Government and Industry Roles in Commercialization of Nuclear Power

Lessons from the First Round

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Government and Industry Roles in the Research, Development, Demonstration, and Deployment of Commercial Nuclear Reactors: Historical Review and Analysis

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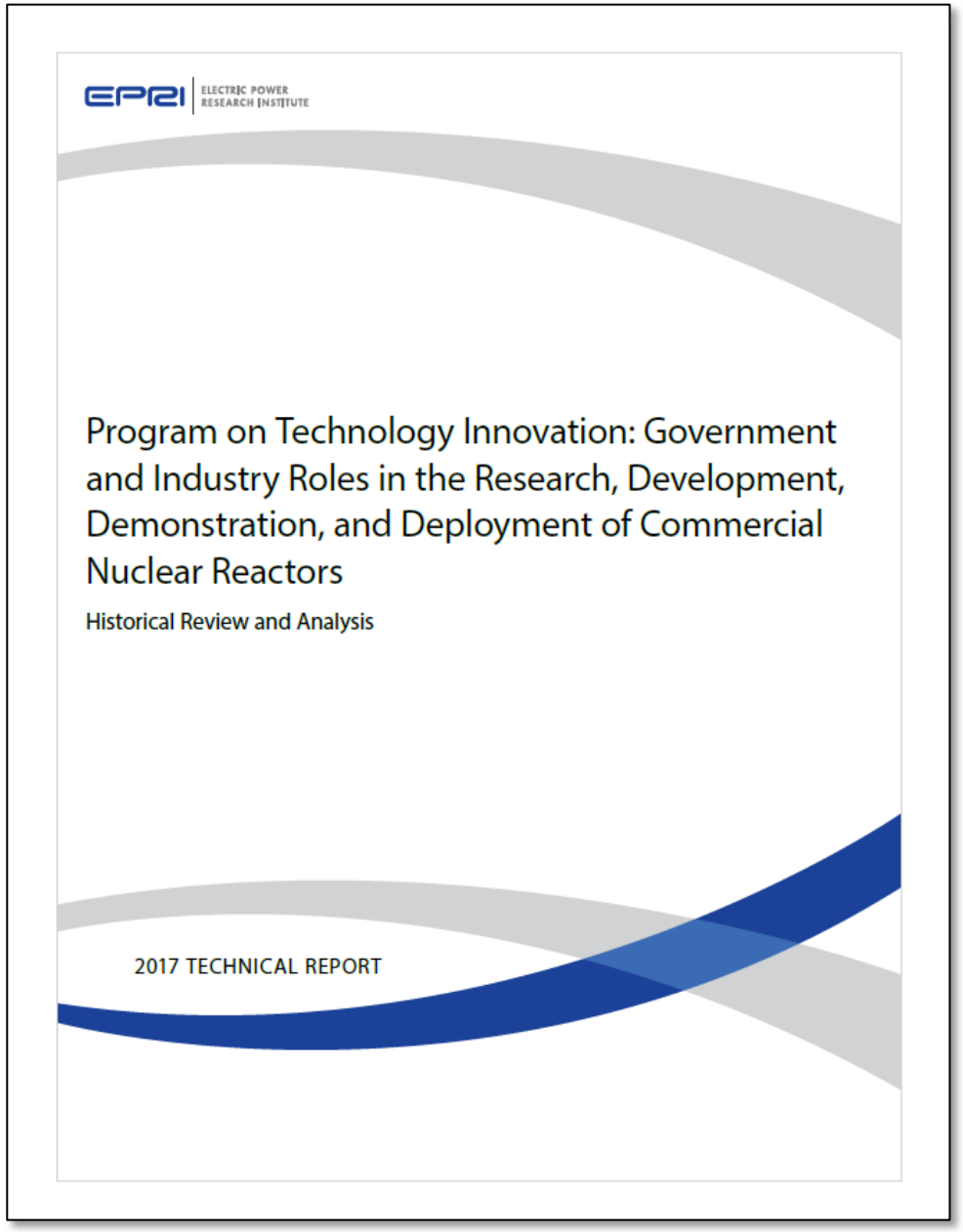


Commercialization Story: Context and Caveats

- Nuclear power grew out of classified national defense programs
- Heady projections for growth in electricity and other energy demands
- Pessimistic projections for uranium supply
- Decision-making and investment driven by a dual track strategy:
  - Urgency: build something now
  - Patience: identify optimum technology for building when ready
- Vision included multiple and expanding missions: electricity and beyond

Utilities and industry played significant roles in early demonstrations.

Part I
Global Nuclear Technologies

Commercialized, Deployed at Fleet Scale, and Exported

Four Technologies Reach Global Commercial Deployment

- Commercialization resulted from close government and private sector collaboration
- Government sponsorship of basic and applied R&D
- Government involvement continued well into commercial deployment (3 of 4 designs)
- Government support also extended to A/E and design firms to accelerate test and demo units
- Governments and private interests utilized a range of collaborative and financing vehicles

PWRs/VVERs

BWRs

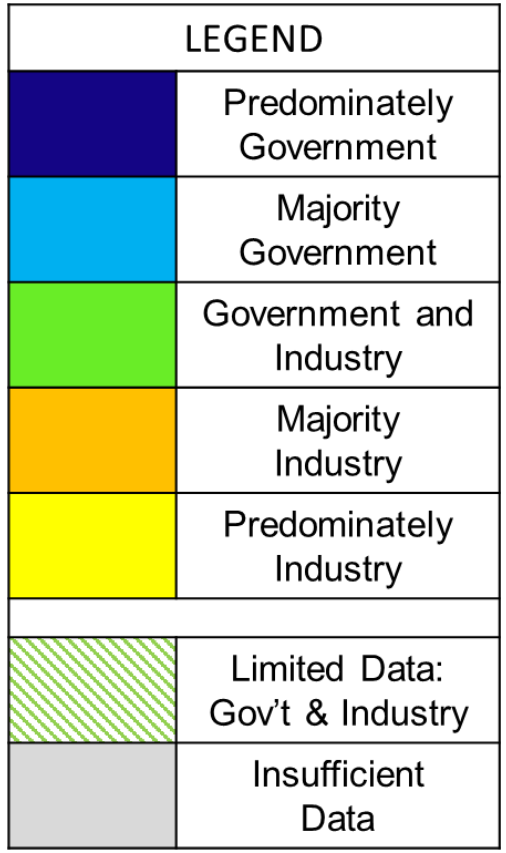
MAGNOX/AGRs

PHWRs/CANDUs

Government and Industry Roles in Commercialization

(PWRs, BWRs, PHWRs and GCRs)

Activity	Test Reactors	Small Demonstration Reactors	Large Demonstration Reactors	First Commercial Reactors
Site Acquisition				
Nuclear Island Owner				
Conventional Island Owner				
Pre-Construction R&D				
Post-Construction R&D				
Nuclear Island Design				
Conventional Island Design				
Fuel Design				
Fuel Fabrication and/or Supply				
Nuclear Island Operator				
Conventional Island Operator				
Nuclear Island Constructor				
Conventional Island Constructor				
Rate Assistance				



Part II
The Early U.S. Program as a Case Study in Public – Private Partnership

The U.S. Atomic Energy Commission's Cooperative Power Reactor Demonstration Program (CPRDP)

US AEC Engagement with Industry

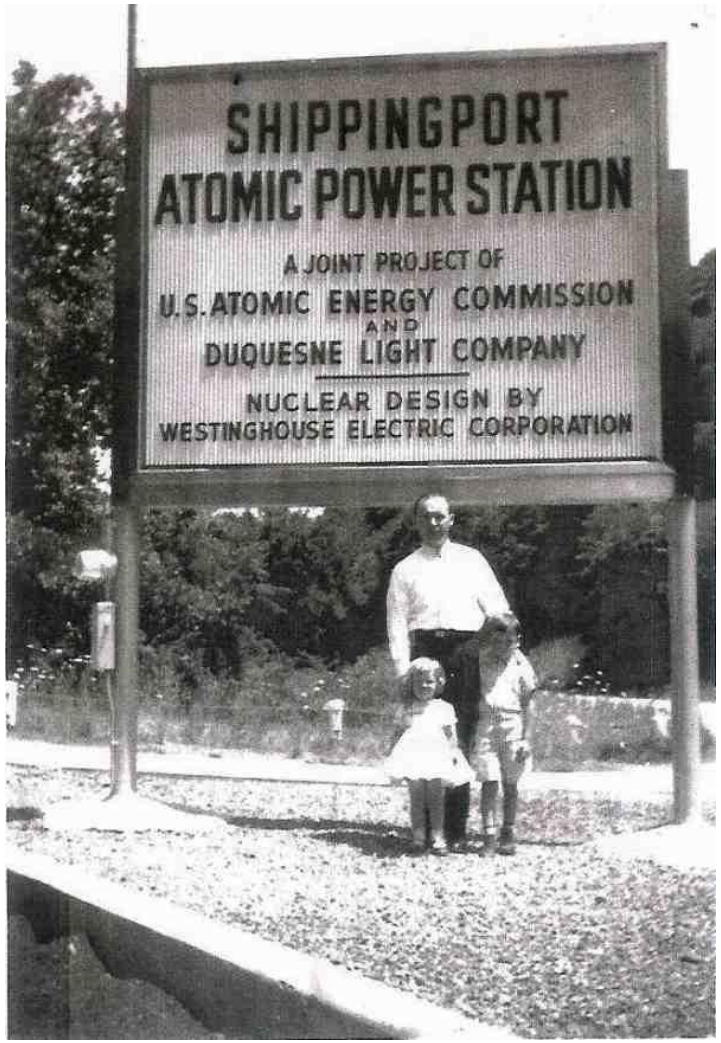
- Industrial Participation Program (IPP) launched in 1951
  - Private sector study teams
  - Companies provided personnel and funding (~$5 million investment)
  - AEC provided access to reactor design info. and labs
  - AEC to receive private sector perspective on engineering and economic feasibility

- 21 study teams comprising 61 companies
  - 60% utilities
  - 25% vendors
  - 15% A/E firms

- AEC approved 21 IPP proposals (not all were built)

Shippingport Atomic Power Station (1953)

- Nuclear island designed by the Bettis Atomic Power Laboratory (operated by Westinghouse) under direction of AEC Naval Reactors Group
- Owner-operator: AEC and Duquesne Light Company (the latter financed balance of plant construction; operated and maintained entire plant; reimbursed AEC for steam produced)
- Operated from 1957 over 30-year period with 3 different core designs and fuel systems:
  - Two PWR cores
  - 60 MWe thorium breeder configuration
- Demonstrated viability of a public-private partnership that included a private electric power utility as the owner-operator



Herb Feinroth *First Criticality at Shippingport*. Posted December 10, 2014. American Nuclear Society Nuclear Café. http://ansnuclearcafe.org/2014/12/10/first-criticality-at-shippingport/

Post-Shippingport Program

- Information access presented early challenge for U.S. Atomic Energy Commission (AEC)
- 1954 Atomic Energy Act amendments empowered the AEC to use a range of approaches to involve industry in reactor RD&D to promote commercialization
- Capping of nuclear liability with 1957 Price-Anderson Act further enabled private investment in commercial nuclear power
- AEC Cooperative Power Reactor Demonstration Program (CPRDP) launched in 1955:
  - *"It is the Commission's intent to stimulate outside groups to undertake developmental or demonstration power reactor projects with financing of the type normal to the particular group's activities."*

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Early US AEC Perspectives on Nuclear (ca. 1953)

Level of Promise

(1 = most; 5 = least)

1. Homogeneous reactor
2. Fast breeder reactor
3. Boiling water reactor
4. Sodium graphite reactor
5. Pressurized water reactor

Developmental Timelines

(1 = shortest; 5 = longest)

1. Pressurized water reactor
2. Sodium graphite reactor
3. Boiling water reactor
4. Homogeneous reactor
5. Fast breeder reactor

AEC top five designs in rank order for ultimate economic competitiveness and developmental timelines as outlined in report to Congress

Down-selected from ~80 concepts

Cooperative Power Reactor Demonstration Program

- Industry incentives to stimulate U.S. commercial nuclear power (1955 to 1963)
  - Three formal rounds + modified third round
  - 13 projects (8 technologies) incentivized and constructed
  - Other designs explored

- Government support generally included:
  - Funding of preconstruction R&D at either federal labs or at private institutions
  - Waiving fuel use fees during early plant operations

- Industry role generally included:
  - Constructing the balance of plant
  - Operating entire facility
  - Purchasing steam from AEC

- **Ownership of nuclear island varied**

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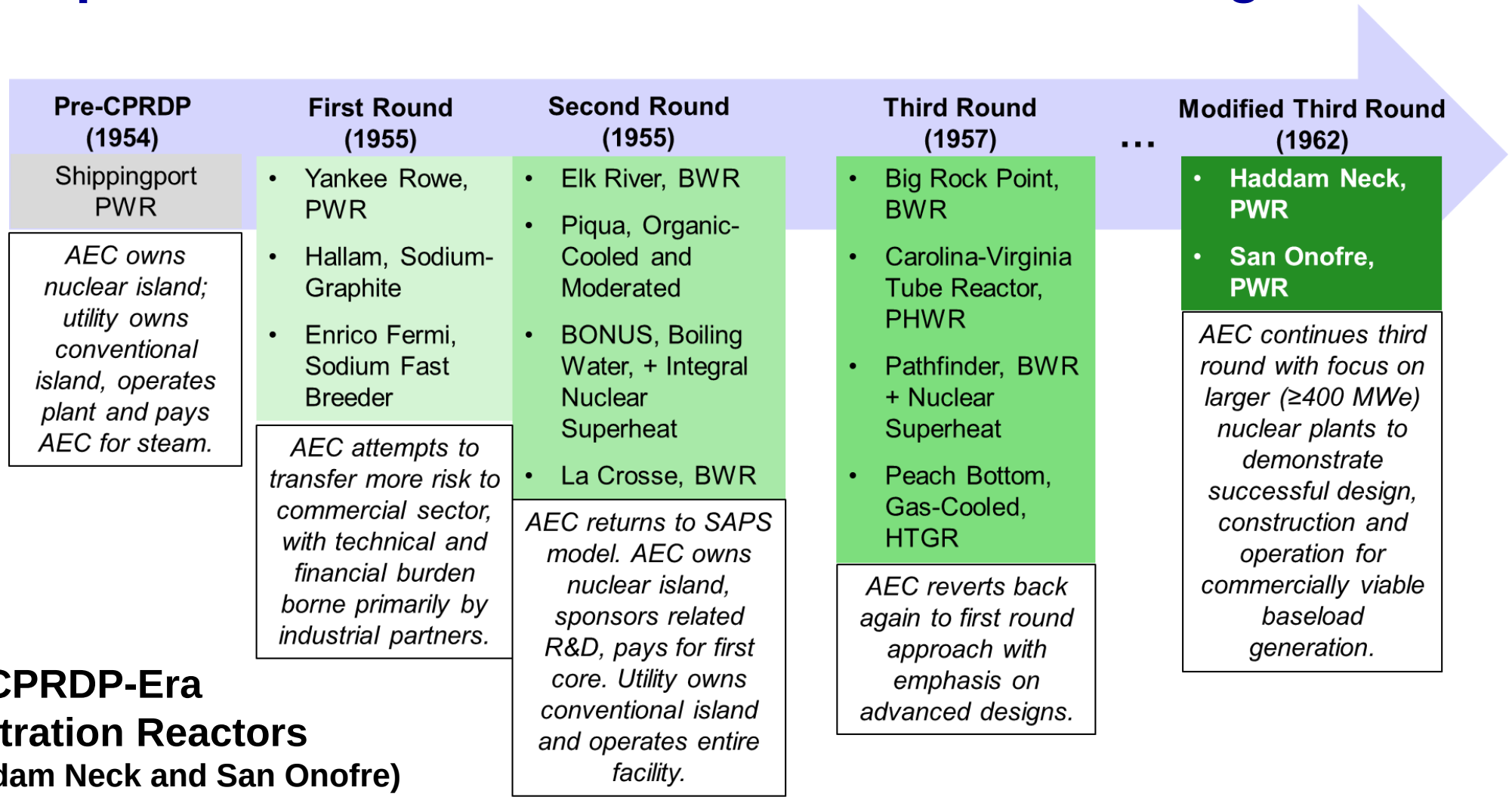
U.S. Cooperative Power Reactor Demonstration Program

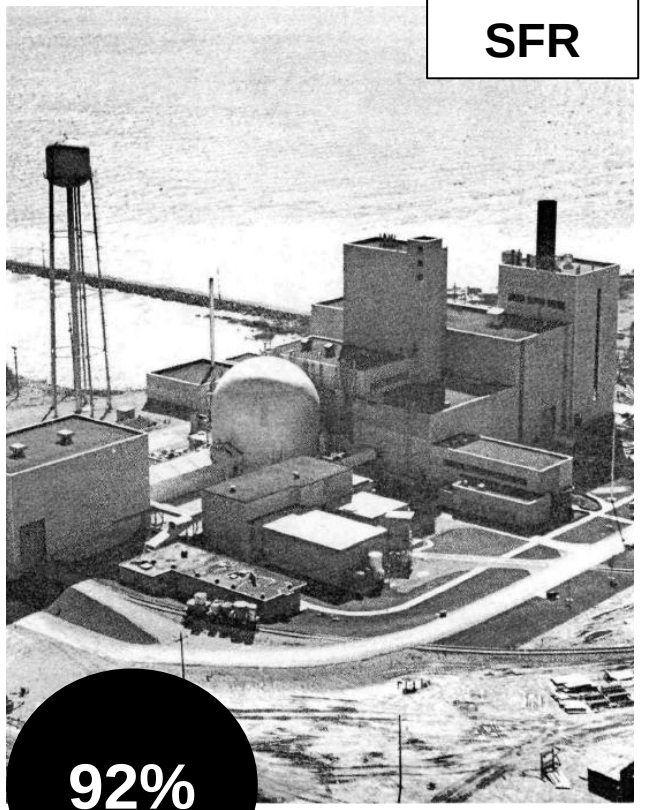


Twelve CPRDP-Era Demonstration Reactors
(Plus Haddam Neck and San Onofre)

U.S. AEC and industry pursued a range of public–private partnership models.

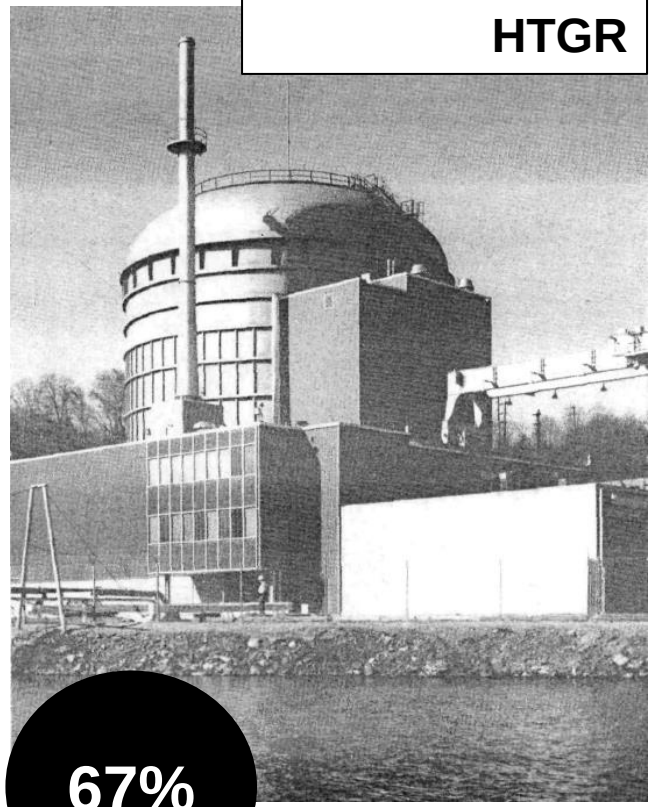
U.S. Non-LWRs Built with >50% Industry Investment

Fermi 1
SFR



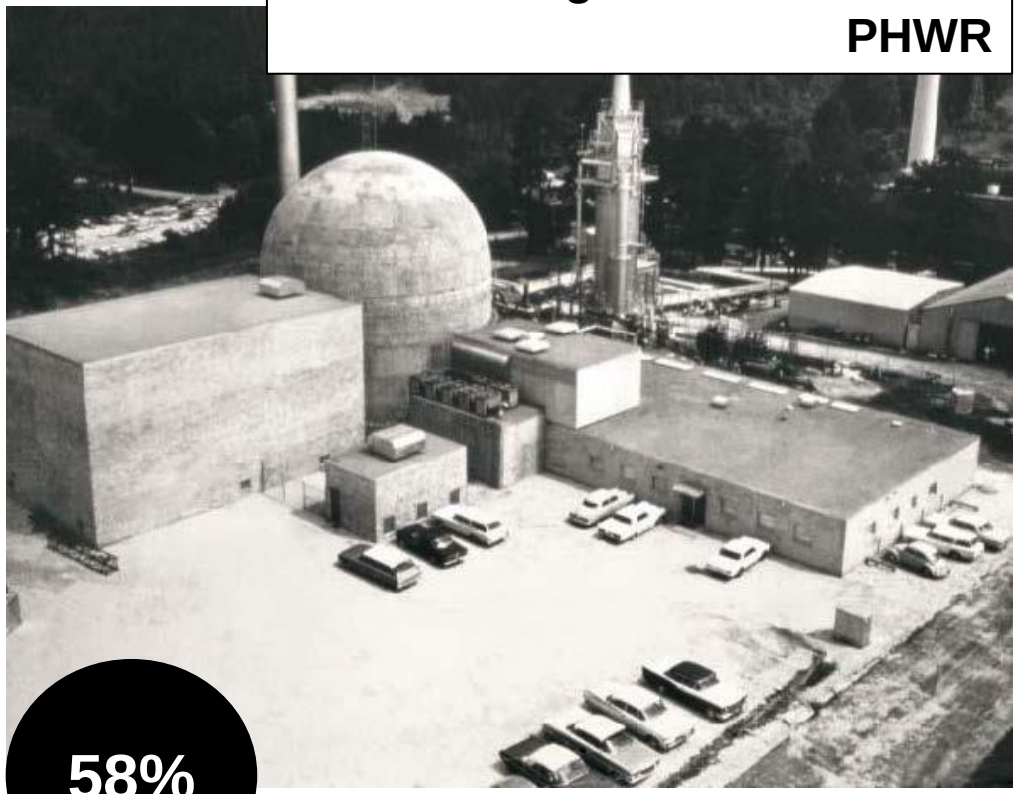
92%

Peach Bottom 1
HTGR



67%

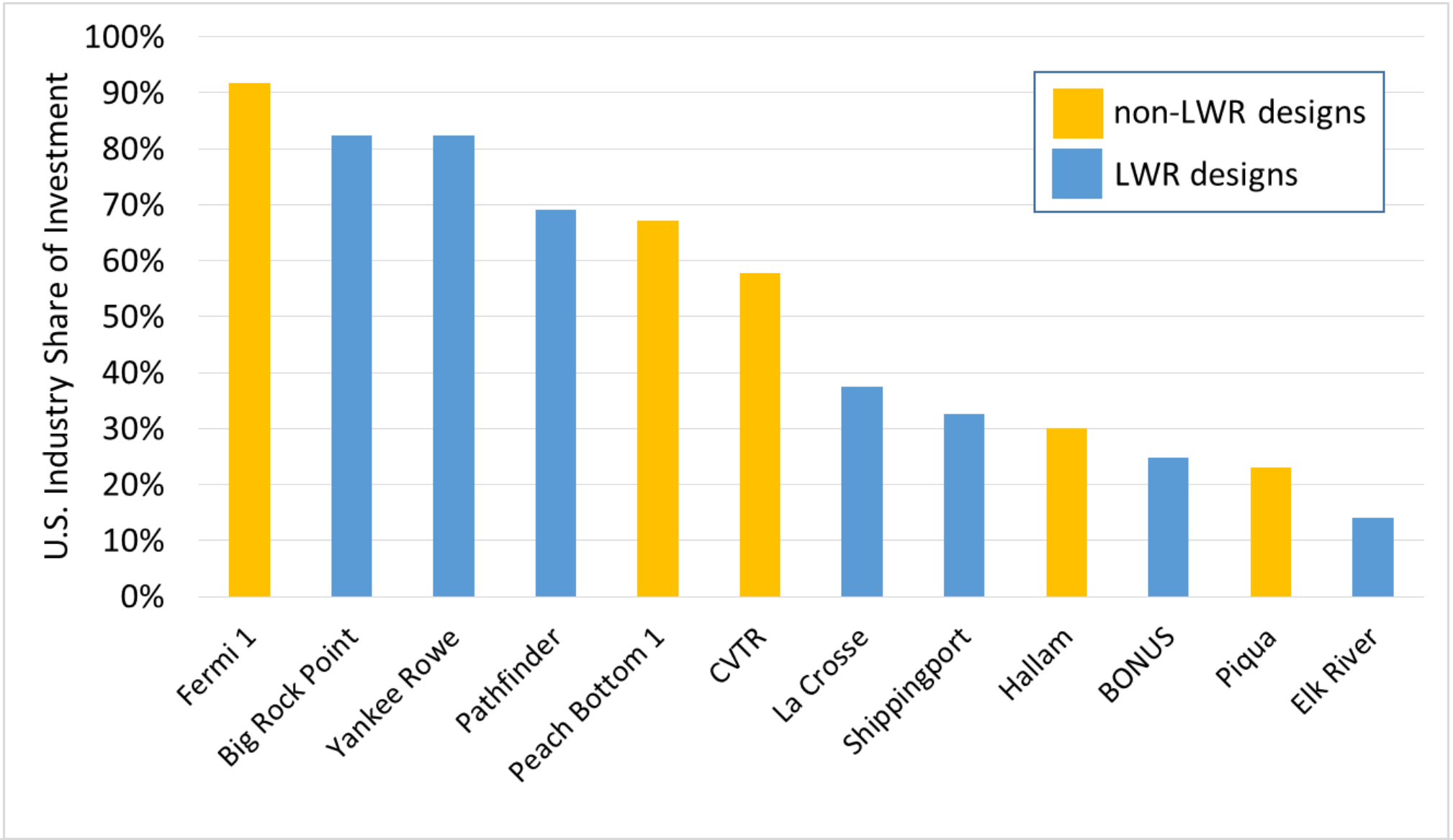
Carolina-Virginia Tube Reactor
PHWR



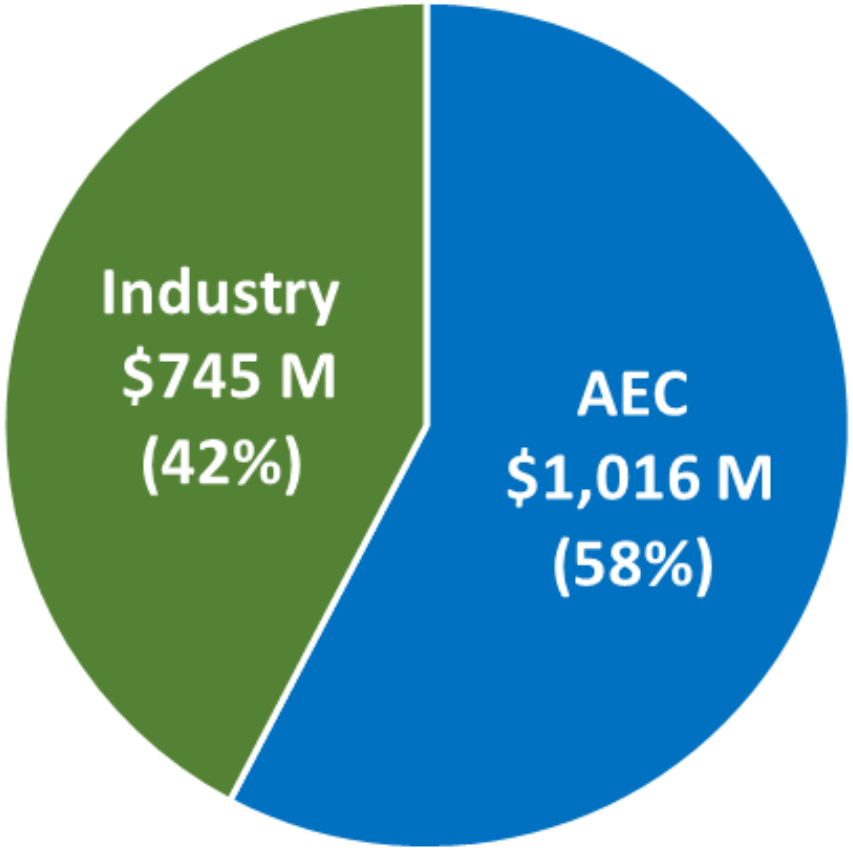
58%

Images from U.S. Atomic Energy Commission (1967)

Public and Private Investment for CPRDP-Era Reactors



Cumulative Public and Private Sector Investment in U.S. Nuclear Power Through 1962



Categories
Civilian Reactor R&D
CPRDP Demonstration Reactors (Rounds 1 -3)
Privately Financed Reactors
Commercial-scale CPRDP Reactors (Modified Round 3)
New AEC Test Reactors
Private Sector Test Reactors
Cooperatively Financed Test Reactors
Industrial Participation

Total estimated U.S. investment = $1.76 billion (~ $11 billion in 2017 USD)

Closing Thoughts

- Past performance does not guarantee future returns
- Public-private partnerships during original nuclear commercialization period varied (not “one-size fits all”)
- Public investment through demonstration remained substantial
- Industrial investment in many demonstration programs was significant, often dominant
- Investment required for demonstration of new technology measured in billions of USD

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