GE Hitachi – State-of-the-art NPP technology

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Vice President, Product Management & International Nuclear Plant Projects
Who we are...
GE’s portfolio ... structured for growth

- 8 businesses operating in more than 100 countries ... 125+ years
- >300,000 employees worldwide
- 2013 revenue $146B

### GE’s Energy Sector Businesses

<table>
<thead>
<tr>
<th>Sector</th>
<th>Sub-sectors</th>
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<tbody>
<tr>
<td><strong>Power &amp; Water</strong></td>
<td><strong>$24.7B</strong></td>
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<td>- Drilling &amp; Surface</td>
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<td>- Global Services</td>
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<td>- Measurement &amp; Control</td>
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<td>- PII Pipeline Solutions</td>
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<td>- Subsea Systems</td>
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<td>- Turbomachinery</td>
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<td><strong>Oil &amp; Gas</strong></td>
<td><strong>$17B</strong></td>
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<td><strong>Energy Management</strong></td>
<td><strong>$7.6B</strong></td>
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<td><strong>Aviation</strong></td>
<td><strong>$21.9B</strong></td>
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<td>- Commercial</td>
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<td>- Military</td>
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<td>- Service</td>
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<td>- Avionics/Systems</td>
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<td><strong>Healthcare</strong></td>
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<td>- Healthcare Systems</td>
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<td>- Life Sciences</td>
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<td>- Healthcare IT</td>
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<td><strong>Transportation</strong></td>
<td><strong>$5.9B</strong></td>
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<td>- Locomotives</td>
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<td>- Services</td>
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<td>- Propulsion Systems</td>
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<td><strong>Home &amp; Business</strong></td>
<td><strong>Solutions $8.3B</strong></td>
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<td>- Appliances</td>
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<td>- Lighting</td>
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<td>- Intelligent Platforms</td>
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<td><strong>GE Capital</strong></td>
<td><strong>$44.1B</strong></td>
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<td>- Consumer&lt;br&gt;</td>
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<td>- Real Estate</td>
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<td>- GECAS</td>
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<td>- Energy Financial Services</td>
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### GE around the world

- **U.S. $69B**
- **Canada & Americas $13B**
- **Europe $25B**
- **Middle East, Africa & Others $14B**
- **Asia Pacific $26B (ASEAN $4B)**
GE Power & Water portfolio

~$25B '13 revenue >37,000 employees >120 countries

**Power Gen Products**
- High Efficiency Gas Turbines
  - Gas Turbines 42MW-350MW
  - Steam Turbines (200-600MW)
  - Generators
  - & Controls

**Power Gen Services**
- Optimizing Plant Performance
  - Long-term Service Agreements
  - Asset Optimization & Upgrades
  - Outage Mgmt & Repairs

**Nuclear**
- Advanced Reactor Technologies
  - ESBWR, ABWR, PRISM
  - Outage & asset optimization services
  - Fuels & engineering services

**Renewables**
- World's Most Efficient Wind Turbines
  - Wind Turbines/Services 1.5MW-3MW
  - Energy Storage
  - Solar PV

**Water/Process Tech**
- Energy Efficient Water Solutions
  - Chemical & Monitoring Solutions
  - Engineered Systems - Filters & Membranes

**Distributed Power**
- Broad, Efficient Portfolio
  - Aeroderivative Gas Turbines (25-100MW)
  - Reciprocating engines (Jenbacher/ Waukesha)/ Diesel: 1-9MW
  - Parts & Services

Diverse Technology & Services Solutions
GE Hitachi Nuclear Alliance

Ownership
- GE 60%
- Hitachi 40%
- GE 60%
- Hitachi 26%
- Toshiba 14%
- GE 51%
- Hitachi 25%
- Cameco 24%
- Hitachi 80%
- GE 20%

Key segments
- Services, New Units, and Canada
- Fuel Fabrication and Engineering
- Uranium Enrichment
- Services and New Units in Japan

Leading global BWR nuclear provider
GE Hitachi’s new reactor portfolio

**Operational Gen III technology**
- Lowest core damage frequency of any Generation III reactor
- Extensive operational experience since 1996
- Licensed in US, Taiwan, and Japan

**Evolutionary Gen III+ technology**
- Lowest core damage frequency of any Generation III+ reactor
- Passive cooling for >7 days without AC power or operator action
- Lowest projected operations, maintenance & staffing costs¹
- 25% fewer pumps, valves & motors than active safety nuclear plants

**Revolutionary Gen IV technology**
- 40 years of development history
- Passive air-cooling with no operator or mechanical actions needed
- The answer to the used fuel dilemma – nuclear waste reduced to ~300-year radiotoxicity² while providing new electricity generation
- Also a solution for Pu disposition

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¹ Claims based on the U.S. DOE commissioned 'Study of Construction Technologies and Schedules, O&M Staffing and Cost, and Decommissioning Costs and Funding Requirements for Advanced Reactor Designs' and an ESBWR staffing study performed by a leading independent firm

² To reach the same level of radiotoxicity as natural uranium
Technology evolution ...
GEH new nuclear plant development

1950’s
- Borax BWR test facility
- Worldwide BWR fleet

1980’s
- K6/K7 – First ABWRs
- US sodium reactor experience
- SEFOR, Fermi I, Seawolf, FFTF

2000’s
- ESBWR
- EBR
- EBR-II
- PRISM

Lessons learned ... customer input ... new features ... testing ... studies ... detailed design
Simplicity increases safety

- U.S. PWRs: $2 \times 10^{-5}$ (avg.)
- U.S. BWRs: $8 \times 10^{-6}$ (avg.)
- APR1400: $2 \times 10^{-6}$
- APWR: $1.2 \times 10^{-6}$
- EPR: $2.8 \times 10^{-7}$
- AP1000: $2.4 \times 10^{-7}$
- ABWR: $1.6 \times 10^{-7}$
- ESBWR: $1.7 \times 10^{-8}$

**PRA of Core Damage Frequency**

References: Plant licensing DCDs and publically available information

Note: PRA of CDF is represented in at-power internal events (per year)

Note: NSSS diagrams are for visualization purposes only.
Advanced Boiling Water Reactor

ABWR
ABWR station blackout prevention and mitigation

3 x 100% nominal safety divisions

Emergency Diesel Generators
- 3 located in Reactor Building
- Each has a 7-day fuel tank that is buried in a concrete vault outside the Reactor Building

Combustion Turbine Generator
- Air-cooled – Service Water not needed

AC Independent Water Addition (ACIWA) System
- Hard-piped connections to reactor
Pulling it all together with technology
ABWR project experience

Operational

Kashiwazaki-Kariwa 6
COD 1996
Kashiwazaki-Kariwa 7
COD 1997

Hamaoka-5
COD 2005

Shika-2
COD 2006

Under Construction

Ohma 1
38% complete

Shimane 3
94% complete

Lungmen 1&2
94% complete
Pre-op testing

The only Gen III Reactor with operating experience ... +25 years

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Economic Simplified Boiling Water Reactor

ESBWR
Evolutionary design

Passive safety utilizing the laws of nature: natural circulation and gravity

- Safest (lowest CDF)
- >7 day passive cooling
- Less equipment
- Lower capital costs
- Lowest staffing levels
- Less maintenance costs
- Lower dose
ABWR to ESBWR evolution

- Standby Liquid Control System – simplified design
- Fuel and Aux Pool Cooling – equivalent designs
- Suppression Pool Cooling & Cleanup System – equivalent capability
- Residual Heat Removal System – equivalent for shutdown cooling
- Reactor Water Cleanup System – equivalent designs
- Hydraulic Control Unit – equivalent design

- High Pressure Core Flooder – replaced by HP CRD makeup
- Reactor Core Isolation Cooling – replaced by Isolation Condenser
- Residual Heat Removal Containment Spray – replaced by PCCS
- Safety Relief Valves – Diversified with Depressurization Valves

Systems are equivalent or simplified
ESBWR passive safety systems

- Passive Containment Cooling System (PCCS)
- Gravity Driven Cooling System (GDCS)
- Automatic Depressurization System (ADS)
- Isolation Condenser System (ICS)
- Standby Liquid Control System (SLCS)

Diagram showing the layout of the ESBWR passive safety systems, including the PCCS, GDCS, Reactor Well, Containment, Suppression Pool, and other safety systems. The diagram includes various components and lines indicating the flow of fluids and the systems' interconnections.

Legends:
- DPV = Depressurization Valve
- = Explosive Valve
- = Safety Relief Valve
- = ElectroHydraulic Valve
- = Solenoid Valve
- = Nitrogen Op Valve

Containment Boundary

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ESBWR ... ‘Proven’ innovation

PCCS heat exchanger test

Depressurization Valve test

drywell to wetwell vacuum breaker test

Panda Full Height Containment Test facility

Isolation Condenser Testing

natural circulation proven at Dodewaard

BiMAC testing

fmcrds from abwr

fuel – modified GNF2e

GIST facility

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Power Reactor Innovative Small Module

PRISM
PRISM development

EBR-I
Experimental Breeder Reactor
Idaho National Lab
December 20, 1951

SEFOR
Southwest Experimental Fast Oxide Reactor
General Electric
1965

CRBRP
Clinch River Breeder Reactor Project
1970 Prototype

SIG
Seawolf Submarine
General Electric prototype 1955

EBR-II
Experimental Breeder Reactor II
Idaho National Lab
1964

PRISM
Power Reactor Innovative Small Module
General Electric

Scaled EBR-II with design improvements
Unique design approach of PRISM

**Active** safety systems
- Recirculation loops
- Oxide fuel
- Large reactors
- Acid chemistry

**Passive** safety systems
- Pool → No LOCA
- Metal fuel
- Small → Factory modules
- Electrochemistry

**PRISM**

- 2 safety systems to remove decay heat
- Simplified design ... cost savings
- Lower stored energy ... higher safety margin
- Cost savings and predictable schedule
- Simpler, cleaner, & more cost effective

**Related Projects**
- JSFR
- MONJU
- Super BN-600
- Astrid
- Phoenix
- JOYO
Recycling used LWR fuel closes the nuclear fuel cycle with two technologies...

**Benefits include:**
- ‘Short’-term Waste: ~300 years versus 10,000+*
- Smaller repository
- Uranium energy: extracts 90%
- Non-proliferation: no plutonium separation
- Environmentally responsible: dry process

*N Time to reach the same level of radiotoxicity as natural uranium

**PRISM - Advanced Recycling Reactor**
Merci