Kansas State University
Energy, Environmental Impacts and Sustainability Intersession Course Workshop

Nuclear Energy

Dr. Lawrence F. Drbal

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Agenda

- Nuclear Energy’s Current Status
- What’s Pushing Nuclear Power’s Resurgence?
- New Advanced and Passive Designs
- Department of Energy (DOE) 2010 Initiative
- Summary
Nuclear Energy’s Current Status

- Coal – 51%
- Nuclear – 20%
- Gas – 16.5%
- Hydro – 7.2%
- Oil – 3.1%
- Renewables – 2.2%

Source: NEI

- Coal – 51%
- Nuclear – 20%
- Gas – 16.5%
- Hydro – 7.2%
- Oil – 3.1%
- Renewables – 2.2%

Source: NEI
## State’s Percentage of Total Electricity Generation (2002)

<table>
<thead>
<tr>
<th>State</th>
<th>Nuclear</th>
<th>Coal</th>
<th>Gas</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arkansas</td>
<td>31.32</td>
<td>52.48</td>
<td>5.74</td>
<td>10.46</td>
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<tr>
<td>Connecticut</td>
<td>50.60</td>
<td>12.25</td>
<td>13.41</td>
<td>23.74</td>
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<tr>
<td>Iowa</td>
<td>9.48</td>
<td>85.26</td>
<td>1.46</td>
<td>3.80</td>
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<tr>
<td>Illinois</td>
<td>51.53</td>
<td>44.38</td>
<td>2.57</td>
<td>1.52</td>
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<tr>
<td>Kansas</td>
<td>23.12</td>
<td>70.99</td>
<td>4.36</td>
<td>1.53</td>
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<tr>
<td>Missouri</td>
<td>10.54</td>
<td>82.66</td>
<td>4.87</td>
<td>1.93</td>
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<tr>
<td>Nebraska</td>
<td>28.62</td>
<td>66.39</td>
<td>1.14</td>
<td>3.85</td>
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<tr>
<td>New Hampshire</td>
<td>57.66</td>
<td>24.59</td>
<td>0.79</td>
<td>17.67</td>
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<tr>
<td>New Jersey</td>
<td>51.28</td>
<td>15.68</td>
<td>28.12</td>
<td>4.92</td>
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<td>South Carolina</td>
<td>55.93</td>
<td>41.16</td>
<td>1.32</td>
<td>1.59</td>
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<td>Vermont</td>
<td>76.11</td>
<td>0.0</td>
<td>0.20</td>
<td>23.69</td>
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<table>
<thead>
<tr>
<th>Type</th>
<th>Operating Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiling Water Reactors (BWR)</td>
<td>35</td>
</tr>
<tr>
<td>Pressurized Water Reactors (PWR)</td>
<td>69</td>
</tr>
<tr>
<td>Total</td>
<td>104</td>
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</table>
Schematic for a Pressurized Water Reactor

- Containment Building
- Pressurizer
- Steam Generator (2 to 4 Typical)
- Saturated Steam
- HP LP LP
- Condenser
- Feedwater
- Feed Pump
- Condensate Pump
- Pressure Vessel
- Reactor Core
- Control Rods
- Reactor Coolant Pump
- LDB(6) - 8
- 01/04/06
Schematic for a Boiling Water Reactor

- Containment Building
  - Pressure Vessel
  - Moisture Separators and Steam Dryers
  - Reactor Core
  - Reactor Containing Fuel Assemblies
  - Control Rods
  - Feedwater

- Saturated Steam
  - HP
  - LP

- Condenser
- Feed Pump
- Condensate Pump
Fissioning Process – Uranium 235

U-235 + Neutron (n) \(\not\equiv\) Fission Products (FP) + Xn

\[ \Delta M = \text{Mass (U-235)} + \text{Mass (n)} - \text{Mass (FP)} - \text{Mass (Xn)} \neq 0 \]

Energy Released = \(\Delta MC^2 \approx 200\) Mev / Fission

Energy Released From Combustion Process\(^1\): \(\approx 2\) ev / Reaction

1. C + O\(_2\) \(\not\equiv\) CO\(_2\)

Note: 1 ev = 1.52 x 10\(^{-22}\) Btu
Annual Fuel Requirements for 1000 MWe Plant

- 2,000,000 mTons of Coal
- 1,960,000,000 Gallons of Oil
- 30 mTons of Uranium
- 0.6 mTons of Tritium and Hydrogen (Fusion)
What’s Pushing Nuclear Power’s Resurgence?
Nuclear Power Growth Projections

- Anticipated Growth in Demand for Baseload Capacity
- High and Rising Cost of Natural Gas
- Global Warming Concerns
- Energy Consumption From Nuclear to Increase 50% by 2025 Just to Maintain Status Quo
- Equates to 50,000 MWe of New Nuclear Generation
- 30-35 New Nuclear Units (1,500 MWe Each)
Building Momentum for Additional Nuclear Plants

- Non Emitting Source of NO\textsubscript{x}, SO\textsubscript{2} and CO\textsubscript{2} (Global Warming)
- Well Suited for Hydrogen Production
- Proven Performance and Safety
- Improved Regulatory Oversight and Licensing (One-Step Process)
- Growing Support From Utilities, Wall Street, Media and Policy Makers
- Supportive Administration
- Passage of Energy Policy Act of 2005 Provides for Loan Guarantees, Production Tax Credits and Risk Insurance
Momentum “Deflators” for New Nuclear Additions

- Spent Fuel Disposal / DOE License Application for Yucca Mountain Repository (Nevada) Pushed Into 2006
- Economics / Demonstrate a 48-Month or Better Construction Schedule
- Transportation of Spent Fuel
- Change in Political Landscape
New Licensing Process (10 CFR Part 52)

- Design Certification of Standard Plant Designs by NRC
- Early Site Approval Prior to Build Decision
- Combined License for Construction and Operation (COL) Prior to Major Construction
New Advanced and Passive Designs
Advanced Reactor Designs

- **Evolutionary**
  - Additional Active Safety Divisions
  - Lower Probability of Accident
  - GE’s Advanced Boiling Water Reactor (ABWR)
  - Areva’s European Pressurized Reactor
  - Westinghouse 80+

- **Passive**
  - No Active Cooling System for Reactor Isolation or Accident Mediation
  - Passive Systems (Natural Circulation, Gravity)
  - Replace Active Systems
  - Westinghouse AP 600, AP 1000
  - GE’s Economic Simplified Boiling Water Reactor (ESBWR)
Advanced Boiling Water Reactor (ABWR)

- 1350 MWe Reactor
- 3-50% Capacity Safety Divisions Each With a Dedicated Diesel Generator
- 60-Year Operating Life
- 87% Plant Availability
- Certified Standard Design by NRC
Advanced Boiling Water Reactor

Active Safety…
Advanced Boiling Water Reactor

WE BRING IT ALL TOGETHER
Areva European Pressurized Reactor (EPR)

- 1600 MWe Reactor
- 4-100% Capacity Safety Divisions Each With a Dedicated Diesel Generator
- 60-Year Operating Life
- 36% Plant Efficiency
- Submitting Standard Design for NRC Certification
Four Independent Safety Trains in Separate Buildings

- Four Trains, Each 100%, Provide Redundancy for Maintenance or Single-Failure Criterion
- Physical Separation Against Internal Hazards (e.g. Fire)
- Shield Building Extends Airplane Crash and External Explosion Protection to Two Safeguard Buildings and Fuel Building
Westinghouse Advanced Passive (AP) 1000 MWe System

- 1000 MWe Reactor
- Passive Reactor Core Cooling System
- Passive Containment Cooling System
- Major Reduction in Safety Related Pumps, Valves, Piping and Electrical Components
- 60-Year Operating Life
- Expect Standardized Plant Certification From NRC Soon
AP1000...Westinghouse New Standardized Passive Plants

- Mature
- Safe
- Simple
- Affordable
Passive Decay Heat Removal
Simplification of Safety Systems Dramatically Reduces Building Volumes

Standard PWR

AP1000
GE Economic Simplified Boiling Water Reactor (ESBWR)

- 1500 MWe Reactor
- Natural Circulation (No Recirculation Pump)
- Passive Safety Systems
- Major Reduction in Safety Related Pumps, Valves, Piping and Electrical Components
- 60-Year Operating Life
- Submitted Standard Design for NRC Certification
GE Economic Simplified Boiling Water Reactor (ESBWR)

Passive Safety…
Department of Energy (DOE) 2010 Initiative
DOE Nuclear Power 2010 Initiative

- Establishing Conditions Needed to Start Construction
- Demonstrating Early Site Permit Process
- Demonstrating NRC Combined Licensing (COL) Processes
Early Site Permit Applications

- Dominion North Anna Site (Virginia)
- Exelon Clinton Site (Illinois)
- Entergy Grand Gulf Site (Mississippi)
<table>
<thead>
<tr>
<th>Consortium Lead</th>
<th>Potential COL Application</th>
<th>Reactor Design</th>
<th>Site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dominion</td>
<td>2006</td>
<td>ESBWR</td>
<td>North Anna</td>
</tr>
<tr>
<td>NuStart*</td>
<td>2006</td>
<td>AP1000</td>
<td>TVA / Bellefone</td>
</tr>
<tr>
<td></td>
<td>2007</td>
<td>ESBWR</td>
<td>Grand Gulf</td>
</tr>
<tr>
<td>TVA (Study)</td>
<td>--</td>
<td>ABWR</td>
<td>TVA / Bellefone</td>
</tr>
</tbody>
</table>

*Entergy, Exelon, Southern, Constellation, Duke, Tennessee Valley Authority, Progress, Florida Power & Light, EDF, Westinghouse, GE (B&V), Bechtel.*
### Other Potential COL Applications

<table>
<thead>
<tr>
<th>Utility</th>
<th>Potential COL Application</th>
<th>Reactor Design</th>
<th>Site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entergy</td>
<td>2007</td>
<td>ESBWR</td>
<td>River Bend</td>
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<tr>
<td>UniStar*</td>
<td>2008</td>
<td>EPR</td>
<td>Calvert Cliffs / NMP</td>
</tr>
<tr>
<td>Duke</td>
<td>2006</td>
<td>AP1000</td>
<td>Greenfield</td>
</tr>
<tr>
<td>Southern Nuclear</td>
<td>2008</td>
<td>AP1000 or ESBWR</td>
<td>Vogtle</td>
</tr>
<tr>
<td>Progress Energy</td>
<td>2 – 2008</td>
<td>TBD</td>
<td>Florida or Carolinas</td>
</tr>
</tbody>
</table>

* Constellation Energy and AREVA.
Summary
Summary

- 20% of U.S. Electrical Generation Is Nuclear
- Nuclear Power Is Undergoing a Resurgence
- Nuclear Is a Non-Fossil Fuel Source (No NOx, SO2 or CO2)
- Projections Show 30-35 New Plants by 2025
- New Plants Will Include the ABWR, EPR, AP1000 and ESBWR Designs
- Nuclear Engineers Will Be Needed
  - New Plant Design / Construction
  - Replace Retiring Engineers