Westinghouse Small Modular Reactor: Taking Proven Technology to the Next Level

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Westinghouse SMR - Market Overview

Market Informed Sizing – 225MWe

• Some market observations that contributed:
  – Incremental base load additions typically range from 200 to 300 MWe - based on coal and combined cycle natural gas units
  – Greenhouse gas emissions reductions such as coal retirements average 150 to 250 MWe - based on actual shutdowns and recent public announcements

• Allows Use of Existing Infrastructure of Non-Nuclear Stations - Nuclear Option for Non-Nuclear Companies

• Provides Option for Small Underserved Markets

♦ Aging Fossil Plants
♦ District Heating
♦ Remote Markets

♦ Small Grid Markets
♦ Desalinization
♦ Process Heat
## SMR Product Specification

### Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Thermal Output</strong></td>
<td>800 MWt</td>
</tr>
<tr>
<td><strong>Electrical Output</strong></td>
<td>&gt;225 MWe</td>
</tr>
<tr>
<td><strong>Passive Safety Systems</strong></td>
<td>No operator intervention required for 7 days</td>
</tr>
<tr>
<td><strong>Core Design</strong></td>
<td>17x17 Robust Fuel Assembly</td>
</tr>
<tr>
<td></td>
<td>8.0 ft / 2.4 m Active Length</td>
</tr>
<tr>
<td></td>
<td>&lt; 5% Enriched U235</td>
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<tr>
<td></td>
<td>89 Assemblies</td>
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<tr>
<td></td>
<td>Soluble Boron and 37 Internal CRDMs</td>
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<tr>
<td></td>
<td>24 month refueling cycle</td>
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<tr>
<td><strong>Reactor Vessel Size</strong></td>
<td>Outer Diameter: 11.5 ft / 3.5 m</td>
</tr>
<tr>
<td></td>
<td>Height: 81 ft / 24.7 m</td>
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<tr>
<td><strong>Upper Vessel Package</strong></td>
<td>280 Tons</td>
</tr>
<tr>
<td><strong>Containment Vessel Size</strong></td>
<td>Outer Diameter: 32 ft / 9.7 m</td>
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<tr>
<td></td>
<td>Height: 89 ft / 27.1 m</td>
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<tr>
<td></td>
<td>Fully Modular Construction</td>
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<tr>
<td><strong>Reactor Coolant Pumps</strong></td>
<td>8 External, Horizontally-Mounted Pumps</td>
</tr>
<tr>
<td></td>
<td>Sealless Configuration</td>
</tr>
<tr>
<td><strong>Steam Generator</strong></td>
<td>Recirculating, Once-Through, Straight Tube</td>
</tr>
<tr>
<td><strong>Pressurizer</strong></td>
<td>Integral to Vessel</td>
</tr>
<tr>
<td><strong>Instrumentation and Control</strong></td>
<td>OVATION®-based Digital Control System</td>
</tr>
</tbody>
</table>
What It Is...

- An integral PWR
- Innovative packaging of proven components
- The highest levels of safety with fewer accident scenarios
- Industry-proven equipment designs
- Compact reactor coolant system and containment
- An engineered solution for today’s clean energy challenges

...Simplicity in Design
SMR Fuel Design: Proven Features, Ease of Licensing

- **Top Mounted Core Instrumentation**
- **Inconel Top Grid**
  - RFA2 Mid-Grid
    - Enhanced strength
    - Enhanced fretting margin
    - ZIRLO® grid
  - Opt. ZIRLO® Cladding
- **RFA2 Mid-Grid**
- **IFBA, ZrB₂ Integral Fuel Burnable Absorber**
- **Inconel Bottom Grid**
- **Oxide Coated Cladding**
- **Low Profile Debris Filter Bottom Nozzle (LP DFBN)**
- **XL Westinghouse Integral Nozzle (WIN)**
  - No potential for loose parts
  - One piece casting
- **Skeleton structure**
  - Enhanced dimensional stability
  - ZIRLO® thimble tubes
  - Thick thimble tubes
  - Tube-in-tube dashpot design
  - Anti-bowing design prevents IRI
- **Intermediate Flow Mixing (IFM) Grids**
  - Heat transfer enhancement
  - Structural capability
  - Enhanced outer strap
- **Stand-off Piece/Bottom Plenum**
- **Protective Grid (P-Grid)**

**Partial-height design incorporating AP1000® technology**
Westinghouse SMR Reactor Vessel Internals

- Design driven by interfaces
  - Steam generator
  - Coolant pumps
  - Reactor vessel
- Utilize AP1000® component designs – e.g. guide tubes, support plates and columns, flow skirt, vortex suppression, etc.

![Diagram of Westinghouse SMR Reactor Vessel Internals]

- Transition Cone
- CRDMs
- Upper Support Plate
- Upper Core Plate
- Lower Support Plate
- Secondary Core Support
- Guide Tubes
- Fuel
- Core Barrel
Integral CRDM Design

- Latch assemblies, controls, and interfaces with fuel are all based on existing, proven designs
- Three-coil magnetic jack based AP1000® design with modifications
  - *High-temperature* coil winding design
  - Sealed, stainless steel coil stack housing
  - Sealed power conduit with leak detection
- Test program initiated
Recirculating Steam Generator

- **Straight-tube steam generator**
  - Flow from top to bottom of tubes
- **Hot leg located in center of tube bundle**
  - Transfers hot water to the upper tube sheet
- **Main steam and two feedwater piping connections**
- **Recirculating steam generator with steam/water mixture delivered to steam drum outside containment**
SMR Reactor Coolant Pumps

- Eight reactor coolant pumps providing 12,500 gpm at 100 ft of head (no seal injection)
- Each motor ~350 hp
  - (460 V, 3 phase)
- Total flow 100,000 gpm
- Driven with 2 variable frequency drives (VFD)
- Mount horizontally through pressure boundary below closure flange
SMR Containment Vessel

- Compact containment
  - High pressure
- Size 32-ft diameter and approximately 89-ft height
- Target is to operate containment at vacuum to:
  - Increase heat transfer inside containment
  - Reduce insulation needs
  - Reduce challenge of containment overpressure
- Water cooled on outside of containment
  - Annulus flooded
- In vessel retention accomplished by draining tanks of water to flood lower reactor vessel
Simplification: Smaller Footprint

Evolutionary PWR

AP1000
How Small is Small?

25 Westinghouse SMR Containment Vessels fit in a single AP1000® Containment Vessel
SMR Plant Layout

- Annex Building
- Turbine Building
- Grade
- Maintenance Hall
- Nuclear Island – Above grade
- Reactor
- Containment
- Nuclear Island – Below grade
Advance Passive Safety

• 100% reliance on natural forces
  – gravity, evaporation, condensation
• Simplicity is fewer pumps, fewer valves, less cable, less human reliance
• Already meeting challenges to address post-Fukushima issues
SMR Safety Overview
Westinghouse SMR - Safety

• 7 Days of Passive Heat Removal with Onsite Inventory
  – Capability to add additional inventory to Ultimate Heat Sink tanks for indefinite cooling

• 100% reliance on natural forces
  – evaporation, condensation, gravity

• Reactor Control
  – Rod Cluster Control Rods
    – Unlatch, Fall under Gravity
  – Diverse shutdown
    – Core Makeup Tanks Gravity-Inject Highly Borated Water

• Based on licensed AP1000 technology
The Westinghouse SMR
Fully Modular and Transportable

• Leveraging experience from established supply base
• Working within existing transportation network
• Maximizing ease of logistics
• Modular design and standardization
• Factory fabricated, installed on site
• 18 months construction time
What We’re Doing...

• Westinghouse expertise mobilized
  – Dedicated, company-wide development team
  – Support from experienced expert groups
• Westinghouse Regional Organizations are Coordinating Potential Opportunities with Global Customers and Partners
• Extending customer relationships to SMR development
• Testing critical-to-licensing areas of development – internal CRDMs

The Westinghouse SMR Design Certification Document is on-schedule for NRC submittal in 2012