Nuclear Technology Innovation Small Modular Reactor

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Acknowledgement and Disclaimer

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Agenda

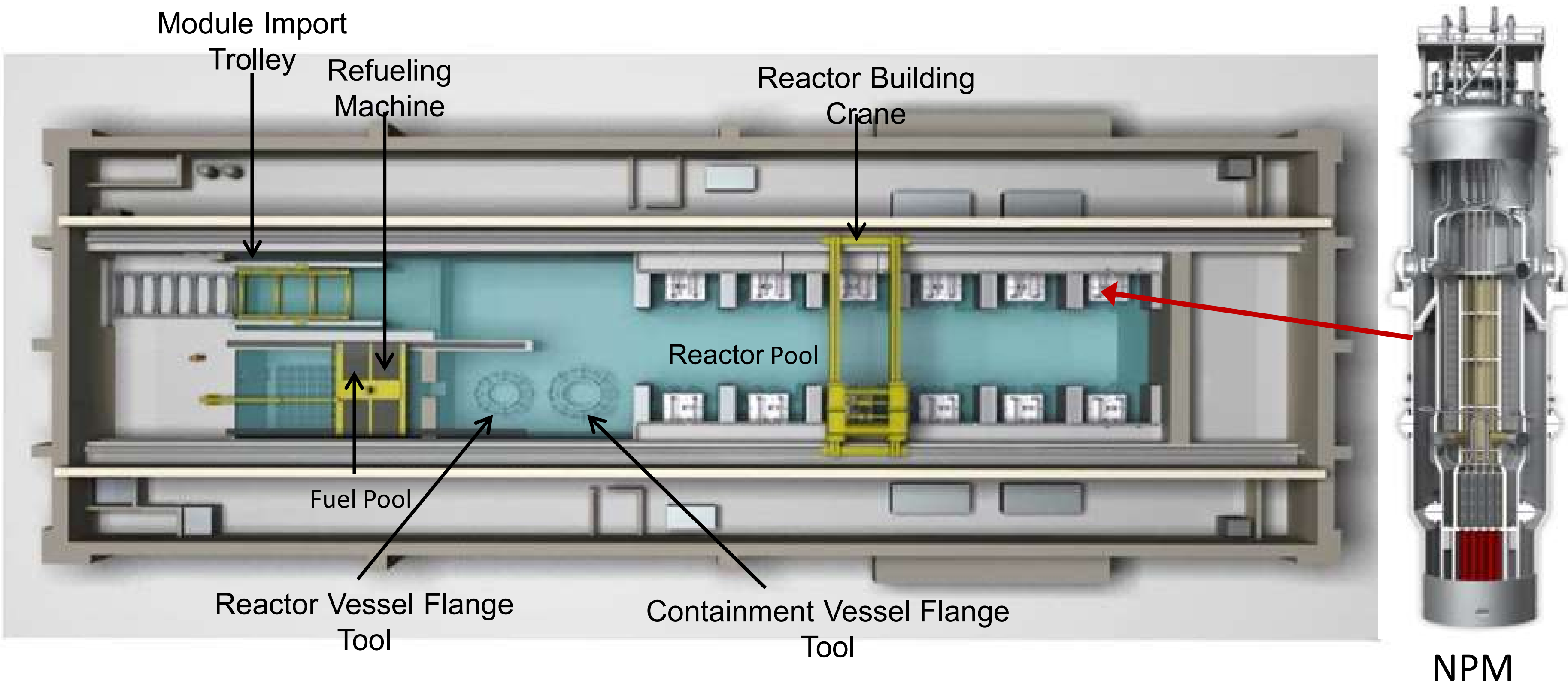
- SMR Overview
- TVA perspective on Clinch River
  - Early Site Permit Application
  - Combined Operating License Application
- Strategy for Quality Assurance
- Next Steps
- Summary

What are Small Modular Reactors (SMR's)?

- Reactors that produce less than 300 MWe
- Shop fabricated; truck or rail shipped; modularly constructed
- Containment underground
- Could be incrementally added to match load growth
- Two varieties:
  - Water-cooled
  - Non-LWR (light water reactor)

NuScale Power Module

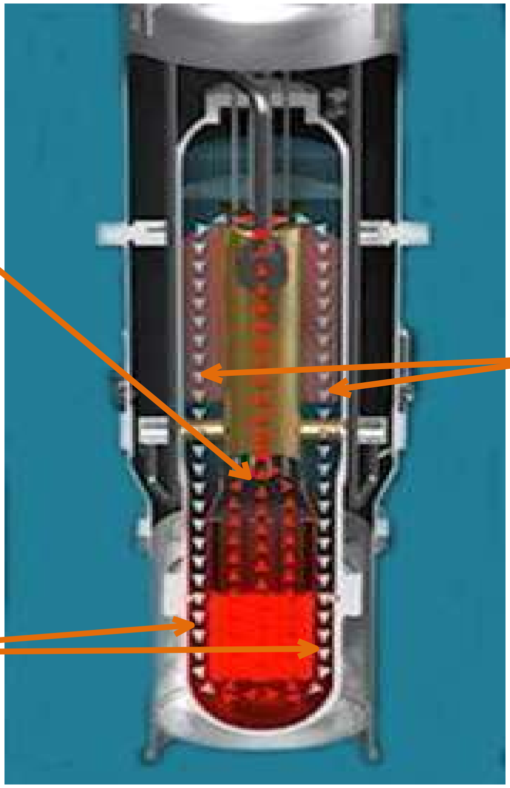
Reactor Building Overhead View



Coolant Flow Driven By Physics

Convection **– energy from the nuclear reaction heats the primary reactor coolant causing it to rise by convection and natural buoyancy through the riser, much like a chimney effect**

Gravity **– colder (denser) primary coolant "falls" to bottom of reactor pressure vessel, cycle continues**



Conduction **– heat is transferred through the walls of the tubes in the steam generator, heating the water (secondary coolant) inside them to turn it to steam. Primary water cools.**

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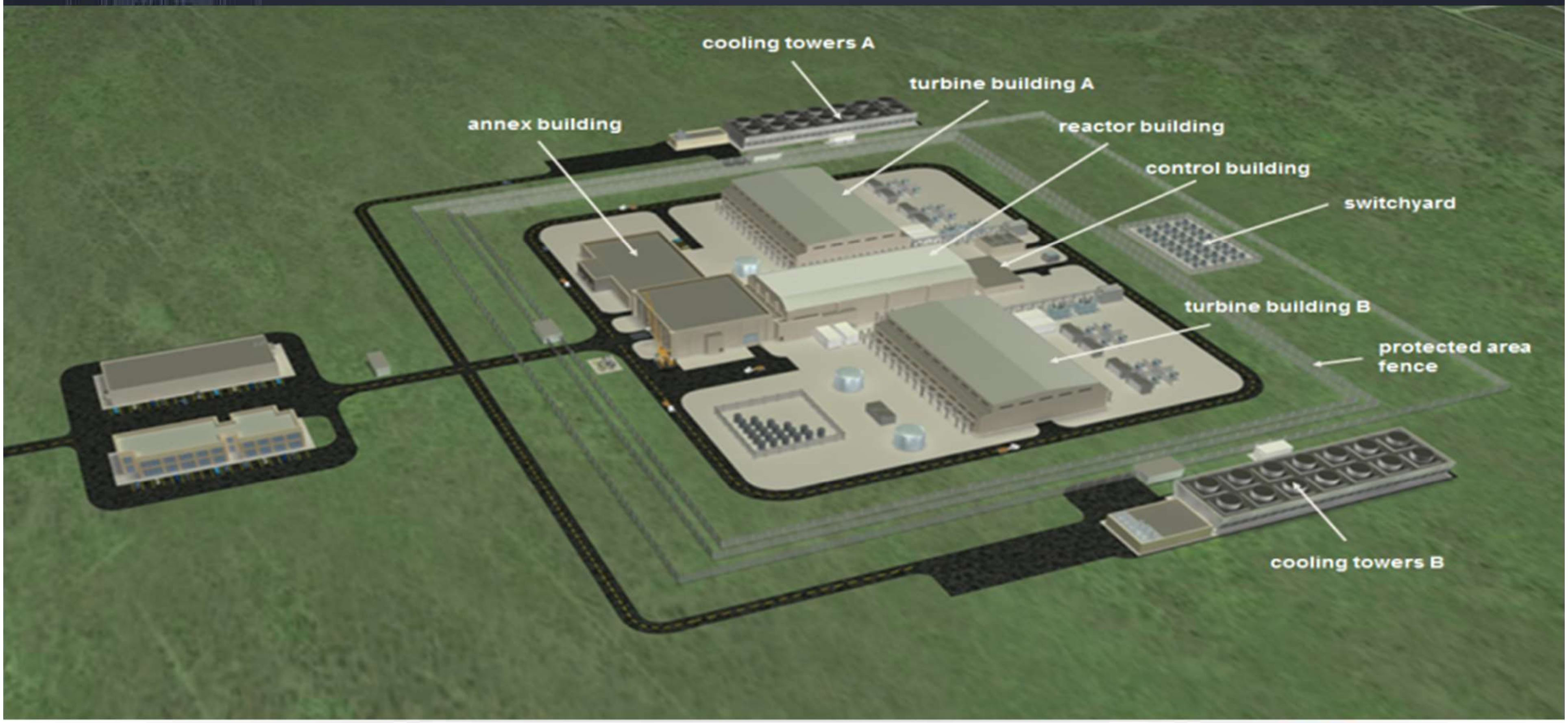
Site Aerial View



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NuScale Power™

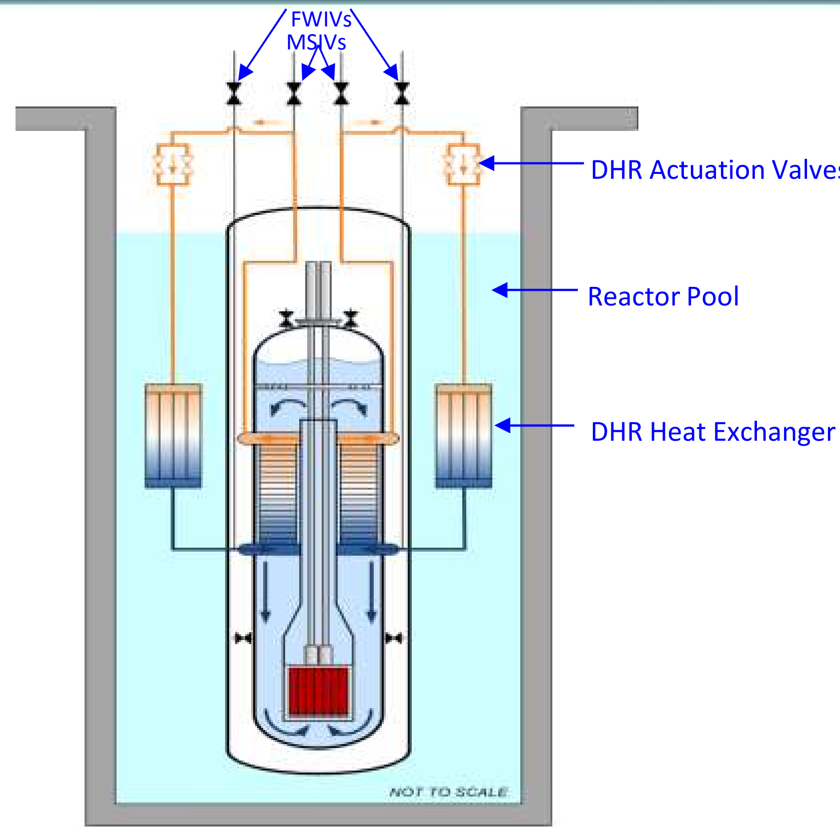
NuScale Safety Systems – Fewer Needed

Systems and Components Needed to Protect the Core:

- Reactor Pressure Vessel
- Containment Vessel
- Reactor Coolant System
- Decay Heat Removal System
- Emergency Core Cooling System
- Control Rod Drive System
- Containment Isolation System
- Ultimate Heat Sink
- Residual Heat Removal System
- Safety Injection System
- Refueling Water Storage Tank
- Condensate Storage Tank
- Auxiliary Feedwater System
- Emergency Service Water System
- Hydrogen Recombiner or Ignition System
- Containment Spray System
- Reactor Coolant Pumps
- Safety Related Electrical Distribution Systems
- Alternative Off-site Power
- Emergency Diesel Generators
- Safety Related 1E Battery System
- Anticipated Transient without Scram (ATWS) System

Decay Heat Removal (DHR) System

- The DHR system is composed of:
  - DHR actuation valves
  - DHR heat exchangers
  - Main steam and feedwater isolation valves
  - Ultimate heat sink (reactor pool)
- Two 100% redundant trains
- Decay heat passively removed via the steam generators and DHR heat condensers to the reactor pool



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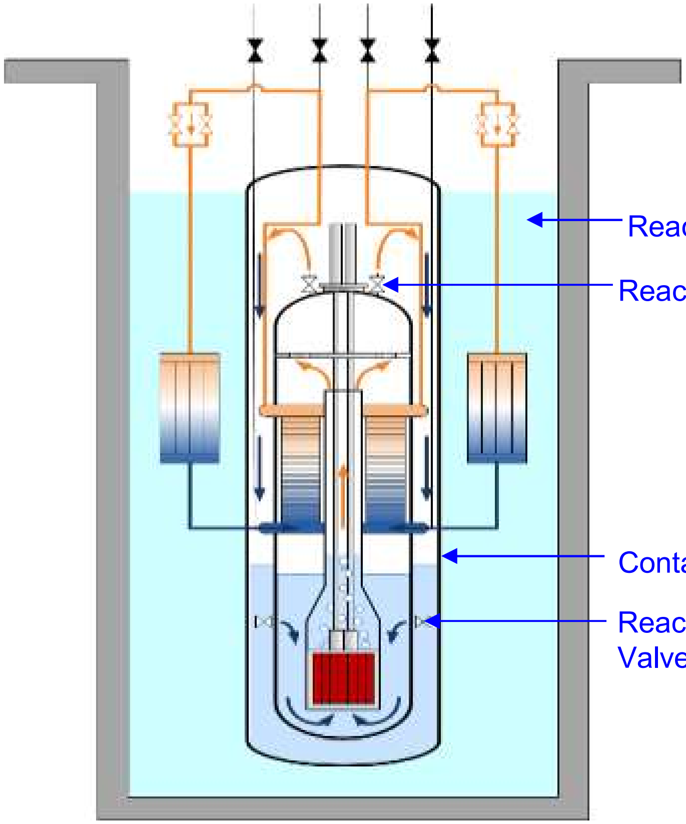
Emergency Core Cooling (ECC) System

- The ECC system is composed of:
  - Two reactor vent valves (RVVs)
  - Two reactor recirculation valves (RRVs)
  - Containment vessel
  - Containment isolation valves
  - Ultimate heat sink (reactor pool)

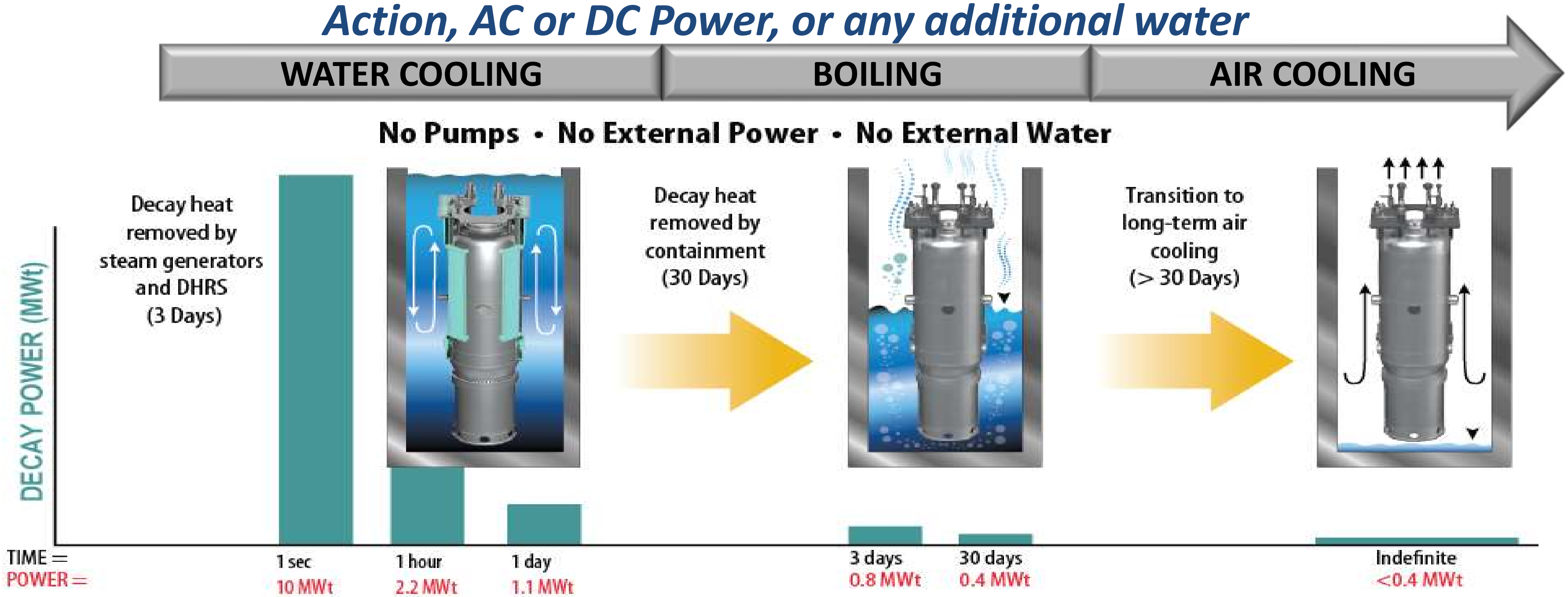
- Only 1 RVV and 1 RRV needed

- Decay heat removed
  - condensing steam on inside surface of containment vessel
  - convection and conduction through liquid and both vessel walls



Triple Crown of Nuclear Safety

Reactor can safely shutdown and self-cool indefinitely with no Operator Action, AC or DC Power, or any additional water



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Current Utility Environment

- Demand is flat to declining
- Customers have changed their electricity use behaviors; more energy efficiency, adjusting to time of day usage
- Gas prices are cheap and expected to stay low
- Regulations are more challenging for both coal and nuclear
- Current policies and incentives are stimulating wide-spread deployment of renewables, affecting grid requirements
- Electricity markets do not currently value many of nuclear energy's favorable attributes (grid stability, carbon-free, highly reliable, many good jobs, stable fuel supply and price)

Biggest Challenge for New Nuclear.....Time

NRC

- Utility COL – 7 to 12 years
- Vendor DC – 8+ years

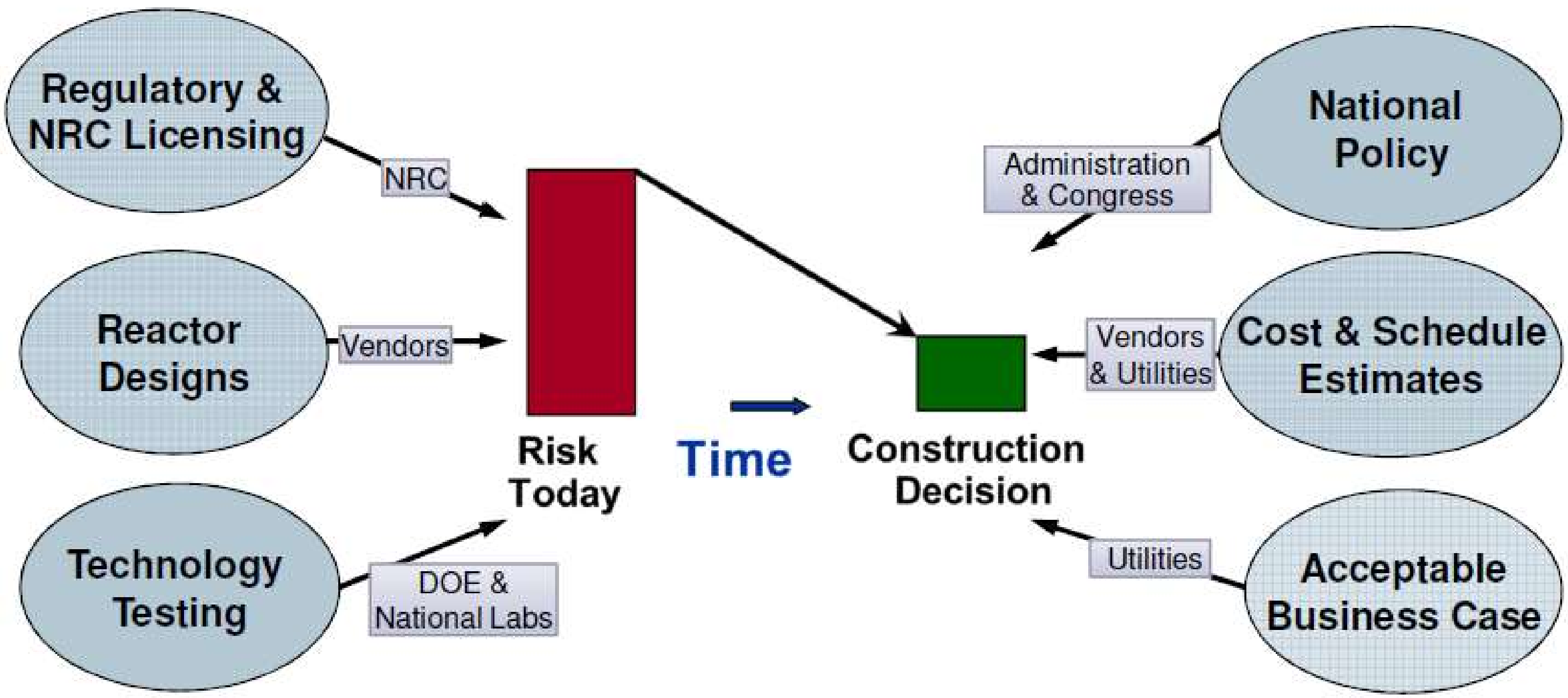
Construction Schedule

- Large – 5 to 11 years
- SMRs – 3 to 5 years
- Other Advanced – ??

The planning horizon for new nuclear generation is 10 – 20 years.

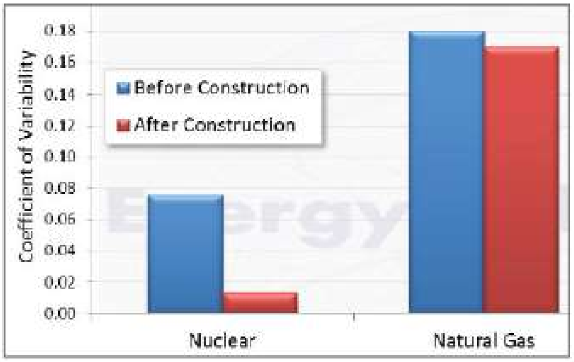
Higher degree of marketplace uncertainty that far out.

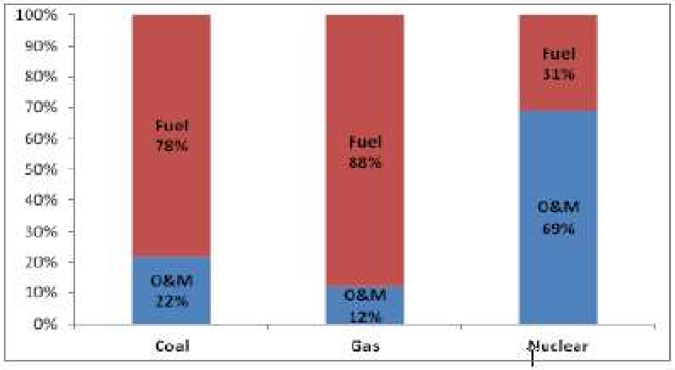
Challenges to an SMR Build Decision



Why Would A Utility Choose Nuclear?

Price Stability





Reliability >90% Capacity Factor Grid Stability Portfolio Diversity

Clean Zero Carbon Emissions

Attractive Features of SMRs

Option for *reliable* and *carbon-free* electricity generation in *affordable* increments!

- Enhanced safety and security
- Lower capital cost capacity additions
- Little or no fuel cycle risk
- More flexibility to meet electricity demand; more distributed and more incremental
- More operational flexibility; load-following and continued operation during loss of off-site power
- Smaller footprint and reduced emergency planning zone lead to more siting options; opportunity to repower coal plants

Work is Underway to Reduce Uncertainties for SMRs

- Maturing designs (NuScale spend >$500M so far)
- Changing regulations (working with NEI to drive NRC)
- Addressing licensing risks in step-wise manner
- Risks analyzed and prioritized
- Sharing risks with DOE and others
- TVA is viewing Clinch River as a demonstration – to reduce uncertainties – to increase viability of option
- Seeking Federal support on Clinch River SMR to keep TVA customer's rates unaffected

Economic Considerations

- Traditional Large Light Water Reactors
  - Average for 2 AP 1000 reactors (Vogtle/Summer) Wikipedia
    - ~ $12B - $14B for 2250 MW
    - ~ 2013: nuclear construction start, 2019 - 2020: forecast completion
- NuScale – current vendor estimate
  - ~ $3B for 570 MW
  - ~ 3 years to construct
- SMR Value Considerations
  - Modular construction
  - Reduced construction period
  - Reduced financing costs
  - Potential for reduced transmission interconnect costs

QA Requirements

- Nuclear Safety Related
  - 10 CFR 50 App B
  - ASME NQA-1 2008/2009
  - 10 CFR 21
  - Nuclear Safety Culture
- Augmented Quality – A quality classification used to identify non-safety related items or services designated that perform functions that are important to safety.

QA – Nuclear Safety Related

- An item/component becomes a Nuclear Safety Related item when it is controlled under a suppliers nuclear QA program that is implemented for design, manufacture, testing, and inspection.
- The process by which a commercial item becomes a Nuclear Safety Related item is known as "Commercial Grade Dedication".

QA – Oversight

- Reactor vendor QA is required to evaluate the supplier’s QA program prior to placing an order.
- Purpose is to evaluate a supplier’s ability to provide items or services in accordance technical and QA requirements.
- Monitoring supper performance through periodic review using annual evaluations, audits, commercial grade surveys, surveillances, and/or the owner acceptance review process.

QA – Lessons Learned from Industry

- Implement improvements in the oversight of suppliers
- Effectively validate procurement (design and testing) requirements including adequate qualification testing.
- Ensure suppliers and sub-suppliers are suitable qualified for and capable of performing the contracted scope.
- Improve the rigor in the development, implementation and assessment of qualification testing to establish or ensure adequate component design.
- Implement a robust Corrective Action Program.

QA – Observations from the Utility

- Not getting quality right the first time is very costly.
- Assign the correct quality requirements to items/components (don’t apply NQA-1 if Commercial Grade Dedication meets requirements).
- Begin the design process with the end quality requirements in mind.
- We are all in this together. Help vendor audit program, utility audit program, and NUPIC audits to be successful and we are all successful.

Summary

- Current market conditions are challenging for new nuclear builds.
- SMR's could provide significant benefits to the nuclear industry.
- Quality Assurance and Control in all phases of the process makes the difference between a project that is successful and one that is not.
- TVA continues their leadership role in SMR development as SMR option remains attractive and continued investment is warranted.