U.S. EPR

The U.S. Deployment of AREVA’s Next Generation Nuclear Power Plants

Massachusetts Institute Of Technology

Cambridge, Massachusetts
April 12, 2006
Today’s Discussion

- Overview of AREVA
- The “Nuclear Renaissance” – Why now?
- U.S. EPR – Key Features
- UniStar Nuclear
- Summary
Overview of AREVA
Energy: AREVA's Core Business
A Leader in the Nuclear Industry

Sales in the nuclear business
in millions of euros

- No.1 worldwide; No.1 in Europe and the US
- No.1 in Plants / Fuel
- No.1 in the Back End

- No. 3 worldwide
- No. 2 in Plants / Fuel

We are the world leader in nuclear power...
A Vertically Integrated Nuclear Energy Company

...and the only company to cover all activities that support nuclear electricity production
The Front End Division includes:
- Uranium mining & concentration
- Conversion
- Enrichment
- Nuclear fuel fabrication

An Integrated provider of nuclear fuel solutions
The Reactors and Services Division:

- Designs and builds:
  - Pressurized Water Reactors (PWR)
  - Boiling Water Reactors (BWR)
  - Research reactors.

- Offers products and services to operate and maintain every type of reactor on the market.

Designing, Building & Servicing a Global Nuclear Fleet
The Back End Division includes:

- Reprocessing and recycling of used nuclear fuel
- Used nuclear fuel dry cask storage (TransNuclear)

Used Fuel Solutions for Today and Tomorrow
Transmission & Distribution Division

- The Transmission & Distribution Division provides:
  - Products, systems and services for the medium and high-voltage electricity markets
  - Products are used to transmit and distribute electricity from the generator to the large end-user

Responding as a Team with Global Resources
Companies of the AREVA Group

Figures:
2005 €10.1B sales ($12.1B)
58,000 employees

SIEMENS

34% 66% 100% 100%

AREVA NP AREVA NC AREVA T&D

ENERGY
AREVA NP in the U.S.

Richland, WA
- 750 People
- Fuel

Cranberry Twp., PA
- 20 People
- Electrical
- Engineering
- Qualification/Dedication
- Project Mgmt

Lynchburg, VA
- 1,300 People
- Engineering
- Service
- Project Mgmt
- Lab

Naperville, IL
- 40 people
- Engineering
- Service
- Project Mgmt
- I&C

Marlborough, MA
- 100 people
- Engineering
- Service
- Project Mgmt

Benicia, CA
- 50 People
- Service

Charlotte, NC
- 550 People
- I&C/Electrical
- Engineering
- Service
- Project Mgmt

Fort Worth, TX
- 45 People
- Engineering
- I&C/Electrical
- Service
- Project Mgmt

Atlanta, GA
- 40 People
- I&C/Electrical
- Project Mgmt

Total Employees: 2,875
Nuclear Engineering: 408
I&C and Electrical: 170

= Major site presence
Awards & Recognition

<table>
<thead>
<tr>
<th>Rank</th>
<th>Company</th>
<th>Overall score</th>
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<tbody>
<tr>
<td>1</td>
<td>AREVA</td>
<td>7.19</td>
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<tr>
<td>2</td>
<td>Duke Energy</td>
<td>7.16</td>
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<tr>
<td>3</td>
<td>Constellation Energy</td>
<td>6.99</td>
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<td>4</td>
<td>TXU</td>
<td>6.97</td>
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<td>5</td>
<td>Edison</td>
<td>6.81</td>
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<td>6</td>
<td>E.ON</td>
<td>6.79</td>
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<tr>
<td>7</td>
<td>Suez</td>
<td>6.69</td>
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<td>8</td>
<td>RWE</td>
<td>6.38</td>
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<td>9</td>
<td>American Electric Power</td>
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<td>10</td>
<td>Reliant Energy</td>
<td>5.71</td>
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<td>11</td>
<td>Gazprom</td>
<td>5.69</td>
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<tr>
<td>12</td>
<td>Williams</td>
<td>5.55</td>
</tr>
<tr>
<td>13</td>
<td>Gasunie</td>
<td>5.54</td>
</tr>
</tbody>
</table>

#11 Anne Lauvergeon
Chairman, The Areva Group
France

-Forbes, 7/28/2005

-Forbes, 7/28/2005
The “Nuclear Renaissance”

Why now?
U. S. is facing dramatic challenges in energy supply
- Rapidly rising fuel costs
- Rising electricity prices
- Increasing environmental obligations
- Insecurity of foreign energy sources

U.S. Successful Economic Growth Depends On a Solution to This Challenge
U. S. Electricity Demand

OCT 2004 to OCT 2005 = 7% annual growth

Source: EEI
Sustained High Natural Gas Prices

Gas Prices will stay “High” Until New LNG Terminals are On-line (2010) and Imports Increase
Coal Spot Prices

Coal Prices have Increased Dramatically

Source: EIA
Fuel Prices to Electricity Generators, 1995-2030
(2004 dollars per million Btu)

Source: EIA
2005 Average Wholesale Electricity

$/MWh - Average Yearly Wholesale On Peak

$59.7

$46.73

$88.51

$82.1

$74.18

$69.79

(Avg. Yearly Wholesale on Peak)

Source: NERC

A growing need for new baseload generation

Source: NERC
New Nuclear Baseload – A Viable Solution?

- Many potential benefits
  - Lowest cost for electricity generation
  - No greenhouse emissions
  - Less susceptible to fuel price fluctuations

- BUT – still perceived as a risky investment
  - Relatively high capital costs ($2-3 B)
  - Public perception/protests (NIMBY)
  - Huge losses “the last time we tried this”

Investment risk MUST be mitigated for new construction to become a reality
Energy Policy Act of 2005

- Passed in August 2005
- Proactive Incentives for Nuclear Growth
  - Investment stimulus
    - Loan guarantee
    - Production tax credit
  - Investment protection

Mitigates Risk to Create a Strong Positive Environment for New Nuclear Construction
Stimulus for Investment

- Loan guarantees
  - Lower debt cost by $200 – $300 million
- Production tax credit
  - $18 per MWhr
  - Limit: $125 million per 1,000-MW per year
  - 6,000-MW eligible
  - Rulemaking: Feb. 2006

Encouraging investment in the first new plants
New Generating Capacity: Estimated Power Costs ($/MWh)

- Nuclear ($2,000/kW): $60
- Combined Cycle Natural Gas ($6.00/MMBtu): $57
- Pulverized Coal ($1.3/MMBtu): $49
- Nuclear ($2,000/kW with 80% Loan Guarantee): $40
- Nuclear ($2,000/kW with 80% Loan Guarantee and PTC’s): $30

$0 $10 $20 $30 $40 $50 $60 $70 $80
Protection of Private Sector Investment

- Insurance protection --- delays (e.g. licensing, litigation)
- Coverage: $500 million -- first 2 units
  $250 million -- next 4 units
The Old “Two-Step” Licensing Process

In this sequential process, regulatory reviews were overlapping: Process was inefficient, unpredictable and invited abuse.

* Opportunity for intervention, hearings and delay
The New Licensing Process

In this process, all regulatory reviews (site, reactor design, construction/operating license) are completed before major capital investment at risk. Potential for delay significantly reduced.

- * Opportunity for public comment
- ** Opportunity for hearing, but threshold very high

Potential for delay significantly reduced
U.S. EPR: The Right Technology
A Mature, Evolutionary Design

- Olkiluoto-3 (Finland)
  - Dec. 2003 – contract signed
  - Feb. 2005 – construction permit received
  - Commercial operation 2009

- Flamanville-3 (France)
  - CP approved, start site construction 2007

- Competitive / viable
  - NSSS / low FOAKE risk
  - Operability and outage management efficiencies
  - Thermal margin
  - Safety improvements

- Firm-price, turnkey basis
- 38% thermal efficiency
EPR Design Heritage

EPR is a global product based on U.S. technology and experience that have been advanced to the next level.

A mature design based on familiar U.S.-based technology
Proven U.S. Technology – Advanced Two Generations
EPR Project Objectives

- Develop “evolutionary” design based on existing PWR construction experience, R&D, operating experience and “lessons learned”
- Reduce generation cost by at least 10%. Simplify operations and maintenance
- Reduce core damage frequency (CDF) and large early release frequency (LERF)
- Accommodate severe accidents and external hazards with no long-term local population effect

Improved investor, operator & community confidence.
MIT: Cambridge, Massachusetts – April 12, 2006

Major Design Features

- **Nuclear Island**
  - Proven Four-Loop RCS Design
  - Four-Train Safety Systems
  - Double Containment
  - In-Containment Borated Water Storage
  - Severe Accident Mitigation
  - Separate Safety Buildings
  - Advanced ‘Cockpit’ Control Room
  - Core Spreading Area

- **Electrical**
  - Shed Power to House Load
  - Load Following Capability
  - Four Emergency D/Gs
  - Two Small, Diverse SBO D/Gs

- **Site Characteristics**
  - Airplane Crash Protection
  - Explosion Pressure Wave

Reflects full benefit of operating experience and 21st century requirements.
## EPR Plant Parameter Comparison

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Current US 3-Loop</th>
<th>Current US 4-Loop (Uprated)</th>
<th>EPR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Life</td>
<td>40</td>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td>Thermal Power, MW</td>
<td>2308</td>
<td>3587</td>
<td>4500</td>
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<tr>
<td>Electrical Power (Net), MW</td>
<td>728</td>
<td>1220</td>
<td>1600</td>
</tr>
<tr>
<td>Plant Efficiency, Percent</td>
<td>32</td>
<td>34</td>
<td>36</td>
</tr>
<tr>
<td>Hot Leg Temperature, F</td>
<td>604.9</td>
<td>619</td>
<td>622</td>
</tr>
<tr>
<td>Cold Leg Temperature, F</td>
<td>543.5</td>
<td>559</td>
<td>563</td>
</tr>
<tr>
<td>Reactor Coolant Flow Per Loop, gpm</td>
<td>88,500</td>
<td>100,500</td>
<td>125,000</td>
</tr>
<tr>
<td>Primary System Operating Pressure, psia</td>
<td>2250</td>
<td>2250</td>
<td>2250</td>
</tr>
<tr>
<td>Steam Pressure, psia</td>
<td>832</td>
<td>1000</td>
<td>1118</td>
</tr>
<tr>
<td>Steam Flow Per Loop, Mlb/hr</td>
<td>3.4</td>
<td>4.1</td>
<td>5.1</td>
</tr>
<tr>
<td>Total RCS Volume, cu.ft.</td>
<td>9343</td>
<td>12,265</td>
<td>16,245</td>
</tr>
<tr>
<td>Pressurizer Volume, cu.ft.</td>
<td>1300</td>
<td>1800</td>
<td>2649</td>
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<tr>
<td>SG Secondary Inventory at Full Power, Ibm</td>
<td>87,700</td>
<td>101,000</td>
<td>182,000</td>
</tr>
</tbody>
</table>
NSSS System Designed to Reduce Welds

<table>
<thead>
<tr>
<th>Typical Number of Welds</th>
<th>US EPR</th>
<th>’70s Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reactor Vessel</td>
<td>5</td>
<td>19</td>
</tr>
<tr>
<td>Steam Generators(4)</td>
<td>32</td>
<td>92</td>
</tr>
<tr>
<td>Pressurizer</td>
<td>4</td>
<td>15</td>
</tr>
<tr>
<td>Primary Piping</td>
<td>52</td>
<td>92</td>
</tr>
<tr>
<td></td>
<td>93</td>
<td>218</td>
</tr>
</tbody>
</table>

**U.S. EPR**
- All forged parts (large forgings)
- Only circumferential welds

**Older Plants**
- Rolled plate steel and castings
- Longitudinal and circumferential welds

**Reactor Vessel Nozzle Shell**
*Single-Piece Forging*
U.S. EPR – Lower Maintenance Cost
Component Comparison with a Typical 4-Loop U.S. Unit

<table>
<thead>
<tr>
<th>COMPONENT TYPES</th>
<th>EPR</th>
<th>4-LOOP PWR</th>
<th>% Change (Absolute)</th>
<th>% Change (Count/MWe)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pumps &amp; Turbines</td>
<td>43</td>
<td>37</td>
<td>16</td>
<td>(16)</td>
</tr>
<tr>
<td>Heat Exchangers</td>
<td>34</td>
<td>44</td>
<td>(23)</td>
<td>(44)</td>
</tr>
<tr>
<td>Tanks</td>
<td>23</td>
<td>33</td>
<td>(30)</td>
<td>(50)</td>
</tr>
<tr>
<td>Valves</td>
<td>2,044</td>
<td>2,766</td>
<td>(26)</td>
<td>(47)</td>
</tr>
</tbody>
</table>

* Information based on AREVA study of Modern 4-Loop facility

MIT: Cambridge, Massachusetts – April 12, 2006
Selected Key Features of the U.S. EPR
**Double-Walled Containment**

- Inner wall pre-stressed concrete with steel liner
- Outer wall reinforced concrete
- Protection against airplane crash
- Protection against external explosions
- Annulus sub-atmospheric and filtered to reduce radioisotope release
Each safety train is independent and located within a physically separate building.
Severe Accident Mitigation:
Views of Corium Spreading Area & IRWST
Operator-Friendly Man-Machine Interface

Capitalizing on nuclear digital I&C operating experience and feedback
U.S. EPR Design Certification

The U.S. is an integral element of the global EPR strategy
Global EPR Standardization

- **Objective:** Globally standardize the EPR design to the extent possible, given the constraints of country-specific codes, standards and regulations.

- **Advantages**
  - Common design philosophy
  - Shared lessons learned and good practices
  - Plant services standardization
  - Economies of production
  - Opportunities for international regulatory cooperation

- **Changes for U.S. design must meet specified criteria:**
  - Changes to meet U.S. codes & standards
  - Changes to meet U.S. regulatory requirements
  - Changes to meet U.S. utility market requirements and customer needs
  - Example: U.S. grid frequency and voltages
EPR Design Conversion

OL3

U.S. Licensing and Design Basis

U.S. EPR Design

U.S. QA Codes & Standards
Design Control
Approved Methods
U.S. EPR Project Summary

- U.S. Design Authority established
- OL3 design transfer complete
- DC project underway
  - Work Breakdown Structure established (SSC-based to facilitate expansion for COL and construction projects)
  - Integrated, resource loaded P3 design certification schedule (~4500 activities) established
  - Global EPR design standardization configuration management practices implemented
  - Incorporation of U.S. codes & standards on going

The U.S. EPR is an American engineered and managed project.
Summary: U.S. EPR Design Advantages

- EPR is evolutionary
- Most features are typical of operating PWRs
- Enhanced Features included to:
  - Improve performance
  - Increase redundancy & separation
  - Reduce core damage frequency
  - Mitigate severe accident scenarios
  - Protect critical systems from external events
  - Reduce O&M costs
  - Reduce fuel costs

- NRC Design Certification Underway
EPR Projects: Olkiluoto 3 and Beyond

Building a global fleet of EPRs
Olkiluoto 3: June 2005

Nuclear Island foundation outline
Olkiluoto 3: October 2005

Bottom section of containment liner assembled and placed on staging pad
Olkiluoto 3: RCS Hot Leg Manufacturing
Olkiluoto 3: February 2006

Panoramic view of site showing winter shelter
Olkiluoto 3: Component Fabrication

Steam Generator Housing & Tube Sheet Welding
Flamanville 3

Construction start 2007; Operational 2012
AREVA Activity in China

4 AREVA plants in service

6 AREVA plants ordered or planned

4 EPR plants currently being considered
.... 1st US EPR Design Could be 7th in the Series
UniStar Nuclear
What is UniStar Nuclear?

- A new and unique business model for U.S. nuclear industry enabled by passage of Energy legislation

- Joint venture between Constellation Energy and AREVA that offers a business framework leading to the development of future joint ventures

- Joint ventures would license, construct, own and operate nuclear power plants as part of a standardized fleet

- A “one-stop shop” approach with AREVA (design), Bechtel (construction) and Constellation Energy (operation)

Best available platform to reduce the risks, costs, and uncertainty of new nuclear.
UniStar Business Model
Objective - Deploy a fleet of at least four identical U.S. EPRs

Standardization of fleet yields efficiencies in project cost, licensing, and operations

- Projects jointly developed with Constellation
- UniStar Nuclear Operations will be licensee and operator
- Project Company Partners will participate in
  - ESP/COL
  - Development/construction
  - Ownership/operation/maintenance
- AREVA is Prime Contractor for Project Companies
- Bechtel is AREVA’s Constructor / Architect Engineer

Same operator/licensee, NSSS vendor, and A-E /constructor ensures fleet standardization.
Fleet Benefits Realized by Constellation Energy

Since 2002
- Electrical generation increased by 12%
- Production costs decreased by 12%
- Safety performance at all-time high

The business value of a nuclear power fleet is proven by experience.
UniStar Nuclear: Fleet Benefits of a Standardized Design

- Engineering (initial and operating)
- Licensing (COL and operating)
- Construction productivity
- Operator training & Maintenance task training (specialized crews)
- Shared resources during Refueling Outages
- Work practices & procedures
- Reduced/common spare parts
- Information systems

Preliminary analyses show one-time savings of over $500M per plant and on-going savings of over $20M annually per plant
New Nuclear: a three-step decision process

1. Commitment to COL Application
2. Procurement of Long-lead time materials
3. Construction

Initial commitment needed:
- Select a site
- Commit to COL application via LOI

Constellation’s NRC LOI committing to a COLA for the 1st U.S. EPR was submitted 11/4/2005
Summary

- Strong positive environment for new U.S. Nuclear Construction
  - Global energy demand
  - Favorable regulatory climate
- AREVA is firmly committed to the U.S. Nuclear Renaissance
  - Certification of U.S. EPR Design
  - UniStar Joint Venture

It is an exciting time to be entering the U.S. Nuclear Industry!
For Additional Information…

http://www.areva.com/
http://www.areva-np.com/
http://us.areva.com/
http://www.arevacareers.com/

Or

Please join us for a reception tonight at
The Asgard Pub
350 Mass. Ave
5:30 – 7:00 PM

Thank you!