Prospects, Challenges and Opportunities for Nuclear Energy After Fukushima Accident

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1. Prospects of Nuclear Energy
1) Global Energy Demand

- Economic growth and the improved living standards will require more energy.
- **Global energy demand** is expected to be about 30% higher in 2040 than in 2010.
2) Global Electricity Demand

- By 2020, global electricity demand will be about 40% higher than today.
- More than 90% of fuel demand growth for electricity generation will come from China, India and the other Non OECD countries.
- Electrification for all area including IT, transportation raise the electricity demand.
- Proportion of renewable source is less than 1.4% (without hydro).
3) Necessity of Nuclear Energy

- The India blackout was the largest power outage in history. The outage affected over 620 million people, spread across 22 states in Northern, Eastern, and Northeast India.
  - Global energy demand and global electricity demand will increase significantly. **Supply < Demand**

- **Nuclear Energy is not optional but essential for future energy problem.**

- We may need Nuclear, Renewables and Management of Demand all together.
1. Prospects of Nuclear Energy

4) World Nuclear Power Plants

<table>
<thead>
<tr>
<th></th>
<th>ELECTRICITY 2011</th>
<th>OPERABLE</th>
<th>CONSTRUCTION</th>
<th>PLANNED</th>
<th>PROPOSED</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>billion kWh</td>
<td>% e</td>
<td>No.</td>
<td>MWe net</td>
<td>No.</td>
</tr>
<tr>
<td>WORLD</td>
<td>2518</td>
<td>13.5</td>
<td>433</td>
<td>371,745</td>
<td>65</td>
</tr>
<tr>
<td></td>
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<tr>
<td></td>
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</tr>
</tbody>
</table>

Operable = Connected to the grid; Construction = first concrete for reactor poured, or major refurbishment under way; Planned = Approvals, funding or major commitment in place, mostly expected in operation within 8-10 years; Proposed = Specific program or site proposals, expected operation mostly within 15 years.
5) Reinforcement of Nuclear Safety after Fukushima Accident

- Improvements for nuclear safety are deducted and being carried out by EU, U.S., Korea, etc.
  - EU conducted a safety inspection for 143 NPPs.
  - U.S. deducted 12 recommendations through a safety inspection and established details plan.
  - Korea deducted 50 actions through a safety inspection and is carrying out the actions.

- IAEA and WANO clarified peer review policy for all world nuclear power plants.
  - IAEA proceeds a plan of peer review for 10% of world nuclear power plants.

- Follow up measures which reflect lessons from Fukushima should be carried out faithfully and nuclear safety research should be reinforced.
6) Competition and Cooperation for World Nuclear Energy Market

- Large LWR Reactor Market
  - Large companies maximize their abilities to obtain order by strategic alliance.
  - Korea try to develop their own nuclear power plants.

- Gen IV Reactor Market
  - Nuclear energy developed country strive to develop innovative nuclear systems such as Gen IV reactors.

- Small-Medium sized Reactor Market
  - U.S. congress proceed Legislation of construction of small medium sized reactor.
  - Korea develop SMART and HTGR.

- Research Reactor Market
7) Near Term Prospects for Nuclear Energy

- Expansion of nuclear capacity is expected to slow down due to Fukushima accident.
  - Japan, Germany, Switzerland, and Italy clarified nuclear power phase-out.
  - Japan stopped all nuclear power plants → re-operation due to shortage of electricity.

- Communication with the public is a key.

- Safety enhancement of the nuclear energy is needed.
8) Long Term Prospects for Nuclear Energy

- Expansion of nuclear power is expected to continue.
  - Korea, U.S. France, China, India continue their nuclear programs.
  - Jordan, Thailand, etc. maintain their nuclear introduction plans.

- IAEA announced the prospect of world nuclear power plants increase after Fukushima accident.
  - 55th IAEA general meeting (2011.09)
  - 90~300 additional construction of nuclear power plants until 2030 is projected.

- Green house gas should be reduced more than 80%.

- Energy supply cannot meet demand through renewable energy only.
2. Challenges of Nuclear Energy
2. Challenges of Nuclear Energy

1) Safety

- Lessons from TMI, Chernobyl, Fukushima accidents are reflected to the nuclear safety system. However this is not enough to guarantee the ultimate safety of nuclear power plants.

- Ultimate safety of nuclear power plants which can prevent large release of radioactivity under the most severe accidents is required.

- Development of Innovative nuclear safety system which can handle station blackout is required.
2. Challenges of Nuclear Energy

2) Economics

- Cost down by reduction of construction period and design innovation is needed.

<table>
<thead>
<tr>
<th>Plant Type</th>
<th>Capacity Factor (%)</th>
<th>Levelized Capital Cost</th>
<th>Fixed O&amp;M</th>
<th>Variable O&amp;M (Including fuel)</th>
<th>Transmission Investment</th>
<th>Total System Levelized Cost</th>
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</thead>
<tbody>
<tr>
<td>Conventional Coal</td>
<td>85</td>
<td>65.8</td>
<td>4.0</td>
<td>28.6</td>
<td>1.2</td>
<td>99.6</td>
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<tr>
<td>Advanced Coal</td>
<td>85</td>
<td>75.2</td>
<td>6.6</td>
<td>29.2</td>
<td>1.2</td>
<td>112.2</td>
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<tr>
<td>Advanced Coal with CCS</td>
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<td>93.3</td>
<td>9.3</td>
<td>36.0</td>
<td>1.2</td>
<td>140.7</td>
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<td>Natural Gas Fired</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Conventional Combined Cycle</td>
<td>87</td>
<td>17.6</td>
<td>1.9</td>
<td>48.0</td>
<td>1.2</td>
<td>68.6</td>
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<tr>
<td>Advanced Combined Cycle</td>
<td>87</td>
<td>17.5</td>
<td>1.9</td>
<td>44.4</td>
<td>1.2</td>
<td>65.5</td>
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<td>Advanced CC with CCS</td>
<td>87</td>
<td>34.9</td>
<td>4.0</td>
<td>52.7</td>
<td>1.2</td>
<td>92.8</td>
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<td>Conventional Combustion Turbine</td>
<td>30</td>
<td>45.0</td>
<td>2.7</td>
<td>79.0</td>
<td>3.0</td>
<td>132.0</td>
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<tr>
<td>Advanced Combustion Turbine</td>
<td>30</td>
<td>31.7</td>
<td>2.8</td>
<td>67.5</td>
<td>3.8</td>
<td>105.3</td>
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<tr>
<td>Advanced Nuclear</td>
<td>90</td>
<td>68.8</td>
<td>11.3</td>
<td>11.6</td>
<td>1.1</td>
<td>112.7</td>
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<td>Geothermal</td>
<td>92</td>
<td>75.6</td>
<td>11.9</td>
<td>9.6</td>
<td>1.5</td>
<td>99.6</td>
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<td>Biomass</td>
<td>83</td>
<td>56.6</td>
<td>13.8</td>
<td>48.3</td>
<td>1.3</td>
<td>120.2</td>
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<tr>
<td>Wind¹</td>
<td>34</td>
<td>63.3</td>
<td>9.7</td>
<td>0.0</td>
<td>3.7</td>
<td>96.8</td>
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<tr>
<td>Wind — Offshore¹</td>
<td>27</td>
<td>300.6</td>
<td>22.4</td>
<td>0.0</td>
<td>7.7</td>
<td>330.6</td>
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<tr>
<td>Solar PV²</td>
<td>25</td>
<td>144.9</td>
<td>7.7</td>
<td>0.0</td>
<td>4.2</td>
<td>156.9</td>
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<td>Solar Thermal²</td>
<td>20</td>
<td>264.7</td>
<td>40.1</td>
<td>0.0</td>
<td>6.2</td>
<td>251.0</td>
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<tr>
<td>Hydro¹</td>
<td>53</td>
<td>77.9</td>
<td>4.0</td>
<td>6.0</td>
<td>2.1</td>
<td>89.9</td>
</tr>
</tbody>
</table>

1Non-dispatchable (hydro is seasonally non-dispatchable)

2Costs are expressed in terms of net AC power available to the grid for the installed capacity

The data show an average overnight capital cost of $4,177 per kW for the OECD countries and an average of $2,521 per kW for the three non-OECD countries.

2012 report of the EIA U.S. DOE
2. Challenges of Nuclear Energy

2) Economics

< International Comparison for Electricity Cost >

<table>
<thead>
<tr>
<th></th>
<th>Korea (the Whole)</th>
<th>Japan (the Whole)</th>
<th>USA (the Whole)</th>
<th>France (EDF)</th>
<th>UK (EDF Energy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sale Cost [₩/kWh]</td>
<td>83.59</td>
<td>202.30</td>
<td>115.48</td>
<td>142.19</td>
<td>184.39</td>
</tr>
<tr>
<td>Relative Values</td>
<td>100</td>
<td>242</td>
<td>138</td>
<td>170</td>
<td>221</td>
</tr>
</tbody>
</table>

- Korean electricity sale cost is ₩83.59/kWh.
- Korean electricity sale cost is the cheapest among the estimated countries due to cheap generation cost of nuclear power.
- Reasons for the cheap generation cost of Nuclear Power in Korea
  ① Short Construction Period  ② Cheap Construction Cost  ③ Effective Operation

[KEPCO, 2009]
3) Spent Fuel

- Most countries have not secured sites for direct disposal except Sweden and Finland.

- Success or failure of spent fuel management facility construction depends on communication with local residents.

- Innovative technology which can reduce radioactivity and half-life of high level wastes should be developed.

- Continuous and consistent management and inspection after disposal of spent fuel are required.
### 3) Spent Fuel

- **Direct disposal**
  - U.S., Sweden, Finland, Canada, etc.

- **Reprocessing**
  - U.K., France, Japan, etc.

- **Interim storage**
  - Wet: France, U.K., Sweden, etc.
  - Dry: U.S., Germany, Canada, Japan, etc.
2. Challenges of Nuclear Energy

4) Nonproliferation

- Global cooperation is important for nonproliferation.

- Innovative technology which can achieve proliferation resistance should be developed.
  - Pyroprocessing System
  - Long Life Reactor Core
5) Public Acceptance

- Public acceptance becomes much more important for policy decision of nuclear energy after Fukushima accident.

- **Communication with local residents** is the most important thing for enhancing the public acceptance of nuclear power.

- **Various supports** such as revitalization of nuclear power site economy and support of education for nuclear power sites are required.
3. Future Tasks of Nuclear Energy
3. Future Task of Nuclear Energy

1) Nuclear Energy Research
   - Nuclear Energy Safety Research
   - Development of Advanced LWR
   - Development of Small and Medium Reactor
   - Development of Future Nuclear Energy System
   - Development of Innovative Fuel Cycle
   - Development of Radiation Technology
3. Future Tasks of Nuclear Energy

- Nuclear Energy Safety Research: Need of Passive Safety
  By the Application of “One or Two Big Tanks” outside Containment,

These Integrated Passive Safety Concepts Can be Achieved for BDBA: IPSS
3. Future Tasks of Nuclear Energy

- **Strength of IPSS**
  1. Wholly Passive System
     - Gravity & Natural Circulation
  2. Very Long Term Cooling
     - Coolant Filling from Containment Outside
  3. Easy Accessibility and Maintenance
  4. Integrated and Simplified Design
  5. No Design Change
     - Addition to Current Operating PWRs
  6. No Radiation Release - Filtered Venting on IPST
  7. Availability of Pressure Control for Depressurization

- **Enhanced Safety from IPSS**
  - In severe accident, a level of radiation can be lower than that of resident evacuation.
  - No Need of Evacuation Plan
3. Future Tasks of Nuclear Energy

❖ Development of Future Nuclear Energy System

- Thermal Reactors: VHTR, SCWR, MSR
- Fast Reactors: GFR, SFR, LFR
- Fusion Reactors
- These systems offer significant advances in sustainability, safety and reliability, economics, proliferation resistance and physical protection.
3. Future Tasks of Nuclear Energy

- Development of Innovative Fuel Cycle – Sustainability and Nonproliferation

- Spent Nuclear Fuel
- Interim storage
- Pyro-processing
- Disposal
- HLW
- U–TRU–Zr fuel

• TRU (Trans-uranics): Pu, Np, Am, Cm
3. Future Tasks of Nuclear Energy

2) Manpower Training

- Many countries have troubles to secure manpower due to aging problem and large retirements.
- Systematic and anticipatory manpower training is required.

3) International Cooperation

- Collaborative research for effective development of innovative nuclear technology.
3. Future Tasks of Nuclear Energy

4) Safety Culture

- Safety culture is an important concept that forms the environment within which individual safety attitudes develop and persist and safety behaviors are promoted.

- The ability to maintain and achieve a safety culture is dependent on the consistent approach in striving to meet organizational policies and objectives through management practices and promotion of individual safety behaviors.

- Elements of a safety culture
  - Organizational Commitment to Safety
  - Operational Personnel
  - Formal Safety System
  - Informal Safety System
5) Public Acceptance

- **Public awareness** should be improved through active and omnidirectional education and public-relations.
- There is a gap between actual nuclear safety level and recognized nuclear safety level.
- Misunderstanding about radiation should be corrected.
  - Low level radiation under 100mSv didn’t show any critical damage.
  - Furthermore **Radiation Hormesis** theory is argued for low level radiation.
- The truth of nuclear safety should be informed to public.
  - After Chernobyl accident, cancer rate increased only for thyroid cancer (thyroid cancer can be avoided and treated).
  - After TMI accident, there is no increase of cancer rate.
3. Future Tasks of Nuclear Energy

5) Public Acceptance

- Regional development projects
  - Support for construction of cement factory which provides cement for management of repository.
  - Support for public works such as school, community hall, etc.
  - Preservation project for local environment.

- Revitalization of local economy
  - Participation of local firm to Construction.
  - Creation of jobs.
4. Conclusions
Expansion of nuclear power is expected to continue although the short depression due to Fukushima accident.

Nuclear energy have challenges of Safety, Economics, Spent Fuel, Nonproliferation, and Public Acceptance.

These challenges should be overcome through Nuclear Energy Research, Manpower Training, International Cooperation, Enhancement of Safety Culture and Public Awareness.
~Thank you~