A Global Nuclear Renaissance?

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Forget the “renaissance”

• “Nuclear Renaissance” is a U.S.-centric term. Asia continues to build; other areas just starting out.

• The cultural renaissance depended on patronage and took a few hundred years to root itself. Do we really want that for nuclear energy?
  • Climate change & energy security point away from nuclear. Need cheapest, fastest, biggest diversity in resources. Better investment would be in efficiency and transformational technologies.

• Without serious attention to reducing risks of nuclear energy, might get more than we bargained for.
  • Regional tensions, latent proliferation?
  • Expansion of enrichment, reprocessing
  • Bigger nuclear material security risks
Instead, Nuclear Energy “Enthusiasm”

- Nuclear energy rebranded as “clean, green, secure”
- Since 2005, >30 non-nuclear states have announced plans for nuclear power; 50 interested?
Nuclear Energy Today

• 16% global electricity demand (and declining...)

• 30 countries (and Taiwan) operating 439 reactors (371 GW)
  • 80% in OECD

• Construction: 61 reactors, 39 of which in Asia (not all are new)

• Enrichment: 9 countries hosting 50 million SWU

• Spent fuel separation: 6 countries
  • UK phasing out, China phasing in

• Waste: 0 countries with geologic repositories for spent nuclear fuel (SNF)
Nuclear Energy Capacity Today
(Gigawatts electric, GWe)
Commercial Enrichment of Uranium, 2009

KEY:
- Existing Commercial Uranium Enrichment
Nuclear energy decisions

• Energy economics
• National/international policies
• Forecasts rely on economics, but can’t separate politics from energy decisions, particularly regarding nuclear energy
Caveats about “forecasts”

- **Nuclear hard to fit in mold of economic models**
  - So large-scale, never strictly an economic decision
  - Government decisions, public support are key
  - EIA does its projections off-line

- **Timeframes disjointed**
  - Nuclear takes 10-15 years to build from start to finish, so how accurate will economic growth forecasts be?

  - Energy security, climate change frames require thinking out to 2030 and 2050
  - But this isn’t what industries or utilities do

- **Costs of new nuclear build unknowable**
U.S. npp cost estimates (Cooper, Vermont Law School, 2009)
A word about climate change and nuclear power

• How much can nuclear energy help?
  o 40% of global CO2 emissions from power sector; nuclear energy provides 16% of global electricity demand.
  o Nuclear’s reduction in CO2 emissions depends on what it displaces -- coal? wind? solar? hydro?

• How urgent?
  o Impact of climate change clearly visible
  o CO2 emissions have risen faster in the past few years than anticipated (vs. rising gas prices)
  o Sustainable reductions path (*UN HDR 2007-2008*)
    • 2012 – 2015 – peak emissions
    • 2020 – 30% reductions
    • 2050 – 80% reductions
## How Many Reactors for How Much CO2 Reduction?

<table>
<thead>
<tr>
<th>Case</th>
<th>Target year</th>
<th>Total capacity</th>
<th>Nuclear % of CO2 reduction</th>
<th>Est’d build rate</th>
<th>Build rate w/ 10-yr lag</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternative (WEO 2007)</td>
<td>2030</td>
<td>524 GWe</td>
<td>10%</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Stabilization (WEO 2007)</td>
<td>2030</td>
<td>832 GWe</td>
<td>16%</td>
<td>22</td>
<td>25.5</td>
</tr>
<tr>
<td>ACT MAP (ETP 2008)</td>
<td>2050</td>
<td>960 GWe</td>
<td>6%</td>
<td>24</td>
<td>29</td>
</tr>
<tr>
<td>BLUE (ETP 2008)</td>
<td>2050</td>
<td>1280 GWe</td>
<td>6%</td>
<td>32</td>
<td>40</td>
</tr>
<tr>
<td>Princeton wedge</td>
<td>2050</td>
<td>1070 GWe</td>
<td>14.5% (NRDC: 6%)</td>
<td>25</td>
<td>33</td>
</tr>
<tr>
<td>MIT 1500 GWe</td>
<td>2050</td>
<td>1870 GWe</td>
<td>25%</td>
<td>45</td>
<td>60</td>
</tr>
</tbody>
</table>
Snapshot of IEA ETP Blue Scenario

- End-use fuel efficiency – 24%
- Renewables – 21%
- End use electricity efficiency – 12%
- End use fuel switching – 11%
- CCS power generation – 10%
- CCS industry and transformation – 9%
- Power generation efficiency and fuel switching – 7%
- Nuclear – 6%

OF CO2 EMISSION REDUCTIONS
Nuclear Expansion Scenarios
Current Capacity: 370 GWe in 30 countries + Taiwan

• Scenario I: Realistic growth to 2030 (economic model EIA) +140 GW
• Scenario II: Wildly optimistic (states’ plans to 2030) +474 GW
• Scenario III: Fourfold increase (MIT’s 2050 “high” scenario for 2050) +1300 GW
Impact of Nuclear Energy Expansion

UNITED STATES 100

KEY:
- Current Capacity
- I. 2030 – EIA Forecast
- II. 2030 – Proposed Expansion
- II. 2030 – Proposed New Capacity
- IIIb. 2050 – MIT Expansion
- IIIb. 2050 – MIT New Capacity

Reactor Capacities for all Scenarios*
Proposed “New” Nuclear States
Proposals as of 2010
Enrichment Implications of Expansion

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Millions SWU/Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>40-50</td>
</tr>
<tr>
<td>2030 Growth (EIA)</td>
<td>52</td>
</tr>
<tr>
<td>2030 States' Plans</td>
<td>72-108</td>
</tr>
<tr>
<td>1000 GWe (&quot;Wedge&quot;)</td>
<td>150</td>
</tr>
<tr>
<td>1500 GWe Capacity (MIT)</td>
<td>112-225</td>
</tr>
</tbody>
</table>
Spent Fuel Implications of Growth

- 1 GWe = 20 tons spent fuel/year
- “New” nuclear states will store SNF, or lease fuel
  - More storage requires more safety, security measures
  - Fuel leasing = more transportation, greater safety, security measures
- But, open or closed fuel cycle is a “choice.”
- Some advanced states still pursuing fast reactors, but no need for uranium alternatives now, if ever. Recycling will continue to produce Pu.
Major expansion could face industrial limits

Need to ramp up industry capacity
- No more than 10 reactors/yr connected to grid for last 20 years
- Bottlenecks for key components (heavy forgings, etc.)
- Skilled labor shortage
  - Not just engineers, but craft labor, qualified construction
- Management experience
  - Olkiluoto and Flammanville

Need to replace aging reactors
- According to World Nuclear Industry Status Report 2008 (Mycle Schneider & Antony Froggatt), 339 reactors will reach retirement age by 2030. The IAEA’s low growth scenario posits
  - Closing 145 units
  - Building 178 new units
  - Extending lives of 193 units beyond 40 years.
By 2050, how many still in operation?
Nuclear Share in Electricity Generation in 2009

Note: The nuclear share in Taiwan, China was 20.7%
Number of Reactors under Construction Worldwide

- **China**: 23 reactors
- **Russian Federation**: 11 reactors
- **Korea, Republic Of**: 6 reactors
- **India**: 4 reactors
- **Bulgaria**: 2 reactors
- **Japan**: 2 reactors
- **Slovak Republic**: 2 reactors
- **Ukraine**: 2 reactors
- **Argentina**: 1 reactor
- **Brazil**: 1 reactor
- **Finland**: 1 reactor
- **France**: 1 reactor
- **Iran, Islamic Republic Of**: 1 reactor
- **Pakistan**: 1 reactor
- **United States Of America**: 1 reactor

**World Total**: 61 reactors of net electrical capacity 59.2 GW_{e}

Note: The World Total includes also 2 reactors under construction in Taiwan, China.
And limits in new nuclear states

Physical, intellectual nuclear infrastructure

• Where are they in the IAEA process?
  o Knowledgeable commitment (Milestone 1)
  o Readiness to invite bids (Milestone 2)
  o Ready to commission and operate (Milestone 3)

Legal, financing, regulatory frameworks
Safety, security cultures?
Funding?
## Plans in the Middle East

<table>
<thead>
<tr>
<th>Country</th>
<th>Plans</th>
<th>Date</th>
<th>Safeguards</th>
<th>Safety</th>
<th>Security</th>
<th>Liability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algeria</td>
<td>2.4 GWe</td>
<td>2027</td>
<td>Y</td>
<td>Not in force</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Bahrain</td>
<td>--</td>
<td>--</td>
<td>Y + SQP</td>
<td>Not in force</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Egypt</td>
<td>4 GWe</td>
<td>2022</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Iran</td>
<td>7 GWe</td>
<td>2020</td>
<td>Yes, but...</td>
<td>Not in force</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Jordan</td>
<td>2 GWe</td>
<td>2025</td>
<td>Y + SQP</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Kuwait</td>
<td>--</td>
<td>--</td>
<td>Y + SQP</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Libya</td>
<td>1 GWe</td>
<td>2050</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Morocco</td>
<td>2 GWe</td>
<td>2020-30</td>
<td>Y</td>
<td>Not in force</td>
<td>Not in force</td>
<td>Y</td>
</tr>
<tr>
<td>Oman</td>
<td>--</td>
<td>--</td>
<td>Y + SQP</td>
<td>N</td>
<td>N</td>
<td>Y</td>
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<tr>
<td>Qatar</td>
<td>--</td>
<td>--</td>
<td>Y + SQP</td>
<td>N</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>S. Arabia</td>
<td>--</td>
<td>--</td>
<td>Y + SQP</td>
<td>N</td>
<td>Y</td>
<td>N</td>
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<tr>
<td>Tunisia</td>
<td>0.9 GWe</td>
<td>2020</td>
<td>Y</td>
<td>Not in force</td>
<td>Y</td>
<td>Y</td>
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<tr>
<td>Turkey</td>
<td>4.8 GWe</td>
<td>2016-19</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
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<tr>
<td>UAE</td>
<td>5.6 GWe</td>
<td>2020</td>
<td>Y + SQP</td>
<td>Not in force</td>
<td>Y</td>
<td>Y</td>
</tr>
</tbody>
</table>
Nuclear Plans and Failed State Index 2009

KEY:
- Planned Reactors – Approvals, funding or construction
- Proposed Reactors – Clear proposals, but without firm commitment
- Exploring Nuclear Option – Declared interest, but proposals incomplete

FOREIGN POLICY'S 2009 FAILED STATES INDEX:
- CRITICAL
- IN DANGER
- BORDERLINE

New kinds of reactors
  • Different choices for advanced vs. developing states
    – Gen IV, grid-appropriate, nuclear batteries, floating reactors?

New suppliers?
  • South Korea (UAE); China; India; Japan?

New locations
  • Middle East, Southeast Asia, Africa

New capabilities
  • Recycling techniques + closed fuel cycles for more states?
  • More states with uranium enrichment?
Trends to watch for (1)

• **New kinds of reactors**
  - Will the advanced states succeed in commercializing fast reactors?
  - If they do, what is effect on less-advanced states’ choices?
  - Will vendors supply what smaller countries need? Will smaller countries want what they need?

• **New suppliers**
  - Will Korea become the nuclear supplier powerhouse it wants to be?
  - Will new suppliers be as/less/more scrupulous in their technology transfer than current suppliers?
  - If one country steps forward to provide cradle-to-grave fuel services, will industry consolidate?
Spotlight on Asia

- Massive npp construction
- Enrichment, uranium production expansion
- Technology acquisition (reactors, forging)

New commitment to export

Uranium enrichment from China
- Seeks to export 80 npms in next 20 (30) years
- Spent fuel storage/disposal problem – pyroprocessing?
Trends to watch for (2)

**New locations**
- Will Middle Eastern states form regional fuel cycle center to gain access to enrichment, reprocessing? Or pursue separately?
- How significant will growth be in Southeast Asia?

**New capabilities**
- Will suppliers succeed in making reprocessing more proliferation-resistant?
  - Debate about pyroprocessing and South Korea
- Will efforts to multilateralize facilities go anywhere?
- Will US efforts to get individual states to foreswear sensitive capabilities take root?
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