U.S. DEPARTMENT OF ENERGY | Nuclear Energy

Small Modular Reactors
United States Market Perspective

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United States Committed to "*All of the Above*" Clean Energy Strategy

"By 2035, 80% of America's electricity will come from clean energy sources. Some folks want wind and solar. Others want nuclear, clean coal and natural gas. To meet this goal we will need them all."

~2011 State of the Union

"All-of-the-above is not merely a slogan, but a clear-cut pathway to creating jobs and at the same time reducing carbon emissions, which recently stood at their lowest level in 20 years… President Obama has made clear that he sees nuclear energy as part of America's low carbon energy portfolio. And nuclear power is already an important part of the clean energy solution here in the United States."

~Secretary of Energy, Dr. Ernest Moniz at National Press Club, February 19, 2014

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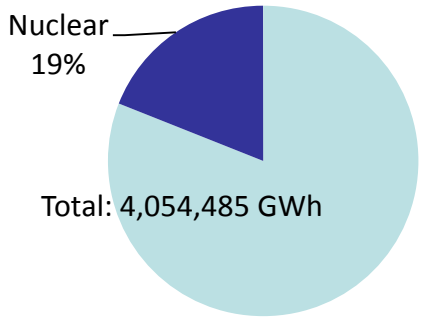
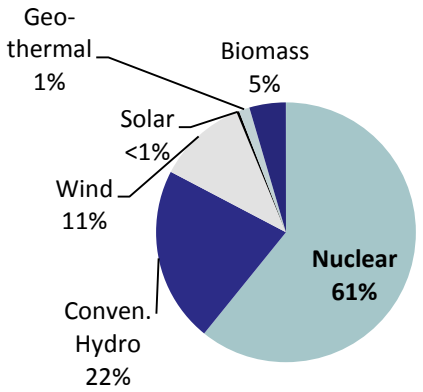
Nuclear Energy Plays an Important Role in US Energy Supply

- **Nuclear power is a clean, reliable base load energy source**
  - Provides 19% of U.S. electricity generation mix
  - Provides 61% of U.S. emission-free electricity
  - Avoids about 700 MMTCO2 each year
  - Helps reduces overall NOx and SOx levels
- **U.S. electricity demand projected to increase ~28% by 2040 from 2011 levels**
- **99 GWe nuclear capacity - 100 operating reactors**
  - Fleet maintaining close to 90% average capacity factors
  - Most expected to apply for license renewal for 60 years of operation

Electricity Production, 2012



Net Non-Carbon Emitting Sources of Electricity, 2012



Source: Energy Information Administration

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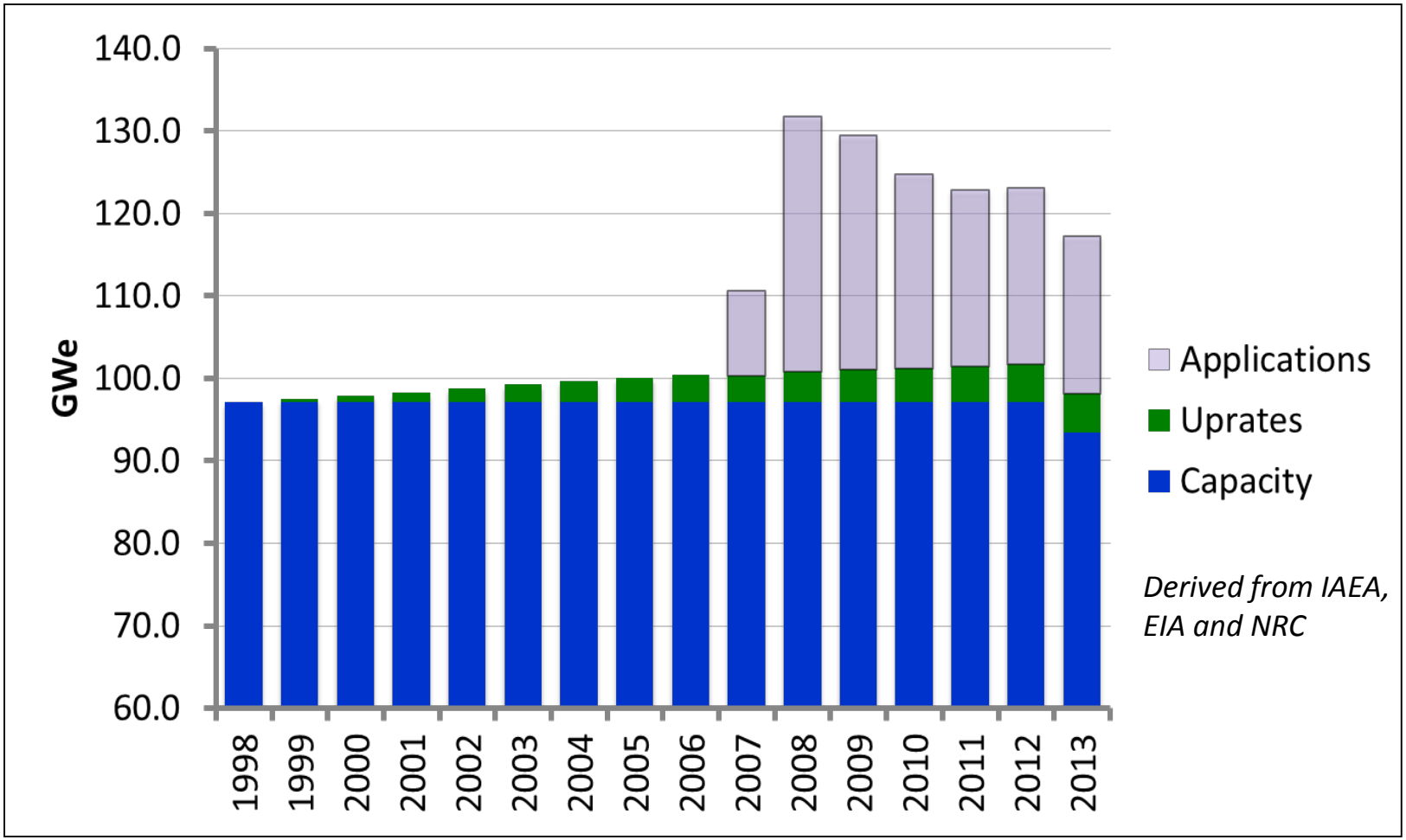
Recent History of U.S. Nuclear Fleet

5 New Reactors under construction



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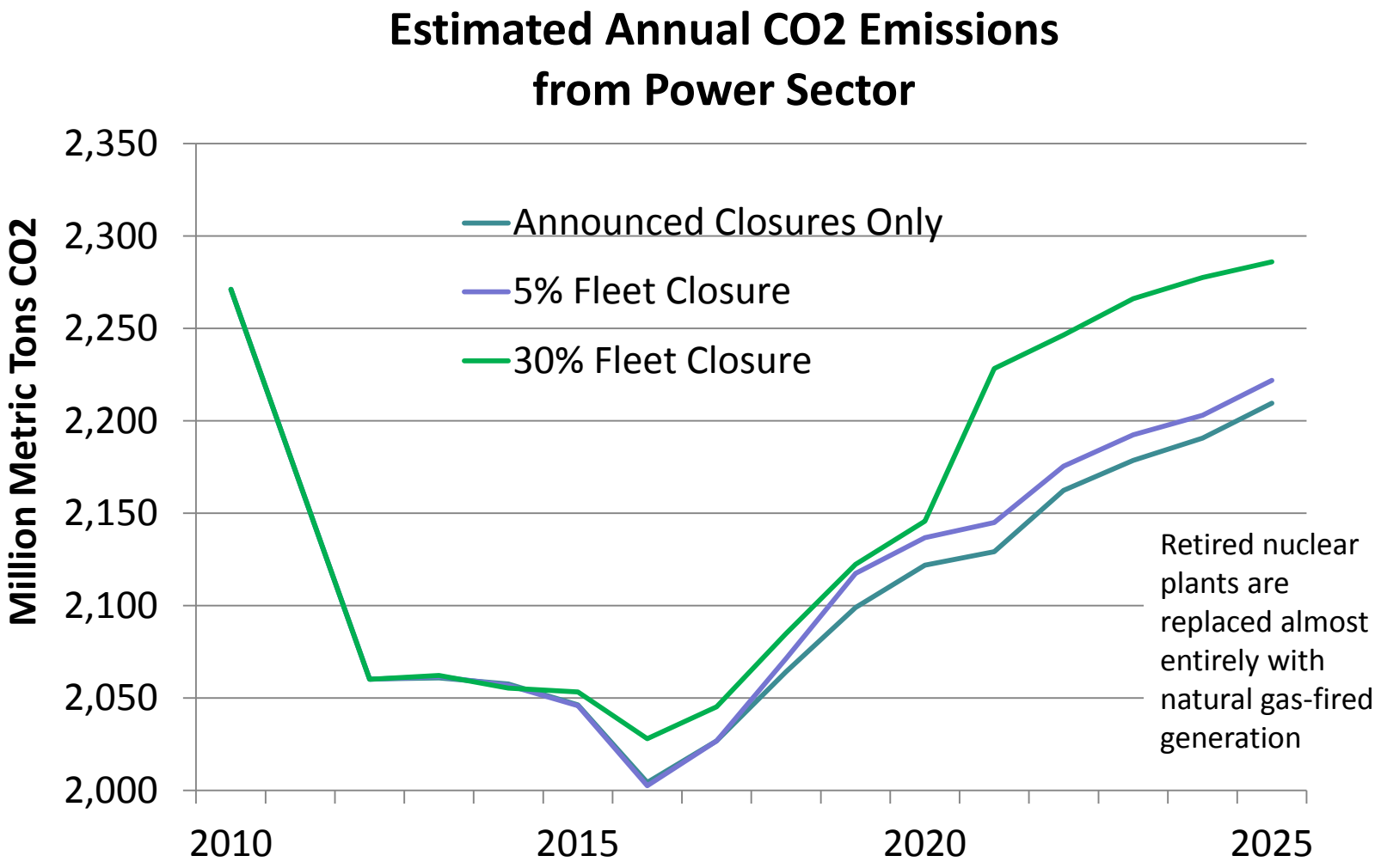
Carbon Implications of Retirements



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President Obama on Cutting Carbon Pollution

"We've got to do more. What we're doing is not enough. And that's why, a couple weeks ago, America proposed new standards to limit the amount of harmful carbon pollution that power plants can dump into the air. And we also have to realize, as hundreds of scientists declared last month, that climate change is no longer a distant threat, but "has moved firmly into the present." That's a quote. In some parts of the country, weather-related disasters like droughts, and fires, and storms, and floods are going to get harsher and they're going to get costlier."

UC Irvine Commencement Ceremony

June 14, 2014

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Role of U.S. Department of Energy for Sustainable and Innovative Nuclear Energy

Conduct Research, Development, and Demonstration to:

- Reduce technical risk
- Reduce financial risk and improve economics
- Reduce regulatory risk
- Used fuel management
- Minimize the risks of nuclear proliferation and terrorism
- Foster international and industry collaboration

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Why is the U.S. Government Interested in Supporting Small Modular Reactor Technologies?

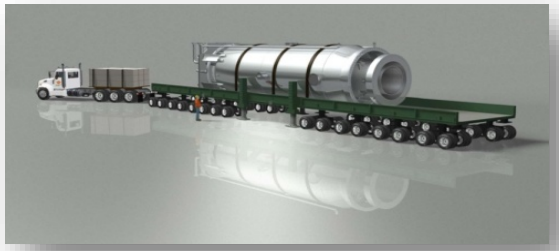
SMRs: reactor units with less than 300 MWe and are able to have large components or modules fabricated remotely and transported to the site for assembly.

Potential Benefits

- Enhanced safety and security
- Reduced capital cost makes nuclear power feasible for more utilities
- Shorter construction schedules due to modular construction
- Improved quality due to replication in factory-setting
- Meets electric demand growth incrementally
- Regain technical leadership and advance innovative reactor technologies and concepts

Potential Markets

- Domestic and international utility markets
- Non-electrical (process heat/desalination) customers



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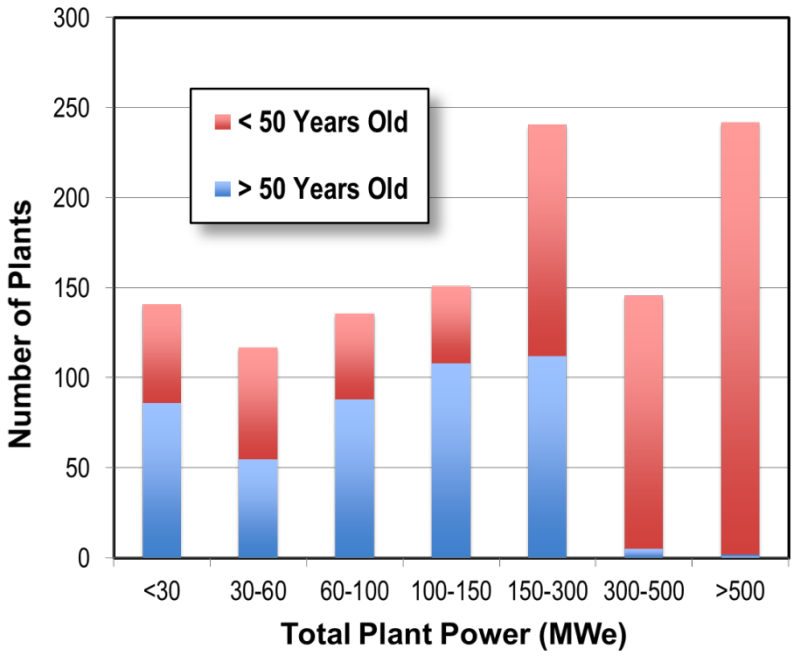
U.S. Utility Considerations

- **Load demand**
  - Better match to power needs - multiple modules
  - Potential replacement of old coal plants
  - Use of existing infrastructure
- **Financial Characteristics**
  - Reduced capital cost makes nuclear power feasible for more utilities
  - Operating units can provide financing for future additional units.
- **Site selection**
  - More siting flexibility than traditional nuclear plants
  - Lower land and water usage

U.S. Coal Plants

99% of plants > 50 years old have less than 300 MWe capacity



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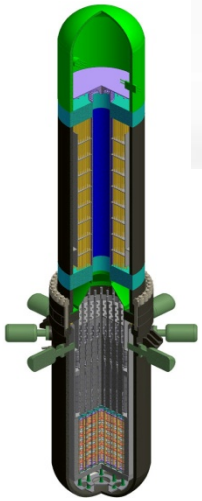
Light Water-Based SMR Designs

- **Well-understood Technology**
  - Uranium oxide fuels
  - Regulatory and operating experience
- **Commercial Interest**
  - At least 4 credible LWR vendors
  - Vendor/Utility coalitions being established
- **Manufacturing industry involved**
  - Could revitalize U.S. nuclear infrastructure and utilize Navy shipbuilding industry
- **U.S. Government as customers for SMR electricity**
  - Private entity constructs, owns, and operates
  - Power purchase agreements with U.S. government agencies


NuScale


Holtec


Westinghouse


MPower

These LW-based designs are considered Integral Pressurized Water Reactor (IPWR) Designs

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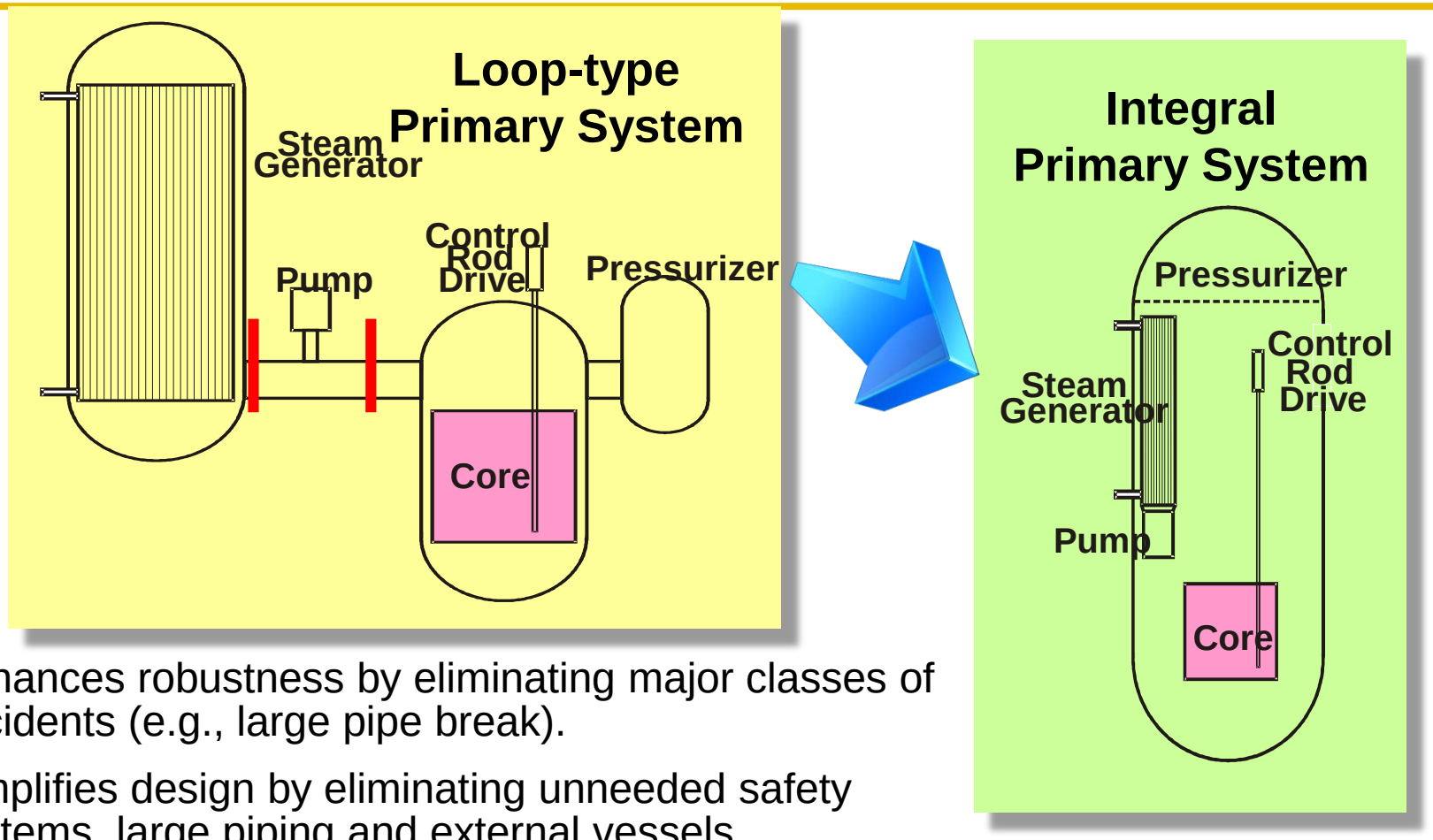
Definition of Integral Pressurized Water Reactor Designs



- Enhances robustness by eliminating major classes of accidents (e.g., large pipe break).
- Simplifies design by eliminating unneeded safety systems, large piping and external vessels.
- Allows for compact containment (small plant footprint) to enhance economics and security.

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Safety and Security Characteristics of Light Water Reactors (LWR) Small Modular Reactor Designs

- **Pressurized Water Reactors (PWR) using Low Enriched Uranium (LEU) fuel** – Established fuel cycle infrastructure
  - Well established non-proliferation attributes
- **Underground Siting**
- **DOE - Funded SMR designs share a common set of design principles to enhance plant safety and robustness**
  - Incorporation of primary system components into a single vessel
  - Passive safety systems
  - Smaller core
  - Increased ratio of water inventory to decay heat for more effective decay heat removal
  - Vessel and component layouts that facilitate natural convection cooling of the core and vessel
  - Below-grade construction of the reactor vessel and spent fuel storage pool for enhanced resistance to seismic events and improved security

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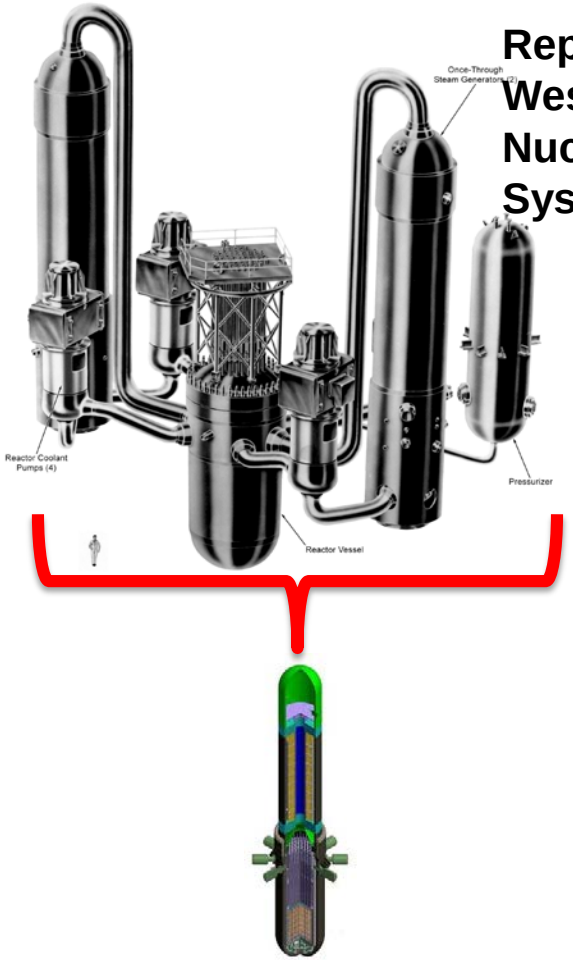
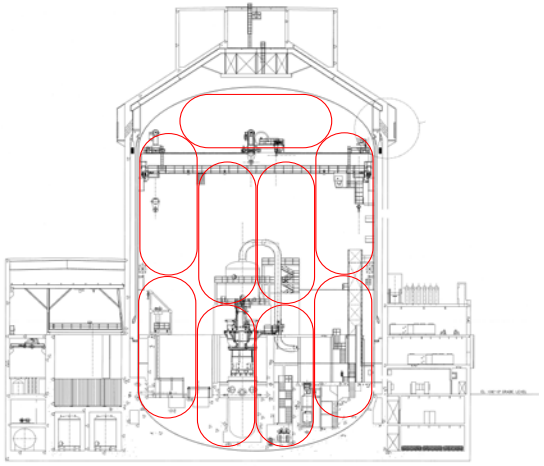
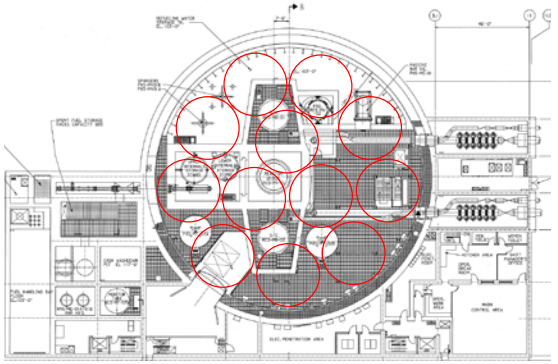
Size Comparison of Conventional Large LWR and SMR



Representative Westinghouse Nuclear Steam Supply System





Westinghouse SMR Integral Nuclear Steam Supply System

25 Westinghouse SMR Containment Vessels fit into single AP1000 Containment Vessel

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Factory Scale Production of SMRs

- **Broad deployment of SMRs may depend on clean energy policies**
- **Output on the order of dozens of SMRs per year by 2040 or sooner based on clean energy policy**
- **Factories established in the U.S. with the potential for future export markets**
- **Sustained factory manufacturing needed to achieve competitive costs**

Obama Administration Blueprint for a Secure Energy Future

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SMR Licensing Technical Support Program

Modeled After NP 2010 Program

- **$1.4B Joint government-industry program to overcome barriers to new reactor deployment**
  - 50-50 cost-share between government and industry

- **Outputs:**
  - Three Early Site Permits (North Anna, Grand Gulf, Clinton)
  - Two Construction and Operating License applications (Vogtle, Fermi)
  - Two Design Certification applications: AP1000, ESBWR

- **Current Status OF AP1000**
  - Four US Plants under construction: Vogtle and Summer
  - Four Chinese plants nearing completion: Sanmen and Haiyang
  - Estimated next phase in China – 26 units
  - Planned for construction in UK by NuGen

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DOE Program to Support SMR Design Certification & Licensing

- **Major challenge for commercialization is completing NRC licensing process**
- **In 2012, DOE initiated the SMR Licensing Technical Support program – Currently a 6 year/$452 M program**
- **Accelerate commercial SMR development through public/private arrangements**
  - Deployment as early as 2022
- **Provide financial assistance for design engineering, testing, certification, and licensing of promising SMR technologies with high likelihood of being deployed at domestic sites**
- **Exploring additional mechanisms for SMR fleet deployment**

The U.S. Government wants to support the safest, most robust SMR designs that minimize the probability of any radioactivity release

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Status of SMR Licensing Technical Support Program

B&W mPower America

- Cooperative Agreement established with team consisting of B&W, Bechtel, and TVA in April 2013
- Initial DOE commitment of $101 M through March 2014
- DOE is working with B&W to establish a path forward for the mPower project

NuScale Power

- Selection of NuScale announced on December 12, 2013
- Cooperative Agreement signed May 27, 2014
- DOE to fund up to $217 M for NuScale SMR development
- DCA submittal currently planned for 2nd half of 2016

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Research, Development & Demonstration Activities Supported under the SMR LTS Program

- **In addition to supporting specific SMR projects, NE is supporting generic activities that can improve SMR commercialization potential**
- **Focus is on the following areas:**
  - User requirements for SMRs
  - Technical analyses to address licensing concerns
  - Economics
  - Market Analysis
- **Efforts being supported by vendors, utilities, the regulator and other stakeholders**
- **Up to 2% of program budget**

We believe that these efforts are yielding cost-effective insights into the commercialization and deployment potential of SMRs

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Conclusion

- **SMRs are needed in our clean energy portfolio and to meet global energy needs and climate change goals**
- **Our SMR program is making a significant impact on accelerating the first movers and building the momentum for the subsequent builds**
- **The Administration is supporting SMRs as having high potential to address many of our domestic clean energy needs**

"The Energy Department is committed to strengthening nuclear energy's continuing important role in America's low carbon future, and new technologies like small modular reactors will help ensure our continued leadership in the safe, secure and efficient use of nuclear power worldwide."

New Investment in Innovative Small Modular Reactor, December 12, 2013

U.S. Secretary of Energy, Dr. Ernest Moniz