Nuclear Renaissance:
The Resurgence of Nuclear Energy

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Director, Nuclear Programs, University of Pittsburgh
Chief Scientist Emeritus, Bettis Laboratory
World View of Nuclear Energy
World View of Nuclear Energy

- 440 nuclear power plants
- 16% of world’s electricity
- Displaces 2.5 billion metric tons of CO₂/year
Substantial New GW (gigawatt = 1 million kilowatts) Targets

<table>
<thead>
<tr>
<th>Country</th>
<th>Operating (GW)</th>
<th>Under Construction (GW)</th>
<th>Target (GW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>7</td>
<td>2.0</td>
<td>36 by 2020</td>
</tr>
<tr>
<td>India</td>
<td>3</td>
<td>4</td>
<td>24 by 2020</td>
</tr>
<tr>
<td>Japan</td>
<td>45</td>
<td>3.2</td>
<td>15 on order or planned by 2015</td>
</tr>
<tr>
<td>Russia</td>
<td>22</td>
<td>1.9</td>
<td>15-25 additional by 2020</td>
</tr>
<tr>
<td>South Korea</td>
<td>16</td>
<td>8.8</td>
<td>10 additional by 2015</td>
</tr>
</tbody>
</table>
## Plants and Capacity Factors

<table>
<thead>
<tr>
<th>Country</th>
<th>Number</th>
<th>% CF</th>
<th>% of Total Generation</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>103</td>
<td>92</td>
<td>20</td>
</tr>
<tr>
<td>France</td>
<td>59</td>
<td>88</td>
<td>78</td>
</tr>
<tr>
<td>Japan</td>
<td>52</td>
<td>70</td>
<td>34</td>
</tr>
<tr>
<td>Russia</td>
<td>30</td>
<td>68</td>
<td>17</td>
</tr>
<tr>
<td>Canada</td>
<td>21</td>
<td>64</td>
<td>13</td>
</tr>
<tr>
<td>South Korea</td>
<td>19</td>
<td>92</td>
<td>40</td>
</tr>
<tr>
<td>China</td>
<td>9</td>
<td>79</td>
<td>2</td>
</tr>
<tr>
<td>Taiwan</td>
<td>6</td>
<td>88</td>
<td>22</td>
</tr>
<tr>
<td>Mexico</td>
<td>2</td>
<td>79</td>
<td>5</td>
</tr>
</tbody>
</table>
World View

- Global electricity demand to increase 50% by 2025
  - 1.6%/yr for industrial world
  - 3.6%/yr for developing world
Environment

**Nuclear**
- Limits greenhouse gas emissions

**Cause of Disruption**
- Emissions from CO₂ from fossil fuel
- Fossil fuel
  - 80% of world’s energy
  - 80% of new capacity brought on line in 2003

**Global Average Temperature**

- Global Emissions and Atmospheric Concentration of CO₂

- Atmospheric concentrations measured directly
- Atmospheric concentrations derived from ice cores

- Emissions (MMTC)
- Atmospheric Concentration (ppm)

Source: NASA’s Goddard Institute for Space Studies

Source: Carbon Dioxide Information Analysis Center
Environment

2 x CO$_2$ of Existing Levels

4 x CO$_2$ of Existing Levels

Temperature Rise

2030

2100

EPRI
U.S. View
U.S. View of Nuclear Energy

- Quick facts
  - 104 nuclear plants
  - 20% of the nation’s electricity

- Displaces 680 million metric tons of CO$_2$/yr
- Equivalent to 131 million passenger cars/yr
U.S. Nuclear Drivers

- Safe
- Proven performance
- Cost effective
- Affordable
- Energy security/energy independence
- Base load generation/grid stability
- Emission-free
Nuclear has best safety record

Deaths from Accidents from Generating Electricity per Billion MWe-hr

- Hydro: 101
- Coal: 39
- Gas: 10
- Nuclear: 1

400-page study of 4,290 energy-related accidents: 15,000 deaths related to oil, 8,000 related to coal, 5,000 related to gas.

*Includes Chernobyl

Paul Scherrer Institute, Switzerland, 2001
United States Nuclear Power’s Proven Performance

Source: Energy Information Administration/Nuclear Regulatory Commission
United States Cost Effective (in constant cents/kWh)

Source: Federal Energy Regulatory Commission /EUCG
Fossil Fuel Supplies

- Western World must reduce their dependence on oil
  - Limit influence on foreign policy
  - Reduce cost to economy of oil price shocks
  - Reduce greenhouse gas emissions
  - Prepare for inevitable resource depletion
  - Husband oil for other uses

- Reducing oil use is not a solution to terrorism but it may help
Consolidation of Nuclear Ownership

- Corporate M&A
- Asset sales by companies desiring to exit nuclear ownership

Last 5 years
- Substantial consolidation
- Top 10 operators have 61% of nuclear market
- Top 5 operators have 42% of nuclear market

1990
50 companies operated 112 nuclear plants

2000
27 companies operating 103 nuclear plants

2005
27 companies operating 103 nuclear plants
## Top U.S. Nuclear Owners

<table>
<thead>
<tr>
<th>Company</th>
<th>Total Nameplate Capacity (MW)</th>
<th>Recent Acquisitions (MW)</th>
<th>Percent of U.S. Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exelon Corp.</td>
<td>15,557</td>
<td>2,329</td>
<td>16</td>
</tr>
<tr>
<td>Entergy Corp.</td>
<td>9,010</td>
<td>3,998</td>
<td>9</td>
</tr>
<tr>
<td>Tennessee Valley Authority</td>
<td>6,695</td>
<td>—</td>
<td>7</td>
</tr>
<tr>
<td>Dominion Resources, Inc.</td>
<td>5,175</td>
<td>2,576</td>
<td>5</td>
</tr>
<tr>
<td>Duke Energy Corp.</td>
<td>5,020</td>
<td>—</td>
<td>5</td>
</tr>
<tr>
<td>FPL Group, Inc.</td>
<td>3,962</td>
<td>1,581</td>
<td>4</td>
</tr>
<tr>
<td>FirstEnergy Corp.</td>
<td>3,760</td>
<td>—</td>
<td>4</td>
</tr>
<tr>
<td>Constellation Energy Group, Inc.</td>
<td>3,748</td>
<td>2,045</td>
<td>4</td>
</tr>
<tr>
<td>Southern Co.</td>
<td>3,598</td>
<td>—</td>
<td>4</td>
</tr>
<tr>
<td>Progress Energy, Inc.</td>
<td>3,597</td>
<td>—</td>
<td>4</td>
</tr>
<tr>
<td>All others</td>
<td>39,090</td>
<td>—</td>
<td>39</td>
</tr>
<tr>
<td>Total</td>
<td>99,210</td>
<td>12,529</td>
<td>100</td>
</tr>
</tbody>
</table>
Utility Stock Performance

Indexed Stock Price Performance

- Nuclear Focus: 107%
- Non-Nuclear Focus: 43%

Jan-00 Feb-01 Mar-02 May-03 Jun-04 Aug-05

Nuclear Focus  Non-Nuclear Focus
## Financial Repercussions of Nuclear Announcements

<table>
<thead>
<tr>
<th>Company</th>
<th>Stock Price before announcement</th>
<th>Stock Price at close on Dec 5, 2006</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constellation Energy Group, Inc.</td>
<td>$53.85 (10/26/05)</td>
<td>$70.10</td>
<td>30</td>
</tr>
<tr>
<td>Duke Energy Corp.</td>
<td>$27.45 (2/15/05)</td>
<td>$32.69</td>
<td>19</td>
</tr>
<tr>
<td>Entergy Corp.</td>
<td>$72.25 (9/21/05)</td>
<td>$91.95</td>
<td>27</td>
</tr>
<tr>
<td>Exelon Corp.</td>
<td>$61.30 (9/28/06)</td>
<td>$62.43</td>
<td>2</td>
</tr>
<tr>
<td>FPL Group, Inc.</td>
<td>$40.14 (3/31/06)</td>
<td>$53.90</td>
<td>34</td>
</tr>
<tr>
<td>NRG Energy</td>
<td>$47.13 (6/20/06)</td>
<td>$58.63</td>
<td>24</td>
</tr>
<tr>
<td>Pinnacle West</td>
<td>$40.12 (5/17/06)</td>
<td>$50.00</td>
<td>25</td>
</tr>
<tr>
<td>Progress Energy, Inc.</td>
<td>$43.06 (8/26/05)</td>
<td>$48.70</td>
<td>13</td>
</tr>
<tr>
<td>SCANA</td>
<td>$41.73 (8/23/05)</td>
<td>$41.91</td>
<td>0.4</td>
</tr>
<tr>
<td>Southern Co.</td>
<td>$33.04 (5/11/05)</td>
<td>$36.71</td>
<td>11</td>
</tr>
<tr>
<td>TXU</td>
<td>$65.00 (8/30/06)</td>
<td>$57.80</td>
<td>-11</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td></td>
<td></td>
<td><strong>16</strong></td>
</tr>
</tbody>
</table>
U.S. Energy Demand

America Is Projected to Need 50% More Electricity by 2025

Source: U.S. Department of Energy
United States vs. Global Nuclear Capacity Additions 1960-2008

- Rest of World
- United States

GW

0 5 10 15 20 25 30 35

Capacity Brought on Line by Fuel Type (1950-2002)

Source: RDI PowerDat database. Last updated 9/15/03.
Reactor Technologies

Gen III+  Gen IV

Today’s Designs  Future Designs
Today’s New Design—*Generation III*+

**Advanced Light Water Reactors (ALWRs)**

- Simplified design
- Passive or redundant systems to enhance safety
- Standardized designs based on modularization producing shorter construction schedules
- Enhanced resistance to proliferation
Today’s New Design—Generation III+ ALWR

- General Electric ➔ ESBWR
- TOSHIBA/
  Westinghouse ➔ AP 1000
- AREVA/
  Framatome-ANP ➔ EPR
Westinghouse—AP 1000 (1,148 MWe)

- Passive safety systems permit simplification and improve safety
- Modularization reduces construction schedule
- NRC design certification provides regulatory certainty:
  - AP 600—December 1999
  - AP 1000—January 2006
## Status of Reactor Designs

### Applications for Design Certification

<table>
<thead>
<tr>
<th>Generation III</th>
<th>Design</th>
<th>Vendor</th>
<th>Type</th>
<th>Design Certification Status</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ABWR</td>
<td>GE Nuclear</td>
<td>BWR</td>
<td>Approved</td>
</tr>
<tr>
<td></td>
<td>System 80+</td>
<td>Westinghouse</td>
<td>PWR</td>
<td>Approved</td>
</tr>
<tr>
<td></td>
<td>AP-600</td>
<td>Westinghouse</td>
<td>PWR</td>
<td>Approved</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Generation III +</th>
<th>Design</th>
<th>Vendor</th>
<th>Type</th>
<th>Design Certification Status</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AP-1000</td>
<td>Westinghouse</td>
<td>PWR</td>
<td>Certification January 2006</td>
</tr>
<tr>
<td></td>
<td>ESBWR</td>
<td>GE Nuclear</td>
<td>BWR</td>
<td>Application—August 2005 Certification—2008</td>
</tr>
<tr>
<td></td>
<td>EPR</td>
<td>Framatome ANP</td>
<td>PWR</td>
<td>Application—August 2007 Certification—June 2010</td>
</tr>
</tbody>
</table>
Future Designs—Generation IV - ARS

- Technology (VHTR)
  - Top priority ➔ Next Generation Nuclear Plant
    - High temperature
    - Passive safety
    - Improved economics
    - Demonstrates hydrogen production
    - High efficiency direct-cycle electricity production
    - Nonproliferation
  - Technology suppliers
    - PBMR (Pty) Ltd. ➔ Pebble Bed Modular Reactor (PBMR)
    - AREVA/Framatome ➔ ANTARES
    - General Atomics ➔ GT-MHR
The Energy Policy Act of 2005
Nuclear

- Loan guarantees
- Risk assurance
- Production tax credit
- Price-Anderson
- Decommissioning funds

- Next generation nuclear plant
- Nuclear hydrogen production
- Advanced fuel cycle initiative
- Nuclear engineering program
- Medical isotopes
# New Plant Construction

## Key Provisions

| Loan guarantees | 80% of project cost | ▪ Higher leverage  
▪ Lower debt cost |
|-----------------|---------------------|---------------------|
| Production tax credit | $18/MW hr | ▪ Through 2021  
▪ $125M/1000 MW per year  
▪ 6,000 MW eligible  
▪ IRS rule making: February 2006 |
| Risk assurance | Delay protection | ▪ $500M for 1st 2 plants  
▪ $250M for next 4 plants  
▪ Final rules: August 2006 |
| Price-Anderson | Nuclear liability insurance | ▪ Reauthorization for 20 years |
| Decommissioning funds | Updates for treatment | ▪ Allows companies to establish funds and make contributions  
▪ Allows transfer of nonqualified funds to qualified funds |
The Licensing Process
Old Process

Two-step licensing process (10 CFR 50)

Construction License

Build Plant

Operating License Proceedings

Operating License Issued

Operation

Opportunity for intervention, hearings, and delay

15 Years
New Process Combined licensing process (10 CFR 52)

- ESP: Early Site Permit
- D.C.: Standard Design Certification

Combined Construction and Operating License (COL)

Build Plant

ITAAC: Verification of Inspections, Tests, Analysis, and Acceptance Criteria

Operations

* Opportunity for public comment
** Opportunity for hearing

9 Years
New U.S. Licensing Process

Early Site Permit (ESP)

1. 

2. Design Certification

3. Combined Construction and Operating License (COL)
Early Site Permits

- Site approval obtained before a utility decides to build a new plant
- Utility “banks” site up to 20 years
- Decision made, design chosen later
- Reduces risk to a utility
Design Certification

- Provides NRC’s advanced approval of a reactor design
- Lengthy delays avoided before site preparation and construction begins
Combined Construction and Operating License

- One license for building and operating a new nuclear power plant
- Early focus of public comment
- Intended to provide greater regulatory certainty
Timeline to New Nuclear Construction

Best-Case Scenario

- Early Site Permit
- Design Certification
  - W—AP 1000
- Design Certification
  - GE—ESBWR
- Design Certification
  - AREVA—EPR
- Construction and Operating License (COL)
- Construction


- Technical
- NRC Rulemaking
- Prep.
- Technical
- NRC Rulemaking
- Prep.
- NRC Application
- Site Prep
- Construction
U.S. Path Forward
Evidence of U.S. Nuclear Revival

- **Energy Policy Act of 2005**
  - Supports nuclear energy as a major component of national energy policy

- **Nuclear Power 2010 program**
  - Cost sharing initiative between industry and government for new deployment

- **Several utilities developing ESPs and COL applications for new reactors**
Evidence of U.S. Nuclear Revival

- Browns Ferry #1 restart
  - Tennessee Valley Authority
    - 1,280 MWe
    - Applied for 20-year license renewal
    - 100% power June 2007
    - on budget
Evidence of U.S. Nuclear Revival—
License Renewals

- 48 Granted
- 26 Renewal Intent
- 20 Not Announced

48

Renewal Application

26

Renewal Application

20

Renewal Application

10

Renewal Application

10

In NRC Review

Renewal Application

Renewal Application

Renewal Application
Evidence of U.S. Nuclear Revival

Increasing Public Support

- **Important for our energy future**: 83%
- **Favor use of nuclear energy**: 70%
- **Keep the option to build nuclear plants**: 74%
- **Definitely build nuclear plants in future**: 58%
- **Accept new reactors at nearest plant**: 69%

Source: Bisconti Research Inc.
Companies have yet to announce locations of four sites where they may seek to build one reactor each.

New Plants on the Way?

A handful of utility companies have expressed interest in building new nuclear power plants. But none have made a firm commitment yet, and industry experts doubt that more than a few of the 27 possible new reactors identified by the Nuclear Regulatory Commission will be built anytime soon. At least initially, any new reactors are expected to be added to existing nuclear power sites.
U.S. Nuclear Industry—First Movers

- Constellation Calvert Cliffs
- Dominion North Anna
- TVA Bellefonte
- Duke Carolina Plant
- Southern Vogtle
- Entergy Grand Gulf
- Southern Hatch
- Progress Energy Crystal River
- Entergy River Bend
- Southern Vogtle
- TVA Bellefonte
- Duke Carolina Plant
- Southern Vogtle
- Entergy Grand Gulf
### Existing or Expected ESP / COL Applications in the U.S.

<table>
<thead>
<tr>
<th>Reactor Type</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>AP1000 (Westinghouse)</td>
<td>11</td>
</tr>
<tr>
<td>EPR (AREVA)</td>
<td>5</td>
</tr>
<tr>
<td>ABWR &amp; ESBWR (GE)</td>
<td>7</td>
</tr>
<tr>
<td>TBA</td>
<td>10</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>33</strong></td>
</tr>
</tbody>
</table>

Source: Nuclear News, January, 2007
Challenges

1. Financial markets
2. Continued Safe Operation
3. Lack of agility (construction time, licensing risk)
4. Infrastructure (workforce, lack of momentum, equipment suppliers)
5. Waste / transport
6. Safety culture tuning and the never-ending challenges (DB, TEPCO, Tokaimura)
7. Public perceptions (safety, security, terrorism, proliferation)
Current Top Issues

1. Accelerating the opening of Yucca Mountain.
2. Creating interim storage sites for spent commercial nuclear fuel.
3. Accelerating R&D and construction funding of prototype advanced reactors.
4. Testing the new licensing procedure.
5. Committing to deployment of a closed fuel cycle, as outlined in the administration's GNEP proposal.
6. Expanding federal funding to train the next generation nuclear workforce.
7. Rebuilding the nation’s infrastructure to manufacture large reactor components.
Questions?
You can't turn back the clock,

"but you can wind it up again."

Bonnie Prudden