Westinghouse: Leading Nuclear Technology Innovation

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James Wyble, Vice President, Americas Carlos Leipner, Vice President, Latin America



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## Westinghouse Electric Company

- Founded in 1886 in Pittsburgh, Pennsylvania, by George Westinghouse
- Responsible for some of the world's most important achievements:
  - Alternating current technology
  - First commercial radio broadcast (KDKA-1920)
  - USS Nautilus nuclear submarine
  - First camera on the moon
  - Commercial nuclear power







## Westinghouse Electric Company Today

#### **Operating Plants Business**

Delivers operating plant products and services, including global field services, instrumentation and control, welding and machining, and installationrelated functions

#### Decommissioning, Decontamination and Remediation

Deploys global technologies and forms local partnerships to carry out long-term projects



#### **Engineering Center of Excellence**

Supports all product lines by driving common engineering capabilities and accelerating innovation

#### New Plants and Major Projects

Delivers both new-plant projects and major projects for new and operating plants on a global basis

#### Nuclear Fuel and Components Manufacturing

Designs and delivers fuel for PWR, BWR, VVER, and AGR reactors, and oversees manufacturing operations worldwide



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## Strategically Positioned to Develop and Support the Worldwide Fleet





#### Westinghouse in Brazil





Actively supports the Brazilian nuclear community and participates with leading universities to develop local talent and leadership







#### **Developing New Talent**



Alice Cunha – Winner of 2015 WNU Nuclear Olympiad



Andre Rebello – 2<sup>nd</sup> Place at INAC 2013 Junior Poster Technical Session



#### Why Nuclear Power

# **7.3 Billion** 2015 World Population

# 1 Billion Live on 750 Million Lack1.3 Billion lackLess thanaccess toaccess toUS\$1.25/dayclean waterelectricity

Access to <u>reliable</u> and <u>clean</u> electricity is an imperative to our future: <u>Nuclear Power has</u> <u>Access to reliable</u> and <u>clean</u> electricity is an <u>imperative to our future</u>: <u>Nuclear Power has</u>

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Ref: United Nations, World Bank, water.org, worldenergyoutlook.com)











#### **Sources of Emission-Free Electricity 2014**





## Nuclear Power: A Sustainable Alternative

#### **Comparison of Life-Cycle Emissions**





Source: Annex III. Technology-specific cost and performance parameters. In: Climate Change 2014: Mitigation of Climate Change, Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Edenhafer, O., et al., Cambridge University Press, 2014. The numbers share are the median of studies examined by the IPCC in grams CO2e, per KWh and are converted to tons CO2e, per GWh



## Nuclear Power: A Sustainable Alternative

Current high-level waste volume after the plant's lifetime of operations would fill an area about the size of a football field five yards deep

- ~48,000 metric tons
- $\sim \frac{1}{2}$  ton per fuel assembly
- ~ 100,000 assemblies
- Only ~5% is waste





## Nuclear Power: A Sustainable Alternative

#### Plant Neighbors More Favorable to Nuclear Energy Than General Public

Overall, do you strongly favor, somewhat favor, somewhat oppose, or strongly oppose the use of nuclear as one of the ways to provide electricity in the United States? (%)



\*6th Biennial National Survey of U.S. Nuclear Power Plant Neighbors 2015





#futureofenergy

#### U.S. Electricity Production Costs 1995-2014, In 2014 cents per kilowatt-hour











#### U.S. Capacity Factors by Fuel Type 2014

Fuel Type	Average Capacity Factors (%)	
Nuclear	91.7	
Geothermal	68.8	
Coal (Steam Turbine)	60.9	
Gas (Combined Cycle)	47.8	
Hydro	37.5	
Wind	33.9	
Solar	27.8	
Oil (Steam Turbine)	12.8	
Gas (Steam Turbine)	10.0	



#### Levelized Cost of Electricity (USD)





## Westinghouse Technology Innovation

- We are proud to have a vast and varied team of world-recognized technical experts who develop, test and refine Westinghouse technology in engineering disciplines that span the nuclear industry
- Westinghouse Technology Innovation is making the operating fleet more efficient, safer and more competitive









## Primary Side Technology Advancements

- <u>Zephyr<sup>®</sup> Advanced Acquisition</u>
  <u>System</u>
  - Suitcase ECT System
    - Streamlined Equipment, Weight, Connections
    - Fast Set-Up/ Start-Up & Tear-Down
    - Intelligent Planning and Optimized Cycle Time
    - Software Flexibility
    - Yields Eddy Current (bobbin) Acquisition 25-35% faster
  - Revolutionary Probe Delivery
    - Air Assisted
    - Probe Speed Optimization

- TITAN<sup>™</sup> Analysis System
  - Two unique, but complimentary EPRI-qualified bobbin auto analysis programs
    - Up to 75% reduction of production analysis crew (for auto/auto)
    - Addresses NDE resource limitations & reduces human performance events
  - EPRI-qualified RPC/Array auto analysis program
  - Single Pass Analysis



## Zephyr<sup>®</sup> Details

- Zephyr<sup>®</sup> Equipment Elements
  - Pegasys<sup>®</sup> Robot
    - End effector w/tubesheet seal
  - Omni Probe Pusher
    - Air regulator
  - Software
    - Eliminates waste
  - Probe
    - Customized LLMC probe
    - Conduit
    - Poly





## Zephyr<sup>®</sup> Details



## Zephyr<sup>®</sup> Details

- Field Experience
  - Pilot Implementations at Catawba and Palo Verde in 2014
  - Zephyr<sup>®</sup> Implementation at Palo Verde in 2015
    - <sup>3</sup>/<sub>4</sub>" Tubing; System 80 Steam Generator
    - Over 25,000 tubes inspected
    - 24 hours of schedule reduction
    - Eliminated the need for a cold core mid-loop/nozzle dams
    - 50% reduction in probe use
    - 50% reduction in dose
  - Zephyr<sup>®</sup> Implementation at Byron 1 in 2015
    - 11/16" Tubing; B&W Steam Generator
    - Over 26,000 tubes inspected
    - 50 hours of schedule reduction
    - 25% reduction in probe use
    - 40% reduction in dose

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## Another excellent FOAK deployment at Bryon

#### Secondary Side Technology Advancements

- Westinghouse's Stellar<sup>®</sup> Nozzles
  - Provides clear jet collimation throughout the entire tube bundle;
    Used at Catawba, Wolf Creek, Farley and Fort Calhoun Spring 2015
  - 70-100% increase in sludge removal
  - More effective removal of scale and hard collars
  - No failed cleanliness exams

#### Demonstrated Significantly Improved Cleaning Power in Less Time





## Secondary Side Technology Advancements

- Reptil Automated Inbundle Inspections
  - Demonstrated on upper support plate at Catawba 2
  - Provides integrated:
    - Positional feedback
    - Speed & safety controls
    - Metadata capture (Column, Row, Elevation)
    - Average of 80% dose reduction
    - Faster, better quality inspections
- Additional Value
  - Industry leading retrieval capabilities and speed
  - Custom designed tooling and mock-ups to aid performance







## **Chemical Based Cleaning**

- Westinghouse has the most comprehensive solution to steam generator secondary side maintenance including:
  - EPRI/SGOG Chemical Cleaning
  - Advanced Scale Conditioning Agents (ASCA)
  - iASCA
  - Consolidated Deposit Extraction (CODE)

#### Westinghouse's portfolio provides maintenance flexibility



#### EPRI/SGOG Chemical Cleaning Reasons for Application

- Address Steam Generator issues:
  - Corrosion risk
  - Tube fouling
  - Degradation of thermal hydraulic performance
    - Heat Transfer
    - Level Instability
- Clean tube support plate crevices
- Remove tube scale from freespan surfaces, which can form artificial crevices and initiate ODSCC
- Improve Eddy Current Inspection Quality



Referred to as "hard" chemical cleaning; the most aggressive cleaning method

#### **EPRI/SGOG Chemical Cleaning**

#### Westinghouse Experience

- Asco 2 Fall 14
- Asco 1 Spring 14
- St. Alban 1 Spring 11
- St. Laurent B1 Summer 11
- Belleville 2 (Summer 2010)
- Cattenom 4 (Spring 2010)
- Chinon B3 (Summer 09)
- Cattenom 3 (Summer 09)
- Cattenom 1 (Spring 09)
- Point Beach (Fall 08)
- Belleville (Fall 08)
- Cruas 2 (Fall 08)
- Cruas 3 (Spring 08)
- Vogtle Unit 2 (Spring 07)
- Vogtle Unit 1 (Fall 06)
- Diablo Canyon Unit 2 (Oct. 2004)
- Diablo Canyon Unit 1 (April 2004)
- •\_\_\_Robinson (Oct. 2002)



- Beaver Valley 1 (Sept. 2001
- Comanche Peak 1 (Oct. 1996)
- Sequoyah 2 (April 1996)
- Wolf Creek (March 1996)
- Bruce A Unit 1 (Nov. 1995)
- Sequoyah 1 (September 1995)
- Callaway (April 1995)
- Surry 1 (Dec. 1994)
- Bruce A Unit 3 E Bank (July 1994)
- Bruce A Unit 3 W Bank (June 1994)
- Surry 2 (June 1994)
- Bruce A Unit 4 Prehtrs (July 1993)
- Bruce A Unit 4 E Bank (July 1993)
- Bruce A Unit 4 W Bank (April 1993)
- Doel 4 (March 1992)
- Kori 1 (Oct. 1990)
- ANO-1 (October 1990)
- Maine Yankee (April 1987)
- Millstone 2 (March 1985)

Westinghouse is the industry leader, safely executing every cleaning

#### **EPRI/SGOG Chemical Cleaning**





#### **Chemical Cleaning Technologies**

#### New Developments

#### ASCA

- More than 40 applications world wide
- Removal totals have significantly increased while still retaining thermal hydraulic benefits
  - Results include 5-24% increase in steam pressure following FB cleanings

#### • iASCA

- Developed to increase removal capacity of ASCA solutions while maintaining low corrosion levels
- Increased deposit dissolution capacity in a single ASCA step over existing ASCA processes
- Not designed for thermal hydraulic benefits, focus on large mass of removal
- Consolidated Deposit Extraction (CODE)
  - Only process available in the industry capable of dissolving TTS collar binding species (e.g. Silica, Aluminum species)







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Westinghouse Non-Proprietary Class 3

#### iASCA/CODE Equipment External Set-up



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Westinghouse Non-Proprietary Class 3

## TTS iASCA/CODE Equipment Containment





#### **Optimizing Steam Generator Chemical Cleaning**

Performance of a chemical cleaning provides many benefits to the plant:

- Removes large amounts of deposits from the SG without excessive corrosion of surface materials
- Helps extend SG operation
- Helps prevent plant capacity loss
- Enhances steam generator and plant performance
- Helps prevent costly steam generator replacement
- Offsets impact of sludge lancing skips
- Can be customized to meet plant needs
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Westinghouse SGCC control room



Westinghouse Non-Proprietary Class 3

## World-Class Training Center at Waltz Mill Site



Above: Reactor Coolant Pump motors



Top: Reactor vessel head; diver training





Left: Steam Generator mock-ups

Right: Refueling system



#### Westinghouse Technology to Enhance Safety

- PWR & BWR External Assessments
  - Seismic, Flooding, PRA,
- PWR SHIELD Passive Thermal Shutdown Seal
- Containment Venting System
- Hydrogen Management
- Spent Fuel Pool Protection
  - SFPIS
  - EFPCS
- SBO Coping Strategies
- Severe Accident Mitigation

#### Enhancing Safety in the 21<sup>st</sup> Century



Solutions in Response to Insights from Fukushima Daiichi



#### RCP Seal Technology Summary

- The SHIELD<sup>®</sup> Shutdown Seal has the most operating experience in US nuclear power plants
- The SHIELD<sup>®</sup> SDS is the only low leakage seal endorsed by the US Nuclear Regulatory Commission for crediting in FLEX applications
- **WEC** is making substantial investments and is committed to working with our customers to improve RCP seal reliability and performance
- Overall objective of programs is to achieve seal life of 12 years



#### **Product Overview – Description of Operation**





#### **Product Overview – Principles of Operation**



## SHIELD<sup>®</sup> Passive Thermal Shutdown Seal Cut-Away: Normal Operation



## SHIELD<sup>®</sup> Passive Thermal Shutdown Seal Cut-Away: Loss of All Seal Cooling - Activation





## SHIELD<sup>®</sup> Passive Thermal Shutdown Seal Cut-Away: Loss of All Seal Cooling - Sealing





#### SHIELD Shutdown Seal



Location of SHIELD passive thermal shutdown seal

#### **Enhancing Safety**



SHIELD passive thermal shutdown seal installed in modified #1 insert



Detailed view with SHIELD passive thermal shutdown seal components identified



#### Innovating for the Future

- Development of thermoacoustic sensors for Sodium-cooled Fast Reactors (Westinghouse-ANL-University of Pittsburgh)
- Integral Inherently Safe Light Water Reactor (Georgia Tech-Westinghouse plus other universities and labs)
- Accident Tolerant Fuel development (WEC and multiple partners
- Consortium for Advanced Simulation of Light Water Reactors (CASL)



Members of the Westinghouse-ORNL team with 2014 high-performance computing (HPC) Innovation Excellence Award for **AP1000<sup>®</sup>** core physics simulations using the CASL Virtual Environment for Reactor Applications (VERA)



Small Modular Reactor SMR

Using collaborative innovation to get ideas into the pipeline and deliver products to market faster

#### Advantages of Westinghouse AP1000<sup>™</sup> Plant

#### Proven Technology and Innovative Passive Safety Systems

Passive safety replaces mechanical and electrical systems – harnesses natural forces like gravity, convection, and condensation to achieve safe shutdown



#### **Delivery Certainty**

Standard design, experience from current projects and modular construction enable "n<sup>th</sup> of a kind" delivery performance



#### **Regulatory Certainty**

Reviewed by multiple countries; first Generation III+ reactor to receive design certification from the U.S. NRC

## AP1000 Plant Simplicity in Safety Design

#### **Passive Technology Employs Natural Forces**

- Evaporation
- Condensation
- Natural Circulation
- Compressed gasses (nitrogen, air)
- System performance has been proven by extensive testing and approved by the U.S. NRC
- No reliance on operator action for 72 hours





AP1000 Passive Containment Cooling System

## AP1000 Plant – Regulatory Certainty

<b>Reviewing Authority</b>	Type of Review	Date
	AP1000 Plant Final Design Approval for DCD Revision 19	December 2011
国家核安全局 National Nuclear Safety Administration	AP1000 Plant Construction Permit Received	March 2009 (Sanmen) September 2009 (Haiyang)
Office for Nuclear Regulation	AP1000 Plant Interim Design Acceptance	December 2011
	AP1000 Plant Passed Phase 2 of 3 Stage Pre-Licensing Review	July 2013
	AP1000 Plant Formal Certification of Compliance	May 2013
	AP1000 Plant Conformance with Advanced Light Water Reactor Utility Requirements Document	February 2003



## AP1000 Plant – Delivery Certainty

- AP1000 plant design minimizes risk
  - Modular approach enables parallel activities and shorter construction
- Engineering is complete
  - Significant effort spent to achieve
- **Eight units under construction** world-wide means subsequent units will derive significant benefit from
  - Design and process maturity
  - Supply chain maturity and experience
  - Lessons learned
- Fleet of AP1000 plant operators will provide network of sister plants who share operating experience





The PCC is staffed by experts who work to overcome delivery challenges and achieve program milestones



Haiyang 1 Control Room is now operational

## The AP1000 PWR: Designed for Greater Project Certainty and Shorter Schedule

#### Modular construction means more work done in parallel





## Progress of U.S. Projects: Summary

- Nuclear Island basemat concrete pours completed for V.C. Summer Units 2&3; Vogtle Units 3&4
- Containment Vessel Bottom Head (CVBH) set in nuclear island for Vogtle Units 3&4; V.C. Summer Units 2&3
- First CV Ring set for V.C. Summer Unit 2 and Vogtle Unit 3; fabrication of additional rings continues at both sites
- Component and module fabrication proceeding; major modules CA20 and CA05 set at Vogtle Unit 3 and V.C. Summer Unit 2
- Reactor Vessels delivered for initial units at each site; additional equipment and component deliveries continue to proceed



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#### V.C. Summer Unit 2 - AP1000 CA20 Module

#### V.C. Summer Unit 2 - AP1000 Containment Vessel Ring #1

#### Sanmen Site Progress: Time Lapse View 2009 to 2015





Photos © Sanmen Nuclear Power Company Ltd.

## Summary

- Nuclear energy continues to provide multiple benefits as a source of electricity generation and will play an increasing role in meeting world energy needs.
- A worldwide fleet approach for standard nuclear design provides <u>maximum efficiencies for long-term, competitive electricity generation</u>
- The AP1000 plant technology is the right size and is <u>passive</u>, <u>standardized</u> and <u>licensed</u>
  - Environmentally responsible source of electricity
  - Unmatched licensing pedigree
  - Provides certainty of schedule and cost; reduced project risk

# Westinghouse: Partnering with Brazil to provide <u>safe</u>, <u>reliable</u>, <u>competitive nuclear generation</u> for years to come!





## http://www.westinghousenuclear.com/



