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SMR-160: An Unconditionally Safe, Certain and Cost-Competitive Advanced Light Water Reactor to Meet the 21st Century's Growing Green Energy Needs

HOLTEC INTERNATIONAL

SMR

March 01, 2022
Holtec International

TOPICS to consider

- Why new nuclear, SMRs?
- Are they, or can they ever be ‘affordable’
- What really is so compelling about new nuclear, and what makes this time different than previous ‘nuclear renaissances?
- LWR-SMRs vs ARs?
- Fuel – new fuel, spent fuel, issues and opportunities
- Anything else you want to talk about …

SMR-160 started over 10 years ago … a natural progression for Holtec's technology portfolio

Heat Transfer Equipment

Designer and manufacturer of heat transfer equipment with projects in over 35 countries

Horizontal Steam Generator

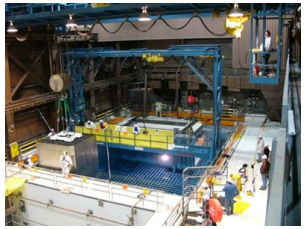
Air Cooled Condensers

NSSS and BOP Equipment Design

Spent Fuel and Waste Management

Over 40% of the world's commercial spent nuclear fuel is stored using Holtec's technologies

Nuclear Fuel Storage and Transport



High Capacity Fuel Storage Racks

Fuel Design and Management Expertise

SMR-160 (160 MWe)

Develop and Deliver walk-away-safe small modular reactor with passive safety

Manufacturing, Construction, Site Services

Three US Manufacturing Facilities and International Site Construction and Site Services Business

Holtec's Advanced Manufacturing Division

Holtec's Site Services and Site Construction

Design Input from Manufacturing, Construction, Site Experience

Safe, Efficient and Compliant Decommissioning

Owner and Licensee of Pilgrim, Oyster Creek, Indian Point 1-3 with 8-year decommissioning plans and Palisades acquisition pending in 2022

Part 50 License Holder, Public Engagement, Security Services, Waste, NPP Operations

SMR 160 Program

- **Holtec has been developing the SMR-160 at our own cost for 10 years**
  - Reactor and Plant developed in accord w 10CFR-50 regs and criteria, US design and construction codes
  - Large program now w large team and partners

- **U.S. DOE Grant for Integral & Separate Effects T/H Testing (ISET) Program Validating Passive Safety Systems with INL Award**
  - 4-phase, multi-year program with collaboration from Idaho National Labs (INL) in ARDP

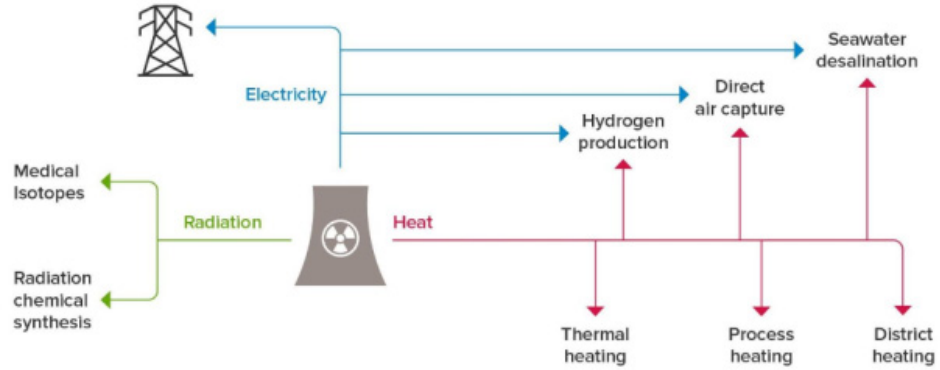
- **U.S. DOE Advanced Reactor Demonstration Program (ARDP) Risk Reduction Pathway Award (2020)**
  - $147.5M cost-share Program fully allocated by Congress for entire 4-year Program
  - including Integral & Separate Effects T/H Testing (ISET) Program with Completion of the Preliminary Safety Analysis Report (PSAR)

- **Detailed Design and Construction specification for USA w EPC Partners Kiewit and Hyundai Engineering & Constrcution**
  - Developing standard plant engineering design – shovel-ready EPC spec – in parallel w ARDP

SMR-160 Applications and Operations Modes

Applications

- Electricity Generation: 160 MWe Net
- Industrial Process Heat & Hydrogen Production
  - ✔ Bypass conditions determined by application
  - ✔ The standard SMR-160 plant produces 1,674,000 lb/hr of superheated steam at 700 psia and 590°F (88°F superheat)
  - ✔ Eliminates need for load following where steam or hydrogen production applications are profitable



Base load, high Capacity Factor w Operational Flexibility

- Able to be operated in Island Mode, enabled by self-powering house loads
- Black-Start-capable, enabled by standby diesel generators and black-start source (base electrical design, source add-on)
- Load Following Capability, enabled by BOP Design and turbine selection

Key Attributes of SMR-160

- Design makes Loss Of Cooling Accident non-credible; consequences of any event well below regulatory limits at fence-line
- Highly automated and inherently safe, w a minimal staff and no operator actions required for design basis events
- Sabotage resistant – minimal security staffing required
- Only EQ-ed parts and materials, qualified fuel system, supplied off-the-shelf

SMR-160 in Single-Unit Configuration

Plant Performance Parameters

Parameter	Value	Parameter	Value
Technology developer	Holtec International	**Configuration of RCS**	Integral type with offset SG
Country of origin	USA	**Power conversion process**	Indirect Rankine cycle
Reactor type	PWR	**Fuel type/assembly array**	UO_2 / rectangular array
Electrical (net) capacity	160 MWe	**Fuel assembly active length**	12.0 ft
Thermal capacity	525 MWth	**Number of fuel assemblies**	57
Capacity factor	≥ 95%	**Fuel Lattice**	17 x 17
Design life	80 years	**Average fuel enrichment**	4.5 wt% U-235
Coolant/moderator	Light water	**Maximum fuel enrichment**	5 wt% U-235
Primary circulation	Gravity-driven	**Average Fuel burnup**	50 GWd/MTU
System pressure	2250 psia	**Fuel cycle**	24 months (flexible)
Core inlet/exit	466.3/610.8 °F	**No. of CRAs**	25
Reactivity control	Soluble boron and RCCAs	**Cogeneration capability**	Capable
RPV height	49 ft	**Engineered safety systems**	Passive
RPV diameter	9.5 ft	**Number of safety trains**	2
RPV or module weight	200 metric tons	**Refueling outage**	10 days

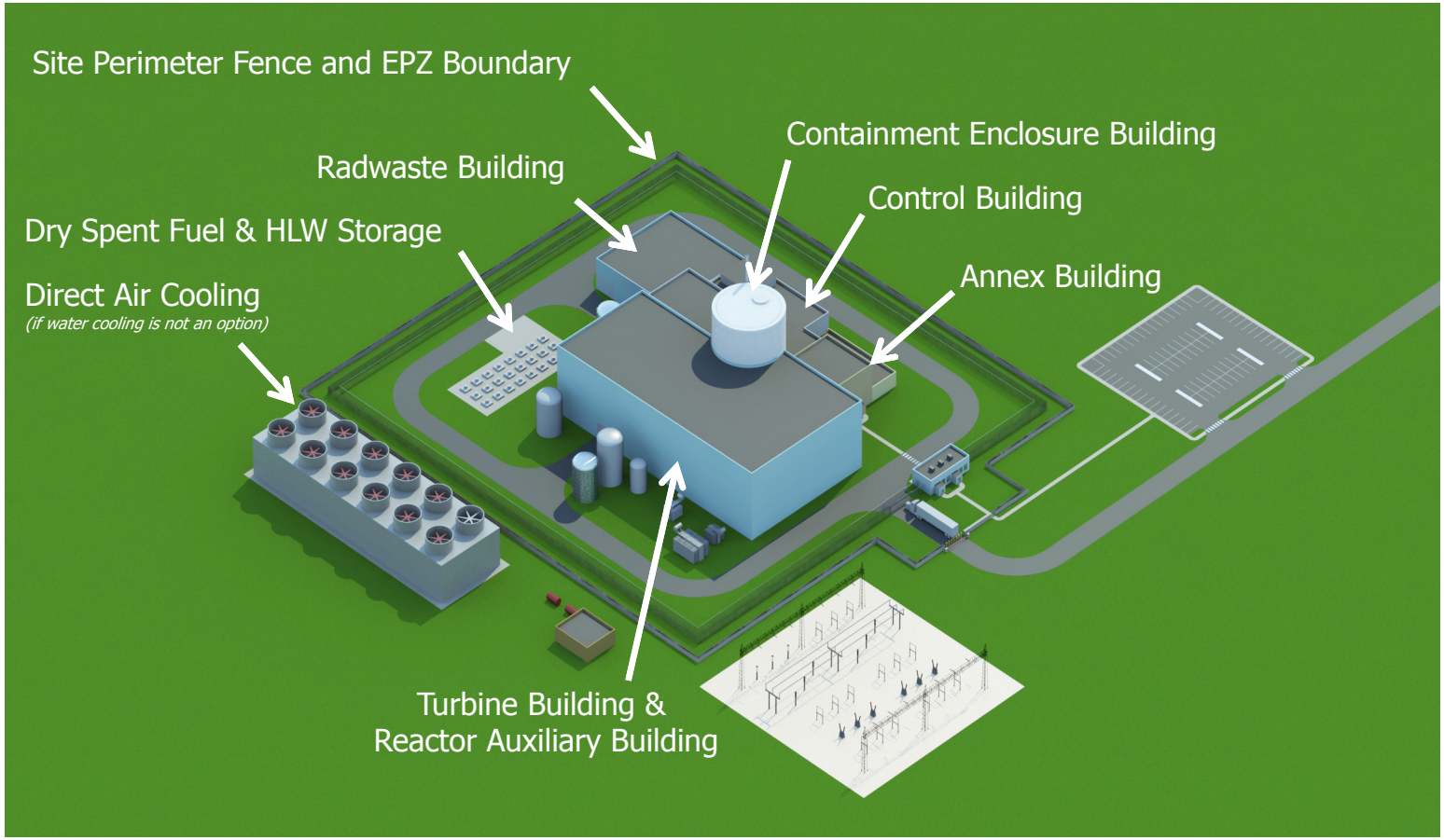
Plant operating temperatures and pressures all within the envelope of existing LWR technologies…

Each SMR-160 Plant is Compact and Autonomous

Land Use

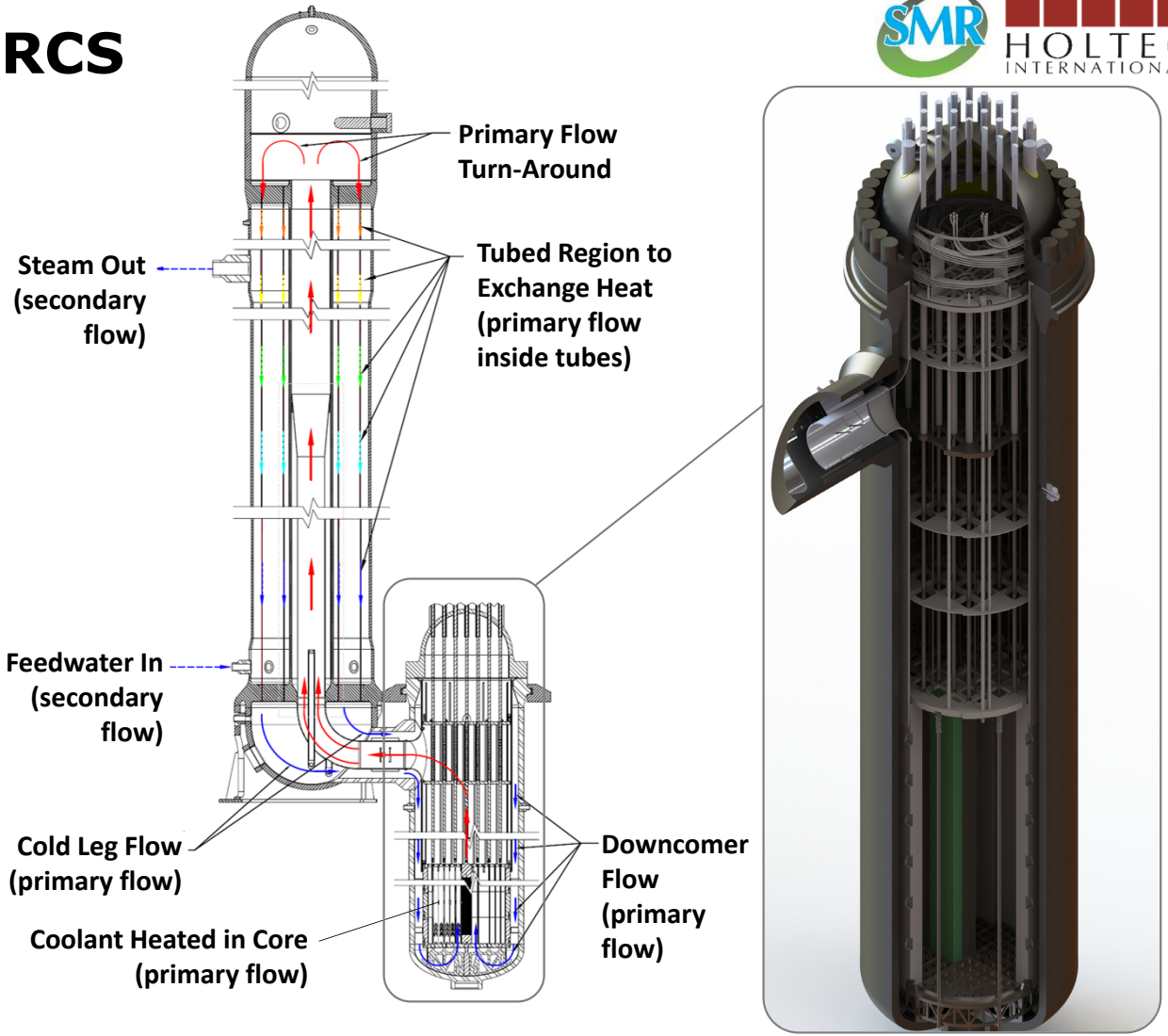
- Single Unit: 5 acre [2 hectare]
- Four-Unit Block: 16 acre [6.5 hectare]

EPZ Boundary = Site Boundary



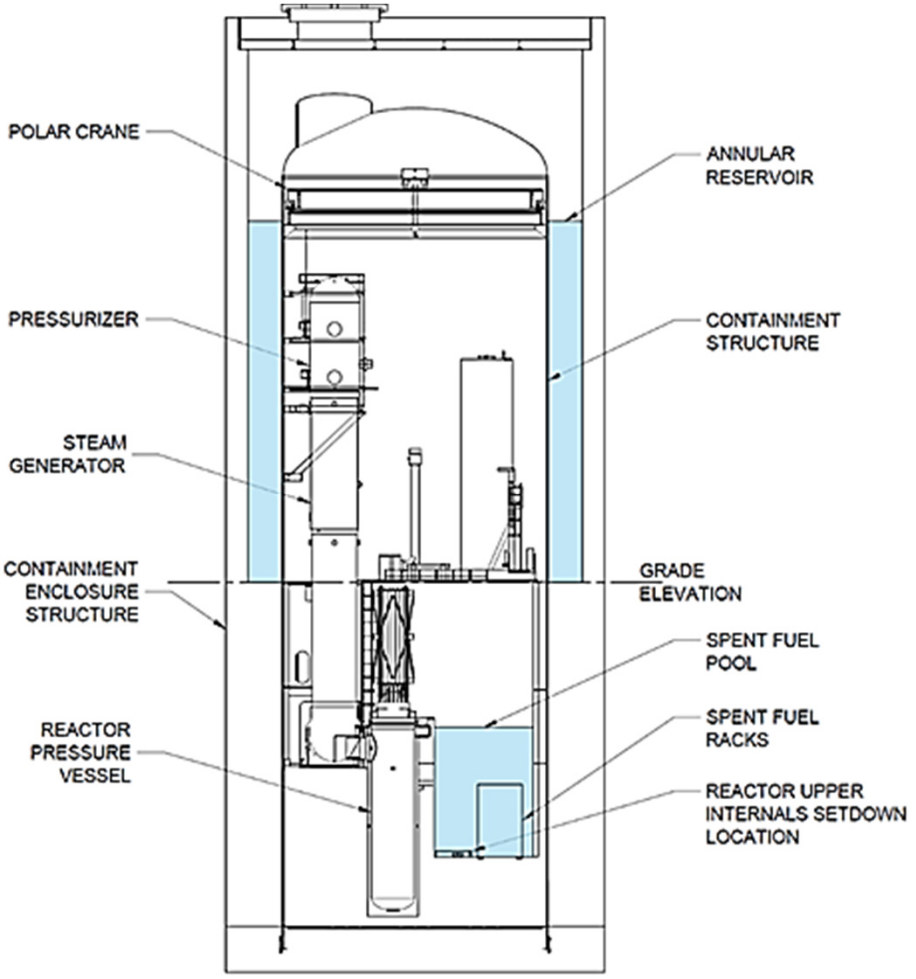
Innovative features in RCS

- Integral PWR design
- Offset SG for easy refueling
- Once-Through Steam Generator produces superheated steam
- Large Pressurizer volume simplifies operations (no charging or letdown during power maneuvers)
- Water volume to power ratio ~4x larger than traditional PWRs
- Large heat removal buffer for postulated transients due to large steam generator shell-side volume (with secondary flow outside tubes)



Essential Design Features of SMR-160

- Standard PWR Core Configuration and Fuel Design
- NSSS, Safety Systems, and Spent Fuel Pool are inside and protected within Containment Structure
- Reactor and Fuel Pool located below grade
- Containment Enclosure Structure is thick steel-concrete-steel structure, ultimate heat sink and resistant to accidents and sabotage
- Natural circulation for primary circuit and safety systems – for assured heat removal for plant all modes and states
- Containment Enclosure Structure and Annular Reservoir act as large heat exchanger during a LOCA to safely cool the containment, passively rejecting the reactor and spent fuel heat to the atmosphere for an indefinite period

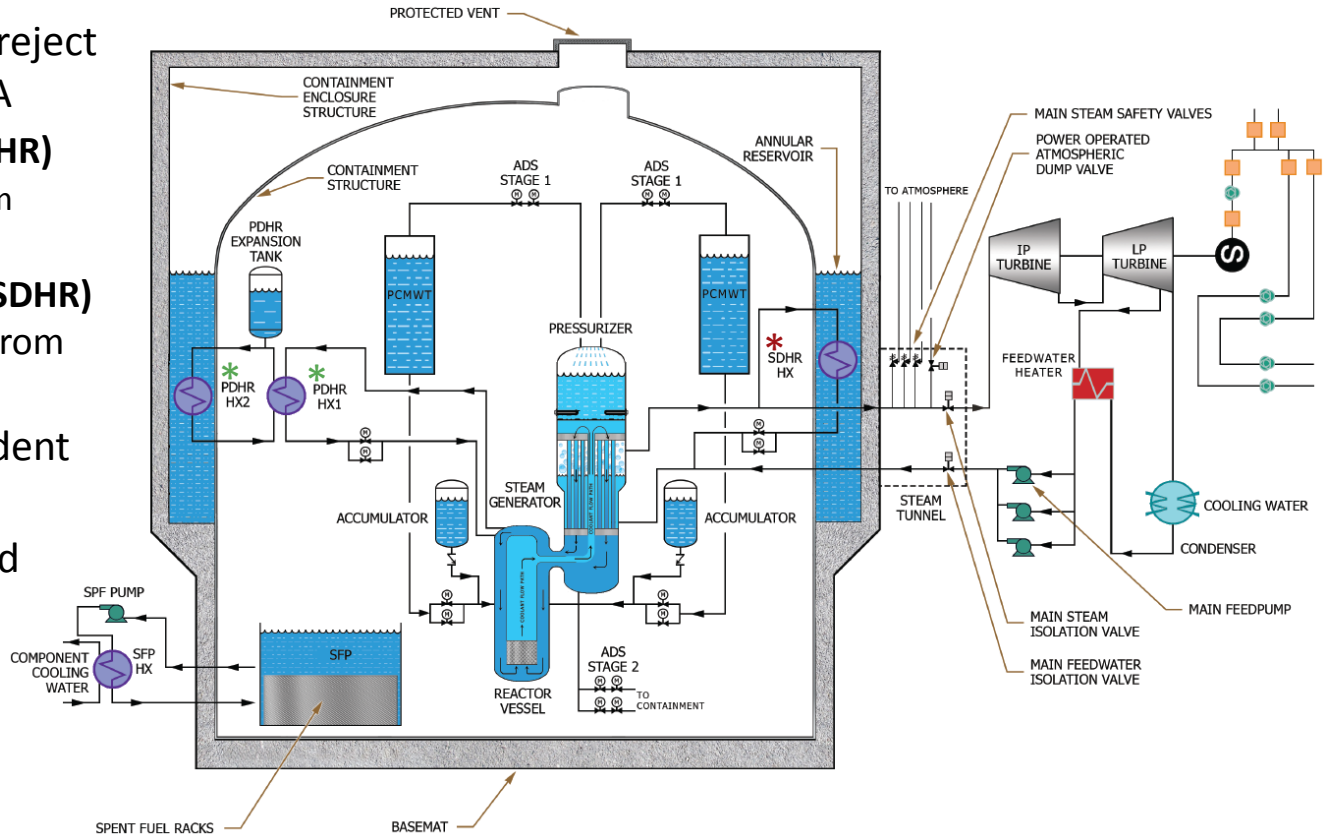


SMR-160 Containment Enclosure Structure and Internals

Essential Design Features of SMR-160

Passive Engineered Safety Systems

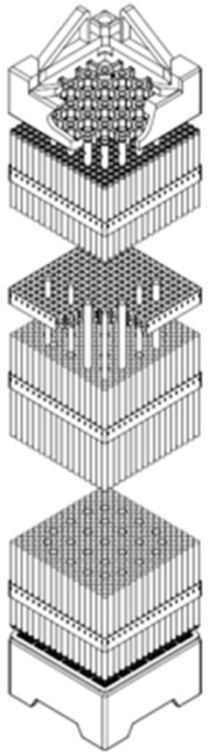
- Redundant and diverse pathways to reject heat in the case of a postulated LOCA
  - ✔ **Primary Decay Heat Removal (PDHR) System -** Removes heat passively from reactor vessel
  - ✔ **Secondary Decay Heat Removal (SDHR) System -** Removes heat passively from steam generator
- No operator action required for accident mitigation ("walk-away safe")
- Exploits gravity-driven convective and conductive heat transfer modes to provide an unlimited post-accident coping period
- Uses only proven materials

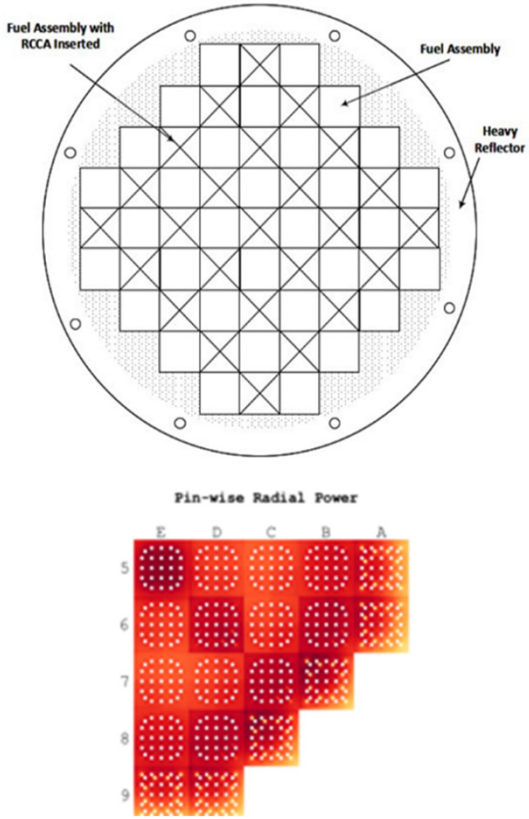


"Elegant Design" according to multiple client comments

SMR-160 uses widely used fuel design to give the owner choice of multiple vendors

- **Proven fuel design**
  - ✓ 57 Assemblies
  - ✓ 17x17 GAIA fuel assemblies
  - ✓ Known materials, available now
- **Design Parameters**
  - ✓ 24-month cycle, burnup ~50 GWd/MTU
  - ✓ 25 RCCAs
  - ✓ Boron for fine reactivity control
  - ✓ Heavy reflector
  - ✓ Gd_2O_3 used as integral poison
  - ✓ Max weight % U-235 < 5%
- **Safe** - Negative reactivity coefficients, large shutdown margin, large margin against departure from nucleate boiling





SMR-160 Fuel Assembly and Reactor Core Configuration

- 17x17 GAIA Bundle
- Standard Fuel Length

SMR-160 Licensing Plan for the USA

- Designed according to **current** US Regulations and Guidance Documents
  - 10 CFR Part 50 Appendix A General Design Criteria
  - NUREG-0800 for Format and Content of Safety Analysis Report
  - Other regulatory guidance documents
- International regulatory requirements and guidance are evaluated and incorporated into the design
- Operating experience and manufacturing experience incorporated into the design
- Follow the 10 CFR Part 50 Two-Part application process – PSAR & CPA

SMR-160 status and actions

- Detailed design is proceeding, along with methods V&V, and long-lead subcontract engineering programs
- Licensing commitments are being codified in a Preliminary Safety Analysis Report to support a construction permit
- Pre-licensing engagements with NRC ongoing
- Developing anchor project(s) in USA, India and Middle East
- Establishing fabrication, supply chain, and licensing certainty for global deployments
  - ✓ Securing major partners through strategic agreements
  - ✓ Establishing relationships with commercial suppliers
  - ✓ Selecting off-the-shelf components to minimize R&D
  - ✓ Identifying localization opportunities to ensure a cost competitive offering

Holtec's SMR-160

Simple **M**odular **A**dvanced **R**eactor **T**echnology

A Safe and Secure Source of Carbon-Free Energy Positioned to Fulfill the World's Energy Needs

Safe and Secure

Reliable and Efficient

Environmentally Friendly

Low Operation and Maintenance Costs

Thank you!