
May 2015

Power Generation Cost Analysis Working Group
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I. Introduction
1. Purpose of Cost Analysis and Viewpoints

- This Working Group estimates the costs of generating power for various power sources, which serve as reference in the review of the future image of a realistic and balanced energy demand and supply structure by the Subcommittee on Long-term Energy Supply-demand Outlook, under the Strategic Policy Committee of the Advisory Committee for Natural Resources and Energy.

- The estimation methods in this Working Group are based on those of 2011 Costs Analysis Committee, and reflect the changes in circumstances after the December 2011 Costs Analysis Committee Report and summary of the points at issue discussed in this Working Group.

- To carry out the estimations based on various data, information from the public was accepted from March 4 to April 10, 2015. Technical reviews based on expertise from various viewpoints, such as presentations made by the Working Group members, were carried out, and the report for the Subcommittee on Long-term Energy Supply-demand Outlook has been summarized.

- This Working Group estimates costs per unit of power generation in yen/kWh. However, with the increasing installation of a variety of renewable energy sources (solar power and wind power), adjustment costs required for ensuring a stable power supply are also estimated. It must be noted that the importance of the performance of power generation facilities (kW values) has increased.
<Committee Members>
(Chairperson)
Kenji Yamaji  Director-General, Research Institute of Innovative Technology for the Earth (RITE).

(Members)
Reiko Akiike  Partner & Managing Director, The Boston Consulting Group
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Toshihiro Matsumura  Professor, Institute of Social Sciences, The University of Tokyo
Hajimu Yamana  Vice President, Nuclear Damage Compensation and Decommissioning Facilitation Corporation, Professor Emeritus, University of Kyoto

<Past Meetings>
- 1st (2/18)  Topic: Discussion on generation costs based on the results of review by 2011 Costs Analysis Committee
- 2nd (3/3)  Topic: Points at issue regarding renewable energy and thermal power generation
- 3rd (3/26)  Topic: Points at issue regarding nuclear power generation
- 4th (4/6)  Topic: Points at issue regarding adjustment costs and costs for policy measures, etc.
- 5th (4/16)  Topic: Points at issue in discussions to date, etc.
- 6th (4/27)  Topic: Summary of discussions to date
- 7th (5/11)  Topic: Report on analysis of generation costs, etc. (Draft)
2. Principles on Cost Analysis

(1) Viewpoints on costs to be verified

(1) To realize stable energy supply with minimal social burden, from the viewpoint of reviewing a future energy demand and supply structure based on 3E+S, not only costs borne by power generation companies but also specific costs that need to be borne by the public to maintain the power supply from specific power sources are regarded as power generation costs for each power source.

(2) In addition, the cost required for transforming from the current power supply structure to one that corresponds to one of the envisioned future energy supply structures being examined, is also summarized as cost to be borne by the public, because it serves as reference information for reviewing future energy demand and supply structures.

(3) However, costs for securing future power supplies that can not be directly attributed to specific power supply activities are categorized as costs for securing choices in the future power supply structures. As they are not directly related to the visions for the future of energy demand and supply structures which are being reviewed specifically, these costs will not be verified.

(2) Estimation method

(1) As a basis for examining future energy demand and supply structures, the power generation costs of each power source are estimated, using the same methods as the 2011 Costs Analysis Committee, which were able to demonstrate future prospects based on model plants.

(2) However, the costs required for transforming from the current to future power supply structure are estimated taking into account the relations with present asset portfolios.

(3) When future energy mix is indicated, methods for presenting the estimates of the power generation costs of each power source are also considered in a way that they can be understood, based on the roles played by each power source in future power supply structures.
3. Estimation Method Based on Model Plant Method

Like the 2011 Costs Analysis Committee, the estimations are carried out based on the model plant method widely applied around the world, by the OECD, EIA (U.S. Energy Information Administration), etc.

⇒ The power generation costs of model plants for each power source are obtained by dividing total costs by the amount of power generated.

* The data for sample plants is applied to the real value for 2014. The generation costs of new plants at specific times (2014 and 2030 in this report) are calculated by dividing the costs (throughout the whole life cycle from construction to disposal, converted to current values, using the discount rate) with the power generated during the years of operation.

⇒ For power sources subject to the Feed-in Tariff, the calculation basis of the purchase price is used as the values of parameters.

Public costs* were also incorporated in the model plant viewpoint.

\[
\text{Yen/kWh} = \frac{\text{Capital costs} + \text{Operating and maintenance costs} + \text{Fuel costs} + \text{Public costs}}{\text{Power generated (kWh)}}
\]

* This report shows the results of estimations which employ a 3% discount rate.

* Public costs: Accident risk (costs for handling severe nuclear accidents), policy measures and Environmental measures (thermal power CO2 measures costs) are the costs considered.

* In the estimation of power generation costs by the OECD based on the model plant method, public costs such as costs for policy measures and nuclear accident cost, etc. are not regarded as power generation costs. (Only CO2 measures costs are included.)

* Adjustment costs are related to power generation, but are difficult to classify as costs unique to single power sources. Therefore, they are not regarded as costs specific to power generation type.
(Reference) Power Generation Costs of Individual Power Sources

○ Capital costs
  Total construction costs, fixed asset tax, water utilization charges, facility disposal costs

○ Operating and maintenance costs
  Total personnel expenses, repair costs, miscellaneous expenses, and work sharing costs

○ Fuel costs
  Value obtained by multiplying fuel price per unit quantity with the required fuel amount (in the case of nuclear energy, separately calculated as nuclear fuel cycle costs)

○ CO2 reduction costs (power sources using fossil fuels)
  Costs required for reduction of CO₂ emissions in the use of fuel for power generation

○ Additional capital cost for new safety standards (Nuclear power)
  Safety measure based on instructions for additional safety measures received from the government on four separate occasions after the Fukushima I Nuclear Power Plant accident, new regulatory requirements related to nuclear power facilities and voluntary safety improvement efforts.

○ Accident risk costs (Nuclear power)
  Costs for severe accident risks

○ Waste heat utilization value (Cogeneration and Fuel Cell)
  As heat produced during power generation can be effectively used, it is deducted from power generation costs based on the waste heat utilization value.

○ Costs for policy measures
  Not cost born by power generation companies for power generation, but public costs considered necessary for power generation by each power source out of the costs for policy measures covered by tax (Budget related costs for policy measures appropriating government’s budgetary provisions, IRR(*) equivalent costs for policy measures)

  (*) Preferred return of purchase price of “Feed-in Tariff”
4. Viewpoints on Adjustment Costs

- In the current analysis of power generation costs, adjustment costs incurred with the installation of a variety of renewable energy sources (solar power and wind power) were also verified.

- Adjustment costs are defined as costs related to the following.

  1. Adjustment costs related to thermal power generation and pumped-storage power generation
     1) Costs incurred with the deterioration of power generation efficiency due to the drop in the availability factor of thermal power generation
     2) Costs incurred with the increase in the frequency of thermal power stoppages
     3) Costs incurred as a result of demand created by pumped hydro-power during variable renewable energy generate power.
     4) Costs required for securing power generation facilities to deal with variable renewable energy.

  2. Costs for expanding interconnection lines, etc. for renewable energy.

  3. Others

- This Working Group calculates “(1) thermal power generation and pumped-storage power generation adjustment costs” based on the premise that there is no regional maldistribution of the installation of solar power or wind power, there is no regional supply-demand imbalance, etc.
5. Points to be Reexamined between All Power Generation in the Estimation Method

(1) Correcting estimation method for initial investments (plant construction, etc.)
- The 2011 Costs Analysis Committee adopted initial investments as depreciation costs after operations start, and thus slightly underestimated the initial investment costs (the method tends to estimate less generation costs with large construction costs) compared to the calculation method used by OECD.
- This Working Group adopted the viewpoints of the OECD estimation method where the initial investments are evaluated as costs for plant construction.

(2) Reflecting costs for policy measures for all electric power sources
- The 2011 Costs Analysis Committee did not appropriate costs for policy measures for power sources generating less than 50 billion kWh. Therefore, costs for policy measures are not reflected in figures for many renewable energy power generation types.
- In this Working Group, given that renewable energy facilities have been increasing since the start of the Feed-in Tariff program, costs for policy measures are categorized into the following groups based on the current power generation types including IRR (preferred amount equivalent to profits of the purchase price in Feed-in Tariff program) included in purchase price as a policy by Feed-in Tariff, and ① and ② are taken as power generation costs.
  ① Costs required for maintaining domestic power generation activities.
  ② Highly probable costs required for maintaining domestic power generation activities.
  ③ Low probability costs required for maintaining domestic power generation activities.
  ④ Costs not directly related to domestic power generation activities, costs aiming mainly at energy security, or double count costs.
### 6. Viewpoints on Costs for Policy Measures (1)

<table>
<thead>
<tr>
<th>Location</th>
<th>Grants for areas where electric power stations located</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disaster prevention</td>
<td>All</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>PR (Neighboring area)</td>
<td>All</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>PR (Nationwide)</td>
<td>—</td>
<td>PR of designated power sources</td>
<td>General energy PR</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Personnel development</td>
<td>Safety/Regulations</td>
<td>General personnel development</td>
<td>—</td>
<td>Contributes to power generation in other countries</td>
<td></td>
</tr>
<tr>
<td>Evaluation/Survey</td>
<td>Safety/Regulations Radioactive waste disposal assurance measures</td>
<td>General evaluation and survey</td>
<td>—</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Contributions from international organizations</td>
<td>Contributes to establishment of safety regulations domestically, etc.</td>
<td>Discusses safety improvement, etc. internationally</td>
<td>—</td>
<td>Discusses energy</td>
<td></td>
</tr>
<tr>
<td>Power generation technological development</td>
<td>Contributes to safety improvement, etc.</td>
<td>Contributes to high efficiency and low cost</td>
<td>—</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Future power generation technological development</td>
<td>—</td>
<td>Costs related to nuclear fuel cycle and nuclear safety</td>
<td>R&amp;D with little connection with current power generation methods</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Installation support</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Resource development</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Storage</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>CCS</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>IRR (Preferred returns of purchase price of “Feed-in Tariff”)</td>
<td>All</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td></td>
</tr>
</tbody>
</table>
6. Viewpoints on Costs for Policy Measures (2)

Basic viewpoints on power generated by each power source using calculation of budget related costs for policy measures

- Based on comments received in the Working Group, the following viewpoint is adopted for power generated by power sources to calculate the budget related costs for policy measures per kWh.

[2014]
- In calculating budget related costs for policy measures, the 2014 budget is used. Therefore, the most recent actual power generated (2013) is used. However, given that circumstances differ by power source, the following viewpoint is adopted for some power sources in order to calculate the budget related costs for policy measures appropriately.

[2030]
- The 2030 power generation outlooks indicated by the Subcommittee on Long-term Energy Supply-demand Outlook will be used.

| Renewable energy: | It is inappropriate to apply the current budget for policy measures and power generated, because renewable energy is presently in the stage of installation. Therefore, power generated is calculated by using the capacity factor of each power source and the total installed capacity (amount of facilities approved between the start of the FIT program and the end of January 2015 are added to current installed capacity). In the case of geothermal power, the power generated is calculated from 1,430,000 kW which includes the amount currently planned, indicated in the 4th Subcommittee on Long-term Energy Supply-demand Outlook. For wind power (onshore), the power generated is calculated from 7,690,000 kW which includes installed capacity and the facilities that are currently being environmentally assessed or which have been completed as indicated by the 9th New Energy Committee. |
| Nuclear power: | All nuclear power plants have stopped operating, so power generated was estimated from 43 reactors, excluding those already set for decommissioning, with capacity factor of 70% or 80%. |
| Cogeneration: | Estimated by using the Survey of Electric Power Statistics, METI (surveyed power generated for 1,000 kW per site) |
| Fuel cell: | Installation targets for household fuel cell by 2020. |

- Power generated by each power source using calculation of budget related costs for policy measures

<table>
<thead>
<tr>
<th>Year</th>
<th>Nuclear power</th>
<th>Coal thermal power</th>
<th>LNG thermal power</th>
<th>Oil thermal power</th>
<th>General hydro-power</th>
<th>Cogeneration</th>
<th>Small and medium hydropower</th>
<th>Geothermal</th>
<th>Solar power</th>
<th>Wind power (Onshore)</th>
<th>Wind power (Offshore)</th>
<th>Biomass</th>
<th>Fuel cell</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014 Power generated (kWh)</td>
<td>257.8 billion</td>
<td>284.5 billion</td>
<td>405.7 billion</td>
<td>139.8 billion</td>
<td>38.8 billion</td>
<td>51.4 billion</td>
<td>52.5 billion</td>
<td>10.4 billion</td>
<td>93.3 billion</td>
<td>13.5 billion</td>
<td>—</td>
<td>28.9 billion</td>
<td>4.3 billion</td>
</tr>
<tr>
<td>2030 Power generated (kWh)</td>
<td>224.25 billion</td>
<td>281 billion</td>
<td>284.5 billion</td>
<td>31.5 billion</td>
<td>43.4 billion</td>
<td>103 billion</td>
<td>44.15 billion</td>
<td>10.75 billion</td>
<td>74.9 billion</td>
<td>16.1 billion</td>
<td>2.2 billion</td>
<td>44.2 billion</td>
<td>16 billion</td>
</tr>
</tbody>
</table>

(*1) Source: "Outline of power source development" for actual value of power generated in 2014. Does not include self-consumed amount. (*2) 70% capacity factor cases for nuclear power generated in 2014

(*3) For power generated in 2030, upper and lower medians are used for the power sources indicated as marginal in the Long-Term Energy Supply-Demand Outlook (nuclear power, geothermal, hydropower and biomass).
## Power Generation Cost of each Power Source in 2014

<table>
<thead>
<tr>
<th>Capacity Factor</th>
<th>Operation Period</th>
<th>Nuclear</th>
<th>Coal</th>
<th>LNG</th>
<th>Wind power (onshore)</th>
<th>Geothermal</th>
<th>Hydro power</th>
<th>Hydropower Small scale 0.8 million yen/kW</th>
<th>Hydropower Small scale 1 million yen/kW</th>
<th>Biomass (unmixed combustion)</th>
<th>Biomass (mixed combustion)</th>
<th>Oil</th>
<th>Solar power (mega)</th>
<th>Solar power (household)</th>
<th>Gas cogeneration</th>
<th>Oil cogeneration</th>
</tr>
</thead>
<tbody>
<tr>
<td>y/m/kWh</td>
<td>Case in 2011</td>
<td>10.1~  (8.8~)</td>
<td>12.3  (12.2)</td>
<td>13.7  (13.7)</td>
<td>21.6  (15.6)</td>
<td>16.9 (10.9)</td>
<td>23.3  (20.4)</td>
<td>27.1  (23.6)</td>
<td>29.7  (28.1)</td>
<td>12.6  (12.2)</td>
<td>30.6  (36.1)</td>
<td>24.2  (21.0)</td>
<td>29.4  (27.3)</td>
<td>13.8  (15.0)</td>
<td>24.0  (27.8)</td>
<td></td>
</tr>
</tbody>
</table>

### Sensitivity analysis of nuclear power (yen/kWh)
- Additional safety measure costs (doubled)
- Abolition costs (doubled)
- Decommissioning and compensation costs (increased by 1 trillion yen)
- Reprocessing and MOX processing costs (doubled)

### Sensitivity analysis of fossil fuel prices (yen/kWh)
- Impact associated with a 10% change in fuel prices

#### Notes:
1. With fuel prices on the decline compared to last year’s levels, the results of sensitivity analysis are as follows:
2. Capacity factor in 2011 case: Coal: 80%, LNG: 80%, Oil: 50%, 10%
3. Numbers in the parentheses are power generation costs excluding policy expenses.
4. As for geothermal power, the budget for development and promotion constitutes a major part of policy expenses, which makes comparison with other power sources difficult. Related costs are automatically deducted from the total power generation of 1,430,000 kW (including that of projects in the planning stage), the results of which are shown here.
## Power Generation Cost of each Power Source in 2030

<table>
<thead>
<tr>
<th></th>
<th>Nuclear</th>
<th>Coal</th>
<th>LNG</th>
<th>Wind power (onshore)</th>
<th>Wind power (offshore)</th>
<th>Geothermal</th>
<th>Hydro power</th>
<th>Hydropower Small scale 0.8 million y/kWh</th>
<th>Hydropower Small scale 1 million y/kWh</th>
<th>Biomass (unmixed combustion)</th>
<th>Biomass (mixed combustion)</th>
<th>Oil</th>
<th>Solar power (mega)</th>
<th>Solar power (household)</th>
<th>Gas cogeneration</th>
<th>Oil cogeneration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation period</td>
<td>70% 40 years</td>
<td>70% 40 years</td>
<td>70% 40 years</td>
<td>20~23% 20 years</td>
<td>30% 20 years</td>
<td>83% 40 years</td>
<td>45% 40 years</td>
<td>60% 40 years</td>
<td>60% 40 years</td>
<td>87% 40 years</td>
<td>70% 40 years</td>
<td>30~10% 40 years</td>
<td>14% 30 years</td>
<td>12% 30 years</td>
<td>70% 30 years</td>
<td>40% 30 years</td>
</tr>
<tr>
<td>yen/kWh</td>
<td>10.3~(8.8~)</td>
<td>12.9</td>
<td>13.4(13.4)</td>
<td>13.6<del>21.5 (9.8</del>15.6)</td>
<td>30.3<del>34.7 (20.2</del>23.2)</td>
<td>16.8 (10.9)</td>
<td>11.0 (10.8)</td>
<td>23.3 (20.4)</td>
<td>27.1 (23.6)</td>
<td>29.7 (28.1)</td>
<td>13.2 (12.9)</td>
<td>28.9<del>41.7 (28.9</del>41.6)</td>
<td>12.7<del>15.6 (11.0</del>13.4)</td>
<td>12.5<del>16.4 (12.3</del>15.6)</td>
<td>14.4<del>15.6 (14.4</del>15.6)</td>
<td>27.1<del>31.1 (27.1</del>31.1)</td>
</tr>
<tr>
<td>Case in 2011</td>
<td>8.9~</td>
<td>10.9</td>
<td>8.8~17.3</td>
<td>9.2~23.1</td>
<td>9.2~23.1</td>
<td>10.6</td>
<td>19.1~22.0</td>
<td>19.1~22.0</td>
<td>17.4~32.2</td>
<td>9.5~9.8</td>
<td>25.1~38.9</td>
<td>12.1~26.4</td>
<td>9.9~20.0</td>
<td>11.5</td>
<td>19.6</td>
<td></td>
</tr>
</tbody>
</table>

### Sensitivity analysis of nuclear power (yen/kWh)

- Additional safety measure costs (doubled): +0.6
- Abolition costs (doubled): +0.1
- Decommissioning and compensation costs: +0.04
- Reprocessing and MOX processing costs (doubled): +0.6

### Sensitivity analysis of fossil fuel prices (yen/kWh)

- Impact associated with a 10% change in fuel prices:
  - Coal: +0.4
  - LNG: +0.9
  - Oil: +1.5

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### Adjustment costs resulting from promotion of variable renewable energy (solar and wind power)

- The share of the power sources is based on a total power generation of 1,650 billion kWh.

<table>
<thead>
<tr>
<th>Share of variable renewable energy</th>
<th>Share of renewable energy</th>
<th>Adjustment costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>66 billion kWh (6%)</td>
<td>19-21%</td>
<td>¥300 billion a year</td>
</tr>
<tr>
<td>93 billion kWh (9%)</td>
<td>22-24%</td>
<td>¥470 billion a year</td>
</tr>
<tr>
<td>124 billion kWh (12%)</td>
<td>25-27%</td>
<td>¥700 billion a year</td>
</tr>
</tbody>
</table>

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*1 Policy efforts are expected to reduce fossil fuel prices. The results of sensitivity analysis are as follows:

*2 Capacity factor in 2011 case: Coal: 80%, LNG: 80%, Oil: 50%, 10%

*3 Numbers in the parentheses are power generation costs excluding policy expenses.
II. Detailed Discussion
(1) Renewable Energy
### [Solar Power] Breakdown of Renewable Power Generation Costs

**Solar power (residential) generation costs (2014)**

<table>
<thead>
<tr>
<th>Costs</th>
<th>Value (2014)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital costs</td>
<td>23.9</td>
<td>Including construction costs (23.3 Yen/kWh) and disposal costs (0.6 Yen/kWh)</td>
</tr>
<tr>
<td>Operating and maintenance costs</td>
<td>3.4</td>
<td>Including periodic inspection costs, power conditioner replacement costs (3.4 Yen/kWh)</td>
</tr>
<tr>
<td>Costs for policy measures</td>
<td>2.1</td>
<td>IRR equivalent costs for policy measures (2.0 Yen/kWh)</td>
</tr>
</tbody>
</table>

* Assuming model plant with installed capacity of 4kW, capacity factor of 12%, and 20 years of operation.

**Solar power (non-residential) generation costs (2014)**

<table>
<thead>
<tr>
<th>Costs</th>
<th>Value (2014)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital costs</td>
<td>17.9</td>
<td>Including construction costs (16.1 Yen/kWh) and disposal costs (0.4 Yen/kWh)</td>
</tr>
<tr>
<td>Operating and maintenance costs</td>
<td>3.0</td>
<td>Personnel expenses, repair costs, miscellaneous expenses, work sharing costs (3.0 Yen/kWh)</td>
</tr>
<tr>
<td>Costs for policy measures</td>
<td>3.3</td>
<td>IRR equivalent costs for policy measures (3.1 Yen/kWh)</td>
</tr>
<tr>
<td>Costs for policy measures</td>
<td>3.3</td>
<td>Budget related costs for policy measures (0.2 Yen/kWh)</td>
</tr>
</tbody>
</table>

* Assuming model plant with installed capacity of 2,000kW, capacity factor of 14%, and 20 years of operation.

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**Breakdown of Renewable Power Generation Costs**

**Solar power (residential) generation costs**

- **2014 Costs**
  - Total: 29.4 Yen/kWh
  - Excluding costs for policy measures: 27.3 Yen/kWh

**Solar power (non-residential) generation costs**

- **2014 Costs**
  - Total: 24.2 Yen/kWh
  - Excluding costs for policy measures: 21.0 Yen/kWh
### Wind energy (onshore) generation costs (2014)

- **21.6 Yen/kWh**
  - (Excluding costs for policy measures: 15.6 Yen/kWh)

<table>
<thead>
<tr>
<th>Costs</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital costs</td>
<td>12.1</td>
</tr>
<tr>
<td>Operating and maintenance costs</td>
<td>3.4</td>
</tr>
<tr>
<td>Costs for policy measures</td>
<td>6.0</td>
</tr>
</tbody>
</table>

* Given that with wind energy (onshore) several years are necessary for certification of facilities due to environmental assessments etc., in calculating budget related costs for policy measures, the value obtained by mechanically dividing related budget with the power generation calculated from the 7690MW, which is the current total operating production, currently assessing and already assessed projects is indicated.

### Wind energy (offshore) generation costs (2020)

- **34.7 Yen/kWh**
  - (Excluding costs for policy measures: 23.2 Yen/kWh)

<table>
<thead>
<tr>
<th>Costs</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital costs</td>
<td>14.7</td>
</tr>
<tr>
<td>Operating and maintenance costs</td>
<td>8.6</td>
</tr>
<tr>
<td>Costs for policy measures</td>
<td>11.5</td>
</tr>
</tbody>
</table>

### Notes

- Assuming model plant with installed capacity of 20MW, capacity factor of 20%, and 20 years of operation.

- Assuming model plant with installed capacity of 30MW to 100MW capacity factor of 30%, and 20 years of operation (2020 model plant).
Geothermal power generation costs (2014)
16.9 Yen/kWh
(Excluding costs for policy measures: 10.9 Yen/kWh)

* Regarding the costs for policy measures related to geothermal power, most of the costs are due to future business expansion. Although comparison with other power sources is difficult, here the value is obtained by dividing related costs with the total calculated power generation of 1430 MW, which is sum of the current and planned projects.

Small hydropower generation costs (2014)
23.3 Yen/kWh
(Excluding costs for policy measures: 20.4 Yen/kWh)

* Assuming construction costs of 800 thousand Yen/kW

Woody biomass power generation costs (2014)
29.7 Yen/kWh
(Excluding costs for policy measures: 28.1 Yen/kWh)

* Assuming model plant with installed capacity of 5,700 kW, capacity factor of 87%, and 40 years of operation.
1. Views on parameters for generation costs

The various parameters used for calculating the purchase price of FY2015 in the Special Committee for Determination of Tariffs and Durations are taken as the parameters for verifying the power generation costs of the 2014 model plants in this working group.

2. Views on power generation costs in future model plants

For solar and wind power, the effects of cost reductions from mass production effects brought about by technological innovation and increased domestic market and global markets, etc. are considered.

For geothermal power, hydropower energy, and biomass energy, technological innovation and mass production effects which have major impacts on power generation costs are not taken into account at this point. For this reason, the same parameters as the 2014 model plants have been used for the 2020 and 2030 model plants.
Relation between Parameters of Costs Analysis Committee (2011) and Special Committee for Determination of Tariffs and Durations

**[Calculation of Purchase Price]**
- The purchase price in Feed-in Tariff is calculated based on costs deemed normally necessary if the concerned supply has been provided efficiently (Act on Purchase of Renewable Energy Sourced Electricity by Electric Utilities Article 3.2).
- Regarding facilities subject to the system, the law obliges the renewable energy producers to submit their cost data, therefore the government can collect the actual cost data.
- The Special Committee for Determination of Tariffs and Durations analyzes the above collected cost data, etc., and uses it for calculating purchase price.

**[Parameters of This Working Group]**
- The parameters used for calculating the purchase price in FY2015 by the Special Committee for Determination of Tariffs and Durations are appropriated according to the classification of costs items, etc. of the Costs Analysis Committee in 2011, and taken as the parameters of the 2014 model plants of this Working Group.
- It should be noted that there exists the following differences in the parameters of the 2011 Costs Analysis Committee and Special Committee for Determination of Tariffs and Durations: (1) Grid connection costs, (2) Land rental, (3) Business tax, (4) Operation years. In particular, regarding (2) Solar power (non-residential), large tracts of land are required, but it should be noted that it is not appropriated as a cost item in cost verification. Regarding (4) operation years, a shorter number of years than the actual operation years is set as purchase period for geothermal power, etc. in the Special Committee for Determination of Tariffs and Durations. However, as the parameter of This Working Group, basically, the parameter “operation years” as defined in the 2011 Costs Analysis Committee are used. (See page 36.)

| <Differences in Parameters of 2011 Costs Analysis Committee and Special Committee for Determination of Tariffs and Durations> |
|---|---|---|
| **Capital costs** | **Cost Verification Committee** | **Special Committee for Determination of Tariffs and Durations** |
| Construction costs | 〇 | 〇 |
| Grid connection costs | — | 〇 |
| Disposal costs | 〇 | 〇 |
| **Operating and maintenance costs** | **Cost Verification Committee** | **Special Committee for Determination of Tariffs and Durations** |
| Personnel expenses | 〇 | 〇 |
| Repair costs | 〇 | 〇 |
| Miscellaneous expenses | 〇 | 〇 |
| Work sharing costs | 〇 | 〇 |
| Land rentals | — | 〇 |

| **Taxes** | **Cost Verification Committee** | **Special Committee for Determination of Tariffs and Durations** |
|—— |—— |—— |
| Fixed asset tax | 〇 | 〇 |
| Business tax | — | 〇 |
| **Others** | **Cost Verification Committee** | **Special Committee for Determination of Tariffs and Durations** |
| Output | 〇 | 〇 |
| Capacity factor | 〇 | 〇 |
| Useful life designated by law | 〇 | 〇 |
| Operation years | 〇 | 〇 (Purchase period) |
| IRR(Before tax reduction) | — | 〇 |
For solar power and wind energy generation facilities, cost reduction of future model plants is calculated as a scenario based on the effects of mass production where prices drop in line with global production increases and technological progress such as improvements to durability and capacity factor.

Furthermore, given that the domestic prices of solar and wind power generation facilities may drop to the international level due to market maturity from the long-term perspective, such further cost is also calculated as another scenario.

The current technological environment of geothermal power, hydropower, and biomass power is not seeing any significant changes. On one hand, there are costs reducing factors such as technological improvements. On the other hand, there are cost increasing factors such as increased costs for exploring a remote and undeveloped area and raw materials. Taking these circumstances into consideration, this Working Group has decided to use the same parameters for the 2020 and 2030 model plants as the 2014 model plant in accordance with the arrangement of the 2011 Costs Analysis Committee.
The cost reduction of solar power generation is estimated using the same method used by the 2011 Costs Analysis Committee.

1) **Reduction of facility costs out of construction costs**

- Regarding the drop in construction costs, as in the 2011 Costs Analysis Committee, facility costs are assumed to decrease and installation costs are assumed to be uniform. Facility and equipment costs (modules, inverter, and other attached devices) are assumed to decrease in line with global cumulative production increases due to international organizations, etc.
- It is assumed these costs will continue to drop at a learning rate of 80% in line with production prospects.
- Further construction costs reductions are anticipated due to the increased installation of solar power generators(*).
- However, it was set as uniform due to the fact that expenses, such as personnel expenses, etc. will increase.

* In the working group it was pointed out that as an effect of the Feed-in Tariff, achievement of low cost as a result of improved efficiency of not only facilities but also installation construction work, etc. can be looked forward to.

2) **Improvement of durability of power generation modules**

- For the operation years of future model plants, the upper limit is set at 30 years, based on “NEDO PV Challenges”.

3) **Reduction of operating and maintenance costs**

- Operating and maintenance costs of small solar power generation facilities (under 10kW) mainly consist of periodic inspection costs (min. once every 4 years - about 20,000 yen) and power conditioner replacement costs (replaced every 20 years, 200,000 yen on average). Regarding the power conditioner replacement costs which is the majority of the burden, cost reduction is expected due to mass production, etc. For this reason, construction, and operating and maintenance cost reductions, were given the same value.
- Operating and maintenance costs of larger solar power generation facilities (over 10kW) consist of repair costs, miscellaneous expenses, general management costs, personnel expenses, and insurance, etc. Given that the operating and maintenance costs estimated by the Special Committee for Determination of Tariffs and Durations are falling every year, the amount equivalent to the personnel expenses (electrical chief engineer) was set as uniform. For other expenses (repair costs, etc.), the same cost reduction as construction costs was predicted.

### Source Outline

<table>
<thead>
<tr>
<th>Source</th>
<th>Outline</th>
<th>2013(Actual results)</th>
<th>2020(Estimate)</th>
<th>2030(Estimate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>World Energy Outlook 2014 (IEA) Current Policies Scenario</td>
<td>Scenario taking into account already adopted policies within 2014.</td>
<td>140 million kW</td>
<td>333 million kW</td>
<td>495 million kW</td>
</tr>
<tr>
<td>World Energy Outlook 2014 (IEA) New Policies Scenario</td>
<td>Scenario taking into account policies adopted or proposed by various countries within 2014.</td>
<td></td>
<td>364 million kW</td>
<td>647 million kW</td>
</tr>
<tr>
<td>World Energy Outlook 2014 (IEA) 450 scenario (Reference)</td>
<td>Scenarios limiting greenhouse gas concentration to within 450 ppm.</td>
<td></td>
<td>371 million kW</td>
<td>856 million kW</td>
</tr>
<tr>
<td>Energy Technology Perspectives 2014 (IEA) Technology Roadmap Solar Photovoltaic Energy 2DS high-Renewable scenario (Reference)</td>
<td>Scenario in which the percentage of renewable energies is increased, for energy systems which can limit the average global temperature increase to under 2 degrees at a probability of 50%.</td>
<td></td>
<td>791 million kW</td>
<td>1721 million kW</td>
</tr>
</tbody>
</table>

*IEA TRENDS IN PHOTOVOLTAIC APPLICATIONS Survey 2014*
The following are the calculations of reduced construction costs for solar power based on the factors mentioned earlier.

### Residential
- Reference values: 36.4
- Actual results (Special Committee for Determination of Tariffs and Durations): 27.4
- WEO2014 New policy scenario: 25.8
- WEO2014 Current policy scenario: 25.8
- IEA 2DS Hi-Ren scenario: 24.1

### Non-residential
- Reference values: 29.4
- Actual results (Special Committee for Determination of Tariffs and Durations): 23.3
- WEO2014 New policy scenario: 22.2
- WEO2014 Current policy scenario: 21.9
- IEA 2DS Hi-Ren scenario: 21.9
Views on Reduction of Solar Power Generation Costs (Potential to decrease to international prices)

- The construction costs for solar power generation in Japan are high compared to other countries. However, it has been pointed out that equipment costs such as solar power modules and inverters, etc. may drop to international prices in the long run.
- In Germany and Italy, module prices have been dropping sharply in recent years owing to the mass introduction of solar power generation facilities. In Japan, module prices are falling, but compared to other countries, they are still high.
- Given that whether facility costs in Japan will shrink to international prices depends on 1) state of market competition 2) overseas production rate in the domestic market and 3) trends in the way renewable energy companies select their equipment, there is a need to monitor progress in the future.

Changes in module price (based on currency unit of each country)

Changes in module price (based on USD conversion)

Share of domestic production making up domestic shipments of solar cell modules (Third Quarter FY2014)

- Overseas production 64%
- Domestic production 36%

Share of Japanese companies making up domestic shipments of solar cell modules (Third Quarter FY2014)

- Overseas production 34%
- Domestic production 66%

Compiled from solar cell shipment statistics (Japan Photovoltaic Energy Association)
Estimation Method on Reduction of Solar Power Generation Costs (Assuming international prices achieved)

- The construction costs of various countries (2013) (not Japan) were averaged based on an IEA survey to determine the international level of construction costs for solar power, and they were found to be 318,000 Yen/kW for residential and 205,000 Yen/kW for non-residential. These were lower than the construction costs in Japan disclosed by the Special Committee for Determination of Tariffs and Durations (364,000 Yen/kW for residential and 294,000 Yen/kW for non-residential).

- Of the construction costs for solar power generation in Japan, facility costs are expected to drop due to the mass production of modules and inverters, etc. In addition to the scenarios of learning curve cost reduction, calculations are carried out for the scenarios where facility costs drop to international levels gradually to 2030 (assuming that international costs also decreases according to the learning curve).

<Construction costs of solar power generation in various countries (2013)>

Structure of construction costs for solar power generation in Europe

Compiled from EC (JRC Science and policy reports) “PV Status Report 2014”.

(Average) 318 000 Yen/kW  
(Average) 205 000 Yen/kW  
* Calculated based on 105.24 Yen/$ (2014 average)  
* Calculated based on 105.24 Yen/$ (2014 average)
For construction costs for solar power generation in Japan, estimates were made using theoretical models where facility costs including modules and inverters dropped to international levels by 2030. The calculations produced estimated costs of 206,000 - 220,000 Yen/kW (for residential) and 185,000 - 194,000 Yen/kW (non-residential).

* As for the prospects for introduction, only the four IEA scenarios were applied, and the two scenarios which back-cast the introduction amount were taken as reference values.

* The construction price changes due to increasing mass production, etc. mentioned on p24 become 258,000 to 274,000 Yen/kW (for residential) and 222,000 to 233,000 Yen/kW (non-residential) as of 2030.

### Residential

![Graph showing changes in facility costs - modules, inverters, etc.](image)

### Non-residential

![Graph showing changes in facility and equipment costs - modules, inverters, etc.](image)

### Construction costs in various scenarios (If international prices achieved)

![Graph showing construction costs in various scenarios](image)

*Installation costs were fixed at a certain level - although costs are expected to decrease with the expansion of solar power generation, they may increase due to personnel expenses.
The construction costs for solar power generation used as the basis for calculating purchase price had been decreasing every year until the calculation of the purchase price for 2014.

When the purchase price for 2015 was calculated, the construction costs used for calculating the purchase price of solar power (above 10kW) increased for the first time. Possible reasons for this include 1) increase in installation costs due to the increase in construction in industries not related to renewable energy, 2) domestic prices of overseas modules may be rising due to the low yen rate.

Although installation construction costs are expected to drop in the future due to better efficiency of operational skills as a result of increased introduction of solar power generation, due to the recent increase in the unit labor cost and inconsistency of data, etc., installation construction costs are set as uniform in this calculation.

With regard to the disposal costs of future model plants, the 2011 Costs Analysis Committee took it to be 5% of the construction costs, and assumed that disposal costs would drop with the drop in the solar power generation system unit price. However, as disposal costs can be broken down into disassembly costs and recycling costs, etc., at this point, the influence on these costs due to the drop in construction costs is unknown. For this reason, disposal costs are left unchanged.
Views on Reducing Wind Power Generation Costs

[Views on costs reduction in this Working Group]
- Estimated based on the two assumptions similar to the 2011 Costs Analysis Committee - “scenario of low costs realized by mass production effects and technical improvements, etc.” and “scenario of costs staying the same due to the special case of Japan”.
- Regarding the scenario of achieving low costs, like the 2011 Costs Analysis Committee, estimated by referring to IEA prospects.

[Scenario of low costs realized by mass production effects and technical improvements, etc.]
- In this cost verification working group, two scenarios (scenario of achieving low costs and scenario of costs remaining the same) are again assumed.
- The 2011 Costs Analysis Committee estimated future reductions in construction costs based on IEA’s “Energy Technology Perspectives 2010”. Based on the way of 2011 Committee’s estimation, this Working Group also made estimates based on IEA’s wind power generation report “Technology Roadmap Wind Energy 2013”.
- “Technology Roadmap Wind Energy 2013” compares several references related to cost reductions and predicts that construction costs for onshore wind power generation will decrease by 25% and that for offshore wind power generation will decrease by 45% by 2050 as a result of improved turbine performance, etc. The drop in construction costs between 2014 and 2030 is estimated by the simple linear projection of the rate of reduction.
- Regarding operating and maintenance costs, a reduction equivalent to construction cost reductions is forecasted due to the drop in the maintenance and inspection costs per kW owing to the installation of large windmills and the drop in repair costs due to reduced parts prices from the effects of mass production, etc.

[Example of scenario of reduced construction costs introduced in Technology Roadmap Wind Energy 2013]
The following shows the estimated reduction in the construction costs for wind power based on the assumptions mentioned earlier.
(In the scenario of achieving low costs, corrections were made by linearization based on the prospects that construction costs would have decreased as of 2050 according to the IEA Technology Roadmap Wind Energy 2013.)

Onshore (*)

<table>
<thead>
<tr>
<th>Year</th>
<th>Construction Costs (Yen/kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>28.4</td>
</tr>
<tr>
<td>2015</td>
<td>28.4</td>
</tr>
<tr>
<td>2016</td>
<td>28.4</td>
</tr>
<tr>
<td>2017</td>
<td>28.4</td>
</tr>
<tr>
<td>2018</td>
<td>28.4</td>
</tr>
<tr>
<td>2019</td>
<td>28.4</td>
</tr>
<tr>
<td>2020</td>
<td>25.2</td>
</tr>
<tr>
<td>2021</td>
<td>25.2</td>
</tr>
<tr>
<td>2022</td>
<td>25.2</td>
</tr>
<tr>
<td>2023</td>
<td>25.2</td>
</tr>
<tr>
<td>2024</td>
<td>25.2</td>
</tr>
<tr>
<td>2025</td>
<td>25.2</td>
</tr>
<tr>
<td>2026</td>
<td>25.2</td>
</tr>
<tr>
<td>2027</td>
<td>25.2</td>
</tr>
<tr>
<td>2028</td>
<td>25.2</td>
</tr>
<tr>
<td>2029</td>
<td>25.2</td>
</tr>
<tr>
<td>2030</td>
<td>25.2</td>
</tr>
</tbody>
</table>

*1 The construction costs for wind power generation indicated by the Special Committee for Determination of Tariffs and Durations is 300,000 Yen/kW. This time, it was set at 284,000 Yen/kW by exempting the grid connection costs for the system of 15600 Yen/kW.

Offshore (Fixed) (**)

<table>
<thead>
<tr>
<th>Year</th>
<th>Construction Costs (Yen/kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>51.5</td>
</tr>
<tr>
<td>2015</td>
<td>51.5</td>
</tr>
<tr>
<td>2016</td>
<td>51.5</td>
</tr>
<tr>
<td>2017</td>
<td>51.5</td>
</tr>
<tr>
<td>2018</td>
<td>51.5</td>
</tr>
<tr>
<td>2019</td>
<td>51.5</td>
</tr>
<tr>
<td>2020</td>
<td>44.6</td>
</tr>
<tr>
<td>2021</td>
<td>44.6</td>
</tr>
<tr>
<td>2022</td>
<td>44.6</td>
</tr>
<tr>
<td>2023</td>
<td>44.6</td>
</tr>
<tr>
<td>2024</td>
<td>44.6</td>
</tr>
<tr>
<td>2025</td>
<td>44.6</td>
</tr>
<tr>
<td>2026</td>
<td>44.6</td>
</tr>
<tr>
<td>2027</td>
<td>44.6</td>
</tr>
<tr>
<td>2028</td>
<td>44.6</td>
</tr>
<tr>
<td>2029</td>
<td>44.6</td>
</tr>
<tr>
<td>2030</td>
<td>44.6</td>
</tr>
</tbody>
</table>

*2 As the track record for offshore wind (fixed) is poor, the cost reductions after 2020 are estimated with the most recent model plants beginning operation in 2020.
Regarding onshore wind power generation, it can be assumed that the facility costs will drop to international prices due to mass production effects of turbines and electrical equipment, etc.

In the Japanese market, the volume of foreign-produced wind power generation equipment is increasing, and prices may drop to international prices with the maturing of the market. For this reason, the projection of prices dropping to international levels gradually through 2030 is also estimated.

However, there is still a wide price gap between the turbine prices in Japan and overseas, with the prices in Japan relatively high. Looking at the current trends, it should be noted that it cannot be said that the probability of prices dropping to international prices is high.
Estimation Method on Reductions of Wind Power Generation Costs (Scenario of reduction to international prices)

- International levels are calculated by averaging the construction costs (2013) for onshore wind power of various countries other than Japan based on the IRENA survey, and found to be 222,000 Yen/kW, which is lower than the construction costs in Japan (300,000 Yen/kW (includes grid system connection costs).

- For the equipment portion of the construction costs for wind power generation in Japan, in addition to the scenario where "construction costs for onshore wind power generation drop by 25% by 2050" according to the “Technology Roadmap Wind Energy 2013,” scenarios gradually dropping to international levels by 2050 (assuming also that international levels itself would also drop 25% by 2050) are also estimated.

- Regarding installation and land and road construction, etc. (used in solar power etc.), although construction costs may drop due to better operational efficiency and usage of large power generation facilities, they are treated as unchanged due to the possibility of increases in unit cost of labor and decreases in suitable land.

**<Construction costs of onshore wind power generation in various countries (2013)>**

<table>
<thead>
<tr>
<th>Country</th>
<th>New capacity in 2013 (GW)</th>
<th>Cost (2014 USD/kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>0.68</td>
<td>1427 - 2384</td>
</tr>
<tr>
<td>Austria</td>
<td>0.37</td>
<td>2403</td>
</tr>
<tr>
<td>Canada</td>
<td>1.60</td>
<td>2296</td>
</tr>
<tr>
<td>France</td>
<td>0.73</td>
<td>2065</td>
</tr>
<tr>
<td>Germany</td>
<td>2.95</td>
<td>1999</td>
</tr>
<tr>
<td>Italy</td>
<td>0.45</td>
<td>2452</td>
</tr>
<tr>
<td>Japan</td>
<td>0.05</td>
<td>2900</td>
</tr>
<tr>
<td>Mexico</td>
<td>0.62</td>
<td>2102</td>
</tr>
<tr>
<td>Netherlands</td>
<td>0.24</td>
<td>1928</td>
</tr>
<tr>
<td>Norway</td>
<td>0.07</td>
<td>1978</td>
</tr>
<tr>
<td>Portugal</td>
<td>0.31</td>
<td>1891</td>
</tr>
<tr>
<td>Switzerland</td>
<td>0.01</td>
<td>2900</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>1.64</td>
<td>1874</td>
</tr>
<tr>
<td>United States</td>
<td>1.13</td>
<td>1657</td>
</tr>
</tbody>
</table>

**<Breakdown of construction costs for wind power generation>**

- Turbines, electrical equipment etc., 77%
- Installation, 13%
- Grid connection, 17%
- Foundation, 16%
- Development plans, etc., 10%
- Project management, etc., 2%
- Land, road construction, 9%
- Other, 2%

**<Average>222,000 Yen/kW**

*Calculated based on 105.24 Yen/$ (2014 average)


<table>
<thead>
<tr>
<th>Current onshore wind power construction costs (Percentage is estimate)</th>
<th>%</th>
<th>International price (10000 Yen/kW)</th>
<th>Japan (10000 Yen/kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbines, electrical equipment, etc.</td>
<td>77%</td>
<td>17.1</td>
<td>23.1</td>
</tr>
<tr>
<td>Installation, land, road construction, grid connection, etc.</td>
<td>23%</td>
<td>5.1</td>
<td>6.9</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>22.2</td>
<td>30.0</td>
</tr>
</tbody>
</table>
For construction costs for onshore wind power generation in Japan, scenarios where facilities costs for turbines and electrical equipment, etc. dropping to international levels were estimated. As a result, costs were 205,000 Yen/kW as of 2030. (151,000 Yen for turbines, electrical equipment, etc. +53000 Yen for installation, land and road construction, etc.).

*The construction costs on p30 are 200,000 to 284,000 Yen/kW as of 2030.

(Note) For installation, land and road construction, project management, etc., costs are assumed to be uniform. Grid connection costs to the system of 15,600 Yen/kW were exempted.
Relation between Large Wind Power Generators and Capacity Factor

- Large windmills are expected to improve power generation and reduce generation costs. In Japan, efforts are being made to develop technologies aiming to increase wind power generation capacity factor to 23% by 2020. (The capacity factor proposed by the 2015 Special Committee for Determination of Tariffs and Durations is 20%.) However, given that capacity factor can exceed 20% at locations with good wind conditions, it should be noted that high capacity factor can bring down power generation costs.

- However, in the U.S., despite the recent trend of installing more and more large windmills, capacity factor has stayed flat in the last 10 years. This may be because the effects of using large windmills to improve capacity factor are offset by the decrease in suitable locations for wind power generation.

- While it should be noted that use of large windmills does not always produce improvements in capacity factor, the estimate of a 23% capacity factor improvement scenario for wind power generators installed after 2020 in Japan was also chosen.

Source: U.S. National Renewable Energy Laboratory (NREL) survey report

Source: Summary of trends in the U.S. wind energy market, Aaron Smith, 26 May, 2014
In the working group discussions, there were many opinions that the amount equivalent to preferred profits from the purchase price of the Feed-in Tariff (hereafter referred to as “IRR equivalent costs for policy measures”) should be appropriated as costs for policy measures.

With the Feed-in Tariff, the calculation of purchase price is based on “costs deemed normally required if energy is supplied efficiently”, taking into account the “appropriate profits that suppliers of renewable electricity should receive”. (Act on Purchase of Renewable Energy Sourced Electricity by Electric Utilities Article 3.2)

Specifically, for each purchase price category such as power source, scale, etc., the following are set: (1) Capital costs, (2) Operating and maintenance costs, and (3) IRR, etc., and then purchase price allowing costs and profits to be collected by selling power throughout the purchase period is fixed.

IRR equivalent costs for policy measures is obtained by deducting “power generation costs” from “power generation costs reflecting IRR equivalent costs for policy measures”. (In other words, the amount equivalent to the discount rate is deducted.)
([1] Views on calculating power generation costs reflecting IRR equivalent costs for policy measures)
- When calculating power generation costs reflecting IRR equivalent costs for policy measures, the value equivalent to the purchase price (differs from actual purchase price) is calculated by using cost items used for verifying power generation costs at the time.

([2] Handling the difference between purchase period and operation years)
- The purchase period set by the Special Committee for Determination of Tariffs and Durations and the years of operation assumed by the 2011 Costs Analysis Committee do not necessarily match. In particular, for geothermal power etc in the Special Committee for Determination of Tariffs and Durations, a shorter time than the actual operation years is set as the purchase period for policy measures. When the purchase period is shorter than the years of operation, IRR equivalent costs for policy measures are calculated by smoothing in years of operation.

<Image of calculating IRR equivalent costs for policy measures when (2) purchase period and operation years differ>

[Results of calculating IRR equivalent costs for policy measures]

<table>
<thead>
<tr>
<th>2014 model plant</th>
<th>Solar power (Non-residential)</th>
<th>Solar power (Residential)</th>
<th>Wind energy (Onshore)</th>
<th>Wind energy (Fixed, offshore)</th>
<th>Geothermal</th>
<th>Small hydropower (Less than 200kW)</th>
<th>Small hydropower (200-1,000kW)</th>
<th>Woody biomass</th>
<th>Coal biomass</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRR equivalent costs for policy measures (Yen/kWh)</td>
<td>3.1</td>
<td>2.0</td>
<td>5.7</td>
<td>9.9</td>
<td>4.6</td>
<td>3.4</td>
<td>2.8</td>
<td>1.4</td>
<td>0.3</td>
</tr>
</tbody>
</table>

* For solar (residential) and coal biomass, IRR equivalent costs for policy measures are calculated based on excess power sales rate and biomass rate.
In calculating the power generation costs of general hydroelectric power plants, data will mainly be updated based on the way of estimation using the model plant method proposed by the 2011 Costs Analysis Committee.

- Sample plant
  - Data of power plants (sample plants, 3 bases) which have operated recently (before last fiscal year).

<table>
<thead>
<tr>
<th>General hydroelectric power plant</th>
<th>Sample plant of 2011 Costs Analysis Committee</th>
<th>New or expanded sample plants by 2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model plant scale: 12,000 kW</td>
<td>Model plant scale: 12,000 kW</td>
<td></td>
</tr>
<tr>
<td>• Eroshi (13,800kW, 2006, conduit type)</td>
<td>• Eroshi (13,800kW, 2006, conduit type)</td>
<td></td>
</tr>
<tr>
<td>• Shinchubetsu (10,000 kW, 2006, dam type)</td>
<td>• Shinchubetsu (10,000 kW, 2006, dam type)</td>
<td></td>
</tr>
<tr>
<td>• Shintaishakugawa (11,000 kW, 2006, dam conduit type)</td>
<td>• Moriyoshi (11,000 kW, 2013, dam type)</td>
<td></td>
</tr>
</tbody>
</table>
Regarding the power sources subject to Feed-in Tariff, the power generated is calculated from the total installed capacity (certified installed capacity from the start of the Feed-in-Tariff system to the end of January 2015 added to pre-existing installed capacity) using the capacity factor of each power source.

- Regarding geothermal power, most of costs for policy measures stipulated in the energy (or METI) budget is funds for future business expansion. For this reason, comparison with other power sources is difficult. Here, 930,000 kW which is the certified capacity with currently planned budgets is indicated.

- Given that wind energy (onshore) takes several years for facilities to be certified due to environmental assessments etc., in calculating budget-related costs for policy measures, the value obtained by mechanically dividing related budget with the power generation calculated from the 7690MW, which is the total of already installed production of currently being assessed and previously assessed projects, is indicated.

For general hydroelectric power which is outside the scope of Feed-in Tariff, power generation is calculated by subtracting the currently estimated power generated from small and medium hydropower plants from the actual value in “Outline of power source Development."

### Appropriate of Costs for Policy Measures (Appropriation of budget-related Costs for policy measures)

<table>
<thead>
<tr>
<th>Capacity factor</th>
<th>Time</th>
<th>Already introduced amount (10,000 kW) (To June 2012)</th>
<th>Certified amount (10,000kW) (July 2012 to January 2015)</th>
<th>Total (10,000 kW)</th>
<th>Power generated (Billion kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar power (Residential)</td>
<td>12%</td>
<td>8760</td>
<td>470</td>
<td>352</td>
<td>822</td>
</tr>
<tr>
<td>Solar power (non-residential)</td>
<td>14%</td>
<td>8760</td>
<td>90</td>
<td>6810</td>
<td>6900</td>
</tr>
<tr>
<td>Wind energy</td>
<td>20%</td>
<td>8760</td>
<td>260</td>
<td>509 *</td>
<td>769</td>
</tr>
<tr>
<td>Geothermal</td>
<td>83%</td>
<td>8760</td>
<td>50</td>
<td>93 *</td>
<td>143</td>
</tr>
<tr>
<td>Small hydropower</td>
<td>60%</td>
<td>8760</td>
<td>960</td>
<td>38</td>
<td>998</td>
</tr>
<tr>
<td>Biomass</td>
<td>87%</td>
<td>8760</td>
<td>230</td>
<td>149</td>
<td>379</td>
</tr>
</tbody>
</table>

- Solar power (Residential) 12% | 8760 | 470 | 352 | 822 | 66 |
- Solar power (non-residential) 14% | 8760 | 90 | 6810 | 6900 | 846 |
- Wind energy 20% | 8760 | 260 | 509 * | 769 | 135 |
- Geothermal 83% | 8760 | 50 | 93 * | 143 | 104 |
- Small hydropower 60% | 8760 | 960 | 38 | 998 | 525 |
- Biomass 87% | 8760 | 230 | 149 | 379 | 289 |

### 2014 Costs for policy measures (Budget related Costs for policy measures)

<table>
<thead>
<tr>
<th>Solar power</th>
<th>Wind energy (Onshore)</th>
<th>Geothermal</th>
<th>Small hydropower</th>
<th>Biomass</th>
<th>General hydroelectric power plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A) Costs for policy measures (2014 budget) (Hundred Million yen unit)</td>
<td>145</td>
<td>47</td>
<td>145</td>
<td>42</td>
<td>53</td>
</tr>
<tr>
<td>(B) Annual total power generated (Hundred Million kWh unit)</td>
<td>933</td>
<td>135</td>
<td>104</td>
<td>525</td>
<td>289</td>
</tr>
<tr>
<td>(A)/(B) (Yen/kW)</td>
<td>0.2</td>
<td>0.3</td>
<td>1.4</td>
<td>0.1</td>
<td>0.2</td>
</tr>
</tbody>
</table>

### 2030 Costs for policy measures (Budget related Costs for policy measures)

<table>
<thead>
<tr>
<th>Solar power</th>
<th>Wind energy (Onshore)</th>
<th>Wind energy (Offshore)</th>
<th>Geothermal</th>
<th>Small hydropower</th>
<th>Biomass</th>
<th>General hydroelectric power plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A) Costs for policy measures (2014 budget) (Hundred Million yen unit)</td>
<td>129</td>
<td>46</td>
<td>35</td>
<td>143</td>
<td>35</td>
<td>59</td>
</tr>
<tr>
<td>(B) Annual total power generated (Hundred Million kWh unit)</td>
<td>749</td>
<td>161</td>
<td>22</td>
<td>107.5</td>
<td>441.5</td>
<td>442</td>
</tr>
<tr>
<td>(A)/(B) (Yen/kW)</td>
<td>0.2</td>
<td>0.3</td>
<td>1.6</td>
<td>1.3</td>
<td>0.1</td>
<td>0.1</td>
</tr>
</tbody>
</table>
(2) Thermal Power Generation
### Breakdown of Thermal Power Generation Costs

#### Coal-fired thermal power generation costs (2014)
- **12.3 Yen/kWh**

  - **Capital costs (2.1 Yen/kWh)**
    - Construction costs, Fixed asset tax 1.4%, Facility disposal costs (5% of construction costs)
    - Total 220 billion yen (For 1 unit)
  - **CO2 measure costs (3.0 Yen/kWh)**
    - Costs when procuring emissions rights equivalent to CO2 emission from thermal power generation.
    - Total 313 billion yen (1 unit, 40 years)
  - **Operating and maintenance costs (1.7 Yen/kWh)**
    - Personnel expenses, Repair costs, Miscellaneous expenses, General management costs
    - Total 184 billion yen (1 unit, 40 years)
  - **Fuel costs (5.5 Yen/kWh)**
    - Coal procurement costs
    - Total 580 billion yen (1 unit, 40 years)

*Assuming model plant with installed capacity of 80,000kW, capacity factor of 70%, and 40 operational years.*

- Unit price was calculated by dividing the total of the parameters with the total power generated per model plant for 40 years (\(106\) billion kWh).

#### LNG thermal power generation costs (2014)
- **13.7 Yen/kWh**

  - **Capital costs (1.0 Yen/kWh)**
    - Construction costs, Fixed asset tax 1.4%, Facility disposal costs (5% of construction costs)
    - Total 185 billion yen (For 1 unit)
  - **CO2 measure costs (1.3 Yen/kWh)**
    - Costs when procuring emissions rights equivalent to CO2 emission from thermal power generation.
    - Total 248.3 billion yen (1 unit, 40 years)
  - **Operating and maintenance costs (0.6 Yen/kWh)**
    - Personnel expenses, Repair costs, Miscellaneous expenses, General management costs
    - Total 118 billion yen (1 unit, 40 years)
  - **Fuel costs (10.8 Yen/kWh)**
    - LNG procurement costs
    - Total 2.1 trillion yen (1 unit, 40 years)

*Assuming model plant with installed capacity of 1,400,000kW, capacity factor of 70%, and 40 operational years.*

- Unit price was calculated by dividing the total of the parameters with the total power generated per model plant for 40 years (\(194.5\) billion kWh).
**Breakdown of Thermal Power Generation Costs**

**Oil-fired thermal power generation costs (2014)**

- **30.6 Yen/kWh**
  - **CO2 measure costs** (2.5 Yen/kWh)
    - Costs when procuring emissions rights equivalent to CO2 emission from thermal power generation.
    - **Total 97.6 billion yen** (1 unit, 40 years)
  - **Fuel costs** (21.7 Yen/kWh)
    - Oil procurement costs
    - **Total 836 billion yen** (1 unit, 40 years)
  - **Operating and maintenance costs** (2.6 Yen/kWh)
    - Personnel expenses, Repair costs, miscellaneous expenses, General management costs
    - **Total 59.4 billion yen** (1 unit, 40 years)
  - **Capital costs** (3.8 Yen/kWh)
    - Construction costs, Fixed asset tax 1.4%, Facility disposal costs (5% of construction costs)
    - **Total 88 billion yen** (For 1 unit)

- **Costs for policy measures** 0.01

- **Unit price was calculated by dividing the total of the parameters with the total power generated per model plant for 40 years (23 billion kWh).**

**Social costs**

- **CO2 measure costs**
  - **Total 97.6 billion yen** (1 unit, 40 years)

- **Fuel costs** (21.7 Yen/kWh)
  - **Total 836 billion yen** (1 unit, 40 years)

- **Operating and maintenance costs** (2.6 Yen/kWh)
  - **Total 59.4 billion yen** (1 unit, 40 years)

- **Capital costs** (3.8 Yen/kWh)
  - **Total 88 billion yen** (For 1 unit)

**Oil-fired thermal power generation costs (2014)**

- **43.4 Yen/kWh**
  - **CO2 measure costs** (2.5 Yen/kWh)
    - Costs when procuring emissions rights equivalent to CO2 emission from thermal power generation.
    - **Total 195 billion yen** (1 unit, 40 years)
  - **Fuel costs** (21.7 Yen/kWh)
    - Oil procurement costs
    - **Total 167 billion yen** (1 unit, 40 years)
  - **Operating and maintenance costs** (7.7 Yen/kWh)
    - Personnel expenses, Repair costs, miscellaneous expenses, General management costs
    - **Total 59.4 billion yen** (1 unit, 40 years)
  - **Capital costs** (11.4 Yen/kWh)
    - **Total 88 billion yen** (For 1 unit)

- **Costs for policy measures** 0.01

- **Unit price was calculated by dividing the total of the parameters with the total power generated per model plant for 40 years (7.7 billion kWh).**

**Social costs**

- **CO2 measure costs**
  - **Total 195 billion yen** (1 unit, 40 years)

- **Fuel costs** (21.7 Yen/kWh)
  - **Total 167 billion yen** (1 unit, 40 years)

- **Operating and maintenance costs** (7.7 Yen/kWh)
  - **Total 59.4 billion yen** (1 unit, 40 years)

- **Capital costs** (11.4 Yen/kWh)
  - **Total 88 billion yen** (For 1 unit)

**Assuming model plant with installed capacity of 40000kW, capacity factor of 30%, and 40 operational years.**
For the calculation of the power generation costs of coal-fired thermal power, LNG thermal power, and oil-fired thermal power, data was mainly updated following the basic ideas of estimations adopted in the model plant methods of the 2011 Costs Analysis Committee.

Calculation method and parameters

(1) Sample plant
   - Data of power plants (four sample plants) which commenced operation recently (prior to this fiscal year), etc.

(2) Fossil fuel prices
   - The first year prices were the 2014 averages of the Japan Customs CIF prices.
   - For the scenario of rising fuel prices, for the next year onwards, the price trends of the Current Policies Scenario and New Policies Scenario of IEA's “World Energy Outlook 2014” are used, and the New Policies Scenario is used as the standard scenario.

(3) Changes in CO2 prices
   - Based on the views of the 2011 Costs Analysis Committee, and on the consistency with IEA's New Policies Scenario as the standard scenario for rising fuel prices, the EU's new policy scenario prices and trends will be extrapolated (logarithm regression). In addition, the first year prices shall be the average prices of the previous year of the representative European emission trading markets.

(4) Technological innovation
   - Technological innovation per fuel type will be prospected based on government plans (for oil-fired thermal power, estimates based on the U.S. DOE data.)
## Thermal Power (1) Calculation Method and Parameters

<table>
<thead>
<tr>
<th>Power Plant Type</th>
<th>Model Plant Scale</th>
<th>Model Plant Characteristics</th>
<th>New and Added Sample Plants as of 2013</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Coal-fired thermal power plant</strong></td>
<td>Model plant scale: 750,000 kW</td>
<td>Thermal efficiency: 42%</td>
<td>Model plant scale: 800,000 kW</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Thermal efficiency: 42%</td>
</tr>
<tr>
<td></td>
<td>Hirono No. 5 (600,000 kW, 2004)</td>
<td></td>
<td>Isogo New No. 2 (600,000 kW, 2009)</td>
</tr>
<tr>
<td></td>
<td>Maizuru No. 1 (900,000 kW, 2004)</td>
<td></td>
<td>Maizuru No. 2 (900,000 kW, 2010)</td>
</tr>
<tr>
<td></td>
<td>Isogo New No. 2 (600,000 kW, 2009)</td>
<td></td>
<td>Hirono No. 6 (600,000 kW, 2013)</td>
</tr>
<tr>
<td></td>
<td>Maizuru No. 2 (900,000 kW, 2010)</td>
<td></td>
<td>Hitachinaka No. 2 (1,000,000 kW, 2013)</td>
</tr>
<tr>
<td><strong>LNG thermal power plant</strong></td>
<td>Model plant scale: 1,350,000 kW</td>
<td>Thermal efficiency: 51%</td>
<td>Model plant scale: 1,400,000 kW</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Thermal efficiency: 52%</td>
</tr>
<tr>
<td></td>
<td>Hhigashi Niigata No. 4-2 (840,000 kW, 2006)</td>
<td></td>
<td>Kawasaki No. 1 (1,500,000 kW, 2009)</td>
</tr>
<tr>
<td></td>
<td>New Nagoya No. 8 (1,600,000 kW, 2008)</td>
<td></td>
<td>Futtu No. 4 (1,520,000 kW, 2009)</td>
</tr>
<tr>
<td></td>
<td>Kawasaki No. 1 (1,500,000 kW, 2009)</td>
<td></td>
<td>Futtsu No. 4 (1,520,000 kW, 2010)</td>
</tr>
<tr>
<td></td>
<td>Futsu No. 4 (1,520,000 kW, 2010)</td>
<td></td>
<td>Joetsu No. 1 (1,190,000 kW, 2010)</td>
</tr>
<tr>
<td><strong>Oil-fired thermal power plant</strong></td>
<td>Model plant scale: 400,000 kW</td>
<td>Thermal efficiency: 39%</td>
<td>Model plant scale: 400,000 kW</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Thermal efficiency: 39%</td>
</tr>
<tr>
<td></td>
<td>Owasemita No. 3 (500,000 kW, 1987)</td>
<td></td>
<td>Owasemita No. 3 (500,000 kW, 1987)</td>
</tr>
<tr>
<td></td>
<td>Miyazu No. 1 (375,000 kW, 1989)</td>
<td></td>
<td>Miyazu No. 1 (375,000 kW, 1989)</td>
</tr>
<tr>
<td></td>
<td>Miyazu No. 2 (375,000 kW, 1989)</td>
<td></td>
<td>Miyazu No. 2 (375,000 kW, 1989)</td>
</tr>
<tr>
<td></td>
<td>Shiriuchi No. 2 (350,000 kW, 1998)</td>
<td></td>
<td>Shiriuchi No. 2 (350,000 kW, 1998)</td>
</tr>
</tbody>
</table>

*For oil-fired thermal power, given that power plants built after the earthquake are small scale power sources which were built for emergency use, or using light oil aiming to switch to gas thermal power, they are not adopted as sample plants in accordance with the view of the past 2011 Costs Analysis Committee.*
In the estimates by the 2011 Costs Analysis Committee, the average of the Japan Customers CIF of the fiscal year before the estimate was taken as the first year prices. In the current estimation, considerable efforts were made to take the influence of the recent drop in crude oil prices into consideration as much as possible, and the average of the 2014 for which definite data is available, is used.


(2) Fuel prices:
- Coal 113.91$/t (2010fy average) → 107.77 $/t (2013fy average) / 97.64 $/t (2014 average)
- LNG 584.37 $/t (2010fy average) → 836.08 $/t (2013fy average) / 842.43 $/t (2014 average)
- Crude oil 84.16$/bbl (2010fy average) → 110.01 $/bbl (2013fy average) / 105.11 $/bbl (2014 average)

Given that fuel prices continue to drop, a sensitivity analysis was carried out. (See next page.)

Source: Trade Statistics of Japan by Ministry of Finance
The price trends of the Current Policies Scenario and New Policies Scenario in the World Energy Outlook 2014 (WEO2014) are used. However, because WEO2014 price trends are global trends (except for LNG), the Japan customs CIF price was used as the first year price, and WEO2014 price trends were adjusted to draw Japan’s fossil fuel trends (as price trend of LNG in WEO2014 is a domestic Japanese trend, error correction is carried out with the actual price data).

Among WEO2014 Scenarios, the New Policies Scenario is taken as the standard case.

The following are the results of analyzing the effects of the increase/decrease in each fuel price on final costs of power generation (sensitivity analysis).

• For coal, every 10% change in fuel prices (as of 2020) causes an increase/decrease of about 0.4 Yen/kWh.
• For LNG, every 10% change in fuel prices (as of 2020) causes an increase/decrease of about 0.9 Yen/kWh.
• For oil, every 10% change in fuel prices (as of 2020) causes an increase/decrease of about 1.5 Yen/kWh.

The EIA World Energy Outlook (Energy Information Bureau of the U.S.) presents the most recent scenario of the increase in crude oil prices. While reflecting the decrease in crude oil prices, it forecasts that it will exceed 140$/bbl by 2040. Therefore, the total fuel costs affecting power generation costs are within the scope of the above sensitivity analysis.

In the future, through policy efforts such as further diversification of suppliers, it may be possible to lower the purchase prices of fossil fuels.
As the New Policies Scenario of the World Energy Outlook 2014 (WEO2014) is taken as the standard scenario for the upward trend of fuel prices, the WEO2014 EU New policies Scenario prices and trend extrapolation (logarithm regression) are used.

As the first year price, the average price of Europe’s representative emissions trade market is adopted, but given that the figures of 2013 and 2014 are not inconsistent with the scenarios of WEO, WEO2014’s scenarios are used as they stand. (Reference)


As for the appropriation of CCS costs, given that CO₂ storage costs, etc. in Japan are not clear, further consideration based on the results of technological development and survey of suitable storage sites, etc. is required. Therefore, CCS was not taken into account in the cost estimations this time, but will be addressed as a future task.

[Analysis of effects of increase/decrease in CO₂ prices on final costs for each type of fuel.]

- For coal, every 10% change in CO₂ prices (as of 2020) causes an increase/decrease of about 0.2 Yen/kWh.
- For LNG, every 10% change in CO₂ prices (as of 2020) causes an increase/decrease of about 0.1 Yen/kWh.
- For oil, every 10% change in CO₂ prices (as of 2020) causes an increase/decrease of about 0.1 to 0.2 Yen/kWh.
2011 analysis

- For the 2020 and 2030 model plants, power sources for which reduction of power generation costs can be expected from technological innovation and mass production effects were reviewed as follows.
  - Regarding coal-fired thermal power generation, provided that the power generation efficiency of the ultra-supercritical steam power plant (USC) is about 42% in the 2010 model plant, and that technological development efforts are being made aiming for further improvement of thermal efficiency including an integrated coal gasification combined cycle power plant (IGCC) and an advanced ultra-supercritical steam power plant (A-USC), costs were estimated on the assumption that the power generation efficiency will be about 48% in the 2030 model plant.
  - Regarding LNG thermal power generation, the 2010 model plant was based on a 1500°C gas turbine with the power generation efficiency of about 51%. For the 2020 and 2030 model plants, costs were estimated assuming that 1700°C gas turbines will already be put to practical application with the power generation efficiency improvement reaching about 57%.

2015 analysis

- 1700°C gas turbines are said to be available for practical use in the 2020’s; thus, their start of use in 2020 is not realistic. For this reason, the thermal efficiency of 2020 remains the same as that of 2014.
- Based on the latest coal and LNG thermal power database published by the U.S. DOE, the power generation efficiency of oil-fired thermal power was estimated to reach 48% on the assumption that super critical oil-fired thermal power plant will be realized by 2030.
Thermal Power (5) Costs for Policy Measures

(2011 analysis)
- Of the initial budget (2011), funds related to “location”, “disaster prevention”, “PR”, “personnel development”, “evaluation/survey”, “power generation technological development”, and “future power generation technological development” were added to the power generation costs. It was assumed that the total power generation volume for each type of fuel would be covered by the annual total power generation (coal: 251,100 million kWh, LNG: 294,500 million kWh, and oil: 75,300 million kWh).

(2015 analysis)
- Basically, cost estimations follow the views of the 2011 Costs Analysis Committee, for the estimations made for 2014, the 2013 total power generation volume was adopted (Coal: 284500 million kWh, LNG: 405700 million kWh, oil: 139800 million kWh). In the 2030 estimation, the figures of the long-term energy supply-demand outlook (draft) announced earlier were adopted.

Calculation method of costs for policy measures
- Coal-fired thermal power
- LNG thermal power
- Oil-fired thermal power

Coal/LNG/Oil costs for policy measures

<table>
<thead>
<tr>
<th></th>
<th>coal-fired thermal power</th>
<th>LNG thermal power</th>
<th>oil-fired thermal power</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Budget (100 million yen)</strong></td>
<td>2014</td>
<td>2030</td>
<td>2014</td>
</tr>
<tr>
<td></td>
<td>111</td>
<td>111</td>
<td>71</td>
</tr>
<tr>
<td><strong>Power generated (100 million kWh)</strong></td>
<td>2014</td>
<td>2030</td>
<td>2014</td>
</tr>
<tr>
<td></td>
<td>2,845</td>
<td>2,810</td>
<td>4,057</td>
</tr>
<tr>
<td><strong>Costs for policy measures (Yen/kWh)</strong></td>
<td>2014</td>
<td>2030</td>
<td>2014</td>
</tr>
<tr>
<td></td>
<td>0.039</td>
<td>0.040</td>
<td>0.018</td>
</tr>
</tbody>
</table>
(3) Nuclear Power Generation
(3)-1. Calculation Method and Parameters
Nuclear power generation costs are estimated taking into account not only costs directly related to power generation, but also future costs including decommissioning costs, nuclear fuel cycle costs (including final disposal of radioactive waste), etc., costs for dealing with accidents (including damage compensation, decontamination), as well as government expenditures including costs for policy measures such as location grant, and R&D costs including those for the Monju Nuclear Power Plant, etc.

**Nuclear accident cost (0.3 yen/kWh)**
- Estimating costs for dealing with Fukushima-Daiichi Nuclear Power Plant accident to be about 12.2 trillion yen, corrected to about 9.1 trillion yen based on power generation output scale, etc.
- Based on previous Mutual Aid Method and 4,000 reactor year and reflecting effects of additional safety measures. (However, in the future, decreasing effects of implementing additional safety measures must be taken into account.)
- As damage costs may increase, lower limit indicated here. If Cost of decommissioning of the reactor facilities damaged by accidents, compensation amount, etc. increases to 1 trillion yen, increases to 0.04 yen/kWh.

**Costs for policy measures (1.3 yen/kWh)**
- Reflects approximately 345 billion yen including location grant (Approx. 130 billion yen), R&D costs for Monju, etc. (Approx. 130 billion yen). *2014 budget

**Nuclear fuel cycle costs (1.5 yen/kWh)**
- Half of spent fuel is reprocessed after storing for 20 years, the remaining half is reprocessed after storing for 45 years.
- Includes front-end 0.9 yen, back-end 0.6 yen (reprocessing: 0.5 yen, high level wastes: 0.04 yen)

**Additional safety measures costs (0.6 yen/kWh)**
- Add additional safety measures costs based on new regulatory requirements. Investigate costs to be appropriated as model plant, and appropriate 60.1 billion yen. (May increase/decrease according to implementation rate of the additional safety measures.)

**Operating and maintenance costs (3.3 yen/kWh)**
- Personnel expenses 2.05 billion yen/year, Repair costs 2.2% (Proportionate to construction costs), miscellaneous expense 8.44 billion yen/year, work sharing costs

**Capital costs (3.1 yen/kWh)**
- Construction costs 0.37 million yen/kW (440 billion yen/1 unit), Fixed asset tax 1.4%, decommissioning costs of 71.6 billion yen.

### Public costs

- Nuclear accident cost: 0.3 yen/kWh
- Costs for policy measures: 1.3 yen/kWh
- Nuclear fuel cycle costs: 1.5 yen/kWh
- Additional safety measures costs: 0.6 yen/kWh
- Operating and maintenance costs: 3.3 yen/kWh
- Capital costs: 3.1 yen/kWh

#### Calculation Method and Parameters of Nuclear Power Generation Costs

*installed capacity 1.2 million kW, capacity factor 70%, Assuming plant with discount rate of 3%, operation years of 40 years
*Calculation for several scenarios in which capacity factor is 60%, 70%, 80%, discount rate is 0, 1, 3, 5%, and 40 years and 60 years of operation.
The 2011 Costs Analysis Committee averaged the construction and decommissioning costs of four sample plants (*) to calculate the capital costs (including fixed asset tax). For the operating and maintenance costs, the average of the four sample plants was also calculated. Personnel expenses was calculated based on annual unit price, while repair costs and miscellaneous expenses (property and third party insurance, etc.) was calculated proportionately to construction costs.

Miscellaneous expenses were calculated not proportionately to capital costs (+additional safety measures cost) but by annual unit price.

* Sample plants were the most recently started Tohoku Power Company Higashidori Plant No. 1, Chubu Power Company Hamaoka Plant No. 5, Hokuriku Power Company Shika Plant No. 2 Hokkaido Power Company Tomari Plant No. 3.

### Capital costs

<table>
<thead>
<tr>
<th>items</th>
<th>This investigation</th>
<th>Calculation methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction costs</td>
<td>0.37 million yen/kW</td>
<td>Implement price revision based on sample plant data.</td>
</tr>
<tr>
<td>Fixed asset tax</td>
<td>1.4%</td>
<td>—</td>
</tr>
</tbody>
</table>
| Decommissioning costs  | 71.6 billion yen   | Average of total estimate for reserve for decommissioning of nuclear power units in sample plant per 1kW multiplied with model plant power generation output scale.  
* Given that the reserve for decommissioning was set with the basic reserve period as the operation years (40 years) + safe storage period (10 years) due to the reassessment of the decommissioning accounting system, the price after 50 years has passed is used to ensure consistency. |

### Operating and maintenance costs

<table>
<thead>
<tr>
<th>items</th>
<th>This investigation</th>
<th>Views</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personnel expenses</td>
<td>2.05 billion yen/year</td>
<td>Ask power companies latest sample plant values</td>
</tr>
<tr>
<td>Repair costs</td>
<td>2.2% (Percentage of construction costs)</td>
<td>—</td>
</tr>
<tr>
<td>Miscellaneous expenses</td>
<td>8.44 billion yen/year</td>
<td>Calculate based on sample plant data with annual unit price</td>
</tr>
<tr>
<td>Work sharing costs</td>
<td>13.4% (Percentage of direct costs)</td>
<td>—</td>
</tr>
</tbody>
</table>
(3) - 2. Additional Safety Measures Costs

1) Summary of 2011 Costs Analysis Committee
2) Summary of This Working Group Views
3) Summary of Costs to be Appropriated
4) Method of Reflecting Estimates
5) Final estimates
After the accident of the TEPCO Fukushima-Daiichi Nuclear Power Plant as a result of the Great East Japan Earthquake, as of November 2011 (before the new standards were enforced), the costs required for the measures designated by the Japanese government etc. as additional safety measures were calculated.

Estimated based on additional safety measures costs quoted for the sample plant (*) targeted as the model plant (average value).

* Sample plants were Tohoku Power Company Higashidori Plant No. 1, Chubu Power Company Hamaoka Plant No. 5, Hokuriku Power Company Shika Plant No. 2 Hokkaido Power Company Tomari Plant No. 3

<table>
<thead>
<tr>
<th>Additional safety measures</th>
<th>Costs (Billion yen)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Emergency safety measures</td>
<td>11.8</td>
</tr>
<tr>
<td>(2) Emergency power generation facilities</td>
<td>1.7</td>
</tr>
<tr>
<td>(3) Assurance of reliability of external power supply</td>
<td>2.6</td>
</tr>
<tr>
<td>(4) Response to severe accidents</td>
<td>1.3</td>
</tr>
<tr>
<td>Others (Safety measures taken individually by companies)</td>
<td>5.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>19.4</strong></td>
</tr>
</tbody>
</table>

*Total excludes duplication and does not match the total of each measure.

This total 19.4 billion yen was appropriated as capital costs (and operating and maintenance costs proportional to capital costs), and the additional safety measures cost per power plant was estimated to be **0.2 yen/kWh**. (capacity factor 70%, discount rate 3%, 40 operational years)
The new regulatory requirements were enforced in July 2013, and given that power companies are carrying out safety measures, additional safety measures costs were estimated again.

1. Classify whether costs are additionally appropriated as the construction costs of model plants or not. (Each power company carries out safety measures for existing power plants. There are costs which are not necessary to allocate as model plants, if new regulatory requirements are known beforehand and they can be reflected in the design and planning stage. These costs were differentiated taking into consideration the nature of safety measures.)

2. Like the current situation where companies procure collectively, safety measures-related facility prices are higher than planned procurement. However, because it is difficult to quantitatively calculate how high they are, it may be overestimated. For this reason, the costs obtained in 1. (above) conservatively will be appropriated as the costs.

3. In the calculation of the Nuclear accident cost, efforts were made to reflected the effects of additional safety measures.

<Outline of new regulatory requirements>

- In addition to “design standards” for preventing severe accidents, “severe accident measures” are mandatory by law in order to deal with severe accidents and terrorist acts.

Design basis to prevent severe accidents (Confirm that a single failure would not lead to core damage)

- Consideration of natural phenomena
- Fire protection
- Reliability of power supply
- Function of other SSCs*
- Seismic/tsunami resistance

Response to intentional aircraft crashes
Measures to suppress radioactive materials dispersion
Measures to prevent containment vessel failure
Measures to prevent core damage
(postulate multiple failures)
Consideration of internal flooding (newly introduced)
Consideration of natural phenomena in addition to earthquakes and tsunamis--volcanic eruptions, tornadoes and forest fires
Fire protection
Reliability of power supply
Function of other SSCs
Seismic/tsunami resistance

Newly introduced (measures against terrorism)
Newly introduced (measures against severe accidents)
Reinforced or newly introduced
Reinforced
Implementation of measures for severe accidents

(1) Prevention of damage to fuel in nuclear reactor
  (E.g.)
  • Construct facility which pours water into the core of the reactor from outside using water cannon truck in the event of emergencies.

(2) Countermeasure for containment failure
  (E.g.)
  • Install facilities to decrease pressure and temperature inside the containments (filtered vent).
  • To prevent containment failure due to melted fuel, install water spraying equipment (fire engines, hose, etc.) for cooling melted fuel.

(3) Measures to prevent spread of radioactive substances outside the premise
  (E.g.)
  • Install outdoor water dispersion equipment (system for spraying large amount of foam water), etc.

(4) Ensure command post in times of emergencies
  (E.g.)
  • Establish emergency response facility implemented with measures against earthquakes and radioactive substances

Based on the TEPCO accident, reinforce measures to prevent accidents

(1) Prevent malfunction of facilities even in large-scale natural disasters
  (E.g.)
  • Install Flooding embankment which can withstand largest Tsunami
  • Install tide gates which prevent water immersion to building
  • Improve earthquake resistance of facilities by reinforcing piping support equipment

(2) Reinforce measures for fire hazards and power failures, etc.
  (E.g.)
  • Reinforce fire hazard measure by installing incombustible cables and fire-resistant walls.
  • Reinforce power failure measures by installing power supply cars
(3) Summary of Costs to be Appropriated

- If the new regulatory requirements (e.g. the remodeling of existing piping facilities, installation of flooding embankment) are known beforehand, optimization of design and planning will lead to reduced costs. Such costs are carefully identified and excluded from the costs to be appropriated for the model plant, as they will be unnecessary.

- Remodel and add pipes already installed to enable nuclear reactor containments to be cooled by natural convection.

- If based on new regulatory requirements, design can be optimized without having to open holes in the wall and replace pipes.

- As measures against Tsunami, in addition to existing ding embankment, construct new ding embankment.

- For sites built under new requirements, ensuring adequate height for the site when building the site enable not to install such a high flooding embankment.
(4) Method of Reflecting Estimates (General Remarks)

(1) Regarding the 15 nuclear power stations (24 nuclear reactors) to be examined by the Nuclear Regulation Authority for review of conformity with the new regulatory requirements, as a result of hearings on electric companies regarding their latest cost estimates for additional safety measures (total 11 items), the costs were forecast to be about 100 billion yen/reactor.

(2) To enhance accuracy, hearings were conducted on the 2 nuclear power stations (4 reactors) which have already obtained permission of reactor installment from the Nuclear Regulation Authority, particularly focusing on the breakdown of costs. (total 38 items) For the 100 billion yen/reactor obtained in (1), costs excluded from the costs to be appropriated for the model plant were specified for each item.

(3) In addition, reflect the percentage of costs not appropriated for the model plant to other nuclear plants, the average value for the 15 nuclear power stations (24 nuclear reactors) was calculated.

### Severe accident measure

<table>
<thead>
<tr>
<th>11 items</th>
<th>38 items</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Response to intentional aircraft crashes</td>
<td>6) Response to intentional aircraft crashes</td>
</tr>
<tr>
<td>2) Measures to suppress radioactive materials dispersion</td>
<td>7) Measures to prevent core damage (postulate multiple failures)</td>
</tr>
<tr>
<td>3) Measures to prevent containment vessel failure</td>
<td>8) Design standards</td>
</tr>
<tr>
<td>4) Measures to prevent core damage</td>
<td>9) Design standards</td>
</tr>
<tr>
<td>5) Others</td>
<td>10) Design standards</td>
</tr>
<tr>
<td>6) Consideration of internal flooding (newly introduced)</td>
<td>11) Design standards</td>
</tr>
<tr>
<td>7) Consideration of natural phenomena in addition to earthquakes and</td>
<td>12) Design standards</td>
</tr>
<tr>
<td>tsunami-volcanic eruptions, tornadoes and forest fires</td>
<td>13) Design standards</td>
</tr>
<tr>
<td>8) Fire protection</td>
<td>14) Design standards</td>
</tr>
<tr>
<td>9) Reliability of power supply</td>
<td>15) Design standards</td>
</tr>
<tr>
<td>10) Earthquake resistance-performance</td>
<td>16) Design standards</td>
</tr>
<tr>
<td>11) Tsunami resistance-performance</td>
<td>17) Design standards</td>
</tr>
</tbody>
</table>

Under review for the conformity of NPPs with the new regulatory requirements (15 power stations (24 nuclear reactors))

⇒ (1) Hearing of outline
- Measures for severe accidents... 5 items
- Design standards... 6 items

(3) Specify percentage to be excluded for each item, and reflect in overall estimation

Acquired permission of reactor installment (Sendai 1 and 2, Takahama 3 and 4)

⇒ (2) Detailed hearing
- Measures for severe accidents... 24 items
- Design standards... 14 items
<table>
<thead>
<tr>
<th>items</th>
<th>Actual content</th>
<th>A) Decision after the 3rd working group</th>
<th>B) Amount to exclude after careful consideration</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Response to intentional aircraft crashes</td>
<td>(1)-1 The examination regarding the facilities to cope with serious accidents</td>
<td>✅ Better to exclude design/site construction costs</td>
<td>✅ Exclude 10% corresponding to site construction cost</td>
</tr>
<tr>
<td></td>
<td>(1)-2 Disperse placement of connected parts/sections</td>
<td>✅ Exclude (already reflected in the design stage)</td>
<td></td>
</tr>
<tr>
<td>(2) Measures to suppress radioactive materials dispersion</td>
<td>(2)-1 Install water discharge facility/equipment outside the site</td>
<td>✅ Include (installation of a new facility/equipment)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2)-2 Measures to stop spread of nuclear materials outside the site</td>
<td>✅ Exclude (already reflected in the design stage)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2)-3 Establish multiple measures to cool down spent nuclear fuel</td>
<td>✅ Include (installation of a new facility/equipment)</td>
<td></td>
</tr>
<tr>
<td>(3) Measures to prevent containment vessel failure</td>
<td>(3)-1 Install filtered vent Measures against hydrogen explosions</td>
<td>✅ Include (installation of new facility/equipment)</td>
<td>✅ Exclude 40% as can be reflected in the design stage</td>
</tr>
<tr>
<td></td>
<td>(3)-2 Implement diversification measures for containment cooling methods</td>
<td>✅ Exclude (can be reflected in the design stage)</td>
<td></td>
</tr>
<tr>
<td>(4) Measures to prevent core damage (postulate multiple failures)</td>
<td>(4)-1-5 Install portable equipment (fire engines, power supply vehicles, etc.)</td>
<td>✅ Include (installation of new equipment)</td>
<td>✅ Exclude 60% can be reflected during design stage or excluded because corresponds to costs for alteration of already-existing facility/equipment</td>
</tr>
<tr>
<td></td>
<td>(4)-6 Install accident monitoring/measuring equipment</td>
<td>✅ Exclude (corresponds to costs of alteration of already existing facility/equipment)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(4)-7-10 Diversify cooling methods, pressure adjustment of reactor core</td>
<td>✅ Exclude (can be reflected in design stage)</td>
<td></td>
</tr>
<tr>
<td>(5) Others</td>
<td>(5)-1-5 Install a space/room to conduct emergency measures, installation of water or battery/electricity facility not included in each item</td>
<td>✅ Include (installation of new facility/equipment)</td>
<td>✅ Exclude 10% as can be reflected in the design stage</td>
</tr>
<tr>
<td></td>
<td>(5)-6 Install necessary equipment in the emergency space/room</td>
<td>✅ Exclude (can be reflected during design stage)</td>
<td></td>
</tr>
<tr>
<td>items</td>
<td>Actual Content</td>
<td>A) Decision after the 3\textsuperscript{rd} working group</td>
<td>B) Amount to exclude after careful consideration</td>
</tr>
<tr>
<td>-------</td>
<td>----------------</td>
<td>-----------------------------------------------------</td>
<td>-------------------------------------------------</td>
</tr>
<tr>
<td>(6) Consideration of internal flooding (newly introduced)</td>
<td>Plumbing leakage detection Equipment/facility to stop spreading of leakage (dam/weir)</td>
<td>✓Exclude (corresponds to installation/layout design costs)</td>
<td>✓Exclude (70% falls under installation/distribution costs)</td>
</tr>
<tr>
<td></td>
<td>Increasing water tightness of the room</td>
<td>✓Exclude (can be reflected during design stage)</td>
<td></td>
</tr>
<tr>
<td>(7) Consideration of natural phenomena in addition to earthquakes and tsunamis--volcanic eruptions, tornadoes and forest fires</td>
<td>Install fireproof region to prevent forest fire Measures to counter flying objects during tornedos, measures for not spreading radioactive substances Measures for volcanos</td>
<td>✓Exclude (can be reflected during design stage)</td>
<td>✓Exclude all</td>
</tr>
<tr>
<td>(8) Fire protection</td>
<td>Install different types of fire detection device Install fire extinguishing devices</td>
<td>✓Exclude (corresponds to additional construction cost)</td>
<td>✓Exclude (50% corresponds to additional construction cost)</td>
</tr>
<tr>
<td></td>
<td>Better anti-fire measures in order to separate relevant systems</td>
<td>✓Exclude (can be reflected during design stage)</td>
<td></td>
</tr>
<tr>
<td>(9) Reliability of power supply</td>
<td>Install emergency diesel fuel tank, etc.</td>
<td>✓Exclude (corresponds to site construction/installation cost)</td>
<td>✓Exclude (20% corresponds to construction/installation cost)</td>
</tr>
<tr>
<td>(10) Earthquake resistance</td>
<td>Construction for better earthquake resistance</td>
<td>✓Exclude (corresponds to additional construction cost)</td>
<td>✓Exclude (60% corresponds to additional construction costs)</td>
</tr>
<tr>
<td>(11) Tsunami resistance</td>
<td>Stabilize slopes in the surrounding area</td>
<td>✓Exclude (can be reflected during design stage)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Build a flood embankment</td>
<td>✓Exclude (can be reflected during design stage)</td>
<td>✓Exclude all</td>
</tr>
</tbody>
</table>

*Voluntary support for improving safety by companies more than new regulatory requirements also shall be included in the same manner as described above arrangement.
As a result of investigating additional costs of safety measures, with the average costs for 15 nuclear power stations (24 nuclear reactors) of 100 billion yen/reactor, about 60% has been identified as costs to be additionally appropriated as construction costs for model plants. In the inspections conducted this time, **60.1 billion yen/nuclear reactor** will be appropriated as additional costs of safety measures.

With a capacity factor of 70%, 40 operational years, and discount rate of 3%, the power generation unit price is equivalent to **0.6 yen/kWh**.

Given that the following opinions were voiced in the working group, there is a need to note them in future estimations.

1. It must be remembered that costs are estimated conservatively because of the following two points: The first is that in cases where it is difficult to determine whether there are costs to be appropriated to the model plants, estimates are made conservatively and everything is appropriated. The second is that the total costs that each companies are procuring at the same time is more expensive than the cost procuring in a planned way. In the future, there will be a need to investigate which expenses should be appropriated in the model plant scenario, and how much higher the procurement costs will be.

2. It is appropriate to consider both additional costs of safety measures and nuclear accidents together as costs related to the safety of the plant. In the future, once accident risk reduction effects due to safety measures based on new regulatory requirements are clear, they will need to be reviewed appropriately.
(3) - 3. Nuclear Accident Costs

1) Summary of 2011 Costs Analysis Committee
2) Summary of This Working Group Calculation Method
3) Calculation of Damage-related Costs
4) Calculation of Mutual Aid Method
5) Basis for Calculation of Mutual Aid Method
6) Final Estimates
Based on the calculation method, power companies will share the damage costs between them (Mutual Aid Method), the amount to be borne for the 40 years while the model plants are operated to be designated as the nuclear accident costs.

A) Damage costs were calculated as about 7.9 trillion yen based on the decommissioning costs for Fukushima-Daiichi Nuclear Power Plant and the estimated compensation costs brought to light in the calculations. Taking this to be the lower limit, and correcting to the power generation output scale, of the model plant, damage costs were calculated as “over 5.8 trillion yen”.

B) The nuclear operators in Japan are expected to accumulate funds throughout the 40 years while the model plants are operating (payment period).

C) The costs for generating energy (kWh) is calculated by dividing the annual generated energy (272.2 billion kWh) of the 50 reactors (except for Fukushima-Daiichi 1 to 4) in 2010, the year before the accident, to be \(\frac{5.8 \text{ trillion (yen)}}{40 \text{ (year)}} = 0.5 \text{ (yen/kWh)}\).

* Lower limit is indicated as damage costs may increase. If damage costs increase to 1 trillion yen, the costs for generating power increases about 0.09 yen/kWh.

(Source) Prepared by secretariat based on 2011 Cost Verifications Committee report.
Nuclear accident cost = (Generally) insurance premium
= (Estimated damage costs x accident probability rate) + risk premium

- Atomic Energy Commission: Adopts the following two approaches
  (1) Proposes three accident probability rate scenarios and calculates damage costs x accident probability rate = Anticipated damage value. However, risk premium is not calculated.
  (2) Estimation from the concept of accident risk cost based on damage compensation system from the concept of the Mutual Aid Method. (One type of quasi-insurance system)
  *In line with international trends such as CSC (Treaty on complementary assurance of nuclear damage)

Regarding (1)
In the event of an accident at a nuclear plant, laws of large numbers do not apply given that the generation probability of the accident is low and the number of subscribers to insurance are limited.
With regard to earthquake and tsunami risk, as these are devastating and massive, it is difficult to predict the risk premium. At this point, no private 3rd party insurance has been established.

- The Committee proposes implementing a method based on quasi-insurance system (2) damage compensation system based on the way of Mutual Aid Method between companies. Because the committee concluded that with approach (1) above, it is difficult to forecast the risk premium and calculate the accident risk cost based only on the expected damage value.
Additional safety measures considered by the 2011 Costs Analysis Committee (hereafter called “emergency safety measures”) are handled as follows.

<table>
<thead>
<tr>
<th>Comments received</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>How are the relations between additional safety measures and current safety regulations / ideal future safety regulations assessed? Please clarify views on how much safer it will be when the additional measures are implemented?</td>
<td>The “additional safety measures” are emergency measures taken based on the knowledge clarified to date. Ideal new safety regulations are currently being reviewed by the Cabinet Nuclear Energy Safety Regulation Organization Reform office. As of now, the “additional safety measures” have not been quantitatively analyzed.</td>
</tr>
</tbody>
</table>

(Source) December 2011 6th Costs Analysis Committee data

Regarding the additional safety measures, the relationship between risk management and additional safety measures needs further investigation, and upon assessing the relationship between additional safety measures and safety regulations, when new safety regulations are brought to light, the effects can be reviewed. But at this point, we are not in a situation to reply to both, so they will be taken as future tasks. (Source) Excerpt from 2011 Costs Analysis Committee report

Regarding the review of the new regulatory requirements, at the time of the 2011 Costs Analysis Committee, NRA was reorganizing the facts and background of the Fukushima-Daiichi Nuclear Power Plant accident, summarizing the causes and technological challenges of the accidents based on this information, and evaluating and analyzing the effectiveness of safety measures implemented until then.
(2) Summary of This Working Group Calculation Method

- Power generation costs are increasing due to the implementation of the additional safety measures. On the other hand, the effects of implementing these measures will affect the nuclear accident cost. Based on this relation, This Working Group views were summarized as follows.

1. Following Mutual Aid Method of 2011 Costs Analysis Committee basically.

2. Although damage costs must be lower than additional safety measures costs in principle, given that there are no methods of estimating the reduction of costs at this point, the effects of safety measures to be incorporated are not reflected, and the views of the 2011 Costs Analysis Committee estimations (damage costs for Fukushima-Daiichi Nuclear Power Plant) are adopted.

3. Based on the assumption that the frequency of accidents will decrease with the enforcement of new regulatory requirements, the basis for the calculation of the Mutual Aid Method is used.

4. In calculating the basis for the calculation, the probabilistic risk assessment (PRA) is referred, which is applied to the review process for the conformity of NPPs with the new regulatory requirements.

<Reference> Implementation of PRA in new regulatory requirements

- In reviewing conformity of NPPs with the new regulatory requirements, nuclear operators indicate the PRA implementation, but only the PRA before the safety measures are implemented, and sensitivity analysis for assessing the improvements if some of the safety measures are implemented will be evaluated.

- The overall PRA evaluation performed after all safety measures are implemented aims to evaluate the situation at the end of the first periodic inspection after operations are resumed, and will be carried out by evaluating safety enhancements within 6 months of the end of the periodic inspections.
The 2011 Costs Analysis Committee reviewed the additional decommissioning costs (accident decommissioning costs) and damage costs in the Business and Financial Survey Committee Report on Tokyo Electric Power Company (October 2011), and the committee corrected them according to generating power, locality, and population.
(Approx. 7.9 trillion yen → after correction 5.8 trillion yen)

In this investigation, the damage costs were reviewed based on the latest prospects in accordance with “Accelerating restoration in Fukushima from the nuclear disaster” (passed by the Cabinet in December 2013), “New Comprehensive Special Business Plan (changes were approved in April 2015)”, and estimates by the Ministry of Environment with regard to decontamination and storage.

As a result, the accident decommissioning costs were 1.8 trillion yen, compensation costs 5.7 trillion yen, decontamination/storage costs 3.6 trillion yen, and other costs were 1.1 trillion yen, totaling 12.2 trillion yen. This was corrected according to generating power, locality, and population ratio using the same method as the 2011 Costs Analysis Committee.
(About 12.2 trillion yen → after correction, 9.1 trillion yen)

* Originally, the implementation of additional safety measures such as measures to prevent the dispersal of radioactive substances could have reduced damage costs, however these effects are not reflected.

<table>
<thead>
<tr>
<th>Accident decommissioning costs</th>
<th>Compensation costs</th>
<th>Decontamination/in intermediate storage</th>
<th>Administrative expenses, etc.</th>
<th>Total</th>
<th>After correction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.8</td>
<td>5.7</td>
<td>3.6</td>
<td>1.1</td>
<td>12.2</td>
<td>9.1</td>
</tr>
</tbody>
</table>

(Source) Created by secretariat based on “Accelerating restoration in Fukushima from the nuclear disaster” passed by cabinet in December 2013”, “New Comprehensive Special Business Plan (changes were approved in April 2015)”, TEPCO 2014 3rd Quarter Financial Results, Ministry of Finance website, etc.
### Calculation of Damage Costs

#### Towards acceleration of restoration in Fukushima from nuclear disaster (Passed by cabinet in December 2013)

#### New Comprehensive Special Business Plan (changes approved in April 2015)

#### Other costs appropriated in previous estimation

#### Costs which cannot be estimated at this point, costs which clearly are not included

#### Forecast that compensation will be required

- 5 trillion yen + α (5.4 trillion yen)

#### Decontamination/Intermediate Storage costs

- Decontamination (Includes disposal of contaminated wastes)
  - 2.5 trillion yen
  - Correction (2): 1475 billion yen

- Intermediate storage (Construction/management, etc.)
  - 1.1 trillion yen
  - Correction (2): 649 billion yen

#### Forecast that compensation will be required

- 5741.2 billion yen
  - Correction (2): 5277.3 billion yen

#### Other costs appropriated in previous estimation

- Reduction of power plants Nuclear fuel loss
  - Correction (3): 111.7 billion yen

- Government administrative costs
  - Correction (3): 999 billion yen

#### After correction total 9108.8 billion yen


* Like 2011 Costs Analysis Committee, except for compensation and decontamination costs, exclude unnecessary costs if next accident occurs from damage cost.

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Total 12242.3 billion yen.
(4) Calculation formula for Mutual Aid Method

- In accordance with the Mutual Aid Method of the 2011 Costs Analysis Committee, funds are accumulated to respond to accidents assuming that an accident occurs once in “(50 reactors) x (40 years)” in other words “2,000 reactor-years”. This “2,000 reactor-years” is considered the basis for calculation of “reactor-years” used in the Mutual Aid Method.
  *The basis of the calculation (reactor-year) is not equivalent to the frequency of accidents.

- In the calculation, to ensure conformity with the overall idea of cost verification which estimates based on model plants, for the annual total power generated by the power company (denominator (C)), “50 reactors” is multiplied by the payment period “40 years” (numerator B).

[2011 Costs Analysis Committee Mutual Aid Method]

Based on Model plant

- 40 years

<table>
<thead>
<tr>
<th>A) Damage costs (yen)</th>
<th>B) Payment period (year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C) Annual power generated of power companies (kWh)</td>
<td></td>
</tr>
</tbody>
</table>

Adjust and express

50 reactors actually running in 2010

[This investigation]

Based on Model plant

- 2,000 reactor-years

<table>
<thead>
<tr>
<th>A) Damage costs (yen)</th>
<th>B') Basis of calculation (reactor years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C') Power generated by model plant (kWh)</td>
<td></td>
</tr>
</tbody>
</table>

Adjust to model plant

Model plant 1 reactor
(5) Basis for Calculating Mutual Aid System

- The effects of additional safety measures to mitigate risk of nuclear accidents were not taken as calculation quantitatively at the time of the 2011 Costs Analysis Committee (see page 65).
- At this point, quantitative effects have not been clarified for all additional safety measures. However, the accident risk which is considered only “accident events contributing most to core damage frequency” have at least been clarified quantitatively compared to the accident risk before the safety measures by analyzing sensitivity during the review for the conformity of NPPs with the new regulatory requirements.
- When quantitatively comparing the frequency of accidents as of the 2011 Costs Analysis Committee and now, the PRA before the safety measures were implemented (which does not take into account quantitative effects of additional safety measures) and the PRA after sensitivity analysis will be compared and the relevant effects will be reviewed.

<table>
<thead>
<tr>
<th>Targets of PRA evaluation before implementation of safety measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old regulations and standards (So-called design standards)</td>
</tr>
<tr>
<td>Consideration of natural phenomena</td>
</tr>
<tr>
<td>Fire protection</td>
</tr>
<tr>
<td>Reliability of power supply</td>
</tr>
<tr>
<td>Function of other SSCs*</td>
</tr>
<tr>
<td>Seismic/tsunami resistance</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Emergency safety measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>* Facilities for cooling used fuel storage tank (fire-extinguishing pumps, hoses)</td>
</tr>
<tr>
<td>Countermeasures for minimizing dispersion of radioactive substances</td>
</tr>
<tr>
<td>Countermeasure against core damage (Assuming malfunctions of several pieces of equipment)</td>
</tr>
<tr>
<td>* Facilities for transporting heat to final heat sink (fire-extinguishing pumps, hoses), power supply facilities (ground power unit trucks)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>New regulatory requirements (Addition of anti-terrorist measures, severe accident measures, reinforced design standards, and newly added sections)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response to intentional aircraft crashes</td>
</tr>
<tr>
<td>Measures to suppress radioactive material dispersion</td>
</tr>
<tr>
<td>Measures to prevent containment vessel failure</td>
</tr>
<tr>
<td>Measures to prevent core damage (postulate multiple failures)</td>
</tr>
<tr>
<td>Consideration of internal flooding (newly introduced)</td>
</tr>
<tr>
<td>Consideration of natural phenomena in addition to earthquakes and tsunamis—volcanic eruptions, tornadoes and forest fires</td>
</tr>
<tr>
<td>Fire protection</td>
</tr>
<tr>
<td>Reliability of power supply</td>
</tr>
<tr>
<td>Function of other SSCs</td>
</tr>
<tr>
<td>Seismic/tsunami resistance</td>
</tr>
</tbody>
</table>

*Measures for doors, interspaces of buildings which can be penetrated.*
### <Goals set by other national regulatory agencies>

<table>
<thead>
<tr>
<th>IAEA (safety goals)</th>
<th>IAEP proposed under international agreement.</th>
<th>Once in 10,000 reactor-years *already existing plants Once in 100,000 reactor-years *plants in foreseeable future</th>
<th>Once in 100,000 reactor-years *already existing plants &quot;early stage&quot; &quot;Minimize influence to the level that it can be excluded&quot; *plants in foreseeable future</th>
</tr>
</thead>
<tbody>
<tr>
<td>US (risk appraisal standards)</td>
<td>NRC proposed qualitative and quantitative goals for plant design</td>
<td>Once in 10,000 reactor-years *new plants</td>
<td>Once in 1,000,000 reactor-years *new plants</td>
</tr>
<tr>
<td>UK (safety goals)</td>
<td>Proposed BSL (Basic Safety Limit), a risk index that reflects normal operating circumstances and accidents</td>
<td>Once in 10,000 reactor-years</td>
<td>Once in 100,000 reactor-years</td>
</tr>
<tr>
<td>Japan (safety goals)</td>
<td>Proposed goals that would be applied to plant construction</td>
<td>—</td>
<td>Once a 1,000,000 reactor-years *new plants</td>
</tr>
</tbody>
</table>

*Note: Frequency of accidents exceeding 100TBq. Cesium reached 15,000 TBq in Fukushima and this equals about 1% of 100TBq.*

### <Positioning within public policy>

<table>
<thead>
<tr>
<th>Korea (safety measures)</th>
<th>Safety goals in view of extreme nuclear accident policy. Were stipulated on the criteria that the risk of mortality due to nuclear accident shall not exceed 0.1% of risk of mortality in all other cancers.</th>
<th>Once in 100,000 reactor-years *new plants</th>
<th>Once in 1,000,000 reactor-years *new plants &quot;early stage&quot;</th>
</tr>
</thead>
</table>

Note: Different types of goals

- **Frequency of nuclear reactor core damage:**
  Frequency of damage to fuel caused by temperature rise in the reactor core. A standard for spotting frequency of severe accidents

- **Frequency of mass radiation:**
  Frequency of occurrence of events leading to large-scale emission of radioactive substances.

In the review process for the conformity of NPPs with the new regulatory requirements, the NRA evaluated PRA through which power companies applied sensitivity analysis to the implementation of some safety measures at Sendai Power Plants No.1 and 2, and Takahama Power Plants No.3 and 4 (which have already received permission of reactor installment) and other power plants currently being screened.

However, sensitivity analysis after the safety measures have been implemented only reflects improvement effects partially as only one countermeasure out of the 30 accidents events was considered.

*For the sensitivity analysis considering all over 30 accidents, the results are expected to drop even more.

---

**<PRA evaluation of core damage frequency, which is carried out by power companies on reactors which have already received permission of reactor installment and reactors currently being reviewed for the conformity of NPPs with the new regulatory requirements >**

| Average for reactors which have acquired permission of reactor installment and reactors under review for the conformity of NPPs with the new regulatory requirements (Tomari 3, Mihama 3, Takahama 1 to 4, Ikata 3, Sendai 1 and 2, Genkai 3 and 4) | PRA before the safety measures were implemented | PRA after sensitivity analysis
| | *Only one countermeasure out of the 30 accident events is considered* |
| 1.9 × 10^{-4} (Approx. once in 5,200 reactor-years) | 8.3 × 10^{-5} (Approx. once in 12,100 reactor-years) |

*For only the Sendai Power Plants No. 1 and 2, and Takahama Power Plants No. 3 and 4 which have received permission of reactor installment, the PRA before the safety measures were implemented (once for 4,500 reactors・year) dropped about 1/1.8 to PRA after the sensitivity analysis (approx. once in 8,400 reactors・year).

*The overall PRA evaluation performed after all safety measures are implemented aims to evaluate the situation at the end of the first periodic inspection after operations are resumed, and will be carried out by evaluating safety enhancements within 6 months of the end of the periodic inspections.

(Source) Prepared by secretariat based on screening meeting material related to new regulatory requirements conformity (Nuclear Regulatory Authority HP).
(6) Results of Estimating Nuclear Accident Costs

- As a result of investigating damage costs, the lower limit of the accident decommissioning costs, compensation costs, decontamination/intermediate storage costs and Government administrative costs totaled 12.2 trillion yen. Like the 2011 Costs Analysis Committee, this figure was corrected to the model plant and appropriated as 9.1 trillion yen.

- Regarding the basis for calculation of Mutual Aid Method, additional implemented safety measures will reduce the frequency of accidents. Therefore, the safety targets of regulatory organizations in other countries and international organizations and improvement margin of risk assessment after the safety measures are implemented (approx. once in 5,200 reactor-years → approx. once in 12,100 reactor-years: dropped by approximately 1/2.4) were comprehensively considered, and estimates were conservatively calculated to be half (2,000 reactors · year) of the 2011 Costs Analysis Committee” at “4,000 reactor-years”.

- Taking capacity factor to be 70%, the nuclear accident cost is 0.3 yen - /kWh.

- Given that the following opinions were voiced in the working group, there is a need to address them in future estimations.

  1. The calculation method of the 2011 Costs Analysis Committee estimate (damage costs for Fukushima-Daiichi Nuclear Power Plant) will be adopted for damage costs, although damage costs are expected to decrease with the implementation of the additional safety measures. Because no method for estimating the decrease in costs exists at this point, the effects of additional safety measures are not to be reflected.

  2. It should be discussed what is the appropriate level of the basis for calculation of accident risk if it were taken to be the costs to be appropriated by power companies for business.

  3. In the previous estimation, the sum of additional safety measures costs and nuclear accident cost was 0.8 yen - /kWh; however, the nuclear accident costs should decrease due to the additional safety measures.

* Although not a responsibility of this working group, in reviewing the nuclear compensation system, if the non-responsible portion exceeding the compensation amount is taken as limited responsibility, and the amount to be borne by the nuclear power company (e.g. insurance premium) is considered, the amount to be borne by the company may be very small if the basis for calculation concluded by this working group is used in its current form.

\[
\frac{\text{Damage costs (Yen)}}{\text{basis for calculation (reactors \cdot year)}} = \frac{\text{12.2 trillion (Yen)}}{\text{4,000 (reactors \cdot year)}} = \text{0.3 yen - /kWh}
\]

\[
\text{(3) Annual power generated by model plant (kWh)} = \text{7.36 billion (kWh)}
\]
Additional safety measure costs and Nuclear Accident Costs

- **2011 Costs Analysis Committee**
  - Nuclear accident costs: 0.54 yen/kWh
  - Total: 0.8 yen/kWh

- **This investigation**
  - Nuclear accident cost: 0.3 yen/kWh
  - Additional safety measures costs: 0.24 yen/kWh
  - Total: 0.9 yen/kWh

- **Future**
  - Nuclear accident costs: ?? yen/kWh
  - Additional safety measures costs: ?? yen/kWh
  - Total: ??? yen/kWh

- Additional safety measure costs: 0.6 yen/kWh

* Evaluated only some of additionally implemented safety measures.

* Will re-calculate once results of evaluations for all additional safety measures are ready.

* Capacity factor 70%, discount rate 3%, operation years 40 years
(3) - 4. Other Parameters

1) Nuclear fuel cycle costs
2) Costs for policy measures
(1) Nuclear Fuel Cycle Costs - Model

- The 2011 Costs Analysis Committee adopted the current model as meeting the actual situation (reprocess and recycle some of the used fuel, and reprocess the rest after storage).

- Given that the Basic Energy Plan (passed by the Cabinet in April 2014) promotes the recycling of nuclear fuel, in the current estimate, the model utilized by the 2011 Costs Analysis Committee shall be adopted.

- However, the changes in the situation after 2011 shall be reflected appropriately in the current estimation. For example, the low yen rate, extension of construction nuclear cycle facilities after reprocessing, and increase in costs of additional measures to meet new regulatory requirements will be incorporated.

[Current model]

- Uranium procurement costs, costs of repeated recycling of used fuel, and it is converted from power generated by uranium fuel and recycled MOX fuel to current price, to calculate the equivalent power generated (yen/kWh).

* Same method as “Operation years equivalent power generation price calculation method” adopted by OECD (so-called Levelized Cost Of Electricity (LCOE) method).

(Source) Prepared by secretariat based on nuclear power generation・nuclear fuel cycle technology review committee data 1 nuclear fuel cycle costs estimation (November 10, 2011)
## (1) Nuclear Fuel Cycle Costs - Estimation Views and Estimation Results

### Final estimates based on changes after 2011 and estimation results

<table>
<thead>
<tr>
<th>Items</th>
<th>Facilities for estimation</th>
<th>Changes from 2011 Cost Verification Committee</th>
<th>Direction of this estimation</th>
<th>Estimation results’ (yen/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uranium fuel</td>
<td>Procurement results</td>
<td>Decrease in uranium procurement amount due to influence of discontinuation of power plant due to earthquake</td>
<td>Latest uranium fuel procurement sharply decrease due to discontinuation of power plants after earthquake. They are not appropriate samples for estimations. For this reason, the changes in exchange rate based on the procurement results between 2008 and 2010 were reflected.</td>
<td>0.9 (0.8)</td>
</tr>
<tr>
<td>MOX fuel</td>
<td>MOX fuel fabrication plant (Rokkasho)</td>
<td>Construction work delayed (2016.3→2017.10) Increase in safety measure costs due to new regulatory requirements</td>
<td>Based on latest construction costs trends</td>
<td>0.1 (0.1)</td>
</tr>
<tr>
<td><strong>Front end</strong></td>
<td></td>
<td></td>
<td></td>
<td>0.9 (0.8)</td>
</tr>
<tr>
<td>Reprocessing</td>
<td>Rokkasho reprocessing plant</td>
<td>Construction work delayed (2012.10→2016.3) Increase in safety measures costs due to new regulatory requirements</td>
<td>Calculated based on recent submissions based on funds saved for reprocessing by power companies and Japan Nuclear Fuel Limited.</td>
<td>0.5&quot; (0.5)</td>
</tr>
<tr>
<td>Transportation of spent fuel</td>
<td>Transportation results</td>
<td>Decrease in transportation amount</td>
<td>Calculated based on recent transportation contracts to Rokkasho reprocessing plant from nuclear power plants</td>
<td>&quot;</td>
</tr>
<tr>
<td>Interim storage</td>
<td>Recyclable fuel storage center (Mutsu)</td>
<td>Delay of start of business (2012.7→2016.10)</td>
<td>As there are no changes in construction costs, continued to use estimations based on 2011 verifications. (No change)</td>
<td>0.1&quot; (0.1)</td>
</tr>
<tr>
<td>High level radioactive waste disposal</td>
<td>Disposal site established by NUMO</td>
<td>Increase in design and construction costs, etc.</td>
<td>Calculated based on disposal amount calculated by government (METI) based on newest final disposal law.</td>
<td>0.0 (0.0)</td>
</tr>
<tr>
<td><strong>Backend</strong></td>
<td></td>
<td></td>
<td></td>
<td>0.6 (0.6)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td>1.5 (1.4)</td>
</tr>
</tbody>
</table>

* Discount rate 3%  
** “Reprocessing” includes costs for transporting spent fuel from power plant to reprocessing plant and from Interim storage facility to reprocessing plant.  
*** “Interim storage” includes costs for transporting spent fuel from power plant to interim storage facility.  
**** Not totaled as rounded to integer  
***** ( ) of estimation results are those of 2011 Cost Verification Committee

### Basic conditions of parameters

| Average discharge burnup | UO₂ fuel : 45,750 MWd/t  
MOX fuel : 40,000 MWd/t  
| Fuel dwell time | 5 years  
| Thermal efficiency | 34.7%  

| Auxiliary power ratio | 4% (3.5% as estimated by Nuclear Committee)  
| Reprocessing: interim storage ratio | 50: 50  
| Next generation production ratio | 15%  

(Source) Prepared by secretariat based on nuclear power generation+nuclear fuel cycle technology review committee data 1 nuclear fuel cycle costs estimation (November 10, 2011)
## (1) Final Estimates Nuclear Fuel Cycle Costs

<table>
<thead>
<tr>
<th>items</th>
<th>Discount rate 0%</th>
<th>Discount rate 1%</th>
<th>Discount rate 3%</th>
<th>Discount rate 5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uranium fuel</td>
<td>0.70</td>
<td>0.63</td>
<td>0.77</td>
<td>0.68</td>
</tr>
<tr>
<td>MOX fuel</td>
<td>0.19</td>
<td>0.17</td>
<td>0.13</td>
<td>0.12</td>
</tr>
<tr>
<td>(Front-end total)</td>
<td>0.89</td>
<td>0.80</td>
<td>0.90</td>
<td>0.80</td>
</tr>
<tr>
<td>Reprocessing, etc.</td>
<td>1.12</td>
<td>1.11</td>
<td>0.82</td>
<td>0.80</td>
</tr>
<tr>
<td>Interim storage, etc.</td>
<td>0.08</td>
<td>0.07</td>
<td>0.07</td>
<td>0.06</td>
</tr>
<tr>
<td>High level waste disposal</td>
<td>0.25</td>
<td>0.24</td>
<td>0.12</td>
<td>0.12</td>
</tr>
<tr>
<td>(Back-end total)</td>
<td>1.44</td>
<td>1.42</td>
<td>1.01</td>
<td>0.98</td>
</tr>
<tr>
<td>Total</td>
<td>2.33</td>
<td>2.22</td>
<td>1.91</td>
<td>1.78</td>
</tr>
</tbody>
</table>

*The total may not correspond to the sum of all the items due to rounding.

*“Reprocessing, etc.” includes costs for transporting spent fuel from power plants to reprocessing plants and from interim storage facilities to reprocessing plants.

*“Interim storage, etc.” includes costs for transporting spent fuel from power plants to interim storage facilities.
1. Nuclear fuel cycle costs

- For example, in reprocessing, the unit cost may increase as a result of the decrease in amount of reprocessing (reduced operating rate) due to delay of rated reprocessing amount (800 tU/year) achievement time, or increase in construction costs of additional facilities planned in the future.

- For this reason, sensitivity analysis is applied if reprocessing, MOX fuel, high level waste disposal, and interim storage unit costs increase.

2. Decommissioning costs

- Although maximum costs which can be estimated within the scope of the current system are adopted, due to the fact that the excess disposal portion (L1 waste) regulations have not been established, costs may increase in the future. For this reason, sensitivity analysis is carried out.

*See graph regarding sensitivity analysis (right).
(2) Costs for Policy Measures (Nuclear energy)

(Summary of 2011 Costs Analysis Committee)
- Regarding the initial budget in 2011 budget related to “location”, “disaster prevention”, “PR”, “personnel development”, “evaluation/survey”, “power generation technology development”, and “future power generation technological development” added to the generation costs. The total power generation was assumed to be covered by the annual power generated by 54 units (288.2 billion kWh).
- As a result, the costs for policy measures was calculated as 1.1 yen/kWh.

(Summary of Current Committee Decisions)
- Basically, the views of the 2011 Costs Analysis Committee have been adopted. The latest budget which can be specified was added based on the same items as the 2011 Committee.
- Regarding the total power generation estimated in 2014. As no reactors are currently in operation, the 43 remaining reactors (excluding decommissioned reactors) are used to calculate the total power generation estimated for 2014. For 2030, the values (median) indicated in the long term energy supply framework (draft) will be used.
- Regarding “future power generation technology development”, costs for recycling nuclear fuel, which include costs for high speed reactors, reprocessing, radioactive waste disposal, and safety technological development costs were appropriated, and the costs for technology with weak continuity in relation to the current nuclear usage such as next generation reactors will be excluded.

[Estimation for 2014]
\[
\frac{\text{Costs for policy measures related to nuclear energy (2014 budget)} (\text{Yen})}{\text{Annual total power generation (kWh)}} = \frac{\text{Approx.344.6 billion (Yen)}}{257.8 \text{ billion (kWh)}} = 1.3 \text{ (yen/kWh)}
\]
*The above assumes a capacity factor of 70%. When capacity factor is 80%, annual power generation is 294.7 billion, meaning 1.2 yen/kWh.

[Estimation for 2030]
\[
\frac{\text{Costs for policy measures related to nuclear energy(2014 budget)} (\text{Yen})}{\text{Annual total power generation (kWh)}} = \frac{\text{Approx.344.6 billion (yen)}}{224.25 \text{ billion (kWh)}} = 1.5 \text{ (yen/kWh)}
\]
(4) Cogeneration and Fuel Cells
### 1. Calculation Method and Parameters

#### Costs for policy measures
- Calculated from budget, etc. (2014 budget) required for maintaining power generation activities.

#### Waste heat utility value
- Cogeneration and fuel cells are able to effectively use the heat generated during power generation. For this reason, the fuel costs required to generate the same amount of heat with a boiler are deducted from the generation costs.

#### CO2 measure costs
- Costs of procuring emissions rights equivalent to the CO2 emitted during power generation. (This method is the same for thermal power generation.)

#### Fuel costs
- Calculated from CIF or local demand area prices for fuel procurement rights for cogeneration and fuel cells. Calculated from the following two types.
  1. CIF costs (same as thermal power generation): LNG CIF price + various expenses of fuel cells, and petroleum CIF price + various expenses.

#### Operating and maintenance costs
- Periodic inspection costs, repair costs, etc.

#### Capital costs
- Equipment costs, construction costs, etc.

---

### Expected plant model (2014)

<table>
<thead>
<tr>
<th></th>
<th>Gas cogeneration</th>
<th>Oil cogeneration</th>
<th>Fuel Cells</th>
</tr>
</thead>
<tbody>
<tr>
<td>installed capacity</td>
<td>6,700kW</td>
<td>1,500kW</td>
<td>0.7kW</td>
</tr>
<tr>
<td>capacity factor</td>
<td>70%</td>
<td>40%</td>
<td>46.8%</td>
</tr>
<tr>
<td>operation years</td>
<td>30 years</td>
<td>30 years</td>
<td>10 years</td>
</tr>
</tbody>
</table>

### Expected plant model (2030)

<table>
<thead>
<tr>
<th></th>
<th>Gas cogeneration</th>
<th>Oil cogeneration</th>
<th>Fuel Cells</th>
</tr>
</thead>
<tbody>
<tr>
<td>installed capacity</td>
<td>6,700kW</td>
<td>1,500kW</td>
<td>0.7kW</td>
</tr>
<tr>
<td>capacity factor</td>
<td>70%</td>
<td>40%</td>
<td>49.5%</td>
</tr>
<tr>
<td>operation years</td>
<td>30 years</td>
<td>30 years</td>
<td>15 years</td>
</tr>
</tbody>
</table>

---

### Generation costs

<table>
<thead>
<tr>
<th></th>
<th>2014</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fuel costs (CIF) (Demand area)</td>
<td>Fuel costs (Demand area)</td>
</tr>
<tr>
<td></td>
<td>15.6 to 17.5 Yen/kWh</td>
<td>14.8 to 16.7 Yen/kWh</td>
</tr>
<tr>
<td>Social costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.3 to 2.5</td>
<td>1.7 to 2.3</td>
</tr>
<tr>
<td></td>
<td>5.3 to 6.5</td>
<td>2.3 to 3.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6,700kW</td>
<td>6,700kW</td>
</tr>
<tr>
<td></td>
<td>1,500kW</td>
<td>1,500kW</td>
</tr>
<tr>
<td></td>
<td>0.7kW</td>
<td>0.7kW</td>
</tr>
<tr>
<td></td>
<td>30 years</td>
<td>30 years</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>70%</td>
<td>70%</td>
</tr>
<tr>
<td></td>
<td>40%</td>
<td>40%</td>
</tr>
<tr>
<td></td>
<td>46.8%</td>
<td>49.5%</td>
</tr>
<tr>
<td></td>
<td>30 years</td>
<td>30 years</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

### Generation costs

- The generation costs are calculated based on the premise of costs detailed in the accompanying table.
2. Handling of Fuel Costs

- There are two perspectives on methods for estimating cogeneration fuel costs: (1) Adopting the same costs as large-scale centralized power supplies, and (2) adopting the fuel price charged in the demand area (city gas prices, etc.).
- As a result of the discussions, both perspectives are considered reasonable, and it was decided that estimates were to be based on both methods.

**Method (1)**

- With the intent of comparing large-scale centralized energy resources such as thermal power generation with distributed energy resources such as cogeneration under the same conditions, in the case of gas cogeneration, the same fuel prices were adopted to compare with LNG thermal power generation costs.

**Method (2)**

- Considered as fuel costs for the actual power generation, for example, gas cogeneration, the price of city gas which includes wheeling cost of gas, etc. is adopted.

---

**[E.g.: Gas cogeneration]**

- **Method (1)**: CIF price → CIF price + various expenses → City gas price
- **Method (2)**: City gas price

![Diagram of energy generation and distribution]
3. Premise of Heat Value

- There are two perspectives on methods for estimating heat value: (1) Calculating the heat value and deducting it from total costs, (2) estimating cost of electricity after dividing the output ratio of electricity and heat by costs.
- As a result of discussion done by the Working Group, Method (1) was adopted, which is the same decision made by the 2011 Costs Analysis Committee.
- It was also pointed out that costs should be reviewed based on heat demand, however, it was decided that costs would be estimated based on the ideal usage of current cogeneration and on the effective use of heat.

**[Views on heat value ((1) is adopted)]**

**Method (1)**

The value of heat simultaneously generated when producing a certain level of electricity is separately calculated, and deducted from the total costs.

\[
\text{Power generation costs} = \frac{\text{Capital costs} + \text{fuel costs} + \text{operating and maintenance}}{\text{The amount of power generated}} - \text{Waste heat value}
\]

\[
\text{Waste heat value} = \text{Total heat used} \times \text{market value per heat unit quantity}
\]

- In this case, there is a need to set the value of heat according to the actual situation of each country.
- Calculation substituting the fuel costs required for obtaining the same amount of heat using a boiler.

\[
\text{Market value per heat unit} = \frac{\text{Fuel price ($/t)}}{\text{Heat generated per heat unit (Wh/t)}} \times \text{Boiler efficiency}
\]

**Method (2)**

Estimate only the cost of electricity by dividing the output ratio of simultaneously produced electricity and heat by costs.
4. Premise of Technological Innovation (Gas cogeneration)

- Compared to the gas cogeneration reviewed by the 2011 Costs analysis Committee, the power generation efficiency of marketed equipment at maximum efficiency has improved by about 1 percent.
- Furthermore, power generation efficiency of gas engines and gas turbines is expected to improve by several percent due to future technological developments. Therefore, values taking these developments into account were chosen as future parameters.

**Power generation Efficiency [%]**

<table>
<thead>
<tr>
<th>Power generation output [kW]</th>
<th>Present Gas engine</th>
<th>Present Gas turbine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Past review (2011)</td>
<td>49.0%</td>
<td>34.5%</td>
</tr>
<tr>
<td>Past review (2011)</td>
<td>48.5%</td>
<td>33.0%</td>
</tr>
<tr>
<td>[2020] Power generation efficiency: Exceed 50%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[2030] Power generation efficiency: Exceed 51%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[2030] Power generation efficiency: over 38%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[2030] Power generation efficiency: over 36%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Prospects of improvements to gas cogeneration efficiency**

- **[Technological innovation of gas cogeneration]**
- Advancement of combustion technology
  - Improvement in combustion due to advancement of simulation technologies
  - Optimization of Miller cycle
- High performance superchargers
  - Realization of two-stage supercharging, etc.
- Advancement of ignition technology
  - Realization of laser ignition, etc.
- Reduction of loss due to mechanical loss, intake and exhaust loss, heat loss, etc.

**Technological development issues of gas engines**

- High compression ratio (High expansion rate), High output
  - Advancement of combustion technology
  - High performance superchargers
  - Advancement of ignition technology
- Reduction of loss
  - Machine
  - Reduction of intake and exhaust
  - Reduction of heat loss, etc.

**Technological development issues of gas turbines**

- High temperature entrance of gas turbine
  - Improved heat resistance of turbine blades
  - Advanced cooling technology
  - High performance superchargers, etc.
- Temperature on slots of gas turbines raises
  - Secure heat resistance to high temperatures
  - Inexpensive and high performance cooling technology and heat transfer control technology

(*) Created from data of power generation efficiency of marketed equipment, and a report from the Advanced Cogeneration and Energy Utilization Center JAPAN, etc. The above power generation efficiency is the maximum efficiency on the market. Indicated as LHV.
4. Premise of Technological Innovation (Fuel Cells)

- Compared to the efficiency of household fuel cells reviewed by the 2011 Costs Analysis Committee, the average power generation efficiency of marketed equipment has improved by about 1 percent. The selling price of fuel cells has dropped by more than 1.5 million yen.
- Further cost reductions and improvements in the power generation efficiency are expected due to future technological developments. Therefore, values considering these developments were chosen as future parameters.

---

[Changes in household fuel cell costs and power generation efficiency]

- Selling price
- Power generation efficiency

[Estimate of future power generation efficiency]

<table>
<thead>
<tr>
<th></th>
<th>Present</th>
<th>2020s</th>
<th>2030s</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEDO Road Map</td>
<td>35.7%</td>
<td>36.5%</td>
<td>43%</td>
</tr>
<tr>
<td>After correction</td>
<td>35.7%</td>
<td>39.4%</td>
<td>43%</td>
</tr>
</tbody>
</table>

* From NEDO's “Fuel Cells/Hydrogen Technological Development Roadmap”, the average values of the figures in the “Polymer Electrolyte Fuel Cells (PEFC) Roadmap (Stationary Fuel Cells System)” and “Solid Oxide Fuel Cells (SOFC) Roadmap” were adopted.
* However, as some current equipment has already exceeded the target efficiency for 2020 in these roadmaps, corrections were made to the estimates for the 2030s.

(*) The selling price is the average grant applied to household fuel cells. The power generation efficiency is the weighted average of the power generation efficiency of equipment sold each year with the number of devices already set to receive grants.
5. Premise of Costs for Policy Measures

<Total power generation of cogeneration>
○ According to the Survey of Electric Power Statistics (METI), the power generated by cogeneration in 2013 was 47.3 billion kWh (limited to power plants for which maximum output per site was more than 1,000 kW). Furthermore, power generated by power plants for which installed capacity per site was under 1,000 kW was estimated to be about 4.1 billion kWh based on the results of private sector surveys (Advanced Cogeneration and Energy Utilization Center JAPAN).
○ Totaling the figures above, the annual total power generated by cogeneration in 2013 was estimated to be 51.4 billion kWh.
○ Regarding the 2030 model plant, the amount of cogeneration implemented indicated in the Long Term Energy Supply - Demand Outlook (draft) mentioned earlier, 103 billion kWh (the figure excluding household fuel cells) was estimated as the annual total power generation of cogeneration in 2030.

< Total power generation of fuel cells>
○ The 2011 Costs Analysis Committee did not record the costs for policy measures given that the power generation was very small. In addition, the power generation based on the number of units currently running continues to be small at 330 million kWh.
○ For this reason, the installation target for household fuel cells for 2020 is about 140 million units. Based on this, this Working Group used the decided installed capacity and capacity factor and estimated the annual total power generation by fuel cells to be 4.3 billion kWh.
○ Regarding the 2030 model plant, the annual total power generation by fuel cells in 2030 was estimated to be 16 billion kWh based on the implementation amount of household fuel cells indicated in the Long Term Energy Supply - Demand Outlook (draft) mentioned earlier.

[Calculation of costs for policy measures]

● Cogeneration

Costs for policy measures related to cogeneration (2014 budget) (yen)
\[
\text{Budget (100 million yen)}
\]
\[
\text{The annual total power generation for cogeneration (kWh)}
\]

● Fuel Cells

Costs for policy measures related to fuel cells (2014 budget) (yen)
\[
\text{Annual total power generation for fuel cells (kWh)}
\]

[Costs for policy measures for cogeneration and fuel cells]

<table>
<thead>
<tr>
<th></th>
<th>Cogeneration</th>
<th>Fuel cells</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Year 2014</td>
<td>Year 2030</td>
</tr>
<tr>
<td>Budget (100 million yen)</td>
<td>16</td>
<td>27</td>
</tr>
<tr>
<td>Power generated (100 million kWh)</td>
<td>514</td>
<td>1,030</td>
</tr>
<tr>
<td>Costs for policy measures (Yen/kWh)</td>
<td>0.03</td>
<td>0.03</td>
</tr>
</tbody>
</table>
(5) System Stabilization Costs
The 2011 Costs Analysis Committee summarized the power system stabilization costs, which consist from (i)-(iii) (1) below. They did not add those costs in calculating the cost for renewable energy.

Following the 2011 Committee, the 2013 Working Group also did not add the system stabilization costs on the individual generation costs. Instead, they investigated the costs from the standpoints of whether or not they are required due to the installation of renewable energy.

(2) (i) will be reviewed by the Subcommittee on Long-term Energy Supply-demand Outlook and (2)-(i) will be verified by the 2013 Working Group.

(1) System stabilization costs calculated in 2011

(i) Adjustment costs using existing thermal power and pumped storage power generation to mitigate fluctuation from renewable energy.

(ii) Costs for reinforcing power system interconnection

(iii) Others

• Adjustment costs using Smart meters / Community Energy Management Systems (CEMS)
• Costs of power conditioners in order to mitigate fluctuation of power voltage
• Battery installation costs, pumped storage power generation costs
• Costs of measures to suppress rise in voltage in distribution lines.

(2) System stabilization costs calculated in 2013

(i) Adjustment costs using thermal power generation and pumped storage power generation

1. Cost for drop in Aggravation of power generation efficiency due to drop in efficiency
2. Costs incurred with increase in number of starts and stops of thermal power generation
3. Costs incurred as a result of demands created by hydro-power generation of pumped storage type during daytime.
4. Costs required for securing power generation facilities to deal with variable renewable energy.

(ii) Costs for increasing renewable energy interregional tie lines, etc.

(iii) Others

Basic viewpoints on items are summarized on next page.
Variable renewable energy such as solar and wind power fluctuate depending on meteorological conditions. Therefore, when incorporating variable renewable energy into grids, they cause short and long cycle fluctuations. That means, it is necessary to hold backup power generation (e.g. LNG thermal power or pumping hydraulic power). In addition, the adjustment cost in accordance with increase of renewable energy include the following:

(i) Adjustment costs for thermal power generation

(1) Costs related to the deterioration in efficiency of thermal power generation.
   - It is necessary for thermal power generation power plants to lower their operation rate when variable renewable energy generates. The operation rate with variable renewable energy is worse compared to the status during high-operation. In addition, it have utility companies to shift coal thermal power plant to LNG or oil, which is costlier than coal.

(2) Costs related to the increase in amount of stopping and starting of thermal power generation.
   - In addition to lowering the generation of thermal power by installing variable renewable energy sources, it is assumed that the stopping and starting of thermal power generation (mainly coal-fired thermal power) will be needed, which has never been performed before. In this case, additional costs for stopping and starting the thermal power generation are expected.
      * Moreover, it is assumed to have more medium to long term maintenance costs in order to compensate the declining of facility bearing ability, as well as additional fees to possess in full adjustment ability.

(3) Costs of generating demands of pumping hydrological power at the power generation of variable renewable energy.
   - The power generation is operated during the daytime as the electricity demand increases. After the installation of variable renewable energy (mainly solar power), it is assumed that there will be additional costs for transferring the power generation to the night time and use pumping-up hydrological power during the daytime.

(4) Costs for keeping the power generation facility to cope with variable renewable energy.
   - There will be costs for maintaining the capacity of thermal power generation when used as backup power to intermittent renewable energy.
      * The costs include (a) the increase in fixed costs (capital costs) per kWh, which were originally stored by operating the thermal power but it can be lower its power generation by enhancing the installation of variable renewable energy, (b) the increase of fixed costs (capital costs) of pumped-storage power generation per kWh used to compensate for naturally variable power generation. This is caused by having to use the pumped-storage power during the daytime as the surplus power for the naturally variable power generation, which cannot be used for normal supply capacity anymore.

These costs are presumed to be the adjustable costs for installing renewable energy. However, as this adjustable cost can be affected not only by the fluctuation from renewable energy, but also by the status of electricity demand and power generation operation, the adjustable costs should be calculated based on various assumptions.
Adjustment costs calculation for system stabilization costs (1)

- There will be some benefit in reducing fuel costs due to installation of variable renewable energy. However, sometimes it requires thermal power plants to lower their operation even though it generate loss since the regulation which electricity from generated from thermal power plants are not allowed to connect grid when renewable energy occupies the capacity of grids, has been in place. That generates costs from inefficiency of operation rate and costs from keeping additional backup power plants.
- As for the pumped-storage power generation, there will also be more costs to maintain and secure the facilities and pump-up loss which are caused by operating regardless of economy per the regulation for power supply priority rules.
- “The adjustment costs for system stabilization” is regarded as the total additional costs so as to integrate renewable energy into grids. Besides the reduction of fuel costs made by the Economic Load Dispatching and Power Supply Priority Distribution.

[Cost Image]

Thermal power output that is operated efficiently when solar and wind power are not installed despite the demand
Thermal power output that is operated after the installation of solar and wind power
Thermal power which will be stopped after the solar and wind power installation

(1) Costs for securing necessary amount of output power in order to meet the variable renewable energy
(2) Fuel costs that is operated efficiently when solar and wind power are not installed
(3) Fuel costs in case with no lowered thermal efficiency
(4) Costs for securing necessary amount of output power in order to meet the variable renewable energy

*capacity factor = Amount of power generation/(8,760 Hrs × rated capacity)

[The contents of system stabilization costs which should be regarded for the installation of variable renewable energy (solar and wind)]
(1) The power will be generated economically (Economic Load Dispatching) but capacity of grids will decline and there will be an increase of costs with lower thermal efficiency rate. This is mainly assumed to be incurred with LNG thermal power plants.
(2) The costs for suppressing and stopping thermal power by prioritizing the supply of variable renewable energy beyond the economical operation. (lowered efficiency, increase of amount of stopping and starting, etc); This is mainly assumed to be incurred with coal.
(3) The costs incurred with pumping loss from the pumped-storage power generation, which is supplied with priority of variable renewable energy, beyond the economical operation; This is incurred with pumped-storage power generation.
(4) In regards to (1), (2), and (3), there will be an increase of costs (fixed costs) in order to maintain and secure the thermal power facilities (the cost of pumped-storage facilities may be included).
(The effectiveness of fuel cost reduction by installing solar and wind power will be evaluated separately from the system stabilization costs)
Main assumptions regarding model

- Since the model analyzes demands and supply capacity all over the country, it is assumed that optimum use of power sources is carried out throughout the country. At this time, it is also assumed that for solar and wind power is located evenly while they are not, and therefore, there is no regional demand-supply imbalance.
  * When there is regional maldistribution in the installation of solar power and wind power, optimum power source operations are not carried out, and adjustment costs would increase.
- In terms of LNG/coal-fired thermal power plants, it is assumed that those power plants can be operated at the minimum load (in respect to all facilities in the country).
- kW restrictions are taken into consideration for pumped-storage power.
- It is assumed that for oil-fired thermal power, etc., regardless of the installed capacity of variable renewable energy, a certain amount of power required for maintaining the buffer during emergencies will be secured.

Precautions

- Regarding the increase in the fixed costs of pumped-storage power, while recognizing that pumped-storage facility functions will change in the future with the increase in the installed capacity of variable renewable energy (e.g. solar and wind power). Therefore, in this cost analysis, this fixed costs will not be included into the adjustment costs of system stabilization costs.
- Since quantification is difficult for the following costs, etc., they will not be included in the estimation at this time.
  - Increase in maintenance costs due to the decrease in the mid and long term tolerance of facilities as a result of load variation, increase in the number of starts/stoppages.
  - Additional costs for increasing adjustment capacity (e.g. additional costs for increasing adjustment ability to coal-fired thermal power plants)
- Due to the above assumptions and measures, adjustment costs of system stabilization costs would be estimated lower than the actual costs.
Estimation Costs

Regarding the capacity of installed thermal power and pumped-storage power facilities and demand, based on certain assumptions, the changes in the various costs are analyzed for when the wind power installed capacity is fixed, and the solar power installed capacity is changed, and for when the solar power installed capacity is fixed and the wind power installed capacity is changed.

Given that the change for wind is relatively small, and changing the solar power installed capacity has greater effects on various costs. If the installed scale of variable renewable energy (solar power, wind power) is approx., 60 million to 100 million kW, the total costs came to between approximately 300 billion yen to 700 billion yen per year (excluding pumped-storage power fixed costs).

The rate of decrease in the capacity factor of thermal power generation increases with increasing installed capacity of variable renewable energy (solar power, wind power). In particular, the decrease in the usage rate of coal-fired thermal power, whose usage for adjustments used to be limited, became even greater. (This trend was particularly evident when the increase for solar power was large.)

*Viewpoints on installation of solar power and wind power are indicated on the next pages.

**[Costs (Per year)]**

**Analysis of effects of installed capacity of solar power**

(Wind power fixed at 10,000,000 kW)

- Decreased utilization rate (Coal)
- Decreased utilization rate (GTCC)

**Analysis of effects of installed capacity of wind power**

(Solar power fixed at 70,000,000 kW)

- Decreased utilization rate (Coal)
- Decreased utilization rate (GTCC)

**[Change in capacity factor]**

- Decreased utilization rate (Coal)
- Decreased utilization rate (GTCC)
Reference: Estimates for Parameters

[Estimated solar power and wind power installed capacity]
Solar power: Calculated based on (1) 50,000,000 kW, (2) 70,000,000 kW, (3) 90,000,000 kW, wind power: (a) 5,000,000 kW, (b) 10,000,000 kW, (c) 15,000,000 kW Calculated using 3×3=9 cases.
At this time, the power generated in each case after output suppression is reflected is as follows.

<table>
<thead>
<tr>
<th>Solar power installed capacity</th>
<th>(a) Wind power 5,000,000 kW</th>
<th>(b) Wind power 10,000,000 kW</th>
<th>(c) Wind power 15,000,000 kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Solar power 50,000,000kW</td>
<td>56.9 billion yen kWh, 8.7 billion kWh</td>
<td>56.8 billion kWh, 17.5 billion kWh</td>
<td>56.8 billion kWh, 26.2 billion kWh</td>
</tr>
<tr>
<td>(2) Solar power 70,000,000kW</td>
<td>78.8 billion kWh, 8.7 billion kWh</td>
<td>78.7 billion kWh, 17.3 billion kWh</td>
<td>78.6 billion kWh, 25.9 billion kWh</td>
</tr>
<tr>
<td>(3) Solar power 90,000,000kW</td>
<td>99 billion kWh, 8.5 billion kWh</td>
<td>98.9 billion kWh, 16.9 billion kWh</td>
<td>98.8 billion kWh, 25.3 billion kWh</td>
</tr>
</tbody>
</table>

*However, the installed capacity was assumed without considering actual restrictions. Thus the installation of this amount is not guaranteed.

[Estimates of other parameters]
• Coal installed capacity: 41,000,000 kW/LNG installed capacity: 68,260,000 kW (Estimated from Hand Book of Electric Power Industry, 2014 Edition)
  * Of LNG, high efficiency LNG (GTCC) was 65% (Estimated from Electric Utility Handbook)
• Pumped-storage power installed capacity: 26,720,000 kW, of which the amount of actual capacity available: 21,220,000 kW (Estimated from estimated amount of pumped-storage power used by each company by the New and Renewable Energy Subcommittee (H.26))
• Demands : 2013 actual results (9 companies)
• Estimated output of solar power/wind power: Based on 2013 results (some estimated), the annual capacity factor was adjusted so that solar power is 13%, and wind power is 20%
• Rated thermal efficiency: Coal 42%, GTCC 52% (Cost WG 2014 model (assuming that the average of coal and GTCC becomes this level)
• Minimum load: Coal, GTCC both 30%
• Thermal efficiency decrease curve: Estimated from sample cases of power companies
• Fuel costs: Fuel costs of 2030 were set from the Cost WG WEO 2014 New Policies Scenario (Coal 5.1 Yen/kWh, LNG10.0 Yen/kWh: Changes according to thermal efficiency)
• Thermal power sources exceeding reserve rate of 8% in respect to H1 (maximum demand) of each month are assumed to stop for repairs.
• Unit price in respect to pumped-storage power loss: Assuming that it is 25 yen/kWh based on recent price trends of solar power selling price.
• Start/stoppage costs: Coal 150,000 yen/stoppage, LNG 50,000 yen/stoppage (per 10000 kW) (Based on interviews with power company)
  *? In the appropriation, the costs for the net increase were obtained by subtracting the costs for the LNG decrease from the costs for the increase in coal.
• Pumped-storage power fixed costs, construction cost unit price 200,000 yen/kW, annual expenses 5%(construction cost unit price is from the Working Group on Low Carbon Power Supply System (H.20). The annual expenses equal the total of capital costs (4%), and operating and maintenance costs (about 1%)
  *? The amount of the pumped-storage power fixed cost which was used for renewable energy was calculated but not included in the total.)
There exists various assumptions for the installed capacity by region for wind power. For this reason, cost estimates for increasing the transmission capacity of power lines are inconsistent. For example, when the unit price of additional costs for renewable energy (assumed to be wind power) in the Hokkaido and Tohoku regions are calculated using the results of estimates in the Master Plan Working Group (WG) (April, 2012), the cost for increasing capacity is about 9 yen/kWh per year, per additional kWh. When these costs are divided by area, costs are calculated to be 4 yen/kWh for Tohoku and 15 Yen/kWh for Hokkaido.

- The Master Plan Working Group made their calculations using the total for solar power and wind power in Hokkaido of 2,700,000 kW. In this WG, however, the 2,700,000 kW was expected to be supplied solely with wind power. The total costs for capacity increase (11.7 billion yen) was assumed to be the same as the costs determined in the Master Plan WG. The costs for the core transmission lines of Tohoku which overlap, were divided according to the installed capacity of each area.

As shown in the “Feed-in Tariff Operations Review, etc.”, by using the available transmission capacity, it may be possible to transmit a certain amount of renewable energy like wind power. (Regarding the rules related to such interconnection lines, etc., they will be established by the Extensive Operations Promotion Organization launched in April this year as send power operations guidelines.)

### Table: Additional costs for installation of wind power for additional capacity based on certain assumptions

<table>
<thead>
<tr>
<th>Additional lines</th>
<th>Hokkaido (Wind power)</th>
<th>Tohoku (Wind power)</th>
<th>Hokkaido and Tohoku total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,700,000 kW</td>
<td>3,200,000 kW</td>
<td>5,900,000 kW</td>
<td></td>
</tr>
<tr>
<td>(4.7 billion kWh)</td>
<td>(5.6 billion kWh)</td>
<td>(10.3 billion kWh)</td>
<td></td>
</tr>
</tbody>
</table>

- **Increase in on site power grid**
  - About 200 billion yen
  - About 70 billion yen
  - About 270 billion yen

- **Increase in interconnection lines and on-site power grid**
  - About 680 billion yen
  - About 220 billion yen
  - About 900 billion yen

- **Approx. total construction costs**
  - About 880 billion yen
  - About 290 billion yen
  - About 1170 billion yen
  - [About 15 Yen/kWh]
  - [About 4 Yen/kWh]
  - [About 9 Yen/kWh]

---

* The kW h unit is calculated as follows taking capacity factor to be wind power generation of 20%, and power transmission facility costs to be 8%. (Calculated in the same way for Hokkaido and Tohoku.)
  1. Annual power generated: (590000 kW × 20%) × 8760 hours = 10.3 billion kWh
  2. Annual expense: 1170 billion yen × 8% = 93.6 billion yen
  3. KWh unit price: 93.6 billion yen ÷ 10.3 billion kWh = about 9 Yen/kWh.

* In some cases, some send lines will not need to be increased depending on the power source situation in the future. On the other hand, in Hokkaido and Tohoku, it is taken that solar power has already been installed to the limit amount that can be connected, and in this case, the on site lines may be filled with solar power. For this reason, other than the following, costs for additional on-site lines may be incurred.

* Regarding the establishment of on site send lines in Hokkaido and Tohoku, efforts are being carried out by a power transmission network demonstration project for wind power generation (2015 government budget of 10.5 billion yen).

* In addition, budgetary measures such as the R&D project to support power line output change (2015 government budget of 6 billion yen) were also implemented as measures to deal with intangible output changes not accompanied by increased lines.
Constructed a LNG and coal operating model, and analyzed the model changes in the operations of the thermal power sources with the operation of renewable energy installations.
* Regardless of the installed capacity of renewable energy, it is assumed that the oil-fired thermal power required at the least as a buffer during emergencies will be secured. For this reason, it is assumed that there is no decrease in the oil-fired thermal power generated due to the introduction of variable renewable energy.
* Costs for additional running of thermal power sources with adjustment capacity (e.g. switch from coal to LNG) are reflected in this analysis.

[Basic viewpoints on model]
- The demand curve of one year is estimated. The output for the installed capacity of solar power and wind power of that period of time is estimated.
- Suppressed in the order of LNG then coal in accordance with the merit order. It is assumed that the minimum output of LNG and coal-fired power will be secured, even under the suppression.
- If the total value of solar power and wind power exceeds the adjustable thermal power amount even when both LNG and coal were suppressed to the lower limit, the pumped-storage power is run and absorbed. If it still cannot be absorbed even with the pumped-storage power, the surplus solar power and wind power are suppressed.
- The above work is calculated every year/8760 hours, and the changes in the capacity factor of the thermal power source are calculated according to whether variable renewable energy is introduced, and the implementation cases. In addition, the absorption amount of variable renewable energy by pumped-storage power is also calculated.

(Note)
- Conventional LNG currently operates at a low capacity factor. It is high efficiency LNG and coal-fired thermal power that drops its capacity factor if variable renewable energy is introduced.
- The model is constructed with the nationwide demand and supply ability integrated. It is assumed that optimum power source operations are carried out throughout the country (cross-regional operations are carried out completely). For this reason, detailed restrictions of interconnection lines are not taken into account.
- It is assumed that surplus variable renewable energy exceeding the capacity of pumped-storage power (kW) will be suppressed.
Additional output adjustments such as suppression of thermal power generation are required following the installation of variable renewable energy. As a result, compared to the thermal efficiency at the rated output state, the thermal efficiency drops due to operations at low output (=decrease in power generated per fuel input). In addition, operations may be more costly when thermal power sources are operated in order to absorb fluctuation of renewable energy output. (E.g.: switch from coal to LNG or oil).

Viewpoints on calculation

(1) Estimating the kW produced by coal and LNG from 8760hr demands for every hour, the demand changes over time (difference from previous period) are added, and this is divided by the installed capacity to calculate the load adjustment times per kW. In addition, the time of the Minimum load operations is also counted.

(2) As the decrease in thermal efficiency can be obtained depending on the operating state at low output, thermal efficiency is calculated from the following equation based on (1).

\[
\text{Thermal efficiency} = \text{Rated thermal efficiency} \times \frac{\text{Rated operation hr}}{\text{Operation hr}} + \text{Minimum load thermal efficiency} \times \frac{\text{Minimum load operation hr}}{\text{Operation hr}} \times \frac{\text{Operation hr during load adjustment time}}{\text{Operation hr}}
\]

*Rated=100%, Minimum load=30%, average during load adjustment is taken to be 65%.

(3) Costs incurred due to thermal efficiency drops are calculated as increases in fuel costs

(Examples of calculation)
Fuel costs of thermal efficiency before introduction of renewable energy: $\alpha$ Yen/kWh
Fuel costs of thermal efficiency after introduction of renewable energy : $\beta$ Yen/kWh
Powered generated (after drop in capacity factor) : Fuel costs increase taking $A$ hundred million kWh,

Fuel costs increase = $A$ hundred million kWh \times ($\beta$ Yen/kWh$-\alpha$ Yen/kWh)
From the earlier mentioned “capacity factor change analysis model”, for the number of stop and start times, it is taken that the operations by new units start additionally only for the changes in load (LNG (or coal) before and after). The number of times new units operate per kW due to load changes in a year are calculated. By comparing these with, before and after introducing variable renewable energy, the difference before and after adjustments in a year can be calculated and this is the number of starts/stops.

[Outline]

In load adjustment, not all units are commanded at the same time. When the unit that is first instructed reaches the rating, the load adjustment of the next unit is started. By adding the changes of each constant time, the change in the unit can be estimated.

[Changes in output of power supply type per day (For LNG and coal)]

Only values with positive fluctuations are added, considering that increases in output lead to the same amount of decreases in output.

*The above shows the simulated operating pattern of units with rated output of a certain scale. On the model, the operating state of all installed capacity by type of power source is analyzed instead of individual units. The amount required by LFC is not taken into account.*
In addition to suppressing output of thermal power generation to allow for the introduction of variable renewable energy, it is assumed that the start/stop of thermal power generation (mainly coal-fired thermal power whose operations have never been stopped thus far) will be required. In this case, costs for additional starts and stops of thermal power generation are expected.

Calculation Method

(1) Assume the increase in the average number of starts and stops in one year of coal-fired power per unit according to the introduction of variable renewable energy: $\gamma$ times (yearly)

(2) Costs accompanying starts and stops per time: $C$ (Yen/time, 1.000,000 kW)

(3) Installed capacity of coal-fired thermal power in calculation stage: $D \times 1,000,000$ kW
   (E.g.: If 45,000,000 kW then $D=45$)

(4) Costs of start/stop = $\gamma \times C \times D$ (Yen)

(Example of calculation)
   Start/stop costs (average) Coal: 15 million Yen/1,000,000 kW/time
   Number of stops increased in one year: $\gamma = 50$ times
   Coal installed capacity: If 45,000,000 kW, then $D=45$

Assuming the above, then the start and stop costs = $50 \times 15 \text{ million} = 34 \text{ billion yen/year}$

(Precautions)
- Regarding LNG, due to the increase in the installation of variable renewable energy, the number of starts and stops may decrease (→ replacement of stopping coal fireplace thermal power). In this case, the decrease in costs (due to decrease in the number of LNG starts/stops) will be deducted and estimated. (The average start/stop costs of LNG: 5 million yen/1,000,000 kW/time)
To date, the pumped-storage hydropower pumped up by using the excess energy in the night and used it in the day time which energy demand is high. In the future, to cope with the increase of variable renewable energy (mainly solar power) it will pump up in the daytime and use it in night, and this will cause additional cost.

Viewpoint on calculation

(1) pumped-storage hydropower in the installation of variable renewable energy: E kWh (Calculated from earlier mentioned capacity factor change model)

(2) Assuming that loss rate of pumped-storage hydropower is 30%, the power which can be generated by pumping E kWh is \((1 - 0.3) \times E\) kWh

(3) Estimated solar power purchase price: \(P_{pv}\) Yen/kWh

(4) When pumped-storage hydropower is used, only 70% of the actual power can be supplied. If we consider this as a cost, it will be \(\{E - (1 - 0.3) \times E\} \times P_{pv} = 0.3 \times E \times P_{pv}\) (Yen)

E.g.) Taking amount of pumped-storage power used to be 10 billion kWh, and solar power purchase price to be 25 Yen/kWh, then the pumped-storage power costs will be \(0.3 \times 10\) billion \(\times 25 = 75\) billion yen/year
With the introduction of variable renewable energy, there is a need to secure fixed amount of installed capacity of thermal power generators, etc., as a backup for variable renewable energy which can suffer from large fluctuations, and funds to maintain and secure the backup generators will be required. 

※The costs can include (a) increase in fixed costs (capital costs) per kWh (which could have been covered by thermal power generation) due to the increased introduction of variable renewable power sources, which leads to decreased thermal power operations, and (b) increased in fixed costs (capital costs) per kWh from using variable renewable power supply, due to the use of pumped-storage power during the day as a measure against surplus variable renewable energy, which disables normal use of pumped-storage.

**Calculation Method**

***<Thermal power>***

When we assume decrease in capacity factor (comparison of before and after) as α%, thermal power fixed costs as F Yen/kWh, coal-fired thermal power installed capacity as D (kW), then the increase in the fixed costs of the required thermal power

\[ \text{Increase in the fixed costs of the required thermal power} = D (kW) \times 8760 \text{ hours(hr)} \times \alpha \% \times F \text{ (Yen)} \]

(Calculation example: In the case of coal-fired thermal power)

When the use rate of coal-fired thermal power drops by 20%. (Example: 80%→60%): η = (80-60)/80 = 25%

coal fixed costs unit price = 3.5 Yen/kWh (Capital costs + Operating and maintenance costs)

Taking the nationwide coal-fired thermal power kW to be 45,000,000 kW, then the increase in the thermal power fixed costs will be 45,000,000 kW × 8,760hr × 25% × 3.5 = about 345 billion yen/year (nationwide total)

* Although it takes fixed costs for the installation of the thermal power regardless of whether variable renewable energy is introduced or not, they are uncollectable costs because even if the owners of thermal power facilities maintain their facilities, they are unable to run the facilities due to the introduction of variable renewable energy. (See illustration (right).) (At this time, the installed capacity which becomes unnecessary with the introduction of variable renewable energy is taken to be zero for simplification.)

* For changes in the capacity factor, the earlier-mentioned capacity factor change analysis model is used. The same calculations apply for LNG.

***<pumped-storage hydropower>***

pumped-storage hydropower kW unit price: G Yen/kW, nationwide pumped-storage hydropower capacity: H(kW), annual expenses δ% (year), sharing ratio with normal operations with the introduction of variable renewable energy: η,

pumped-storage hydropower fixed costs pro rate payment = G × H (kW) × δ × η (Yen)

(Example of calculation)

pumped-storage hydropower kW unit price  G = 200,000 Yen/kW

nationwide pumped-storage hydropower kW  H = 2,700,000 kW

Annual expenses δ=6% /year, sharing ratio: η = 1/2(Model which calculates the number of days pumped-storage hydropower is operated during the daytime from the earlier mentioned model),

then pumped-storage hydropower fixed costs shared amount: 200,000 yen × 27,000,000 kW × 6% × 1/2 = Approx. 162 yen/year (nationwide total)

* As pumped-storage hydropower generators are relied on as daytime power supplies, there is a need to fill up the tank at night. When variable renewable energy such as solar power increases, there is a need to empty the tank assuming that it will be pumped up during the day. However, in the costs analysis this time, the additional pumped-storage hydropower plant fixed costs will not be directly appropriated in the adjustment costs of system stabilization costs, taking into account that functions of the pumped-storage hydropower will change in the future with the increasing introduction of variable renewable energy (solar power, wind power).
Regarding the periodic inspection and repair of pumped-storage hydropower, conventionally these were carried out in spring and autumn changeover periods when power demands are low. (See left drawing.) Repair work is generally carried out once every two to three years for about one to two months. It can take up to as long as a few months to one year. For this reason, the amount which can be used at changeover periods is limited for both kW and kWh.

In the calculations of the connectable amount by the System WG, the highest possible output control of thermal power and pump up operations are estimated. In the calculation, operations are estimated high in the spring changeover period where demands are small and solar power output is large. (See Right drawing: Kyushu Electric Power company example)

For this reason, when a renewable power source such as solar power which has fluctuation in output is connected to connectable solar power amount, the repairs and periodic inspections of pumped-storage hydropower normally carried out in spring and autumn cannot be carried out in those seasons. As a result, it may become difficult to use pumped-storage hydropower generators for demand-supply operations during the high power demand months of summer and winter. In the low power demand periods of spring and autumn, as pumped-storage hydropower operations of pumped-storage hydropower generators are performed at maximum output, the power generators may not be able to adequately carry out their demand-supply adjustment role.

In this way, if pumped-storage hydropower generation is to be maintained and operated to deal with fluctuations in renewable energy, the effects of decreases in peak supply ability in periods of high demand and determining responsibility for cost burdens will both become challenges. However, in this Working Group, the costs will not be directly appropriated for adjustments cost in the system stabilization costs.

*Calculated by System Working Group (3rd Meeting, December 16, 2014) with connectable amount calculation conditions

(Based on the usage results and System WG meeting, December 16, 2014) with connectable amount calculation conditions

*Reference* pumped-storage hydropower Generation Operations Pattern (related to (4))
## Estimation Results: Details

<table>
<thead>
<tr>
<th>Variable renewable energy</th>
<th>Wind power fixed at 5 million</th>
<th>Wind power fixed at 10.5 million</th>
<th>Wind power fixed at 15 million</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind power fixed at 5 million kW</td>
<td>5,000</td>
<td>6,640</td>
<td>9,000</td>
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<tr>
<td>Wind power fixed at 10.5 million kW</td>
<td>1,050</td>
<td>1,050</td>
<td>1,050</td>
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<tr>
<td>Solar power generation (100 million kWh)</td>
<td>569</td>
<td>756</td>
<td>1,025</td>
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<tr>
<td>Wind power generation (100 million kWh)</td>
<td>88</td>
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<td>88</td>
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<tr>
<td>Solar power after suppression (100 million kWh)</td>
<td>569</td>
<td>749</td>
<td>990</td>
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<tr>
<td>Wind power after suppression (100 million kWh)</td>
<td>87</td>
<td>87</td>
<td>85</td>
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<tr>
<td>Renewable energy amount after suppression (100 million kWh)</td>
<td>656</td>
<td>836</td>
<td>1,075</td>
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<tr>
<td>Coal</td>
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<td></td>
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<tr>
<td>Operating rate change (%)</td>
<td>-7.3%</td>
<td>-10.2%</td>
<td>-14.1%</td>
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<tr>
<td>(4) Fixed amount uncollected amount (100 million yen)</td>
<td>1,003</td>
<td>1,395</td>
<td>1,924</td>
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<tr>
<td>(1) Fuel costs increased amount (Heat efficiency decrease loss) (100 million yen)</td>
<td>131</td>
<td>182</td>
<td>245</td>
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<tr>
<td>(2) Start stop costs (100 million yen)</td>
<td>503</td>
<td>640</td>
<td>777</td>
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<tr>
<td>LNG (GTCC)</td>
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<tr>
<td>Capacity factory change (%)</td>
<td>-9.8%</td>
<td>-11.4%</td>
<td>-13.2%</td>
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<tr>
<td>(4) Fixed amount uncollected amount (100 million yen)</td>
<td>834</td>
<td>973</td>
<td>1,132</td>
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<tr>
<td>(1) Fuel costs increased amount (Heat efficiency decrease loss) (100 million yen)</td>
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<td>790</td>
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<tr>
<td>(2) Start stop costs (100 million yen)</td>
<td>-93</td>
<td>-106</td>
<td>-118</td>
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<tr>
<td>pumped-storage hydropower</td>
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<tr>
<td>pumped-storage hydropower used (100 million kWh)</td>
<td>43</td>
<td>89</td>
<td>179</td>
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<tr>
<td>pumped-storage hydropower loss (100 million kWh)</td>
<td>13</td>
<td>27</td>
<td>54</td>
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<td>(3) pumped-storage hydropower loss (100 million yen)</td>
<td>324</td>
<td>670</td>
<td>1,345</td>
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<tr>
<td>Renewable energy pumped-storage hydropower days</td>
<td>101</td>
<td>162</td>
<td>226</td>
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<td>(4) Fixed costs (pumped-storage hydropower) collection loss (100 million yen)</td>
<td>739</td>
<td>1,186</td>
<td>1,654</td>
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<tr>
<td>Total</td>
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<tr>
<td>(1) Loss due to decrease in heat efficiency (100 million yen)</td>
<td>439</td>
<td>691</td>
<td>1,035</td>
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<tr>
<td>(2) Start/stop (coal increase-LNG decrease) costs (100 million yen)</td>
<td>409</td>
<td>534</td>
<td>659</td>
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<tr>
<td>(3) pumped-storage hydropower loss (100 million yen)</td>
<td>324</td>
<td>670</td>
<td>1,345</td>
</tr>
<tr>
<td>(4) Fixed costs (ignition) collection loss (100 million yen)</td>
<td>1,837</td>
<td>2,368</td>
<td>3,056</td>
</tr>
<tr>
<td>Adjustment costs total (1)+(2)+(3)+(4) (Excluding pumped-storage hydropower fixed costs) (100 million yen)</td>
<td>3,010</td>
<td>4,262</td>
<td>6,095</td>
</tr>
</tbody>
</table>
(6) Other Items
There is a viewpoint that in addition to securing the normal reserve margin, surplus capacity should also be secured in case of power shortages due to large-scale power source failures or the inability to use specific power sources.

There are two types of surplus capacities: power generation facilities which can begin operation in a short period of time as reserve power and power generation facilities which can start operations within a certain period of time. It should be noted that they are different in nature.

However, with the reformation and liberalization of power systems, it has been pointed out that there will be less and less power companies adopting power sources whose operations in peacetime. Furthermore, in actual power failures, measures other than surplus capacities may require such demand side measures as demand response, emergency power sources installed only for a short time and used only during emergencies.

* In reality, the whole facility does not have to be new. The surplus of existing facilities can also be used. For oil-fired thermal power, etc. as most facilities have also ready depreciated, there may be no need to appropriate additional construction costs for securing surplus capacity. However, if these are not disposed but continuously used, some costs will be incurred, although they will not be as high as the operating and maintenance costs of currently operating power generation facilities. The challenge lies in finding the means of covering these costs.

* On the other hand, should new power generation facilities be required, additional costs such as construction costs may arise.

There is a need to review the portion of this surplus capacity which is required, the type of mechanisms necessary to maintain these facilities and to what extent current facilities can be used, and compare the cost effectiveness of these facilities with other measures in the design of future systems. At this point, it is difficult to produce specific figures.
The IEA’s Energy Technology Perspectives 2014 stresses the need for CCS and states that “the future of CCS is not clear. At this point, the high costs and lack of involvement of the political and financial sectors have resulted in the slow progress of CCS technology. In order to secure long term foundations with competitive edge to meet weather change targets, short-term progress in CCS research, development, and demonstrations are required.

The main global CCS trend is CO2 flooding, where CO2 is flooded into oil fields to increase crude oil (EOR).

In Japan which has few oil resources, there is little room for EOR and CO2 flooding is mainly carried out on the strata (including aquifer). In Tokomae Hokkaido, a demonstration project attempting to separate, collect and flood has started.

It is crucial to extend CCS to the industrial sector and power generation sector to achieve sustainable energy systems ensuring the reduction of greenhouse gas emissions. At this point, the progress of CCS technology is slow due to high costs and lack of political and financial involvement.

Taking the carbon price to be around $100/t-CO2 (and when gas and coal prices are also reasonably estimated), CCGT which incorporates CCS has lower equivalent generation costs (LCOE = Levelized cost of electricity) than CCGT alone, and is cheaper than supercritical pulverized coal power generation.
For discount rate, the lower the risk and higher the value of the power source like the sun, the lower the profit can be. It should be possible to use the solar loan interest rate of 2.3%.

On the other hand, the risks of nuclear power and thermal power have increased due to transactions like fuel procurement. Moreover, as discount rate settings are executed in the organization unit by the centrally managed energy, the company capital profit rate will be required. The capital costs of Japanese companies is 5 to 6%, which is the weighted average of amount borrowed and capital owned, and is thus much higher than solar power.

| Provided by | Individual |

Discount rate is the percentage of converting to the current value based on the uncertainty of money in the future by society in general. It is expressed as the percentage for one year. It is a different concept from individual business profit rate and interest expenditure.

The 2011 Costs Analysis Committee commented that “Considering the purpose of the Renewable Energy Law, the 1 to 5% discount rate is too low. It should be set to 8 to 10% taking into account business profit”, and concluded that it will not be included in the flat rate for all power sources.

Discount rate is estimated with margins of 0, 1, 3, 5%, and does not aim to prevent estimates where discount rate is individually changed.

⇒ As what is provided differs from the viewpoint on estimation, it is not possible to change it. Like the 2011 Costs Analysis Committee, it has been decided that the discount rate will be expressed with a margin, and it can be estimated individually.
Regarding the power efficiency of future oil-fired thermal power, the figures considered to be “appropriate as report details” (2020: 42%, 2030: 48%) in the 2011 Costs Analysis Committee’s Call for Evidence should be adopted.

Overview 2
2011 Costs Analysis Committee 9th Meeting materials “Information obtained from Call for Evidence, etc. and actions based on this (draft)”

**Viewpoints on information provided**

Oil-fired power generators in Japan have not been replaced or renewed in recent years, and above that, the power generation efficiency is calculated based on construction results, etc. of more than 20 years ago. For this reason, no data which takes into account latest technologies, etc. exists.

As indicated in the information provided, based on the database of the latest coal-fired thermal power generator announced by the U.S. DOE and database of LNG thermal power, the power generation efficiency of oil-fired thermal power, should super-critical pressure oil-fired thermal power generators be realized, can be estimated to be 48% in 2030.

On the other hand, for the year 2020, no specific construction plan exists at this stage, and because the only data available indicated that it is unlikely, the data was not used.

⇒ The proposed details will be reflected in the 2030 model plant.
[Coal, LNG] Thermal efficiency

It seems like coal and LNG thermal efficiency are set somewhat lower. They should be set to the thermal efficiency of leading-edge plants such as IGCC (Nakoso Power Plant), high efficiency LNG thermal power (Himeji No. 2 Power Plant), etc.

<Viewpoints on information provided>

This estimate is based on the model plant method. Several plants which started running commercially before 2013 have been extracted as sample plants, and the efficiency, etc. is set considering their circumstances. For this reason, the thermal efficiency given is that (generating end, JJV) of power generation facilities considered to be leading edge at this point.

The Himeji No. 2 Power Plant mentioned is used as one of the sample plants. With regard to IGCC (Nakoso Power Plant), because it has been converted from a government aided project to a commercial use project, it is not appropriate to use it as a sample plant given that it is a purely commercial facility.

Regarding the thermal efficiency for 2030, based on technological development trends, coal-fired thermal power is estimated to be 48%, and LNG thermal power, 57%.

Thermal efficiency can differ depending on the generating end, sending end, higher heating value (HHV), and lower heating value (LHV). It is necessary to establish appropriate parameters for the discussion of figures. (Generating end and HHV are used in this estimate.)

⇒ Since the information provided had already been taken into account when the sample plants were selected, no changes are required.
[Solar power] Solar power generation operation years

The Costs Analysis Committee calculated the residential solar power generation costs to be 33 Yen/kWh. Isn’t the useful building life span of 20 years set here too short? If the generation costs are calculated with the useful life span and operation years set as 35 years from an independent standpoint, the residential solar power will be 17.5 Yen/kWh (400,000 Yen/kW) and non-residential solar power will be 15.2 Yen/kWh (300,000 Yen/kW). In April 2012, the Purchase Price Calculation Committee set the useful life designated by law at 17 years and operation years at 20 years even through the actual lifespan was more than 20 years. It is incorrect to apply these figures as they are.

<Submitted data>

<table>
<thead>
<tr>
<th>Costs Analysis Committee (As of 1998)</th>
<th>This paper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building useful life span</td>
<td>20 years</td>
</tr>
<tr>
<td>Construction costs per 1 kW</td>
<td>480,000 yen</td>
</tr>
<tr>
<td>Conditioner per 1 kW</td>
<td>60,000 yen</td>
</tr>
<tr>
<td>Conditioner renewal time</td>
<td>10 years</td>
</tr>
<tr>
<td>Maintenance costs (Periodic inspection) per 1kW</td>
<td>10,000 yen once in 4 years</td>
</tr>
<tr>
<td>Decommissioning costs</td>
<td>5% of construction costs</td>
</tr>
<tr>
<td>Discount rate</td>
<td>3%</td>
</tr>
<tr>
<td>Power generated per 1kW</td>
<td>1,000kWh</td>
</tr>
<tr>
<td>Unit cost</td>
<td>33.4 Yen/kWh</td>
</tr>
</tbody>
</table>

<Viewpoints on information provided>

Independent estimates that are not supported by papers, etc. are not considered. The 2011 Costs Analysis Committee uses the useful life designated by law of 17 years and operation years of 20 years. Given that the grounds for the “35 years” used in the information provided are not clear, 20 years, it is thought to have been obtained from the parameters of the 2030 model plant.

⇒ In addition to the fact that information provided lacks supporting evidence, and the provided parameters do not match the generation costs proposed at this time even when they are applied to the 2011 Costs Analysis Committee estimation sheet, they cannot be reflected as they do not match the proposed power generation costs. The operation years of solar power generation shall be set based on interviews conducted with related businesses.
The evidence data referenced is from before the new regulatory requirements were implemented. In the current analysis, it was assumed that the frequency of accidents would decrease with the addition of safety measures implemented in accordance with the new regulatory requirements, and discussions have been carried out centering around the basis of calculation of the “mutual aid” approach, so that projection will be reflected. Use of the probabilistic risk assessment (PRA) which is used in the assessment of the suitability of the new regulatory requirements is also suggested. PRA is based on past accidents and failures. The capacity factor was set at 70% and 80% based on the past track record including failures and its nature as a base load power source. For these reasons, nuclear accident costs will not be re-calculated based solely on the comment made.

⇒ This proposes that the situation before measures such as the new regulatory requirements, etc. were taken should be reflected, but we have no intention of changing the nuclear accident costs.
The Costs Analysis Committee revised the Fukushima Daiichi accident costs which were said to be many trillions of yen, to 8 trillion yen as the lower limit, and divided it with the tentative total power generation which assumes that 50 reactors will resume operations and run for 40 years. This optimistic standpoint is very unrealistic. Moreover, the further-revised figure of 5.8 trillion yen does not include the costs of measures for dealing with highly concentrated contamination, costs for treatment of waste resulting from decontamination, damage to health and property, and damage to local public organizations, etc., and it is therefore taken to be the “lower limit”. Still the amount is excessively small as a lower limit. Essentially, the losses resulting from nuclear accidents cannot be expressed by money alone. Stating that that costs which cannot be measured by money are massive, sub energy-mix committees are saying that accidents costs should also be taken into account for other energies.

The 2011 Costs Analysis Committee corrected the additional decommissioning costs (accident decommissioning costs) and compensation costs in Tokyo Power Electric Company’s Business and Financial Survey Committee report (October 2011) according to the output scale, locality, and population. (Approx. 7.9 trillion yen → later corrected to 5.8 trillion yen).

In this analysis, compensation costs were reviewed based on the latest prospects which take into account “Towards accelerating the restoration of Fukushima from nuclear disaster” (passed by the cabinet in December 2013”, “New General Special Business Plan” changes approved in April 2015), and estimations of the Ministry of Environment related to decontamination/Intermediate storage. As a result, accident decommissioning costs became 1.8 trillion yen, compensation costs were 5.7 trillion yen, decontamination/intermediate storage costs were 3.6 trillion yen, and other costs were 1.1 trillion yen, totaling 12.2 trillion yen. Using the same method as the 2011 Costs Analysis Committee, these costs were revised according to the output scale, locality, and population ratio. (Approx. 12.2 trillion yen → revised to 9.1 trillion yen).

⇒ In this analysis, as a result of investigating damage costs, the lower limit of accident decommissioning costs, compensation costs, decontamination/intermediate storage, administrative costs, etc., the total came to 12.2 trillion yen. Like the 2011 Costs Analysis Committee, the figures will be corrected to the model plant, and 9.1 trillion yen will be included as damage costs.
With regard to the commend “It does not seem right that the 3rd meeting materials even reports on the research and development of high speed furnace even though the materials are regarding light-water reactor generation costs (they are different types of power generation)”, high speed breeder reactors were researched and developed with the hope of multiplying the plutonium generated by the light-water reactors. Since R&D costs are required for running the light-water reactor they should be counted as costs for policy measures.

Basis of information
Ministry of Education H13 Science and Technology White Paper

<Viewpoints on information provided>
The materials mentioned are part of the summary of comments made by members up to the 3rd meeting. Of the “Future power generation technological generation” for nuclear power, costs related to the nuclear fuel cycle such as high speed reactors and reprocessing, radioactive waste disposal, etc. and technological development costs related to safety will be appropriated and other expenses will be excluded.

⇒ Of the “Future power generation technological generation” for nuclear power, costs related to the nuclear fuel cycle such as high speed reactors and reprocessing, radioactive waste disposal, etc. and technological development costs related to safety will be appropriated and other expenses will be excluded.