Small Modular Reactors

An Overview

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Trend in attitudes about risk and acceptability of nuclear energy in US between 1973 and 2013
Trend in preferred energy sources in US

- Nuclear energy still seen as important energy source in next 20 years, as measured since 2006

![Graph showing trends in energy sources from 2006 to 2013]

- Renewables: 0.0%
- Fossil: +20.7%
- Nuclear: -27.3%
A Small Modular Reactor (SMR) is a nuclear reactor with a nominal power output of 300 MWe of less.

The SMR designation is not dependent on technology:
- Light Water Reactor SMRs
- Advanced SMRs (e.g., molten salt, liquid metal, high-temperature gas, etc.)

SMRs being developed in the US, Korea, Argentina, Russia, etc.
Domestic SMR Interest

- **Value Proposition**
  - Enhanced safety and security
  - Potential for reduced capital cost makes nuclear energy feasible for more utilities
  - Shorter construction schedules due to modular construction
  - Improved quality due to replication in factory-setting
  - Meets electric demand growth incrementally

- **Potential Markets**
  - Replacement/repowering aging or costly fossil plants
  - Air cooling, reduced water usage & reduced BOP acreage expands potential siting options
  - Non-electrical (process heat/desalination) customers
  - Co-location with industrial and district heating applications
  - International markets
“Complexity” Versus “Simplicity”
Small Modular Reactors

Near-Term LWR Designs

- Well Understood Technology
  - LWR based designs
  - Standard <5% UO2 fuel
  - Regulatory & operating experience
  - Planned deployment next decade (2020s)

Longer-Term SMRs

- New Innovative Technologies
  - Mostly non-LWR based designs
  - Deployment 20-25 years

- Broader Applications
  - Process heat applications
  - Transportable/mobile
  - Long-lived cores
Design Features that Improve LWR-based SMR Safety

- LWR SMR designs share a common set of design principles to enhance plant safety and robustness
  - Incorporation of primary system components into a single vessel
  - Smaller decay heat
  - More effective decay heat removal
  - Increased water inventory ratio in the primary reactor vessel
  - Increased pressurizer volume ratio
  - 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
  - Enhanced resistance to seismic events
DOE SMR Program*

- Nuclear power remains a key element of the U.S. energy strategy and portfolio
- Government role – Invest in clean energy
- DOE’s Office of Nuclear Energy is ready to invest resources to address and resolve challenges that confront the U.S. commercial nuclear industry
- Reestablish U.S. technical leadership and innovation domestically and globally

*Source: Presentation by Dr. John Kelly, DOE DAS for Nuclear Reactor Technologies, SMR Conference, April 19-20, 2011
Benefits to the Nation

• Supports energy security, climate change mitigation and economic growth
• Regain technical leadership and innovation
• Improve U.S. manufacturing capability and supply chain infrastructure
• Create high-quality manufacturing, construction and engineering jobs
• Become global leader in SMR technology based on mature nuclear infrastructure and NRC certified designs
DOE NE’s Office of Advanced Reactor Concepts
Small Modular Reactor Program

DOE Small Modular Reactor Program

• Enable the deployment of a fleet of SMRs in the United States
• Structured to address the need to accelerate the deployment of mature SMR designs based on LWR technology
• Conduct needed R&D activities to advance the understanding and demonstration of innovative reactor technologies and concepts

SMR Program Elements

• Cost-shared Industry Partnership for SMRs
  ▪ Public-Private Partnerships for design certification & licensing activities
• SMR Advanced Concepts RD&D
  ▪ Conduct R&D on innovative technologies/systems/components and support generic licensing work
  ▪ Support nuclear codes & standards development activities
  ▪ Collaborate with NRC on SMR licensing framework to support SMR commercialization
SMR Activities at SNL

- Support of NuScale Power LLC under DOE NE’s Industrial Partnership for SMRs
- iPWR Containment Aerosol Deposition Behavior for the Electric Power Research Institute
- SMR Security Analysis for DOE NE
Support for NuScale Power

- Under the DOE NE’s Industry Partnership SMR Program, SNL is supporting NuScale Power by performing key analyses as well as safety code development activities that NuScale may use in its design certification application to the US Nuclear Regulatory Commission
  - Spent Fuel Pool Accident Assessment
  - Enhancing MELCOR code
Propose to measure enhanced aerosol removal from containment atmospheres due to higher deposition surface area/containment volume, and particle removal by high steam concentration gradients.
Surtsey Facility: Large Sealed Pressure Vessel for Studying Containment Atmospheric Processes

- 100 m³ ASME Steel Pressure Vessel
- 1 MPa Working Pressure
- Insulated - Prototypic Steam/Air/H₂ Atmosphere
- Realistic Scaled Containment Structures
- Removable Upper/Lower Heads
- Instrumentation Ports At Six Levels
- High Volume Gas and Steam Supply Systems
- Flexible Data Acquisition and Control
SMR Security Analysis

• SMRs face regulatory and economic challenges in how to apply security to a smaller facility while keeping overall plant costs manageable.

• Increasing security threats lead to high protection costs for nuclear facilities, and commercial facilities need new approaches for optimizing cost.

• The overall goal of this work is to evaluate alternative methodologies for Proliferation and Terrorism Risk Assessment to guide design.

• We are applying the RIMES (Risk-Informed Management of Enterprise Security) methodology for sabotage and terrorism threats to nuclear facilities, using Small Modular Reactors (SMRs) as an example application.
Assessing Security Risk

- Traditional risk is based on a scenario’s likelihood and consequence, but to use this for security, one must either
  - Assess the probability of an attack that has never occurred before (highly uncertain, and can change in an instant), or
  - Limit the adversary (e.g., with a design basis threat) and assess the conditional probability that this adversary will succeed if they attempt this attack scenario (neglects deterrence of the adversary and makes both risk aggregation and defender cost-benefit analysis difficult)
- The RIMES methodology instead focuses on the degree of difficulty for an adversary to successfully accomplish an attack:

  Attack scenarios that are both easier and higher consequence are of greater risk. Focus security investments on these “high-risk” scenarios.