Update on Japan’s Nuclear Energy Development and Spent Fuel Management Plans and Options

May 28 2013
Tomoko (Tom) Murakami
Manager, Nuclear Energy Group
The Institute of Energy Economics, Japan
Contents

   (1) Nuclear power plants in operation, under construction and planning
   (2) Discussions on the energy policy and nuclear development
   (3) New safety regulatory standards and the way to restart
   (4) Active faults under the reactor building

2. Spent fuel management options and strategies
   (1) Currently proposed options on spent fuel management
   (2) Possible scenarios
   (3) Rough estimates on the inventories of spent fuels

3. Prospects and implications

(1) Nuclear power plants in operation, under construction and planning
(2) Discussions on the energy policy and nuclear development
(3) New safety regulatory standards and the way to restart
(4) Active faults under the reactor building
1(1) Nuclear power plants in operation, under construction and planning

(Commercial Plant: As of April 2013)

- Kashiwazaki-Kariwa, Tokyo Electric Power Company
- Shika, Hokuriku Electric Power Company
- Tsuruga, The Japan Atomic Power Company
- Mihama, Kansai Electric Power Company
- Ohi, Kansai Electric Power Company
- Takamaka, Kansai Electric Power Company
- Shimane, Chugoku Electric Power Company
- Kaminoseki, Chugoku Electric Power Company
- Genkai, Kyushu Electric Power Company
- Higashidori, Tohoku Electric Power Company
- Tomari, Hokkaido Electric Power Company
- Ohma, Japan Power Development Company
- Onagawa, Tohoku Electric Power Company
- Namie-Odaka, Tohoku Electric Power Company
- Fukushima Daiichi, Tokyo Electric Power Company
- Fukushima Daini, Tokyo Electric Power Company
- Tokai Daini, The Japan Atomic Power Company
- Hamaoka, Chubu Electric Power Company
- Sendai, Kyushu Electric Power Company
- Ikata, Shikoku Electric Power Company

Output
- 500 MW and less
- 1000 MW and less
- 1000 MW and more

<table>
<thead>
<tr>
<th>In operation</th>
<th>Under construction</th>
<th>Planning</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Units</th>
<th>Total output (GW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>In operation</td>
<td>50</td>
</tr>
<tr>
<td>Under construction</td>
<td>3</td>
</tr>
<tr>
<td>Planning</td>
<td>9</td>
</tr>
<tr>
<td>Total</td>
<td>62</td>
</tr>
</tbody>
</table>

【Permanent Shutdown】
- Tokai: The Japan Atomic Power Company 1998.3.31
- Hamaoka No1, No2: Chubu Electric Power Company 2009.1.30
- Namie-Odaka, Tohoku Electric Power Company 2011.3.31

Upptäckning på Japan kärnkraft utveckling och tillbringade planer bränslehantering och optioner
1(2) Discussions on the energy policy and nuclear development
Restructuring the “Strategic Energy Plan of Japan 2010”

- July 2011? Energy and Environment Council suggested to:
  - Reduce share of nuclear power
  - Seek to realize new energy systems
  - Stimulate national public discussion based on objective data

- **Proposed options** from Fundamental Issues Committee in July 2012

![Energy policy and nuclear development diagram](chart)

- **2010**
  - CHP: 3%
  - Thermal: 60%
  - Renewable: 11%
  - Nuclear: 26%

- **Plan 1**
  - CHP: 15%
  - Thermal: 50%
  - Renewable: 30%
  - Nuclear: 15%

- **Plan 2**
  - CHP: 15%
  - Thermal: 40%
  - Renewable: 15%
  - Nuclear: 35%

- **Plan 3**
  - CHP: 15%
  - Thermal: 35%
  - Renewable: 25-30%
  - Nuclear: 20-25%

- **Reference**
  - CHP: 15%
  - Thermal: 25%
  - Renewable: 25%
  - Nuclear: 35%

- **Present Plan**
  - CHP: 8%
  - Thermal: 27%
  - Renewable: 20%
  - Nuclear: 45%

Energy conservation ▲10%
1(2) Discussions on the energy policy and nuclear development
Can renewables be alternative options for zero-nuclear?

◆ Decreasing nuclear will push THERMAL forward, not renewables

![Diagram showing nuclear versus renewables with percentages and strategic energy plans.](chart.png)
1(2) Discussions on the energy policy and nuclear development
Contradictory issues in the new Innovative Strategy

  - No more new nuclear power plant construction
  - Restrict the operation period of existing plants strictly to 40 years
  - Nuclear restart would be permitted under the consensus of NRA
  - Make every effort to achieve “zero nuclear power generation” in 2030s
  - But CONTINUE the current nuclear fuel cycle policies

Source: National Policy Unit

On September 19, 2012, the Cabinet decided that the government will continue its energy and environmental policies, “taking into account” the decision of the EEC, “with flexibility and continuous verification”.

Not yet decided anything certain
After the landslide victory at the Lower House election in December 2012, the Prime Minister Abe Cabinet started.

Prime Minister Abe declared:
“DPJ’s energy policy is only wish, therefore we make a firm energy policy.”

Minister of Economy, Trade and industry said:
“It is necessary to review DPJ’s Energy Policy.”
“Concerning about construction new NPP, we make political decision accumulating expert knowledge.”

A new governmental committee, “General Subcommittee” has started a comprehensive discussion on the energy policy in March 2013.

- The energy policy to be determined should focus on sustainable supply of energy and cost reduction.
- Nuclear would be more discussed together with the back-end policy.

“Zero-nuclear” is likely to be reconsidered, but would not be quantified.

...Due to the unclear application of the new regulation standard.
1(3) New safety regulatory standards and the way to restart Nuclear Regulation Authority launch in September 2012

Core value

- The NRA was established to absorb and learn the lessons of the Fukushima Daiichi nuclear accident of March 11, 2011.
- The nuclear safety system and management must be rebuilt on a solid basis, placing the highest priority on public safety and a genuine safety culture.

Guiding Principles for activities: Independence and Transparency

- Independent Decision Making
- Effective Actions
- Open and Transparent Organization
- Improvement and Commitment
- Emergency Response (preparedness)

Guiding Principles for activities:

- Independence and Transparency
- Effective Actions
- Open and Transparent Organization
- Improvement and Commitment
- Emergency Response (preparedness)
### 1(3) New safety regulatory standards and the way to restart

**What actions have been taken since Fukushima accident?**

<table>
<thead>
<tr>
<th>Year</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Utilities</td>
<td>11 March Fukushima Accident</td>
<td>March – August Immediate Safety Measures</td>
<td>July 2012 Ohi-3/4 restart</td>
</tr>
<tr>
<td>Safety Regulatory Authority</td>
<td>March 23 Order on Immediate Safety Measures</td>
<td>July 2011 – August 2012 Assessment on the Stress Test -&gt; 30 units submitted</td>
<td>Preparing for licensing documents for restart</td>
</tr>
<tr>
<td>Safety Regulatory Authority</td>
<td>March 23 Order on Immediate Safety Measures</td>
<td>6 July Order on the Stress Test</td>
<td></td>
</tr>
<tr>
<td>Safety Regulatory Authority</td>
<td>March 2012 Ohi-3/4 Report approved by NISA/ASC</td>
<td>September 2012 NRA Launch</td>
<td></td>
</tr>
<tr>
<td>Safety Regulatory Authority</td>
<td></td>
<td>October 2012 – Expert Committees (13 as of March 2013)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Study Team on the New Safety Standard</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Study Team on the On-site Faults</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>...</td>
<td></td>
</tr>
<tr>
<td>Safety Regulatory Authority</td>
<td></td>
<td>6-28 February Public comment inquiry to the Draft Safety Standard</td>
<td></td>
</tr>
</tbody>
</table>
(3) New safety regulatory standards and the way to restart
Supplementary safety measures taken immediately after Fukushima

- Station blackout
- Loss of ultimate heat sink
- Flooding of critical equipment

1) Continuously monitoring
2) Adding power sources required for monitoring the plant
3) Preventing water flow into buildings

1) Ensuring power source
2) Add water supply
3) Anti-flood barrier

Source: Kansai Electric Power Co.
1(3) New safety regulatory standards and the way to restart
Study teams / expert meetings under NRA discussing the new regulations

- 18 Study Teams are active as of April 2013.

<table>
<thead>
<tr>
<th>Study team/expert committee</th>
<th>Focus on</th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Oct</td>
<td>Nov</td>
</tr>
<tr>
<td>Study Team on the New Safety Standards for LWRs</td>
<td>Terms and conditions required for commercial NPPs</td>
<td>25</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td></td>
<td>31</td>
<td>29</td>
</tr>
<tr>
<td>Study Team on the issues and conditions formulating the New Safety Standards</td>
<td>Technical specifications fit for the new standards</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Study Team on the new safety design standards for earthquakes and tsunamis</td>
<td>Terms and conditions tolerant with tsunami</td>
<td>19</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td></td>
<td>27</td>
<td>27</td>
</tr>
<tr>
<td>Expert Meeting on the fracture zone on Tsuruga NPP</td>
<td>Investigation on the faults in Tsuruga</td>
<td>23</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Preliminary Site investigation</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>Expert Meeting on the fracture zone on Ohi NPP</td>
<td>Investigation on the faults in Ohi</td>
<td>22</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>Preliminary Site investigation</td>
<td>22</td>
<td>28</td>
</tr>
<tr>
<td>Expert Meeting on the fracture zone on Higashidori NPP</td>
<td>Investigation on the faults in Higashidori</td>
<td>21</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Preliminary Site investigation</td>
<td>22</td>
<td>20</td>
</tr>
</tbody>
</table>

Source: NRA
1(3) New safety regulatory standards and the way to restart
New Safety Standard

- The draft New Safety Standards have been released in April 2013, public comments were inquired until 10 May.
- NRA and their study teams will put the public comments together to endorse the new safety standards. New safety standards expected to be enforced in July 2013.
- NRA released three draft safety standards:
  - Safety Standard for Design Basis
    - Safety measures against natural phenomena (e.g., tornados, forest fires)
    - external man-made hazards (e.g., an aircraft crash), the reliability of off-site power supply, ultimate heat sink and the functions of SSCs, as well as fire protection measures
  - Safety Standard for Severe Accident
    plants are to be equipped with such facility as:
    - filtered containment vessel venting system
    - permanent and portable coolant injection equipment
    - portable alternate coolant injection equipment to the spent fuel pool
    - power generation vehicles and connecting facilities
    - Specific Safety Facilities (SSFs) etc.....
  - Safety Standard for Earthquakes and Tsunamis
    - protective measures such as sea walls against tsunamis, anti-inundation measures, no construction of Class S nuclear facilities on the exposure of active faults should be prepared.

Before Fukushima accident, there was a safety standard for design basis. New safety standard for design basis is based on the old one but a few regulations are changed;

- Considerations for internal flood, airplane crash, terrorism (including cyber terrorism), etc.
- Considerations for fire protection (by a new guide to be decided later)
- Preparation of fuel for emergency diesel generators for 7 days
1(3) New safety regulatory standards and the way to restart Safety Standard for Severe Accident

- Preparation for severe accident is required by the new law passed in Jun.27, 2012.
- Under this standard, many measures are required to install.
  - Equipment to manage the severe accident (portable electricity power supply and water supply pumps etc.)
  - Emergency headquarters and specific safety facilities (to mitigate the release of radioactive material after core damaging by natural hazard, air plane crash etc.)
  - Preparation of procedures, implementation of drills, and development of emergency response organization

Source: NRA, The Japan Times
Before Fukushima accident, “Regulatory Guide for Seismic Design” was a safety standard for earthquakes and tsunamis. But old guide was written little about tsunami.

In the new safety standard, requirement for assessment of tsunamis (and earthquakes) is strengthened;

- Required to decide design based tsunami
  (Operator have to consider not only the tsunami caused by earthquake but also by volcano etc.)
- Important equipments have to be a waterproof or installed higher than the design based tsunami height
- Important equipments do not have to be installed on active faults
  (It was indirectly required before Fukushima)
- Active faults are defined as those that have moved in the last 400,000 years.
  (120,000 – 130,000 years before Fukushima)
1(3) New safety regulatory standards and the way to restart
Opinions from the operators/experts

Operators and experts say their opinions as follow;
The new Safety Standards should be:
- Based on Defense-in-Depth, evaluate the management under beyond-design condition.
- Discussed and determined based on scientific and technically reasonable evidences.
  - Plant life limit within 40 years
  - Definition and assessment of active faults etc
The current draft Safety Standards fail the exam by:
- Not the performance-based regulation but only the hardware regulation, little room for alternative measures
  - Diversified emergency power sources
  - Containment venting systems
  - Alternative control center etc
- Violate the Defense-in-Depth concept not prepared for unexpected events
- Little consideration on the relative risk
- Excessively severe among other countries in the world
- Beyond the international standards

Examples of the hardware regulation required by NRA:
Permanent facility for lower PCV coolant injection/
Filtered venting system

Source:
- “Lessons learned from Fukushima Daiichi NPP Accident and Japanese regulations,” Professor Koji Okamoto, the University of Tokyo, Nuclear Safety Symposium, 26 February 2013, Tokyo
- “Electric Utilities submit comments to NRA”, Denki Shimbun, 1 March 2013
1.(4) Arguments on the on-site fracture zones - Tsuruga

- 4 expert meetings, 1 site visit and 1 peer reviews were held from December 2012 to May 2013.
- On May 22, NRA concluded that the fracture zones under the reactor building of Tsuruga Unit 2 is surely an active fault, which should be avoided as a nuclear facility, though JAPC is still continuing the survey.
- JAPC asked an international expert group to assess the fracture zones and the interim report has been issued on May 21.

What made NRA jump to conclusions??

Source: JAPC website, April 24, 2013
1.(4) Arguments on the on-site fracture zones - Higashidori

- 6 expert meetings and 1 site visit were held from December 2012 to May 2013.
- On May 17, the expert team concluded that the on-site fracture zone is surely an active fault, which should be strictly assessed by seismic analysis, though Tohoku Electric is still continuing the investigation.

What made NRA jump to conclusions??

Source: NRA website, February 18, 2013
http://www.nsr.go.jp/committee/yuushikisyaya/higashidori_hasaitai/data/0004_05.pdf
2. Spent fuel management options and strategies

(1) Currently proposed options on spent fuel management
(2) Possible scenarios
(3) Rough estimates on the inventories of spent fuels
2.(1) Currently proposed options on spent fuel management

Present policy on nuclear fuel cycle in Japan

- All spent fuel from NPP reprocessed in Japan and abroad
- Plutonium is used in thermal reactors now, and will be used in FBRs after 2050

- NPP (BWR & PWR)
  - Spent-fuel
  - MOX-fuel
  - MOX-fuel Assembly plant (At Rokkasyo)

- Reprocessing plant (At Rokkasho)
  - Reprocessed Uranium and Plutonium
  - Interim Spent-Fuel storage

- Future FBR Cycle
  - MOX-fuel (FBR)
  - Spent FBR-fuel
  - FBR-fuel Assembly plant
  - HLW Repository
  - Reprocessed Uranium and Plutonium
  - Interim HLW Storage (At Rokkasho)
  - Vitrified Waste
  - HLW (Vitrified Waste)

- Present policy on nuclear fuel cycle in Japan
  - Plutonium is used in thermal reactors now, and will be used in FBRs after 2050
  - NPP (BWR & PWR)
    - Spent-fuel
    - MOX-fuel
  - MOX-fuel Assembly plant (At Rokkasyo)
  - Reprocessing plant (At Rokkasho)
    - Reprocessed Uranium and Plutonium
    - Interim Spent-Fuel storage
  - Future FBR Cycle
    - MOX-fuel (FBR)
    - Spent FBR-fuel
    - FBR-fuel Assembly plant
    - HLW Repository
    - Reprocessed Uranium and Plutonium
    - Interim HLW Storage (At Rokkasho)
    - Vitrified Waste
    - HLW (Vitrified Waste)
2.(1) Currently proposed options on spent fuel management  
Three options evaluated an implicated by JAEC

- The Japan Atomic Energy Commission (JAEC) evaluated fuel cycle policy options in accordance with the energy policy options.

<table>
<thead>
<tr>
<th>Option for nuclear ratio in 2030</th>
<th>Basic policy of spent fuel management</th>
<th>Recommendation to the existing/planned facilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) 0%</td>
<td>“Full direct disposal” is appropriate</td>
<td>◆ Reprocessing Rokkasho Reprocessing Plant.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>◆ Long-term storage of spent fuel.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>◆ Commencement of work for direct disposal.</td>
</tr>
<tr>
<td>(B) 15%</td>
<td>“Coexistence of reprocessing and direct disposal” is appropriate</td>
<td>◆ Proceed operation of Rokkasho Reprocessing Plant.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>◆ Spent fuel exceeding reprocessing is stored.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>◆ Efforts for reprocessing and directly disposing of stored spent fuel should be both pursued.</td>
</tr>
<tr>
<td>(C) 20-25%</td>
<td>“Coexistence of reprocessing and direct disposal” is a likely option</td>
<td>◆ Proceed full operation of Rokkasho Reprocessing Plant.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>◆ Spent fuel exceeding reprocessing is stored until further reprocessing facility is licensed.</td>
</tr>
<tr>
<td></td>
<td>“Full reprocessing” is appropriate likely option</td>
<td>◆ Efforts to prepare for future reprocessing plants.</td>
</tr>
</tbody>
</table>
2.(1) Currently proposed options on spent fuel management “Renewing Approaches to Geological Disposal of HLW” by JAEC

- JAEC sent a request titled “Issues concerning HLW Disposal” to the Science Council of Japan (SCJ) in September 7, 2010 to deliberate recommendations for activities to disclose literature and information on the disposal of HLW to the public.
- In reply to the request, SCJ sent “Issues concerning HLW Disposal (Reply)” back to JAEC on September 11, 2012.
- JAEC reconsidered and issued the following approaches based on the reply:

1. Clarify the amount and nature of HLW for disposal in association with nuclear energy and fuel cycle policies.
   “how much radioactive waste is disposed of and in what form, within what scale of disposal facilities and in what fuel cycle in future” should be clarified.

2. Apply the latest earth science knowledge to a viability study of geological disposal, and share the result with the public.

3. Confirm the definitions, utility and its importance of interim storage.

4. Provide a system of sharing disposal techniques and the site selection process with the public.

5. The government should start restructuring the whole operation and reviewing the ”Basic Policy” of HLW disposal, including re-examining the laws and institutions.
2.(2) Possible scenarios
4+1 cases assumed in accordance with the options by JAEC

(a) Zero nuclear in 2030
(b) 15% nuclear in 2030
(c) 25% nuclear in 2030

Full direct disposal (DD)
Half reprocessing (RP)
Half DD
Full RP

Case 1: zero nuclear + 100%DD
Case 2: 15 nuclear + 50%DD/50%RP
Case 3: 25 nuclear + 50%DD/50%RP
Case 3.5: 25 nuclear + 100%DD
Case 4: 25 nuclear + 100%RP
### 2.(2) Possible scenarios
Features and points to watch in each cases

<table>
<thead>
<tr>
<th>Case</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1: zero nuclear + 100%DD</td>
<td>Since the spent fuels are not reprocessed, the spent fuels are being piled up in the storage pools or depositories. Along with the decreasing nuclear power generation, spent fuels will not be increased after 2030.</td>
</tr>
<tr>
<td>Case 2: 15 nuclear + 50%DD/50%RP</td>
<td>Since the spent fuels are reprocessed while nuclear power generation is decreasing, the accumulated spent fuels will decrease.</td>
</tr>
<tr>
<td>Case 3: 25 nuclear + 50%DD/50%RP</td>
<td>Since the spent fuels are reprocessed but not more than to be generated, the spent fuels will be slightly increasing.</td>
</tr>
<tr>
<td>Case 3.5: 25 nuclear + 100%DD</td>
<td>Since the spent fuels are not reprocessed while generated, they will be piled up. However, this case will not be likely realistic.</td>
</tr>
<tr>
<td>Case 4: 25 nuclear + 100%RP</td>
<td>Since the spent fuels are reprocessed more than to be generated, the accumulated spent fuels will be slightly decreasing.</td>
</tr>
</tbody>
</table>
2.(3) Rough estimates on the inventories of spent fuels – Nuclear power generation toward 2050

The nuclear power generation in each scenarios
2.(3) Rough estimates on the inventories of spent fuels – Production of the spent fuels toward 2050

Possibly produced spent fuels per year in each scenarios

- 25% nuclear in 2030
- 15% nuclear in 2030
- 0% nuclear in 2030

Capacity of Rokkasho Reprocessing Plant
2.(3) Rough estimates on the inventories of spent fuels
– Accumulated amount of spent fuels toward 2050

Accumulated spent fuels in each cases
3. Prospects and implications
3. Prospects and implications (1/2)

- Nuclear share target in the long term is still under discussion in Japan. 25%, 15% or zero in 2030? Who knows??

-> We need to have alternative options wide and to look more deeply into each one.

- Discussions and R&Ds for direct disposal have been just launched and some findings will be expected to be introduced by Atomic Energy Society of Japan.

- Discussions for expanding the existing on-site pools, on-site dry casks and for large scale off-site dry storages should be also more developed.
3. Prospects and implications (2/2) : Implications to the each cases

- If we choose the option of “25% nuclear”, one or more actions among these should be taken as soon as possible:
  - To resume operation of Rokkasho Reprocessing Plant and Mutsu Interim Storage Facility
  - To investigate the possibility of another on- or off-site storages

- If the nuclear share is 15% and Rokkasho Reprocessing Plant works beyond 50% of the capacity factor, then the spent fuels would not accumulated anymore.

- Even though the option of “zero nuclear in 2030” is chosen, some alternative methods for managing spent fuels should be considered in 10 years so that the spent fuels would not accumulated beyond the current control level.
Thank you

Vielen Dank
非常感谢
 정말 감사합니다
Tack så mycket