# Westinghouse Nuclear Technology: Helping Deliver the Nuclear Promise

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**October 2017**
**INAC 2017**
**Belo Horizonte, Brazil**

# Westinghouse Nuclear Technology: Helping Deliver the Nuclear Promise

**Westinghouse Overview**

What are we doing today

**Driving towards the Nuclear Promise**

Global Products & Services

**Global AP1000 ™ Plant Projects Update**

From Construction to Testing to Operation

**Innovation for the Future**

Leading the development of the future technologies for the nuclear sector

**Leveraging 130+ Years of Technology Heritage**

Westinghouse

# Westinghouse Electric Company
# 130+ Years of Innovation

- **Global Products and Services (GPS)**
  - **Consolidation of the company's global business operations:**
    - **Nuclear Fuel**
    - **Global Components & Manufacturing**
    - **Global Engineering Services**
    - **Technology Office**
    - **Global I&C**
    - **Global Field Services & Plant Modifications**
    - **Global Decommissioning, Decontamination, Remediation & Waste Management**
    - **Global Project Management Office**
    - **Global Regulatory Affairs**
- **New Projects Business**
  - **Westinghouse Government Services**
  - **New Plant Projects**

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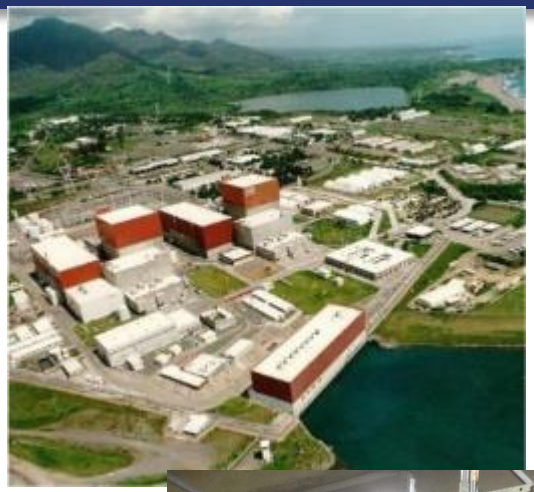
# Westinghouse is Actively Present in all Nuclear Markets in Latin America

**Argentina**

- Atucha 1 inspection equipment
- Embalse Life Extension Program
- INVAP Engagement

**Brazil**

- Angra 1 OEM Services, I&C Modernization
- Angra 2 Inspection Services
- INB Fuel Technology Transfer

**Mexico**

- Laguna Verde 1 and 2 Outage Support
- Steam Dryer Services
- SFPIS, etc.

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# Internship Process

- Brazilian Mobility Program - Science Without Borders-2014
- Pennsylvania State University & UFRJ Alignment
- Summer Internship at Westinghouse Headquarters


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# Interning at Westinghouse is not only just about the technical projects.

- Orientation day
- Mentoring relationship
- Breakfast with the CEO
- Intern competition within the Core Engineering group
- Wrap-up
- Barbecue with the Young Generation group from Pittsburgh

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# June 2016 – We got hired!

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# Alice's Worklife at Westinghouse

- Thermal Hydraulics Design
  - Important Specific Subjects: Thermodynamics, Heat Transfer I and II, Reactor Engineering....
- Qualification
  - Learning the codes
    - VIPRE-W, BYPASS, KSBOIL, THINC...
  - Weekly Video Conferences
  - Pass the board to be qualified
- Perform Thermal Hydraulics Reload Calculation
  - Examples: Calculate DNBR in a accident situation to check if the limit is still meet; Calculate CORE Limits to define the trip setpoints
- Assigned a Customer to provide technical support
  - Indian Point Units 2 and 3
- Visit to Westinghouse sites
- Support Westinghouse Latin America Operations
  - Business Development
- Active Participation in Professional Associations
  - ABEN, LAS, WIN, YGN

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# Fuel Manufactured Products

## Pressurized Water Reactors (PWRs)

### W-PWR

14x14
15x15
16x16
17x17
AP1000

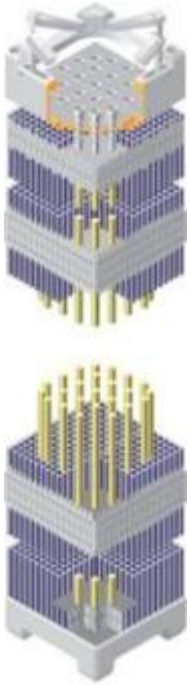
### CE-PWR

14x14
16x16

### KWU/Siemens PWR

14x14
16x16
18x18

### NFI PWR



14x14
15x15
17x17
MOX

## Boiling Water Reactors (BWRs)

### W-BWR

Optima2
Optima3

### NFI BWR

9x9
MOX

## VVER (PWR)

VVER-1000
VVER-440

## Advanced Gas Reactors (AGRs)

AGR Fuel

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# Utility Drivers That Challenge the Fuel Performance Margins

- Higher Fuel Burnup
  - Increase Capacity Factors
  - Increased enrichments/smaller feed batches
- Plant Uprates
  - Higher core power density
  - Increased clad heat flux
  - Increased RCS Temperatures
- Changes to RCS Chemistry
  - Zinc Addition (to protect Steam Generators)
  - Elevated Lithium and Hydrogen (to reduce outage dose)

➢ *Must understand how changes in operations will impact mechanical and materials performance of fuel assembly*

***"Need Robust Methods + Rigorous Testing! "***

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# Westinghouse Test Loops

## VISTA Loop

- 5x5 bundle facility run-to-measure component pressure drop, strap-and-rod vibration at cold temperature conditions


## FACTS Loop

- Single assembly hydraulic test assembly to measure component pressure drop and assembly vibration near reactor Reynolds number
- FACTS-D Loop also used to perform debris efficiency tests

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# Westinghouse Test Loops (continued)

## VIPER Loop

- Two bundle endurance test facility typically run near reactor conditions for at least 500 hours - measure rod vibration and wear
- Can simulate transition core effects between two assemblies with different hydraulic losses

## ODEN/FRIGG DNB Test Loops

- 5x5 or 6x6 test facility electrically heated to measure DNB or Critical Heat Flux for typical PWR reactor accident conditions
- Up to 11x11 test facility electrically heated to measure DNB or Critical Heat Flux for typical BWR reactor accident conditions

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# Waltz Mill: Home of Westinghouse's Global Field Services Business

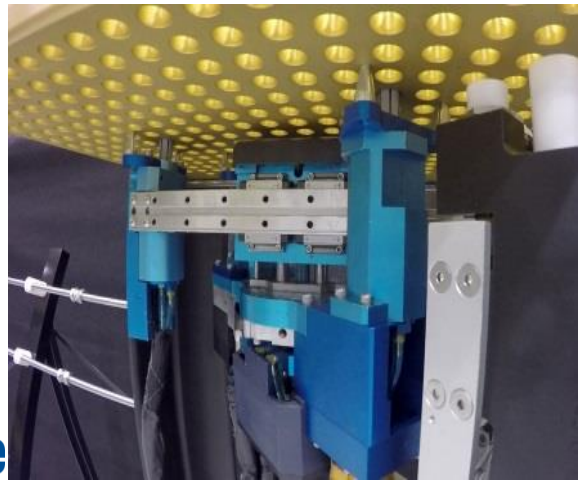
**PWR Outage Services**

**Reactor Services**

**Shop & Field Services**

**Rotating Equipment**

**Steam Generator Inspection & Repair**



**Inspection Services**

**WesDyne**

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# Westinghouse BWR Service Center

- **Facility Overview**
  - Full size BWR cavity/vessel simulator
  - Spent Fuel Pool
  - Under-vessel simulator
- **Training Services**
  - Outage Management
  - Refueling Services
  - Under-Vessel Services
  - Inspection Services
  - Dry Cask Services
  - Industry Training

**Chattanooga, TN - USA**

**Safely, Correctly, Committed.**

**We Deliver with Energy**

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# AP1000 Plant – Regulatory Certainty

ONR Office for Nuclear Regulation

Home | About ONR | What we do | News | Resources | Contact ONR | Work for ONR

Home » News » Design acceptance for the AP1000® reactor

- News and updates
- News archive
- Latest website updates
- eBulletin
- Events

## Design acceptance for the AP1000® reactor

30 March, 2017

The AP1000® nuclear reactor, designed by Westinghouse, is suitable for construction in the UK said the regulators today following completion of an in-depth assessment of the reactor design.

*Dr Richard Savage, ONR Chief Nuclear Inspector*

The Office for Nuclear Regulation (ONR), the Environment Agency and Natural Resources Wales, the regulators who undertake the Generic Design Assessment of new reactor designs, are satisfied that the reactor meets expectations on safety, security and environmental protection at this stage of the regulatory process.

ONR has issued a Design Acceptance Confirmation (DAC) to Westinghouse and the environment agencies have issued a Statement of Design Acceptability (SoDA).

Dr Richard Savage, ONR's Chief Nuclear Inspector, said: "The closure of our assessment of the generic design of the AP1000® reactor is a significant step in the process, ensuring the design meets the very high standards of safety we expect.

*Reference: UK's Office of Nuclear Regulator website*

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# Sanmen Site Progress: Time Lapse View

*2009 to 2017*

*Photos © Sanmen Nuclear Power Company Ltd.*

# The Path to Completion: Next Milestones for Sanmen and Haiyang

**RCP Deliveries/ Installations**




**100% Power Operation**

*Photos © Sanmen Nuclear Power Company Ltd. All rights reserved*

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# U.S. Projects Recent Updates
# Vogtle Unit 3 Nuclear Island & Turbine Building



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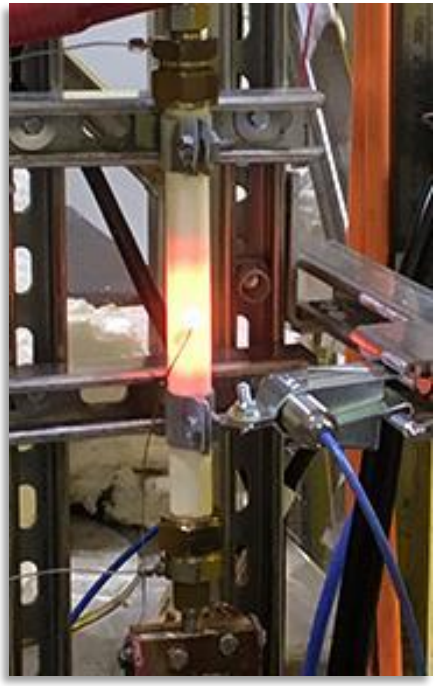
# Fueling the Future Through Innovation

Advanced cladding materials, such as AXIOM™ and Lined Optimized ZIRLO™

TRITON11™ revolutionary BWR fuel design

VVER-1000 and 440, next-generation design for Russian-type reactors



EnCore™ Fuel; shown here are lead test rods in the Westinghouse Ultra-High Temperature (UHT) test facility

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# EnCore™ Fuel

*We're changing nuclear energy ... again*

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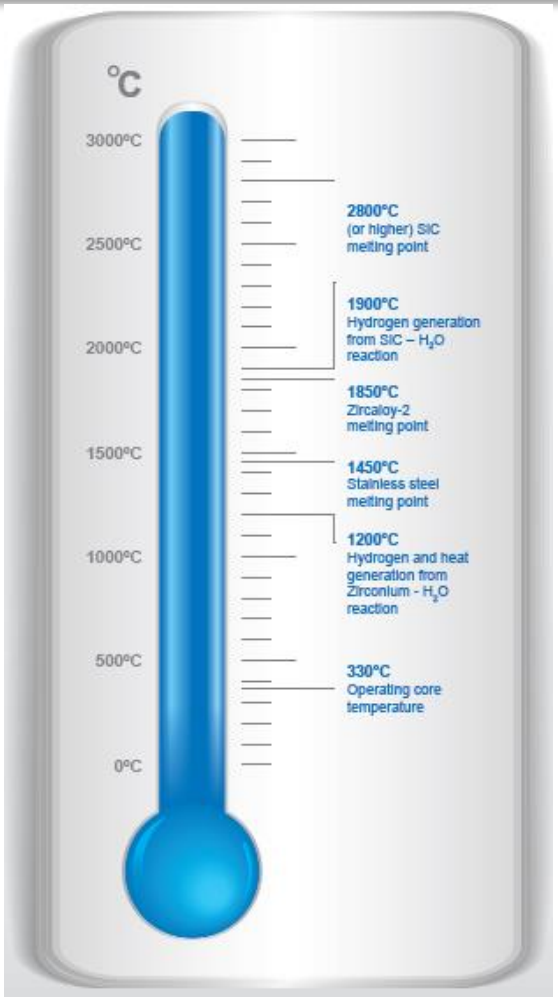
# Westinghouse EnCore Fuel

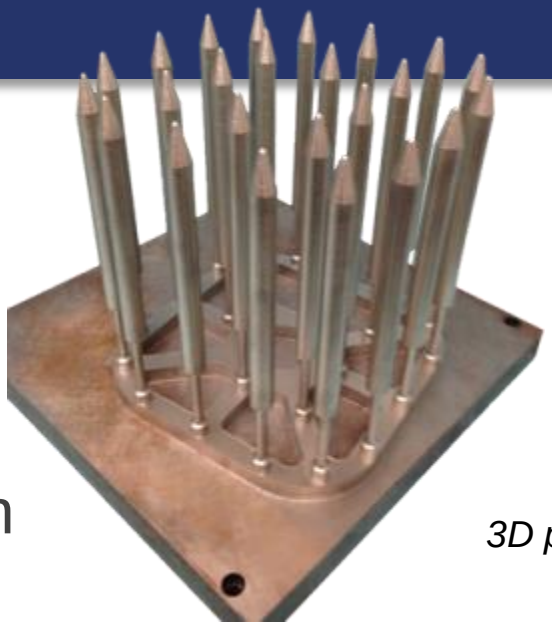
## $U_3Si_2$ Based Fuel Key Characteristics

| | $UO_2$ | $U_3Si_2$ | Improvement |
|---|---|---|---|
| Uranium Content ($gm/cm^3$) | 9.66 | 11.3 | 17% |
| Average Thermal Conductivity (w/cm/°C) | 0.032 | 0.209 | 550% |
| Max. Power to Centerline Melt (Kw/ft) | 22.5 | 94 | 318% |
| Fuel Cycle Costs ($\$/MWhr_e$) | $9.21 | $8.87 | -3.6% |

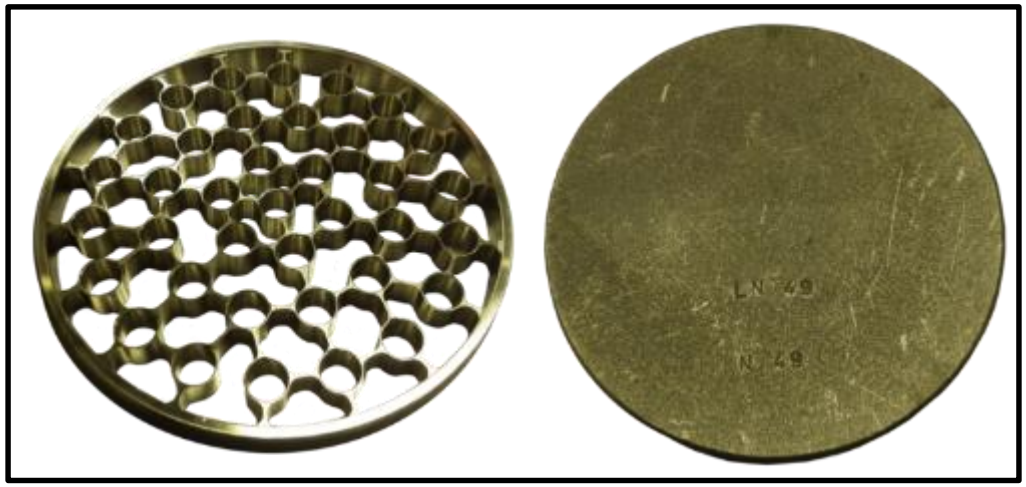


# Manufacturing Innovation

- Advanced cladding materials
- 3D printing
- Plasma spray
- White light deflectometry inspection
- Microwave de-nitration reconversion

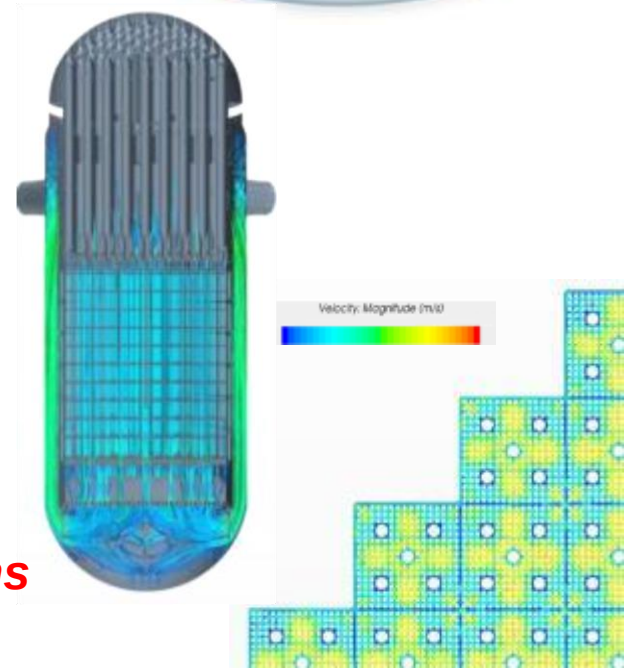


*3D printing*



# Modeling and Simulation for Fuel Performance

- Consortium for Advanced Simulation of LWRs (CASL)
  - Vision: Create a virtual reactor for predictive simulation of LWRs
  - Challenge areas: DNB, cladding integrity, reactor vessel integrity, crud, fretting, PCI, FA distortion
  - Relates to power uprates, high burnup, life extension aspects
- Overall goals for a true multiphysics approach:
  - Better decision making capability for issue diagnosis and change evaluations
  - Operational enhancements through better understanding of design margin


***VERA: Virtual Environment for Reactor Applications***

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# New Reactor Development Strategy

Westinghouse's 50+ years of proven nuclear power plant design, development and deployment experience are being leveraged to develop the next generation of nuclear plants

- Westinghouse Small Modular Reactor (SMR)
  - Baseload
  - Incorporates latest AP1000® plant technology with modular deployment model to deliver power at a competitive cost
- Westinghouse eVinci™ Micro Reactor
  - Distributed energy
  - Designed to serve remote off-grid and/or micro-grid markets
- Westinghouse Lead-Cooled Fast Reactor (LFR)
  - Baseload
  - Replacement for today's baseload capacity, including Westinghouse's light-water reactor fleet

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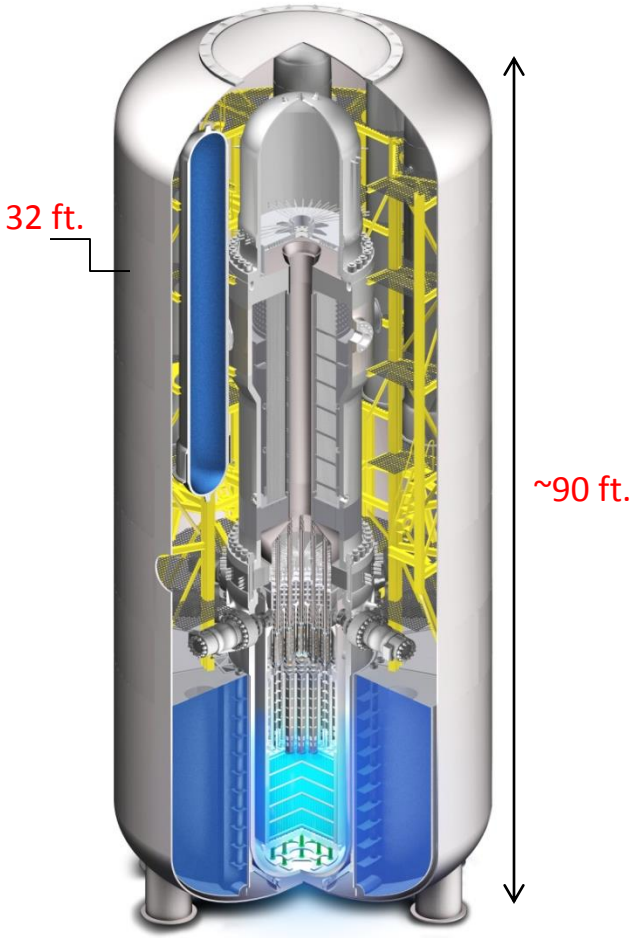
# Westinghouse SMR (cont.)




| Specifications | |
|---|---|
| Thermal Output | 800 MWt |
| Electrical Output | >225 Mwe |
| Passive Safety Systems | No operator intervention required for 7 days |
| Core Design | 17x17 Robust Fuel Assembly<br>8.0 ft. Active Length<br>< 5% Enriched U235<br>89 Assemblies<br>Soluble Boron and 37 Internal CRDMs<br>24-Month Refueling Interval |
| Reactor Vessel Size | Outer Diameter: 11.5 ft.<br>Height: 81 ft. |
| Upper Vessel Package | 280 Tons |
| Containment Vessel Size | Outer Diameter: 32 ft.<br>Height: 91 ft.<br>Fully Modular Construction |
| Reactor Coolant Pumps | 8 External, Horizontally-Mounted Pumps<br>Sealless Configuration |
| Steam Generator | Recirculating, Once-Through, Straight-Tube |
| Pressurizer | Integral to Vessel |
| Instrumentation and Control | Ovation®-based Digital Control System |

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Ovation is a trademark or registered trademark of Emerson Process Management Power & Water Solutions, Inc. Other names may be trademarks of their respective owners.

# Westinghouse SMR Fuel

*More Than a Name…*


**Prototypes built; fuel manufacturing readiness and vibrational performance confirmed**

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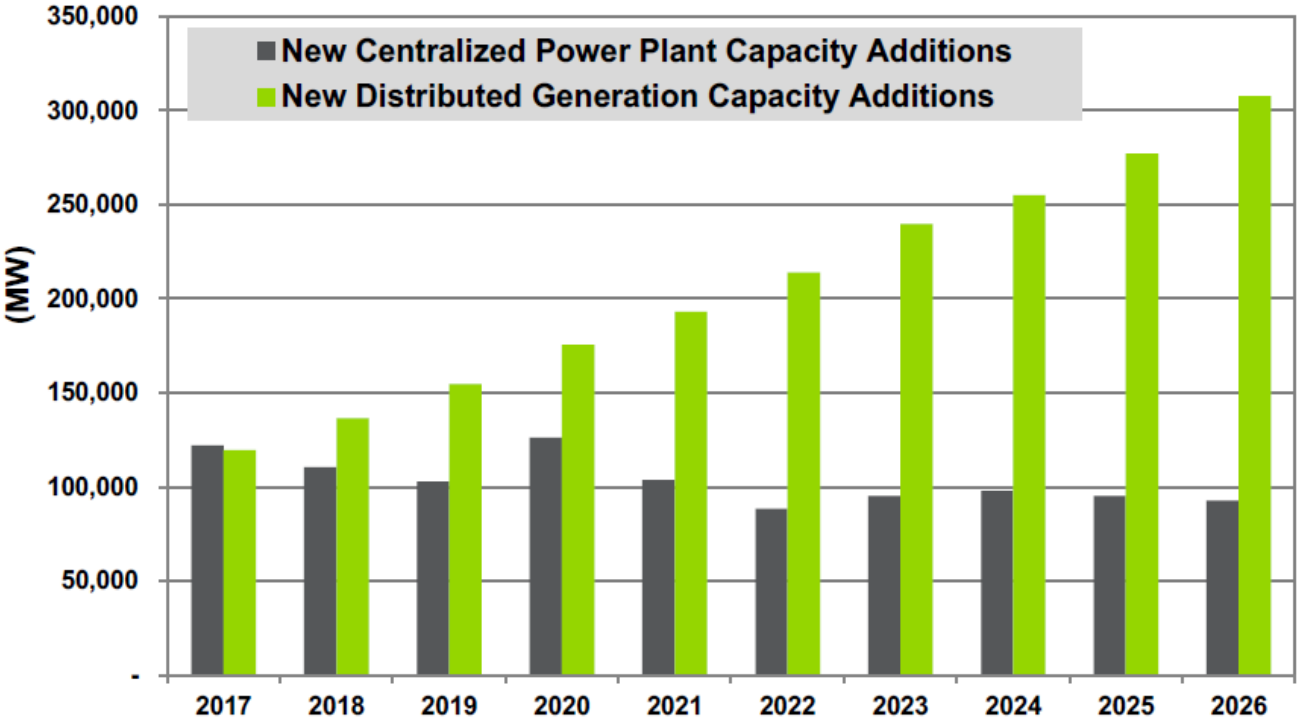
# Evolving Energy Market

**A turning point:** In 2018, new distributed generation (DG) power capacity will overtake new centralized generation




*Source: Navigant Research*

**Forecast:**
DG may displace 300 gigawatts of new large-scale power plants by 2026

**The market is changing to smaller, decentralized generation**

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# eVinci™ Micro Reactor

Ultimate Energy Solution for the Off-grid Customer

Long-life nuclear battery **eliminates fuel supply**

**Affordable energy** for remote communities and mines

**Enables Economic Development** with abundant power

**Clean energy** with low environmental impact

**Scalable power** for complete energy needs

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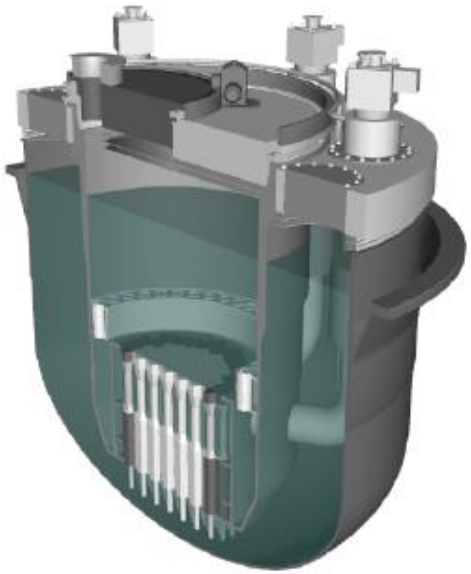
# The Westinghouse Lead Fast Reactor

- Solid safety case, addressing post-Fukushima concerns: walk-away safe

- Enhanced sustainability from operation in fast neutron spectrum
  - Better utilization of natural uranium resources, with potential to close the fuel cycle
  - Reduced amount and long-term radiotoxicity of nuclear waste

- Built-in scalability
  - Minimizes re-design/licensing efforts for different power offerings
  - Base version sized at 950 MWt (~400 MWe)

- Technology readiness higher than generally thought
  - Increased International interest for LFR technology
  - Impressive testing facilities operated worldwide



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# How can you prepare for the future?

- **Build a strong academic record**
  - Learn the basic science and fundamentals of engineering
  - Explore across technical disciplines
- **Get involved in projects**
  - Develop leadership and experience
  - Practice teamwork
- **Get involved in professional organizations**
  - Build a network
  - Learn about industry trends and opportunities
- **Get involved in community service and activities**
  - Make a difference . . . Even in social networks
- **Maintain a balanced personal and professional life**
  - Focus on Excellence!
  - Have fun!

# Summary

- Westinghouse continues to be a ***leader*** in the nuclear sector
- Westinghouse continues to be ***committed*** to the successful and safe reactor operations in Latin America
- The ***AP1000 plant technology*** is the right size, it is passive, standardized and licensed – Building a fleet now!
- Investing in ***innovation*** to drive future nuclear technologies
  - Developing the next generation of nuclear professionals
- Westinghouse Nuclear Technology and Engineering Development:
  - ***Driving to achieve the Nuclear Promise***

***Westinghouse: Partnering with our global Customers to provide safe, reliable, clean, competitive nuclear generation for years to come!***

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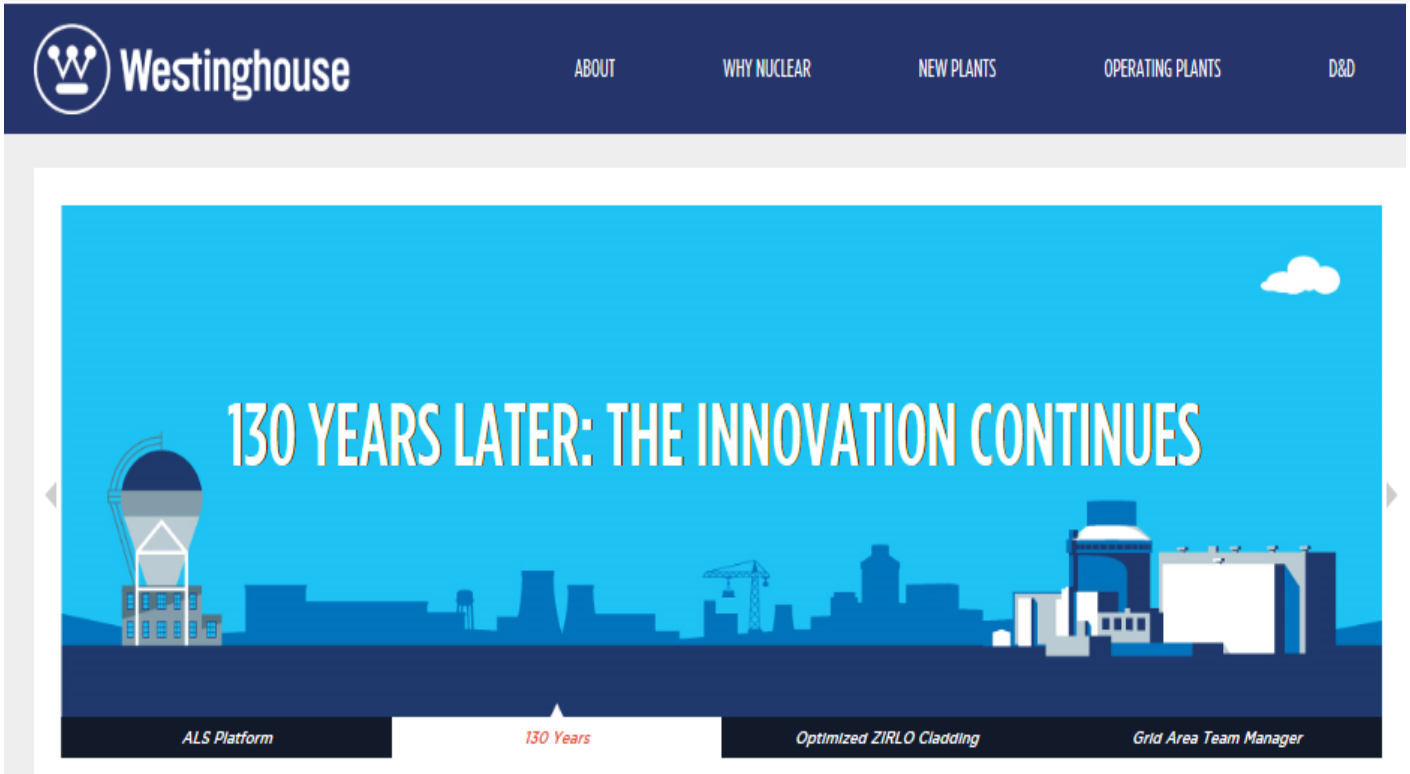
# Thank You




**Visit us at**
**http://www.westinghousenuclear.com/**

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