Prospects for Nuclear Energy: Clear Skies or Stormy Weather?

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Presentation to Short Course on Physics of Sustainable Energy
EPIC, University of Chicago
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Agenda

- How Risky is Nuclear Power?
- What Role Can Nuclear Power Play in Countering Climate Change and Generating a Greater Proportion of Global Electricity?
- What is the Status of Nuclear Operations in the U.S.?
- What are the Barriers to New Nuclear Power Plants’ Construction?
- What are the Financial and Utility Regulatory Considerations?
- What is the Effect of Shale Natural Gas?
- What are the Global Implications of the Fukushima Daiichi Accident?
- Can Small Modular Reactors Revive Nuclear Power?
- What Can and Should be Done with Spent/Irradiated Fuel and Associated Nuclear Waste?
There will always be risk

“... there is no way to eliminate all risk entirely ... despite all the design improvements that we conceive, systems still fail; despite all the training and lessons learned in exercises that are conducted, human beings will still make mistakes, particularly when confronted with once-in-a-lifetime events.”

Dr. Richard Meserve, Former NRC Chairman and Chairman of International Nuclear Safety Advisory Group, remarks in response to Fukushima accident
Will Fission Reactors be Phased Out?

"I’ve never seen a movie that’s set 200 years in the future and the planet is being powered by fission reactors—that’s nobody’s vision of the future. This is not a future technology. It’s an old technology, and it serves a useful purpose. But that purpose is running its course."

Former NRC Chairman Gregory Jaczko, as quoted in IEEE Spectrum in 2013
Greening of Nuclear Industry

- Nuclear Energy Institute promotional ads
- Presidential support for growing “clean nuclear energy”
Nuclear Energy’s Contribution to Improving Energy Security and Cleaner Air

How much nuclear growth will be needed to provide “cleaner” electricity for transportation?

- Would need an additional 700 GWe or about 700 new 1,000 MWe nuclear reactors to fill one “wedge”
Can Nuclear Power Provide More Electricity?
Global electricity demand is estimated to nearly double by 2030, with nuclear power currently accounting for about 15 percent of global use.

**Global Electricity Demand**
(in billion kilowatt hours)

<table>
<thead>
<tr>
<th>Year</th>
<th>Electricity Demand</th>
</tr>
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<tbody>
<tr>
<td>2005</td>
<td>15,750</td>
</tr>
<tr>
<td>2010</td>
<td>19,050</td>
</tr>
<tr>
<td>2015</td>
<td>21,700</td>
</tr>
<tr>
<td>2020</td>
<td>24,370</td>
</tr>
<tr>
<td>2025</td>
<td>27,130</td>
</tr>
<tr>
<td>2030</td>
<td>30,120</td>
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</tbody>
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For nuclear to do nothing more than maintain its current share of global electricity to 2030—15 percent—a 1,000-megawatt reactor must be built...

...every 16 days for the next 21 years.

Can Nuclear Power Reduce Emissions?
Annual emissions of greenhouse gases are similarly expected to double by 2050, from a current 7 billion tons of carbon dioxide each year to more than 14 billion tons.

**Global Emissions**
(in billions of tons)

<table>
<thead>
<tr>
<th>Year</th>
<th>Emissions</th>
</tr>
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<tbody>
<tr>
<td>2000</td>
<td>6.7</td>
</tr>
<tr>
<td>2010</td>
<td>7.8</td>
</tr>
<tr>
<td>2020</td>
<td>9.1</td>
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<tr>
<td>2030</td>
<td>10.5</td>
</tr>
<tr>
<td>2040</td>
<td>12.2</td>
</tr>
<tr>
<td>2050</td>
<td>14.2</td>
</tr>
</tbody>
</table>

For nuclear energy to offset just a small fraction of those additional 7 billion tons—say, 1 billion tons by 2050—a 1,000-megawatt reactor will need to come online...

...every 14 days between now and 2050.

Sources: EIA, Oak Ridge National Laboratory, and Ferguson & Smith, *Foreign Policy*, 2009
Good news: Power up-rates have added the equivalent of about 6 large reactors.
Other Good News: U.S. Nuclear Power’s Power Capacity has Gone up Substantially and is at World Class Levels
Nuclear Electricity Production in the World 1990-2014

in TWh (net) and share of electricity production (gross)

Sources: IAEA PRIS and Mycle Schneider Consulting
Ref: Mycle Schneider Consulting: 2015 Status Report:
Aging U.S. Nuclear Fleet: Retirement Cliff
(graph assumes 20 year life extensions for all 100 currently operating reactors and does not include 4 reactors now under construction or several other proposed new reactors)
Construction is about 60 percent complete for 2 AP1000s at Vogtle Nuclear Plant in Georgia; 2 other AP1000s are being built at Summer NPP in South Carolina: planned start up in 2019-2021
AP1000 [AP = Advanced Passive]
Westinghouse designed with major components from Toshiba
AP1000 Modular Construction

1. Plant Order
2. Site survey and preparation
3. Site construction
4. Factory production of modules
5. Transport modules
6. On-site module assembly
7. Plant operation
8. On-site module assembly
ESBWR, developed by Hitachi-GE

- Design approved by NRC in Sept. 2014
- Example of Japan-U.S. Corporate Partnership
- Much greater safety features (estimated 100 times better than earlier generation BWRs) including seismic protection
Example of Enhanced Active Safety Systems, Areva’s EPR
U.S. Reactor Shutdowns in Past Few Years

- Five reactors since 2013 have been shut down or slated for shut down
- About a half dozen or more may be shut down in coming years even before the end of their nominal end-of-life
- Reasons range from safety fixes that are too expensive to competition from cheap natural gas to faulty equipment
Kewaunee NPP in Wisconsin closes because it can’t compete with natural gas, announcement made in May 2013.
“Costs for San Onofre nuclear power plant shutdown exceed $550 million, may be retired,”
Michael R. Blood | AP | April 30th, 2013, 6:05pm
Exelon

The Clinton Power Station in Clinton, Ill., will close on June 1, 2017, and the Quad Cities Generating Station in Cordova, Ill., will close on June 1, 2018. Quad Cities and Clinton have lost a combined $800 million in the past seven years, despite being two of Exelon's best-performing plants. Effect of being in a “merchant” or market-based utility system.
Very recently up to 100 with the addition of Watts Bar 2 in Tennessee
Potential New Build Sites but Many are Stalled or Suspended
What are the Barriers to New Nuclear Build?

Many factors complicate new nuclear build

- Cost
- Time
- Personnel

Sources: IAEA PRIS and *Foreign Policy*
What Determines Nuclear Power’s Usage in a Country?

- A country’s use of nuclear power has much to do with government intervention:
  - Streamlined regulations
  - Loan guarantees, tax credits, and additional incentives
  - Other policies, possibly carbon pricing in the future

- Use also depends on availability and pricing of fossil fuels (coal, oil, and natural gas)

- Capital costs for coal and natural gas power plants are much lower than for nuclear plants
Economic Competitiveness: Increasing Globalization of Nuclear Industry

- **TOSHIBA**: BWR business
- **Westinghouse**: Centering on PWR business

To become the world leader in the nuclear power plant business
Challenge: Construction risk

Investment Cost over time by Site ($/kW) - 2013 prices

Challenge: NPP investment cost uncertainty

Overnight capital cost range by region (US $/kW)

Note: Data collected from various publications and studies to keep track of nuclear power plants investment costs, since 2008 (updated August 2014), all data in 2013 USD

Figure 3  Generation Cost Scenarios

“Natural Gas is Queen” – John Rowe, then-CEO of Exelon, quote from speech at American Enterprise Institute, March 6, 2011 → Five days before Fukushima Daiichi accident started
Natural Gas Prices in US, Europe, Japan

US$ per million btu

Jan-02 | Oct-02 | Jul-03 | Apr-04 | Jan-05 | Oct-05 | Jul-06 | Apr-07 | Jan-08 | Oct-08 | Jul-09 | Apr-10 | Jan-11 | Oct-11

US | Europe | Japan

Legend:
- Blue: US
- Red: Europe
- Green: Japan
Natural Gas Forecasted Prices

Forward Price Projections
Past Annual Energy Outlooks (EIA)

Oct. 2012 forecast report by Nick Hodge, Energy & Capital Investment,
Fukushima Daiichi Plant Design

Boiling Water Reactor System

- Reactor Building (Secondary Containment)
- Inerted Drywell (Primary Containment)
- Reactor Core
- Control Rods
- Torus
- Feedwater Pumps
- Main Steam Lines
- Turbine Generators
- Condenser
- Electricity to Switchyard
“Safety Myth”

• Cover ups of safety violations
• A few dozen violations at Fukushima Daiichi alone many years before 2011
• Warning in 2009 about potential for massive tsunami
“Made in Japan”

- Main conclusion of Japanese Diet Commission’s report, published in summer 2012 and headed by Dr. Kiyoshi Kurokawa, M.D.
- The accident was preventable.
- Japan is still struggling to restart dozens of shut down reactors.
China’s reaction

- Beijing temporarily halted construction in 2011 and into 2012, but still needs to deal with “safety gap”
- China seemed to be building too fast and had not kept pace with training high-quality workforce
- China is now building the most nuclear plants in the world
- China may become a major exporter in the not too distant future
Republic of Korea’s Safety Issues

• Soon after F-D accident, Korean government recognized it needed an independent regulatory agency and has been forming it.

• But recent safety scandals (certificates were forged) and corruption in Korean nuclear industry have resulted in shut down of some reactors and slowed growth of nuclear power in Korea and possibly in the UAE.
Regional Nuclear Safety Concerns

• If Japan exits domestic use of nuclear energy, it will have little or no influence on safety practices in China and the Republic of Korea as well as others in East Asia.

• China and Korea are committed to keep operating and building nuclear plants.

• President Park Geun-hye of ROK has put forward trilateral safety cooperation.
France generates about 70% electricity from nuclear energy; may reduce down to 50% under Hollande’s government.

Germany had generated about 30% electricity from nuclear power but is phasing nuclear energy out by 2020.
Reversal of the Reversal

• Soon after F-D accident, German Chancellor Merkel reversed previous reversal in 2010 that had extended life of reactors.

• In April 2011, unveiled 6 point plan to phase out nuclear power in 10 years
More Reactions in Europe

• Switzerland decided to phase out nuclear power by 2030
• Italy has pulled back from considering new build—referendum in June 2011 was very opposed
• But other European countries are still committed to nuclear power such as many in Eastern Europe (concerns about energy security and dependency on Russia), UK, Sweden, and Finland.
• EU Regulatory Network required “stress tests” on nuclear plants following F-D accident
• Estimated $47 billion global costs to improve safety post Fukushima accident
What is SMR?

- Small Modular Reactors
- Ranging in size from approx 25 MWe (nuclear battery!) up to approximately 300 MWe
- Several potential technologies
  - Light water reactors
  - Gas-cooled reactors
  - Metal cooled fast reactors

Hyperion 25MWe fast reactor

Toshiba 10-50MW

NuScale
Small Modular Reactor: Soon to be Licensed? Goal is by end of 2016/early 2017 for NuScale for Regulatory Process, now majority owned by Fluor

**NuScale Module**

- Initially developed by INL/OSU then licensed to NuScale Power
- 45 MWe capacity
- Integral PWR configuration
- Natural circulation of primary coolant
- Standard 17x17 pin fuel assemblies with 3.5-yr refueling cycle
- Dual helical coil steam generators
- Reference plant contains 12 modules
Spent Nuclear Fuel Pools and Waste Storage

- Most of the almost 70,000 tons of spent U.S. nuclear fuel stored in deep pools of water; Yucca Mountain has essentially been halted … Blue Ribbon Commission called for public dialogue in consent-based process

- Almost all other nuclear power countries in similar situation

- No permanent storage available in almost all countries but Sweden is making significant progress to opening permanent waste repository

Some technical experts have raised concerns about safety and security of SNF pools --Robert Alvarez et al., e.g.
Dry Cask Storage: Interim Solution?

- Estimated $3 to $5 billion to transfer all overcrowded spent fuel to dry casks in the U.S.

- Germany applies this method

- Used to a limited extent in the United States and Japan, e.g.

- Companies reluctant to spend money on dry cask storage
Thank You Very Much for Your Attention

For more information about the Federation of American Scientists, please see: www.fas.org

For more info on nuclear energy ➔