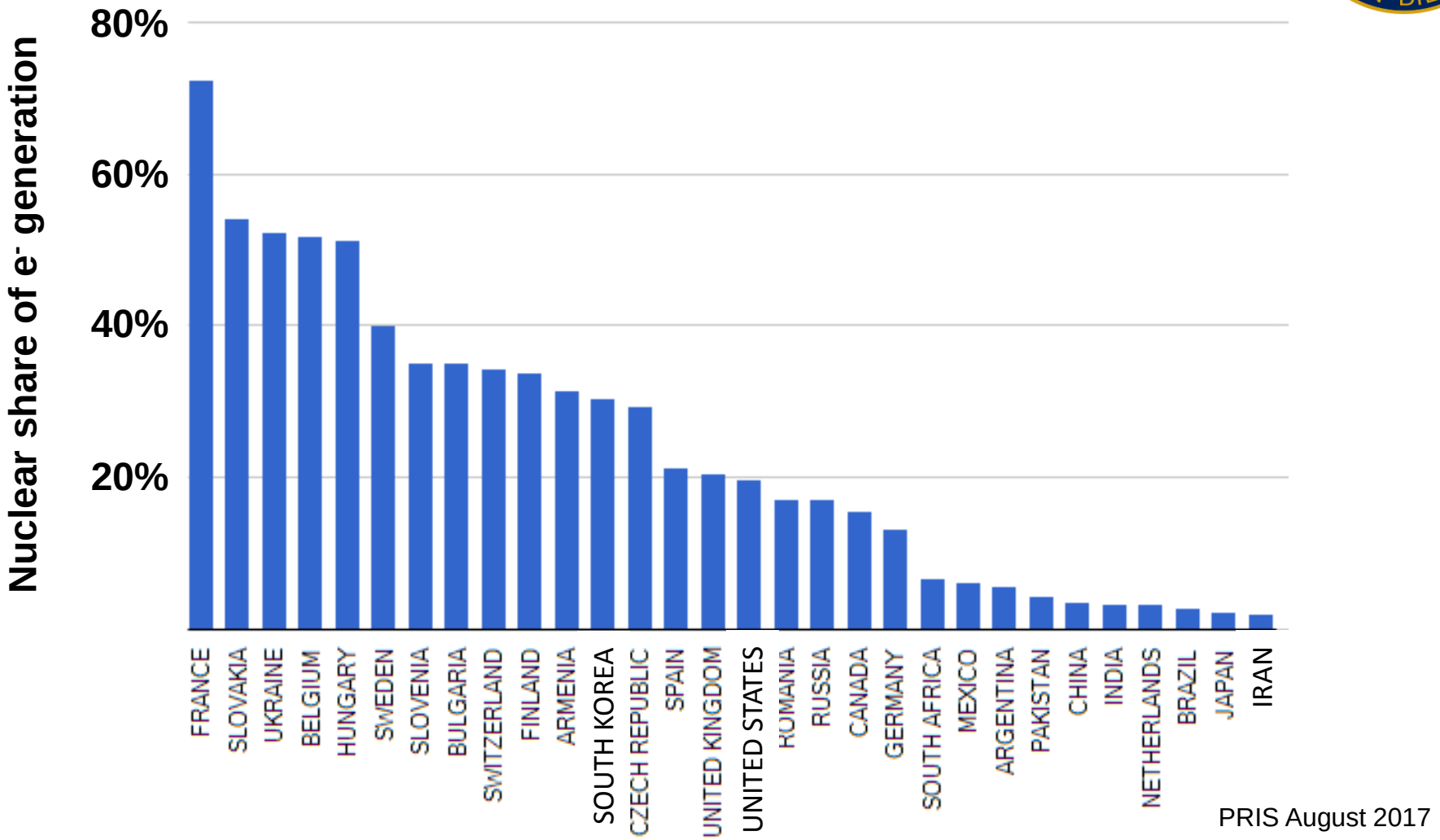
A total of 447 reactors operating today.

(This includes 42 currently closed reactors in Japan.)



PRIS August 2017

Globally, a diminishing contributor to e-



PRIS August 2017

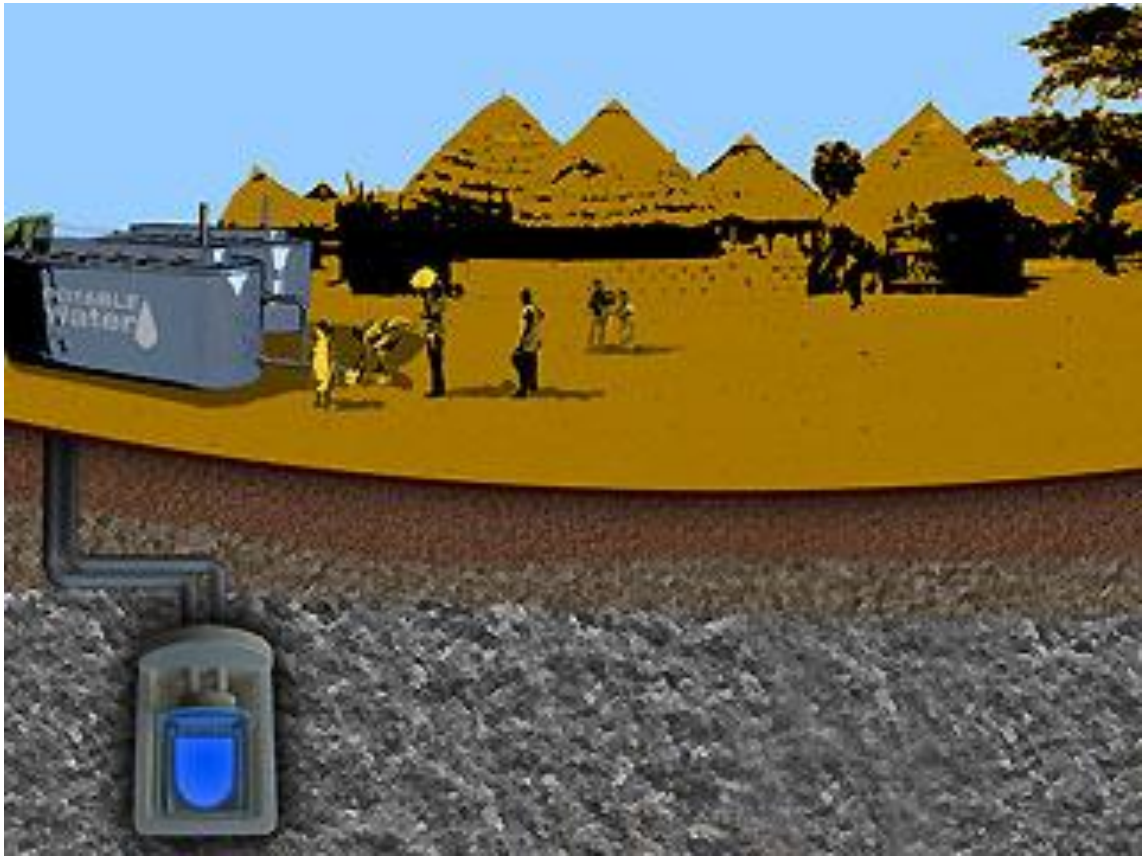
Compare this to initial expectations

Everything would get better and better; there would be “better, finer, and more nourishing plants, better, cheaper, and more abundant fertilizer; better and richer soils, farms, and gardens; better metals and machines; better and finer clothing and homes; better men and women.” Nuclear plants would “pump underground water to turn the world’s deserts into “blooming gardens,” turning swamps and jungles into “vast new lands flowing with milk and honey.”

William L. Laurence, 1948

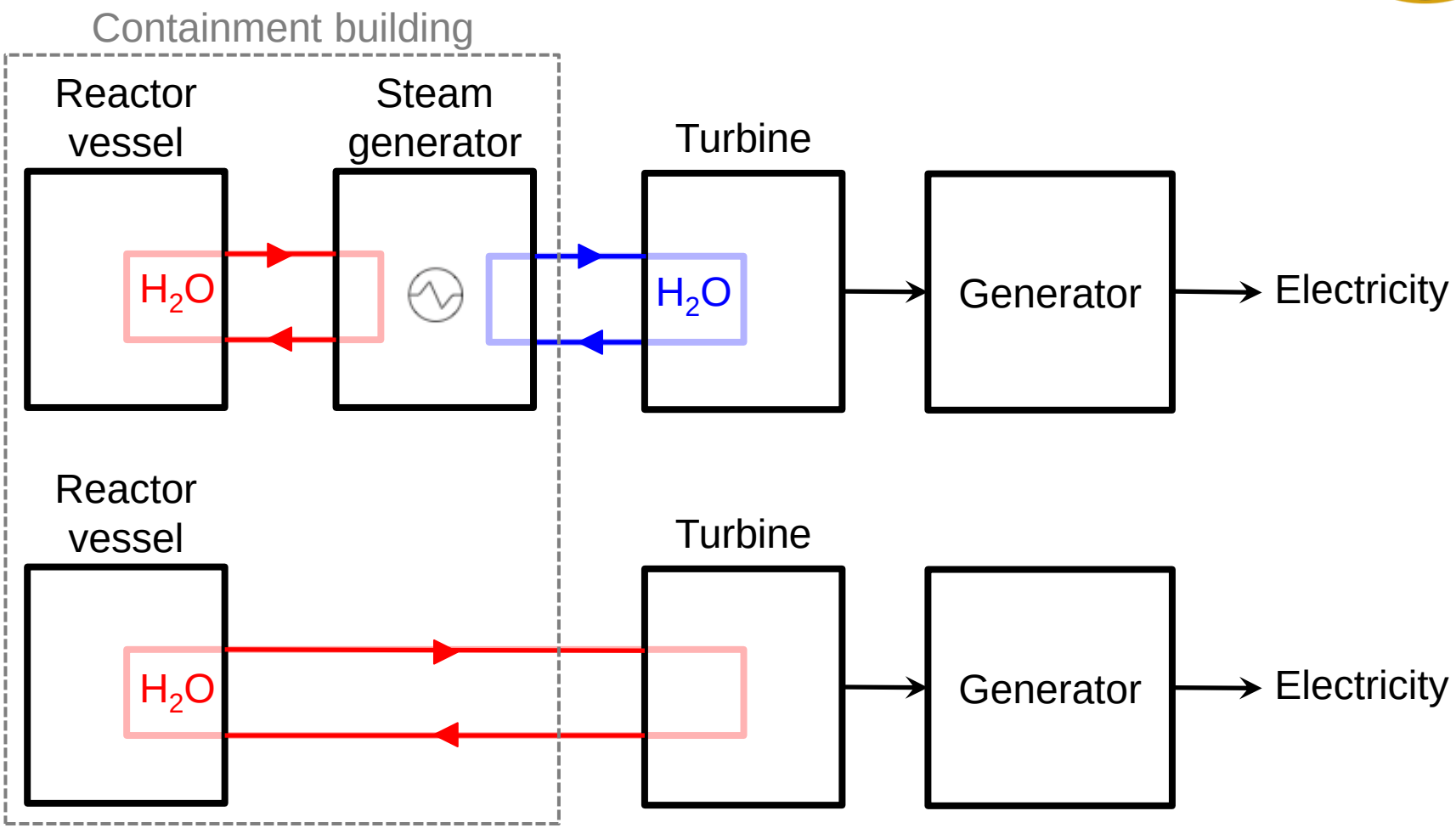
Hilgartner S., Bell, R.C. & O’Connor R. (1982). Nukespeak: Nuclear Language, Visions and Mindset. NewYork, N.Y. : Penguin Books.

Wishful thinking yet to be conquered

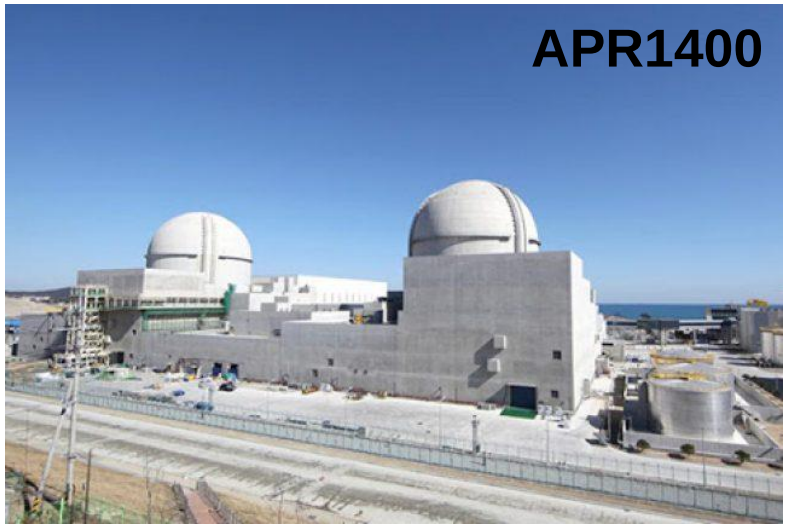


Wagenseil, P. (2008, November 12). Portable Nuclear 'Hot Tubs' Could Power America. Fox News. Retrieved October 1, 2011.

It remains a light reactor world



A snapshot of current technologies



http://www.french-nuclear-safety.fr/var/asn/storage/images/media/images/epr-flamanville/vue-generale-epr-03-2010/391710-1-fre-FR/Vue-generale-EPR-03-20101.jpg
http://www.power-eng.com/content/pe/en/articles/2016/05/cold-hydrostatic-testing-finished-at-sanmen-1-nuclear-project/_jcr_content/leftcolumn/article/thumbnailimage.img.jpg
http://www.world-nuclear-news.org/NN-First-VVER-1200-reactor-enters-commercial-operation-02031701.html
https://www.nextbigfuture.com/wp-content/uploads/2016/02/Shin-Kori-3-4_KHNP-1-730x430.jpg?x71037

Country-by-country review

"The nuclear industry is facing strong headwinds in almost every country, and the technology's problems extend across the technical, economic, and institutional spheres, though the latter remain perhaps the biggest challenges to a radical expansion in nuclear power."

1) What commercial opportunities and challenges is the industry facing in major markets?
2) What major nuclear innovations are being touted?
3) What can an emergent nuclear nation – like the Philippines – learn from both of these things?

Let us start with South Korea

Opportunities:

- Two-dozen reactors with more than 23GW$_e$ of capacity
- Provided ~30% of country's electricity in 2016.
- Competitive nuclear supplier, with its greatest success in the UAE (4 x APR1400s sold for the Barakah site).
- Interest in (and industrial policy suited for) becoming major nuclear exporter.


https://www.enec.gov.ae/images/8p3a1930-59144d0a6549f.jpg

Now for the bad news

Challenges:

- The ascendant nuclear supplier ***until 3 months ago***
- Strong anti-nuclear movement: Fukushima + North Korea.
- New president who is backing away from nuclear power domestically, but still touting its export potential:
  - *"I expect the government of South Korea to continue to sell its world renowned expertise in nuclear technology to the world even if it is cut back at home" – M. Whitaker*
- Only managed to convince the world that APR1400 reactor was "proven" because it was building it at home. Hard to sustain a reactor export market if it rolls back domestically.
- Operational experience would be marginal; that is a recipe for poor execution and devastating consequences.

Anti-nuclear move not idle talk

Remarks made by President Moon that the nation will only be nuclear power free in "at least 60 years" at a presidential press conference yesterday has garnered comparisons between South Korea's nuclear power deactivation policy and other nations.

Held to mark his 100th day in office, President Moon expressed the current administration's position on the handling of the nation's nuclear power plants by saying that "policies to deactivate the reactors will not be implemented in an urgent matter".

Furthermore, the president stated that the official policy going forward would be to **"close down power plants that reach the end of their operational lifespans"**.

http://koreabizwire.com/s-korea-will-be-nuclear-free-in-65-years-about-60-years-behind-germany-taiwan-belgium/91973

Japan is an eminent nuc supplier

Opportunities:

- More than 40 reactors with ~40GW$_e$ of capacity.
- Provided ~2% of country's electricity in 2016.
- Interest in (and industrial policy suited for) becoming major nuclear technology supplier.

A look at Japan's troubles

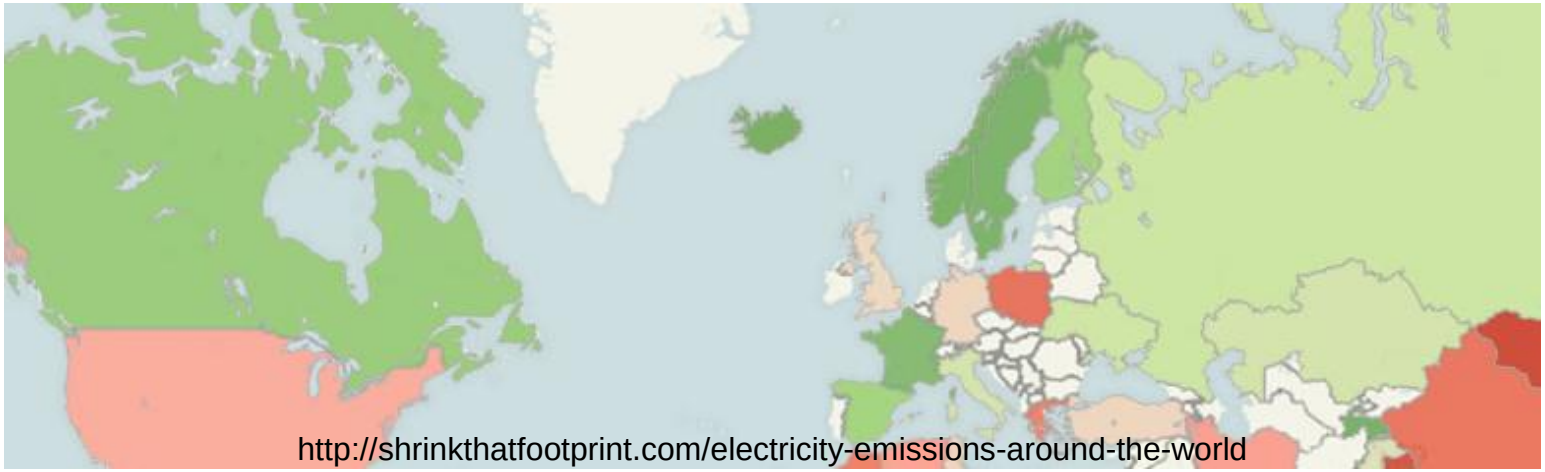
Challenges:

- Fukushima remains TEPCO's main attention hog. To a large extent, it remains the nation's also.
  - *Ice wall nearing completion; WWII bomb found on-site.*
  - *Anti-nuclear movement far more mature.*
- Delays compromise achievement of its Paris targets.
  - Japan pledged a 26% reduction of its 2013 emissions by 2030, *"because that's what the Americans pledged".*
- Eager to dilute responsibility, Japan pushes coal on world.
- Remains a crucial supplier of nuclear technologies, supplies, specialized equipment, especially for US and rest of developed world.
- Its more innovative projects cancelled (Monju).

Nuclear has done much for France

Opportunities:

- 58 reactors with ~63GW$_e$ of capacity.
- Traditionally provides ~70% of country's electricity.
- Most nuclear-dependent nation on Earth.
- Dependence has traditionally made it an energy-secure electricity exporter with some of the lowest electricity environmental footprint in the OECD.



http://shrinkthatfootprint.com/electricity-emissions-around-the-world

France's commitment being tested

Challenges:

- In 2016, 20 to 30% of France's nuclear reactors were shut down due to safety concerns (carbon segregation).
- Consolidation's disadvantages (common mode failures).
- This in addition to post-Fukushima change in attitude.

Bloomberg Markets | Markets | Tech | Pursuits | Politics | Opinion | Businessweek

French Nuclear Woes Push Power Prices in Europe to Record

By Rachel Morison and Weixin Zha
October 6, 2016, 10:00 PM PDT *Updated on* October 7, 2016, 2:55 AM PDT

The French "nuclear crisis" – did Europe dodge a bullet?

Posted on March 16, 2017 by Roger Andrews

Late in 2016 France began shutting nuclear plants down for inspection, and depending on which source one consults either 12, 18 or 20 of France's 58 nuclear plants were off-line at one point. Since France has historically been a nuclear power exporter this raised fears of possible power shortages and blackouts in France and its neighbors during the coming winter.

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France's Nuclear Storm: Many Power Plants Down Due to Quality Concerns

Regulator orders review of all Creusot-made components on EDF nuclear reactors

August 16, 2017, 10:30:00 AM EDT By Reuters

PARIS, Aug 16 (Reuters) - French nuclear regulator ASN said on Wednesday that

Russia is Russia

Opportunities:

- 35 reactors with ~26GW$_e$ of capacity.
- Traditionally provide one-sixth of country's electricity.
- Large, well developed, integrated nuclear supply chain.
- First nation to offer a serious Build-Own-Operate-Return (BOOR) option to customer nations:
  - *Nation would build the reactor in the customer/host nation, have a stake in its ownership, contract to operate it for its lifetime, and then take back the fuel.*
  - *Very attractive to emerging nuclear nations, though not always, and certainly not proven.*

Russia is Russia

Challenges:

- BOOR deployment strategy not proven:
  - *Fuel take-backs politically unpalatable in most polities.*
  - *Depends entirely on geopolitical relationships.*
  - *You are acquiring a strong geopolitical ally, but are entering a long-term (likely looooong-term) political alliance, which can be risky.*
- Quality concerns regarding components.
- Security concerns regarding I&C systems.
- Spotty project management and execution.

China: the last great hope

Opportunities:

- 38 reactors, 19 more under construction.
- Providing 3-4% of country's electricity.
- Largest nuclear build program, one of largest in history
  - *Able to negotiate advantageous terms with overseas nuclear suppliers, laying foundation for future Chinese development and deployment.*
- Enormous, though not unlimited, financial resources.
  - *Willing and able to support nuclear builds overseas.*
- Burgeoning supply chain and human resource base.
- Politically and financially strong advanced fission innovation program, benefiting from knowledge transfer from U.S. labs and knowledge exchange among the two.

Event in China would be nightmare

Challenges:

- An accident at a Chinese nuclear power plant is the enterprise's ultimate nightmare.
- There are well-founded fears regarding quality control and assurance, and compliance with safety standards.
  - *Are the National Nuclear Safety Administration and the Ministry of Environmental Protection overwhelmed?*

Chinese City Backs Down on Proposed Nuclear Fuel Plant After Protests

点击查看本文中文版 | Read in Chinese

By CHRIS BUCKLEY AUG. 10, 2016

The U.S. built the nuclear enterprise

Opportunities:

- 99 reactors with ~100GW_e of capacity.
- Traditionally provide 20% of country's electricity.
- Enormous market, a legacy of nuclear innovation, a strong human resource base on which to build.
- The U.S. rules-based order (or one like it) is the only one in which nuclear power can be deployed safely and securely (happy to defend that claim during the open forum).
- Most nuclear reactors in operation today are either derived from U.S. designs or have been iteratively refined to include U.S. innovations that enhance economics, reliability, safety, or security.

But its leadership is ending

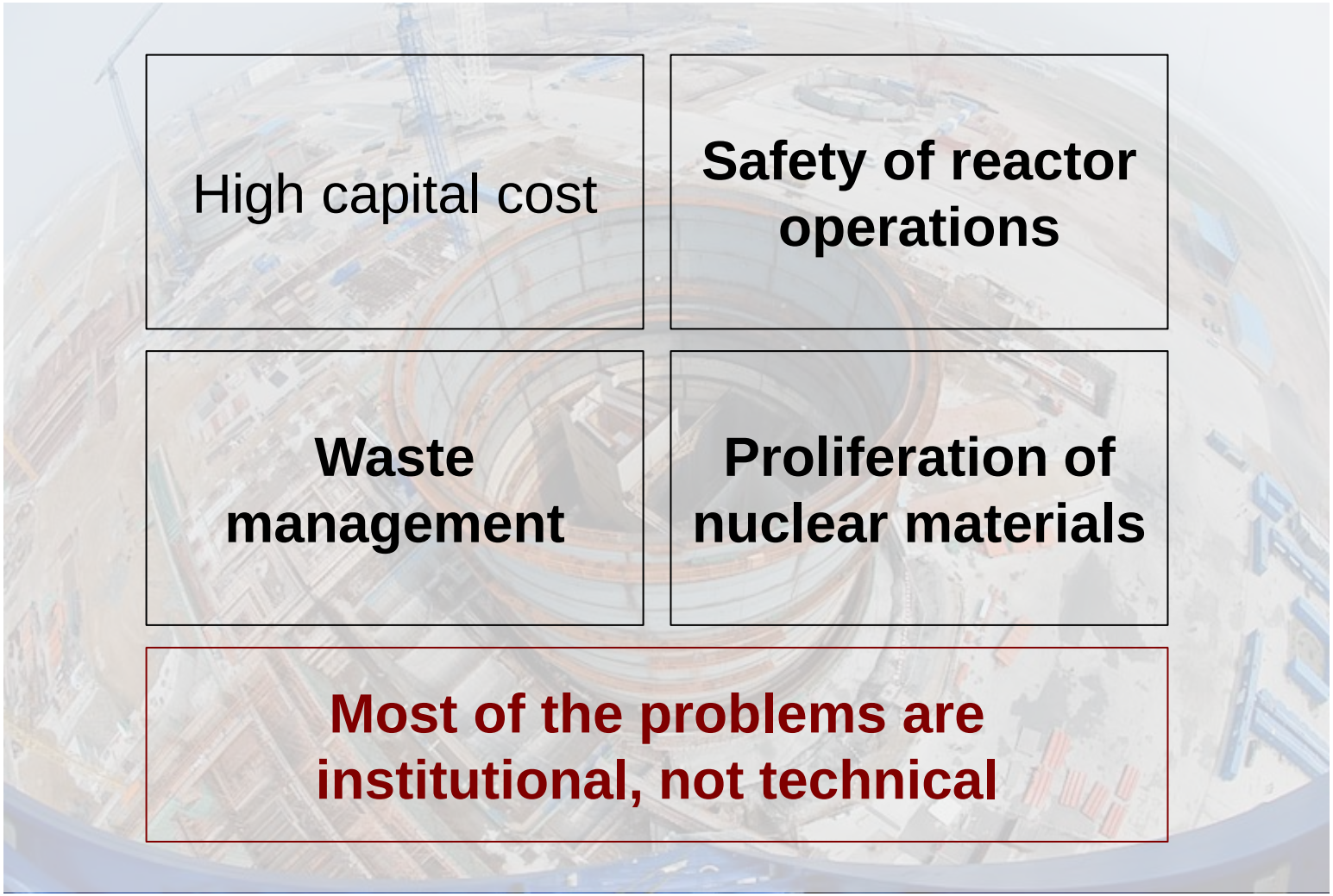
Challenges:

- Warped power market that does not price carbon emissions, does not encourage long-term investment, and does create a need for ”fudges” – include the creation of new (expensive, silly) markets – to patch the system.
- Existing reactors, cash cows 10 yrs ago, being shut down.
- 1 or 2 utilities with balance sheet to sustain new nuclear, and nuclear has already created headaches for them.
  - *Of two new builds (each with two reactors), one was recently abandoned, and the other will probably cost taxpayers a staggering $12,500/kW$_e$.*
- Stagnant innovation program, failing nuclear supply chain, lack of human capital (with some fields extinct).

Strategic priorities matter

- **The U.S.** does consider nuclear science and nuclear weapons a strategic priority, but the social compact does not fully embrace the notion that civilian nuclear power is a strategic priority.
- **Russia absolutely does.**
  - *For geopolitical reasons.*
- **Japan, Inc. and Korea, Inc. do as well.**
  - *These are structurally protectionist economies, not capitalist ones.*
- **China does for both reasons.**
- **The French model sits between these and equivocates.**

What role can nuclear play in future?



High capital cost

Safety of reactor operations

Waste management

Proliferation of nuclear materials

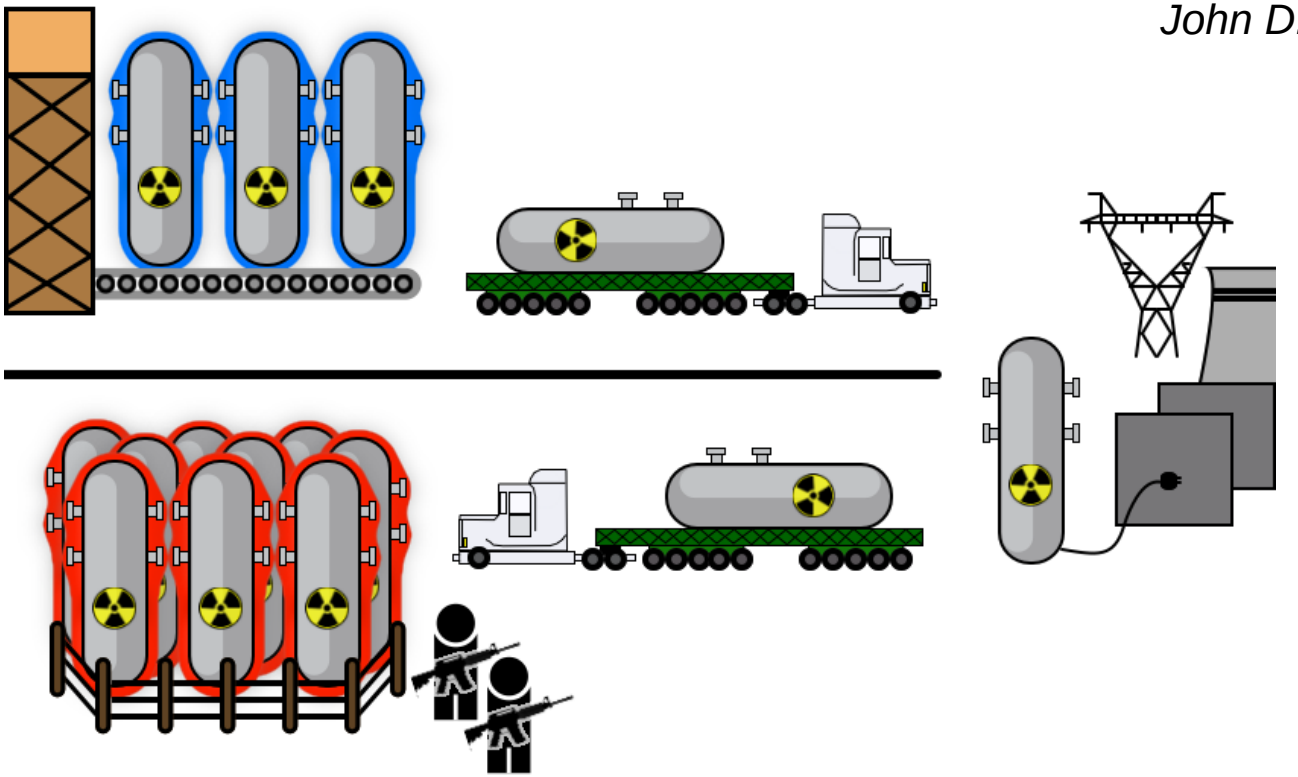
Most of the problems are institutional, not technical

China AP1000® Project Photos (May 2011)

Radical deployment options exist

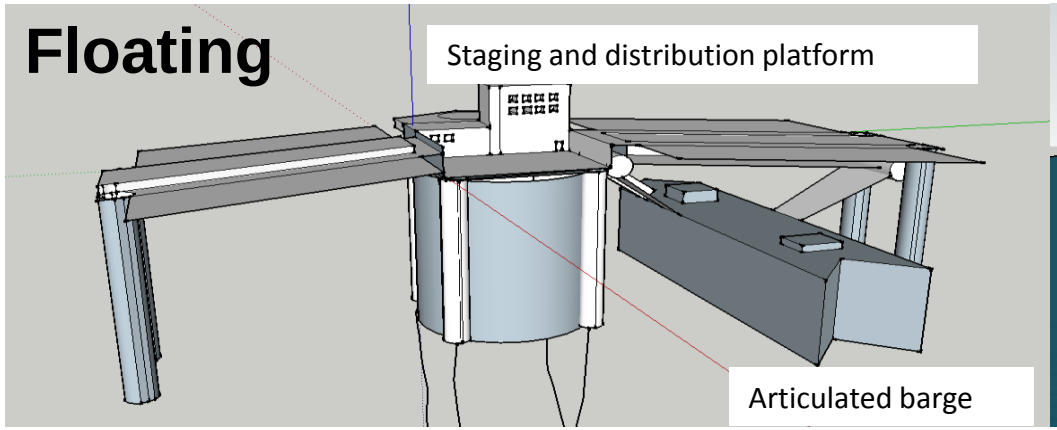
"prototype development and serial production [and material control and accounting of small modular nuclear reactors with sealed cores] will have to be managed by…consortia."

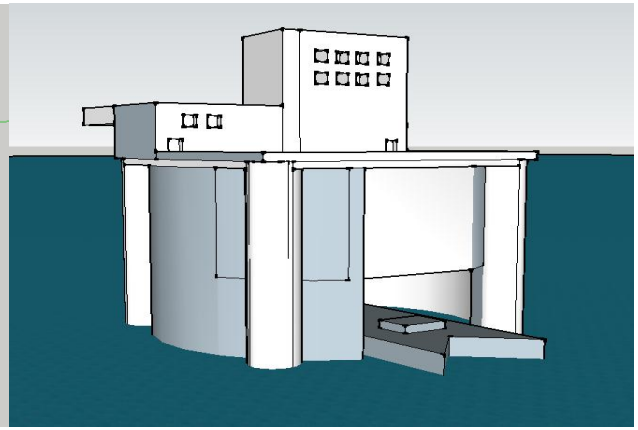
John D. Steinbruner



Small reactors increase flexibility

Notional SMR Site – Westinghouse design





Even promising strategies carry risks

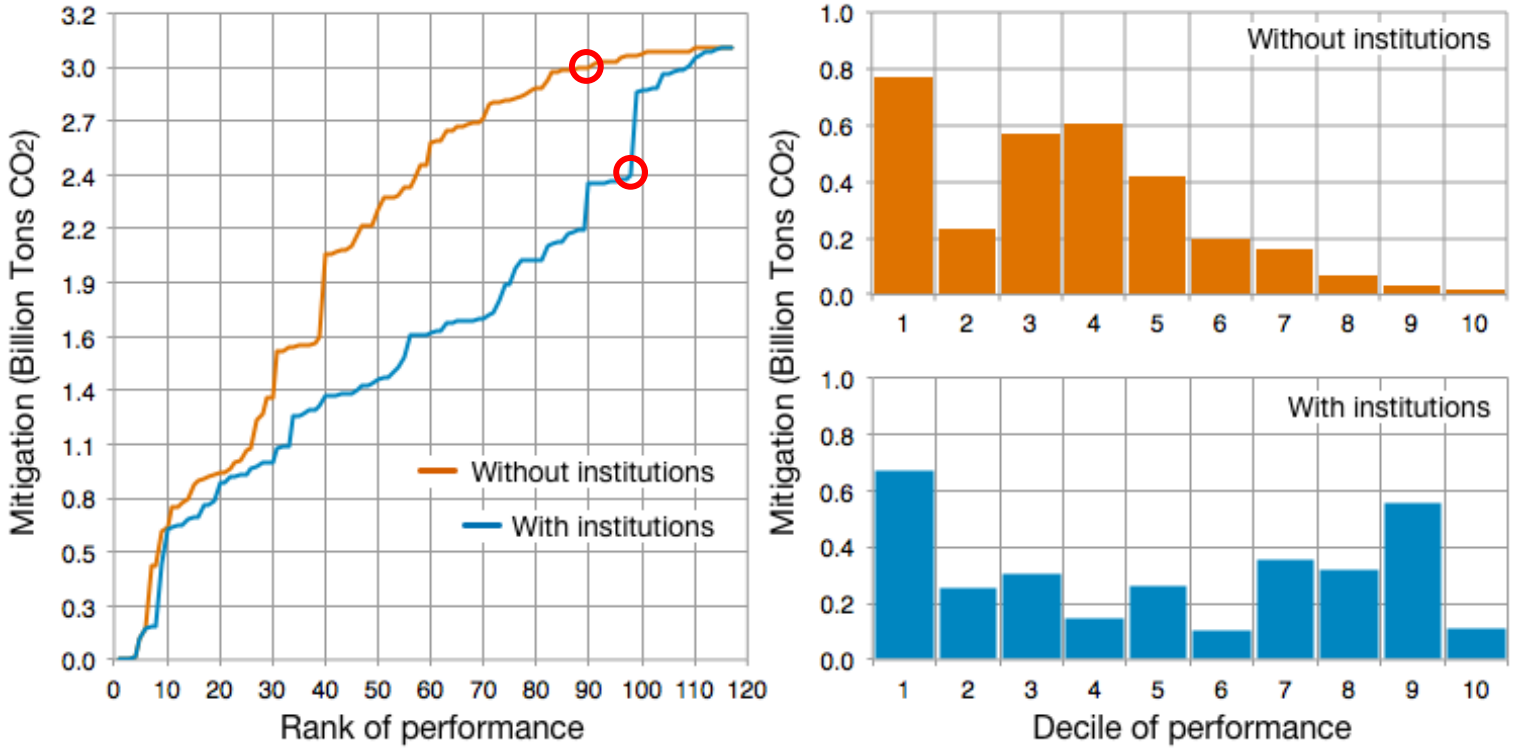
- A floating small reactor plant deployed using the BOOR model may provide advantages in terms of construction costs, EPZ risk, water withdrawal, and decommissioning costs (using nuclear vessel inactivation costs).
- Once construction standards grow to approximate military specifications, cost will be prohibitive.
- A BOOR floating plant could significantly enhance proliferation resistance and limit technology spread.
- Transmission and material costs always favor land-based nuclear deployment. However, these costs are small when compared with overnight costs.

Few models study impact of institutions

- Few systematic analyses of the impact of institutions on nuclear deployment have been attempted.
  - International Atomic Energy Agency (IAEA) conducts in-depth studies once a nation embarks on a nuclear power program.
  - Exceptionally thorough studies exist of the challenges facing individual countries (e.g. M.V. Ramana on India).
  - Studies that pay attention to institutional challenges in a large number of countries do so by building indices of nuclear readiness or by comparing these countries across multiple criteria.
    - *These approaches contribute little to policy debates.*

Our efforts quantifies scale of challenge

- We utilize Data Envelopment Analysis (DEA), a linear programming technique that estimates a “performance frontier” against which unit performance is measured.



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