TVA's Clinch River Small Modular Reactor Project

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Acknowledgement and Disclaimer

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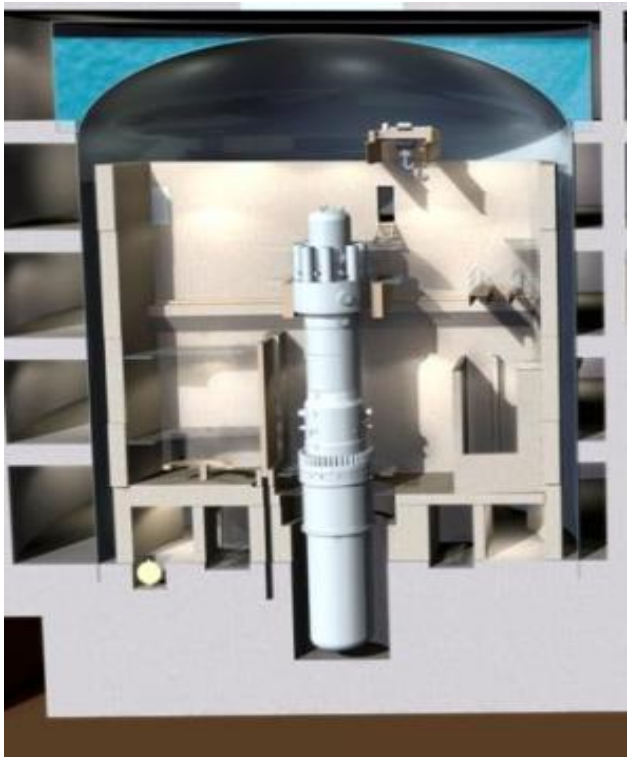
Why is TVA Evaluating SMRs?

- The need for a more diversified generating fleet with increased use of reliable, cleaner, low-cost energy generation
- Potential for next generation nuclear that is cost efficient and flexible
- Technology Innovation is part of TVA's mission and charter
- SMRs could help TVA and the nation improve energy security with clean and reliable new nuclear technology

Option for clean and reliable energy in lower cost increments

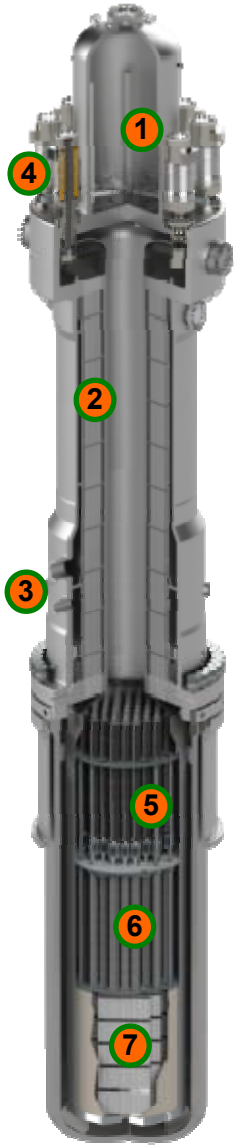
Attractive Features of SMRs



- Improved safety and security
- Higher reliability than other clean options
- Improve grid resiliency
- Lower financing costs
- Reduced construction time
- Increased standardization
- Smaller footprint; more site options
- Ability to load follow; more compatible with renewables
- Re-establishes U.S. manufacturing base for nuclear components
- Good job creation in manufacturing, construction and operation

B&W mPower™ Reactor Design

- 530 MWt reactor results in 180 MWe
  - Core, CRDMs, SG, Pressurizer, and Coolant Pumps
  - No penetrations below top of core
- 4-Year fuel cycle with “standard” PWR fuel
  - 69 fuel assemblies with <5% ^{235}U enrichment
  - Reactivity controlled with rods, not boron chemistry
- Simple, fully “passive safety” design
  - Core remains covered during design basis accidents
  - No power required for emergency core cooling



1. **Pressurizer**
2. **Once-Through Steam Generator**
3. **Feedwater Inlet / Steam Outlet**
4. **Reactor Coolant Pumps**
5. **Electro- Hydraulic CRDMs**
6. **Upper Internals**
7. **Reactor Core**

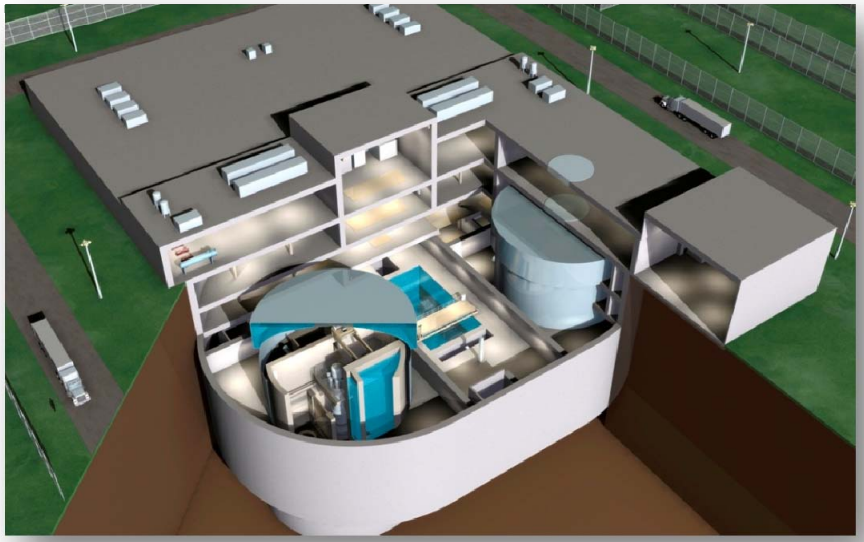
Nuclear Island Features

Fully underground

- Protected from external threats
- Security-informed architecture
- More efficient seismic design
- Steel containment, with space for O&M activity

"Passive safety" design

- No safety-related emergency AC power
- 72-hour safety-related control/monitoring battery
- No shared active safety systems between units
- 14-day underground ultimate heat sink
- Defense-in-depth layers deliver ~10^{-8} core damage frequency

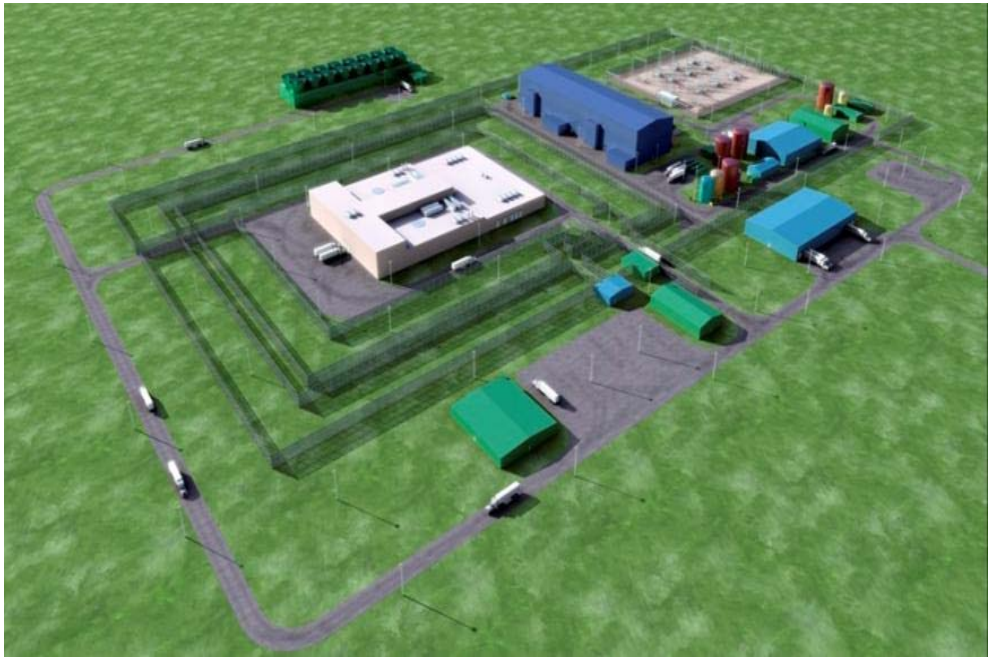


Enhanced Spent Fuel Pool (SFP) configuration

- 20-year wet storage capacity
- SFP inside reactor building
- Large heat sink with 30-day "coping time"

Simple, robust architecture enhances safety, lowers licensing risk

Plant Site Layout



mPower “Twin Pack” Site Layout

- 2 x 180 MWe units
- 38 acre site footprint
- Low site profile
- Safety systems underground
- Conventional steam systems
- Smaller high security footprint

Small, low-impact footprint could offer more siting options

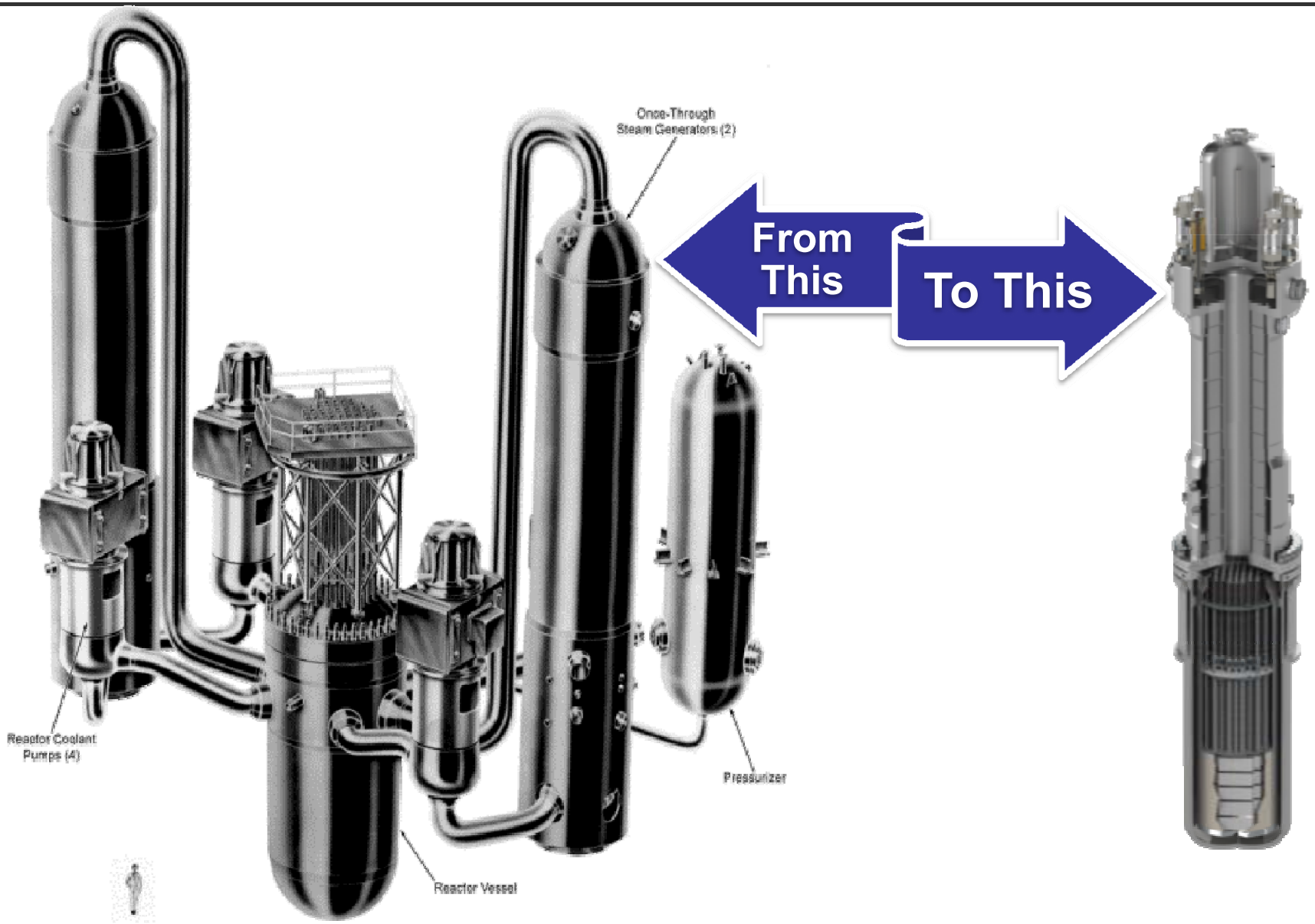
Modular Manufacturing & Construction

Modularization Attributes:

- Modularity part of the design process
- More than 70% of construction to be modular
- Design optimization through “area design”
- Strong attention to tolerances, interfaces, & integration
- Repeatability through automation and common tooling
- Robust quality assurance in fabrication facilities

“Economies of Replication vs. Economies of Scale”

Complexity Reduced



B&W Footprint

Total Employees = 501

Location	FTEs	Activity
Charlotte	35	HQ
Charlotte	21	Generation mPower LLC
Cambridge	6*	Manufacturing and SG design
Rockville	3	Licensing
Lynchburg (Ramsey)	**200**	**B&W mPower™ design & test**
Barberton	30*	Thermal-hydraulics engineering
Euclid	40*	CRDM design and development
Frederick - BPC	162**	BOP design
Lynchburg – BPC	4**	Engineering interface & licensing

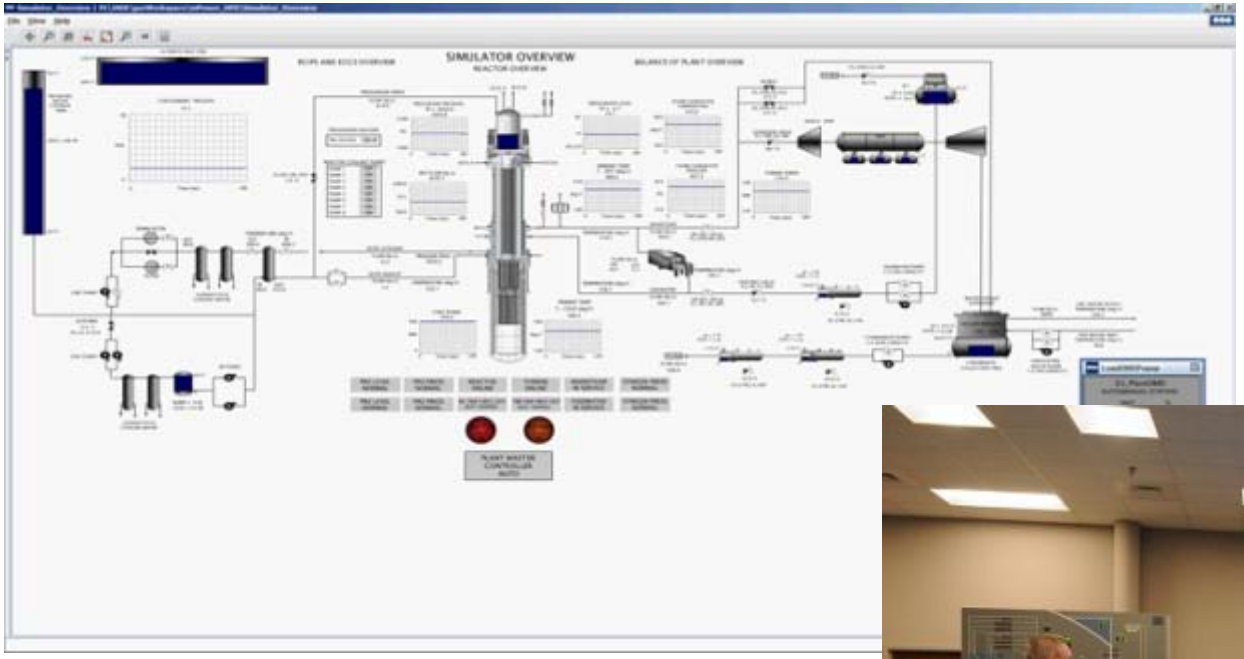
* Dedicated FTEs from other B&W business groups
** Subcontracted/partner Bechtel workforce

Lynchburg, VA

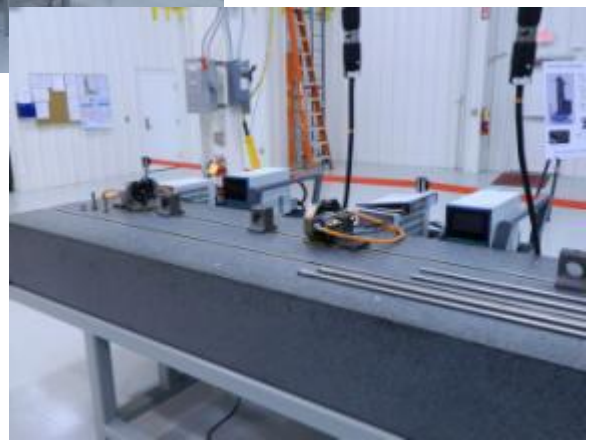
Mt. Vernon, IN

Cambridge, ON

Simulation & Control Room



Fuel Technology Center



Integrated System Test Facility

2009 January – Identified need for integrated system test

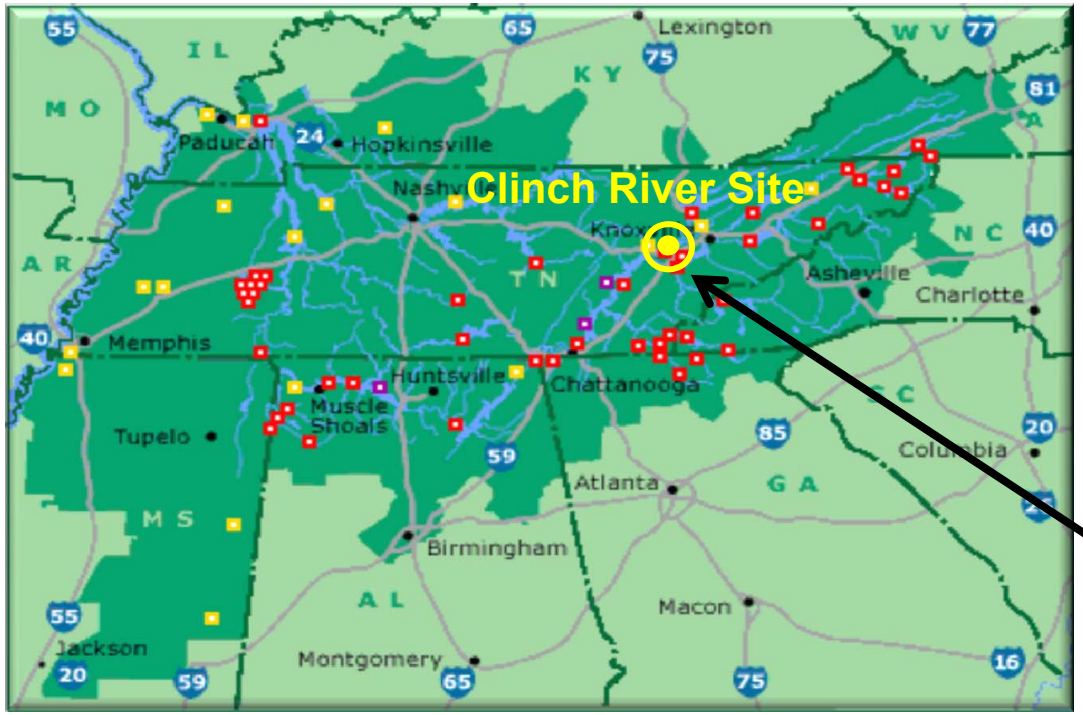
2010 Mar – Decided to construct in Lynchburg
Aug – First steel installed
Nov – Steel installation complete

2011 Mar – First equipment installed

2012 Feb – Equipment Installation Complete
Mar – Startup testing initiated

2013 Mar – Steam Generator testing completed
Apr – ECC upgrades completed

Site Adjacent to Oak Ridge Reservation



Those who cannot remember the past are condemned to repeat it (George Santayana)

Completed site excavation.

Lessons From More Than 60 Years Ago

- From Rickover's June 5, 1953 Congressional testimony regarding the differences between paper (academic) reactors and real (practical) reactors

An academic reactor or reactor plant almost always has the following basic characteristics: (1) It is simple. (2) It is small. (3) It is cheap. (4) It is light. (5) It can be built very quickly. (6) It is very flexible in purpose. (7) Very little development will be required. It will use off-the-shelf components. (8) The reactor is in the study phase. It is not being built now.

On the other hand a practical reactor can be distinguished by the following characteristics: (1) It is being built now. (2) It is behind schedule. (3) It requires an immense amount of development on apparently trivial items. (4) It is very expensive. (5) It takes a long time to build because of its engineering development problems. (6) It is large. (7) It is heavy. (8) It is complicated.

Site Infrastructure Development

Site Characterization

Site Characterization

Meteorological tower

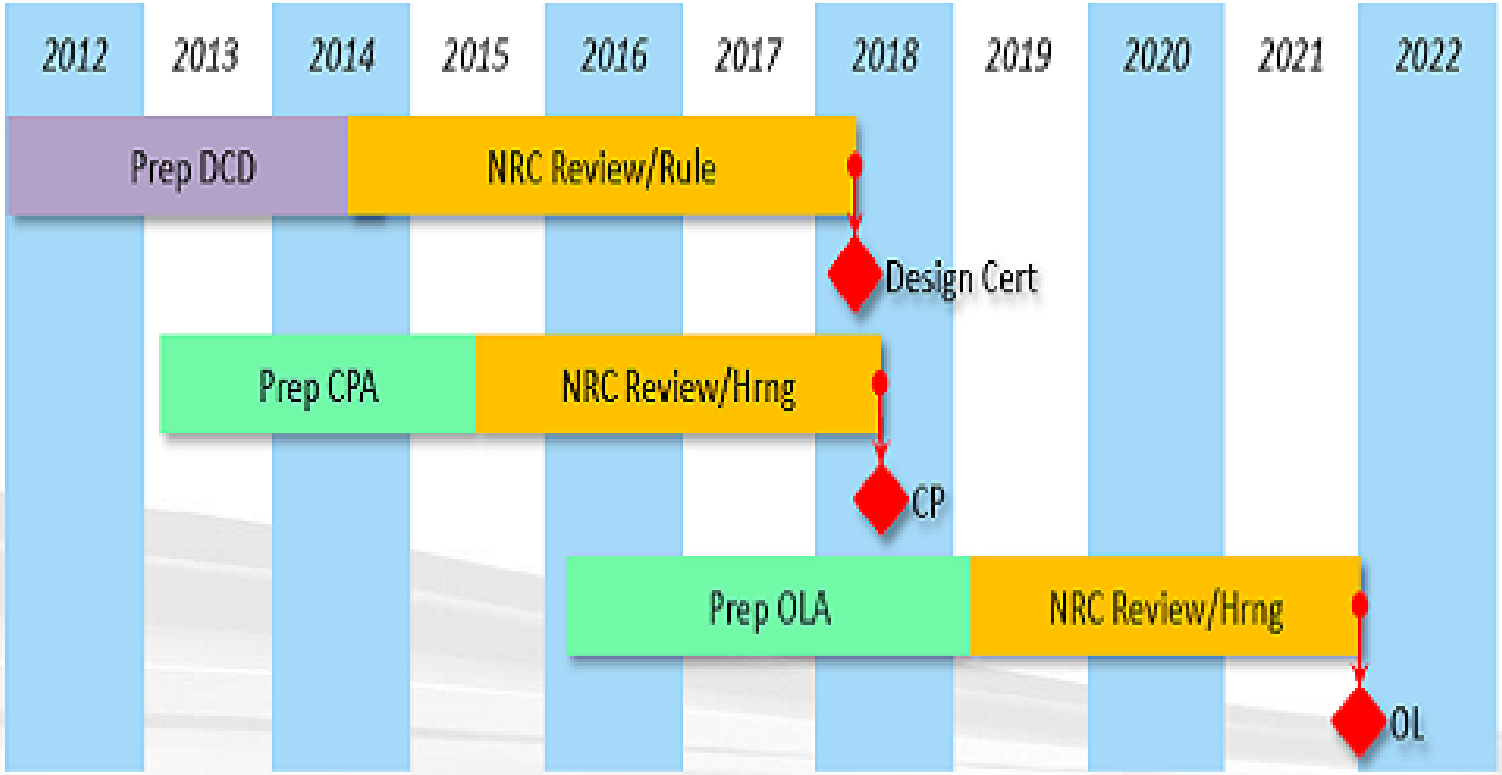
Core Borings

NRC Licensing/Design Approach

- Using 10 CFR Part 50 approach for first nuclear plant, subsequent plants would be licensed under Part 52
- Anticipate opportunities to make design changes for improved constructability/cost savings
- As minor changes are made to the design during Clinch River Plant construction, the Certified Design will be updated to be the Clinch River design
  - TVA does not want a “one-off design”
  - B&W wants its Standard Design to be informed by lessons learned during construction of the first plant

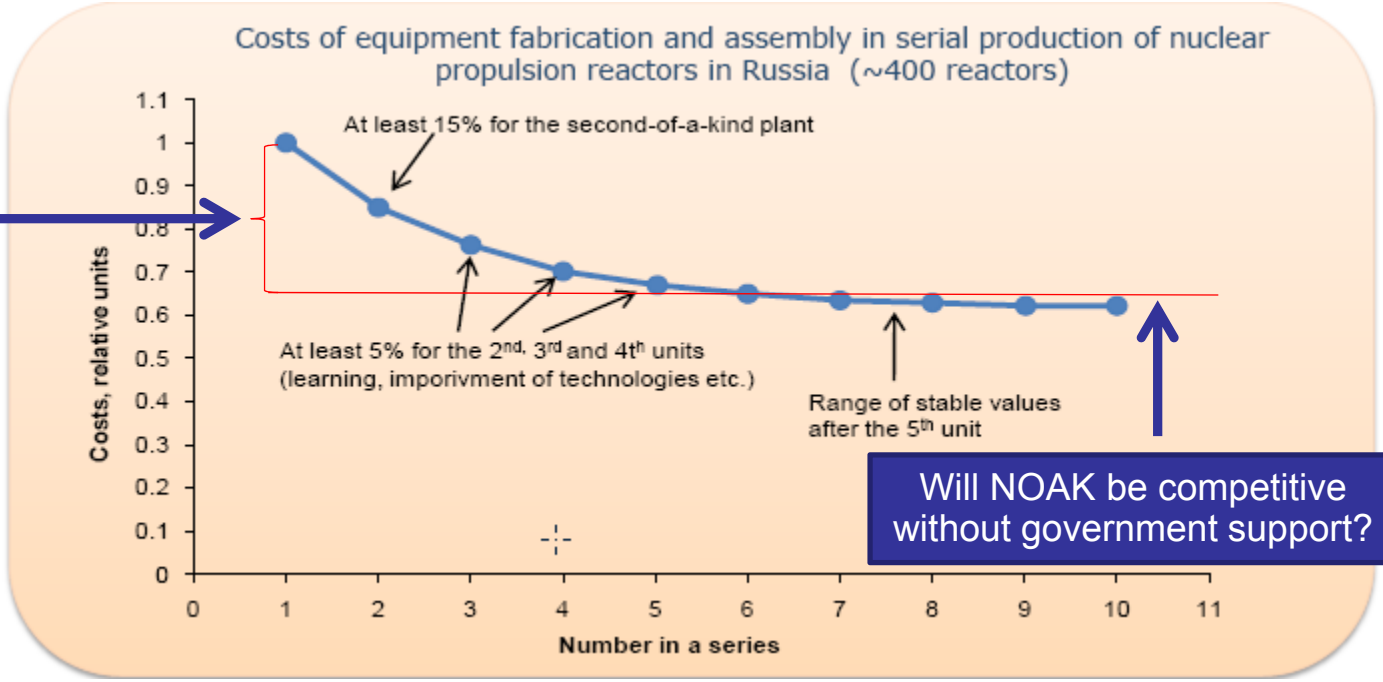
Licensing Schedule

Coordinated Part 50/Part 52 Process: One Design, One Review



The Learning Curve

Will FOAK risks be addressed by the Federal Government?



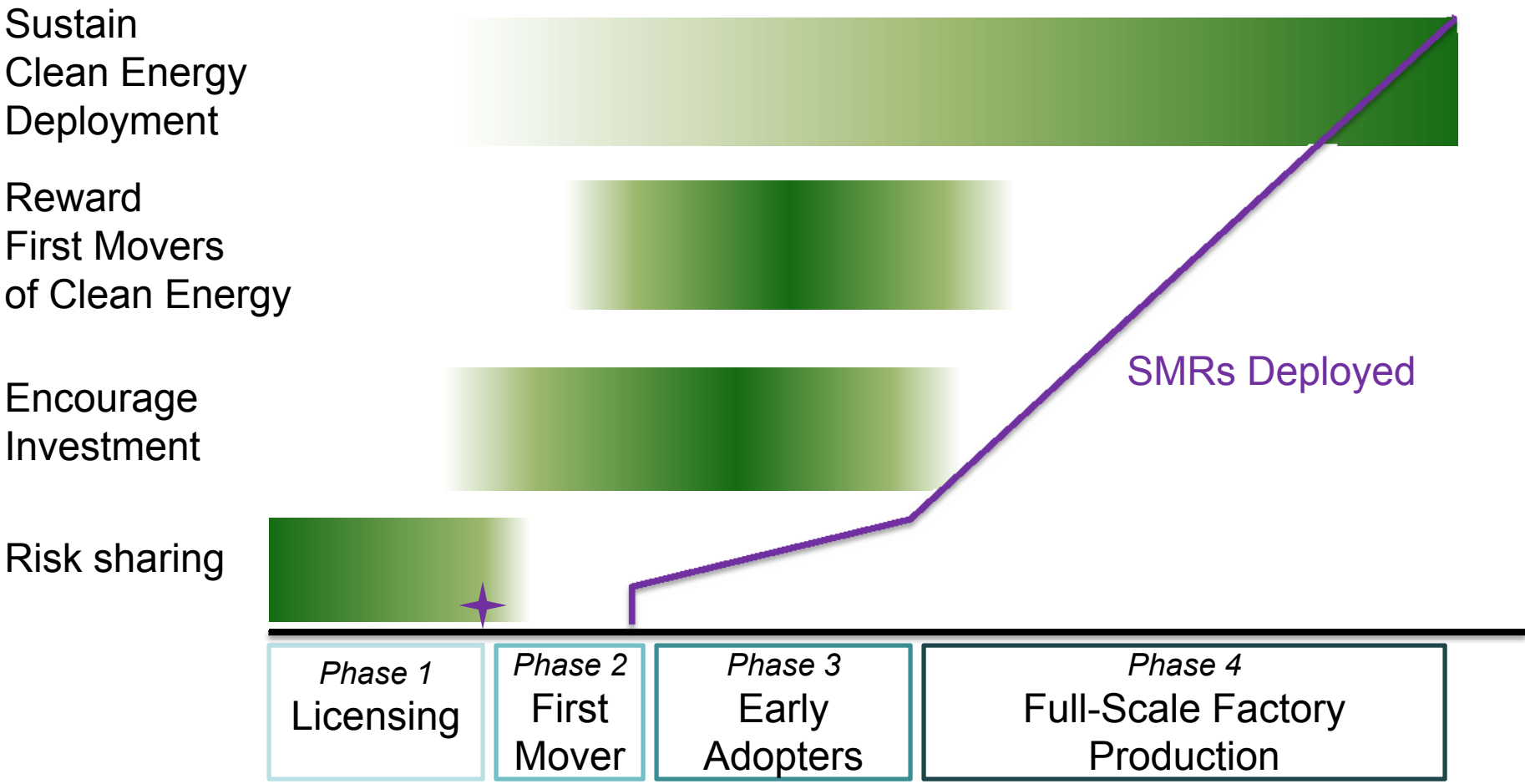
Will NOAK be competitive without government support?

First-of-a-kind factors and economy of subsequent units on the site/ multi-module plants:

- Factory fabrication is also subject to “learning”
- FOAK plants are reported to be 15-55% more expensive than the second one
- For serial units, the reduction of the effective (per unit) SMR capital cost could be 10-25%.

© OECD/NEA 2011 – Graph and data

DOE is Examining Policies and Programs to Facilitate Broader SMR Deployment



Presented by DOE at Platts Conference, February 2013

Federal Policy/Programs

2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025

Enabling Legislation

Licensing Technical Support (5-year, $452M, cost-shared, up to 2)

- Supports reactor design
- Proves out licensing process

- FOA
  - Selection
    - Cooperative Agreement
    - 2nd FOA
      - 2nd Selection?
        - 2nd Cooperative Agreement?

First Mover(s)

- Serves as “model home”
- Reduces uncertainties
- Enables creation of order book

Early Adopters

- Creates manufacturing infrastructure
- Drive towards Nth-of-a-kind
- U.S. exports contribute to trade balance
- Significant job creation

Clean Energy with Enhanced Reliability

- Helps meet Executive Order for Federal Agencies to meet carbon reduction goals with clean energy
  - Potential Power Purchase Agreement (PPA) with DOE to supply the Oak Ridge Reservation
- Capable of demonstrating enhanced reliability
  - mPower reactor has “Island Mode” operation
    - Does not lose power during loss of off site power
    - Able to connect and disconnect from grid
  - Could supply “mission-critical” loads with enhanced reliability
    - Never schedule outage of both mPower units at same time
    - Potential for underground transmission to serve mission critical loads
    - Potential to demonstrate capability at Clinch River for other DOE/DOD sites
  - Could “load follow” which is more compatible with renewables
  - Potential to supply through a long-term Power Purchase Agreement

Conclusion

- SMRs fit with TVA's Vision of having a clean, balanced generation portfolio
- SMRs fit with TVA's Technology Innovation Mission
- TVA views B&W's mPower design as an appropriate advancement in nuclear technology
- TVA has a suitable site with an interested key customer
- Significant work remains to mature the design, test key components, obtain an NRC license, understand cost, schedule and economic projections before making a construction decision
- SMRs offer TVA an attractive option for safe, clean, and reliable electricity generation worth continued investment