Renewal & Upgrading of Hydropower Plants

IEA Hydro Technical Report

Volume 1: Annex-XI Summary Report

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IEA Hydropower Agreement: Annex XI

AUSTRALIA JAPAN NORWAY USA

International Energy Agency

The International Energy Agency (IEA) is an autonomous body which was established in November 1974 within the framework of the Organization for Economic Co-operation and Development (OECD) to implement an international energy programme.

It carries out a comprehensive programme of energy co-operation among twenty-nine of the OECD's thirty member countries.

The basic aims of the IEA are:

- to maintain and improve systems for coping with oil supply disruptions;
- to promote rational energy policies in a global context through co-operative relations with non-member countries, industry and international organizations;
- to operate a permanent information system on the international oil market;
- to improve the world's energy supply and demand structure by developing alternative energy sources and increasing the efficiency of energy use;
- to assist in the integration of environmental and energy policies.

IEA Hydropower Implementing Agreement

(Implementing Agreement for Hydropower Technologies and Programmes)

The IEA provides support for international co-operation and collaboration agreements in energy technology R&D, deployment and information dissemination, called the IEA Framework for International Technology Cooperation.

The Framework sets out the legal and management support for activities of more than 40 active technology agreements in the programme, called Implementing Agreements.

The Hydropower Implementing Agreement (IEA Hydro) is a collaborative programme among member countries and consists of an Executive Committee and a number of task forces which have been set up within its organization to track specific study themes, called "Annexes". Member countries are represented by various organizations including electric utilities, governmental department and regulatory organizations, electric research organizations, and universities.

The overall objective is:

- to improve both technical and institutional aspects of the existing hydropower industry;
- to increase the future development of hydropower in an environmentally and socially responsible manner;
- to provide objective, balanced information about the advantages and disadvantages of hydropower.

There are currently eight participants, namely Australia, Brazil, China, France, Finland, Japan, Norway, US.

In the first phase of activity (Phase 1: 1995-1999), surveys and studies on four tasks had been carried out, they are:

1. Hydropower Upgrading (Annex I),
2. Small Scale Hydropower (Annex II),
3. Hydropower and the Environment (Annex III),
4. Education and Training in Hydropower (Annex V).

In the second phase (Phase 2: 2000-2004), three tasks that took over the theme in Phase 1 in expanded form and one new task were set up, they are:

1. Small Scale Hydropower (Annex II),
2. Public Awareness (Annex VI),
3. Hydropower Competence Network for Education and Training (Annex VII),
4. Hydropower Good Practices (Annex VIII).

In the third phase of activity (Phase 3: 2005-2009),

1. Small Scale Hydropower (Annex II),
2. Hydropower Service (Annex-Ⅸ),
3. Wind Hydro Integration (Annex-Ⅹ),
4. Hydropower and the Environment (Annex-Ⅻ) were endorsed.

In the fourth phase of activity (Phase 4: 2010-2014),

1. Small Scale Hydropower (Annex II),
2. Hydropower Service (Annex-Ⅸ),
3. Renewal and Upgrading of Hydropower Plants (Annex-XI),
4. Hydropower and the Environment (Annex-Ⅻ),
5. Fish and Hydropower (Annex-XIII) were approved and put into action.

We have now entered the fifth phase (Phase 5: 2015 to 2019), with one further Annex being

6. Management Models for Hydropower Cascade Reservoirs (Annex XIV).

Acknowledgement

Many hydropower facilities in advanced hydropower countries are approaching the time for renewal. Given this situation, it is necessary to renew or upgrade such facilities in a way that accommodates changes in the social and natural environment, changes to the electricity market and changes to the functions or values expected of hydropower today.

Until now, there has not been any document that provided a systematic summary of the renewal & upgrading of hydropower facilities. This may have been because each hydropower plant is unique and designed to suit specific conditions, and with so many elements affecting renewal & upgrading, a systematic manual was considered difficult to produce. However, it is recognized that in many countries, hydropower stakeholders' interest has been focused in recent years on renewal and upgrading, rather than new developments. Against this backdrop, Japan suggested to the IEA Executive Committee, the compilation of a guide for hydropower plant renewal & upgrading. This was accepted and Japan became the Operating Agent (OA) of Annex-XI to work in collaboration with other member countries.

Following the kick-off meeting in Kyoto in September 2010, the Annex convened a total of 24 international meetings to exchange opinions on the outcome of its activities, including 12 expert meetings, 4 public workshops / symposiums and 8 Executive Committee meetings. These meetings were held in an open and friendly atmosphere, allowing all the participants to mutually deepen common understanding about the purport of Annex-XI and make steady progress in its activities. 70 examples of best practice, gathered from around the world, have been systematically analyzed under two categories and nine key points and presented as processes leading to renewal & upgrading and these include economic rationale and environmental feasibility that serve as judging criteria. Japan hopes that this report will become a significant reference source for hydropower operators, E&M manufacturers and various specialized consultants.

In concluding this report, Japan would like to express its gratitude to the following IEA members for their tremendous cooperation over the last five years; Niels Nielsen, Lori Nielsen, Torodd Jensen, Kjell Erik Stensby, Boualem Hadjerioua, Brennan T. Smith, Alex Beckitt, Emmanuel Branche, Raimo Kaikkonen, Jukka Alm, Jorge Machad Damazio, Kearon Bennett, Lei Xiaomeng, Karin Seelos, Yoshiki Endo and Yoichi Miyanaga. I would also like to thank the METI (Ministry of Economy, Trade and Industry) for their extensive and valuable guidance, the former OA Yoichi Yoshizu working with the Kansai Electric Power Co., all the members of the expert committee in Japan involved in preparing reference materials, and the New Energy Foundation which provided support as the secretariat.

Annex-XI Operating Agent

Takashi Akiyama

Executive Summary

Annex XI on 'Renewal & Upgrading of Hydropower Plants' is one of six ongoing working groups established under IEA Hydro. The primary objective of this report is to provide information and facilitate appropriate decision-making by businesses currently planning to renew or upgrade their hydropower facilities. It is also intended to provide information to government agencies, institutional investors, non-governmental organizations, local residents and a wide range of stakeholders to help them appropriately and objectively assess the sustainability of hydropower and the need for life extension and modernization programs. However, there is a diverse range of renewal and upgrading types and social or natural environments surrounding such projects. The most efficient way of utilizing this report is to read thoroughly about the key points applicable to each type of the projects in Volume I, use the keyword search function to find a case similar to your project in Volume II and read it in close detail.

The Annex initially collected information on renewal & upgrading projects from around the world with an emphasis on trigger causes. Of the case histories submitted, 70 were selected for more detailed examination. Trigger causes considered at the time of data collection were
(A) Degradation due to ageing and recurrence of malfunction,
(B) Environmental deterioration,
(C) Needs for higher performance,
(D) Needs for safety improvement
(E) Needs due to third party factors, and (F) accidents / disasters.

In conducting a detailed selection process, the group focused on the background of each project, and performed close analysis on why these cases were considered to be best practices, and which of their aspects could be applied to other hydropower projects. The outcome was divided into two categories, and further broken down into ten key points to enable the compilation of a systematic report. The following is the description of the key points:

Category 1: Public policies, facilitation measures, etc.
a) Energy policies of countries & states
Analyzing cases in which national or local energy policies played a major role in promoting the renewal & upgrading of hydropower facilities, and providing information about each country's policies that have been effective in promoting renewal & upgrading
b) Investment incentives
Examining cases in which investment incentives contributed to the renewal & upgrading of

hydropower facilities, to analyze, for each country, to what extent these measures were utilized and proved to be effective

c) Integrated management of water resources and river systems

Providing an overview of the integrated approach to the management of water resources and verifying its effectiveness; analyzing cases of flushing mechanisms across the entire river system; analyzing cases of management practices in conjunction with other water usages such as irrigation and water supply

d) Asset management, strategic asset management, life-cycle cost analysis

Gathering, analyzing and describing useful information about cases that incorporate asset management, strategic asset management or life-cycle cost analysis approaches in their assessment methods. This to cover facility operations and maintenance and the scope, scale and timing of renewal & upgrading programs

e) Projects justified by the non-monetary valuation of stabilizing unstable power systems in the up-coming low-carbon society

Gathering information about project cases for stabilizing power systems in low-carbon society and describing new values expected of hydropower operation

f) Environmental conservation and improvement

Examining environmental conservation measures adopted alongside hydropower projects from various perspectives amidst rising environmental awareness; Focusing on rare birds / fish species, sedimentation, turbidity, landscape and cultural assets to summarize the approach to conserving or improving the environment during the renewal & upgrading of existing facilities

Category 2: Modern technologies, systems, material, etc.

a) Technical innovation and deployment expansion of electro-mechanical equipment

Collecting renewal & upgrading cases including those that use CFD for improving plant facilities, and those applying technological innovation to electro-mechanical devices for enhanced efficiency, economy and serviceability

b) System and reliability improvements in protection & control (P&C)

Collecting renewal & upgrading cases involving improvements in reliability or operability of control equipment in relation to IT advancement

c) Technological innovation, deployment expansion and new materials used for civil and building works

Collecting renewal & upgrading cases involving technological innovation concerning dam’s seismic resistance and remodeling, expanded application of rubber weirs and the use of new materials for penstock refurbishment or replacement

d) Integration of other renewable energies into hydropower systems

Collecting cases of hydropower systems that integrate solar, wind and other renewable energies in a way that takes advantage of their strengths, and describing their effects

In order to disseminate the findings of this report to as broad a range of stakeholders around the world as possible, this work will be presented at important national and international conferences and through the Internet to engage in public relations activities. In the process, this report will help to convey how renewal & upgrading projects should be carried out, and highlight the importance of information sharing among hydropower owners and engineers. In addition, it will demonstrate the need for far-reaching cooperation within the water-energy nexus on decisions for renewal & upgrading of hydropower facilities into the future.

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1. Introduction

Many hydropower facilities worldwide have reached or are near the end of their original life, with both growing needs and opportunities for their renewal and upgrading. In most cases, this is economically more attractive, per unit of energy produced, than developing new projects.

Annex XI has gathered case histories from around the world covering good practice in the renewal and upgrading of existing hydropower plants, covering two main categories:

- Public policies, decision indicators, facilitation measures, asset management criteria and life cycle cost evaluation.
- Modern technologies and good practices in terms of systems and materials.

This knowledge will be used to identify and convey effective policies, assistance measures, criteria for decision–making and innovative technologies and approaches to the broad hydropower community.

This report describes the outcome of activities with regard to the expert committee (Annex-XI) 'Renewal & Upgrading of Hydropower Plants' under IEA Hydro. The work is reported under Volume 1 (Summary Report) and Volume 2 (Case Histories Report).

Volume 1 describes the methodology for implementing the work of the Annex activities, including the outcomes of the case history collection and analysis of the findings for each of the key points selected for detailed studies. Appendix 1 provides a more detailed description of the outcome of the case history collection. Appendix 2 provides a detailed analysis of the findings.

Volume 2 contains original data from the 70 case histories selected for detailed studies.

2. Methodology

An outline of the methodology adopted for the collection of Case Histories is described below:

2.1 Trigger Causes and Key Points of Renewal and Upgrading of Hydropower Plants

There are many drivers for the renewal and upgrade of a hydropower plant. One of the most important aspects of this work is to understand these drivers and how they can vary between owners, countries and jurisdictions.
In this Annex, case histories covering renewals and upgrades of hydropower plants were collected from a very wide perspective. For this, six trigger causes were selected (A to F below) and ten 10 key points were established for a systematic analysis. (Table 1)

A. Degradation due to ageing and recurrence of malfunction
B. Environmental deterioration
C. Needs for higher performance
D. Needs for safety improvement
E. Needs due to third party factors
F. Accidents/Disasters

Table -1 Trigger Causes of Renewal and Upgrading of Hydropower Plant

Trigger Causes	Expected Performance	Executed Items for Renewal or Upgrade
(A) Degradation due to ageing and recurrence of malfunction	(a) Improvement of efficiency	Increasing power or watt hour (changing the number of water wheels and generators)
	(b) Improvement of durability and safety	Improving endurance (using stainless steel, ceramic coating), improving aseismicity (dams, gates, water channels (bridges), penstock, power house), and improving safety (imposing more rigorous technical standards, replacing spillways)
	(c) Cost reduction	New materials (FRP, resin metal), re-use of existing products (water turbine, penstock, bridges), standardization, size reduction and simplification (head tanks, spillways, energy dissipaters, buildings, cranes), greater concentration (integrated governor-generator control panel), elimination (spillways, gate for draft tube and head tank, overhead cranes), water turbine and generator number reduction
	(d) Easy maintenance with less labor	Maintenance-free (brush-less, governor oil-less, cooling water-less, compressed air-less, gate-less)
(B) Environmental deterioration	(a) Sedimentation reduction	Measures for sedimentation and sediment management (dredging, sand-flushing gate, sand-flushing bypasses, extension of tailrace)
	(b) Improvement of river environment	River environment conservation(ecological flow, fish ladder installation, measures against turbid or cold water, selective water intake facilities, oil-less, oil-free for Kaplan runner boss, electric motor driven actuator)
	(c) Others	Regional environment conservation(landscape architecture, afforestation, stocking for sightseeing purposes, freshwater red tide), native ecosystem (birds of prey, precious species, biotopes, small animal passages, water flowing channels), measures against flooding (gate-less, Inflatable weir, higher embankments)
(C) Needs for higher performance	(a) Efficiency Improvements. Addition power & energy. Loss reduction	Turbine and Generator upgrades. Water channel and tunnel expansion, penstock branching, power generation using ecological flow
	(b) Role change of hydropower generation. Addition of new functions	Frequency adjusting functions (variable speed pump-turbine, variable-speed type conventional water turbine generator), reservoirs with pumping functions (installation of pumps), additional installation of reservoirs, hybrid power generation system
(D) Needs for safety improvement	(a) Meet all safety, regulatory and operational compliance requirements	Dam safety: adequate discharge facilities, improving aseismicity (dams, gates, water channels (bridges), penstock, power house)
(E) Needs due to third party factors	(a) Sustainable operation (sometimes accompanied by power reduction)	Reduction in river flow rate due to an upper-stream dam or climate changes
(F) Accidents/Disasters	(a) Recovery	Water turbine/generators, steel structures, civil engineering structures

<REMARKS> Trigger Causes (B), (C), (D), (E) and (F) are causes not associated with degradation as set in (A)

For the compilation of case histories and analysis of data, each trigger cause can have various characteristics such as those in Category 1:"Exploitation of Public Policies, Facilitation Measures", and those in Category 2: "Application of Modern Technology" . The characteristics under each category are listed as Key Points.

The following categories were used as the basis for selecting case histories:

Category-1: Public Policies, Facilitation Measures.

1-a) Energy Policies of Countries & States:

National or regional (state) energy policies or cases which play important roles in promoting renewal and upgrading of hydropower generation facilities have been analyzed. The relationship between energy policies and renewal & upgrading was found to vary depending on national conditions, such as economies, policies, laws, etc. Thus, information on relevant energy policies should be gathered separately for each country, and analyzed based on the background conditions.

1-b) Investment Incentives (Feed-in-Tariff (FIT), Renewable Portfolio Standard (RPS), Subsidies, Financial Assistance, Tax Deductions, etc.):

This key point targets investment incentives or policies which support renewal and upgrading of hydropower generation facilities. The utilization levels and effectiveness of these policies has been analyzed. Details of investment incentives and the relationship between investment incentives and renewal & upgrading vary among countries. Therefore, when analyzing the case histories, information on the types of incentives and details of the incentive policies, as well as the relationship with energy policies, has been gathered separately for each country.

1-c) Integrated Management of Water Resources and River Systems:

Integrated management of water resources and river systems is a key point as the improved use of the resource is a cost effective component of upgrading hydropower plants to increase output. Examples of different approaches to managing the water resource have been gathered to determine their effect on renewal and upgrade programs or projects. Case histories of renewal & upgrading projects, executed as part

of an integrated water resource management program were collected and the methods adopted and the results achieved were analyzed.
Specific examples for studied were water rights across international borders. Case histories of renewal & upgrading projects on international rivers were collected, in which interest and rights were successfully negotiated and resolved between countries.

1-d) Asset Management, Strategic Asset Management and Life-cycle Cost Analysis:

Case histories were collected and analyzed, in which the concepts of asset management, strategic asset management and life-cycle cost analysis had been incorporated. The case histories covered the following components of asset management, strategic asset management and life-cycle cost analysis:

- Asset Management
  Covers the overall process to assess and manage a power station in a holistic manner. This includes the assessment of condition, performance and risk exposure and the optimum approach for maintenance, upgrading or renewal. It includes the costs and timing of necessary activities based on standardizing workloads and budgets.
- Strategic Asset Management
  Covers the approach to asset management for individual or a portfolio of assets, to meet the overall business objectives for those assets. It is based on a fluid transformation between the individual hydropower station (or asset) strategies and the overall business (or portfolio) strategy. In other words, the overall business strategy starts from an assessment of the health, performance and risk profiles of the individual asset, which is translated into necessary work items (plant level asset plan). This bottom-up approach is then adjusted to meet corporate business drivers, including trading requirements, and forms the overall business plan. Finally, the overall plan outcomes are translated back to the asset level as action items and projects.
- Life-cycle Cost Analysis (LCA)
  There can be problems with concrete and steel structures, in that early deterioration can occur within the expected service life. This can be due to factors such as salt damage or alkali-aggregate reaction, leading to a degradation of performance. Equipment, such as water turbines, requires regular repairs and replacements. LCA is an approach to determine total costs of these structures and equipment over their life-cycle and determine the necessity and the timing of repairs and replacements.

1-e) Projects Justified by the Non-monetary Valuation of Stabilizing Power Systems in the Up-coming Low-carbon Society:

Case histories were gathered on projects to stabilize power systems in the up-coming low-carbon society. With the increasing use of variable (non-firm) power sources such as solar and wind power, measures are required to stabilize network systems. Hydropower is considered a suitable source of balancing power to provide this service and appropriate case histories have been gathered, including projects in the planning phase,

1-f) Environmental Conservation and Improvement:

Case histories were gathered from renewal & upgrading projects that were implemented or included measures to meet environmental conservation and improvement requirements. These included examples where the case histories did not explicitly list environmental conservation/improvement measures as the primary justification.

Category-2: Modern Technologies, Systems, Material, etc.

2-a) Technological Innovation & Expansion of Electro-Mechanical (E/M) Equipment:
This covered renewal & upgrading projects implemented that include technological innovation and expansion of E/M equipment. Equipment manufacturers were encouraged to provide examples.

2-b) System and Reliability Improvements to Protection & Control (P&C):
This covered projects implemented that include system and reliability improvements to P&C. Equipment and system manufacturers and suppliers were encouraged to provide examples.

2-c) Technological Innovation, Deployment Expansion and New Materials used for Civil and Building Works:
This covered projects that include technological innovation, deployment expansion and new material used for civil and building works. Material manufacturers and contractors were encouraged to provide examples.

2-d) Integration of Other Renewable Energies into Hydropower Systems:
This covered projects that enabled the effective integration of variable renewables into hydropower systems. Where the case histories do not list integration as the primary justification, this information was included in the compilation of results.

The six Key Points in Category-1 : Public Policies, Facilitation Measures are summarized in Table-2

The four Key Points in Category-2 : Modern Technologies, Systems, and Material are summarized in Table-3

Table-2 Key Points for Category-1: Public Policies, Facilitation Measures, etc.

1-a)	Energy Policies of Countries & States
	- The relationship between the project and the energy policies of the jurisdiction where it is located
1-b)	Investment Incentives (Feed-in-Tariff (FIT), Renewable Portfolio Standard (RPS), Subsidies, Financial assistance, Tax Deductions, etc.
	- Investment incentives which facilitate or relate to the project
1-c)	Integrated Management of Water Resources and River Systems
	-The relationship between the project and "the integrated management of water resources and river systems"
1-d)	Asset Management, Strategic Asset Management and Life-cycle Cost Analysis
	- Asset management, strategic asset management and life-cycle cost analysis which was used in the decision process for the renewal/upgrading project.
1-e)	Projects Justified by the Non-monetary Valuation of Stabilizing Unstable Power Systems in the Up-coming Low-carbon Society
	-The project which has a role as stabilizing unstable power systems caused by solar/wind power generation and other non-firm renewables.
1-f)	Environmental Conservation and Improvement
	-Environmental conservation and improvement executed in renewal/upgrading projects (including cases in which environmental conservation and improvement were achieved as a byproduct of cases in which environmental conservation or improvement was not the primary objectives). -Social demand and restrictions concerning environmental conservation related to this project.

Table-3 Key Points for Category-2: Modern Technologies, Systems, Material, etc.

2-a)	Technological Innovation & Deployment Expansion of Electro-Mechanical (E/M) Equipment
	- A new E/M technology or a new application of conventional E/M equipment which were adopted in the project.
2-b)	System and Reliability Improvements in Protection & Control (P&C)
	- Improvement of systems concerning controlling devices and other facilities including grid systems.
2-c)	Technological Innovation, Deployment Expansion and New Materials used for Civil and Building Works
	- A new technology, material or a new application of conventional art of civil/architecture which were adopted in the project. - Planning/design which make an additional function to the existing facilities. (Enlargement of the headrace tunnel, Additional headrace tunnel etc.)
2-d)	Integration of Other Renewable Energies into Hydropower Systems
	- Integrated use of hydropower generation and other renewable energies such as wind and solar power generation

2.2 Case History Collection

2.2.1 Process for Case History Collection

The collection of Case Histories for this Annex was undertaken in three phases:

Phase1: "Initial collection of Case Histories", in which overview information was collected.

Phase2: "Screening of Case Histories" in which the initial collection of case histories was subject to a detailed survey, with pertinent projects selected for the next phase.

Phase3: "Definition of Case Histories" in which detailed information was sourced and analyzed of the selected case histories.

2.2.2 Format for Individual Case History Reports

Since Case History has multiple facets, it would not be appropriate to define or introduce it in a uniform manner. Nevertheless, from the reader's point of view, a certain uniformity of format is desirable to facilitate understanding, coherence and comparisons. Having this in mind, the working group decided to use the following Formats to collect information in a systematic and rigorous way.

Case History Format:
Firstly, some general information was addressed such as Category and Key Points, Project Name, Name of Country, Implementing Agency/Organization, Implementing Period, Trigger Causes for Renewal and Upgrade, Keywords and Abstract, and followed by next 6 items.

1. Outline of the Project (before Renewal and Upgrading)

2. Description of the Renewal and Upgrading of the Project
   2.1 Trigger Causes and Driver for Renewal and Upgrading
   2.2 Process to Identify and Define Renewal and Upgrade Work Measure
   2.3 Description of Work Undertaken (detail)

3. Feature of the Project
   3.1 Best Practice Components
   3.2 Reasons for Success

4. Points of Application for Future Projects

5. Others (monitoring, ex-post evaluation, etc.)

6. Further Information
   6.1 References
   6.2 Inquiries

2.2.3 Quality Assurance of Case History Reports

A number of methods were adopted to ensure a high level of quality and reliability of the submitted Case History reports. Peer reviews by experts in hydraulic power and interviews with the authors considered the essential items forming the content of the Case History Reports. Materials and comments from third party organizations were published as appropriate.

3. General Description and Analysis of Case Histories

3.1 Results of the Collection of Case Histories (See Appendix 1 for diagrams and tables)

During the activity period that spanned over five years, information was collected on 70 case histories from ten countries (See Volume 2 for data of individual cases), showing the projects to be both diverse and very interesting. This chapter organizes data into items (1) – (6) below, where possible, to best allow the analysis and distribution of trends

3.1.1 Regional distribution

The breakdown of the 70 cases collected from 10 countries is: Japan, 45 cases (64.3%), Norway, 9 cases (12.9%), USA, 7 cases (10.0%), Australia and New Zealand, 2 cases each (2.9%), Finland, France, Switzerland, China and Brazil, 1 case each (1.4%),

3.1.2 Trend based on trigger causes

The data aggregation broken down by trigger cause, showed that A (degradation due to ageing and recurrence of malfunction) was the most common cause with 40 cases (33.9%), followed by C (needs for higher performance) at 36 cases (30.5%) and B (environmental deterioration) at 16 cases (13.6%). F (accidents / disasters) was the lowest at just 5 cases (4.2%) (Figure 2).

Data breakdown by the number of trigger causes showed that 57.1% of all the renewal / upgrading cases had a single trigger cause, although 18 other cases (25.7%) had two trigger causes (Figure 3). As for the combination of two or more trigger causes, the combination of A and C was the most common (18 cases), indicating strong correlation between degradation due to ageing and recurrence of malfunction and needs for higher performance.

3.1.3 Trend based on key points

As for the main key points of collected cases, '1-d) asset management, strategic asset management, life-cycle cost analysis' was the highest at 19 cases (27.1%), followed by '2-a) technical innovation and deployment expansion of electro-mechanical equipment' and '2-c) technological innovation, deployment expansion and new materials used for civil and building works' at 13 cases (18.6%) each (Figure 4).

Data breakdown by sub-key points listed '2-c) technological innovation, deployment expansion and new materials used for civil and building works' as the highest at 23 cases (22.8%), followed by '2-a) technical innovation and deployment expansion of electro-mechanical equipment' at 20 cases (19.8%).

3.1.4 Trend based on age

Data breakdown by age showed that the largest proportion of cases (13 cases / 18.6% each) involved facilities that had in-service dates -1921 – 1930 and 1951 – 1960, followed by 12 cases (17.1%) with in-service dates 1961 – 1970 (Figure 6).
In the breakdown by the length of renewal interval, 19 cases (27.1%) had the interval of 41 – 50 years, which coincides with the standard renewal interval for turbine generators (Figure 7).
Cases with a shorter renewal interval of 0 – 10 years involve the effective use of minimum flow or problems.

3.1.5 Trend based on power plant types and size

The trend based on type and output of power plant showed 24 cases (almost half) was run-of-river (Figure 8). By capacity, 18 cases (25.7%) were under 10MW, followed by 20 cases (28.6%) between 100 MW and 1 GW (Figure 9).

3.1.6 Others

Data on the collected cases was organized as follows for trend analysis:
Data breakdown by renewal-requiring period showed that 12 cases (17.1%) required renewal in three or four years. While integrated hydropower developments undergo renewal & upgrading over the span of more than 10 years, around one to four years is the most typical period requiring renewal & upgrading as a whole (Figure 10).
The breakdown by output increase and power generation increase showed that the largest number of cases reported the increase of less than 20% (Figure11, Figure 12).
Cases reporting the increase of over 100% involved reviewing miscellaneous elements (e.g. volume of water to use) of their power generation operation according to the current flow conditions to boost their output and power generation.

3.2 Analysis by Category & Key Point (See Appendix 2 for more details.)

Numerous elements encountered, such as natural conditions and social environments require renewal & upgrading projects to be considered as unique or ‘tailor-made’, as is the case for new hydropower development projects. These aspects are strongly associated with the approach of the power plant owners and operators. This section presents the outcome of analysis on renewal & upgrading projects, for each of the key points.

3.2.1 Category-1 Public Policies, Facilitation Measures, etc.

1-a) Energy Policies of Countries & States

1-b) Investment Incentives (Feed-in-Tariff (FIT), Renewable Portfolio Standard (RPS), Subsidies, Financial Assistance, Tax Deductions, etc.)

Hydropower development projects as well as renewal and upgrading projects are normally funded as capital investment, with a high initial cost and long payback period. It is also necessary to address risks concerning the natural environment, e.g. topography, geology, hydrology and natural disasters, and resolve a large number of challenges including noise and vibrations during construction work and amicable co-existence with local communities. A natural disaster could extend the payback period covering even just the initial cost. There are examples whereby a national or local government clarified the positioning of hydropower in their respective countries’ energy policy and provided appropriate investment incentives.

This Annex shows that where the following investment incentives were applied to renewal and upgrading projects in Japan and Norway, a certain level of success was achieved.

- Japan used a subsidy program to offer assistance toward initial investments, and a Renewables Portfolio Standard (RPS) system to promote the introduction of renewable energies, which produced a certain level of effectiveness for hydropower renewal and upgrading projects as well. Now, the launch of a feed-in-tariff (FIT) scheme is expected to promote further development.
- Norway worked in collaboration with neighboring Sweden to introduce the Norwegian-Swedish Electricity Certificate Market (Green Certificate Market), obligating the procurement of a specific amounts of electricity from the green market.

This has helped recover the cost of renewable energy developments including hydropower.

1-c) Integrated Management of Water Resources and River Systems

Since river water is considered as a precious domestic resource, it is crucial, in integrated river system developments, to make maximum use of the difference of elevation and flow volume and efficiently install power generation facilities. At the same time, there has been an increasing call for diverse use of river flows in response to the run-off issue associated with dam construction and the change of social and natural environments. This Annex has identified the following successful examples among projects related to these key points:

- The integrated development of a single river system by a single developer enables a more systematic and efficient development, although this might be difficult for rivers that cross national borders.
- From the perspective of run-off management, there are projects that see an entire river as a single run-off system and use the collaborative sand discharging approach, etc. to efficiently manage run-off across the entire river system.
- There are also pioneering projects based on general development planning with balanced multi-purpose applications including water treatment, irrigation, flood prevention and industrial water, in addition to power generation.

1-d) Asset Management, Strategic Asset Management, Life-cycle Cost Analysis

For the economic and effective administration of existing hydropower facilities, it is extremely important to carry out renewal and upgrading projects from the perspective of asset management. This Annex has shown that asset management approaches incorporating a holistic approach can lead to more effective improvements to existing facilities, safety, economics and the overall efficiency of renewal and upgrading projects.

- Making maximum use of existing facilities, after confirming the integrity of such facilities, contributes significantly to reducing costs and shortening the period of a renewal or upgrading project. And therefore it should be considered at the early stage of project planning.

- Power plant operators are required to carry out risk assessment in advance on possible faults and implement safety measures so as to fulfill their social responsibility.
- It is very meaningful to carry out asset management at one or multiple power plants, and reflect the findings to renewal and upgrading projects from the perspective of optimizing costs, work volume, etc. Furthermore, strategic asset management from broad-based business perspectives will serve the added role of providing ancillary services, etc., leading to the developer's growth and streamlined control of assets.
- The current condition, performance and risk profile of power generation assets must be accurately identified before attempting to boost the performance and value of aged existing hydropower facilities. There are good practice examples on the method for selecting hydropower plants that should be given priority in renewal & upgrading work, and the use of assessment manuals that present reinforcement methods based on latest technologies.

1-e) Projects Justified by the Non-monetary Valuation of Stabilizing Unstable Power Systems in the Up-coming Low-carbon Society

Amidst the increase of complexity and diversity in the configuration of power sources, there is a growing importance in stabilizing power systems through voltage and frequency adjustments. This Annex has presented an approach of contributing to the stabilization of power systems through large-scale repair projects for pumped storage power plants and projects that involve a review or adjustment of operation methods.

- At an existing pumped storage hydropower plant, a constant-speed generator was replaced with a variable-speed generator to actively contribute to the stabilization of power systems in the mix of different power generation sources.
- The use of phase-adjusting operation involving a Francis turbine raising the water level is expected to stabilize the system voltage.

1-f) Environmental Conservation and Improvement

Since hydropower plants have a very long service period, it is necessary to implement various measures to accommodate environmental changes and social needs. This Annex shows that renewal and upgrading projects can be effective for environmental conservation and improvement measures, when designed to include measures for rare birds, sedimentation, turbidity, fish, landscape and cultural asset protection.

- For the conservation of rare birds and other elements of the ecosystem, it is necessary to carry out a fact-finding investigation, impact assessment of renewal and upgrading projects, and impact mitigation actions; furthermore, continue to monitor activities even after the completion of the projects to ensure harmony with the environment.
- In order to prevent sedimentation from causing river bed rise and reservoir capacity decrease upstream, river bed drop and recession of coast lines downstream, it is important to carry out appropriate monitoring, and install dredging, sand discharging facility and bypass tunnel to prevent faults / failures at an early stage.
- The installation of a surface water intake facility, counter-turbidity fence and bypass tunnel is effective in averting the adverse effects of turbidity downstream.
- If the installation of structures within the river basin may be preventing fish from traveling upstream or downstream, it is desirable to carry out environmental study / assessment to arrange fish transfer through fish passage, fish screen and hoist.
- Historic facilities that have value as cultural assets and are also loved by local communities should be preserved as much as possible, with considerations to be paid to ensure harmony with surrounding landscape.
- Concrete debris from dismantlement, generated in renewal & upgrading projects, should be subject to industrial waste measures (3R: Reuse, Recycle, Reduce), e.g. being recycled as backfill.

3.2.2 Category-2: Modern Technologies, Systems, Material, etc.

2-a) Technological Innovation & Deployment Expansion of Electro-mechanical (E/M) Equipment

For the renewal of electromechanical equipment, there are various restrictions on matters such as the design flow, head, and the installation site space. However, it is possible to increase the power output and generation by adopting an improved runner and distributor, with hydro passages optimized through Computational Fluid Dynamics (CFD) analysis, and other measures. Furthermore, it is possible to improve economic efficiency and the maintainability of operation by adopting electro-mechanical equipment with innovative technologies. Downstream flow releases preserve the lower river environment and landscape, and increased turbine design flow within the limits of allowable flow and existing structures can be effective to increase maximum output and power generation. The case histories show that upgrades and renewal can provide excellent results.

- Despite the various physical and flow restrictions posed by working in an existing power house, output and power generation can be increased. Methods include; changing the type and numbers of turbine runners, completely replacing the existing water turbines and generators and improved replacement runners, stay vanes, wicket gates and water passages based on CFD analysis.
- Improving maintainability using countermeasures against sediment abrasion such as modifications to the equipment and water passages using CFD analysis. Other measures include the adoption of new materials with improved anti-cavitation features, the application of electric motor driven servomotors and/or oil hydraulic-electric hybrid servomotors, and measures applying oil-less bearings and water-less cooling systems.
- The effective capture of excess energy and improvement of power generation by installing additional power generating facilities in an existing power house, including the turbining of environmental flow releases.
- While minimizing the civil costs by re-using existing concrete embedded structures and associated facilities, increase the maximum output and power generation through the speeding-up or smaller sizing of the turbine-generator unit as well as making turbine efficiency improvements.
- Increasing the maximum output by increasing the plant discharge within the allowable range of water rights. The facilities were expanded in sequence while maintaining operation of adjacent units and defining project civil boundaries with existing intake gates and draft tube outlet stop logs.

2-b) System and Reliability Improvements in Protection & Control (P&C)

With the recent establishment of new IT technologies, digital control systems are becoming widely used in newly installed hydropower plants. It is therefore becoming difficult to procure replacement parts such as the old magnetically-operated relay circuit types for analog control system in existing power plants. With control system replacement, control reliability is enhanced and maintenance eased, through the application of supervisory control and data acquisition (SCADA) systems, including programmable logic controllers (PLCs). In another example, with space being too limited to install a conventional turbine generator unit, two sets of package type turbine generators were arranged in series in the available space. These two units were controlled simultaneously by a specific turbine generator control system to operate both units stably. This control system was applied on the generating unit on the environmental flow discharge outlet to use this untapped hydropower potential. This Annex confirmed that renewal and upgrading existing facilities led to the achievement of excellent results.

- Enhanced reliability and ease of maintenance were achieved by installing an integrated control panel, composed of the governor, the automatic voltage regulator and the turbine-generator control system, with the supervisory control and data acquisition (SCADA) systems including programmable logic controllers (PLCs).
- Improvements were made to the control equipment of a pumped storage power plant, which has two (generation and pumping) operation modes. Maintainability of operation was improved through a collective renewal of auxiliary equipment, including the distribution board, governor, turbine generator control panel and other control systems equipped with automatic control sequencer and digital protection relays.
- Enhanced reliability and optimized control of the entire control system of a pumped storage power plant were achieved by separating and decentralizing the existing control system, in which every control system for turbine generator, substation, dam equipment and auxiliary equipment are now integrated.
- In small spaces where it is difficult to install a conventional water turbine and generator, a multiple water turbine/generators package was arranged in series. These were controlled simultaneously by the specific turbine generator control system to operate both units stably, and allowed previously under-utilized energy from the environmental flow releases to be effectively captured.

2-c) Renewal and Upgrading Technologies for Civil and Building Works

Civil engineering and building facilities at a hydropower plant must have their functionality maintained, new functions added according to conditions, and modifications applied to meet new regulatory requirements. This Annex identified cases of upgrading dams to provide functional improvement, applying seismic upgrades to improve the safety of dam gates/water channel bridges, applying new materials to intake weirs and penstock, and reusing existing facilities for provide reductions in cost

- Upgrading of dams, e.g. adding / reinforcing the sediment sluicing function and improving the flood passage capacity, has improved safety, established a sound water environment and made effective use of water resources.
- Dynamic analysis has been carried out on dam gates and water channel bridges to assess their seismic resistance and implement measures for improved seismic safety in preparedness for a large-scale seismic event.
- Existing aged intake weirs have been replaced with an SR-synthesis shutter weir or flexible membrane shutter weir to improve their discharge capacity and reduce the maintenance workload.
- FRPM pipes and high-density polyethylene pipes have been used for replacement penstocks to reduce costs.
- Excess flow capacity of existing weirs and penstock has been utilized for efficient expansion.
- The effective use of existing facilities and decommissioned plant facilities has reduced costs.

2-d) Integration of Other Renewable Energies into Hydropower Systems

Hydropower is the largest provider of renewable energy and in most cases this energy is both firm and reliable. This attribute provides the capability to enhance both its value and the value of other non-firm or variable forms of renewable energy, such as wind and solar power. Rather than competing with other renewable energies in terms of power generation cost, hydropower is increasing utilized to help provide synergistic effects through the integration of these variable renewable sources. This is to the advantage of all renewable energy sources and helps in the overall proliferation of renewable energy.

- At intake points deep in the mountains where power supplies are unavailable, there are systems that combine solar power on sunny days and wind power at night and also during rough weather in winter, and store generated electricity in batteries to operate gates, etc. required for hydropower operation.

4. Summary and Recommendations

We are entering into a period when there is a growing importance about energy and water resource issues on a global scale, which have direct implications to hydropower. To hasten a low-carbon society, it is necessary to increase the development of renewable energies including hydropower across national borders. With respect to water resource issues, composite development must be explored to make effective use of hydropower as part of the water and sewage systems, e.g. to ensure the safety of drinking water and make appropriate treatment of sewerage.
It should also be noted that large-scale or new hydropower projects could have a major environmental impact despite the fact that hydropower is a renewable form of energy. Given the situation, the renewal and upgrading of existing hydropower facilities are becoming a mainstream due to their relatively minor environmental impact.
Based on these findings, we wish to present the following recommendations to those who are involved in the maintenance and management of hydropower plants or plan to initiate a new hydropower project in the future:
There are two very important points to make about upgrades.

1. It is generally considered that any hydropower plant over about 30 years old has the potential to increase capacity and output by up to 10%. This can be dome very quickly (2 years) and often at a small fraction of the cost of new hydropower.
2. Hydropower provides storage and flexible generation for network stability and integration of variable renewables. The only real alternative is CCGT gas turbines, but that is more expensive, except for pumped storage.

4.1 Approach to renewal and upgrading projects for hydropower facilities

Hydropower power plants have a very long service life. It is desirable both economically and environmentally to keep using them as long as possible while applying appropriate renewal and upgrading work. As times change, environmental awareness and roles expected of hydropower also change. Existing and future conditions must be considered in planning renewal and upgrading projects.
Figure 1 describes the contents of renewal and upgrading projects examined in this Annex, broken down by trigger cause. The horizontal axis shows development stages (periods) and the vertical axis shows measures that have added new values. Different

times called for different measures. We can see, for example, measures that were not required in the initial stage of development, could become a requirement as society matures. Being proactive will help create a pioneering power plant that withstands the test of time.

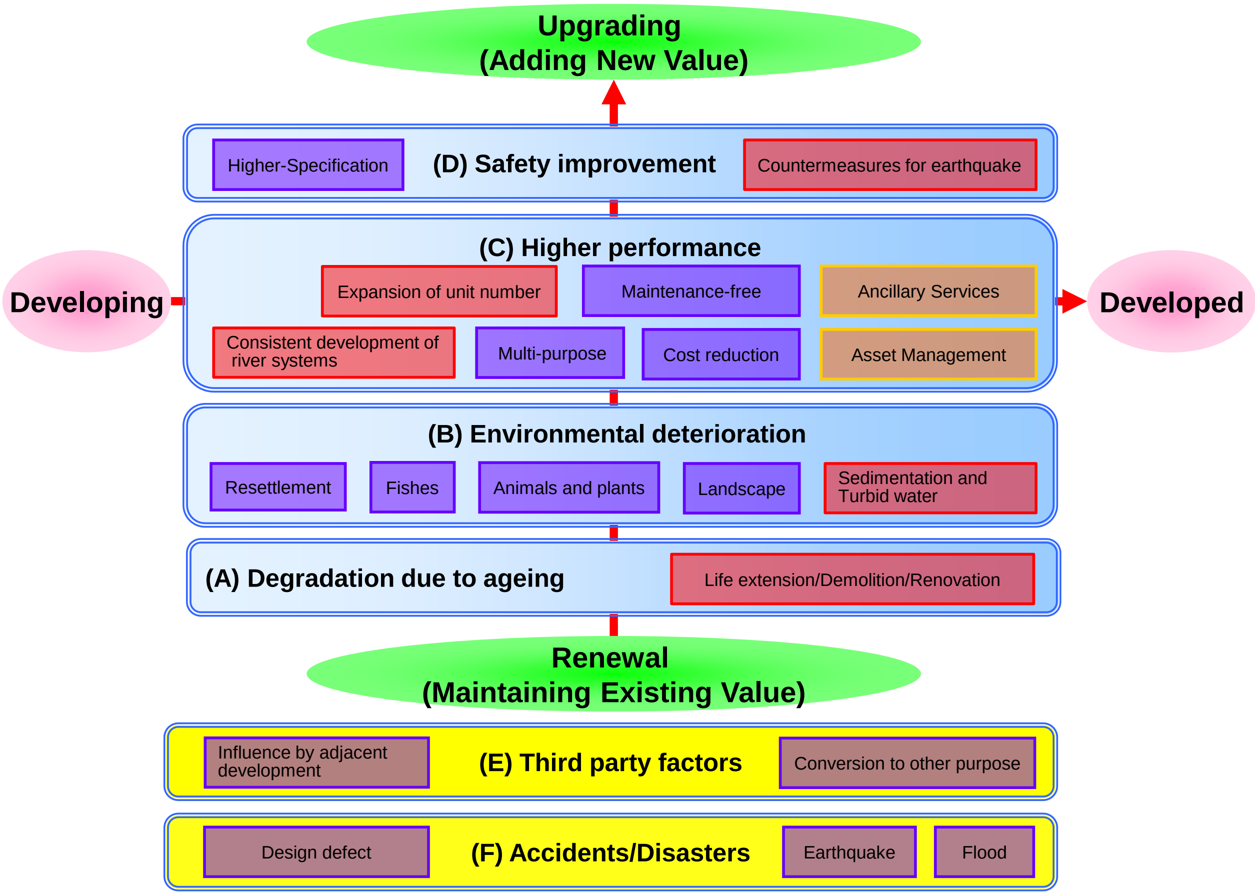


Figure 1 Trigger causes against the background of development stages and Newly-added values

4.2 Information sharing

The development and design of a hydropower plant is often described as experience-based engineering. While each plant is custom-designed, design philosophies of other plants can be a valuable reference. Best practices at other sites should be used for reference as much as possible in applying effective renewal and upgrading approaches to hydropower plants. However, until now, such information has not been systematically organized due to the diversity of renewal and upgrading works. This Annex has examined each project with emphasis on trigger causes and key points to summarize information that represents the key to renewal and upgrading projects. We hope that many developers will utilize the information for reference and that this type of initiative will continue in the future.

4.3 Promoting cross-functional cooperation

The development of hydropower plants involves the IEA Hydro, to which we belong, as well as international hydropower associations (International Commission on Large Dams (ICOLD), International Commission on Irrigation and Drainage (ICID), International Hydropower Association (IHA), etc.) and each of the countries' hydropower organizations. Hydropower operations are also considered to be part of the water cycle, which includes waterworks and sewerage systems. It is therefore important to strengthen cross-functional cooperation, with all parties complementing each other in undertaking hydropower projects.

4.4 Future challenges

Cases collected by this Annex should have the quality of their data enhanced further in terms of regional imbalance and the number of cases involved. Collecting information on faults and failures should also enhance the content of the report. We hope to see continuous and systematic addition and accumulation of cases concerning new renewal and upgrading projects.

Appendix 1

Results of the Collection of Case Histories

（Figure 1 - 12）

Appendix 1

Figure 1 Number of Annex XI Report by Region / Country

Region / Country	No. of Case	%
Japan	45	64.3
Norway	9	12.9
Finland	1	1.4
Australia	2	2.9
New Zealand	2	2.9
United States of America	7	10.0
Brazil	1	1.4
France	1	1.4
Switzerland	1	1.4
China	1	1.4
Total	70	

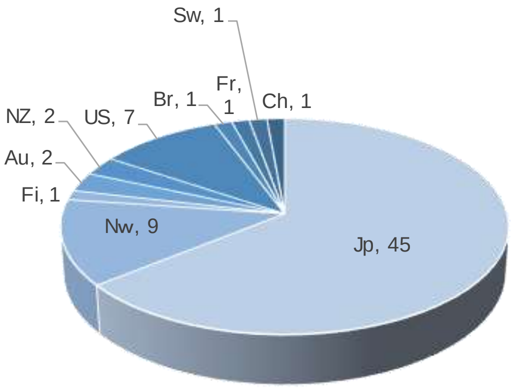


Figure 2 Number of Annex XI Report by Trigger Cause

Trigger Cause	No. of Case	%
A : Ageing, etc.	40	33.6
B : Environmental Deterioration	16	13.4
C : Higher Performance	37	31.1
D : Safety Improvement	12	10.1
E : Third Party Factor	9	7.6
F : Accidents / Disasters	5	4.2
Total	119	

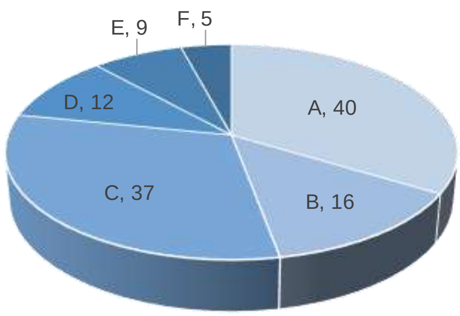


Figure 3 Number of Annex XI Report by Trigger Cause Combination

Trigger Cause Combination	No. of Case	%
1 cause	40	57.1
2 causes	18	25.7
3 causes	7	10.0
4 causes	3	4.3
5 causes	2	2.9
6 causes	0	0.0
Total	70	

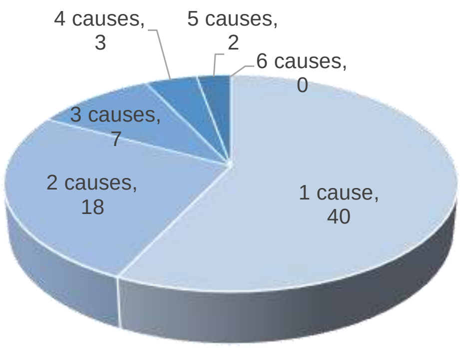


Figure 4 Number of Annex XI Report by Key Point (Main)

Key Point (Main)	No. of Case	%
1-a : Energy Policies	1	1.4
1-b : Investment Insentives, etc.	9	12.9
1-c : Water Resources / River Systems	6	8.6
1-d : Asset Management	19	27.1
1-e : Stabilizing	2	2.9
1-f : Environmental	4	5.7
2-a : E / M Tecnologies	13	18.6
2-b : P /C Tecnologies	2	2.9
2-c : Civil / Building Tecnologies	13	18.6
2-d : Integration	1	1.4
Total	70	

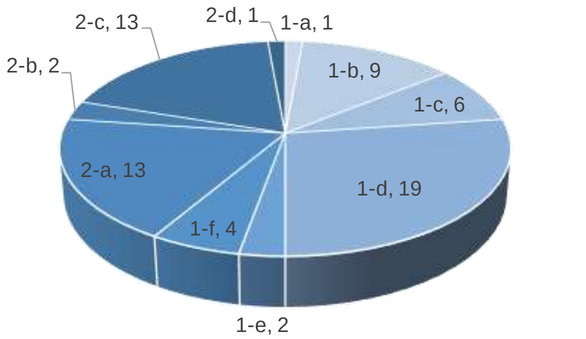


Figure 5 Number of Annex XI Report by Key Point (Sub)

Key Point (Sub)	No. of Case	%
1-a : Energy Policies	11	10.9
1-b : Investment Insentives, etc.	8	7.9
1-c : Water Resources / River Systems	5	5.0
1-d : Asset Management	5	5.0
1-e : Stabilizing	2	2.0
1-f : Environmental	18	17.8
2-a : E / M Tecnologies	20	19.8
2-b : P /C Tecnologies	9	8.9
2-c : Civil / Building Tecnologies	23	22.8
2-d : Integration	0	0.0
Total	101	

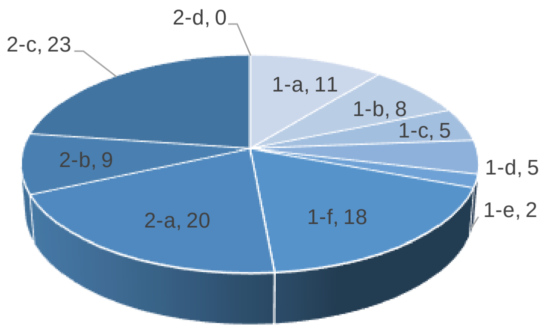


Figure 6 Number of Annex XI Report by Commissioning Year

Commissioning year	No. of Case	%
1900～1910	1	1.4
1911～1920	4	5.7
1921～1930	13	18.6
1931～1940	7	10.0
1941～1950	5	7.1
1951～1960	13	18.6
1961～1970	12	17.1
1971～1980	9	12.9
1981～2014	4	5.7
Not applicable	2	2.9
Total	70	

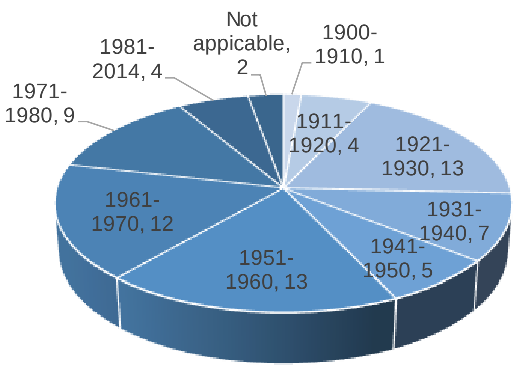


Figure 7 Number of Annex XI Report by Renewed Year after Commissioning

Renewed year after Commissioning	No. of Case	%
0～10 years(*)	2	2.9
11～20 years	4	5.7
21～30 years	0	0.0
31～40 years	11	15.7
41～50 years	19	27.1
51～60 years	7	10.0
61～70 years	7	10.0
71～80 years	9	12.9
81～90 years	6	8.6
90～100 years	3	4.3
Not applicable	2	2.9
Total / Average	70	

(*)Factors by additional equipment

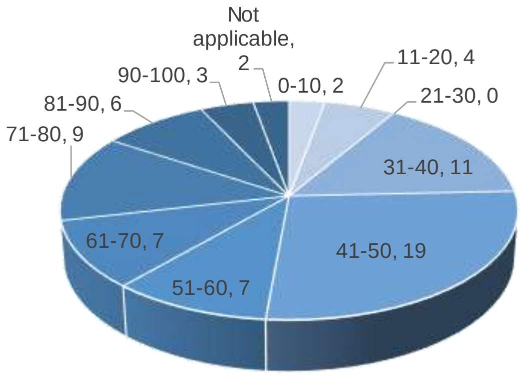


Figure 8 Number of Annex XI Report by Plant type

Plant type	No. of Case	%
Run of River	24	34.3
Pondage	14	20.0
Reservoir	11	15.7
Pumped Storage	6	8.6
Unclear	15	21.4
Total	70	

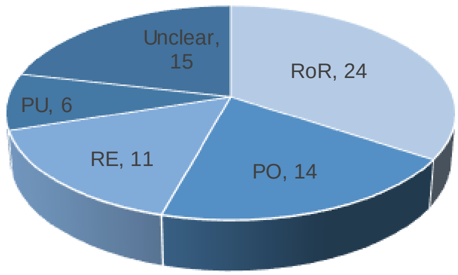


Figure 9 Number of Annex XI Report by Output

Output	No. of Case	%
～10MW	18	25.7
11～30MW	13	18.6
31～50MW	4	5.7
51～100MW	11	15.7
101～1000MW	20	28.6
1001MW～	4	5.7
Total	70	

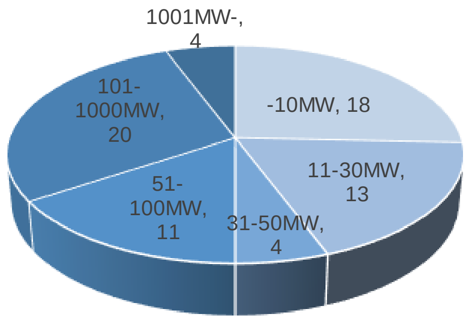


Figure 10 Number of Annex XI Report by Project Term

Project Term	No. of Case	%
1 year less than	10	14.3
2 years	11	15.7
3 years	12	17.1
4 years	12	17.1
5 years	9	12.9
6 years	2	2.9
7 years	3	4.3
8 years	1	1.4
9 years	1	1.4
10 years not less than	5	7.1
Not applicable	4	5.7
Total	70	

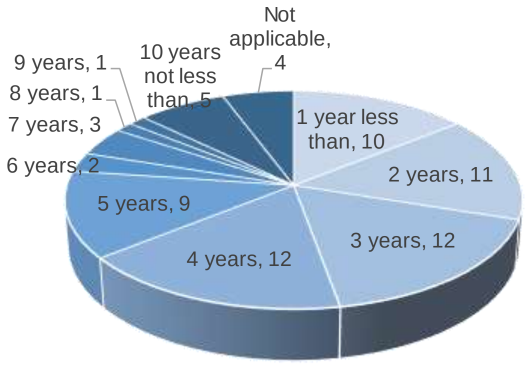


Figure 11 Number of Annex XI Report by Increasing Output

Increasing Output	No. of Case	%
Not alteration	27	38.6
～20%	26	37.1
21～40%	5	7.1
41～60%	1	1.4
61～80%	2	2.9
81～100%	5	7.1
101%～(*)	4	5.7
Total	70	

(*) For change of turbine discharge etc

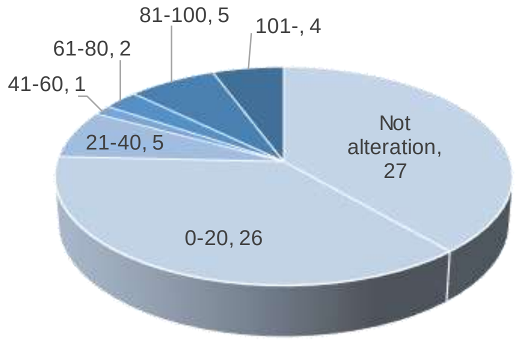
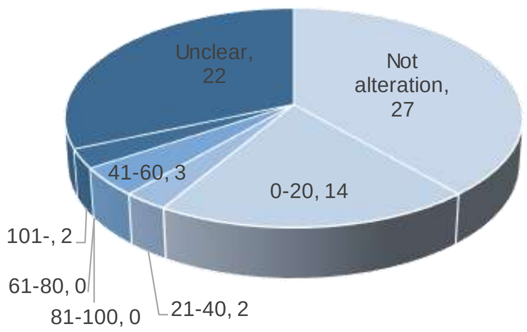


Figure 12 Number of Annex XI Report by Increasing Energy Production

Increasing Energy Production	No. of Case	%
Not alteration	27	38.6
～20%	14	20.0
21～40%	2	2.9
41～60%	3	4.3
61～80%	0	0.0
81～100%	0	0.0
101%～(*)	2	2.9
Unclear	22	31.4
Total	70	

(*) For change of turbine discharge etc



Appendix 2

Analyses by Category &Key Point

（Detailed Report）

Appendix 2

Category-1: Public Policies, Facilitation Measures, etc.

1-a) Energy Policies of Countries & States

Energy is essential for the stabilization and improvement of people's life and for the preservation and development of national economy, and its usage has a significant impact on the regional and global environment. Every country, according to its own conditions, has defined specific energy policies with the aim of establishing sustainable development and a recycling society.

Energy policies are heavily reflected in the individual measures and policies including supportive measures from the government, and have a significant impact on business activities. This report contains, amongst energy policies of each country for which we received the 2nd Round Data Collection and relevant information, mainly the information about renewable energy policies of countries which are actively pursuing its introduction.

Japan

According to the 4th Strategic Energy Plan approved by the cabinet meeting in April 2014, the energy self-sufficiency rate as of 2012 in Japan declined to 6.0%. This is a vulnerable energy supply structure with an extremely low self-sufficiency rate, and the country is facing the following issues related to the energy supply-demand structure:

- Fundamental vulnerability of the energy supply system due to high dependency on overseas energy resources.
- Mid- to long-term changes in the energy demand structure through population decrease and technological innovation, etc.
- Instability of resource prices due to increased energy demand in emerging countries, etc.
- Increasing global greenhouse gas emissions.

Under these circumstances, Japan must pursue an energy policy that makes it possible to produce development achievements targeted at challenges, including the realization of a society achieving thorough energy conservation, acceleration of the introduction of renewable energy, improvement of the power generation efficiency of coal and natural gas thermal power generation, further dissemination of distributed energy systems through the use of storage batteries and other technologies, development of methane hydrate and other unconventional resources, and reduction of the volume and harmfulness associated with radioactive waste. At the same time, the energy policy must enable Japan to meet the people's mandate, while taking on international responsibilities, including contributions to resolving global warming problems.

The Government of Japan (GOJ) has accelerated the introduction of renewable energy as far as possible for three years since 2013, followed by continuous active promotion. The GOJ thereby steadily proceeds with the enhancement of power grids, rationalization of regulation, research and development for cost reduction etc. In considerations for the energy mix, the GOJ pursues higher levels of renewable energy introduction compared to the levels indicated based on former Strategic Energy Plans. As concrete measures, an appropriate management of the Feed-in-Tariff system (FIT) and deregulation measures, such as reducing the period of the environmental assessment, will be promoted. At the same time, in order to resolve problems such as the high power generation cost, unstable power output, and the limited availability of suitable locations, diligent efforts will be made to develop technologies for cost reduction and efficiency improvement, to conduct development and demonstration projects for large storage batteries, and to build power grids.

As hydropower serves as an energy source that excels in terms of stable supply, with the exception of drought-related problems, it will keep fulfilling an important role in the energy supply structure. Regarding ordinary hydropower, including large-scale hydropower, the GOJ promotes effective use of existing dams through cooperation among relevant parties. For example, it will install power generation facilities at existing dams which do not have such facilities and increase output by replacing existing power generation facilities of existing dams. Small and medium-scale hydropower is expected to be used as an energy source that forms the foundation of a regional distributed energy supply-demand structure in light of challenges related to the business environment, such as the high-cost structure. Furthermore, under the revised River Law, it has become simpler and easier to apply for river rights with regard to power generation using agricultural water that has already obtained permission. In the future, proactive steps will be taken to expand the introduction of such power generation.

Norway

The installed capacity in the Norwegian hydropower system is approximately 32 000 MW (32 GW). The total reservoir capacity is 85 TW, which is approximately 65% of mean annual production of some 132 TWh. The majority of electricity generation (approximately 95%) is from hydropower.

The power exchange with Sweden, Denmark, Finland and Russia has been working for many decades. Norway introduced the power market in 1990 and this expanded to include Sweden in 1996, when its name was changed to “Nord Pool”. Further expansion of the Nord Pool included Denmark (1997) and Finland (1998) and created a leading international power exchange market in Europe.

Norway is engaged in positive countermeasures against global warming, and has targets in line with European Union (EU) policy.

With regard to renewable energy, “Directive 2009/28/EC of the European Parliament and of the Council of 23rd April 2009 on the Promotion of the Use of Energy from Renewable Sources” became effective in the EU in June 2009 and was incorporated into the European Economic Area (EEA) agreement in 2011. Along with this, Norway has set the target in the National Renewable Energy Action Plan of June 2012 that by 2020, the percentage of renewable energy in gross final energy consumption is to be increased from the current 62.5% to 67.5%.

The Norwegian-Swedish Electricity Certificate Market, which is a technology neutral market-based support system for renewable electricity production started in January 2012. Under this scheme, which runs until 2035, Norway and Sweden have a combined goal of establishing an additional 26.4 TWh of renewable electricity production during the period 2012 - 2020.

Taxes are also effective and important elements in energy policy. For the time being, energy from hydropower has more tax burdens than energy from wind generation plants.

Important political elements in the framework for hydropower are the Protection Plans for Watercourses, the Master Plan for Water Resources and the EU Water Framework Directive (WFD).

The Water Framework Directive expands the scope of water protection to all water bodies and sets clear objectives that a minimum of “good ecological status” must be achieved for all European water bodies and that water use should be sustainable throughout Europe. For Norway it is important to find a balanced effect regarding environment and hydropower development.

The WFD has a target to ensure sufficient, reliable, environmentally sound and sustainable energy support also in the future. Challenges are the need to reduce climate gas releases and increased variable renewable energy production. In line with changing weather and new technology, consumption patterns will also change. For Norway the developed 132 TWh hydropower, with reservoir capacity of 85 TWh, has increased value in the support of other renewables. With extremely low climate gas releases (down to 2g CO_2/kWh), Norwegian hydropower plays an important role as a substitute for other energy technologies which provide heat and electricity services, but with higher climate gas releases. There is potential for additional hydropower generation capacity of approximately 31 TWh that can compete in the market in price per kWh. A market with higher cost for CO_2 will also influence exploitable Norwegian hydropower potential of about 600 TWh gross productions. Related to Annex XI, a glance at renewal, upgrading and extension of existing hydropower plants is included in the 31 TWh and will be higher with higher market cost for clean renewable electricity”.

The growth of the Norwegian hydropower system is shown in the figure below, by development per decade and distribution of plant size within each decade.

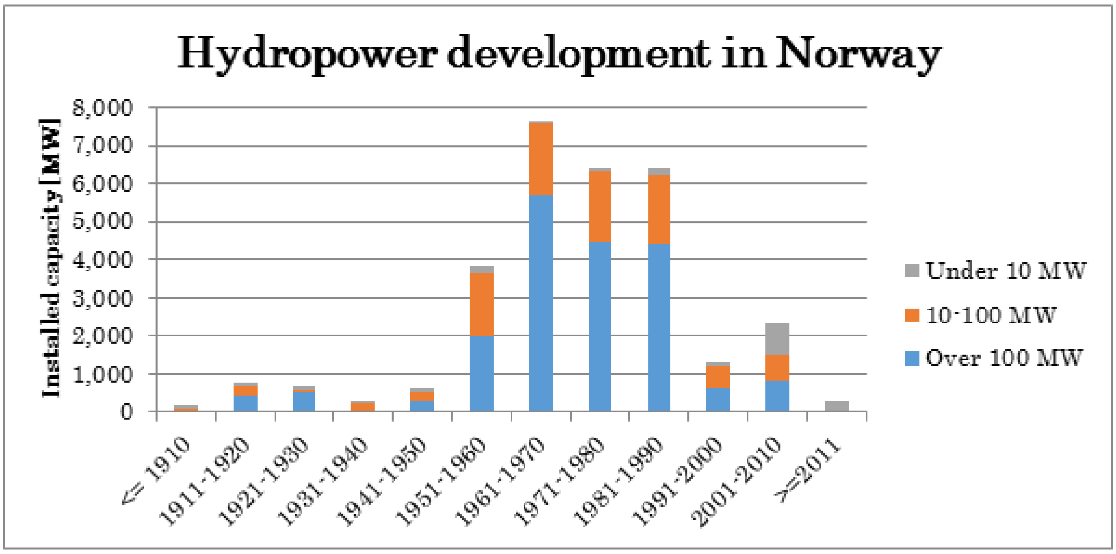


Figure Hydropower development in Norway (2011)

The figure shows that considerable capacity was installed in the four decades between 1950 and 1990. Hence, many power plants have reached an age when renewal, upgrading and also extension are relevant, due to the condition of mechanical and electric equipment, new market requirements, climate change and design philosophy. These trigger economic initiatives for additional production through improvements to and extension of existing schemes. The viable potential for additional production by different efforts is about 6 TWh, but may be increased in line with an increased CO_2 market.

Renewal, upgrading and extension of existing plants normally have significant lower environmental impacts than the development of new power plants in unexploited watercourses. It is therefore an expressed policy for the Government to promote measures for increasing production in existing plants. Additional production from existing plants also qualifies for Certificates in the Norwegian-Swedish Electricity Market, similar to production from other renewables.

Norwegian specific examples in category 1-a) (sub):

❑Nw. 8 : Kongsvinger Hydropower Plant – Unit No.2(Norway):
Kongsvinger Hydropower Plant (output=21MW, plant discharge=250m^3/s)

❑Nw. 9 : Rendalen Hydropower Plant – Unit No.2(Norway):
Rendalen Hydropower Plant (output=92MW, plant discharge=55m^3/s)

However, in principle, all Norwegian cases are to some degree related to category 1-a). All hydropower projects have their origin in energy policy, even though the other categories in Annex XI may be a stronger driver.

USA

Until recently, the USA was the world's largest country in terms of production, consumption and import of energy, but with the development of shale gas, which is an unconventional type of natural gas, and shale oil, the country is expected to achieve energy self-sufficiency by 2035. At the same time, the USA set an energy strategy to swiftly reduce reliance on oil from overseas countries by using all sorts of its available domestic energy sources and increasing the country's self-sufficiency rate. The USA defines not only green energies such as hydropower, wind power, and solar power, but also nuclear energy and natural gas as clean energy, and promotes increasing investment and usage of these areas. By these policies and measures, the USA aims to stabilize energy supply, improve energy security, and promote job development.

According to the Annual Energy Outlook 2013 (AEO2013) compiled by the USA EIA, coal-fired power plants continue to be the largest source of electricity generation, but its market share will decline from 42% in 2011 to 35% in 2040. Generation from natural gas will increase from 24% in 2011 to 30% in 2040, and generation from renewable sources will grow with their market share to rise from 13% in 2011 to 16% in 2040. The non-hydropower share within total renewable energy generation (e.g. wind power or solar power) will increase from 38% in 2011 to 65% in 2040.

Although policies and measures for renewable energy promotion vary by state, the introduction of renewable electricity facilities is increasing generally as a result of a preferential tax system, the Renewable Portfolio Standard (RPS) system, and market development. Under such conditions, electricity storage technologies are attracting attention as a method to stabilize the power supply system that accompanies the mass introduction of renewable energy.

Australia

Energy policy in Australia

- Australia has significant reserves of energy including fossil fuels (primarily coal and gas), renewables and nuclear; this abundance underpins Australia's position as a major exporter of energy resources.
- Australia's energy sector is undergoing a significant transformation including changing demand patterns, integration of new technologies, increased vertical integration, tightening gas supply and changes to international markets.
- Against this backdrop, Australia's energy policy framework is being reviewed through an Energy White Paper process. This process will address key issues such as energy prices, reliability, long term security, gas market development and energy productivity.

The Australian electricity market

- Australia's National Electricity Market (NEM) is a wholesale market for the supply of electricity to retailers and end-users in the Australian states of Queensland, New South Wales, the Australian Capital Territory, Victoria, South Australia, and Tasmania.
- The NEM operates on the world's longest interconnected power system – from Port Douglas in Queensland to Port Lincoln in South Australia – a distance of around 5,000 kilometres
- More than $10 billion of electricity is traded annually in the NEM to meet the demand of more than eight million end-use consumers. Total generation in Australia, from all sources, totalled approx. 220,000 GWh in 2012.

Renewable energy in Australia

- Renewable energy supplies approximately 13% of electricity generated in Australia (coal is the largest source for electricity generation in Australia).
- Of Australia's renewable energy generation, hydropower continues to contribute the largest share (58 per cent) but wind power (26 per cent) and solar power (8 per cent) are making significant inroads
- In 2012 $4.2 billion was invested in new renewable energy projects and energy smart technologies (predominantly solar and wind)

Renewable energy policies in Australia

A number of government policies have been applied at both the state and federal levels to enhance the development and deployment of renewable energy in Australia.

Renewable energy target

- A key renewable energy policy in Australia is the national Renewable Energy Target (RET), which requires that 20% of Australia's electricity generation is sourced from renewable sources by 2020. The RET has been highly successful in developing Australia's renewable resources and is the primary support mechanism for the Australian renewable energy industry.
- The RET scheme creates a financial incentive for investment in additional generation of electricity from renewable energy sources through the creation and sale of renewable energy certificates. These certificates are generated by eligible renewable energy sources based on the amount of electricity they produce; retailers then have an obligation to purchase and surrender a certain amount of these certificates each year.
- The RET scheme is split into two parts: The Large-scale Renewable Energy Target (LRET) and the Small-scale Renewable Energy Scheme (SRES).
- The SRES scheme provides an incentive for small scale generation; mainly the residential installation of solar water heaters, heat pumps and small-scale solar panels.

- The Large-scale Renewable Energy Target (LRET) requires 41,000 GWh of new renewable generation by 2020. The LRET provides incentives for the development of large scale market ready technologies such as wind, solar and hydropower.
- The RET provides incentives for additional generation from new renewable stations as well as existing renewable energy power stations. For hydropower, the RET has provided a financial incentive for the hydropower industry in Australia to maintain, upgrade and modernise Australia's existing hydropower resources. The RET provides the incentive to ensure that modernisation and efficiency options, which might not otherwise occur, can be under taken. The RET thereby ensures the ongoing and enhanced contribution of Australia's hydropower resources.

Carbon pricing and emission reductions

The Australian government has made a commitment to reduce Australia's GHG emissions by 5% by 2020 (based on 2010 levels). Under current law, Australia has a carbon pricing mechanism where liable entities are required to pay a price for their carbon pollution. Following a change in government in late 2013, the Australian government will remove the carbon price and implement its 'Direct Action Plan' to meet Australia's 5% emissions reduction target.

Federal government energy policies

In addition to the RET, the federal government also provides incentives for renewable energy through other means including those programmes administered by the Australian Renewable Energy Agency such as the Emerging Renewables Program and Regional Australia's Renewables.

State government energy policies

Feed-in tariffs exist in a number of Australian states and territories for small-scale renewables. These schemes have helped support the strong growth in residential solar installations. Many of the states also provide incentives for energy efficiency.

Finland

Finland has developed a lot of massive energy consumption industries and is in cold climates, as a result, lots of energy is consumed. While there are only a few domestically produced energies, they therefore rely on importing energy sources from foreign countries. Thus, Finland has set securing of stable energy supplies as the main target in their energy policies.

Taking into account the trend that global warming attracts serious attention, climate change issues are added to the discussions of the energy policies and measures. Based upon discussions in the European Commission (EC), as a goal toward 2020, Finland has announced a target to increase the share of renewable electricity in total final energy consumption up to 38% in 2008, along with measures for improving energy efficiency (the Long-term Climate and Energy Strategy, 2008 revision). By 2013 revision, the long term approach toward 2050 for reducing greenhouse gas emissions by 80% from the level of 1990 has been presented.

As for hydropower generation, though about 180 thousand lakes exist in Finland; and they constitute huge water resources, the majority of national territory is rolling terrain, keeping the share of hydropower about 19 % of electricity production in Finland. It is likely difficult to increase hydropower generation, so it is expected to increase wind power and biomass generation for the future.

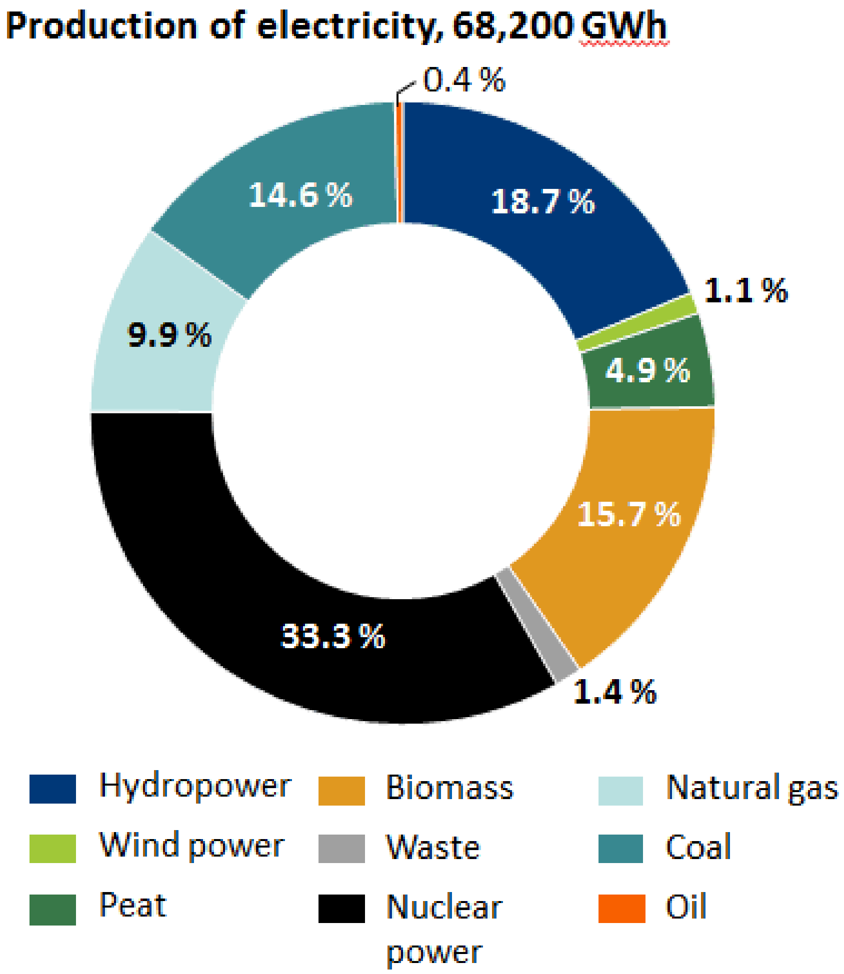


Figure Production of electricity in Finland (2013)

France

Taking the first oil crisis as an opportunity to reduce reliance on oil imports, France has put in place energy policies and measures focusing on three views: the development of domestic sources, the promotion of energy savings, and the diversification of energy supplies. Focusing their consistent efforts particularly on the development of nuclear energy as a domestic source, France has greatly improved self-sufficiency in energy supply commensurately to its use of nuclear energy.

The current administration aims to increase renewable energy, promote energy savings, and reduce the share of nuclear power in electricity production from the present 75% to 50% by 2025. Thus the trend of legislation concerning energy transformation regulations has been attracting a lot of attention.

With regard to renewable energy, after the Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the Promotion of the Use of Energy from Renewable Sources became effective, France has instituted the "First Grenelle Act" in which the share of energy generated from renewable sources will be increased up to 23% of the total final energy consumption by 2020. Through the FIT and the electricity bidding (Appel d'offres) systems, France aims to achieve the electricity generating targets by power sources. These targets are planned in the Programmation Pluriannuelle des Investissements (PPI plan), which has been drawn up by the government.

As for hydropower, although economically and environmentally appropriate projects are becoming scarce, France plans to increase the annual average electricity generation by 3 TWh and the installed capacity by 3 GW by the end of 2020. The value for the former was 61.8 TWh and the latter at 26.20 GW as of 2009.

Brazil

Brazil is a major economic power in Latin America, and is expected to develop even further. The country domestically produces petroleum oil, natural gas, and ethanol, and is the largest consumer of energy in the region.

Hydropower generation facilities in Brazil have the second largest capacity in the world, and the share of hydropower among total electricity generation was 90% in 2005. However, the country's electricity mix consisting mainly of hydropower tends to be influenced by weather, such as drought, and this is a significant issue for future electricity supply diversifications and power grid developments. In order to meet the increasing electricity demand that accompanies economic growth, Brazil put in place policies to develop large-scale hydropower as its main power source while giving due considerations to the ecosystem and indigenous people's rights. The policy also pursues renewable energy sourced electricity generation other than hydropower, in conjunction with nuclear and gas-fire based power from new gas-field developments.

In 2002, the Brazilian government set the Renewable Energy Promotion Program and plans to increase the share of renewable energy up to 5%. Since Brazil has a large land area and strong agricultural productions, alcohol fuel (ethanol), bagasse (sugarcane waste), and solar generation have significant development potential as electricity sources in addition to small-scale hydropower and wind power generation.

Since the CDM has been developed based on the scheme that Brazil had proposed, Brazil was early in preparing a system for the CDM. Brazil's cumulative number of registered CDM is the third largest in the world. They are composed mainly of: projects for cogeneration plants using bagasse and waste treatment in farms, small-scale hydropower, an energy efficiency project, and a methane recovery project from livestock and refuse landfills.

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Note: EU "Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the Promotion of the Use of Energy from Renewable Sources".

This directive took effect in June 2009 as a component of the new EU policies package regarding climate change and energy. This directive mandated a commitment for EU Member Countries to set national indicative targets for energy efficiency, greenhouse gas emissions and renewable energy, and to draft and submit to European Commission National Renewable Action Plans in consideration of the EU strategic targets such as, by 2020, achieve a 20% increase of energy efficiency, to reduce GHG emissions by 20% from the level of 1990, and to increase the renewable electricity in the final energy consumption from the current 8.5% up to 20%. The progress will be monitored as for whether the targets are achieved or not, but there are no punitive clauses to address failure to achieve the targets.

1-b) Investment Incentives (Feed-in-Tariff (FIT), Renewable Portfolio Standard (RPS), Subsidies, Financial Assistance, Tax Deductions, etc.)

In consideration of the specific energy statuses and policies of each country, investment incentives are determined individually in each country or economic block so as to secure the necessary renewable energy amount. Typical investment incentives are Feed-in-Tariff (FIT), the RPS system, financial support, and tax credit. The following are the outline of the investment incentives for renewable energy promotion, in the countries for which we received the 2nd Round Data Collection and relevant information, and show how these incentives have contributed to achieving their goals.

Japan

In Japan, most of the hydropower projects that are economically feasible have already been developed, so it is essential to provide investment incentives for further development of the projects. The following state measures have been implemented so far in terms of four categories: “Fostering of Developers,” “Reduction of Initial Electricity Generating Costs,” “Promotion of Establishment of the Facilities” and “Improvement of Conditions for Promotion of Hydropower Development,” and they are indicated after the table below:

Table State Measures for Renewable Energy Promotion

Measures	1971-1980 / 1981-1990 / 1991-2000 / 2001-2010 / 2011-
Training of developers	Subsidy for small to medium scale hydropower development promotion project（1986-2008）
Reduction of initial cost of power generation	Subsidy program for small to medium scale hydropower development cost（1980-2008）
	Aid and support program for suppliers of new energy（2007-2009）
	Subsidy for promoting the introduction of local new energy（2007-2009）
	Subsidy for small-scale hydropower and geothermal development（2007-）
	Promotion program for the acceleration of new energy introduction（2011-）
	Promotion program for the introduction of renewable energy and energy saving for waterworks system（2013-）
	Promotion program for the citizen participation type introduction of renewable energy in Fukishima Pref.（2013-）
Policy to promote establishment of power source locations	Subsidy on policies to promote establishment of power source locations（1974-）
Ordering the condition for promotion of hydropower development	Renewable portfolio standard(RPS)（2003-2011）
	Feed-in Tariff(FIT)（2011-）

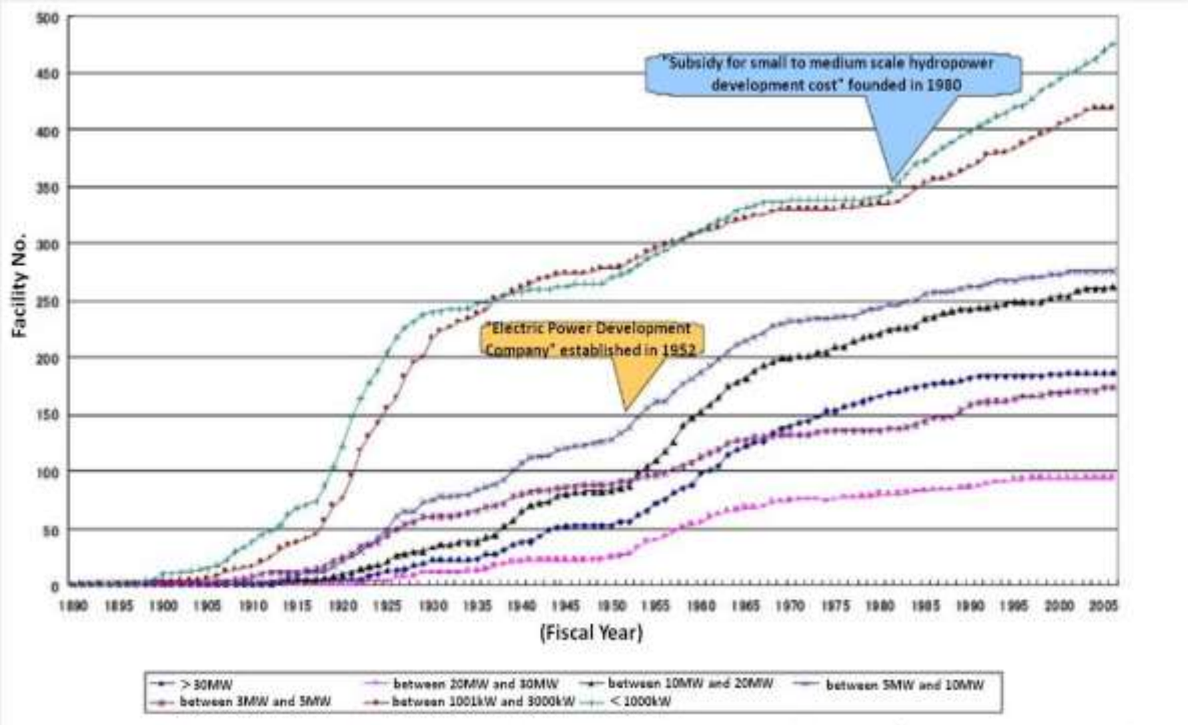
1) Subsidy Program for Small to Medium Scale Hydropower Development Cost

The biggest factors hindering hydropower development include poor economies of scale due to downsizing future developments, high construction costs resulting from sites being located in mountains inland, and higher initial electricity generating costs compared to other energy sources. Therefore, the Subsidies Program for Small to Medium Scale Hydropower Development Cost was established to compensate the difference of costs compared to mono-fuel oil power and to support the development of new small to medium scale hydropower plants.

Table Overview of the Subsidy Program

Title	Subsidy program for small to medium scale hydropower development	
Project Output	Between 1MW to 5MW or less	Between 5MW and 30MW, both inclusive
Subsidy Rate	Within 20%	Within 10%
	For businesses with noticeably low economic efficiency, a rate with an additional 10% is applicable.	

The following chart shows the trend in the number of small- and medium-scale hydropower facilities developed by year. From this chart it becomes clear that there are some advantageous effects after this program was started (1980), demonstrated by the accelerated development of small- and medium-scale hydropower.



(Source : Ministry of Economy, Trade and Industry/Resources and Energy Agency)

Figure Number of Small- and Medium-Scale Hydropower Facilities Developed

Specific Examples:

❑Jp.2 : Construction (renewal) works of Kikka Power Station (Japan) :
Subsidy system for small-scale hydropower development

❑Jp.7 : The upgrading project of Shin-Kuronagi No.2 Power Station (Japan) :
Subsidy system for small-scale hydropower development

❑Jp.23 : Construction Project of Kawabaru Ecological Discharge Power Station (Japan) :
Aid and support program for suppliers of new energy

❑Jp.41 : The Redevelopment construction project of the Hanakawa Power Station (Japan) :
Aid and support program for suppliers of new energy

2) Renewables Portfolio Standard Law (RPS Law)

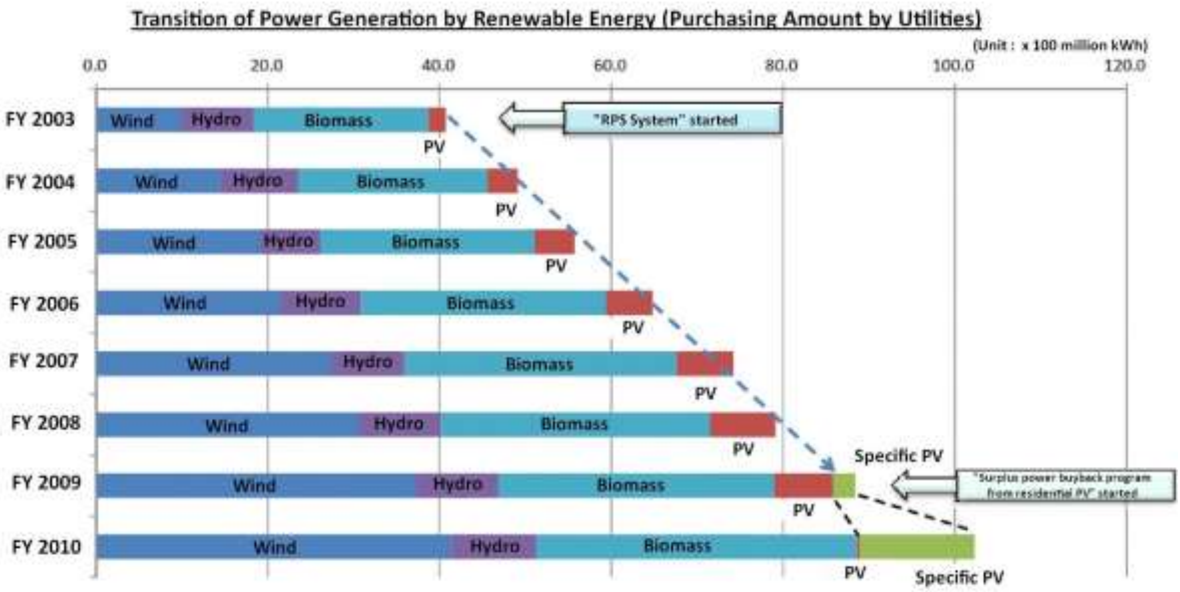
In 2003, the RPS Law went into effect so as to promote use of renewable energy by electric power suppliers. This law mandated an obligation to use renewable energy greater than a certain level depending on the amount of electricity sold.

Figure obligatory usage amount

FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	**FY 2010**	(Unit)
7.32	7.66	8.00	8.34	8.67	9.27	10.33	12.20	(billion kWh /Year)

The renewable energy in the RPS system is defined as follows: i) wind power, ii) solar, iii) geothermal, iv) hydropower (limited to the forms prescribed by the legislative decree), and v) biomass (organic matters that originate from animals and plants and are applicable as energy sources).

From the following electricity generation by year, it is obvious that this system has achieved firm and good results, although outcomes vary on the set obligatory usage amount. Incidentally, along with the introduction of the FIT system (see the following clause (3)), this system was abandoned.



(Source: Ministry of Economy, Trade and Industry / Resources and Energy Agency)

*These data illustrate the amount of power supplied from RPS law-certified facilities. The data does not include the following: electricity prior to enforcement of the RPS law, electricity generated from facilities uncertified by the RPS law, and electricity generated from RPS law-certified facilities and were self-consumed.

*Solar power generation facilities subjected to the excessive power purchase scheme from November 2009 have been calculated as specific PVs.

Figure Transition of Electricity Generation by Renewable Energy

Specific Examples:

❏Jp.01 : Houri No.2 Hydropower Project (Japan) :

RPS and New energy introduction project in Bureau of Enterprise

3) Act on Purchase of Renewable Energy Sourced Electricity by Electric Utilities (FIT)

The utilization of renewable energy greatly contributes not only to securing a stable and adequate energy supply according to the socioeconomic environment at home and abroad, but also to the reduction of the environmental burden associated with energy supplies. In July 2012, FIT went into effect with the aim of promoting the use of renewable energy sources, and to strengthen the international competitive power of Japan and to develop industries, as well as to contribute to keeping the community alive and to develop a sound national economy.

FIT demands that electricity suppliers purchase renewable electricity at a fixed price, and these prices and their procurement lead periods are as follows:

Table Fixed Price and Procurement Lead Periods of Small- and Medium-scale Hydropower (as of 2014.3)

Small and medium scale Hydropower (New Construction)	1,000kW≦ 30,000kW	200kW≦ 1,000kW	＜200kW
Fixed price (yen/kWh)	24yen + Tax	29yen + Tax	34yen + Tax
Procurement lead periods	20years	20years	20years

Small and medium scale Hydropower (Utilization of existing headrace tunnel)	1,000kW≦ 30,000kW	200kW≦ 1,000kW	＜200kW
Fixed price (yen/kWh)	14yen + Tax	21yen + Tax	25yen + Tax
Procurement lead periods	20years	20years	20years

(Source: Ministry of Economy, Trade and Industry / Resources and Energy Agency)

The criteria for small- and medium-scale hydropower is an output less than 30 MW, and not being a pumped storage hydropower. The introduction progress of hydropower facilities before and after the launch of this system is as shown in the following chart.

Table Introduced Amount of Renewable Energy (as of, 2014.3)

<table>
<tr><th colspan="4">Introduced Amount of Renewable Energy (Operation already commenced)</th><th>Certificated Amount</th></tr>
<tr><td rowspan="2">Type of renewable energy</td><td>Before FIT system started</td><td colspan="2">After FIT system started</td><td>After FIT system started</td></tr>
<tr><td>Introduced amount
(by the end of June,2012)</td><td>Introduced amount
(from July,2012
to March,2013)</td><td>Introduced amount
(from April ,2013
to March,2014)</td><td>(from July, 2012
to March, 2014)</td></tr>
<tr><td>PV(residential)</td><td>Approx. 4,700MW</td><td>969MW</td><td>1,307MW</td><td>2,688MW</td></tr>
<tr><td>PV(non-residential)</td><td>Approx. 900MW</td><td>704MW</td><td>5,735MW</td><td>63,038MW</td></tr>
<tr><td>Wind</td><td>Approx. 2,600MW</td><td>63MW</td><td>47MW</td><td>1,040MW</td></tr>
<tr><td>Small and medium scale Hydropower</td><td>Approx. 9,600MW</td><td>2MW</td><td>4MW</td><td>298MW</td></tr>
<tr><td>Biomass</td><td>Approx. 2,300MW</td><td>30MW</td><td>92MW</td><td>1,565MW</td></tr>
<tr><td>Geothermal</td><td>Approx. 500MW</td><td>1MW</td><td>0MW</td><td>14MW</td></tr>
<tr><td rowspan="2">Total</td><td rowspan="2">Approx. 20,600MW</td><td>1,769MW</td><td>7,185MW</td><td rowspan="2">68,642MW</td></tr>
<tr><td colspan="2">8,954MW</td></tr>
</table>

(Source: Ministry of Economy, Trade and Industry / Resources and Energy Agency)

The currently undeveloped sites for hydropower are at the heart of mountains and suitable only for small plants, and the method to decide the purchase price (procurement price) from past development results is not likely to serve as an effective support measure. Thus, related parties demand to review the purchase price.

Norway

In June 2001, the public enterprise Enova was established under the control of the Ministry of Petroleum and Energy with the aim of achieving the goals of the energy policies. These were to promote energy saving and usage of renewable energy and the usage of natural gas which has a small environmental load. Funding necessary for Enova's activities is provided by the Energy Fund, financed through a levy on the electricity grid tariff, and through allocations from the Government's budget. With these funds, Enova has granted support for wind energy farms, renewable heat production and energy saving projects, as well as provided information on energy conservation.

The Norwegian-Swedish Electricity Certificate Market, which is a technology neutral market-based support system for renewable electricity production, started in January 2012. Under this scheme, which runs until 2035, Norway and Sweden have a combined goal of establishing 26.4 TWh of new renewable electricity production by 2020. Both countries have targets within the EU under the EU Renewable Directive. New energy generation capacity under the Electricity Certificate Market will help to achieve the EU targets. With the introduction of the Electricity Certificate Market, the Market became the principal renewable energy support mechanism for renewable electricity generation capacity. Enova shifted its focus to support Research and Development and pilot schemes to verify new technologies.

With the Electricity Certificate Market in place, an electricity producer who has certificated renewable electricity facilities receives the electricity certificates of one unit per MWh of electricity generation from the government. The producers can sell the certificates to electricity suppliers who have the obligation by law to buy electricity certificates corresponding to a certain proportion (quota) of their electricity sales or usage. The purchasers include retail suppliers and commercial-scale customers, with the exception of some energy-intensive industries. The electricity certificates that electricity suppliers are obligated to buy annually are cancelled on 1st of April. Electricity certificates are then deleted and cannot be reused. This means that suppliers with quota obligations must buy new electricity certificates in order to fulfil their next year's quota obligation. This creates a constant demand for electricity certificates.

The electricity end-users pay for the development of renewable production because the cost of electricity certificates is included in the electricity bills.

If electricity suppliers fail to buy the required number of certificates, a penalty of 150% of average certificate value for a given period of time must be paid for each missing certificate. Electricity certificates are mainly traded through brokers. There are two types of broker contracts in the electricity certificate market, spot price contracts and forward contracts. Forward contracts with delivery in March are available for the next five years.

The term for which electricity certificates can be received is 15 years. Plants put in operation after 2020 will not be granted the right to receive certificates. The Electricity Certificate Market will therefore expire in 2035 according to the present Act and valid regulation. Plants where operation started before the 1st of January 2012 are granted 15 years minus the approved time in operation before 2012. This is valid for all plants where construction started after 7th of September 2009 and for small hydro with capacity less than 1 MW where construction started after 1th of January 2004. All new renewable energy (including small-scale hydropower) is covered by the abovementioned Electricity Certificate System.

The average value for the electricity certificates in 2014 at the common Electricity Certificate Market was 19.6 EUR/MWh.

According to the Strategy for Small-scale Hydropower presented by the Ministry of Petroleum and Energy in 2003, hydropower plants less than 5 MW are exempt from the Natural Resource and Ground Rent Taxes.

The following Norwegian projects in Annex XI have been, or will be, approved for the Electricity Certificates:

- ❑Nw. 1 : Upgrading and Rebuilding of Embretsfoss Hydropower Plant (Norway)
  Embretsfoss No.4 Hydropower Plant (output=52.5MW, plant discharge =340m^3/s)
- ❑Nw. 3 : Planning for Upgrading and Extension of Hemsil No.2 Hydropower plant (Norway)
  Hemsil No.3 Hydropower Plant (output=83MW, plant discharge =25m^3/s)
- ❑Nw. 6 : Iveland No.2 Hydropower Plant (Norway)
  Iveland No.2 Hydropower Plant (output=45MW, plant discharge =110m^3/s)
- ❑Nw. 7 : Upgrading of Rånåsfoss Hydropower Plant (Norway)
  Rånåsfoss No.3 Hydropower Plant (output=81MW, annual power production=280GWh)

USA

Policies and incentives for the promotion of renewable energy in the US are generally divided into three types, i.e, tax credits, setting goals and standards, and market formation. With these policies and incentives, the rate of renewable energy introduction is expected to maintain its increasing trend. The following are explanations for these policies and incentives.

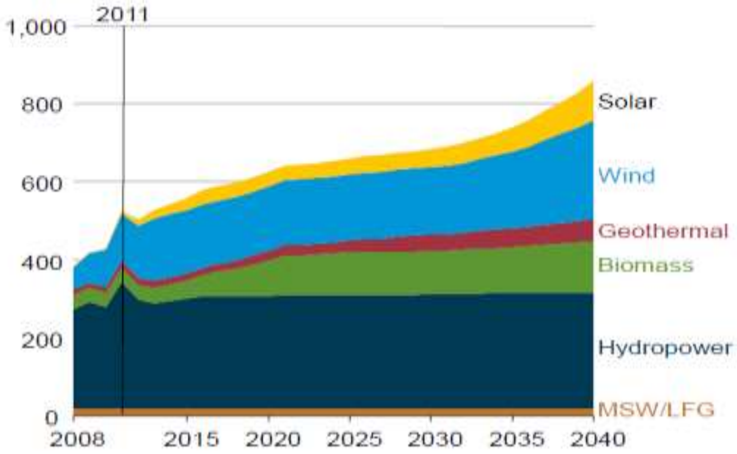


Figure Renewable Electricity Generation by Type including End-Use Generation

(Source: EIA, "Annual Energy Outlook 2013")

1) Tax Credits

The Renewable Electricity Production Tax Credit (PTC) has contributed mainly to the promotion of wind- and solar-power generation as federal incentives. As for specific renewable electricity, this system deducts a defined tax amount (currently 2.3 cents/kWh; inflation adjustment) per 1kWh of generation for a certain period of time from the commencement of operation. Thus, for developers, the more power they generate, the more income tax they can deduct.

The PTC system has been extended several times up until now, and currently facilities that had its construction started by the end of 2013 are to be subject to the PTC.

2) Setting Goals & Standards

Many states have adopted the Renewable Portfolio Standard (RPS). This standard mandates that electricity suppliers must obtain a certain rate of their power from renewable energy resources. Consequently, in order to achieve this standard, they must generate the renewable electricity first-hand or otherwise purchase the credit from other operators. However, many RPS schemes have an exemption clause based on generation costs. Therefore, some states have postponed the achievement of goals and have yet to concretely set up the procedures for the scheme. As of March 2013, 29 states and Washington DC have adopted the RPS.

The adoption of RPS has previously been discussed several times on a federal level, but it has not yet been realized because some states and local governments with poor renewable resources remain opposed to the introduction of the RPS.

Figure　RSP requirements of Each State(2013.3)

State	RPS overview
Arizona	15% by 2025
California	33% by 2020
Connecticut	27% by 2020
Colorado	30% by 2020 (investor-owned utilities)
Delaware	25% by 2026
Washington D.C.	20% by 2020
Hawaii	40% by 2030
Illinois	25% by 2025
Iowa	105MW
Maine	30% by 2000 Class I (new resources) 10% increase by 2017
Maryland	20% by 2022
Massachusetts	22.1% and Class I (new resources) 15% increase by 2020 Additional 1% per annum thereafter
Minnesota	25% by 2025 (30% by 2020 for Xcel Energy)
Montana	15% by 2015
Nevada	25% by 2025
New Hampshire	24.8% by 2025
New Jersey	20.38% by 2021 and 4.1% for solar energy by 2028
New Mexico	20% by 2020 (investor-owned utilities)
New York	29% by 2015
North Carolina	12.5% by 2021 (investor-owned utilities)
Oregon	25% by 2025 (large utilities)
Pennsylvania	18% by 2021
Rhode Island	16% by 2020
Texas	5,880MW by 2015
Washington	15% by 2020
Wisconsin	10% by 2015 (varying conditions between utilities)
Kansas	20% by 2020
Missouri	15% by 2021
Michigan	10% by 2015 and 1,100MW
Ohio	12.5% by 2024

(Source: Database of State Incentives for Renewables & Efficiency (DSIRE)

3) Market Formation

Many states have implemented the RPS through a system of tradable Renewable Energy Certificates/Credits (RECs). This system certifies the REC to be sold to electricity suppliers, and the sales to be used for renewable energy projects. Some states have strengthened the REC market by mandating an electricity supplier to implement the renewable electricity production or to take over the generating facilities, to reduce dependency on fossil fuel generation.

The following five examples collected from the US were given the DOE's financial assistance (grants) by means of the program under the American Recovery & Reinvestment Act of 2009, with a total funding of approx. 32 million US$ for the program. The cost share from the government was 50% or 80% of the total project cost. Seven projects in total have been selected and underwent construction for up to two years. The implemented projects were aimed to modernize hydropower infrastructure by increasing efficiency and reducing environmental impacts at existing facilities, and to demonstrate improvements through the use of advanced hydropower technologies.

Specific Examples:

The following US projects have been implemented with the funds by DOE through the hydroelectric facility modernization program.

❑US.1 Installation of a Low Flow Unit at Abiquiu Hydroelectric Facility (USA)
Abiquiu Hydropower Plant (output=16.9MW, plant discharge =43.9m^3/s)

❑US.2 Modernization of Boulder Canyon Hydroelectric Project (USA)
Boulder Canyon Hydropower Plant (output=5MW)

❑US.3 Cheoah Upgrade (USA)
Cheoah Hydropower Plant (output=144.7MW, plant discharge =268m^3/s)

❑US.4 North Fork Skokomish Powerhouse at Cushman No.2 Dam (USA)
New North Fork Hydropower Plant (output=3.6MW)

❑US.5 Fond du Lac Hydroelectric Project (USA)
Fond du Lac Hydropower Plant (output=12MW)

Australia

The "Renewable Energy Target (RET)" has been established in Australia on the federal level as the main support measure to introduce renewable electricity. The RET started in January 2001 as an alternative to the previous "Mandatory Renewable Energy Target (MRET)" with the aim to deliver a 20% share for renewables in Australia's electricity mix, that is, 45 TWh annually, by 2020.

Table Change of Renewable Energy Amount (kWh in millions)

	FY2005	FY2006	FY2007	FY2008	FY2009
Total Energy	244,660	248,394	253,959	244,395	241,567
Rotal of Renewable Energy	18,867 (7.7%)	18,291 (7.4%)	16,333 (6.4%)	17,338 (7.1%)	19,711 (8.2%)
Biomass/Wood	935	950	960	1,440	1,220
Biogas	85	90	68	884	893
Windpower	1,713	2,611	3,093	3,806	4,798
Hydropower	16,029	14,517	12,057	11,052	12,522
Solarpower	105	123	156	156	278

Source:Bureau of Resources and Energy Economic(2012), "Energy in Australia

Only wholesale electricity suppliers and retail operators which engage in transactions of more than 100 MW (hereinafter referred as “liable parties”) are subject to the obligation to procure renewable energy. The mandatory renewable electricity procurement amount is calculated by multiplying the total electricity sold by liable parties under the application of a renewable energy ratio determined by the Clean Energy Regulator (CER).

Whether or not the liable parties have achieved their mandatory amount is demonstrated by the Renewable Energy Certificates (REC) that they submit. A system to carry forward certificates to the subsequent year’s mandatory amount is also accepted (certificate banking system), and these certificates become invalid when they are used to achieve the mandatory amount. CER evaluates and certifies whether the electricity producer’s facilities are eligible for the renewable electricity or not. Although certificates are tradable, registration information such as the owner and other data are necessary for every trade. Eligible renewables for the RET includes hydropower, wind power, solar, bagasse, landfill gas, and wood waste.

The law giving the RET a legal basis is “the Renewable Energy Act (December 2000)” and this law has been amended twice so far. With the amendment in 2009, the introduction target for 2020 was increased by some five times from the initial 9.5 TWh to 45 TWh, and the system name was changed from MRET to RET. By the amendment in 2011, REC trades have been divided into two: the “Small scale Renewable Energy Scheme (SRES)”, which is composed of mainly small power sources such as solar panels that are not connected to the main grid, and the “Large scale Renewable Energy Target (LRET)”, which is for commercial-scale operation by electricity suppliers of wind generation, large-scale solar generation, and geothermal generation. On the back of these amendments was the generous subsidy system for solar panel installations, as well as solar panels for household use becoming widespread as a result of state government FIT. Since it was possible to earn a profit on sales simultaneously with these subsidies, the number of RECs rapidly increased while the price of RECs fell. Accordingly, there were growing concerns that the investment for the large-scale commercial power sources, such as wind generation, would not advance. By this amendment, the initial target of renewable electricity by 2020 is to be achieved by large-scale commercial power sources that are subject to LRET.

Since around 2008, state and territorial governments have independently implemented FIT for renewable energy such as solar power.

Finland

In Finland, biomass is the main source of renewable energy. Although the number fluctuates depending on factors such as hydropower generation, the portion of renewable energy within primary energy supply in 2013 accounted for 31.0% of the total. Biomass amounted to the largest 24.2%, with hydropower ranking next but accounting for only 3.4%. Wind power was 0.2% and solar energy was only at 0.003%, both showing extremely small numbers. On the other hand, in 2013, renewable electricity accounted for 36.0% (25 TWh) of the total electricity supply, which was almost the same as the level of 2000 (23.0 TWh). 52% of the renewable electricity (12.8 TWh) was generated by hydropower, followed by biomass marking 41% (10.0 TWh), and wind power amounting to 3% (777 MWh). It is difficult to expand hydropower hereafter, and thus biomass generation and wind power is expected to increase until 2020.

While other EU member countries support renewable energy promotion mainly by means of FIT, Finland has primarily offered support by subsidies for investment on facilities. In Finland, newly constructed facilities for renewable energy receive a maximum subsidy of 40% (30% for solar power and small-scale wind power), and from 2008 to 2011, the country provided a total subsidy of 240 million Euros. In 2012, investment subsidies for generating facilities employing small-scale hydropower, wind power, biogas, and wood chips were discontinued.

Two premium feed-in tariff systems have been introduced in 2011, as new incentives for renewal energy promotion, and these remain to date. One of which is a system that targets electricity generation by small cogeneration facilities using wind, biogas, and wood. In this system, power suppliers can, as a premium, receive the difference between defined prices and spot prices on the market (3 month average) by generation type. For 1MWh, a minimum of 83.5 Euro is guaranteed. and in addition to the cogeneration facilities including biogas, bonus money is added. This premium is guaranteed for 12 years, and it will be revised only with a 2 year advance notice. The upper limits of the total installed capacities are, by type of generation: less than 2.5 GW for wind power, less than 19 MW for biogas, and less than 150 MW for small-scale cogeneration. The other system is intended to support electricity produced from wood-based energy (with the exclusion of the abovementioned small-scale cogeneration facilities).

Finnish laws do not allow adding the cost necessary for a premium feed-in tariff system onto the electricity price; therefore, the system has been operated by the state government. It is estimated that the necessary cost for this system was 120 million Euros in 2012, and is expected to increase up to 250 million Euros by 2020.

Table Total energy consumption

	2008	2009	2010	2011	2012	2013*		Annual change, %					
	petajoule (PJ)						%	2008	2009	2010	2011	2012	2013*
Wood fuels	306	270	322	317	332	324	24,2	1,2	-11,7	19,0	-1,5	4,6	-2,3
Oil	348	335	353	336	325	314	23,4	-3,7	-3,6	5,3	-5,0	-3,3	-3,2
Nuclear energy	241	247	239	243	241	248	18,5	-2,0	2,5	-3,1	1,7	-0,9	2,9
Coal	142	152	189	148	125	147	10,9	-25,8	7,0	24,4	-21,5	-15,6	17,3
Natural gas	151	135	149	130	115	107	8,0	2,2	-10,7	10,5	-12,5	-11,6	-6,9
Net imports of electricity	46	44	38	50	63	57	4,2	1,7	-5,4	-13,1	31,9	25,9	-9,9
Peat	82	72	95	85	65	49	3,6	-20,4	-11,8	31,4	-10,2	-23,5	-25,2
Hydro power	61	45	46	44	60	46	3,4	20,9	-25,6	1,4	-3,6	35,7	-23,7
Wind power	1	1	1	2	2	3	0,2	38,3	6,2	6,4	63,6	2,7	57,2
Other energy sources	30	32	36	36	45	48	3,6	19,3	6,9	10,4	1,3	23,6	6,6
Total	**1 407**	**1 333**	**1 467**	**1 391**	**1 372**	**1 341**	**100**	**-4,4**	**-5,3**	**10,0**	**-5,2**	**-1,4**	**-2,2**
Renewable energy sources [1], %	27,5	25,7	27,1	28,4	31,6	31,0							

1) Includes, inter alia, wood fuels, hydro and wind power, the biodegradable proportion of recycled fuels
* preliminary data

Source: Statistics Finland, Energy

Table Supply and total consumption of electricity

	2008	2009	2010	2011	2012	2013*		Annual change, %					
	GWh						%	2008	2009	2010	2011	2012	2013*
Hydro power	16 909	12 573	12 743	12 278	16 667	12 716	15,2	20,9	-25,6	1,4	-3,6	35,7	-23,7
Wind power	261	277	294	481	494	777	0,9	38,3	6,2	6,4	63,6	2,7	57,2
Nuclear power	22 050	22 601	21 889	22 266	22 063	22 698	27,1	-2,0	2,5	-3,1	1,7	-0,9	2,9
Condensing power etc.	8 779	8 963	14 179	9 822	5 177	8 162	9,7	-39,0	2,1	58,2	-30,7	-47,3	57,7
Combined heat and power, industry	11 203	9 000	10 359	10 079	8 781	10 034	12,0	-3,8	-19,7	15,1	-2,7	-12,9	14,3
Combined heat and power, district heat	15 273	15 793	17 738	15 463	14 505	13 795	16,4	1,0	3,4	12,3	-12,8	-6,2	-4,9
Total production	**74 475**	**69 207**	**77 203**	**70 390**	**67 687**	**68 182**	**81,3**	**-4,3**	**-7,1**	**11,6**	**-8,8**	**-3,8**	**0,7**
Net imports	12 772	12 085	10 501	13 851	17 443	15 715	18,7	1,7	-5,4	-13,1	31,9	25,9	-9,9
Total consumption	**87 247**	**81 292**	**87 703**	**84 241**	**85 131**	**83 897**	**100**	**-3,5**	**-6,8**	**7,9**	**-3,9**	**1,1**	**-1,4**

* preliminary data

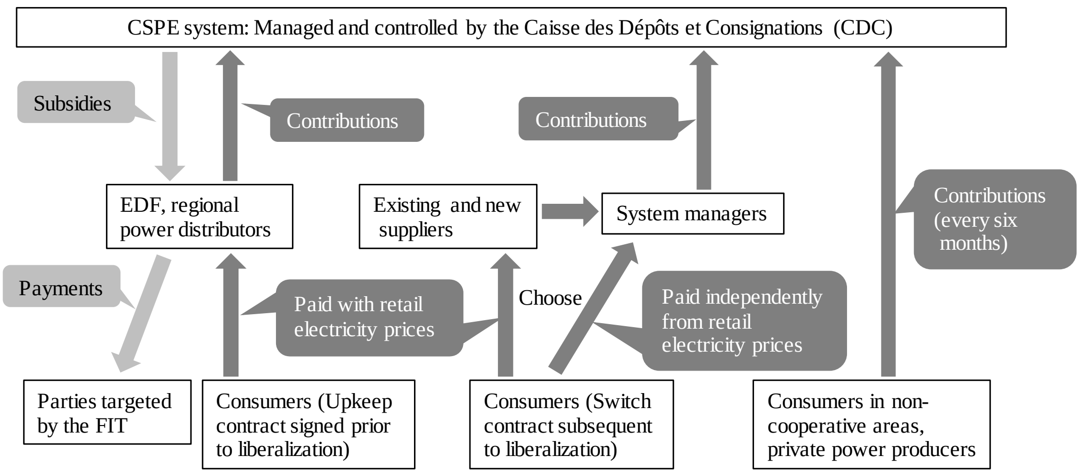
Source: Statistics Finland, Energy

France

In order to achieve the level defined by the EU "Directive 2009/28/EC on the Promotion of the Use of Energy from Renewable Sources", France has been implementing promotion by electricity bidding (Appel d'offres), FIT, and tax credits, despite the limited capacity for renewable energy introduction. The respective assistance measures are explained as follows:

1) The electricity bidding system for the renewable energy (from 2005)

The "Electricity Liberalization Act" enacted in February 2000 defined that generation facilities of less than 4.5 MW requires a notification procedure for construction, whereas larger facilities are to be constructed through a licensing procedure. When the total generation capacity does not reach the target level determined by PPI, the French government calls for bids on the shortfall. The EDF and regional power distributors sign a power sale and purchase contract with a successful bidder on the bidding terms. On the other hand, the EDF and regional power distributors recover the added costs incurred by the power sale and purchase contract through the Contribution au Service Public de l'Électricité (CSPE) system.



Source : JEPIC

Figure Contribution au Service Public de l'Électricité (CSPE) System

2) Purchase obligation of electricity generated by the renewable energy (from 2000)

The aforementioned "Electricity Liberalization Act" defines that the EDF and regional power distributors buy the electricity generated by solar heat, small hydropower, household garbage, onshore and offshore wind power, tidal power, biomass, geothermal and other means (FIT system). Given that generation costs for these energies are generally higher, and that they fall short of the purchase level of customers targeted for liberalization, the purchase obligation has been placed on the EDF and regional power distributors from the viewpoint of promoting environmental preservation. The details of the purchase conditions are determined by the government decree and ministerial order as shown below.

Table　Details on FIT System Conditions

Power source	Purchase price
New and existing	The following facilities, i.e. facilities launched prior to the introduction of the FIT, and facilities that have engaged in electricity production for captive consumption or marketing (non-applicable facilities in the FIT), are purchased at prices obtained by multiplying the coefficients (S) ○Electricity generation by biomass, solar power, hydropower, and such S=(20-N)/20(N<20),S=1/20(N≧20) ○Wind power electricity generation, etc. S=(15-N)/15(N<15),S=1/15(N≧15) N refers to the period between the day of the facility's launch to the day in which the FIT was signed.
Output enhancement	An additional 20 years of the FIT will be signed for facilities that undergo a 10% increase in maximum output, as well as their average annual capacities for electricity generation.
Purchase-oriented approach	The Electricity Liberalization Act of February 2000 defines the EDF and regional power distributors to undertake an obligation to sign an electricity purchase contract. This is to apply when electricity suppliers (that will be subject to the FIT) carry out applications.
Approach on deducted amount concerning purchase price determinations	Additional purchase prices are determined by deducting, from the purchase price, the portion that are in conjunction with the purchase and corresponding to avoidable costs. The Electricity Liberalization Act of February 2000 defines that the avoidable cost of EDF is evaluated by reference to the price in the electricity market. The Energy Regulatory Commission (CRE) previously determined avoidable costs in pursuant to EPEX Spot's average spot market price. From 2010 and onwards, however, CRE has been determining these costs by combining spot market and future contract prices.

Source:JEPIC

With regard to purchase cost based on FIT for renewable electricity, at the time when this system started, the majority of the purchasing cost was for electricity generated by hydropower. From around 2006, however, the purchase cost for electricity generated from wind power started to rise. In 2011, due to rapid increase of solar electricity generated with a high fixed price, its purchasing cost increased explosively.

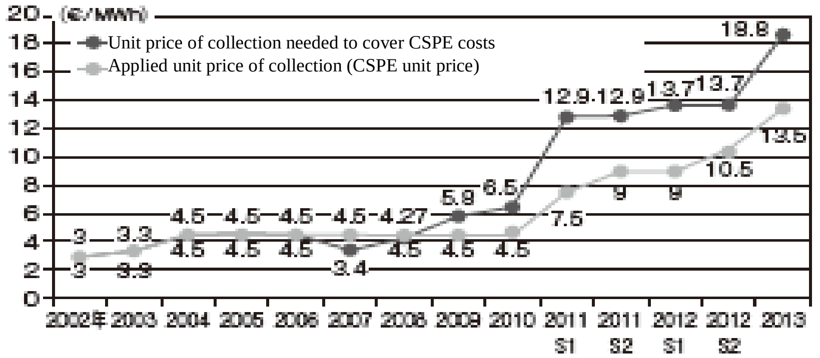
Incidentally, the added costs for which the EDF and the regional power distributors must pay based on FIT are to be recovered from consumers by a surcharge system based on the Contribution au Service Public de l'Électricité (CSPE), in the same manner as the electricity bidding system for renewable electricity.

Table Fixed Price of FIT System
(Solar power as of January 2013; other sources as of March 2011)

Power source	Purchase period	Purchase price
Hydropower	20years	6.07 Euro cents/kWh + Small power source premium (0.5 – 2.5 Euro cents/kWH) + regular operation premium for winter (0-1.68 Euro cents/kWH)
Ocean nergy(e.g. tidal power)	20years	15 Euro cents/kWH
Geothermal	15years	20 Euro cents/kWH + Energy efficiency premium (0-8 Euro cents/kWH)
Windpower(onshore)	15years	8.2 Euro cents/kWH (10 years in the first term), 2.8 – 8.2 Euro cents/kWH (5 years in the latter term)
Windpower(offshore)	20years	13 Euro cents/kWH (10 years in the first term), 3 – 13 Euro cents/kWH (10 years in the latter term)
Solarpower(Models built in to buildings:residences	20years	31.59 Euro cents/kWH
Solarpower(Models built in to buildings:educational and medical facilities	20years	21.43 Euro cents/kWH
Solarpower(Simplified models built in to buildings)	20years	18.58 Euro cents/kWH
Solar power (Simplified models built in to buildings)	20years	18.17 Euro cents/kWH
Solar power (others)	20years	8.18 Euro cents/kWH
Cogeneration	12years	6.1 – 9.15 Euro cents/kWH
Household garbage	15years	4.5 - 5 Euro cents/kWH + Energy efficiency premium (0 – 0.3 Euro cents/kWH)
Biomass	20years	4.34 Euro cents/kWH + Energy efficiency and designated fuel premiums (7.71 – 12.53 Euro cents/kWH)
Biogas	15years	8.121 – 9.745 Euro cents/kWH + Energy efficiency premium (0 – 4 Euro cents/kWH)
Methane gas	15years	11.19 – 13.37 Euro cents/kWH + treatment premium for rearing water discharge (0 – 2.6 Euro cents/kWH)
Small power sources (<36 kVA)	15years	7.87 – 9.6 Euro cents/kWH (Corresponds to household electricity prices)

Source: DGEC website

The CSPE system determines the manners of collection from consumers as follows: i) the upper limit of the contributions by the point of demand are determined to be 550 thousand € annually, ii) for private power producers, electricity generated over 240 MWh are subject to collection, iii) for industrial customers which consume more than 7 MWh annually, the upper limit of the contributions is defined to be 0.5% of their value added (gross profit), offering a burden relief measure for commercial-scale utility customers. The unit price of the collection from consumers based on the CSPE system is determined by the following process: the Energy Regulatory Commission proposes the following year's price to the Minister of Energy by 15th October each year, which is followed by the Minister's issuance of a ministerial order setting the unit price.



Source: CRE website

Figure CSPE Price Transitions

3) Tax credits for the renewable electricity generating equipment and facilities

When renewable electricity equipment and facilities are constructed, a system by which operators are able to receive a tax credit is available. The tax deduction ratio decreases in incremental steps and the tax deduction ratio for hydropower is currently at 45%.

Table Tax Credits for the Renewable Electricity Generating Equipment and Facilities

Power source	Tax credit rates for 2010	Tax credit rates for 2011
Energy production facilities utilizing solar heat, wind power, and hydropower	50%	45%
Solar electricity generation panels		
Heater facilities utilizing biomass	25%(New)	22%(New)
	40%(Upgraded existing facility)	36%(Upgraded existing facility)
Heat pump facilities utilizing atmospheric heat and hydrothermal power	25%	22%

Source:ADEME website

Table Transition of Renewable Energy Generation (kWh in millions)

	1970	1980	1990	2000	2005	2010	2011
Hydropower	57,379	70,312	54,975	68,748	53,257	63,896	46,523
Windpower				92	990	10,031	12,294
Solarpower				9	21	731	2,275
Geothermal			19	21	95	15	56
Trash	114	112	221	1,021	1,642	2,100	2,213
Biomass	713	814	1,158	1,768	1,669	1,792	1,902
Wood, scrap	713	814	1,116	1,398	1,254	1,443	1,558
Grain residue			42	370	415	349	344
Biogas	49	50	73	295	481	1,117	1,117
Total	58,255	71,288	56,446	71,954	58,154	79,652	66,400

Values provided for 2010 are provisional, and those for 2011 are

Source: MEDDE website

In 2009, with the view to promote the introduction of renewable energy, the French government has set the Programmation Pluriannuelle des Investissements (PPI plan). The plan defines that the electricity generated from solar power is planned to be increased up to 5.4 GW, and that 2.3 GW for biomass generating facilities are to be added by the end of 2020. For the wind power and ocean energy generation by the end of 2020, the country targets the introduced electricity to be increased up to 25 GW (19 GW by onshore wind power, and 6 GW by offshore wind power and ocean energy). Furthermore, with regard to hydropower, the annual electricity generated as of 2009 was 61.8 TWh and the installed capacity was 26.2 GW. In this plan, the following targets are incorporated by the end of 2020: 3 TWh of average annual electricity generation and an addition of 3 GW of new facilities to existing facilities.

Brazil

According to a long term power demand forecast (Plano Nacional de Energia 2030), the demand in 2030 will be 1,030 TWh, with, by source, hydropower accounting for the majority in the future as well. However, the increase of thermal power generation (natural gas, coal) and nuclear generation, is expected to result in a fall of hydropower share from 90% in 2005 to some 75% in 2030. 5% of the total annual generation regarding the share of renewable electricity (biomass, wind power and small hydropower, etc.) is planned to be secured with the support of the federal government. The long term power development plan estimates that by 2030, the total installed capacity will reach approximately 220 GW. Amongst this, hydropower is expected to account for 88 GW, gas–fired thermal power for 12.30 GW, coal-fired thermal power for 4.60 GW, biomass for 6.30 GW, wind power for 4.60 GW, other renewable electricity for 1.30 GW, and nuclear power for 5.35 GW. The middle term power development plan (Plano Decenal de Expansão de Energia 2021) is as shown in the following table. The installed capacity of projects which had been awarded a contract or under construction as of 2012 was approximately 32.61 GW in total, consisting 9.15 GW by renewable electricity (wind power 6.63 GW, biomass 1.80 GW, small hydro 770 MW) and 22.41 GW by hydropower (excluding small hydro), thermal power, and nuclear power. A total of 32.61 GW is planned to be incorporated in the power grid by 2016.

	2012		2016		2021	
	Generation capacity	Share(%)	Generation capacity	Share(%)	Generation capacity	Share(%)
Total of Renewable Energy	101,057	83.0	122,616	81.0	152,952	83.9
Hydropower	78,959	64.8	92,352	61.0	111,723	61.2
Hydropower(imported)	6,200	5.1	5,829	3.9	5,114	2.8
Solar power	5,009	4.1	5,448	3.6	7,098	3.9
Biomass	8,908	7.3	9,604	6.3	13,454	7.4
Wind power	1,981	1.6	9,383	6.2	15,563	8.5
Other power	20,766	17.0	28,756	19.0	29,456	16.1
Nuclear	2,007	1.6	3,412	2.3	3,412	1.9
Natural gas	10,350	8.5	12,055	8.0	13,102	7.2
Coal	2,845	2.3	3,205	2.1	3,205	1.8
Oil	3,482	2.9	8,002	5.3	8,002	4.4
Diesel	1,395	1.1	1,395	0.9	1,048	0.6
Petroleum	687	0.6	687	0.5	687	0.4
Total	121,823	100.0	151,372	100.0	182,408	100.0

Source : MEE(2012),"Piano Decenal de Expansao de Energia 2021".

Table Mid-long Term Power Development Plan (2012 - 2021) (unit: 1,000kW)

Renewable energy in Brazil is expected to have significant potential for development in the future. It is estimated in the development plan that the installed capacity for respective renewable energies will be increased up to 15.56 GW for wind power, 13.45 GW for biomass and 7.10 GW for small hydro by 2021.

With the view to actively promote the introduction of renewable energy, Brazil has established Programa de Incentivo às Fontes Alternativas de Energia Elétrica (PROINFA) in 2002. The facilities subject to construction by PROINFA were renewable energy power stations from wind power, small hydro, and biomass, and in June 2004, 115 projects (total installed capacity of 3.15 GW) were chosen. All of these power stations are connected to the Sistema lnterconectado Nacional (SIN), and they have reached a purchase agreement (for 50% of the total output) with Electrobras at a fixed price for 20 years.

The purchase price is decided based on the cost of each power source, but for the variable sources such as wind power, the purchased price has been adjusted based on monthly-basis fluctuations.

On top of that, Brazil also is focusing on the investment for renewable energy using CDM. The current CDM has been developed based on the scheme Brazil had proposed. In 2002, Brazil approved the Kyoto Protocol, and in 2003 established regulations regarding CDM; Brazil has been preparing a system for CDM from early times. As of December 2012, 274 projects under CDM were formally registered. Amongst them, the majority of the projects to be implemented were composed of cogeneration using bagasse (sugarcane waste), waste treatment projects of farms, small hydro, energy efficiency projects, and methane recovery projects from livestock farming and trash landfills. With Brazil’s large potential for development in bagasse or small hydropower power generations, further findings and implementations of new projects in these fields are expected to be made in the future.

1-c) Integrated Management of Water Resources and River Systems

c-1) Water System Integrated Development

An effective method to utilize a valuable domestic resource, river water, is water system integrated development. Water system integrated development refers to effectively utilizing the water resource in view of total optimization of the water system throughout the year, by taking into account seasonal and daily water volume fluctuations, various terrain conditions on which rivers are located, a wide variation of power demand, and other factors.

When there are several business operators involved in one river, or, as with international rivers, when a river flows through several different countries, it may take a longer time to reconcile interests between stakeholders. For example, with regard to the Mekong River, the Mekong River Commission (MRC), consisting of countries along which the Mekong River flows, has been making effort for sustainable water resource utilization, development, and reservations. However, since the MRC lacks mandatory power, the organization is not functioning effectively in some areas. In Japan, one business operator exclusively develops one water system, which allows a much streamlined process to develop a water system.

The Hidaka Water System Integrated Development enabled to generate large-scale peak power by effectively utilizing the river water of a whole river basin in the following ways: connecting four rivers that flow toward the southwest with a water channel, as well as utilizing several reservoirs, regulating reservoirs, and hydropower plants (hereinafter “HPP”) responding to different large and small peaks.

In the case of the integrated development of the Kurobegawa and Kisogawa water systems, the annual water flow status was improved by constructing a large reservoir on the river’s uppermost stream. In order to fully utilize water heads and water volumes, the developments were conducted from upstream to downstream, thus obtaining massive peak power from the entire water system. These redevelopments have increased the output of the generated power by 55% on the Kurobegawa water system and by 56% on the Kisogawa water system.

Specific Examples:

❏ Jp. 3: Hidaka integrated development (Japan):
The integrated development of a total output of 643MW by 4 water systems and 13 HPPs.

❏ Jp. 4: The consistent development in Kurobe river system (Japan):
The integrated development of a total output of 894MW by one water system and 11 HPPs.

❏ Jp. 5: The consistent development in Kiso river system (Japan):
The integrated development of a total output of 1,047MW by one water system and 33 HPPs.

c-2) Integrated Sediment Management in River Basin

When a dam is constructed on a river, the necessity for sediment management becomes inevitable. At the upstream of a dam, sedimentation reduces effective pondage, while at the downstream, the river bed level lowers and the shoreline retreats due to a decrease in sediment flowing down. Notable cases are terrains with a steep river slope and subsiding surrounding mountains where, the existing balance between earth and sand collapses as a result of the dam stemming sediment flows. It is necessary in these cases to apply effective and integrated sediment management measures on the entire water system, based on the idea that the whole river system is a single sedimentation system. In preparing sedimentation management measures, it is needless to say that conducting reconciliation of the interests between stakeholders, such as the river administrator and residents living along the river basin, is essential.

Japan's Kurobegawa water system is one of the steepest sloping rivers in the country. Scour gates are therefore installed on the Dashidaira Dam and Unazuki Dam so as to conduct sedimentation flushing as sedimentation control measures. Although these dams are operated by different business operators, sand washouts are conducted with collaboration between the two dams by establishing a committee inclusive of local residents and academic experts. In concrete terms, a cooperative sand washout flushing is conducted during the rainy season when more than 300m^3/second of flooding is forecasted, by reducing the water level of these two dams concurrently in advance, and thereby securing a certain level of tractive force.

A Specific Example:

❑Jp. 4: The consistent development in Kurobe river system (Japan):
Two dams which conduct concurrent sand washout. (Dashidaira Dam, Unazuki Dam)

c-3) Comprehensive Development Plan

Rivers are utilized in a variety of ways depending on social environments, such as the economic growth of the nation or population increase, or changes in the natural environment due to heavy rain and other factors. Functions expected for a dam in a river have a wide range of purposes besides power generation, such as drinking water, irrigation, flood control, and industrial water. A comprehensive development plan is a program which reconciles interests between different stakeholders and, based on the idea of total optimization, promotes river utilization.

The comprehensive development by the Shin-Maruyama Dam in Japan is a restoration construction project mainly conducted by the central government with a view of improving water control, and Japan's largest-class bank raising construction for a large-scale, multi-purpose dam will be carried out in this project. Power business operators agree with this project on the ground of executing their corporate social responsibility (CSR), and will conduct the upgrading construction of the HPP facilities with national subsidies. The Shin-Maruyama Dam comprehensive development plan is to be conducted with an ingenious plan in design and construction, such as construction work proceeding while maintaining generation functions, cost saving, and stabilization of the dam. Consequently, this project is expected to be an advanced model for the future.

A Specific Example:

❑Jp. 44: Dam rising project (Shin-Maruyama Dam) (Japan):
Rising Dam for improving the floodwater regulating capacity etc. (Dam height=122.5m)

1-d) Asset Management, Strategic Asset Management and Life-cycle Cost Analysis

d-1) Asset Management using Existing Facilities

Using existing facilities will enable to achieve significant cost saving compared to a new construction of the entire HPP. However, in terms of reusing the existing facilities, it is necessary to conduct asset management for economic and general efficiencies in consideration of the remaining life of the facilities, and on the basis that the necessary strength and functions are confirmed and secured in the future as well.

This report describes cases in which small scale HPPs have been newly installed along with existing HPPs, where water intake volume has been increased by utilizing the capacity of unused water flows associated with the existing water intake weir, headrace, water tank, and hydraulic steel pipe. This project compared a case in which only water turbine generators are replaced and a case in which an existing HPP was expanded. As a result, the latter, which was economically preferable, was adopted.

Nagatono was damaged due to the massive landslide. In calculating the restoration cost, the acceptable level of damage and remaining period for service life of existing facilities was considered. Finally the restoration cost is compared against the cost of replacing it with an LNG thermal power plant in terms of the unit cost of power generation.

A Specific Example:

❑Jp. 7: The upgrading project of Shin-Kuronagi No.2 Power Station (Japan):
Kuronagi No.2 HPP (output=7,600kW, plant discharge=6.2m^3/s), Shin-Kuronagi No.2 HPP (output=1,900kW, plant discharge=1.7m^3/s)

❑Jp.40 : The Survey of the flood disaster of Nagatono HPP and its restoration project (Japan) :
Nagatono HPP (output=1.53MW, plant discharge=9.46m^3/s)

❑Jp.42 : Restoration construction project of the earthquake of the Ishioka No.1 HPP (Japan) :
Ishioka No.1 (output=5.5MW)

d-2) Asset Management for Improvement of Safety

Safety issues are directly linked to human life. It is therefore absolutely essential for hydropower engineers to think safety first and pursue it as a top priority. Asset management is required in safety measures, in consideration of its necessity, immediacy, and cost-benefit performance.

The following is a description of approaches for the safety improvement of Ontake HPP. The risks were quantitatively assessed by two criteria; that is, by the likelihood of failure to occur, and by the magnitude of damage from failure. Various approaches have been effectively conducted as safety measurements for the people who enter the vicinity of the river. Countermeasures which prevent third parties from being injured by installing an energy dissipator at the outlet of the spill channel particularly have demonstrated profound effects.

A Specific Example:

❑Jp. 6: The efforts to prevent risks caused by the surplus waste water of the Ontake HPP (Japan):

Ontake HPP (output=66MW, plant discharge=34.4m^3/s)

d-3) Strategic Asset Management

Asset management indicates efforts to effectively manage and control the existing assets with an aim to reduce lifecycle cost and extend the life of the facilities.

The Pirttikoski HPP, a facility of Finland’s Kemijoki Oy, is part of a group of power plants along Kemijoki River that has undergone upgrading work since 1996. The project has systematically improved plant efficiency for output boost and enhanced the surrounding environment. Facility upgrading has successfully increased power generation in flood periods and also during peak-demand hours, while also reinforcing ancillary services. These outcomes are in line with the plant operator's asset management to make effective use of existing facilities at the maximum.

On the other hand, instead of conducting uniform asset management on the targeted asset (HPP), strategic asset management is an approach in which comprehensive consideration of the respective issues of various areas sets goals so as to increase asset values including investments, and sets strategies to achieve those goals from a long term point of view, and manage and control assets.

The Poatina HPP with the output of 360MW is one of the operator's six main hydropower plants that affect its revenues. In order to lower the risk of anticipated plant faults to below the allowable level, the company determined the amount of investment in the power plant, also from the perspective of the portfolio. Work to be performed includes measures for improving plant efficiency and facilitating ancillary services. In terms of risk and feasibility judgment, the project incorporates lifecycle cost analysis over 30 years, raising expectations for improved accuracy. Other success factors of this project include the continuous involvement of a key person, the development of a mechanism that gets multiple cross-functional teams involved in the project, and the addition of local plant operators to the project team.

The Tungatinah HPP adopted an approach similar to that of the Poatina HPP in making capital investment, to achieve the IRR of 13%, outperforming its own target.

The Hunsfos HPP is a good example of asset management incorporating changes in the use of water resources. This HPP was once owned by a paper-manufacturing factory, but competing with the factory for the use of water, the hydropower plant had difficulty in securing a sufficient amount of water for power generation. When the factory discontinued water use in recent years, a decision was made to sell the hydropower plant to a local electric utility based on the judgment that the facility will continue to have an economic value in the power generation business into the future. The plant's output has been doubled from the original 15MW, and its power generation has also been increased by 45% from the initial 145GWh.

The Kongsvinger HPP is having a new generator installed to make use of excess river water. In determining the most optimum scale of power generation facilities, the plant operator examined the amount of reduced power generation associated with the upgrading of existing power plants, outages and maintenance work, as well as the effect of installing a higher-efficiency generator at the new facility. The project plans to add 22MW to the existing output of 21MW, boosting the current annual power generation of 130GWh by 54%.

The Rendalen HPP is a hydropower plant launched in 1971 with the output of 92MW and annual power generation of 675GWh. Its recent management challenges include reduced power generation due to replacement of deteriorated equipment and maintenance of sediment flushing facilities. In view of future profitability, the plant's operator decided that the installation of a high-efficiency water turbine generator of the equivalent scale would contribute to its financial stability. The upgrading work was completed in 2013.

The Waitaki HPP is an 80-year-old hydropower plant, retaining most of its original water turbine generators. The plant operator adopted the strategic asset management approach to review its assets, explored issues, risks and effective actions in the scenario of continued power generation and carried out the assessment of associated risks and economic feasibility. When it was decided to make capital upgrading work, the company conducted further lifecycle cost analysis to determine the project's cost effectiveness in terms of economy, facility administration and risk management.

Specific Examples:

❑Jp. 45: Upgrading of the Kumagawa No.1 HPP (Japan) :
Kumagawa No.1 HPP (output=2.6MW)

❑Fi. 1: Upgrading of Pirttikoski HPP (Finland) :
Pirttikoski HPP (output=152MW)

❑Au. 1: Poatina modernization project (Australia) :
Poatina HPP (output=360MW), Adoption of the new water turbine runner and bearing, improvement of control and protection system for the inlet valve and increase the output by 24 MW.

❑ Au. 2: Tungatinah modernization project (Australia):
Tungatinah HPP (output=125MW), Renewal of 3 main generators and increase the output by 15MW

❑ Nw. 5: Hunsfoss East HPP (Norway) :
Building Hunsfoss East HPP(output=15MW, plant discharge =120 m^3/s)

❑ Nw. 8: Kongsvinger Hydropower Plant - Unit No.2 (Norway) :
Expansion new generating Unit No.2(output=22MW,plant discharge =250 m^3/s)

❑ Nw. 9: Rendalen HPP – Unit No.2 (Norway) :
Expansion duplicating unit (output=94MW, plant discharge =55 m^3/s)

❑ NZ. 2: Waitaki HPP Refurbishment (New Zealand) :
Upgrade turbine generator (output=105MW, plant discharge =360 m^3/s)

d-4) HAP (Hydropower Advancement Project)

The Hydropower Advancement Project or HAP is a US program for asset management, which is led by the Oak Ridge National Laboratory under the US Department of Energy (DOE). It examines existing hydropower plants' aging and their potential for output increase, selects hydropower plants that should be given upgrading priority, and implements recommended reinforcement measures that can be carried out.

The recommended measures include the most efficient use of available river water, review for reducing leakage, upgrading of runners and guide vanes, and the control of pulsation attributable to draft intake.

The application of the HAP is being planned for the Flaming Gorge HPP and Rhodhiss HPP.

Specific Examples:

❑ US. 6: Flaming Gorge Hydropower Facility: Final Assessment Report (USA) :
Flaming Gorge Hydropower (output=152MW)

❑ US. 7: Rhodiss Hydropower Facility: Final Assessment Report (USA) :
Rhodiss Hydropower (output=28.2MW)

1-e) Projects Justified by the Non-monetary Valuation of Stabilizing Unstable Power Systems in the Up-coming Low-carbon Society

e-1) Stabilization of Power Systems

In Japan, frequency adjustments have been conducted by the cooperation of large and middle scale thermal power plants and hydro power plants with reservoirs and regulating reservoirs. Typically, a hydro power plant, whose startup time is short and response to output change is faster than thermal power plants, adjusts for load changes whose fluctuation range is small and change speed is fast. On the other hand, thermal power plants adjust to load changes whose fluctuation range is large and speed of change is relatively slow, thus the frequency of the system is adjusted. Especially during late night hours, the number of power stations with the ability of frequency adjustment decrease along with the decrease of the load, leading to an increased use of variable speed systems at pumped storage power stations.

Thus, since the commencement of the operation, the variable speed type pumped storage power stations have been run at a high load rate, and along with these conditions, facility degradation has been accelerating. Consequently, a large scale restoration project requiring a long time is planned in the near future, and there are anticipations for a decrease in the frequency adjustment capability during late night hours. Therefore, along with the large scale restoration work of the Okutataragi pumped storage HPP (Output 1,932MW), constant speed generators were replaced with variable speed generators, and a frequency adjustment capacity of 180MW (2 machines×90MW) during pumping operations has been secured. Technologies that expand the operation range of the existing hydro power plant were introduced in this restoration project as well.

On the other hand, pumped storage HPP have a function to push down water inside the water turbine by compressed air once the pumping operations start. The system voltage is maintained by using this function for phase adjustment on top of the aforementioned frequency adjustment. This phase adjustment operation by pushing down the water level inside pump turbines has been introduced domestically and internationally, and is not a new technology. For example, in Brazil's Estreito HPP (Output: 1,050MW), Francis turbines were converted to add this system along with the upgrading of existing facilities. This example is shared here given that it is an important example of effective future utilization of water power. In this case, adopting a new material allowed for an extension of repair intervals of the water turbine runner cavitation by 1.5 times.

The Veytaux HPP is doubling its 240MW output to 480MW for increased ancillary services. A high-elevation Pelton turbine and five-step storage pump are employed to handle the elevation of around 900 meters. The adopted tandem system is generally more expensive than a variable storage pump system. However, it provides an advanced level of flexibility on the input from the power grid, since the ability to switch between the turbine and storage pump during power generation and storage offers maximum efficiency.

A specific example of the stabilization of an electric power system.

❑ Jp. 8: The project to upgrade the Okutataragi No.1 & 2 HPP into adjustable speed generator motors (Japan) :
  Okutataragi HPP (output=1,932MW), Remodeling power generators from constant speed type to variable speed type

❑ Br. 1: Estreito HPP – Project of synchronous condenser (Brazil) :
  Estreito HPP (output=1,050MW), Addition of phase adjustment functions on the existing HPP

❑ Sw. 1: FMHL+ extension project (Switzerland) :
  Veytaux HPP (output=480MW), Extension of the existing power plant

1-f) Environmental Conservation and Improvement

f-1) Measures for Rare Birds

With regard to the influence that hydropower plants exert on the ecosystem, it is necessary to assess the impact on birds by the water flow change and land modification, such as reservoir constructions, in consideration of determining the activity range and distribution of bird groups on which HPP constructions will make an influence on. If an influence is identified, it is necessary to conduct mitigation measures to reduce this in the business plan territory, and also to conduct an environment restoration plan by environmental offsets.

The expansion work of the Okutadami-Ootori HPP is a large development undertaking that results in a total of about 300MW. In this project, various environmental preservation measures have been conducted with an aim to preserve golden eagles and *Kuma* falcons (Spizaetus nipalensis), the natural ecosystem itself, and to continuously reduce the environmental burden from the expansion work.

In concrete terms, the following measures were conducted: a voluntary restraint of construction cars and vehicle traffic during nest building periods, reduction of noise and vibration by a multistage blast method, cleanup of the construction water discharge by a turbid water treatment system, and adoption of lights and colors which have less influence on insects and plants.

Specific examples:

❏Jp. 36: Expansion project for the Okutadami and Ohtori HPP (Japan):
Expansion of the Okutadami-Ootori HPP (output=560MW), Okutadami maintenance flow discharge HPP (output=2.7MW), Expansion of the Ootori HPP (output=182MW)

f-2) Countermeasures for Sedimentation and Muddy Water

When a dam is constructed on a river, a variety of impacts may occur. This includes sedimentation resulting as the reduction of effective pondage, the lowering of the river bed level and a retreat of the shoreline due to a decrease of sedimentation flowing downstream of the dam, and muddy water continuing for an prolonged period due to changes river water flow characteristics.

Countermeasures for sedimentation include sediment dredging, scour gates, sediment pool dams, and scour bypass tunnels, and the appropriate measure must be adopted depending on the condition. Meanwhile, as countermeasures for muddy water, selective water intake systems and scour bypass tunnels are adopted as physical measures.

The following introduces specific examples of Japan’s countermeasures for dam sedimentation and long-term muddy water control.

The Asahi Dam Reservoir bypass scouring facility project resolved the problem of long-term muddy water by constructing bypass scouring facilities that go around the reservoir in an effort to prevent the muddy water from flowing into the reservoir and settling.

The sediment sluicing measures at Yamasubaru and Saigo Dams of the Mimikawa water system sets an example of measures to address Typhoon No.14 (2005)'s flood damage, as well as sediments flowing into the reservoir. With cooperation between regional communities, local governments, and private sectors associated with the river basin, discussions were made on how to manage flood control and how to utilize water. As a result, the talks concluded to construct a sediment sluicing system by conducting a major dam reconstruction.

In expanding the clear water bypass and surface water intake system at Nishiyoshino No.1 and 2 HPPs, a surface water intake system was installed on the water inlet of the No.1 HPP and, on the back of concerns for muddy water, a clear water bypass was constructed to skirt the Kurobuchi Dam of the No.2 HPP as a countermeasure to mitigate muddy water,

There is another case in which an anti-turbidity fence and other facilities have been installed as part of an initiative for reducing protracted reservoir turbidity, thereby improving the river environment.

<u>Specific examples:</u>

- ❑Jp. 9: Sand discharging bypass facility project at the Asahi Dam reservoir (Japan):
  Asahi Dam (H=86m, Arch dam), Scour bypass (H=3.8m B=3.8m L=2,370m)
- ❑Jp. 11: Sediment sluicing engineering works of the Yamasubaru and Saigo Dams in the Mimikawa river system (Japan):
  Yamasubaru Dam (H=29m, two central gates of the spillway gate were removed, cope level was lowered by 9.3m), Saigo Dam (H=20m, four central gates of the spillway gate were removed, cope level was lowered by 4.3m)
- ❑Jp. 12: Expansion project of surface water intake equipment and limpid water bypass tunnel at Nishiyoshino No.1 and 2 HPP (Japan):
  Clear water bypass (ID=0.4m, extension=400m, discharge=0.3m^3/s), Surface water intake system (surface water intake range HWL436m - WL422m, gate width=5m, gate height=26m, flow rate =16.7m^3/s)
- ❑Jp. 33: The installation project of the fence to countermeasure of muddy water (Japan):
  Nagasawa Dam (H=71.5m,Concrete gravity dam), Muddy water prevention fences (H=10m, L=220m)

<u>f-3) Countermeasures for Fishes</u>

Many dams have constructed fish passes so that the movement of migrating fishes is not blocked by the dam. Screens or fish-friendly water turbines have been adopted in order to prevent fish from straying into water turbines.

In Japan's new construction project of the Shin-Takatsuo HPP, considering the HPP's location at the heart of an area well-known for sweetfish, screens to prevent sweetfish from entering were installed concurrently with the renewal of the HPP's aging facilities. This project improved the water inlet screens and changed the water turbine into a more fish-friendly model to reduce the impact caused on fish. In order to minimize the impact on power generation and to secure its effect on a continuous basis, fish straying prevention measures were conducted by improving the existing water intake screen models into a lifting & lowering double screen type, and the screens are currently operated based on the seasonal behavior of the sweetfish. On top of that, special gates were installed to aid sweetfish with weakened swimming abilities to return to the original river.

The North Fork Skokomish HPP was a redevelopment project with subsidization from the ARRA, but required special considerations due to the presence of "threatened" fish species. A very unique approach was taken to transfer fish to upstream areas. In this system, the water discharged from the turbine was used to guide fish into a hatch, which was then transported to the top of the dam by tram. The numbers and types of applicable fish were examined before being released upstream or to hatcheries. This is a good example of cases adopting countermeasures for fish.

The Embretsfoss HPP is a run-off-river hydropower plant. Its upgrading work was aimed at renewing its facilities as well as enhancing its use of excess water and discharge capacity. With the acquisition of the green electricity certificate, the plant has increased its annual power generation by 156% from 215GWh to 335GWh. The project has improved the survival rate of fish traveling past the turbine. The emphasis is particularly on the protection of salmon and trout stock through the installation of a fish passage and a gravity flow gate.

Specific examples:

- ❑Jp. 10: Installation project of screens which prevent descending Sweetfish from entering by the new construction of the Shin-Takatuo HPP (Japan) :
  Shin-Takatuo HPP (output =14.5MW, discharge=32m^3/s), Specifications for the descending Sweetfish entry prevention screen (Lifting & Lowering double screen: two spans, Width of water channel; 6.2m, Height of the screen; 4.3m, Effective mesh; 24mm)
- ❑Nw. 1: Upgrading and Rebuilding of Embretsfoss HPP (Norway) :
  Increasing the size of turbine runner and change of turbine type, Installation of fish passage and gravity flow gate
- ❑US. 4: North Fork Skokomish Power house at Cushman No.2 Dam (USA) :
  North Fork Skokomish HPP (output =3.6MW), Innovative fish transfer system which sends fish upstream

f-4) Preservation of Landscape and Cultural Assets

Some old power stations and their structures, such as the housing, are integrated with the surrounding scenery and have become a cultural asset, resulting in becoming local heritage. Depending on the characteristics and values of the cultural assets, it may be necessary to take active measures to preserve or relocate them.

Japan's Shin-Takatsuo HPP has been redeveloped with an aim to renew the HPP, which was built in 1918, and to more effectively utilize river water. The Takatsuo HPP building, a large brick structure that boasts beautiful designs with round-arched windows divided by horizontal and vertical bands, has been highly evaluated as an important cultural asset by the Civil Engineering Academy and Wakayama Prefecture. Accordingly, when the redevelopment was conducted, the building's external wall was finished with red-brick style tiles paying respect to the previous appearance, and furthermore, taking into account harmony with nature, the surface of the ferroconcrete and concrete structures were all colored brown. The redevelopment was well-received by the local community.

The Ranasfoss HPP is 90 years old. The full replacement of turbines and generators has boosted its output by around 50% from the original 54MW. Efforts were made during the course of major upgrading work to preserve the original plant building which has a historic significance. A new building has been built adjacent to the original one.

Specific examples:

❏Jp. 10: Installation project of the screen which prevent descending sweetfish from entering by the new construction of the Shin-Takatuo HPP (Japan) :

Shin-Takatuo HPP (output =14.5MW, discharge=32m^3/s)

❏Nw. 7: Upgrading of Ranasfoss HPP (Norway) :

Ranasfoss III HPP (output=98MW), Preserve historic plant building

f-5) 3R Measures (Reuse, Recycle, Reduce) for Industrial Waste

Renovations of power plants generate large quantities of industrial waste, such as concrete rubble. It is thus important to reduce these wastes by implementing 3R measures to the extent possible.

In the restoration works of the Toyomi HPP in Japan, around 20,000 m^3 generated by the construction work, which is equivalent to 80% of the entire demolished concrete, was reused as recycled concrete to give due considerations on the environment.

The recycled concrete was used to fill the hollow portion of the power plant foundation created when removing the existing water turbines. This project is highly evaluated in terms of its contribution to reducing industrial waste, and received an Award by the Minister of Land, Infrastructure, Transport and Tourism.

Specific example:

❏Jp. 15: Restoration works on Toyomi HPP (Japan) :

Toyomi HPP (output=618MW), Using Recycled concrete by the construction work

f-6) Countermeasures for Social Environment

The construction of a hydropower plant involves a large civil engineering cost compared to the costs of equipment, necessitating high-value local contracts. Such projects typically include road development, and contribute both to local infrastructures and economy.

The Benmore HPP, which commenced operation in 1965, has six 90MW generators. For enhanced safety and reliability, the plant operator has installed new turbine runners, overhauled the mechanical parts of the generators, changed the structure of grid connection, and modernized auxiliary facilities. Although the main equipment representing 40% of the project had to be procured from overseas, the company gave its main focus on the use of local contractors and distributed the remaining contracts locally according to individual contractors' performance, engineering capacity, and management status. These efforts serve as a part of the company's approach for community symbiosis, enabling mutual sustainable growth. Active communications were exchanged during the construction, making it easy to gain support from other departments. The resulting boost in morale led to the project's accident-free completion.

Specific example:

❑NZ. 1: Benmore Refurbishment project (New Zealand) :

Benmore HPP (output=540MW), Allotment project budget to New Zealand contractors

Category-2: Modern Technologies, Systems, Material, etc.

<u>2-a) Technological Innovation & Deployment Expansion of Electro-mechanical (E/M) Equipment</u>

<u>a-1) Upgrade of Output and Power Generation under Restricted Conditions in Discharge, Head and Location to be Installed</u>

When the facilities are to be renewed, the existing facilities are replaced with equipment that offers economic and easy operation & maintenance under the various restricted conditions such as the site space, upon taking into consideration the following:

- Countermeasures based on the failure histories of the existing facilities
- The range of reusable facilities and their condition determined based on remaining life assessment
- Re-selection of the optimal turbine generator type and its unit number based on the new flow duration curves reviewed by the past running records of existing unit within the licensed water right

As a method to upgrade plant output and its power generation without increasing the maximum plant discharge under the licensed water right, the following approaches were investigated:

- Replacing to the turbine runner and guide vanes with the optimal hydro passage distributor while leveraging Computational Fluid Dynamics (CFD), by investigating the variation ranges of head and flow based on the past running records
- Upgrading the water turbine to a model with higher efficiency corresponding to the reviewed flow duration curve
- Changing the unit number into optimal numbers corresponding to the reviewed flow duration curve

<u>Specific Examples in which the Type and Number of Turbines were changed:</u>

❏Jp. 15: Restoration works on Toyomi Hydro Power Station (Japan) :

Six vertical shaft Francis turbines (56.4MW) were replaced by two vertical shaft bulb turbines (61.8MW). Vertical installation of bulb turbines into the shaft makes it possible to install them in the confined space of existing site. A commutated sloping plate was installed to prevent the air suction due to eddy occurrence at the upper part of the shaft (inlet of casing).

❏Jp. 21: Renewal of the Doi Hydro Power Station (Japan):

Renewed from 2 units of vertical shaft Francis turbine (8MW) to one unit of horizontal shaft, double type Francis turbine (8.2MW). The existing pressure regulator was eliminated by reviewing the pressure and speed rises at load rejection.

❑Jp. 17: The restoration work of the Nishikinugawa Hydro Power Station (Japan):
Renewed from 2 units of horizontal shaft, open flume-twin type Francis turbine (1MW) to one unit of horizontal shaft, S type tubular turbine (1.2MW).

Specific Examples in which an entire Renewal was achieved with the Same Types of Generator & Turbine as the Existing One:

❑Jp. 18:The restoration Minakata Hydro Power Staiton (Japan):
Upgraded the output from 24.1MW to 26.7MW. Applied the countermeasure for draft tube low-frequency vibration of existing unit. (13.8MW vertical shaft Francis turbine x 2units)

❑Jp. 22: Renewal project of Kamishiiba Hydro Power Station (Japan):
Upgraded the output from 90MW to 93.2MW (46.6MW vertical shaft Francis turbine generator x 2units)

Specific Examples in which a Partial Renewal in Turbine Runner & Distributor was achieved by CFD analysis:

❑Jp. 24: Refurbishment of the Tagokura Hydro Power Station (Japan):
The efficiencies of peak point and partial load for about 40-50% of turbine rated output were improved (100MW vertical shaft Francis turbine generator x 4units)

❑Fr. 1: Refurbishment of thrust bearings and Francis turbines at Sisteron Hydro Power Plant (France):
The weighted average efficiency of the new turbine generator was improved by 1.6% or more, which corresponds to an average power generation of 11,700MWh/year for the 2 units (130MW vertical shaft Francis turbine generator x 2 units).

a-2) Facilities' Renewal to Improve Maintainability

Long-term usage of water turbine generator equipment causes deterioration, making it difficult for the equipment to keep its original performance. This is especially true with aggravated erosion due to silts and sands or worsened cavitation on the turbine runner. When these damages are to be repaired, various countermeasures are conducted to extend the repairing interval, such as:

- Employing CFD to conduct a weld-overlay reform in order to achieve an optimum guide vane shape that can reduce sand erosion on the guide vane
- Repairing the turbine runner eroded by the cavitation, using new material (cobalt alloy welding rod) with improved anti-cavitation characteristics

Hydraulic servomotors have long been used to operate the guide vane apparatus and runner blade operating mechanism. However, replacing these with electric motor-driven actuators will allow eliminating oil pressure supplies and air compression systems, which will result in simplified auxiliary equipment, reduced maintenance costs, and improved maintainability. The application range of this electric motor driven actuator used to be limited to the guide vane servomotor for small-scale Francis turbines; however, the actuator's application range has been expanded to a guide vane servomotor with a 30 – 40MW output of medium-capacity Francis turbines, as well as guide vanes and runner blade servomotors for small-scale Kaplan turbines. On the other hand, a new technology of Hybrid Servomotors (electric-hydraulic hybrid servomotors), composed of a hydraulic servomotor using a small amount of hydraulic oil and a reversible oil hydraulic pump, has been developed as well.

When these facilities were renewed, various new approaches were applied to improve the maintainability of the system's operation, such as:

- Rendering oil-free the parts in contact with the turbine, the guide vane stem bearings, and the mechanism inside the Kaplan runner boss
- Water-lubricating the turbine bearing and/or eliminating cooling water from the bearing oil bath, and
- Introducing electric motor driven inlet valves

Furthermore, various approaches were conducted to pay due considerations on the environment around the plant.

A Specific Example in which Turbine Guide Vane was upgraded by CFD analysis:

❑Jp. 19: The application of guide vanes which have a shape for reducing and abrasion for Himekawa No.2 Hydroelectric Power Station (Japan) :

The optimal guide vane shape which enables the reduction of sand erosion at turbine distributor, caused by the sand containing in the turbine flow, was developed by applying the CFD analysis. (14.4MW vertical shaft Francis turbine)

A Specific Example in which Cavitation Performance was improved by applying a New Material:

❑Br. 1: Refurbishment of Estreito HPP - Project of synchronous condenser (Brazil) :

Applied the new material (Cavitalloy: Cobalt alloy welding rod) and processes for repairing cavitation on Francis turbine blades. Welding repair interval was extended approximately 1.5 times compared to the repair by austenitic welding rod (175MW vertical shaft Francis turbine x 6 units).

Specific Examples in which Electric Servomotors were adopted:

❏Jp. 17: The restoration work of the Nishikinugawa Hydro Power Station (Japan):
Applied the electric motor driven actuator on guide vane and runner blade servomotors (1.22MW S type tubular turbine)

❏Jp. 21: Renewal of the Doi Hydro Power Station (Japan):
Applied the electric motor driven actuator on guide vane and turbine inlet valve servomotors (8.47MW horizontal shaft, double type Francis turbine)

❏Jp. 22: Renewal project of Kamishiiba Hydro Power Station (Japan):
Applied the electric motor driven actuator on guide vane and turbine inlet valve servomotors (47.6MW vertical shaft, Francis turbine)

Specific Examples in which Hybrid Servomotors (Electric-hydraulic Hybrid Servomotors) were Adopted:

❏Jp. 13: Redevelopment of Shin-Nogawa No.1 hydropower plant (Japan):
Applied to guide vane and runner blade servomotors (10.5MW vertical shaft, diagonal turbine)

❏Jp. 20: Renewal of the Oguchi Power Plant (Japan):
Applied to guide vane servomotor (6.26MW Francis turbine x 2 units).

Specific Examples in which Oil-less (Greaseless) Bearings and Cooling Water-less were adopted:

❏Jp. 13: Redevelopment of Shin-Nogawa No.1 Hydro Power Plant (Japan):
Eliminated the cooling water system by applying the turbine head cover cooling system to turbine guide bearing oil bath, and phenol resin type gland packing to turbine shaft sealing (10.5MW vertical shaft, diagonal turbine)

❏Jp. 15: Restoration works on Toyomi Hydro Power Plant (Japan):
Applied the water lubricated bearing to turbine guide bearing, oil-less bearing to runner blade operating mechanism in runner boss, and improved the cooling system for generator (30.9MW vertical shaft, Bulb turbine)

❏Nw. 2 Hemsil 2 Upgrading of Hydropower Plant (Norway):
Applied the oil-less bearing to guide vane operating mechanism (49MW vertical shaft, Francis turbine x 2 units)

❏Fi. 1 Upgrading of Pirttikoki HydroPower Plant (Finland):
Lubricating oil in runner hub was replaced with oxygen-free water (76MW vertical shaft, Kaplan turbine x 2 units)

❑Au. 2 Tungatinah Modernisation Project (Australia):

Applied the water lubricated hydro static design type bearing to turbine guide bearing, and oil-less bearing to guide vane operating mechanism (25MW vertical shaft, Francis turbine)

❑US. 3 Cheoah Upgrade (USA):

Applied an oil-less bearing to guide vane stem (33.5MW vertical shaft, Francis turbine x 4 units)

a-3) Higher Performance of Hydropower by using Environmental Flow from a Dam

The environmental flow is intended to conserve the downstream landscape of the dam and to preserve the river ecosystems, and this flow was discharged from the exclusive-use facility provided on the dam. In recent years, there are many cases in which the maximum output and power generation of the plant is increased by providing a small-scale hydropower unit beneath the dam or at another site, thereby effectively utilizing the un-used energy of the environmental flow.

In general, the generating facilities using environmental flow are installed in existing power plants or inside dam facilities, and are often subject to the restrictions of the site space to be installed, construction techniques, and other matters. Since the output of the facilities are relatively small, high-speed and compact type units, simplified turbine generator constructions and control systems, and easier operation and maintainability is applied to secure economic efficiency. When selecting the suitable turbine generator type for this environmental flow plant, the following ingenuities were exercised:

- The characteristics of flow and head variations at the site were taken into consideration to adopt a sufficient turbine generator type and control system for the site.
- The unit was selected from not only previously used, conventional turbine generators, but also micro hydro units newly developed by many makers.

Specific Examples and Applied Technologies:

❑Jp. 1 :Houri No.2 hydropower Project／Environmental Flow Facility (Japan):

Simplified Francis Turbine Generator (35kW)

❑Jp. 16: New construction work of the Tsutimurokawa HPP using unused head of the existing dam／Utilization of natural discharge from lower dam of pumped storage power plant (Japan):

Horizontal shaft, 3 jet Pelton turbine（350kW、2 jets of fixed nozzle and 1 jet of adjustable nozzle）

❑Jp. 23: Construction project of Kawabaru ecological discharge power station／Environmental Flow Facility (Japan):

Integrates a turbine and a generator, Submersible type turbine generator (output=150kW)

❏Jp. 36 :<u>Expansion project for the Okutadami and Ohtori Hydropower Plant</u>／Environmental Flow Facility (Japan):
Horizontal shaft, Francis Turbine Generator (output=2,700kW)

<u>a-4) Upgrade of Facilities by Reusing Existing Embedded Steel Structures in Concrete</u>

If a remaining life assessment of existing facilities, by means of vertical barrel type turbine generators, demonstrate that it is feasible to re-use concrete-embedded generator barrels, turbine spiral casings, and draft tubes, the economic efficiency of plant renewals are enhanced by reducing civil cost through minimizing the excavation areas of the existing concrete basement. At the same time, renewal works are proceeded under operation of the adjacent units to reduce the waste electric energy as much as possible.

Furthermore, amid dimension restrictions of existing turbine casing and draft tubes, CFD is leveraged to accelerate or downsize the turbine generator, thereby enabling to renew the stay ring, guide vanes, and turbine runner. Likewise, the turbine efficiency and its maximum output are improved as well.

<u>Specific Examples in which Spiral Case and Draft Tube were left and used continuously:</u>

❏Jp. 24: Refurbishment of the Tagokura Hydro Power Station (Japan):
Upgraded sequentially in about two years per unit for the 4 units of vertical-shaft Francis turbine generator. Output upgraded from 380MW to 400MW.

❏Nw. 4: Upgrading of Hol No.1 Hydro Power Plant (Norway):
Renewed and output upgraded for vertical shaft Francis turbine
No.1 & 2 Unit: Output upgraded from 44MW to 57MW
(Head: 385⇒395m、Discharge : totally 6.0m^3/s increased for both units)
No.3 & 4 Unit: Output upgraded from 49MW to 53MW (Head : 350m⇒355m)

<u>a-5) Upgrade of the Turbines which Increases the Design Discharge within the Range of the Vested Water Right</u>

A particular case upgraded the output of adjacent turbine generators to increase power generation. This was achieved within the licensed water range by utilizing intake gates and draft tube outlet stop logs as well as coordinating the interfaces with other civil works.

In this case, the feasibility of various applicable turbine types such as Bulb, Kaplan, S type tubular and propeller turbines were investigated, and finalized by evaluating with a cost/benefit calculation method. The selected turbine performances were confirmed with a turbine model test after CFD analysis including the profiles of the water intake and draft tube.

Specific Example and Applied Technologies

❏Nw. 7: Upgrading of Rånåsfoss No.3 Hydro Power Plant (Norway):

Upgraded from the six units of horizontal shaft twin type Francis turbine (90m^3/s, 9MW) to the six units of vertical shaft propeller turbine (125m^3/s, 13.6MW)

2-b) System and Reliability Improvements in Protection & Control (P&C)

b-1) Renewal of the Conventional HPP Control System

Along with the establishment of recent IT technologies, digital control systems are becoming widely used in newly installed hydropower plants, and it is getting difficult to procure replacement parts such as the old magnetically operated analog relay circuit types and generator protection-control systems in existing power plants.

When these control systems are replaced, the reliability of the control system is improved by applying the new protection-control system based on PLCs with multiple control system-integrated panels.

The PLC based protection-control system integrated with the governor, automatic voltage regulator (AVR) and generator control panel has also been adopted to improve the system reliability. In some other cases, maintenance easiness has been enhanced, which can be observed in cases with integrated data acquisition (SCADA) systems and programmable logic controllers (PLCs) for supervisory control and failure diagnoses. (Refer to Case Au.1.)

Specific Examples in which the PLC Based Electronic Governors and Protection & Controls were installed:

❏Au. 1 : Poatina Modernization Project (Australia):

60MW x 6units Pelton turbine generator

❏Au. 2 : Tungatinah Modernization Hydro Power Plant (Australia):

25MW x 5units Francis turbine generator

b-2) Upgrade of the Pumped Storage Power Plant Control System

Since the pumped storage power plant has two operation modes, generation and pumping, the control system becomes more complicated compared to the system of conventional hydropower plants. Hence, the control system for the pumped storage power plant has been equipped with the automatic control systems as much as possible. Because these pumped storage power plants are often operated in generation and pumping modes in a short time, the old control panels equipped with the magnetically operated relay circuits are often likely to cause control failures due to aging, resulting in many problems in the operation of the plant.

In order to prevent these control failures, improvements in the operation and maintenance have been pursued by adopting PLC, digital protection relays, and also by collectively updating auxiliary equipment such as switch boards, governor, and turbine control panel.

Specific Examples:

❑Jp.14 :The first renewal of Shiroyama Hydro Power Station (Japan):

Collective update of control panels to automatic control sequencer, digitalized protection relays, switchboard, governor and turbine control panel (output=250MW)

❑Jp.25 :The renewal project of the control and monitoring system of the Okawachi Hydro Power Station (Japan):

Aiming to increase the reliability of control system, collective updates were executed by separating/decentralizing control system for power plant, switchgear and dam facilities. This separation/decentralization of existing control system was taken the advantages of existing total control systems, and taken into consideration not to affect the whole control system of the plant at the maintenance as well as the failure of each control system.

#1, #2 Unit (Turbine: 329kW, Pump: 340MW Constant speed type)

#3, #4 Unit (Turbine: 331MW, Pump: 392MW Adjustable speed type)

b-3) Constant Flow System Applied on a Standardized Package Type Water Turbine, and its Location Arranged

When small hydro power plants plan to use existing environmental flow facilities, the space to install the equipment is often subject to restriction. In some cases, the problem of space restriction could be resolved by adopting a package type turbine generator unit without expanding the space for the existing facilities. For example, two turbine generator units were installed in series to solve a space restriction problem, and the head and flow of both units were regulated by the control circuit so as to keep the environmental flow constant.

A Specific Example:

❑Jp. 26: The expansion of the power generation using ecological discharge facilities for the Kagehira Power Station (Japan):

Two units of horizontal shaft propeller turbine generator are arranged in series, and keep the environmental flow in constant. (Output=150kW)

2-c) Technological Innovation, Deployment Expansion and New Materials used for Civil and Building Works

c-1) Upgrading Dam under Operation

Adding new functions to an existing dam may require the dam's upgrading.

There were cases of adding the sediment sluicing function to a dam to resolve various issues such as dam sedimentation and coastal erosion due to sediment load, or upgrading a dam for effective use of water resources.

The cases of the Yamasubaru Dam and Saigo Dam, which added the sediment sluicing function, restored the respective rivers' original flow that had been blocked with the dams, so as to re-establish a sound water environment. Since the existing dam structures could not reduce the water level to enable sediment sluicing, the dams' height was partially reduced within the scope that would not cause structural problems. These were Japan's first-ever attempt of this kind. The cut-out shape of the dams was determined based on river safety, environmental conservation and effects on power generation, as it is an important factor that determines the effectiveness of sediment sluicing.

The Oguchi No.1 Dam adopted the gate-less system, removing the aging spillway gate, which required frequent discharge even with minor rainfall.

The Taishakugawa Dam underwent structural reinforcement and upgrading of its flood-handling capacity so as to make more effective use of water resource. The additional installation of spillway was combined with the laying of additional concrete on the downstream surface of the existing dam body to meet safety conditions. In laying the additional concrete on the downstream surface of the existing dam body, measures were taken to bond the new and existing concrete and address thermal stress.

Furthermore, in the upgrading of these existing dams, efforts were made not only to secure the stability and flood-handling capacity of the existing dams, but also to use the designs and construction methods that enabled continuous power generation.

Many of these cases are believed to provide useful reference in future upgrading of existing dams, e.g. when adding a new function to an existing dam.

Specific Examples:

❑ Jp.11 :Sediment sluicing engineering works of the Yamasubaru and Saigo Dams in the Mimikawa water system (Japan)
Yamasubaru Dam (H=29m, two central gates of the spillway gate were removed, cope level was lowered by 9.3m), Saigo Dam (H=20m, four central gates of the spillway gate were removed, cope level was lowered by 4.3m)

❑Jp.20 :Renewal of the Oguchi power station (Japan):
Gateless outlet design for Oguchi No.1 Dam (Dam height=26.943m, crest length=41.7m)
❑Jp.32 :The conservation measures construction of the Taishakugawa Dam (Japan):
Reconstructing Taishakugawa Dam (Concrete gravity Dam height =62m, crest length =36m)

c-2) Seismic Upgrading Measures of Water Channel Bridges (Water Tube Bridges) and Dam Gate Facilities of the Existing Dam

In Japan, amidst growing social awareness on emergency preparedness in recent years, power generation facilities are required to adopt emergency preparedness measures for large-scale earthquakes, from the perspective of preventing a disaster or business loss.

Existing dam gates and water channel bridges meet the seismic performance required under today's engineering standards. However, due to safety concerns in the event of a large-scale earthquake, a range of measures has been implemented to boost their seismic safety margin based on seismic performance assessment, such as dynamic analysis.

Four dams including the Sasamagawa Dam installed high attenuation dampers to the dam management bridge's bearings to improve the seismic safety margin of their dam gates, while two dams including the Jinichi Dam changed their radial gate's planar structure to increase the gates' seismic safety margin. The Kuttari Dam used gear couplings on the main torque shaft to improve the seismic safety margin of the spillway gate's winches.

Cases currently in progress include the Sekinosawa water tube bridge, whose steel locker supports are being upgraded for seismic isolation, and the Nojiri water tube bridge, whose Langer girders and ring girders are being reinforced to boost the bridge's seismic safety margin.

In implementing the seismic margin improvement work, project designs and methods were determined in view of the impact of having a lower water level at the dams on power generation operation, the projects' effect on national motorways running directly underneath the bridges, and the assurance of the sites' flood control capacity.

Many of these cases are believed to provide useful reference in the future implementation of emergency preparedness measures in anticipation for a large-scale earthquake.

Specific Examples in which Seismic Performance for Dam Gate Facilities was improved

❑Jp.28: The development of the seismic upgrading method of the dam spillway piers using existing control bridge (Japan):
Sasamagawa Dam (Radial gate×2, H=11.8, Width=9.0m) and other 4 Dams were applied
❑Jp.31: The replacement work of the radial gates of the Jinichi, Jinni, Hotokebara, Dams(Japan):
Jinichi Dam (Radial gate×9, H=12.35m, Width=9.2m) and other 2 Dams were applied
❑Jp.37: Repair and countermeasure of Kuttari Dam spillway gate damaged by earthquake (Japan):
Kuttari Dam (Roller gate×3、H=13.5m, Width=12.7m)

Specific Examples in which Seismic Performance for a Waterway Bridge was improved:

❏Jp.30: The aseismic bearing construction work of water-tube bridge (Japan):
Sekinosawa Waterway Bridge (Lohse arch bridge, L=60.0m, D=4.4m)

❏Jp.38: Anti-seismic reinforcement of the Nojiri Waterway Bridge of Totsugawa No.1 Power Station(Japan):
Nojiri Waterway Bridge（Pipe beam type waterway bridge、L=217.0m、D=4.2m）

c-3) Remodeling of Existing Intake Weir and Facilities

This section describes remodeling cases of existing intake weirs resulting from degradation due to ageing and recurrence of malfunction and accidents / disasters.

In remodeling due to aging / recurrence of malfunction, the Saigawa River Weir removed part of the weir and aged scour gate and transformed itself into a large-scale SR-synthesis shutter weir, as the small discharge capacity of the scour gate led to the frequent flushing of the fixed weir's gabions during overflow.

SR-synthesis shutter weir, flexible membrane shutter weir and steel shutter weir were considered as options. The steel shutter weir was excluded from the perspectives of economy and serviceability, as it would require the installation of large-scale facilities in the river bed. SR-synthesis shutter weir was selected in the comparison with flexible membrane shutter weir, from the perspectives of flow volume adjustment, energy loss and durability. SR-synthesis shutter weir has adopted various improvements for weir incline, fixing rubber cover, etc. to accommodate installation in Japan, where many river systems have rapid water flow and contain a large volume of soil and sand.

The intake weir at the Kawabegawa Daiichi Power Station was a case of restoring the existing intake weir, damaged in emergency. After the weir was damaged in overflow resulting from heavy rainfalls in the rainy season, it was remodeled into flexible membrane shutter weir, which offers better economic performance and easy discharge operations, thereby reducing management workload.

The SR-synthesis shutter weir was also considered. However, it was rejected because it had never been applied on a similar scale in Japan, and was considered to be technologically immature. Another reason was the extended amount of time required for designing, making it difficult to achieve swift restoration.

Many of these cases are believed to provide useful reference in the future remodeling of existing weirs.

Specific Examples:

❏Jp.29: Renovation construction work of the dam of the Saigawa HPP (Japan):
Suigawa river weir (Gabion structural weir, H=5.8m, L=268m) transformed into SR weir

❏Jp.35: The restoration work of the intake weir and others of the Kawabegawa No.1 HPP(Japan):
Fixed weir (Concrete gravity, H=11.5m, L=71.5m) transform into inflatable rubber weir

c-4) Application of New Materials for Penstock

This section describes cases that applied new materials for penstock in projects for renewing aged power plants and redevelopment projects using decommissioned power plant facilities.

The Yusuharagawa Daisan Power Station used FRPM pipes as penstock in the large-scale renewal of the 75-year-old power plant from the perspective of achieving minimum maintenance by eliminating paintwork. The use of FRPM pipes posed difficulty in achieving water-tightness at the joints between existing riveted pipes and FRPM pipes. However, the issue was resolved by developing and applying conjugating tubes added with tapered steel liners.

The Hanakawa Power Station, in its redevelopment project using decommissioned plant's facilities, inserted high-density polyethylene pipes into existing penstock to use them as double pipes. The conversion into double pipes eliminated the cost of removing existing facilities, thereby reducing the overall project costs.

Many of these cases are believed to provide useful reference in the future application of new materials for penstock.

Specific Examples:

❑Jp.34: The renovation project of the Yusuharagawa No.3 HPP (Japan):
Yusuharagawa No.3 HPP (Output=2,580kW, Discharge=7.79m^3/s, Head=41.8m), Employment FRPM pipe

❑Jp.41: The redevelopment construction project of the Hanakawa HPP (Japan):
Hanakawa HPP (Output=130kW, Discharge=1.00m^3/s, Head=17.8m), Employment Polyethylene pipe

c-5) Reuse of Existing Facilities and/or Equipment

This section describes cases that reused existing facilities in expansion or redevelopment projects. Making maximum use of existing facilities in expansion or redevelopment projects is important from the perspective of reducing construction costs.

The Shin-Kuronagi No. 2 Power Station used excess water flow in existing intake weir, headrace, water tank and penstock to expand its capacity. The Shin Onagatani No.1 Power Station arranged headrace routes to reuse existing penstock in the redevelopment project. The Shin-Taishaku Power Station reused an existing dam in its redevelopment, while the Hanakawa Power Station a decommissioned power plant's intake weir, headrace, water tank, plant foundation and discharge canal in the redevelopment project.

At the Shin-Kuronagi No. 2 Power Station, the project cost was around 40% less than the cost of building a new power plant of the same scale and system. At the Hanakawa Power Station, the civil engineering cost, which would normally accounts for around 60% of the overall cost, was kept at just 30%, enabling the redevelopment project to proceed.

Specific Examples in which Existing Facilities and/or Equipment are reused:

❏Jp.7 :The upgrading project of Shin-Kuronagi No.2 Power Station (Japan):
Shin-Kuronagi No.2 HPP (Output=1,900kW, Discharge=1.70m^3/s, Head=142.1m), Use of existing hydraulic department for the upgrading project

❏Jp.27 :The construction of project of the Shin-Oonagatani No.1 Power Station (Japan):
Shin-Oonagatani #1HPP (Output=7,500kW, Q=6.00m^3/s, Head=152.0m), Reusing existing penstock for the renewal project

❏Jp.32 :The conservation measures construction of the Taishakugawa Dam(Japan):
Shin-Taishakugawa HPP (Output=11,000kW, Discharge=10.00m^3/s, Head=129.0m), Use of existing dam for the renewal project

❏Jp.41 : The redevelopment construction project of the Hanakawa HPP (Japan):
Hanakawa HPP (Output=130kW, Q=1.00m^3/s, Head=17.8m), Reusing abolished facilities for the renewal project

2-d) Integration of Other Renewable Energies into Hydropower Systems

A hydropower plant generates electricity, but also requires some electric power for its operation. Electricity may be sourced easily if the power plant is located close to commercial power sources. However, this is not always easy, as hydropower plants are typically located in mountainous areas, or even in extremely remote locations.

The Togagawa II Power Station in Japan has one of the intake facilities in mountain streams, where commercial electricity for running the intake control gate is unavailable. Solar and wind powers are therefore used on the site to set up a power supply system. It combines solar power for providing power during the day, wind power for supplementing the solar system on rainy days and snowfall during winter and batteries for storing generated power. This case involved the integration and utilization of other renewable energies (solar and wind) for hydropower operation. The system can be applied to other hydropower cases requiring power supplies in remote areas.

The extent of development by power source tends to be emphasized with respect to the use of renewable energies as the power source. However, this case, which has developed a system that takes advantage of different renewable energies, could provide useful reference in standalone, small-scale operations in regional areas.

Specific Examples:

❏Jp.43 Gate control system by hybrid power system at Togagawa No.2 power station (Japan):
Solar power (84W×4), Wind power (3,200W×1), Battery (12V×105Ah×8)