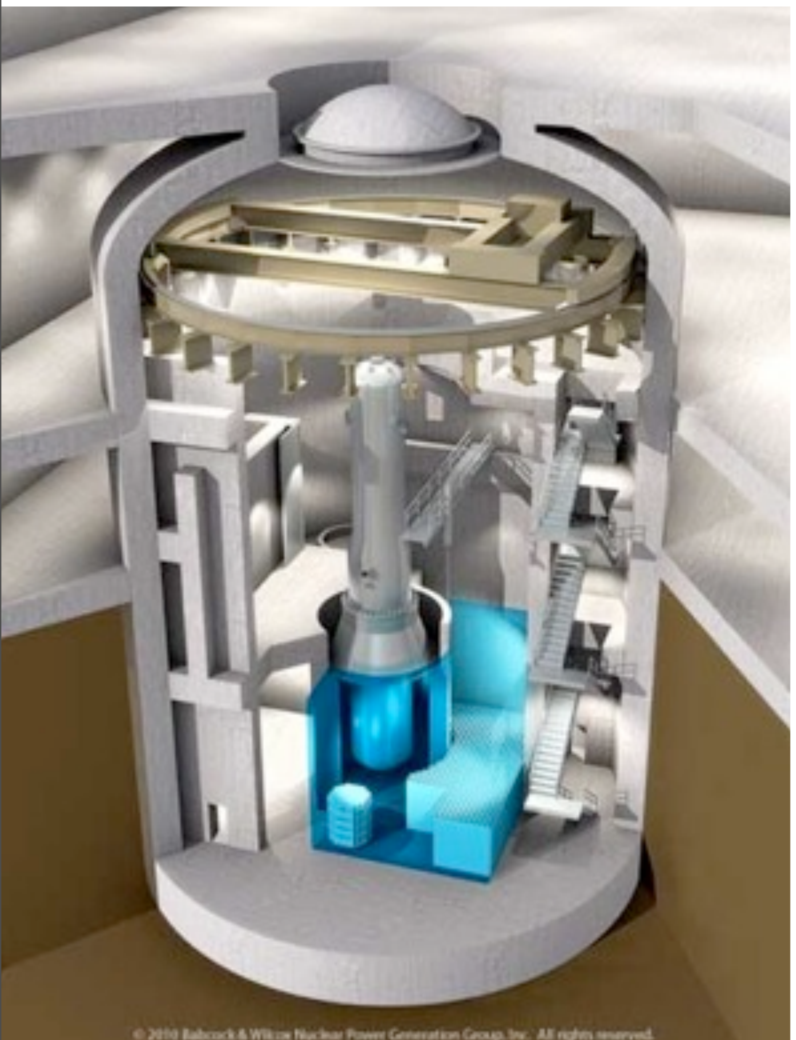


Nuclear Power in the United States:
Large or Small?

Alexander Glaser

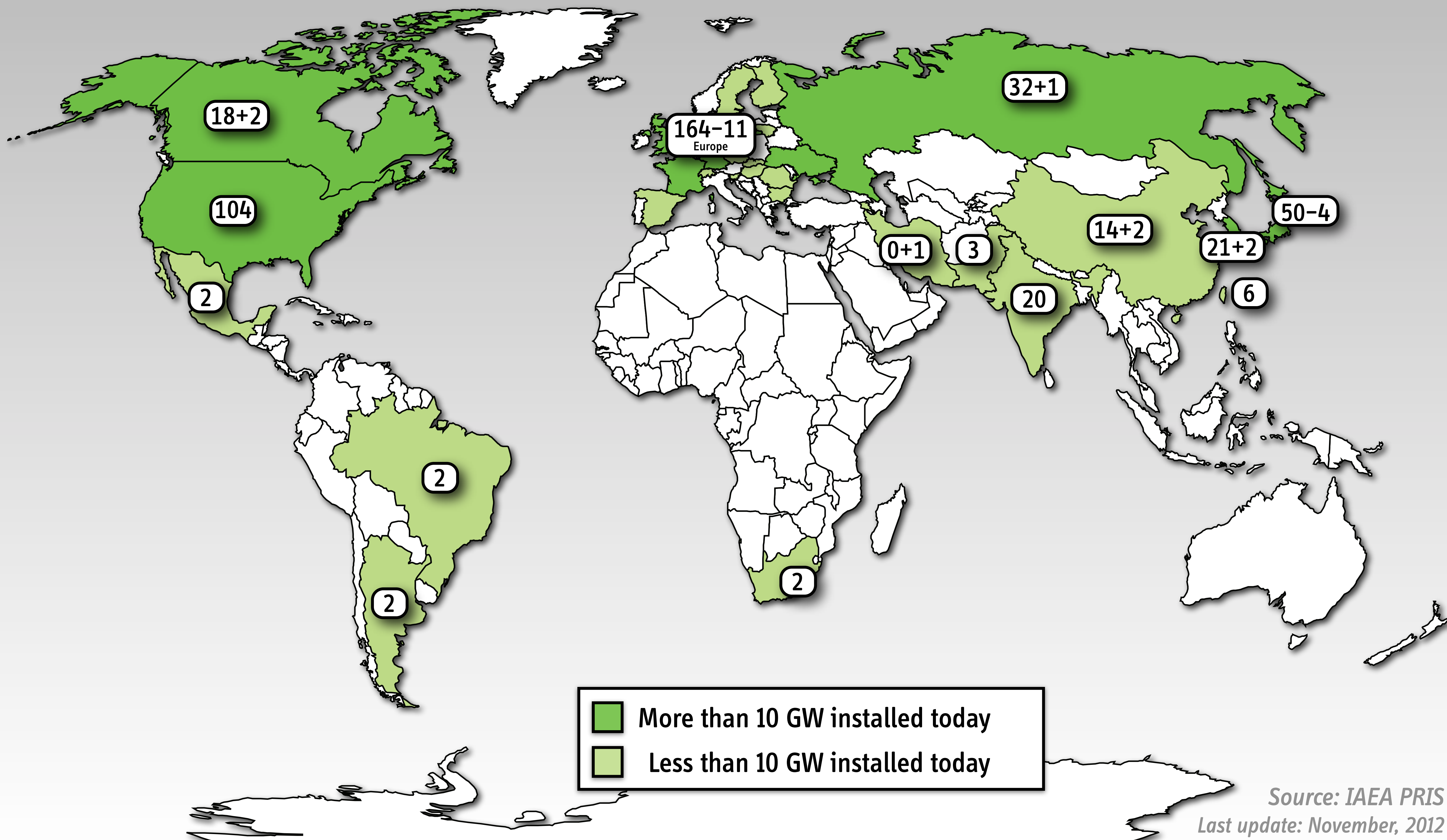
Department of Mechanical and Aerospace Engineering
and Woodrow Wilson School of Public and International Affairs
Princeton University

Synergize 2012
Princeton, November 12–13, 2012

Revision 3

Nuclear Power Reactors in the World, 2012

437 operational reactors (7 fewer than 18 months ago) in 31 countries provide about 13% of global electricity

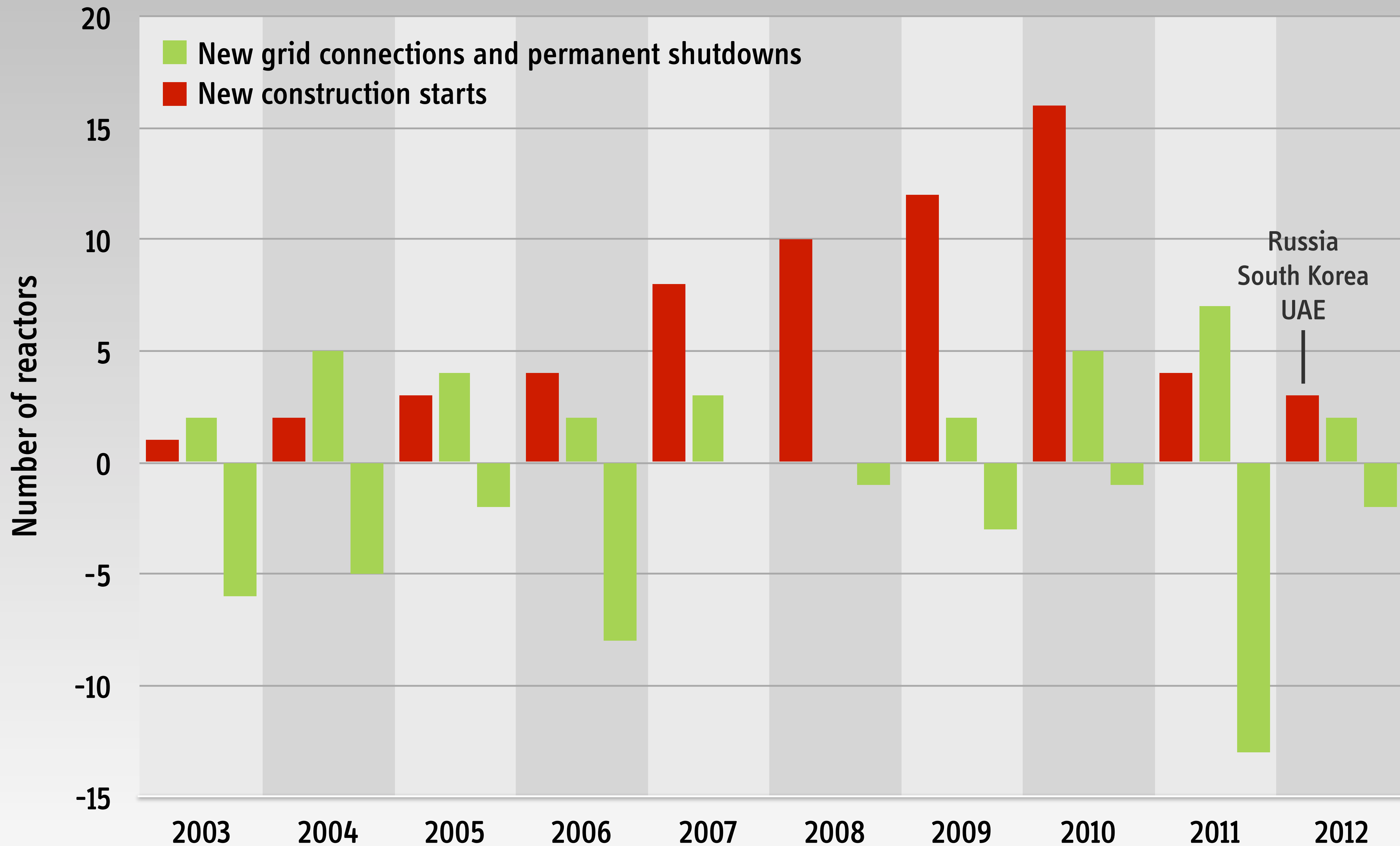


Source: IAEA PRIS

Last update: November, 2012

Hitting the "Reset" Button in 2011?

New Grid Connections, Permanent Shutdowns, and New Construction Starts over the Past Decade

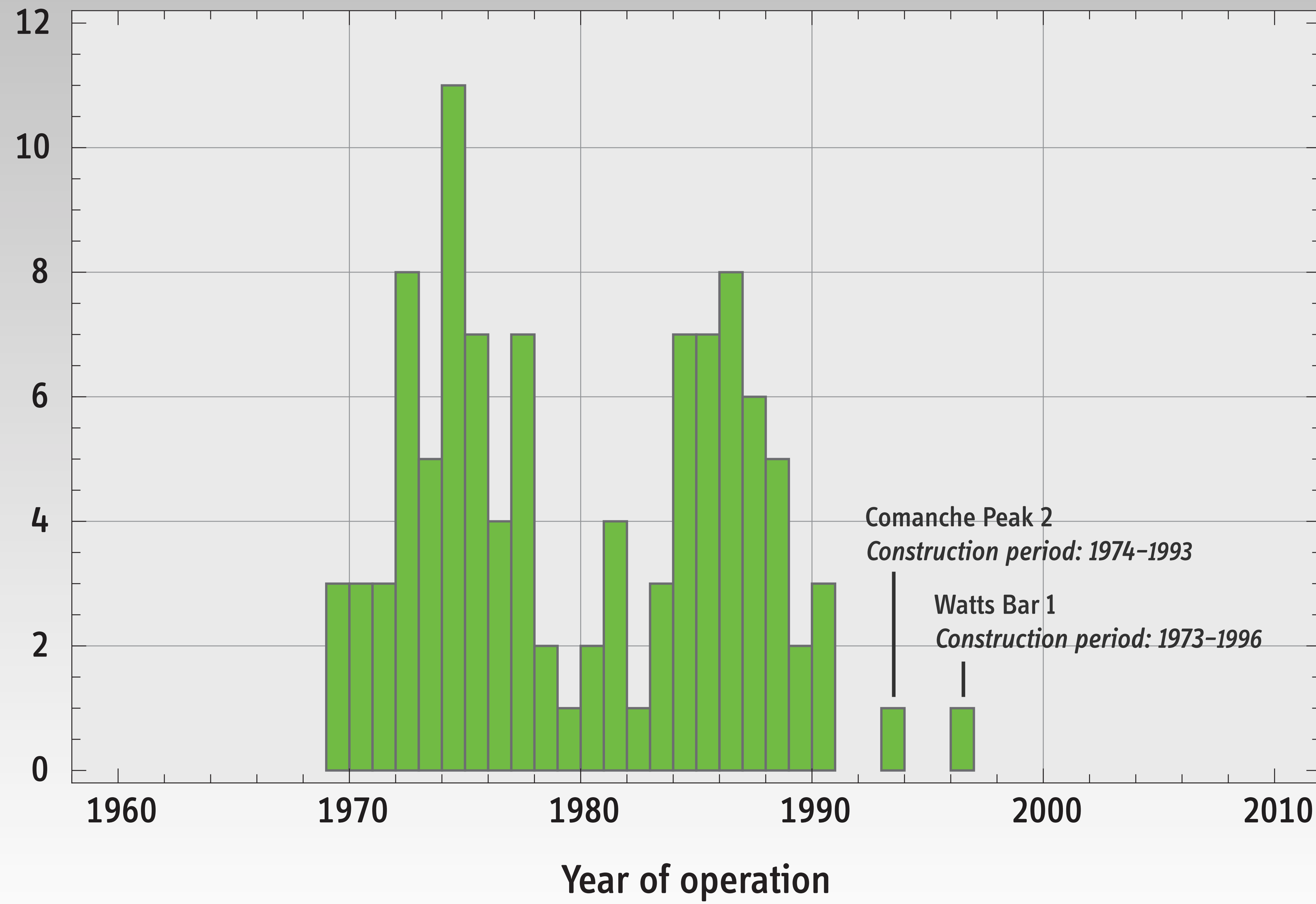


Source: Power Reactor Information System (PRIS), International Atomic Energy Agency, http://pris.iaea.org/public, November 2012

Nuclear Power in the United States

The Nuclear Reactor Fleet is Aging

104 operational reactors; about 40% near 40-year life, life-extensions granted



New Nuclear Power in the United States

Federal Loan Guarantees
as part of the Energy Policy Act of 2005, up to $18.5 billion
Obama Administration has sought to increase amount to $54.5 billion

Several proposed construction projects have stalled
some before and some after the Fukushima Accidents

Vogtle-3 and -4 Project (Waynesboro, GA) moving forward
2 x Westinghouse AP-1000, 2200 MWe, expected for 2016 and 2017
Combined Construction and Operating License issued in February 2012
$14 billion investment; $8.3 billion in Federal loan guarantees

"Let me state unequivocally that I've never met a nuclear plant I didn't like;
Having said that, let me also state unequivocally that new ones don't make any sense right now."

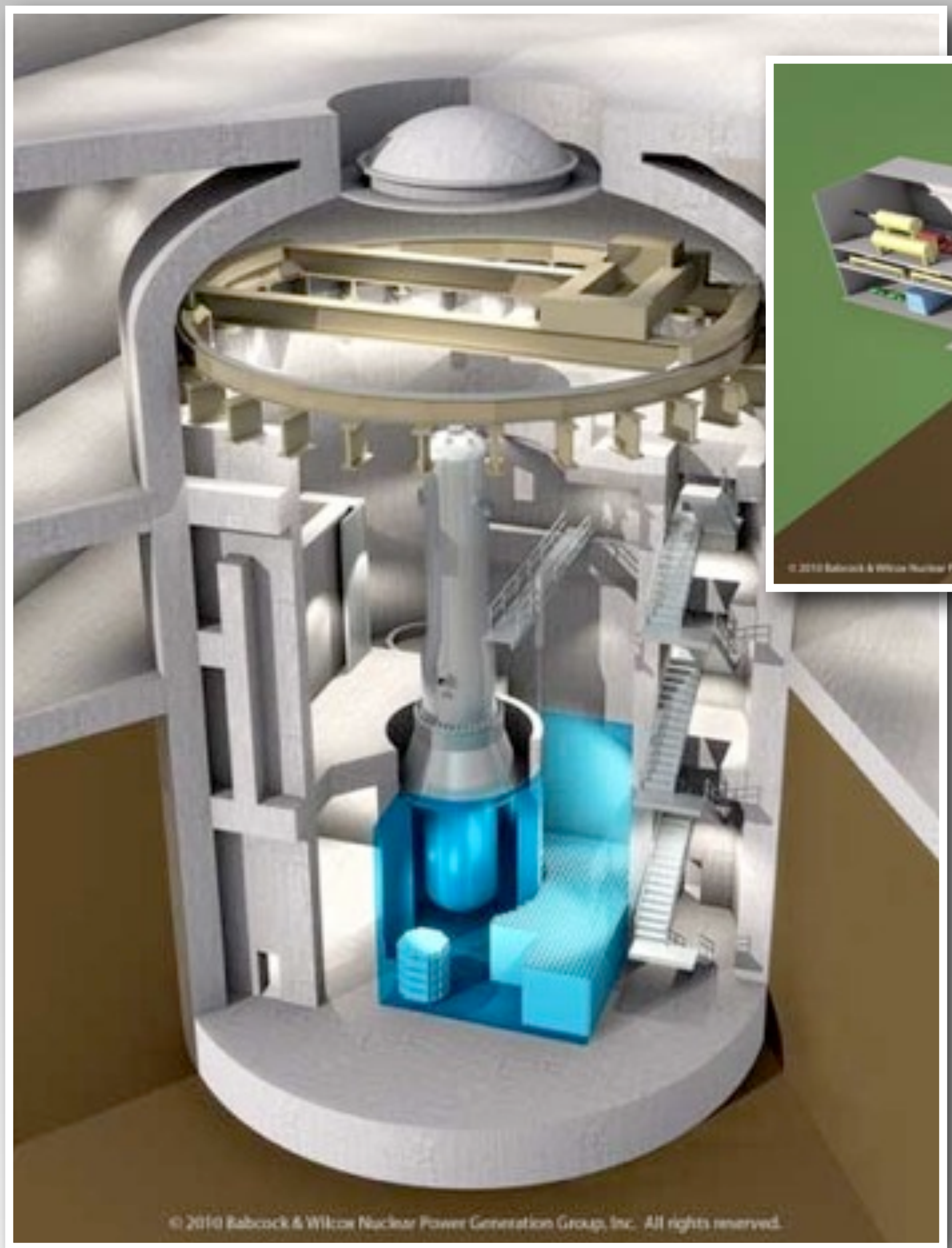
John Rowe, Former CEO Exelon, March 29, 2012
quoted in www.forbes.com/sites/jeffmcmahon/2012/03/29/exelons-nuclear-guy-no-new-nukes

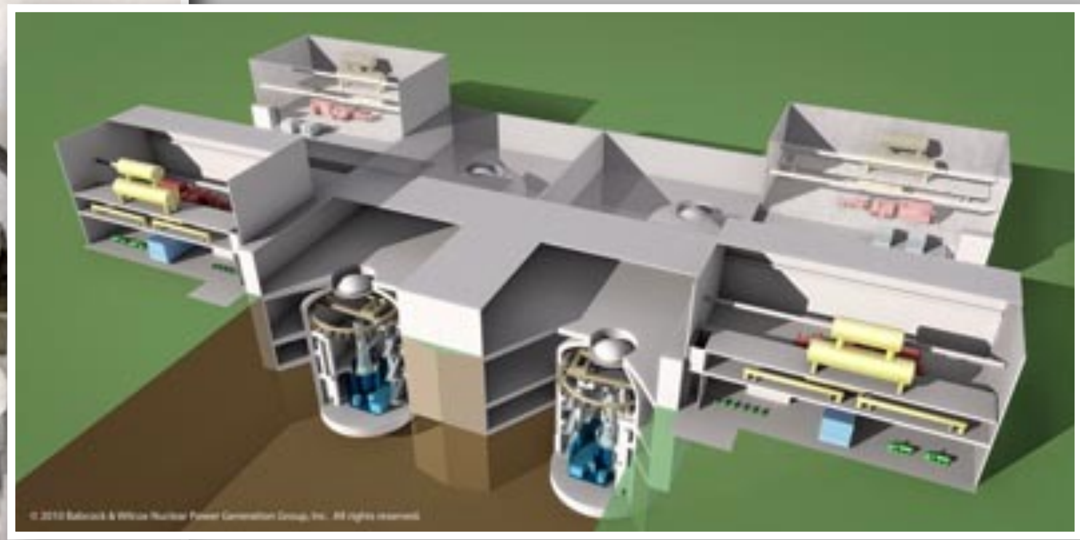
Are New Technologies on the Horizon?

The Case of Small Modular Reactors

Could Small Nuclear Reactors Play a Role?

Several designs are based on standard light-water reactor technology





Babcock & Wilcox mPower Concept

- Light-water cooled
- 180 MWe per module, up to 10+ modules
- Underground construction
- 60-year spent fuel storage onsite
- Quasi-standard LWR fuel
- Factory-based serial production

Source: www.babcock.com/products/modular_nuclear/

Why Consider Small Modular Reactors?

- **Substantially lower investment risks**
  $500 million vs $5 billion projects; combined with shorter construction times
- **Better suited for electricity markets with low growth rates**
  Modules can be added to existing plants “on demand”

- **Promise of enhanced safety and security**
  Almost all designs envision underground or other-nonconventional siting modes
- **Potential nonproliferation benefits**
  Long-lived cores

In January 2012, DOE announced a 5-year $452 million cost sharing program
to support engineering, design certification, and licensing for up to two first-of-a-kind SMR designs

www.grants.gov/search/search.do?mode=VIEW&oppId=138813

Critical Policy Issues for SMR Licensing

1. Number of Units Controlled per Control Room

Current NRC regulations permit at most two reactors to be controlled from a single control room

(SECY-10-0034. ML093290290)

2. Security Requirements

“Security-informed design” versus “brute force method of securing the plant”

Chris Mowry, Babcock & Wilcox to U.S. Nuclear Regulatory Commission, March 29, 2011

3. Insurance, Liability, Annual Fees, Decommissioning Funding

SMR applicants argue that current regulations impact SMRs disproportionally

Michael Mayfield, Overview of Small Reactor Licensing, U.S. NRC, May 30, 2012

4. Size of Emergency Planning Zone

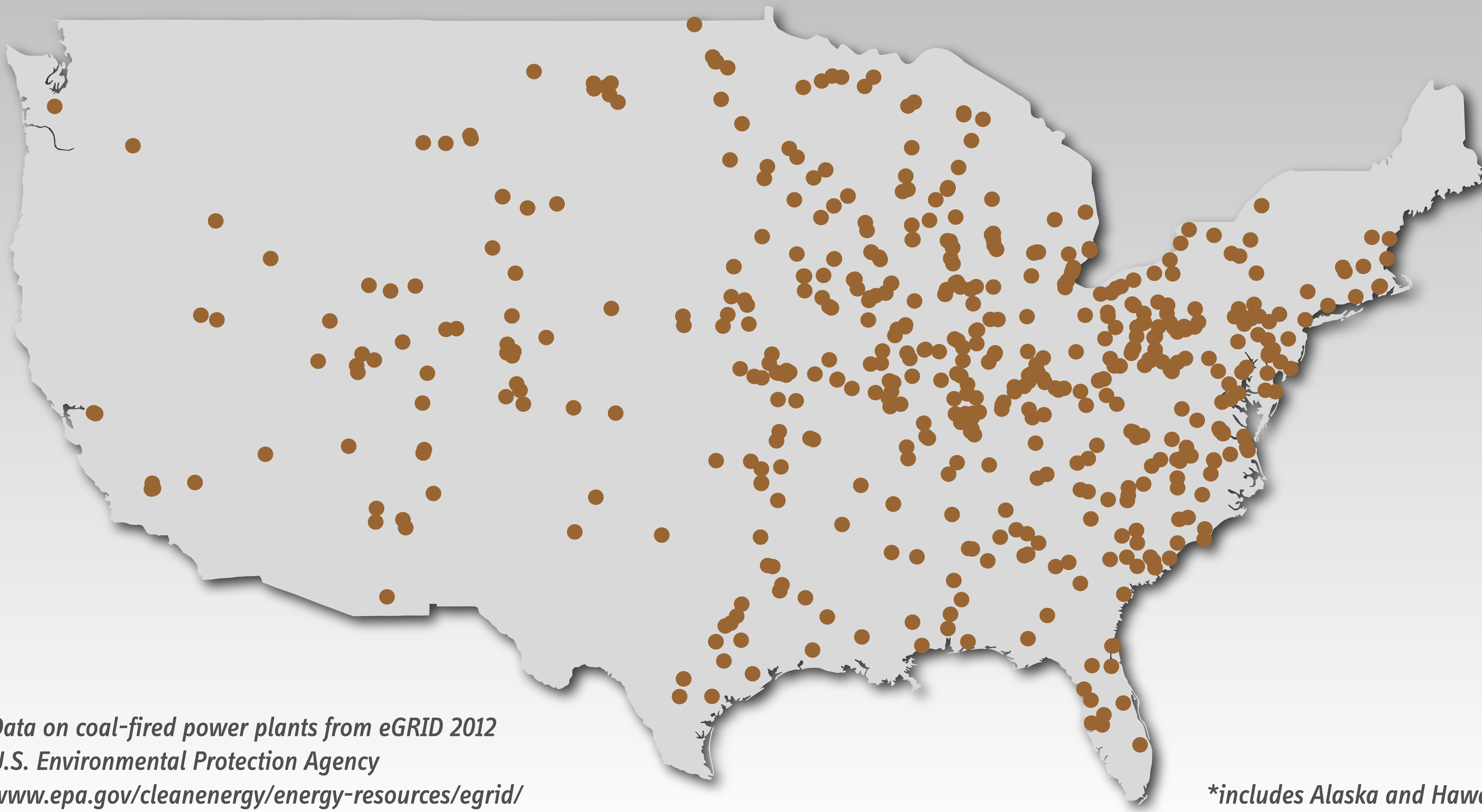
SMR applicants advocate for “scalable EPZ” to take into account power level and new safety features

Could also determine viability of some proposed deployment schemes

Could Small Modular Reactors Be Deployed at Sites That Previously Hosted Coal-fired Plants?

Coal-fired Power Plants in the United States

1370 generators at 560 sites with an installed capacity of 330 GWe*



Data on coal-fired power plants from eGRID 2012
U.S. Environmental Protection Agency
www.epa.gov/cleanenergy/energy-resources/egrid/

**includes Alaska and Hawaii*

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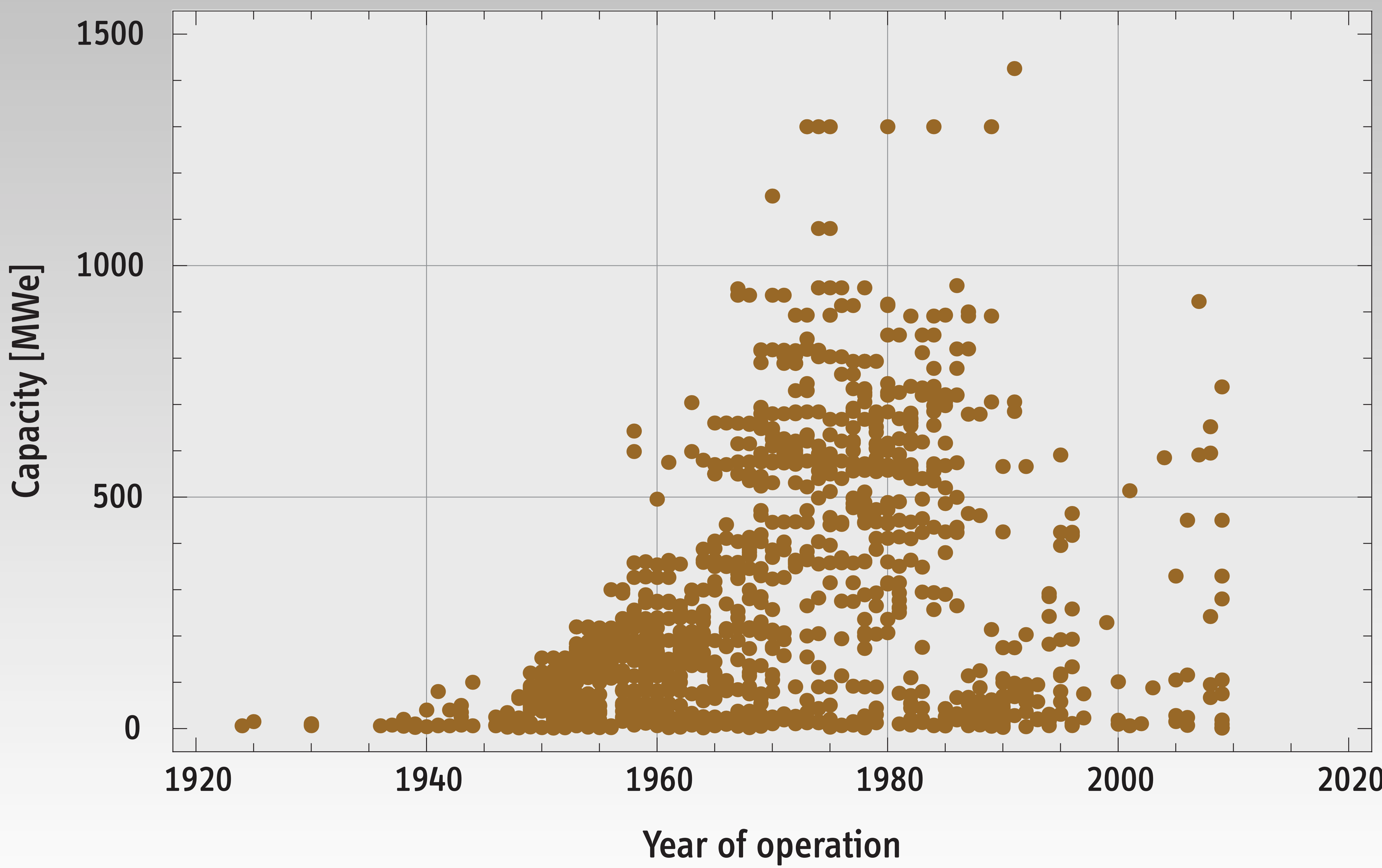

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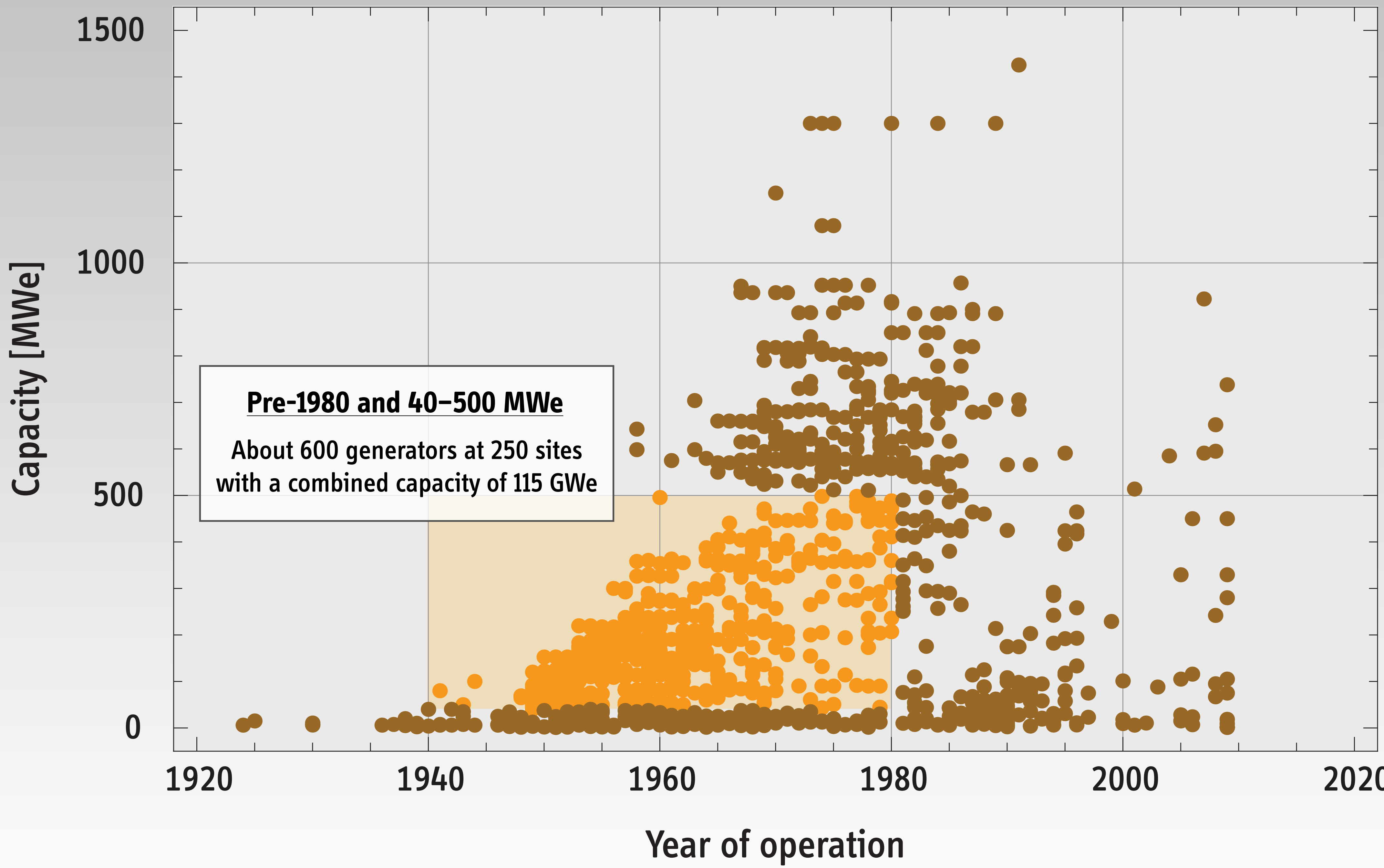
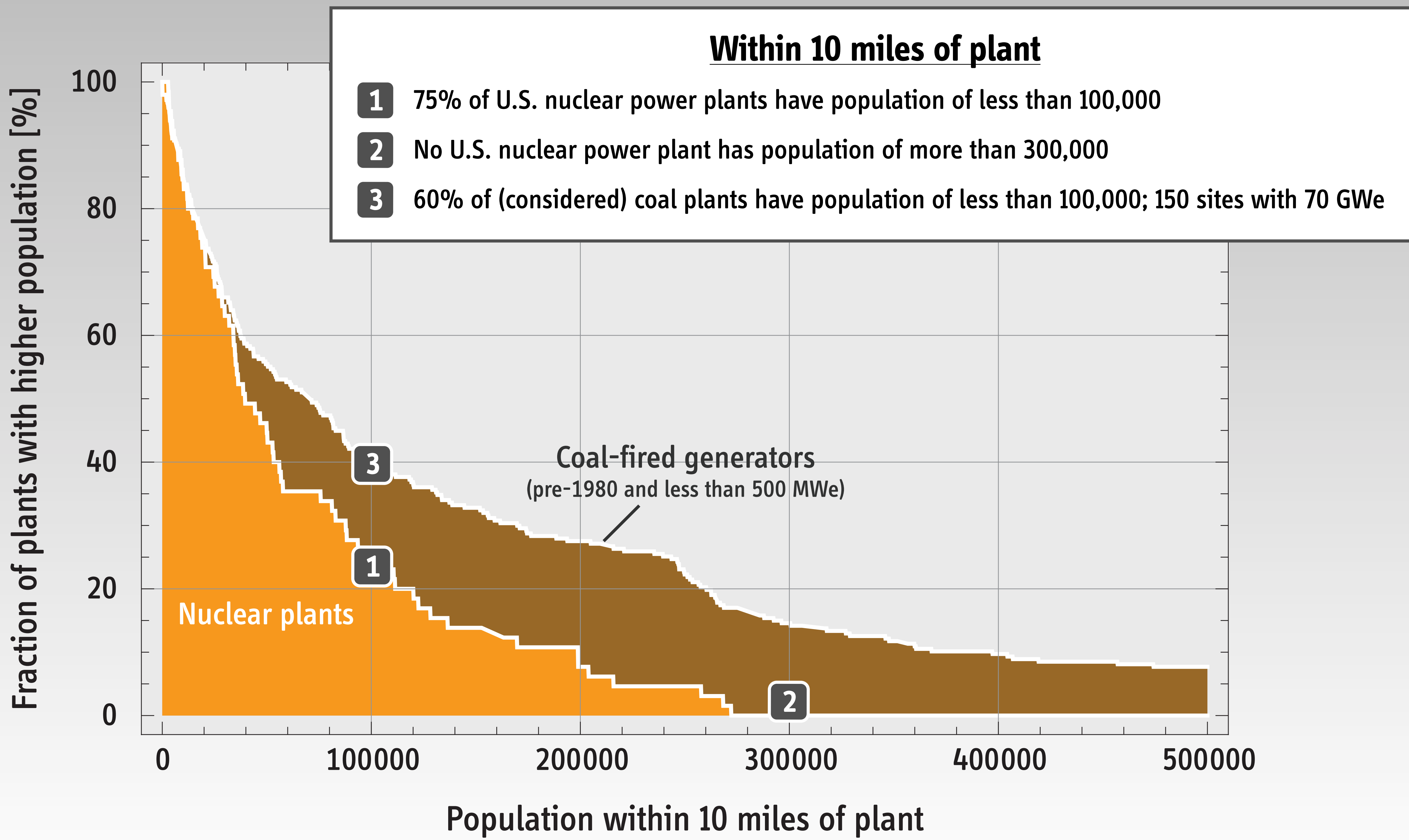


Similar idea, first proposed by Peter Lyons, Presentation to Secretary of Energy Advisory Board (SEAB), SMR Subcommittee March 9, 2012

Coal-fired Power Plants Are Generally Closer to Urban Areas



Population data from the United States 2010 Population Census; Digital Map and Geospatial Information Center, Princeton University

Technology Choices for SMRs

Two important examples

SMRs based on established light-water reactor technology

to demonstrate commercial viability of the concept over a relatively short period of time

(often: integral pressurized-water reactors (iPWRs) using standard fuel elements)

Propose enhanced safety features resulting from reduced power level

SMRs with long-lived cores

that do not require refueling for two or three decades

Typically fast neutron spectrum (helium, sodium, or liquid-metal cooled)

(often: targeted at newcomer countries or remote locations)

Some Advanced Designs Rely on Major Departures from Established Technologies and Approaches

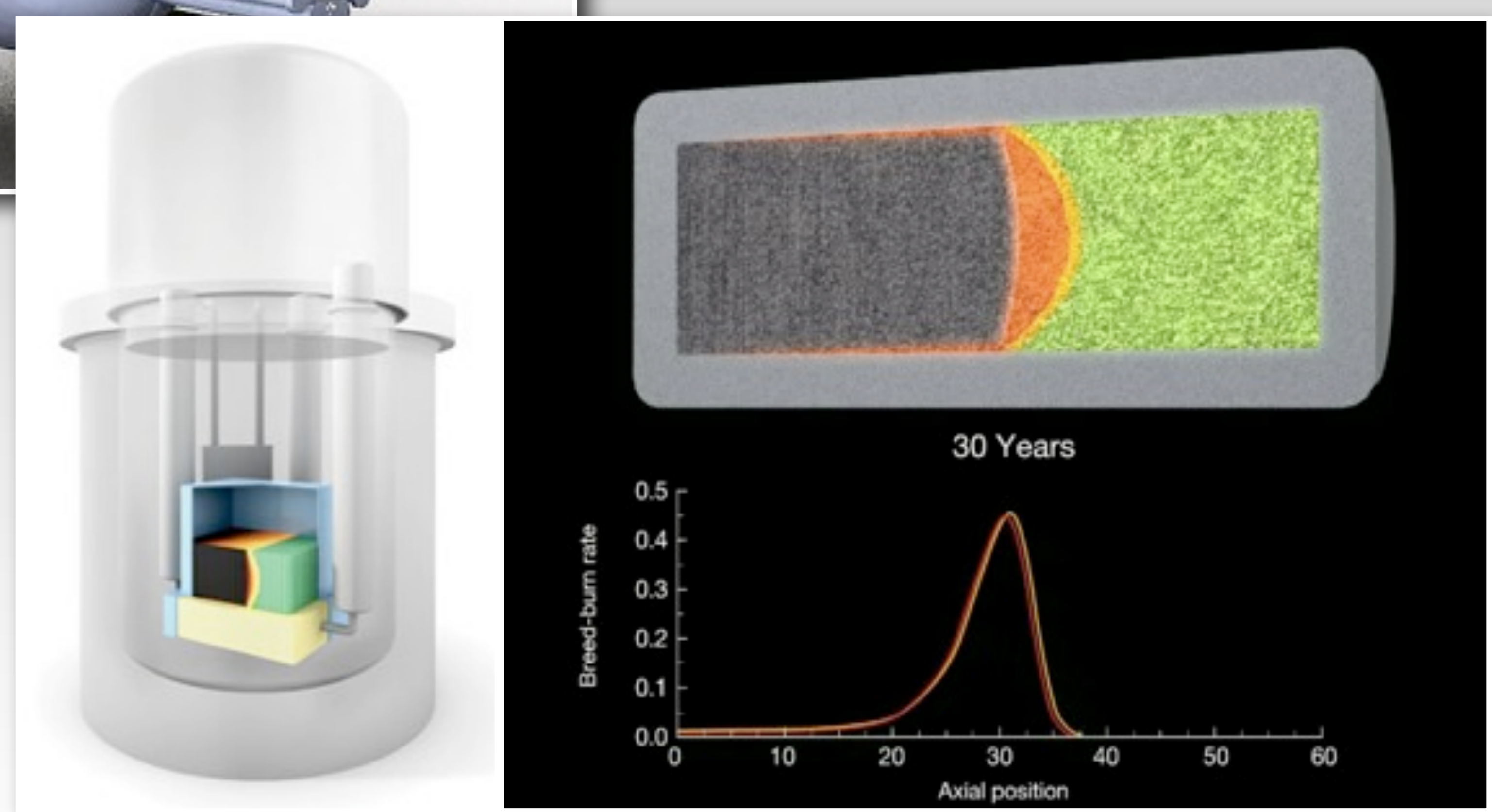
Mostly at conceptual stage today ... and decades away from deployment

EM²: "Nuclear Waste to Energy"

www.ga.com/energy/em2/

Traveling Wave Reactor

www.terrapower.com



Where Is Nuclear Power Heading?

Some Concluding Observations

Many countries (including the United States) remain committed to nuclear power

Internationally, deployment and role of nuclear power is likely to be more uneven

Small Modular Reactors

SMR attract significant attention; many innovative features; some prototypes will be built

Design choices will determine viability of systems for large-scale deployment

Resource utilization and proliferation risks may or may not be significantly different (relative to gigawatt-scale reactors in use today)

Small may be beautiful ... but it is small

Even under most optimistic assumptions, little generating capacity based on SMR technologies could be deployed by 2030