Royal Government of Bhutan
Ministry of Economic Affairs
Department of Renewable Energy

Data Collection Survey on Renewable Energy in the Kingdom of Bhutan

Final Report

November 2013

Japan International Cooperation Agency (JICA)
Tokyo Electric Power Company (TEPCO)

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Executive Summary

1. Objectives of the Survey

The objective of Data Collection Survey on Renewable Energy in the Kingdom of Bhutan (hereafter "the Survey") is to review the significance of the Renewable Energy Master Plan (REMP , which was on the request of RGoB to the GoJ in September 2012), and also to conduct potential survey of the renewable energy sector including economic and technical feasibility. The objective of the REMP is to promote diversification of energy resources to enhance energy security in Bhutan.

2. National Energy Strategy

With regard to the national strategy of the country under the national philosophy of GNH, various policies such as visions and roadmaps have been proposed up to now. Regarding hydropower development, the "Sustainable Hydro Power Development Policy 2008" acts as a roadmap, and the Five-year Plan functions as the Action Plan to embody the roadmap. Alternative Renewable Energy Policy 2013 (AREP2013) is the roadmap for renewable energy in particular.

Source: JICA Survey Team

Figure 1 National Energy Strategy Framework

3. Current Power Supply and Demand Situation

The peak power demand recorded 280MW in November 2012. There exists approximately 1,500MW of hydropower generation, and it seems that there is sufficient supply capacity. However, since all hydropower stations are run-of-the-river types, electricity generation varies widely by season. Therefore, the amount of water will decline significantly in the dry season, and will only provide a supply capacity of approximately 300MW.

4. Promotion Scheme and Policy Challenges

(1) Implementation system for renewable energy promotion

The Department of Renewable Energy (DRE), Ministry of Economic Affairs plays the central role in promoting renewable energy.

(2) Target values

According to AREP2013, a preliminary minimum target of renewable energy is 20MW by 2025 through mix of renewable energy technologies.

- Electricity generation: solar 5MW, wind 5MW, biomass 5MW
- Energy Generation: biomass heat system 3MW equivalent, solar system 3MW equivalent

(3) Implementation Mechanism

- Fund Management works
  DRE acts as the leading party to carry out fund management works such as Renewable Energy Development Fund (REDF).
- Power Purchase Agreement (PPA) development works
  DRE takes the leading role to establish rules and/or framework of PPA. In addition, it is responsible for coordinating with related organizations. In the future, it will hire consultants and determine the details in approximately one year.
- Examination of and decision making for electricity costs (Feed-in Tariff)
  According to the related terms of the Electricity Act, Bhutan Electricity Authority (BEA) shall determine the fee for grid interconnection projects. In the future, it will examine and decide the details, assuming the process takes over a year before a decision is made.

(4) Possibility of Foreign Direct Investment

The Renewable Energy Policy states that "Investments in RE projects are open for investments from the private sector including FDI." According to the interpretation of DRE, RE projects (excluding small hydro power) can be invested 100% by foreign investors. Only minority share is admitted in case of small hydro power businesses.

In case of the electric power business using renewable energy, the company sells the generated electricity to BPC, and BPC makes payments to the company in the domestic currency (Nu.). However, as for the manufacturing sector (including electric power business), foreign currency exchanges of dividends are not allowed, and as a result, all earnings are in the domestic currency. Thus, the system does not attract foreign investors even if the level of FIT is high enough.

(5) Grasp of Royalty income level in the future

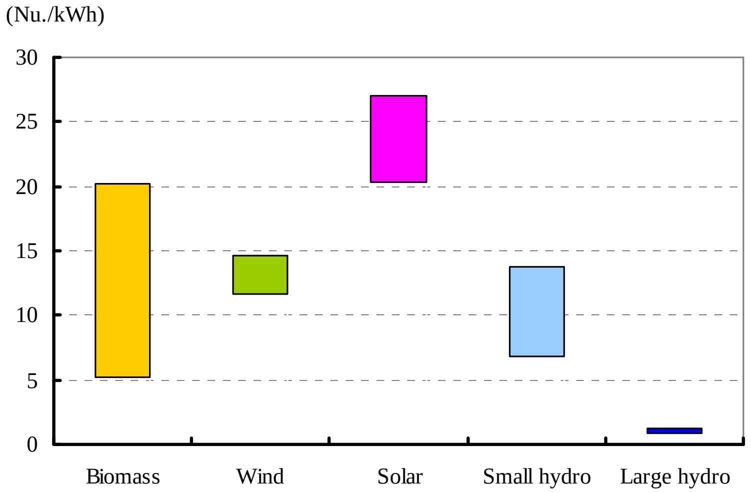
Assuming that the demand for electricity up to 2025 will be about twice the current level, and the subsidies for electricity tariffs will double as well, the compensation amount is estimated to be about

2,200 million Nu. This number when compared to the Royalty sum (15,000 million Nu.) is not a very large portion.

Therefore, it is presumed that if hydropower were to be developed smoothly, funding sources of REDF that rely heavily on Royalty revenue from hydroelectric power would be sufficient.

5. Cost Estimation of each Renewable Energy

The calculation result of the power generation cost of various power sources is shown below. As expected, the power generation cost of various renewable energy is different, and the cost of all renewable energies is higher than 2.3 Nu/ kWh which is the average cost of supply shown by BEA.



Source: JICA Survey Team

Figure 2 Power Generation Cost of various Power Sources

6. Significance of REMP and Road map for creation of REMP

(1) Significance of REMP

The Survey Team assessed the necessity of energy portfolio in Bhutan and concluded that it is difficult to find any basis for the urgent necessity of energy diversification by renewable energies: there is ample electricity supply to suffice domestic demand now and in the future in Bhutan compared to the total electricity generated because of the development of large-scale hydro power projects; promoting renewable energy could be so much more costly compared to large-scale hydro power, which could be a financial burden to Bhutan; and there are studies reporting that global warming is actually increasing the river flow rate due to an increase in sea water evaporation and then rainfall. From the above reasons, the level of necessity of urgently developing renewable energies is not so high.

However, proactively promoting the utilization of unused energy is of significance as this will lead to effective usage of the resources on earth and the mitigation of GHG emissions. In addition, according to the GNH policy that is the basic policy of Bhutan, there are 4 pillars, which are "promotion of sustainable development", "preservation and promotion of cultural values", "conservation of the natural environment", and "establishment of good governance". Considering very small environmental impact of renewable energy development, it is thought that renewable energy is an excellent tool to satisfy "promotion of sustainable development" and "conservation of the natural environment" simultaneously.

(2) Road map for formulation of RE Master Plan

According to AREP2013, the renewable energy master plan will be prepared in 3 years. However, because data reliability is very low, it is difficult to make the master plan now, and therefore it is necessary to accumulate reliable data through the entire area of Bhutan.

If Bhutan were to create the RE Master Plan, then the recommended road map is as follows.

Table 1 Road Map for RE Master Plan

		Year 1	Year 2	Year 3
Potential Survey				
Accumulation of reliable data	DRE			
Estimation of RE potential	DRE			
Estimation of RE economical potential	DRE			
Prioritization of RE potential area	DRE			
Preparation of Promotion Scheme				
Check cost level of each RE	DRE			
Establishment of FIT	BEA			
Establishment of PPA	DRE			
Revision of FDI policy	DOI			
Arrangement of Study Structure				
Establishment of new organization	DRE			
Preparation of measurement instruments	DRE			
Training (Study tour)	DRE			

Source: JICA Survey Team

It is very important that the DRE staff act as a leader in the master plan creation and make the master plan from Bhutanese people's view points. However, it is the first time that Bhutan creates its own renewable energy master plan, and the DRE staff have little experience and knowledge. Therefore, support by overseas specialists can be considered, if necessary.

7. Study for Specific Project

(1) Photovoltaic Generation Project

The candidate site is Shingkhar (Bumthang), which is about 20 km in a straight line and 40 km along the road from Jakar in Bumthang to east-northeast. The coordinates are 27 30'15" N and 90

57'25" E, and the altitude is about 3,500m. It is an unused slope area of about 7.7% facing south-southwest, a wetland area with huge patches of marshes across the area. The proposed area is government land and the buffer area of a protected area, and there are no residents. The proposed area is located near an unpaved road and 1.3km away from the closest 33 kV distribution line. Moreover, Bumthang is an area where the amount of solar radiation is relatively high, so the proposed area can be considered as an appropriate choice for the installation of a mega solar system in Bhutan.

(2) Small Hydropower Project

Small hydropower plants can be introduced to a number of potential areas if there are sufficient funds for the hydropower development. The Survey Team considered Khoma (Lhuntse) as potential site for small hydro due to high average specific discharge (2.3 m3/s/100km2), and consequently Chapcha (Chhukha), Chuzomsa (Wangdue), Tingtibi (Zhemgang), Chella (Trongsa), Langthel (Trongsa) and Lingmethang (Mongar) seem to be also economically equivalent to Khoma site. There seem to be high priority of development in these candidate sites. However, it is important that several arrangement pattern regarding the powerhouse, intake facility should be examined and that the most economical plan should be selected among the several patterns when actual hydropower development is planned.

(3) Windpower Project

It seems to be possible to develop an extension to the ongoing windpower pilot project supported by ADB at the Rubessa (Wangdue) site according to the information given by DRE. There is also a Sibsoo (Samtse) area as a potential site which the Survey Team feels could be a potential site besides Rubessa. Sibsoo is the only potential site out of 17 Meteorological weather observation data points in Bhutan. From the conditions of the whole transportation route in Bhutan, the Survey Team assessed that a vehicle with approximately 12m of full length could transport materials in Bhutan. With this transportation limitation, the longest blade which is part of the component parts of Wind Turbine Generator (WTG) would be approximately 15m (equivalent to 300kW/unit).

(4) Biomass Generation Project

For biomass resources in Bhutan, 76.9% of the total is forest resources, amounting to 1.56 million t/ year, which is equal to 20.97 million GJ/ year. The potential quantity of biomass resources, supply of biofuel, and the point of effective utilization were considered, and it became clear that a Haa point was advantageous. Regarding the generation capacity, a system with 20 to 30kW should be suitable, and a system with around 100kW also could be applied by collecting material from 3 or 4 sawmill factories.

(5) Comprehensive Evaluation

The position of each specific project is shown below.

Source: created by JICA Survey Team based on the Google earth

Figure 3 Position of each Specific Project

The calculation result of the generation costs of the projects that have been proposed in this report becomes as follows.

Table 2 Generating Costs of the concrete Renewable Energy Projects

	Site	Dzongkhag	Capacity (kW)	Unit const. cost (USD/kW)	Life (years)	O&M cost to const. cost	Generation cost (Nu/kWh)	Const. cost (million USD)
Solar	Shingkhar	Bumthang	1,000	3,400	25	1.0%	18.9	3.40
Small hydro	Khoma	Lhuntse	4,170	2,500	30	0.6%	3.4	10.40
Wind	Rubessa	Wangdue	300	2,000	20	2.5%	14.2	0.60
Biomass	Haa	Haa	100	1,300	20	3.1%	7.2	0.13

Source: JICA Survey Team

The annual availability rate of small hydro power is high compared with other renewable energy even if the supply power decreases in winter, thus a lot of electric power is expected to be generated and the power generation cost is the cheapest. However, the generation cost is higher than the large-scale hydroelectric power plants and is about twice the electric tariff rate. Some support measures such as FIT is still necessary though the economical possibility is the highest and there are a number of project sites at an equal level besides the proposed projects.

As for biomass, wind power, and solar, annual availability rate is low with 20% or less, and the power generation cost is greatly higher than the electric tariff rate. Therefore, great support measures, such as high FIT, subsidy by REDF, are necessary for executing a concrete project.

8. Proposal for Direction of Future Cooperation

- Technical cooperation for renewable energy master plan
- Support for pilot project(s)
- Production of bio-fuel

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Abbreviation

Abbreviation	Words
ABC	Arial Bunched Conductors
ADB	Asian Development Bank
AED	Alternative Energy Division
AMC	Agriculture Machinery Centre
AREP	Alternative Renewable Energy Policy
ASEB	Assam State Electricity Board
ATF	Aviation Turbine Fuel
BBP	Bhutan Biogas Project
BDBL	Bhutan Development Bank Limited
BDFCL	Bhutan Development Finance Corporation Limited
BEA	Bhutan Electricity Authority
BOO	Build Own Operate
BOOT	Build-Own Operate Transfer
BPC	Bhutan Power Corporation
BLSS	Bhutan Living Standard Survey
BTFEC	Bhutan Trust Fund for Environmental Conservation
CA	Competent Authority
CDM	Clean Development Mechanism
CEA	Central Electricity Authority
CFD	Computational Fluid Dynamics
CFT	Cubic Foot
CSO	Civil Society Organizations
DAC	Development Assistance Committee
DCR	Development Control Regulations
DEO	Dzongkhag Environment Officers
DF/R	Draft Final Report
DGPC	Druk Green Power Corporation
DHMS	Department of Hydro-Met Services
DHPS	Department of Hydropower & Power System
DNA	Designated National Authority
DNHS	Department of Hydro-meteorological Services
DNI	Direct Normal Irradiance
DoA	Department of Agriculture
DOE	Department of Energy
DoFA	Department of Forests and Agriculture
DoFPS	Department of Forest & Park Services
DOL	Department of Livestock
DOP	Department of Power
DPR	Detailed Project Report
DPT	Druk Phuensum Tshogpa
DRE	Department of Renewable Energy

Abbreviation	Words
DYT	Dzongkhag Yargay Tshogdu
EC	Environmental Clearance
EIA	Environmental Impact Assessment
EPC	Engineering, Procurement, Construction
EU	Environment Unit
FDI	Foreign Direct Investment
FIT	Feed-in Tariff
FMU	Forest Management Unit
FR	Final Report
F/S	Feasibility Study
FY	Fiscal Year
GAO	Gewog Administrative Officer
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GIS	Geographic Information System
GLOF	Glacial Lake Outburst Flood
GNH	Gross National Happiness
GNHC	Gross National Happiness Commission
GYT	Gewog Yargay Tshogchung
HCFC	Hydrochlorofluorocarbon
HMSD	Hydro-met Services Division
HP	Hydroelectric Power
HPP	Hydroelectric Power Plant
HV	High Voltage
ICB	International Competitive Bidding
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IEE	Initial Environmental Examination
IRR	Internal Rate of Return
Ic/R	Inception Report
IS	Indian Standard
It/R	Interim Report
IUCN	International Union for Conservation of Nature
JICA	Japan International Cooperation Agency
JPEA	Japan Photovoltaic Energy Association
JV	Joint Venture
LCMP	Land Cover Mapping Project
LPG	Liquefied Petroleum Gas
LV	Low Voltage
MBO	Mutual Benefit Organization
MDGs	Millennium Development Goals
MoAF	Ministry of Agriculture & Forests
MoEA	Ministry of Economic Affairs

Abbreviation	Words
MSTCCC	Multi-sectoral Technical Committee on Climate Change
MSW	Municipal Sewage Waste
MTI	Ministry of Trade and Industry
MV	Medium Voltage
NA	Nodal Agency
NASA	National Aeronautics and Space Administration
NBC	National Biodiversity Center
NCCC	National Climate Change Committee
NDFB	National Democratic Front of Bodoland
NEC	National Environment Commission
NEDO	New Energy and Industrial Technology Development Organization
NEF	New Energy Foundation
NGO	Non-Governmental Organizations
NLC	National Land Commission
NORAD	Norwegian Agency for Development Cooperation
NOK	Norwegian Krone
NRDCL	Natural Resources Development Corporation Limited
NRPC	Natural Resource Pricing Committee
NREL	National Renewable Energy Laboratory
NSB	National Statistics Bureau
NTGMP	National Transmission Grid Master Plan
NWFP	Non-wood Forest Product
OECD	Organization for Economic Co-operation and Development
O&M	Operation and Maintenance
PBO	Public Benefit Organization
PLF	Plant Load Factor
PPA	Power Purchase Agreement
PDD	Project Design Document
PDP	People's Democratic Party
PV	Photovoltaic
RE	Renewable Energy
REDD	Reducing Emissions from Deforestation and Degradation
REDF	The Renewable Energy Development Fund
REMP	Renewable Energy Master Plan
RGOB	Royal Government of Bhutan
RSPN	Royal Society for the Protection of Nature
SEA	Strategic Environmental Assessment
SHS	Solar Home System
SNV	Netherlands Development Organization
SRBE	Bhutan Sustainable Rural Biomass Energy
SVR	Step Voltage Regulator
TOE	Tonne of Oil Equivalent
TOR	Terms of Reference

Abbreviation	Words
UN	United Nations
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
ULFA	United Liberation Front of Assam
USAID	United States Agency for International Development
UWICE	Ugyen Wangchuck Institute for Conservation and Environment
WB	World Bank
WBSEB	West Bengal State Electricity Board
WTG	Wind Turbine Generator
WWF	World Wildlife Fund

Chapter 1 Introduction

1.1 Background

The Royal Government of Bhutan (hereafter “RGoB”) has implemented national development plans with consideration not only for financial or physical prosperity, but also traditional social manners and culture or environment, based on Gross National Happiness (hereafter “GNH”), which regards people’s spiritual wealth as important. Environmental protection is an important consideration in overall political decisions. Recently in Bhutan, the generation capacity of hydro power (1,497MW as of 2010) has been beyond the maximum demand (257MW as of 2010) due to rich water resources and differences in elevation. The surplus power is sold to India, the sale of which contributes to the economic growth in Bhutan. Although Bhutan depends on hydro power generation at the rate of 99% of the total generation capacity, there is a possibility that river water necessary for hydro power will dry up due to climate change. Therefore, the RGoB started to consider diversification of energy resources, rather than depend on large-scale hydro power as the only resource.

Based on the above-mentioned background, in Sustainable Hydro Power Development Policy 2008 and Economic Development Policy 2010, the RGoB declared the significance of its Renewable Energy Master Plan (hereafter “REMP”) to enforce energy security, with the development of renewable energy other than hydro power.

On 8th April 2013, the RGoB published “Alternative Renewable Energy Policy 2013,” including the promotional measures of financial incentives and restructuring of electricity tariffs, while recognizing that the renewable energy sector has relatively low competitiveness from the view of generation cost than that of hydro power. In addition, in September 2012, the RGoB requested the Government of Japan (hereafter “GoJ”) to support the establishment of its REMP.

1.2 Objectives and Survey Contents

1.2.1 Objectives

The objective of Data Collection Survey on Renewable Energy in the Kingdom of Bhutan (hereafter “the Survey”) is to review the significance of the REMP (as creation of REMP was requested by the RGoB to the GoJ in September 2012), and also to conduct potential survey of the renewable energy sector including economic and technical feasibility. The objective of the REMP is to promote diversification of energy resources for energy security in Bhutan. Specifically, upon review of past projects, data collection on the renewable energy sector, such as solar, wind, biomass, and small hydro is to be conducted across all 20 districts in Bhutan. The significance of the REMP, through economic and technical review as well as future cooperative projects in the renewable energy sector with JICA is also discussed.

1.2.2 Survey Area

All 20 districts in Bhutan

1.2.3 Survey Contents

(1) Basic Information

- Past projects and current issues on power policy in Bhutan and the position of Renewable Energy in power policy
- Necessity of electricity and heat in the central government and other target area
- Current situation and issues of electrification rate and heat usage rate, countermeasures for the issues
- Electricity usage rate in electrified housings and buildings
- Utilization of energy as heat source
- Current situation and forecast of market mechanisms in the renewable energy sector
- Policies and experience of renewable energy in Japan
- Support from NGOs and donors
- Current issues of transmission and distribution lines in Bhutan
- Environmental and social considerations and safety and security for the renewable energy sector
- Trends, current situation and forecast of Japanese businesses in Bhutan for the renewable energy sector
- Current situation and forecast of ongoing projects of Japanese businesses
- Potential areas and projects for the renewable energy sector
- Calculation for economic calculation (estimation) and procurement for the renewable energy sector

(2) Review of the Renewable Energy Sector

- General information of potential areas and sectors for the renewable energy sector
- Projects of Japanese businesses in the potential areas and sectors
- Projects of RGoB and donors in the potential areas and sectors
- Expectations and interests of RGoB in the potential areas and sectors
- Data collection on decision making mechanism, key persons and their opinions relating to the potential areas and sectors
- Possible contribution by Japanese companies for the renewable energy Sector in Bhutan
- List of Japanese businesses which are interested in renewable energy business development
- Significance, necessity and urgency of development of the potential areas and sectors
- Economic and technical feasibility for development of the potential areas and sectors
- Possibility of renewable energy utilization as an alternative resource to fossil fuels, and improvement factor in environmental issues
- Possibility of registration for renewable energy CDM projects

- Issues after connecting renewable energy into the grid (interconnection, power system operation, collection of electricity tariff)
- Possibilities and trends of other projects in the renewable energy sector
- Possibility of cooperation with other donors

(3) Significance of REMP

- Contents of survey, merits/ demerits
- Specific proposals for future cooperative projects with JICA
- Content which JICA needs to follow up on the Survey

1.3 Implementation Structure of the Survey

1.3.1 Counterpart

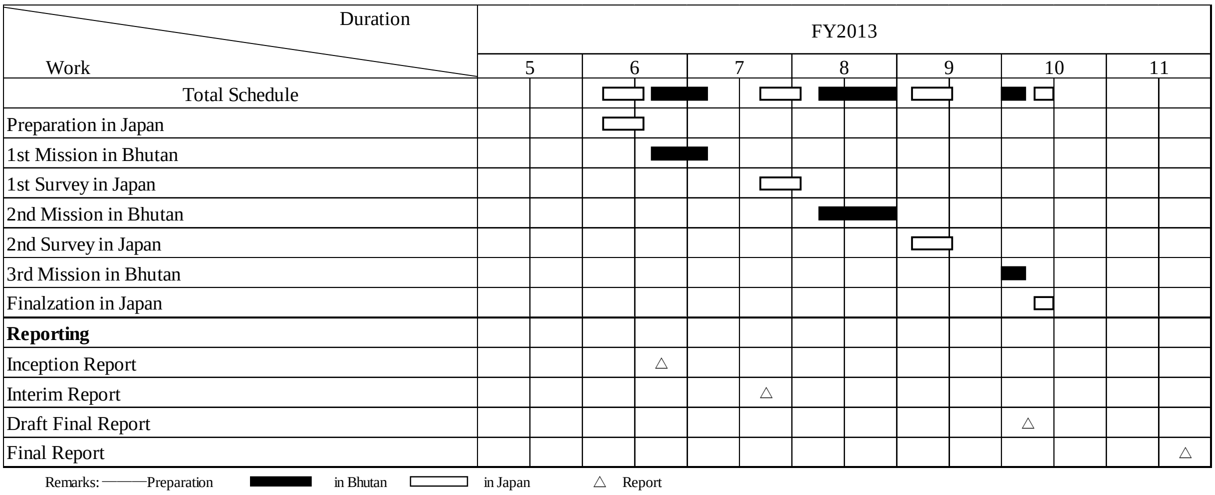
Department of Renewable Energy, Ministry of Economic Affairs

1.3.2 Survey Team

- Team Leader/ Power Policy, Energy Cooperation Plan A: Noboru Seki
- Power Policy, Energy Cooperation Plan B: Toshiyuki Kobayashi
- Renewable Energy (Solar Power): Keiichi Fujitani
- Renewable Energy (Wind Power): Takashi Suzumura
- Renewable Energy (Biomass A: Combustion/ Generation Technology): Yoichiro Kubota
- Renewable Energy (Biomass B: Fuel Procurement): Genshiro Kano
- Renewable Energy (Small Hydropower): Yoshihiro Shindo
- Social Consideration: Mitsue Mishima
- Environmental Consideration: Mayo Mukai
- Power System: Shinichi Funabashi
- Japanese Business Contribution: Yoko Kimura

1.4 Survey Schedule

The following figure shows the survey schedule.



Source: JICA Survey Team

Figure 1-1 Survey Schedule

Chapter 2 Basic Information on Bhutan

2.1 Political and Economic Situation

2.1.1 Political Situation

RGoB maintains a bicameral system with the National Assembly (Gyelyong Tshogdu) established by the 3rd king in 1953, and the State Council (Gyelyong Tshogde) newly established by the new Constitution in 2008. The National Assembly consists of 47 lawmakers elected by a popular election and a single member constituency system, and the State Council consists of 20 persons elected for each district from the 20 districts, and five well-informed persons whom the king appoints, for a total of 25 persons. A lawmaker's term of office is five years in both houses.

The first National Assembly election was held on March 24, 2008; the Virtuous Bhutan Party (hereafter, DPT) acquired an overwhelming 45 seats, and the People's Democratic Party (hereafter, PDP) of the 2nd party acquired two seats. Five appointment lawmakers of the State Council were determined and the bicameral composition was decided on March 28. The Jigme Yoser Thinley, leader of the DPT which won in April of the same year in the House of Representatives election, was appointed as the prime minister, the new cabinet was inaugurated, and the new diet was called in May. The new constitution was enforced in July.

The 2nd National Assembly election was carried out on July 13, 2013. As a result of the election, the PDP gained a majority and became the governing political party.

2.1.2 Economic Situation

The shift to the market economy from subsistence economy has been progressing and high economic growth rate has been attained, primarily due to electric power exports to India in recent years. Moreover, there is a plan to build a special industrial area and an industrial complex in order to attract foreign investments by using the advantage of the cheap electricity. During the "Tenth Five Year Plan" (From July 2008 to June 2013) in order to accelerate economic growth and to narrow the regional gap, the Plan set a higher rank target to lower the poverty rate from 23.2% in 2007 to 15% in 2013, with Vitalizing Industry as core strategy. The following items were determined as important and the required measures were devised.

(1) National spatial planning
(2) Synergizing integrated rural urban development
(3) Expanding strategic infrastructure
(4) Investing in human capital
(5) Enhancing enabling environment

Although the major industry is agriculture (including rice, wheat and forestry), making up about 35% of GDP, the greatest export commodity is electric power from hydro power plants. Taking advantage of a country being located on the slopes of the Himalayan Mountains, hydro power generation via abundant hydraulic power was performed, and income from overseas has been obtained by selling off electric power to India. The main exports are electric power, silicon iron, nonferrous metal, metal goods, cement, and the main imports are light oil, gasoline, metal goods, rice, small excavators and coal. Moreover, there is a plan to build a special industrial area and an industrial complex in order to attract foreign factories by using the advantage of the cheap electric rate.

2.2 Geographic and climate condition

Bhutan is located in the southern foot of the Himalaya Mountains. The size of the country is almost the same as Kyushu prefecture in Japan (approximately 38,000 km^2). The altitude ranges from more than 7,000 m in the northern area along Chinese border to 300 m in the southern area.

The climate classification of Bhutan can be roughly divided into three. The northern area at above 3,000 m around the Himalaya Mountains is classified as alpine climate or tundra climate. The middle area at approximately 1,200 m – 1,300 m belongs to monsoon climate. The southern area of Terai plain at below 1,200 m is under torrid climate.

Regarding a change of the seasons, Bhutan has four seasons, such as spring (March to May), summer (June to August), autumn (September to November), and winter (December to February). The rainy season starts in June, and ends in August. During the other period, it is dry season. As for the characteristics of each area, Punakha, Wangdue Phodrang, Mongar, Trashigang and Lhuntse are classified as monsoon climate. Even in winter, it does not get very cold in those areas. On the other hand, the climate of Thimphu, Trongsa and Bumthang is comparatively warmer. In summer, it is humid due to rainy season. The temperature of summer is around 22-28 °C on average. In winter it rarely rains due to dry season. The temperature of winter is up to around 16-19 °C at noon and declines below 0 °C. In spring, it is warm at 20-25 °C on average.

For Bhutan, forest is precious natural resources, and 70 % of the population makes a life from the forest sector. Forest accounts for 80.88 % of the total land. Bhutan ranks in the top ten percent of countries with the highest species density in the world, and it has the highest fraction of land in protected area with 50 % of forest cover. Therefore, in the whole countries, a number of forests are managed at community level, and forests under communities are 388 as of July 2013. Among them, 60 communities manage the forest resources which are not classified into trees such as bamboo thicket, medicinal herb, and lemongrass, but into non-wood forest product (NWFP), and this is to preserve the forest totally and aim at sustainable, economic development.

2.3 Social Situation

2.3.1 Characteristics of Each Region (Dzongkhag)

(1) Population and Area

In terms of administrative divisions, it is divided into 20 districts, or Dzongkhag in Bhutanese. Area, population, and population density in each district are shown in Table 2-1. The urban population is 37% of the total and the remaining 63% is rural population. Bhutan's capital, Thimphu, has an approximate population of 110,000, which means, one seventh of the population is concentrated there. Chukha, Samtse, and Trashigang have populations of over 50,000, while other districts have populations of around 10,000 to 40,000. Gasa has a very small population of around 3,000 people. Population density is relatively small, with 62 inhabitants/ km² in the capital and about 19 inhabitants/ km² across the whole country.

Table 2-1 Area, Population, Population Density by Region

District	Area (km^2)	Population	Population Density (habitants/km^2)
Bumthang	2,718	18,412	6.8
Chhukha	1,880	85,608	45.5
Dagana	1,723	26,553	15.4
Gasa	3,135	3,580	1.1
Haa	1,905	13,147	6.9
Lhuentse	2,859	17,200	6.0
Monggar	1,945	42,843	22.0
Paro	1,287	41,852	32.5
Pemagatshel	1,022	24,646	24.1
Punakha	1,110	26,981	24.3
Samdrup Jongkhar	1,877	39,405	21.0
Samtse	1,305	68,579	52.6
Sarpang	1,656	43,915	26.5
Thimphu	1,796	111,305	62.0
Trashi Yangste	1,449	20,266	14.0
Trashigang	2,204	54,768	24.8
Trongsa	1,814	15,502	8.5
Tsirang	638	21,209	33.2
Wangduephodrang	4,036	36,279	9.0
Zhemgang	2,417	20,956	8.7
Bhutan	**38,776**	**733,006**	**18.9**

Source: Office of the Census Commissioner "Result of Population & Housing Census of Bhutan 2005"

(2) Industry

The Industry sector in Bhutan has not been developed much until recent years. In terms of the main mineral resources, although there are dolomite (for cement production), lime stone, gypsum, coal, marble and others, development of mineral production for these is relatively limited and on a small scale. With respect to the number of enterprises by type, as indicated in Table 2-2, 94% of the total is service-related (including the category of "Contract"). The others are agriculture and forestry-based enterprises. In terms of district-wise in the same table, there are many agriculture-based enterprises in Chukha, Thimphu, Sarpang and relatively more forestry-based enterprises exist in Paro, Chukha, Haa, Thimphu, Bumthang, Mongar and Trashiyangtse. Examining the scale of domestic enterprises in the industry sector, they are mostly in the category of cottage industry (87%), with the next being small-scale (12%). Medium and large-scale enterprises are only 0.02% (353 enterprises) of the total.

Table 2-2 Number of Enterprises by District and Type

District	Agro based	Forest based	Mineral based	Services	Contract	Other	Total
Bumthang	19	63	2	671	293	6	1,054
Chukha	53	55	32	2,841	916	113	4,010
Dagana	2	1	4	416	318	1	742
Gasa	1	1	0	74	43	0	119
Haa	2	46	1	228	298	3	578
Lhuntse	2	8	0	187	176	1	374
Monggar	13	61	6	869	465	6	1,420
Paro	15	144	20	1,419	615	32	2,245
Pemagatshel	10	28	18	513	317	9	895
Punakha	1	8	1	425	321	1	757
Samdrup Jongkhar	16	27	7	856	383	14	1,303
Samtse	24	19	44	725	384	16	1,212
Sarpang	51	35	11	1,281	581	13	1,972
Thimphu	46	165	31	7,323	4,506	408	12,479
Trashigang	8	39	5	762	614	14	1,442
Trashiyangste	2	60	1	201	221	1	486
Trongsa	5	11	2	452	255	0	725
Tsirang	11	8	5	334	173	0	531
Wangduephodrang	3	24	18	885	730	7	1,667
Zhemgang	7	28	1	337	307	1	681
Bhutan	**291**	**831**	**209**	**20,799**	**11,916**	**646**	**34,692**

Note: "Contract" means the contractor company in construction work.

Source: NSB "Bhutan Statistical Year Book 2012"

(3) Poverty Analysis

According to the most recent "Bhutan Poverty Analysis 2012" by the National Statistics Bureau (NSB) and World Bank (WB), the national poverty rate is 12%. The report stated that it had been reduced to approximately half (improvement of 11 points) of the 23.7% figure recorded in 2007. Comparing the districts (Table 2-3), improvement is observed in each district. However, while Lhuntse and Mongar in the Eastern area and Samtse in the Western area improved dramatically by more than 20 points, Zhemgang and Samdrup Jongkhar in the same Eastern area improved by only 3 and 5 points respectively. Districts which have a poverty rate of over 20% are Lhuntse (32%), Pemagatshel (27%), Samdrup Jongkhar (21%), Zhemgang (26.3%), Samtse (22%), and Dagana (25%).

Table 2-3 Transition of Population Poverty Rate by Region

District	Population Poverty Rate (%)	
	2007	2012
Bumthang	10.9	3.4
Chukha	20.3	11.2
Dagana	31.1	25.1
Gasa	4.1	<0.5
Haa	13.2	6.4
Lhuntse	52.9	31.9
Mongar	43.0	10.5
Paro	3.9	<0.5
Pemagatshel	44.4	26.9
Punakha	15.6	10.0
Samdrup Jongkhar	26.2	21.0
Samtse	46.8	22.2
Sarpang	19.4	4.2
Thimphu	2.4	0.5
Trashigang	38.0	11.5
Trashiyangste	14.3	13.5
Trongsa	22.2	14.9
Tsirang	13.9	14.8
Wangdue Phodrang	15.8	10.9
Zhemgang	29.3	26.3
Bhutan	**23.2**	**12.0**

Source: NSB "Bhutan Statistical Year Book 2012"

2.3.2 Local Administrative Organization (in connection to local community) and Governance

Since 1980, with the principle of participation of local residents, decentralization has been promoted in Bhutan, and a local administrative structure has been established. As a decentralized public administrative organization, there are 20 districts and 205 blocks (Gewog) under the districts, with district/dzongkhag administrator and gewog/block head man (in Bhutanese, “Gup”) at the top of each administration.

Upon formulating the development plan at each district, the district development committee (in Bhutanese, Dzongkhag Yargay Tshogdu: DYT), which consists of representatives selected by local people and district public officers, is in charge of drafting the plan. Similarly, for formulation of development plans at block level, there is a block development committee (Gewog Yargay Tshogchung: GYT), which consists of block head, sub head (Mangmi), representatives of communities in the block (Tshogpas), and block/gewog administrator (GAO) who has the role of secretary for GYT.

Each block comprises several communities; however, each community unit can be one or several villages. Community representative “Tsogpas” perform the important role of collecting residents’ opinions in the community and reflecting them in the public administration.

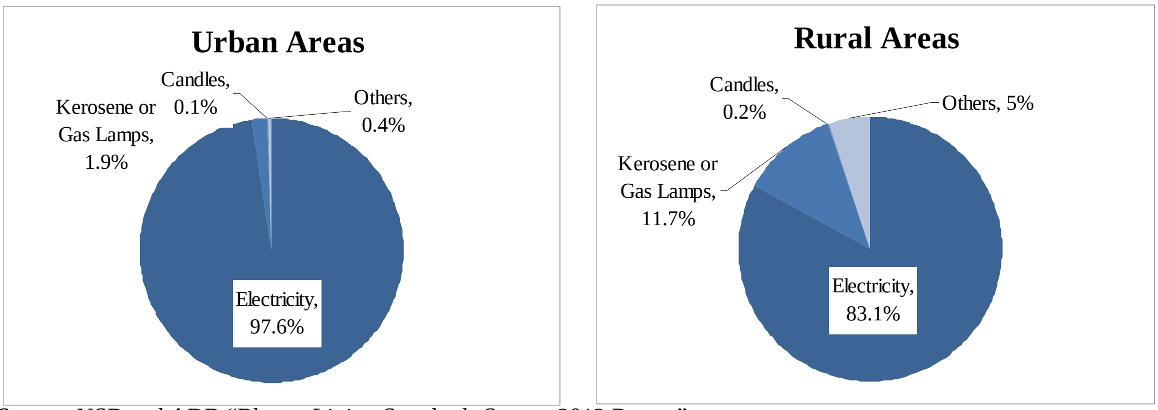
2.3.3 Energy Use in Daily Life

(1) Access to Electricity

In Bhutan, access to electricity has improved remarkably in recent years as a result of the promotion of the policy, “rural electrification coverage to 100% by 2013” through grid extension or the supply of solar power generation facilities in areas where it is difficult to provide grid extension. According to the “Bhutan Living Standard Survey (BLSS) 2012 Report”, the share of households with electricity access is 92% in urban areas and 87% in rural areas. In terms of the same figure by district, Zhemgang (70%), Mongar (82%) and Samdrup Jongkhar (80%), in the Eastern area, and Dagana (80%), in the Central area, are relatively lower than other districts. These districts have a lower share of access to electricity by grid extension, 46% in Zhemgang and 70% or more in the other three districts. In these areas, the share of households which use solar power generation as a source of electricity is higher than in other areas. In the case of Zhemgang, access to electricity by solar power generation is 18%, and by generator, 6.1%. In the case of Gasa, a high mountainous area, the electrification rate by grid is 36%, and by solar power generation, 61%.

(2) Main Energy Sources by Purpose of Use

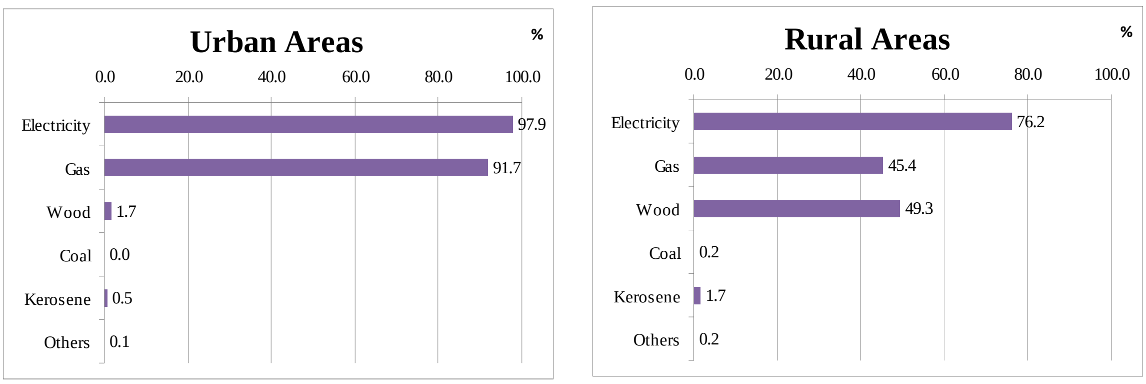
As a result of the remarkable improvement in nationwide access to electricity, the main source of energy for lighting in daily life is electricity. In rural areas, however, the use of kerosene or gas lamps still occupies 12% of the total (refer to Figure 2-1). Reviewing the same figure among only poor rural households in "Bhutan Poverty Analysis 2012", the share of households which use electricity for lighting is 69%, with 22% using kerosene lamps.



Source: NSB and ADB "Bhutan Living Standards Survey 2012 Report"

Figure 2-1 Share of Energy Use for Lighting by Source in Urban and Rural Areas

As a heat source for cooking, several energy sources are used and the majority in urban area uses gas or electricity. In rural areas, most households (76% of the total) use electricity, 49% use fire wood and 45% use gas. This implies that firewood is still often used in rural areas (refer to Figure 2-2).



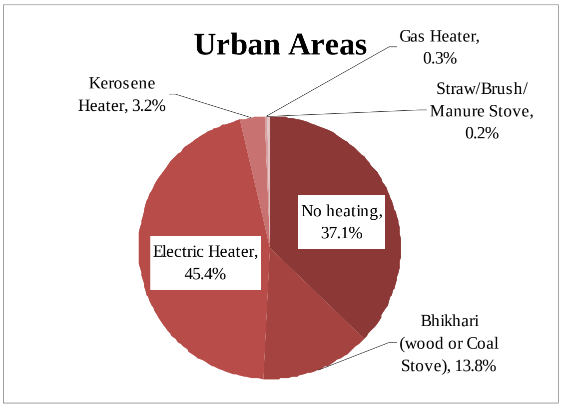
Source: NSB and ADB "Bhutan Living Standards Survey 2012 Report"

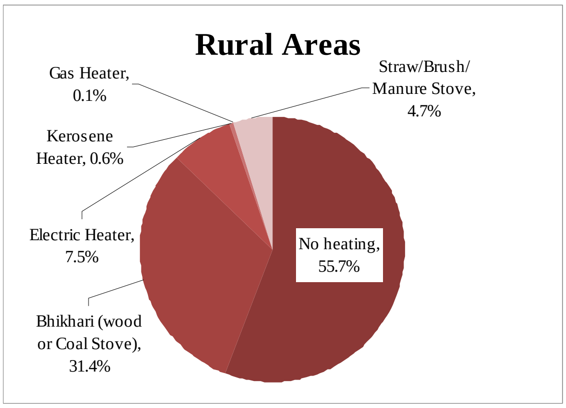
Note: Multiple answers

Figure 2-2 Share of Energy Use for Cooking by Source in Urban and Rural Areas

As an energy source for heating, the share of people who have no heater is 56%, which is still high. Even in urban areas, 37% answered that they do not use a heater. Among those who use heaters, electric heaters are the most utilized in urban areas; traditional Bhutanese stoves, "Bhikhari", which use firewood or coal as the heat source, are the most utilized in rural areas, at 31%, followed by electric heaters, at 7.5%.

One of the reasons for the high number of "no heating" responses is that the target interviewees included people in warm areas in the south of Bhutan[1]. Verifying the result of each district, in Samtse, Sarpang, Samdrup Jongkhar and others located in the south, 90% of the total interviewees answered "no heating".





Source： NSB and ADB "Bhutan Living Standards Survey 2012 Report"

Note：Multiple answers

Figure 2-3 Share of Energy Use for Heating by Sources in Urban and Rural Areas

[1] This is confirmed with National Statistics Bureau (NSB).

Chapter 3 Basic Energy Information

3.1 Basic Energy Information

3.1.1 National Energy Strategy

(1) GNH - Gross National Happiness

At the root of the national strategy of the Kingdom of Bhutan is a consideration by Jigmi-Singye, the king of the previous generation, made in the 1970s, to review attitudes to focus on economic growth as evaluated by Gross National Happiness (GNH). The aim was to achieve "happiness of the people", taking into consideration traditional society and culture, as well as the will of the people and the environment. While paying attention to economic growth as indicated by GDP indicators, it also assesses the degree of growth under the original concept of GNH.

In particular, the 4th king of Bhutan has misgivings about focusing on the value of Growth Domestic Product (GDP) to evaluate National economic growth., and advocated adopting GNH (Gross National Happiness) rather than GDP based on the concept of GNH that sustainable human development comes into existence only when psychic and physical development coexist, and cover mutually.

(2) Bhutan 2020 - A Vision for Peace, Prosperity and Happiness

Bhutan 2020 was formulated in 1999, to indicate the country's long-term direction up to 2020, setting maximization of GNH as the basic principle of development. It listed 1) human development, 2) protection and promotion of culture and traditional heritage, 3) well-balanced equal development, 4) improvement of governance, and 5) environmental protection as the 5 backbones for environmental protection, and set key issues and performance targets in each field.

(3) Economic Development Policy 2010

The Policy set as a goal of economic development, the achievement of complete (100%), self-sustaining economic development and a high level (97.5%) of employment rate by 2020, covering a very wide range of fields including energy, industry, trade, tourism, mining, construction, education, health, information, agriculture, transportation, water source management, etc. Strategic priority areas listed in the Policy include the promotion of economic diversification taking into account the environmental impact, effective utilization of sustainable development resources, expansion of exports, and suppression of the use of fossil fuels. In particular, regarding power development as a strategic resource to support national strength, in the form of quoting Sustainable Hydro Power Development Policy 2008, the Policy strongly advocates the promotion of hydropower development, aiming for 10,000 MW by 2020.

(4) Rural Electrification Master Plan 2005

The Plan has set the goal of achieving a 100% rural electrification rate by 2020, and has developed a basic plan of electrification at the village level throughout Bhutan by a combination of off-grid and grid electrification. Meanwhile, the technology transfer of the power development planning method has been carried out in such a way that the country can update the formulated Master Plan independently. The technology transfer has been implemented by mainly JICA's support.

(5) Sustainable Hydro Power Development Policy 2008

The potential hydropower capacity in the country is estimated to be approximately 30,000 MW. In 2006, the equipment capacity of hydroelectric power plants was 1,488 MW. This remained at a level of approximately 5% in the development of the entire occluded hydropower. The Plan has set a goal to aim for the promotion of hydropower development to a minimum level of 10,000 MW by 2020. The Policy does not apply to Micro/Mini/Small hydropower with output under 25MW. Applicable to the Policy are the following 3 sections, Medium Hydropower (25-150MW), Large hydro (150-1,000 MW), and Mega hydro (over 1,000 MW).

In particular, financing for hydropower development promotion is one of the key objectives in the Policy. The developer is obligated to pay an up-front premium to the government as a down payment before commencement of construction. In addition to this, after starting operation, for 12 years, it has to pay the government as a royalty, the equivalent of a minimum of 12% of power generation output, and for the remaining period, the equivalent of a minimum of 18% of power generation output. Some of these funds are pooled into the Renewable Energy Development Fund (REDF) managed by the government, and utilized for hydropower development-related costs, environmental costs, compensation of electricity prices, development of other renewable energy etc.

Furthermore, foreign direct investment (FDI) is also covered by the Policy. Medium hydro requires 26% of equity participation by Bhutan national companies as a minimum, but for large hydro, 100% of foreign capital or a Joint venture (JV) with a Bhutan national company is possible. It is also noted that the FDI investors, for the first 10 years, can enjoy preferential treatment, including corporation income tax exemption.

Regarding donors' support, NORAD has implemented grant and technical cooperation project.

(6) Integrated Energy Management Master Plan 2010

This Master plan examines the primary energy demand in four scenarios (Business-as-usual scenario, Energy-efficient scenario, High growth scenario, High growth coupled with energy efficiency scenario); in terms of sector wise (Residential sector, Industrial sector, Commercial and institutional sector, Transport sector); and fuel wise (Electricity, Diesel, Coal, ATF, Petro, LPG, Kerosene, Fuel wood). In addition, as options for energy supply, economic analysis for hydro, biomass and energy, solar, wind and thermal power are being conducted, and Demand Side Management and an institutional framework for investment implementation are mentioned. The policy development project supporting BPC and DOE was conducted by Indian consulting company, TERI (The Energy and Resources Institute).

(7) Five-Year Plan

In the 9th Five-Year Plan period (2002-2007[2]), approximately 9% in the five-year average was achieved. During the 10th Five-Year Plan period (2008-2012), in 2011, GDP growth rate reached 11.77%[3]. Furthermore, for the 11th Five-Year Plan (2013-2018) which will be announced this summer, a goal has been set to maintain a high GDP growth rate of 9-10% up to 2018. In all five-year plans, there are overall goals to reduce poverty, and promote economic growth, while adjusting regional disparities, in particular, by the promotion of large-scale hydropower development relying greatly on national income. It can be said that power development as a national strategy has been playing a vital role, when considering the current situation whereby the expansion of power exports to India, together with the promotion of rural electrification, have been supporting economic growth.

(8) Alternative Renewable Energy Policy 2013 (AREP2013)

AREP2013 sets out a minimum specific target by 2025 as indicated below.

(a) Long-term goals

The long-term purposes of this policy are defined as follows.

・To contribute to energy security and expand the portfolio of energy by utilizing the available renewable energy potential.

・To reduce greenhouse gas emissions and contribute to the mitigation of climate change.

・To promote development of environmentally superior energy and contribute to the development of a sustainable society economy.

・To improve manufacturing technology in the field of renewable energy.

・To create a framework for carbon trade mechanism.

(b) Target values

The specific goals related to the power sector targeted in this Policy are as follows. As the target value indicated below shows only the minimum target, revision shall be made based on the detailed potential survey.

・Electricity generation: solar 5MW, wind 5MW, biomass 5MW

・Energy Generation: biomass heat system -3MW equivalent, solar Thermal system -3MW equivalent

・Fossil Fuel Energy substitution in Transport Sector

2 As the duration of the 9th Five-Year Plan was extended for 1 year, the total period of the plan became 6 years from FY2002 to FY2007.

3 Guidelines For Preparation of the 11th Five Year Plan (2013-2018), GNHC, MoEA Homepage

・1000 kiloliters of oil equivalent = 111,000MWh

・20% of the state owned and 10% of the private vehicle fleet shall be developed separately on an as needed basis.

(c) Framework of the policy

The following is an overview of the policy.

・Background, purpose, target value setting

・Clarification on the implementation system led by Department of Renewable Energy (DRE)

・Implementation mechanism, from investigating potential finding, project bidding, up to government approval.

・Investment mechanism including foreign direct investment (FDI)

・Financial scheme build-up by Renewable Energy Development Fund (REDF)

・Presentation of risk mitigation plan, such as power purchase agreement (PPA), to investors

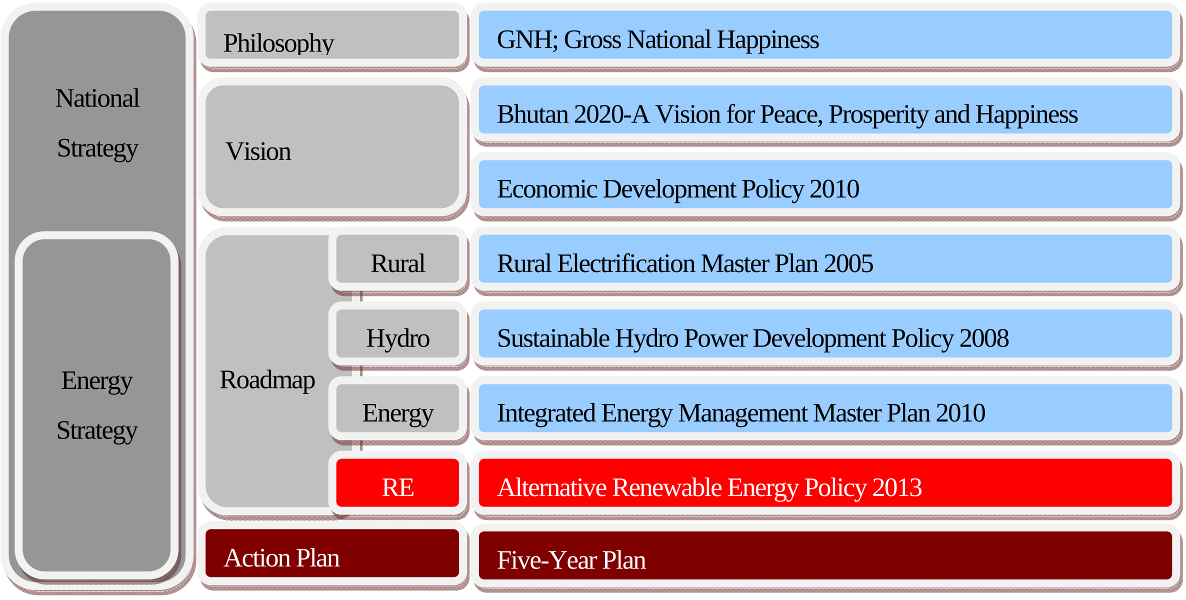
(d) Preparation of Master Plan

Necessity of Master Plan preparation within 3 years is stipulated as a higher prioritized issue on the AREP 2013.

(9) General comments

The RGoB defined a clear position on strengthening energy security by promoting renewable energy through its Sustainable Hydro Power Development Policy 2008 and Economic Development Policy 2010. In addition, the government recognizes the need for a fundamental change of incentive and tariff structure to promote renewable energy, knowing the lack of price competitiveness compared with the generation cost of hydropower. Under such circumstances, the government published the Alternative Renewable Energy Policy 2013 in April 2013, aiming at diversification of fuel resources.

For the Efficiency Policy in terms of the demand side, as shown in the figure below, with regard to the national strategy of the country under the basic national basic philosophy of GNH, various policies such as visions and roadmaps have been proposed up to now. Regarding hydropower development, the "Sustainable Hydro Power Development Policy 2008" acts as a roadmap, and the Five-year Plan functions as the Action Plan to embody the roadmap. AREP2013 is the roadmap for renewable energy in particular, but many items overlapping with the hydropower roadmap are observed in its content. Therefore, under the conditions that technical and environmental feasibility are ensured, in order to ensure the same level of economic viability with hydropower, the development of a concrete action plan for improving the investment climate is urgent, in view of securing economic viability including the setting of a feed-in tariff and PPA.



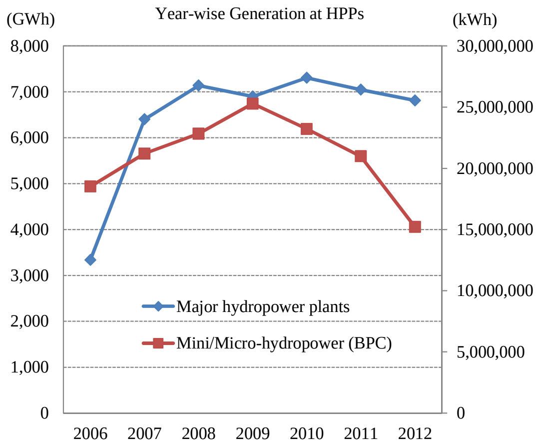
Source: JICA Survey Team

Figure 3-1 National Energy Strategy Framework

3.1.2 Verification of AREP2013

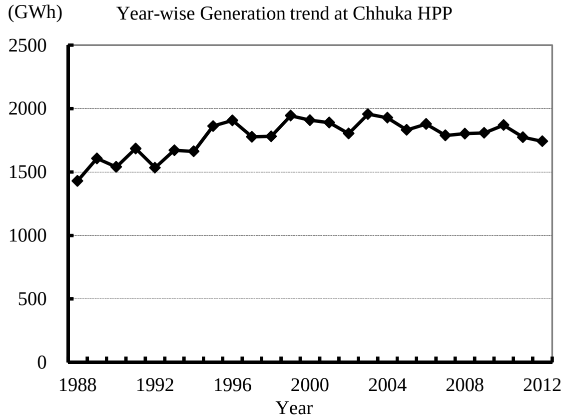
In Bhutan, the possibility that river water required for hydropower might dry up due to climate change has recently been predicted. The country is exploring diversification of energy in order to avoid depending on only a single energy resource. Under such circumstances, AREP2013 was developed.

Figure 3-2 shows the power generation performance during seven fiscal years from 2006 to 2012 of major hydropower plants (Chukha, Kurichhu, Basochhu, Basochhu-II (lower stage), Tala) and Mini/Micro hydro power plants owned by BPC. In addition, Figure 3-3 demonstrates the power generation track record of Chukha power plant for a period of 25 years from 1988 to 2012. In the short term, results of the Mini/Micro hydro power plant have a tendency to decrease significantly, but for major hydropower (short-term) and, in for the long term in Chukha alone, it is impossible to find a significant trend in power generation output. Therefore, in order to grasp long-term trends in the future, it is necessary to carry out hydrological analysis of river flow data for the long term.



Source: JICA Survey Team based on BPC data

Figure 3-2 Generation Performance (Whole Hydro)



Source: JICA Survey Team based on DRE data

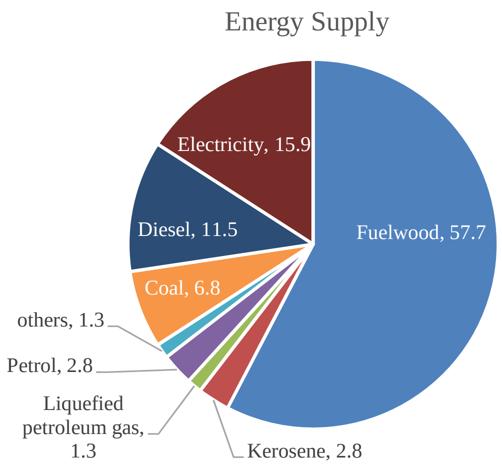
Figure 3-3 Generation Performance (Chukha Hydro)

3.1.3 Primary Energy Balance

When analyzing the energy balance of a country, the "Energy Balance and Statistics", published annually by the International Energy Agency (IEA), is widely used all over the world. Bhutan is an exception. For Bhutan's energy balance, the "Energy Data Directory 2005" published by the Department of Energy in 2007, is the latest version. After this, Bhutan's energy balance data has not been updated.

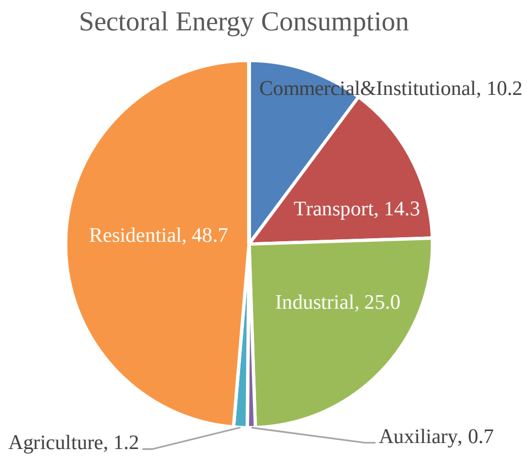
The supply of energy in 2005 was 402,000 tons of oil equivalents (TOE). The breakdown of energy sources is as follows: fuel wood - 57.7%, electricity - 15.9%, diesel oil - 11.5%, coal - 6.8%, oil - 2.8%, and kerosene - 2.8%. It can be seen that as a heat resource, firewood is very much used.

In addition, when looking at the breakdown of final energy consumption by sector, the proportion of households is as high as 48.7%. Furthermore, when paying specific attention to household use, since electrification is progressing in urban areas compared to rural areas, it is understood that the use of heat sources other than electricity is extremely low. In addition, in rural areas, firewood and charcoal are widely used for cooking and feeding animals.



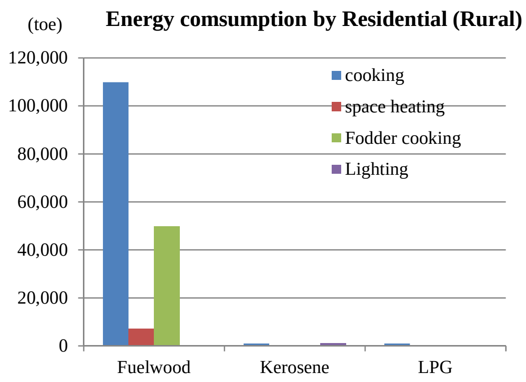
Source: Energy Data Directory 2005 Unit:%

Figure 3-4 Energy Supply



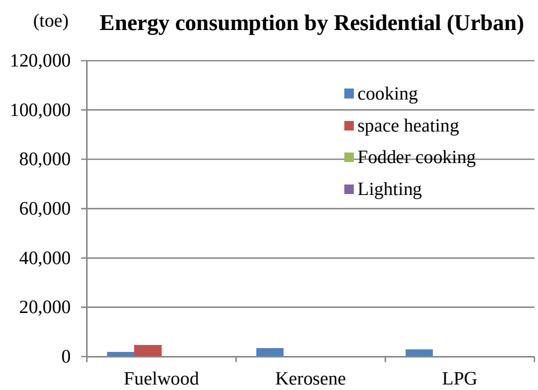
Source: Energy Data Directory 2005 Unit:%

Figure 3-5 Sector-wise Final Consumption



Source: Energy Data Directory 2005

Figure 3-6 Final Consumption excluding Electricity (Rural)



Source: Energy Data Directory 2005

Figure 3-7 Final Consumption excluding Electricity (Urban)

3.1.4 Fuel Prices

For the price of Diesel, Petrol, Kerosene, LPG, and Electricity, the figure below shows the price trends based on the unit of Nu/toe.

(1) Price of Diesel, Petrol, Kerosene, LPG

During the period of 1995-2010, the cost of fuel has soared to about 3-6 times. The official price of Petrol fuel by city on June 30, 2013 is as follows - Thimphu: 50.52Nu / L, Bumthang: 50.51Nu / L, Trashigang: 48.24Nu / L, P/Ling: 48.86Nu / L., which demonstrates that regional differences in fuel prices are not significant.

(2) Electricity price

A weighted average tariff based on the voltage-wise tariff indicated in chapter 4 is adopted for electricity price.

- A weighted average tariff (Nu/kWh) : FY2007: 1.399, FY2008: 1.546, FY2009: 1.684, FY2010: 1.712,
- Cost on toe basis: 16,200Nu/toe～19,800Nu/toe

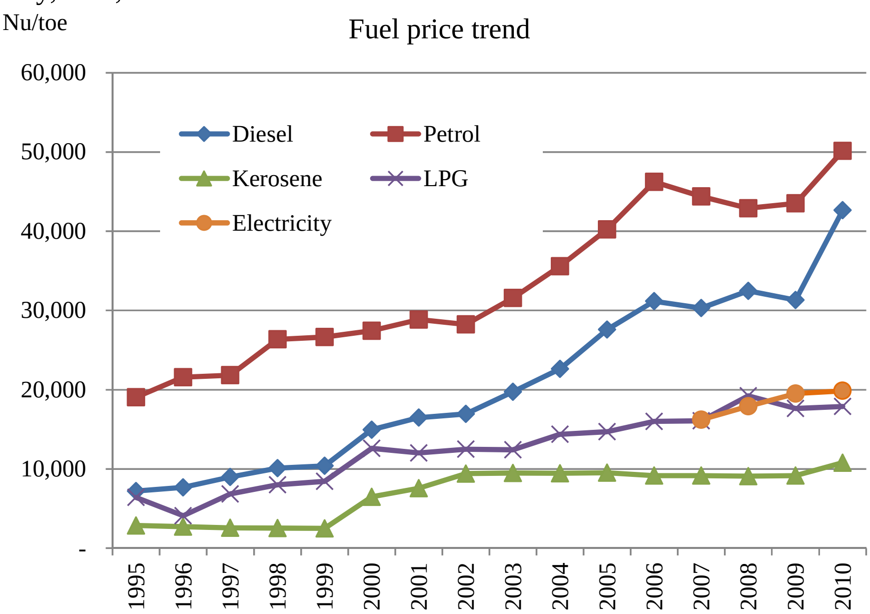
(3) Fire wood price

The sales price of fire wood is determined on an annual basis by NRPC (Natural Resource Pricing Committee), and the price differs from (i) region, (ii) size, and (iii) wood type. Fire wood price is determined based on the following assumptions;

- To adopt controlled price determined by NRPC (Market price does not exists)
- Highest price (2012) : (i) Thimphu, (ii) normal size, and (iii) needle leaf tree →6.177Nu/kg
- Lowest price (2012) : (i) Monggar, (ii) normal size, and (iii) needle leaf tree→1.072Nu/kg
- Calorific value when moisture content 0%= 4,600kcal/kg
- Calorific value when moisture content 15%-30%= 3,220～3,910kcal/kg
- Cost on toe basis: 15,800～19,180Nu/toe (at Thimphu)

(4) Evaluation

In 2010, when calculated in terms of per toe, the price of Petrol is the highest, followed by Diesel, Fire wood & Electricity, LPG, and Kerosene.



Source: JICA Survey Team based on DRE data

Figure 3-8 Fuel Price Trend

Table 3-1 Energy Balance

[toe]

	ATF	Briquettes	Coal	Diesel	Electricity	FO	Fuel wood	Kerosene	LDO	LPG	Petrol	Total
SUPPLY												
Total supply	**957**	**65**	**27,498**	**46,263**	**63,933**	**1,638**	**231,871**	**11,065**	**2,448**	**5,053**	**11,311**	**402,102**
Generation/supply	0	65	24,049	0	216,107	0	0	0	0	0	0	240,221
Import	957	0	17,091	46,263	1,577	1,638	231,739	11,065	2,448	5,053	11,311	329,142
Export	0	0	13,642	0	153,751	0	0	0	0	0	0	167,393
	0	0	0	0	0	0	0	0	0	0	0	0
Losses	0	0	0	0	9,635	0	0	0	0	0	0	9,635
CONSUMPTION												
Total consumption	**957**	**65**	**27,498**	**46,263**	**54,297**	**1,638**	**231,871**	**11,064**	**2,448**	**5,054**	**11,311**	**392,466**
Agriculture	**0**	**0**	**0**	**489**	**68**	**0**	**3,997**	**0**	**0**	**0**	**0**	**4,554**
Cardamom drying	0	0	0	0	0	0	3,997	0	0	0	0	3,997
Power tillers	0	0	0	489	0	0	0	0	0	0	0	489
Water pumps etc	0	0	0	0	68	0	0	0	0	0	0	68
Residential	**0**	**0**	**0**	**0**	**7,633**	**0**	**173,921**	**5,682**	**0**	**3,980**	**0**	**191,216**
Rural	**0**	**0**	**0**	**0**	**2,635**	**0**	**166,985**	**2,175**	**0**	**1,027**	**0**	**172,822**
Cooking	0	0	0	0	1,607	0	109,910	989	0	1,027	0	113,533
Space heating	0	0	0	0	0	0	7,232	0	0	0	0	7,232
Fodder cooking	0	0	0	0	0	0	49,843	0	0	0	0	49,843
Lighting	0	0	0	0	1,028	0	0	1,186	0	0	0	2,214
Urban	**0**	**0**	**0**	**0**	**4,998**	**0**	**6,534**	**3,507**	**0**	**2,953**	**0**	17,992
Cooking	0	0	0	0	3,974	0	1,903	3,485	0	2,953	0	12,315
Space heating	0	0	0	0	0	0	4,631	0	0	0	0	4,631
Fodder cooking	0	0	0	0	0	0	0	0	0	0	0	0
Lighting	0	0	0	0	1,024	0	0	22	0	0	0	1,046
Others	**0**	**0**	**0**	**0**	**0**	**0**	**402**	**0**	**0**	**0**	**0**	402
Institutional	**0**	**65**	**0**	**0**	**10,191**	**0**	**23,636**	**5,140**	**0**	**1,074**	**0**	**40,106**
Royal Bhutan Police	0	0	0	0	0	0	2,036	0	0	0	0	2,036
Army	0	0	0	0	0	0	2,757	0	0	0	0	2,757
IMRAT	0	0	0	0	0	0	1,370	0	0	0	0	1,370
Royal Body Guards	0	0	0	0	0	0	1,255	0	0	0	0	1,255
Dzong and monasteries	0	0	0	0	0	0	1,257	0	0	0	0	1,257
Hospitals	0	0	0	0	0	0	243	0	0	0	0	243
Roads	0	0	0	0	0	0	6,047	0	0	0	0	6,047
Schools	0	0	0	0	0	0	5,014	0	0	0	0	5,014
Hotels and restaurants	0	0	0	0	0	0	2,697	0	0	0	0	2,697
DANTAK	0	0	0	0	0	0	960	0	0	0	0	960
Transport	**957**	**0**	**0**	**43,783**	**0**	**0**	**0**	**0**	**0**	**0**	**11,311**	**56,051**
Industrial	**0**	**0**	**27,498**	**706**	**35,131**	**1,638**	**30,317**	**242**	**2,448**	**0**	**0**	**97,980**
Lemon grass	0	0	0	0	0	0	261	0	0	0	0	261
BBPL (Bhutan Board)	0	0	0	0	0	0	3,200	0	0	0	0	3,200
BCCL/BFAL	0	0	0	0	0	1,638	14,880	0	183	0	0	16,701
Hand-made paper	0	0	0	0	0	0	2,560	0	0	0	0	2,560
Rosin and terpentine	0	0	0	0	0	0	107	0	0	0	0	107
Yarn dying	0	0	0	0	0	0	29	0	0	0	0	29
Carbon manufacturing	0	0	0	0	0	0	9,280	0	0	0	0	9,280
BAPPL	0	0	236	0	0	0	0	0	0	0	0	236
PCAL	0	0	13,101	0	0	0	0	242	0	0	0	13,343
Mines	0	0	0	706	0	0	0	0	0	0	0	706
Other industries	0	0	14,161	0	0	0	0	0	2,265	0	0	16,426
Auxiliary consumption	**0**	**0**	**0**	**1,285**	**1,274**	**0**	**0**	**0**	**0**	**0**	**0**	**2,559**

Source: Energy Data Directory 2005

3.1.5 Support from NGOs and other Donors

Current situation of assistance from main donors to RGoB is described in the following paragraphs.

Table 3-2 Renewable Energy Projects Implemented by Main Donors

RE Sector	UNDP	ADB	SNV	NORAD
Solar PV	-	Solar Home Lighting System Project	-	-
Wind	-	Funding for Wind Power Project in Rubessa	-	-
Small/ micro/ pico Hydro	-	-	-	-
Biomass	Rural Biomass Project(SRBE)	Funding for Biogas project	Implementation of Biogas project	-

(1) ADB (Asian Development Bank)

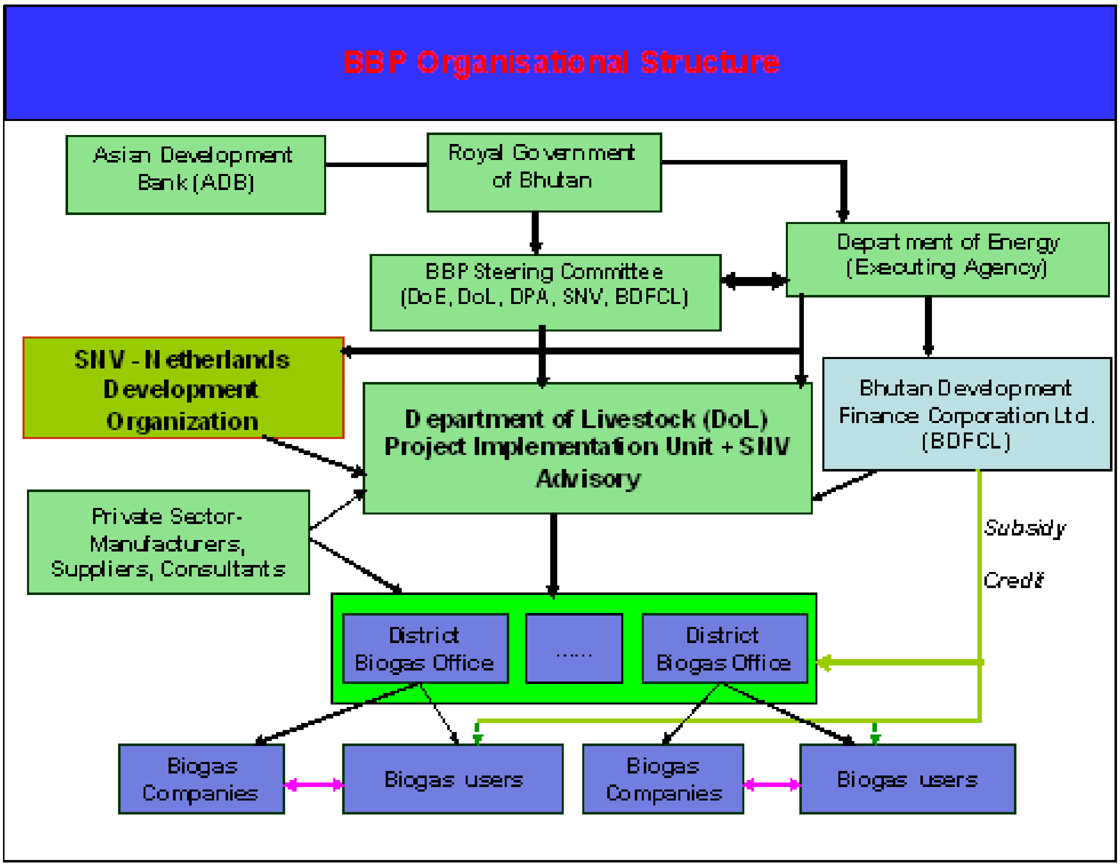
For the Rural Renewable Energy Development Project in RGoB approved in May 2010, USD 21.59 million was funded as grant from ADB during the period of 2010 to 2015. In the project, four components are set, (i) on-grid rural electrification (RE), (ii) off-grid solar RE, (iii) establishment and grid-connection of pilot wind power generation mills, and (iv) a pilot program to promote biogas plants.

Based on the ADB's assistance, RGoB started loans to construct and operate biogas plants since 2012. The plant construction is increasing with financial assistance from ADB, technical cooperation from Netherlands Development Organization, SNV. The detailed information is described in the next paragraph.

(2) SNV（Netherlands Development Organization）

As of July 2013, SNV's assistance has continued for 25 years. The SNV Bhutan is composed of 3 members for the RE sector, 5 for the water and hygiene sector and 4 for the agricultural sector. Regarding RE projects, a potential survey in Bhutan has implemented by SNV since 1980's, however there was no entities responsible to be an executing agency in Bhutan, and therefore, no project was formulated. Afterwards, the potential survey was conducted in 2009 based on SNV's experience of biogas projects from other countries (Nepal, Vietnam, Laos, Indonesia, Bangladesh, Pakistan and African countries). In the Phase I (March 2011 to February 2014) of an ADB fund project which targets installation of 1,600 plants for 3 years, SNV became a responsible organization for technical assistance with ADB fund. As of July 2013, 800 units have been completed.

The next figure shows an organizational structure for Bhutan Biogas Project.



Source: Website of SNV[4]

Figure 3-9 Organizational Structure for Bhutan Biogas Project

RGoB injects funds from ADB to responsible organization and Bhutan Development Bank Limited (the present BDBL, the former BDFCL). SNV and local private entities work together to bring up the technical engineers who are engaged in supporting users (technical support in the initial operation, periodical inspection, dealing troubles) in the local biogas offices. The target of loans from BDBL is individuals.

According to interviews with SNV in July 2013, the number of members in charge of the biogas project is 2 full-time in the Secretariat, 2 part-time from Department of Livestock and 15 part-time from other relating agencies.

Regarding "Bhutan Sustainable Rural Biomass Energy Project (SRBE) funded by UNDP," SNV was in charge of planning in the beginning. Currently SNV has not taken part in the project.

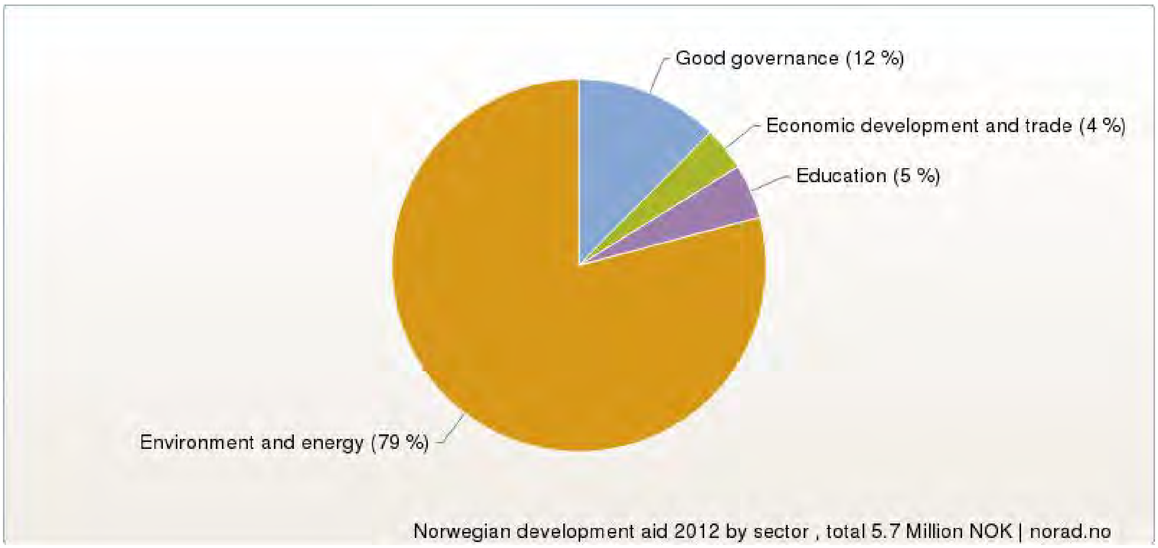
4 Website of SNVhttp://m.snvworld.org/en/countries/bhutan/about-us/organisation/track-record/bhutan-biogas-project-bbp

(3) NORAD (The Norwegian Agency for Development Cooperation)

NORAD implements a total financial assistance of 5.7 million NOK in the year 2012. As shown in the following figure, approximately 79% of total assistance accounts for environment and energy sector.

Currently, NORAD mainly focuses on and has conducted technical cooperation on human resource development for RE and hydropower sector, capacity building and data analysis for hydropower sector towards Bhutan Electricity Authority (BEA) and Department of Hydropower & Power Systems (DHPS), Department of Renewable Energy (DRE) and Department of Hydro-meteorological Services (DNHS) of the Ministry of Economic Affairs (MoEA).

Besides above, NORAD has been supporting for preparation of Detailed Project Reports (DPR, similar to F/S report) Unit 2 and 3 of Chamkharchu Hydropower Station under Druk Green Power Corp.(DGPC) and Gagachhu Hydropower Station. Regarding future plans, NORAD and ADB plan on discussing the possibility of "Energy +" funding scheme (New financial scheme for RE funded by Norway) in the beginning of September 2013.



Source: Website of NORAD[5]

Figure 3-10 Sectoral Distribution of Development Aid from NORAD to Bhutan (As of 2012)

(4) UNDP

UNDP has provided a financial and technical support to RGoB for a long time. The supporting policy changed in the phases with economic development as described below[6].

5 Website of NORAD http://www.norad.no/en/tools-and-publications/norwegian-aid-statistics
6 Website of UNDP http://www.undp.org.bt/undpbhu.htm

1960's to 1970's:

Supporting Up-grading of Human Resource and Infrastructure

(The 5th and 6th Five Year Plans, Total 2.5million USD)

1980's to 2008:

Supporting Key Challenges and Attainment of the MDGs

(Enforcement of local government, Improving the efficiency and accountability of the public sector, Expanding and protecting the asset base of the poor, Environmental management and energy development to improve the livelihoods and security of the poor and Promoting gender equality in the decision-making process at all levels)

2008 to 2012:

Consolidating interventions, sharpening focus and "Delivering as one"

(Base-up assistance for the poor, Policy development with a key component of environmental conservation, Small rural enterprises、Risk management for natural disaster)

As of September 2013, the UNDP implemented the following projects in the environment and energy sector. The number of on-going projects is 8.

Table 3-3 UNDP Projects in Environment and Energy Sector

No.	Project Title	Project Location	Project Duration	Status
1	Integrated Livestock & Crop Conservation Project	Nationwide	July 2007 - July 2012	Closed
2	Enabling activities for the preparation of Bhutan's Second National Communication to the UNFCCC	Thimphu	August 2007 - September 2011	Closed
3	Earthquake Risk Reducation and Recovery Project	Central and Western Region	November 2007 - May 2010	Closed
4	Reducing Climate Change-induced Risks and Vulnerabilities from GLOF[7]	Punakha-Wangdue Valley	April 2008 - June 2013	On-going
5	Mainstreaming Poverty Environment Linkages in National Plans	Thimphu	July 2008 - December 2009	Closed
6	Low Emission Capacity Building	Nationwide	2008- December 2013	On-going
7	National Capacity for Self Assessment	Thimphu	June 2008 - March 2012	Closed
8	HCFC Phase out Management Plan for Bhutan	Nationwide	2008- December 2013	On-going
9	Building Capacity for Sustainable Land Management	Central and Western Region	January 2009 - December 2010	Closed
10	Human-Wildlife Conflict Management Project	Central and Eastern Region	January 2009 - December 2012	Closed
11	Piloting Public-Private Partnership in Solid Waste Management	Thimphu	January 2010 - December 2012	Closed

[7] GLOF：Glacial Lake Outburst Flood

12	Joint Support Programme	Central and Eastern Region	January 2010 - December 2013	On-going
13	Bhutan Recovery and Reconstruction Project	Central and Eastern Region	January 2010 - December 2011	Closed
14	Multi-Sector Pandemic Preparedness	Thimphu	July 2010 - June 2011	Closed
15	Coordination and Recovery support following 2011 Earthquake	Central, Western	October 2011 - December 2012	Closed
16	Support to Environment Education in Bhutan	Central Region	January 2012 - December 2012	Closed
17	UN support to National Human Settlement Policy	Central	January 2012 - December 2012	Closed
18	UN support to REDD[8]+ Readiness Strategy	Central	January 2012 - December 2012	Closed
19	Energy Efficiency baseline study	Central	January 2012 - December 2012	Closed
20	Revision of National Environment Strategy	Central	January 2012 - December 2013	On-going
21	Low Emission Capacity Building	Central	May 2012 - October 2012	On-going
22	Engendering Energy and Environment Portfolio in Bhutan	Nationwide	2012-2014	On-going
23	Bhutan Sustainable Rural Biomass Energy Project	Nationwide	Jan 2013 December 2015	On-going

Source: Website of UNDP[9]

As described in Table 3-3, a project of "Bhutan Sustainable Rural Biomass Energy (SRBE)" which continues from January 2013 to December 2015 and funded with 4.2 million USD by UNDP/GEF and ADB targets the efficient use of wood biomass utilizing forest resources. The main implementing organizations are MoEA and MoAF. SRBE belongs to a part of the fund named "Support to MoEA & MoAF towards Renewable Energy and Energy Efficiency" which targets RE and energy efficiency during 2008-2015.

(5) NGOs

Since 2007, when "The Civil Society Organizations Act of Bhutan (CSO Act)" was established, the number of civil society organizations (CSOs) has increased. The purpose of the CSO Act is to facilitate the establishment and growth of two types of CSOs, such as Public Benefit Organizations (PBOs,) which are CSOs established in order to benefit a section or the society, and Mutual Benefit Organizations (MBOs,) which are CSOs established in order to advance the shared interested of their members or supporters. As of September 2013, there are 31 CSOs in Bhutan. The representative organizations are Royal Society of the Protection of Nature (RSPN) and Bhutan Trust Fund for Environmental

[8] REDD：Reducing Emissions from Deforestation and Degragation
[9] UNDP http://www.undp.org.bt/projects.htm

Conservation (BTFEC). RSPN and BTFEC belong to the High Committee of NEC and those two organizations play an important role in advocating public opinion on environmental issues in Bhutan.

In addition, the World Wildlife Fund (WWF) is the most familiar international NGO in Bhutan. WWF collaborates with MoAF to conserve various endangered species in Bhutan.

(a) Royal Society for the Protection of Nature（RSPN）

RSPN is one of the environmental NGOs in Bhutan. It was established in 1987. In the beginning, RSPN focused only on conservation of Black-necked cranes. Now RSPN works on environmental education and advocacy, conservation and sustainable livelihoods, research and emerging issues like climate change, solid waste and water. RSPN is one of the High Committee members of NEC.

As of September 2013, there is 31 proper staff, and they are working for the head office in Thimphu and for 3 local offices. The number of supporting members is approximately 500, including children and foreigners. Supporting members can gain a certificate if they join volunteer work.

Regarding educational programs based on the BTFEC fund, RSPN has been providing technical support to the project to set up environmental clubs, collaborating with the Ministry of Education, since 2009.

(b) Bhutan Trust Fund for Environmental Conservation (BTFEC)

BTFEC was one of the environmental NGOs established in 1992 for the purpose of funding nation-wide nature conservation projects in Bhutan, composed of 10 full-time members. The project selection is conducted twice a year (May and December). After screening projects, a maximum of 6 projects (maximum USD 300,000/ project) are selected for half a year.

As of September 2013, 10 projects funded by BTFEC are under implementation. Among 10 projects, one biomass project is funded b y BTFEC and conducted by RSPN.

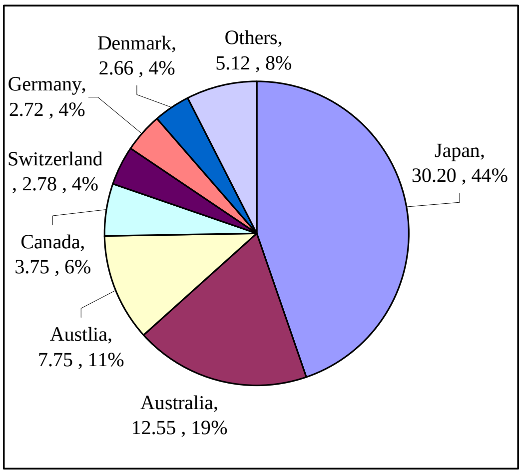
(c) World Wildlife Fund（WWF）

WWF is an international NGO which promotes environmental conservation activities. WWF Bhutan especially focuses on endangered species such as Royal Bengal Tiger, Snow Leopard, Asiatic Elephant, White-Bellied Heron and Black-necked Cranes, conducts surveys in national parks and protected areas and promotes the conservation of those species.

3.1.6 Supporting Policy and Experience of Japan

Japan has provided various supports to RGoB with the policy that Japanese support self-help efforts and development strategy based on GNH aiming at the main issues of poverty reduction.

According to OECD in 2011, the value of the aid from Japan to RGoB was the largest among donors, which accounts for USD 30.2 million, or approximately 40%, of the total aid to RGoB.



(Unit: million USD)

Source: OECD/DAC

Figure 3-11 Comparison of Aid for Bhutan (in 2011)

Since 2001, the number of Japanese ODA amounts to 83[10]. Among them, the number of grant is 76, of which the number of grassroots support is 44.

3.2 Basic Information concerning Power

3.2.1 Current Situation in the Power Sector

The Electricity Act of Bhutan was amended in July 2001 to effectively and efficiently implement the promotion of rural electrification and hydropower development. The Electricity Act enables the restructuring of the power sector, splitting the Department of Power (DOP), under the Ministry of Trade and Industry (MTI), into three newly established organizations: the Department of Energy (DOE), the Bhutan Energy Authority (BEA), and Bhutan Power Corporation (BPC). Major hydropower stations were also publicly incorporated in July 2002.

DOE performed various functions, such as formulating energy policy and power development plans, and administrating the power and mining sectors.

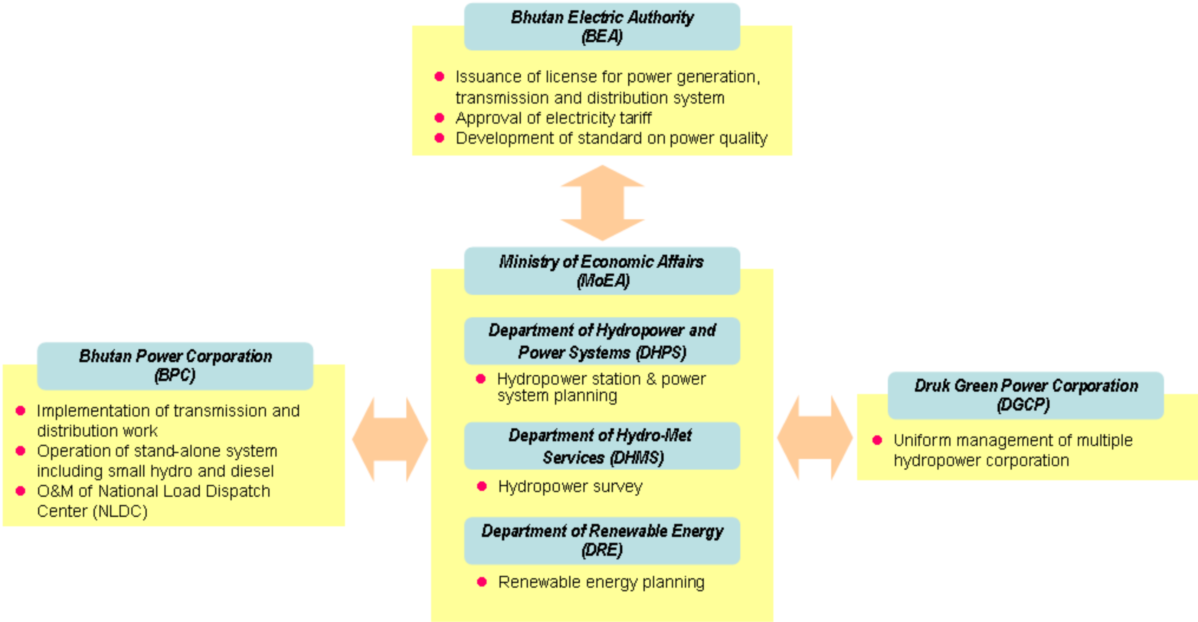
As part of an administrative reform on 17th October 2007, DOE became a subsidiary of the Ministry of Economic and Affairs (MEA).

[10] As of July 2013, Website of Ministry of Foreign Affairs in Japan

BEA is the regulatory authority in charge of developing licensing for generation and tariff-setting.

In December 2011, DOE, under the MoEA, split into three Departments: the Department of Hydropower & Power System (DHPS), the Department of Hydro-Met Services (DHMS), and the Department of Renewable Energy (DRE).

The organization chart for the power sector is shown in Figure 3-12.



Source: JICA Survey Team

Figure 3-12 Organizational Structure of Power Sector

3.2.2 Current Power Supply and Demand Situation

(1) Imbalance between supply and demand

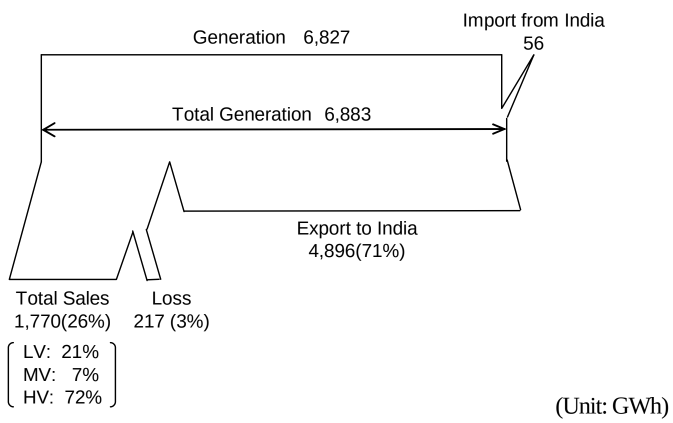
Bhutan has abundant hydropower resources with a total potential of over 30,000 MW. The Chukha hydropower station, with an installed capacity of 336 MW, was commissioned in 1986 as the first large-sized hydropower station in the country and after that, similar stations financed by India were developed for the purpose of power exports to India. As a result of the commissioning of Tala hydropower station in 2006, with an installed capacity of 1,020 MW, the total installed capacity of hydropower, including small hydropower, amounts to 1,488 MW as of June 2013, as shown in Table 3-4. This has easily exceeded domestic peak power demand of approximately 280MW. During FY 2012 power exports were 4,896 GWh, accounting for 71% of the total electricity generation (6,883 GWh), as shown in Figure 3-13.

The peak power demand records the maximum in winter, which is approximately 280 MW in November 2012. There exists approximately 1,500 MW of hydropower generation, and it seems that there is sufficient supply capacity. However, since all hydropower stations are run-of-the-river types, electricity generation varies widely by season. Therefore, the amount of water will decline significantly in the dry season, and will only provide a supply capacity of approximately 300 MW. As a result, there are some regions where supply capacity will be insufficient, and only a small amount of electric power may be imported from the Assam State Electricity Board (ASEB) and the West Bengal State Electricity Board (WBSEB) of India. The total amount of power imports from India was 56 GWh in FY 2012. The supply capacity and peak demand on a month-by-month basis is shown in Figure 3-14.

Table 3-4 Generation Facilities (FY 2012)

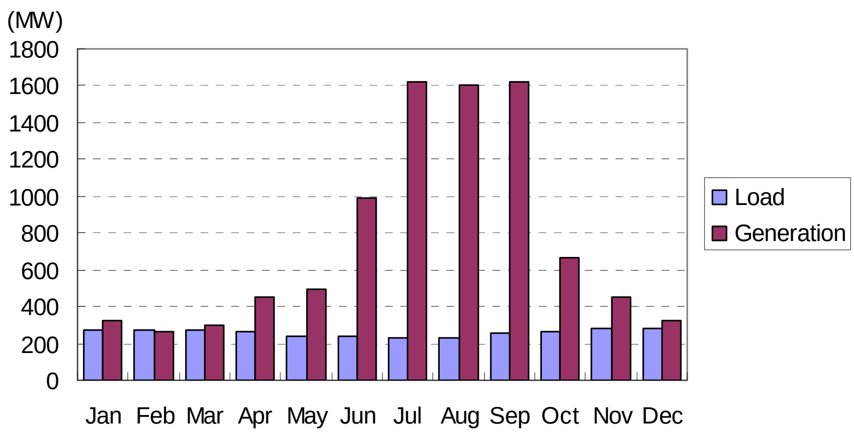
	Installed capacity (MW)	Electricity generation (GWh)
Chukha hydropower	336	1,745.3
Kurichhu hydropower	60	360.9
Basochhu-I hydropower	24	299.8
Basochhu-II hydropower	40	
Tala hydropower	1,020	4,405.2
Other hydropower	8	15.2
All diesel generators	9	0.2
Total	1,497	6,826.7

Source: POWER DATA BOOK 2012 (BPC)



Source: JICA Survey Team (based on POWER DATA BOOK 2012 (BPC))

Figure 3-13 Imbalance between Supply and Demand in FY 2012



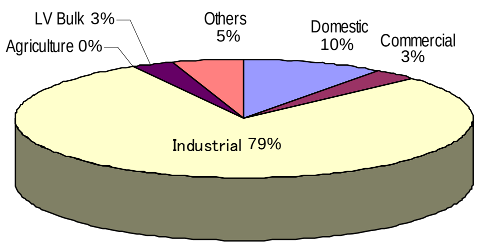
Source: BPC

Figure 3-14 Monthly Supply and Peak Demand in FY 2012

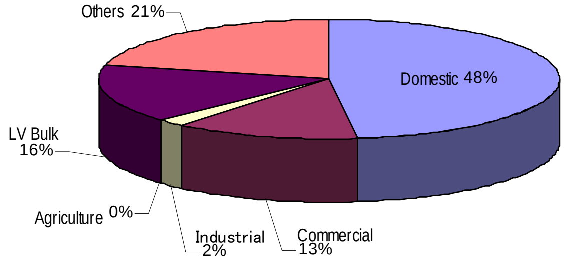
(2) Electricity sales

In FY 2012, electricity sales for domestic consumption were 1,770 GWh. The composition by use was 79% for industrial, 10% for domestic, and 3% for commercial, etc. and most notably, the demand for industrial use has been increasing. As a reference, Figure 3-16 shows the composition by use in Thimphu for urban area, Trashiyangtse for rural area, and Chukha for the biggest industrial zone in Bhutan.

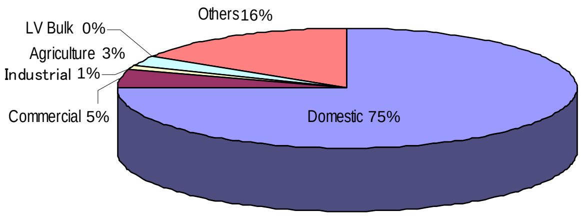
Electricity sales have been increasing in recent years due to the increase in industrial and domestic use (Figure 3-16). They are expected to increase steadily due to developmental activities, such as construction power requirements for hydropower projects, establishment of new special economic zones for manufacturing and processing industries, and completion of rural electrification plans. Incidentally, the rural electrification coverage ratio as of the end of 2012 was up to 89%.



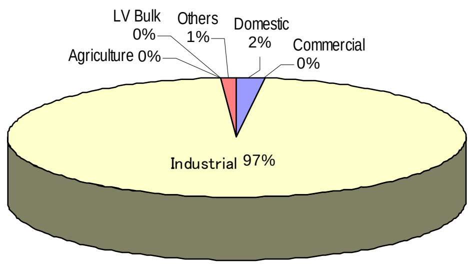
(a) Whole of country



(b) Thimphu for urban area



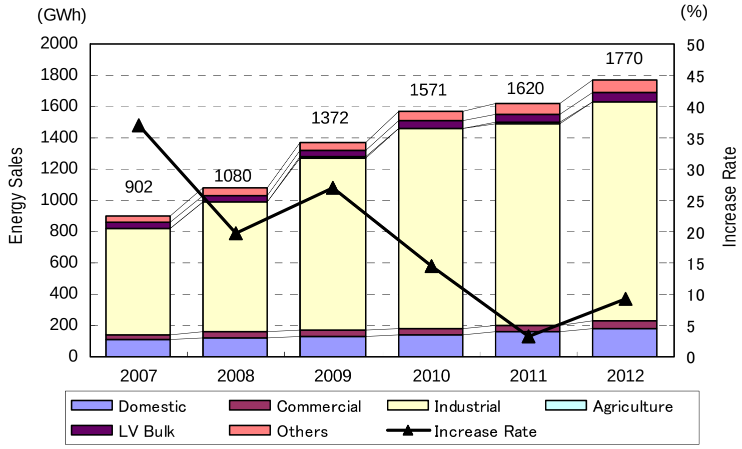
(c) Trashi Yangtse for rural area



(d) Chukha for biggest industrial zone in Bhutan

Source: POWER DATA BOOK 2012 (BPC)

Figure 3-15 Electricity Sales by use in FY 2012



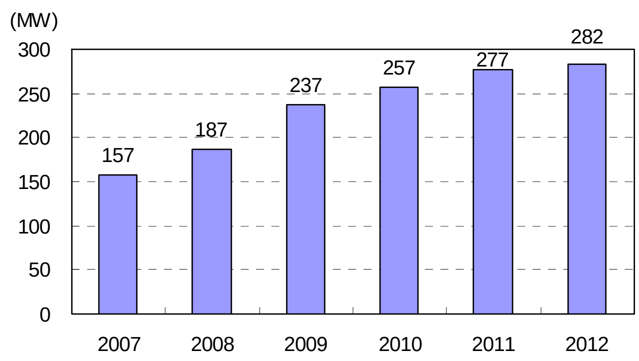
Source: POWER DATA BOOK 2012 (BPC)

Figure 3-16 Changes in Electricity Sales by Use

(3) Peak power demand

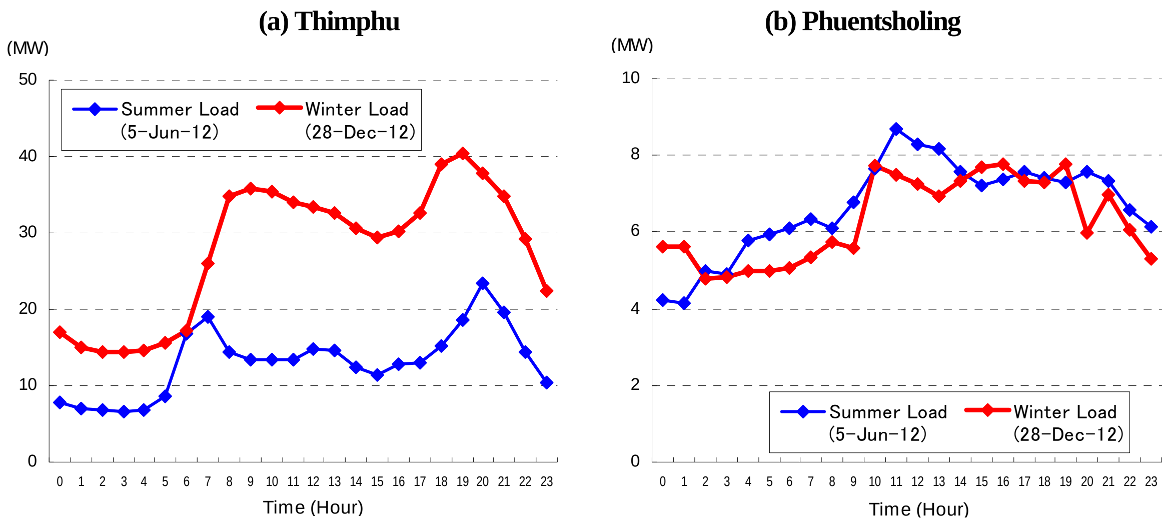
Peak power demand is increasing year by year and recorded 282 MW in FY 2012, with a steady increase of 2.2% from the previous year amounting to 1.8 times that of FY 2007 (Figure 3-17).

As a reference, the daily load curve in June and December in the capital, Thimphu, and Phuentsholing, near the border with India, is shown in Figure 3-18. In Thimphu, the four seasons are very distinct like Japan. The difference in temperature is large and power demand becomes significant according to the heating demand in winter. On the other hand, there is no noticeable difference throughout the year in Phuentsholing, which has a subtropical climate.



Source: POWER DATA BOOK 2012 (BPC)

Figure 3-17 Changes in Peak Power Demand



Source: POWER DATA BOOK 2012 (BPC)

Figure 3-18 Daily Load Curve

According to the "National Transmission Grid Master Plan (NTGMP) for Bhutan", formulated jointly by DHPS and CEA in India in 2012, the power demand forecasts in Bhutan for 2020 and 2030 are estimated to be approximately 1,500 MW and 2,500 MW, respectively. The reason for the very much higher load forecast is that the attraction of factories, such as an aluminum production factory in southern Bhutan, is taken into consideration.

Meanwhile, a more realistic load forecast until 2020 was formulated by BPC as shown in Table 3-5. The main assumptions are as follows.

- Trend analysis was adopted for the industrial and residential load for eastern and western region.
- Forecasting for construction power was included based on the hydropower development plan.
- Annual average growths observed for industrial and residential sectors from 2012-2020 were 9% and 7% respectively in line with the anticipated GDP growths of 6-7% on average for the same duration.

Table 3-5 Load Forecast until 2020 by BPC

Summary of Demand Forecasts (MW)

	Observed Annual Peak Loads							Forecasted Peak Loads								
Consumer Category/ Year	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Res'l+Comm'l			62.00	63.29	68.08	86.45	88.13	96.21	103.76	111.30	118.84	126.38	133.92	142.40	149.32	156.89
Industrial			95.36	123.76	169.09	170.50	188.11	219.04	242.26	265.49	288.71	311.94	335.16	358.38	381.61	404.83
Construction Power								12.69	21.02	44.55	66.83	87.75	114.75	94.95	61.92	29.75
Total (MW)	**120.00**	**128.00**	**157.36**	**187.05**	**237.17**	**256.95**	**276.24**	**327.94**	**367.03**	**421.33**	**474.37**	**526.07**	**583.83**	**595.73**	**592.84**	**591.48**

Source: BPC Engineering/designing & Contracts Dept.

(4) Transmission facilities

The transmission voltages of the western system are 400 kV, 220 kV and 66 kV, whereas that of the eastern system, which is isolated from the western system within the country, is 132 kV. Up until recently, both systems had been interconnected through a transmission system in northeastern India. There are three interconnection points with India - Siligri (400kV) and Birpara (220kV) in the western system, and Rangia (132kV) in the eastern system.

However, the newly completed 220 kV transmission line between Tsirang and Jigmeling enabled a domestic eastern – western system interconnection (Figure 3-19).

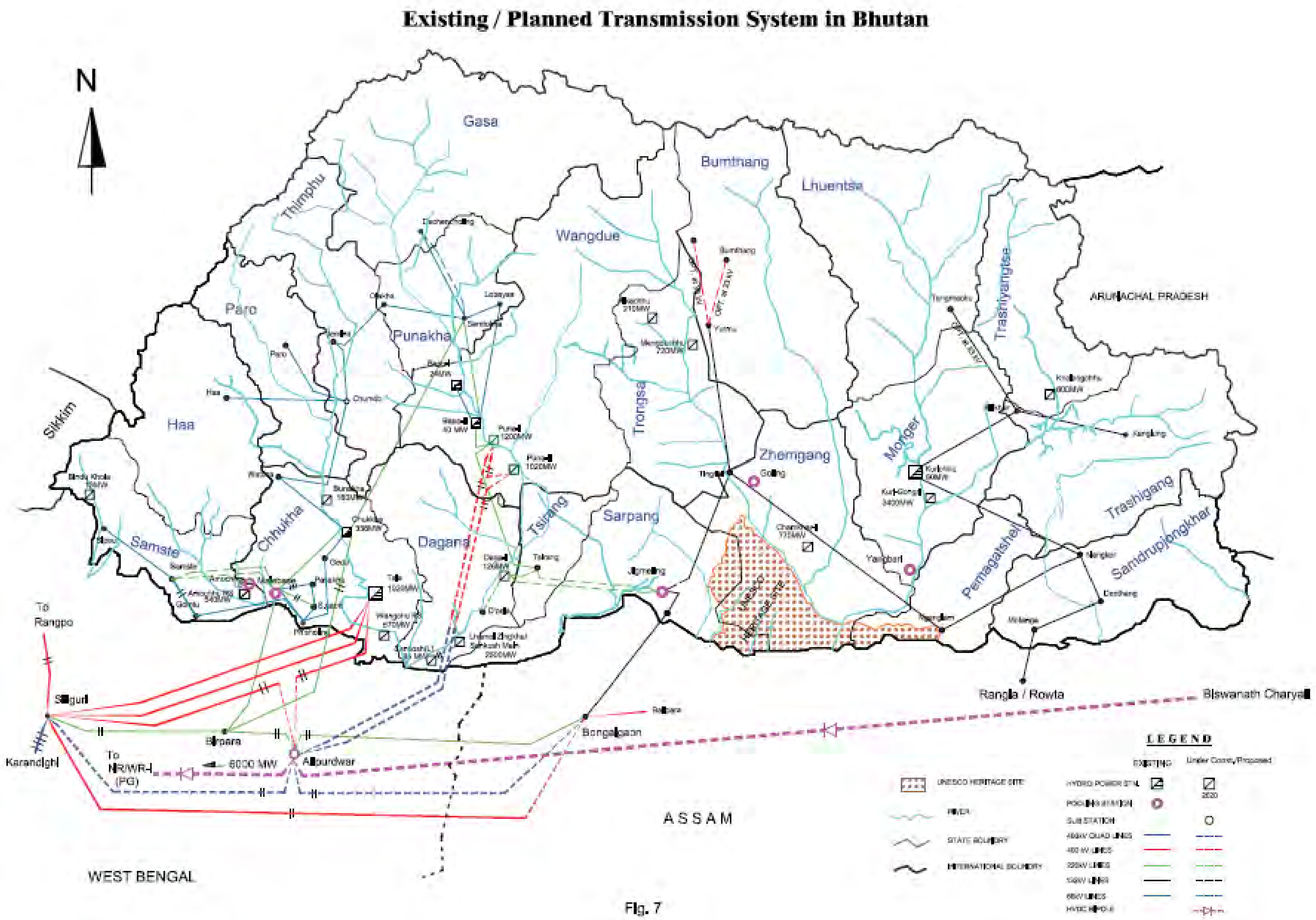
(a) Tsirang substation (b) Jigmeling substation

Source: Website of BPC

Figure 3-19 220kV Substation for Eastern – Western System Interconnection

In addition, since the generation output of the Kurichhu hydro power station (60MW) in the eastern system declined in the winter and dry season and supply capacity did not meet demand, electric power had been imported from India. However, power imports from India can now be avoided via power interchange from west to east, with the domestic 220kV eastern – western system interconnection.

The existing power transmission system in Bhutan is shown in Figure 3-20.



Source: National Transmission Grid Master Plan (NTGMP) for Bhutan Vol-1 (CEA)

Figure 3-20 Existing Power Transmission System in Bhutan

(5) Distribution facilities

The Medium Voltage (MV) distribution line is a three-phase three-wire system, and the voltage class consists of 33kV, 11kV and 6.6kV. Most of the MV distribution system is of a radial configuration. In rural areas with low power demand density, a 33kV long distance distribution line is adopted for power loss reduction or voltage drop mitigation. However, most of the 33kV distribution system is of a long length and radial configuration. Since some of the transmission substations, such as Gomtu, Gedu, Jemina, Paro, Lobesa, and Watsa, consist of a single 66/33kV transformer, any maintenance on the single transformer needs complete shutdown of the 33kV system. Therefore, the related system reliability is remarkably low.

In addition, the Low Voltage (LV) distribution line is a three-phase four-wire system (415V, 230V) and a single-phase two-wire system (230V). The limits of voltage variation are ±6% for LV, ±10% for MV and High Voltage (HV).

Table 3-6 Number of Distribution Facilities (as of June 2013)

		Unit	Amount
MV Line	33kV	km	2,060 (10)
	11kV	km	2,112 (71)
	6.6kV	km	138 (0)
LV Line	415V, 230V	km	6,163 (193)
Number of transformers		-	3,741
Transformer capacity		kVA	622, 952

Note: 1. Figures in parentheses are underground cable.
2. Number of transformers includes privately owned transformers.

Source: JICA Survey Team

Source: Photo taken by JICA Survey Team

Figure 3-21 Mountain Route of Distribution Line (Wangdue)

(6) System reliability

In recent years, system reliability has been improved for the distribution system with the replacement of all the LV conductors by Arial Bunched Conductors (ABC) cable in rural areas, and the adoption of an underground distribution system and construction of 33kV substation with Gas Insulated Switchgear (GIS) in urban areas.

3.2.3 Electricity Tariff System

BPC has levied an electricity tariff on its customers. The wheeling charge including the tariff by DGPC to BPC, and export and import prices, are shown in Table 3-7.

Table 3-7 Unit Price of Electricity

(a) Domestic electricity tariffs

Category		August 2010 – June 2011	July 2011 – June 2012	July 2012 – June 2013
For Low Voltage Customers		**Energy Charge Nu/kWh**		
Block I (Lifeline)	**0 to 100 kWh/month**	0.85	0.85	0.85
Block II	**101 to 300 kWh/month**	1.47	1.54	1.62
Block III	**Above 301 kWh/month**	1.94	2.04	2.14
Low Voltage – Bulk Customers		1.94	2.04	2.14
Medium Voltage Customers (33/11/6.6kV)		**Energy Charge Nu//kWh**		
		1.63	1.71	1.79
		Demand Charges Nu//kW/Month		
		95	105	115
High Voltage Customers (66kV and Above)		**Energy Charge Nu/kWh**		
		1.51	1.54	1.54
		Demand Charges Nu/kW/Month		
		85	105	105

(b) Average domestic electricity tariffs

Category	August 2010 – June 2011	July 2011 – June 2012	July 2012 – June 2013
HV	1.67 Nu/kWh	1.74 Nu/kWh	1.74 Nu/kWh
MV	1.91 Nu/kWh	2.05 Nu/kWh	2.16 Nu/kWh
LV	1.49 Nu/kWh	1.55 Nu/kWh	1.62 Nu/kWh

(c) Wheeling charges

	August 2010 – June 2011	July 2011 – June 2012	July 2012 – June 2013
Charges	0.111 Nu/kWh	0.111Nu/kWh	0.111Nu/kWh

(d) Electricity tariff levied by generating companies

Name of Plant	Export Tariff (Nu/kWh)	Domestic Tariff
Chukha	2	0.13 Nu/kWh for 15% of energy generated and the remaining at 1.2 Nu/kWh
Kurichhu	1.8	0.13 Nu/kWh for 15% of energy generated and the remaining at 1.2 Nu/kWh
Tala	1.8	0.13 Nu/kWh for 15% of energy generated and the remaining at 1.2 Nu/kWh

(e) Import tariff

Particulars	Tariff (Nu/kWh)
ASEB	1.98 + Wheeling Charge (0.2) + 12% loss
WBSEB	2.00 + Wheeling Charge (0.2) + 12% loss

Source: POWER DATA BOOK 2012 (BPC)

3.2.4 Technical Requirements for Grid Connection

The compliance rules for the distribution system with generator are regulated as follows especially in "6 EMBEDDED GENERATION" of "DISTRIBUTION CODE 2008" by BEA.

- Connection agreement including dispatch, connection and disconnection as stipulated by the Distribution Licensee
- Continuous operation with the supply frequency between 49.0-50.5Hz
- Compliance of "DISTRIBUTION CODE 2008" and maintenance of operation in a safe condition
- Protection equipment coordinated with the distribution system
- Possession of excitation control system, governor system, safe shutdown arrangement, appropriate restart arrangement, and response to disturbances
- Negative sequence voltage at connection point to be less than 1%
- Failure level which does not exceed the withstand capabilities of the distribution system.

In addition, other requirements, such as the voltage for inter-connection of generators with distribution system, power quality, power factor, and protection for system, insulation coordination, outage planning, and incident/accident reporting procedure, etc. are covered in other chapters of "DISTRIBUTION CODE 2008". For the further expansion of grid connection with RE sources, development of a "System Access Rule" by BPC will be recommended based on the "DISTRIBUTION CODE 2008", from the aspect of RE power producer to define fundamental policies including system access services operation, such as a reception desk, a term for completion of system access study and necessary information on system access study and access study in case of grid connection with RE sources. This might be beneficial to secure efficiency, fairness, and transparency in the services concerned. In addition, technical requirements for a distribution system with generation facilities contain the following:

- Connection method;
- Power factor;
- Countermeasures for voltage fluctuations;
- Countermeasures for power quality;
- Countermeasures for short-circuit current mitigation;
- Protective device and protection coordination;
- Neutral grounding;

- Overload protection on distribution line;
- No-voltage on line confirmation device;
- Communication equipment for power security maintenance;
- Countermeasures for prevention of reverse power flow through distribution transformer; and
- Point of disconnection of generation facilities

Chapter 4 Promotion Scheme and Policy Challenges

In this chapter, the JICA Survey Team carries out an overview of the renewable energy promotion policy and the present status of the promotion system in Bhutan, and clarifies the issues which occur with the renewable energy master plan formulation and renewable energy development.

4.1 Implementation system for renewable energy promotion

4.1.1 Implementation system for renewable energy promotion

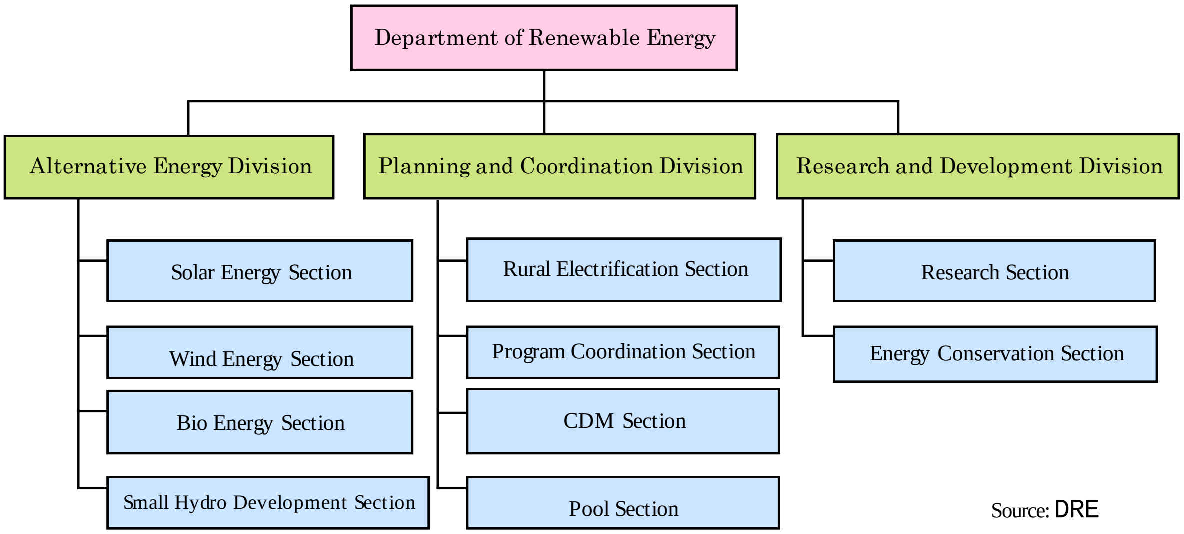
The Department of Renewable Energy, Ministry of Economic Affairs plays the central role in promoting renewable energy. According to the Alternative Renewable Energy Policy 2013 (April 2013), the following implementation system for renewable energy promotion is indicated.

Table 4-1 Implementation System for Renewable Energy Promotion

Implementation System	Major roles
Ministry of Economic Affairs (MoEA) Department of Renewable Energy (DRE)	Playing major roles for implementing renewable energy policy; ▪ Managing Renewable Energy Development Fund ▪ Developing RE Master Plan ▪ Coordinating and promoting PPA negotiation among relevant agencies ▪ Policy making for RE targets ▪ Developing financial mechanisms such as subsidy and feed-in tariff systems
Bhutan Electricity Authority (BEA)	Developing regulatory framework ▪ Designing framework of Feed-in-tariff ▪ Examining power system
Ministry of Agriculture & Forests (MoAF)	▪ Pico and micro hydropower/biomass/ bio-fuels/biogas resources ▪ R&D for development of sustainable bio-energy technologies. ▪ Responsible for providing sustainable source of biomass
National Environment Commission (NEC)	Support for the promotion and development of renewable energy projects

Source: JICA Survey Team

The organization structure for DRE of MoEA is as follows.



Source: DRE

Figure 4-1 Organizational Structure of Department of Renewable Energy, Ministry of Economic Affairs

4.1.2 Implementation Mechanism

Currently, AREP2013 has already been published, but in terms of its specific content, discussions have not yet started. In the future, DRE will play a leading role in developing the specific content by inviting consultants etc. An outline of the enforcement mechanism in the Policy is as follows.

(1) Fund Management works

DRE acts as the leading party to carry out fund management works such as REDF.

(2) Power Purchase Agreement (PPA) development works.

DRE takes the leading role to establish rules and/or framework of PPA. In addition, it is responsible for coordinating with related organizations. In the future, it will hire consultants and determine the details in approximately one year.

(3) Examination of and decision making for electricity costs (Feed-in Tariff)

According to the related terms of the Electricity Act, BEA shall determine the fee for grid interconnection projects. In the future, it will examine and decide the details, assuming the process takes over a year before a decision is made. The schedule is as follows.

- BEA prepares a proposal, and then applies to the Public Consultation. In addition, since the Tariff Division of BEA is now concentrating on underwriting in accordance with the tariff revision scheduled in September or October, 2013, the kick-off for the study is assumed to be held after completion of the tariff revision task.

- Based on the comments from the Public Consultation, BEA will create the proposal again, and then deliver it to the Public Consultation again.
- Based on the opinion of the Public Consultation for the second time, BEA will modify the proposal again to obtain the approval of the Board of BEA.

4.2 Improvement Plan

In AREP2013, the positive financial incentives for promoting investment in renewable energy are described. Hereinafter, the main articles are extracted.

4.2.1 Financial incentives

- Participants in renewable energy projects are exempt from payment of all import duties and taxes for the plant and equipment during the construction period.
- Even after starting operation of the project, for 10 years, they are exempt from corporate tax and individual income tax.
- Regarding re-investment by project participants, up to 25% of the re-invested amount is allowed to enjoy the tax deduction.
- R&D fees related to renewable energy development are allowed to be deducted from income.

4.2.2 Possibility of Foreign Direct Investment

(1) Framework of Foreign Direct Investment (FDI)

The policy concerning foreign investment is described in "Foreign Direct Investment (FDI) Policy 2010". For foreign investment, maximum foreign investor's equity and minimum project cost of each business sector are stipulated in the policy. Foreign equity of less than 20% shall not be permitted.

Sector is roughly divided into two; these are the manufacturing sector and the service sector. The energy business, including renewable energy, belongs to the manufacturing sector.

(2) Foreign investment in Energy business

The upper limit of foreign investor's share in the Energy business is shown below.

Table 4-2 Upper Limit of Foreign Investor’s Share in the Energy Business

Type		Maximum share	Regulation
Hydro	P<=1MW	Not available	Renewable Energy Policy
	1MW< P <=25MW	minority	Renewable Energy Policy
	25MW< P <=150MW	74%	Sustainable Hydro Power Policy
	150MW< P <=1000MW	100%	Sustainable Hydro Power Policy
Other Renewable Energy		100%	Renewable Energy Policy

Source: JICA Survey Team based on Sustainable Hydro Power Policy, Renewable Energy Policy

The maximum share of large hydro-power by foreign investors is stipulated by Sustainable Hydro Power Policy. On the other hand, the maximum share of the renewable energy business by foreign investors is stipulated by Renewable Energy Policy. The Renewable Energy Policy states that "Investments in RE projects are open for investments from the private sector including FDI." According to the interpretation of DRE, it is acceptable to invest in an RE projects (excluding small hydro power) can be invested 100% by foreign investors. Only minority share is admitted in case of small hydro power businesses. Only domestic enterprises have a right to develop small hydro power of 1MW or less, and foreign investor participation is not allowed.

(3) Exchange for the foreign currency of dividends

It is described in Article 12 clause 2 of "Foreign Direct Investment Rules and Regulations 2012" as "Repatriation of dividends shall be in the currency of earning of the business." Therefore, foreign currency exchanges of dividends are not allowed. There is no description concerning the Manufacturing Sector though there are the exception articles[11] that the foreign currency exchanges of dividends are allowed up to five million USD per year in the case of the Service Sector.

Therefore, the manufacturing sector doesn't have the means to earn foreign currency except by exporting a product to a foreign country and receiving foreign currency. When it is necessary to buy a product from a foreign country with foreign currency for maintenance etc., the exchange of foreign currencies that corresponds to the amount of money is allowed.

In the case of the electric power business using renewable energy, the company sells the generated electricity to BPC, and BPC makes payments to the company in the domestic currency (Nu.), and as a result, all earnings are in the domestic currency. Thus, the system does not attract foreign investors even if the level of FIT is high enough.

4.2.3 Sources of REDF funding

The funding sources for promoting renewable energy described in AREP2013 are as follows.

- Up-front premium collected from developer when developing hydroelectric power plant
- Royalty from large hydroelectric power plants
- Donor’s Support
- CDM credit
- Government funds

Among the above, up-front premium differs from development scale and bidding condition, in that 1~2% of the construction fees shall be paid, only once at the start of construction. The largest source of funding

[11] For investments in Priority Activities in the service sector, where the investment in the project was made in convertible currency and the earnings are in non-convertible currency, the Royal Government shall allow the purchase of convertible currency for the purpose of repatriation of dividends. Such purchases can be up to US$ 5 million per annum for the first ten years of the project’s commercial operation.

is the Royalty paid from large hydroelectric power plants. For large-scale hydro power plants (1,500 MW as the sum of Tala, Chukha, and Kurichhu), based on the purpose of exports to India, the government has the right to use 15% of the power generation output (average value 12% during the first 12 years, 18% during subsequent years). Its value is multiplied by the right based amount of power, about 2 Nu / kWh selling price of electricity to India.

4.2.4 Verification of the Necessary Funding Source for Promotion Measures

In AREP2013, for the creation of a beneficial investment environment in renewable energy in the country, the establishment of a renewable energy development fund (REDF) to provide financial assistance has been stipulated. The existence of this fund plays a very important role in promoting renewable energy.

To establish an REDF fund mechanism, continued promotion of renewable energy by funding sources has been described, but nothing is actually mentioned about the assumed funds' scale and the certainty of the financing. In this section, grasping the current situation and predicting the future trend of Royalty income scale based on the hydropower development plan has been examined.

(a) Prerequisites

- Assumed period: 2013-2025
- Royalty Ratio: 15%
- PPA scenario:
  - -Base scenario: maintain selling price of electricity to India - about 2 Nu / kWh
  - -Incremental Scenario: 10% price increase every four years
- REDF allocation scenario:
  - - 30% allocation, 20% distribution, 10% Distribution
- Hydropower development scenario
  - - Major hydropower development scheme is shown in the following table.

Table 4-3 Major Hydropower Development Scheme

No.	Projects	Completion Year	Installed Capacity (MW)	Energy Generation [GWh]
Existing				
1	Chukha	1988	336	1,745
2	Kurichhu	2002	60	361
3	Basochhu	2002	24	300
4	Basochhu-II (lower stage)	2005	40	
5	Tala	2006	1,020	4,405
	Total		**1,480**	**6,811**
On-going & Planned Projects				
1	Punatsangchhu-I	2016	1,200	5670

No.	Projects	Completion Year	Installed Capacity (MW)	Energy Generation [GWh]
2	Punatsangchhu-II	2017	1,020	4300
3	Mangdechhu	2017	720	2923
4	Dagachhu	2014	124	515
5	Sankosh	2023	2,560	6215
6	Kuri-Gongri	2025	2,640	10056
7	Chamkharchhu-I	2024	770	3252.92
8	Kholongchhu	2021	600	2592.83
9	Wangchhu	2022	570	2526
10	Bunakha	2020	180	1669.27
11	Amochhu	2022	540	1835
12	Nikachhu	2019	130	475
	Total		**11,054**	**42,030**
Grand Total (GWh)			**12,534**	**48,841**

*Energy generation: Existing plants=actual value (FY2012), On-going & Planned projects=design value

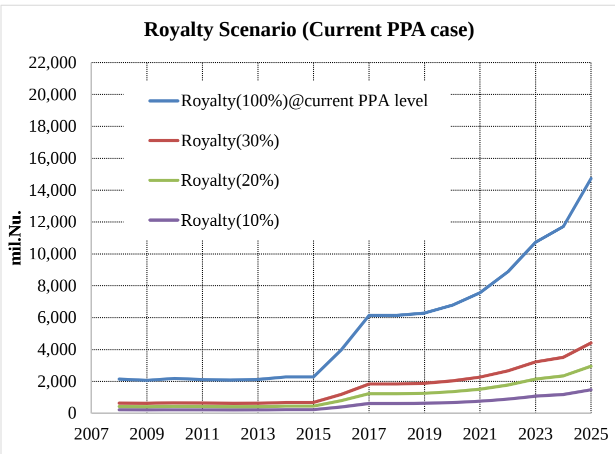
Source: MoEA

(b) Conclusion

At present, there is a Royalty income of about 2,100 million Nu. If large-scale hydropower development goes smoothly, in 2025, the entire amount of Royalty revenue and the assumed amount available for distribution to REDF would be as follows.

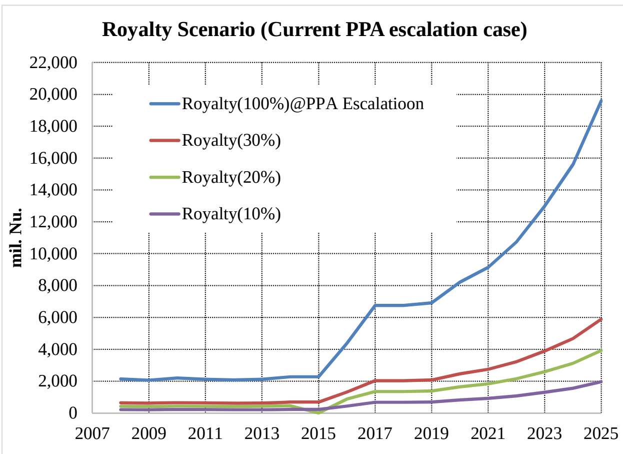
(i) Base scenario: the entire amount - 15,000 million Nu. REDF allocations - about 1,500 ~ 4,500 million Nu.

(ii) Incremental scenario: the entire amount - 20,000 million Nu. REDF allocations - about 2,000 ~ 6,000 mil Nu.



Source: JICA Survey Team

Figure 4-2 REDF allocation scenario (base PPA)



Source: JICA Survey Team

Figure 4-3 REDF allocation scenario (incremental PPA)

(c) Relation between tariff and supply cost

As shown in the table below, in line with the weighted average supply cost in 2012 (2.3Nu/kWh), the average tariff is 1.7Nu/kWh, with a compensation of 0.6Nu/kWh.

The required subsidy from the Government is computed by multiplying the compensation of 0.6Nu/ kWh by total generation. The subsidy in 2007 was 600 mil Nu, and this increases to 1,100mil.Nu in 2012.

Table 4-4 Relationship between Planned Supply Cost and Electricity Prices

Category	Items	2007	2008	2009	2010	2011	2012
LV	Cost (Nu./kWh)	3.23	3.34	3.42	4.21	4.21	4.21
	Tariff(Nu./kWh)	1.31	1.44	1.54	1.56	1.56	1.56
	GWh	231	259	275	304	339	378
MV	Cost(Nu./kWh)	1.93	2.01	2.15	2.54	2.54	2.54
	Tariff(Nu./kWh)	1.43	1.58	1.72	2.05	2.05	2.05
	GWh	83	80	89	108	110	124
HV	Cost(Nu./kWh)	1.62	1.64	1.74	1.74	1.74	1.74
	Tariff(Nu./kWh)	1.43	1.58	1.72	1.72	1.74	1.74
	GWh	589	733	1008	1159	1171	1267
Average	Cost(Nu./kWh)	2.059	2.081	2.103	2.273	2.311	2.324
	Tariff(Nu./kWh)	1.399	1.546	1.684	1.712	1.723	1.723
	Difference	0.660	0.534	0.419	0.561	0.588	0.601
Subsidy (mil.Nu.)		595	573	575	882	952	1,062

Source: JICA Survey Team based on BEA data

(d) Structure of royalty fund flow

For a better understanding of the royalty fund flow, Figure 4-4 shows the procurement flow for electric power of BPC and Table 4-4 shows the breakdown of the procurement of electric power. According to the BPC financial statements in 2012 that described the electricity purchased by BPC, the amount of electric power generation was 1,835GWh and the amount of purchased electric power was Nu. 1,159mil. Of the 6,730GWh of electricity generated from the existing 5 hydroelectric power plants in 2012, namely, Chukha, Kurichhu, Basochhu, Basochhu-II (lower stage), and Tala, DGPC is selling 1,009GWh (④), which corresponds to 15% of the total electric power generation, to BPC at a unit price of 0.13Nu./kWh as the royalty energy obligation to be paid for the government. Since it is impossible to generate enough electricity to cover the domestic demand only from the royalty energy obligation, the shortage is procured from DGPC by compensating 776GWh@1.2Nu./kWh (⑥) of electricity from those existing 5 hydroelectric power plants as additional energy, in addition to the 50GWh@1.86Nu./kWh (⑤) imported from India. On top of these, BPC owns the right to take over 1.7GWh of electricity (⑧) for free from the Jaldakha hydroelectric power plant, located on the border between India and Bhutan. Additionally, BPC is procuring 1.39GWh@2.47Nu./kWh of electricity (⑨) and 0.57GWh@2.45Nu./kWh of electricity (⑩) from WBSEB and ASEB, respectively. As a result, BPC has bought 1,835GWh of electricity for a total of 1,159mi.Nu, which is going to be recorded on the financial statements as an electricity purchasing cost.

BPC needs to buy at 1.20Nu./kWh, which is the original power generation cost of DGPC, but since it has bought 1,009GWh (④) as the royal energy obligation at a very low unit price of 0.13Nu./kWh, about 1,100mil.Nu, which is the amount multiplied by 1.07Nu./kWh (the difference of the two) with 1,009GWh, is going to be virtually paid to BPC from the government in the form of grants.

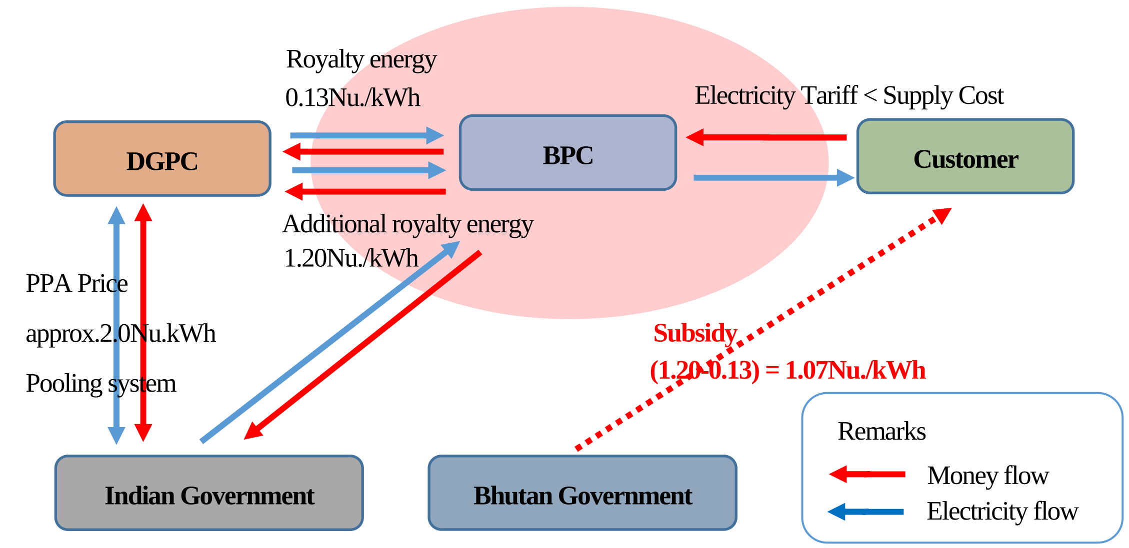
Assuming that the demand for electricity up to 2025 will be about twice the current level, and the subsidies for electricity tariffs will double as well, the compensation amount is estimated to be about 2,200 million Nu. This number when compared to the Royalty sums (15,000 million Nu), calculated in the previous clause as a base case, is not a very large portion.

Therefore, it is presumed that if hydropower were to be developed smoothly, funding sources of REDF that rely heavily on Royalty revenue from hydroelectric power would be sufficient.

Table 4-5 Power Purchase by BPC (FY2012)

No.	Items	Output [MW]	Energy Generation [GWh]	Unit price [Nu/kWh]	Total expense [mil. Nu]
HP-1	Chukha	336	1,745	-	-
HP-2	Kurichhu	60	361	-	-
HP-3	Basochhu	24	300	-	-
HP-4	Basochhu-II (lower stage)	40		-	-
HP-5	Tala	1020	4,405	-	-
①	Total generation	1480	6,811		
②=①×1.2%	Allowable technical loss (1.2%)		82	-	-
③=①-②	Net energy available for sale	1480	6,730	-	-
④=③×15%	Royalty energy obligation (15%)		1,009	0.13	131
⑤	Purchases of import energy		50	1.86	92
⑥	Additional energy sales		776	1.2	931
⑦=④+⑤+⑥	Total		1,835		1,154
⑧	Royalty energy from Jaldakha HP		1.70	0	0
⑨	WBSEB		1.39	2.47	3
⑩	ASEB		0.57	2.45	1
⑪	Total		3.66		5
⑫=⑦+⑪	Total	1480	1,839		1,159

Source: JICA Survey Team based on BEA data



Source: JICA Survey Team

Figure 4-4 Power Purchase Flow

4.3 Risk Assessment of RE Project Developers (PPA)

When participating in renewable energy projects, the developer needs to reduce or mitigate the implementation risk through PPA with RGoB, represented by DRE. From the viewpoint of risk aversion, with regard to the following items, it is necessary for DRE to carry out discussion and study with related organizations, during its process to build the frame of the PPA.

- Security of receipt of power generation output
- Payment currency selection system
- Determining method of cost (Purchase price of the PPA)
- Any modification on unit price
- Subsidy (any change in preferential policies)
- Guarantee system in the case of outages attributable to the trustee (BPC)
- Guarantee system for accidents in transmission facilities and capacity shortage
- Penalties due to accident on power plant side

4.4 Feasibility of Economic Aspects

4.4.1 Cost Estimation of each Renewable Energy

According to the following conditions, the power generation cost of each renewable energy (biomass, wind power, solar PV, and small hydro power) explained in detail in Chapter 6 is calculated based on the project scale that was able to be executed in Bhutan.

<Assumption>

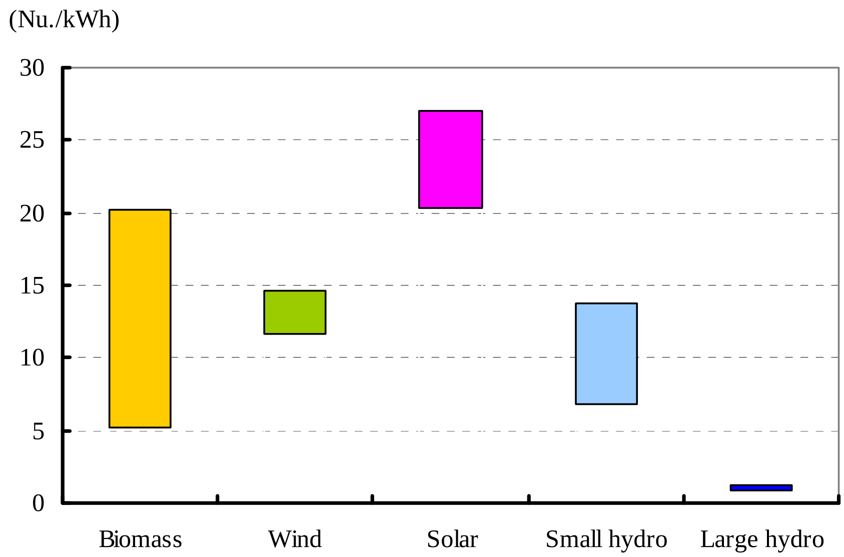
- Discount rate = 12%, Salvage value = 10%
- Exchange rate = 65 Nu./USD
- Refer to the Project parameter to the table below

Table 4-6 Project Parameter of Each Renewable Energy Sector

	Life (years)	Availability factor (%)	Unit construction cost (USD/kW)	O&M cost to construction cost
Biomass	20	30%	1,300 – 5,000	3.1%
Wind	20	20%	2,000 – 2,500	2.5%
Solar	25	15%	3,000 – 4,000	1.0%
Small hydro	30	35%	2,500 – 5,000	0.6%
Large hydro	30	50%	450 – 620	0.6%

- As for biomass, the range of the unit construction cost is large because there is a difference in the adopted technology and the fuel type. The biomass fuel is assumed to be obtained free of charge.
- As for wind power and solar PV, there are cost differences in the reinforcement of roads and the development of land, though the cost difference is small with equipment cost. Moreover, if the expected availability factor is less than the value shown in the table, it is judged that the economic efficiency is inferior and development will not be carried out.
- As for small hydro power, the construction cost differs greatly depending on the site.
- Large hydro power is calculated referring to the value of the three power plants of Punatsangchhu-I, II, and Mangdechhu.

The calculation result of the power generation cost of various power sources is shown below.



Source: JICA Survey Team

Figure 4-5 Power Generation Cost of Various Power Sources

As expected, the power generation cost of various renewable energy is different, and the cost of all renewable energies is higher than 2.3 Nu/ kWh, which is the average cost of supply shown by BEA.

4.4.2 FIT Level of each Renewable Energy

(1) Estimation of FIT level

The FIT level is estimated according to the following conditions based on the power generation cost provisionally calculated in Chapter 4.4.1. It is thought that development of RE will be advanced in the order corresponding to cheap unit construction cost after the FIT system is introduced. Therefore, the unit construction cost of renewable energy to be supported is set a little higher than the lowest value.

- Target IRR = 10%
- FIT supporting periods = 20 years

The calculation result is shown below.

Table 4-7 FIT Level of Each Renewable Energy Sector

	Unit construction cost (Nu./kW)	O&M cost (Nu./kW/year)	FIT level (Nu./kWh)
Biomass	133,000	4,110	7.5
Wind	137,000	3,410	11.1
Solar	208,000	2,080	20.2
Small hydro	195,000	1,170	7.8

Source: JICA Survey Team

A FIT of biomass and small hydro power becomes about 8 Nu./kWh, that of wind power becomes about 11 Nu./kWh and that of solar PV becomes about 20 Nu./kWh.

(2) Achievement of target value and fiscal resources

Fiscal resources needed to achieve the development target value indicated with AREP 2013 when the above-mentioned FIT is introduced are calculated. The result is as follows. Because the target value of small hydro power was not indicated in AREP 2013, the target value of the 11th 5-year plan (draft) is used.

Table 4-8 Achievement of Target Value and Fiscal Resources

	Target (MW)	Load factor (%)	FIT level (Nu./kWh)	Necessary fund (million Nu./year)
Biomass	5	30%	7.5	98
Wind	5	20%	11.1	97
Solar	5	15%	20.2	132
Small hydro	12	35%	7.8	287
Total	27			614

Source: JICA Survey Team

More than 600 million Nu. is needed every year in order to achieve the target value of renewable energy by using FIT. This amount corresponds to about 10% of the value of Royalty Energy after 2017 when three large hydro power plants will start operation.

(3) Sensitivity analysis

The level of IRR changes depending on the bank interest rate and the risk level of each renewable energy. The relation between IRR and FIT is shown below.

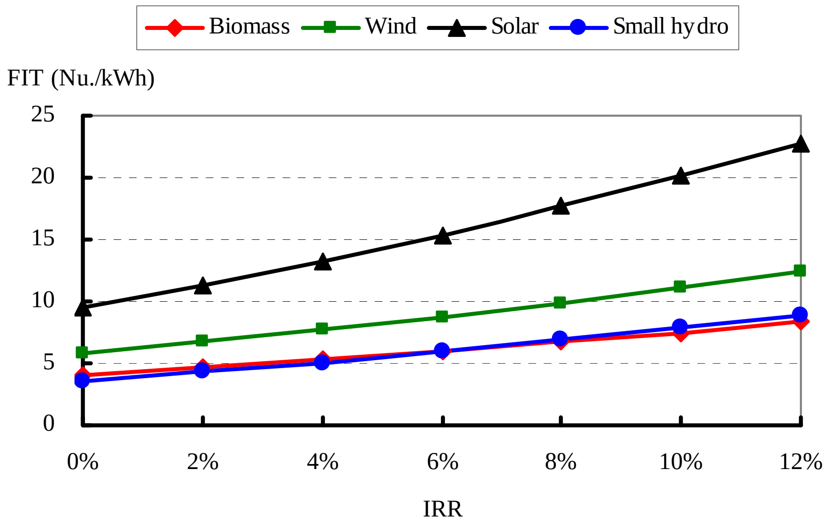
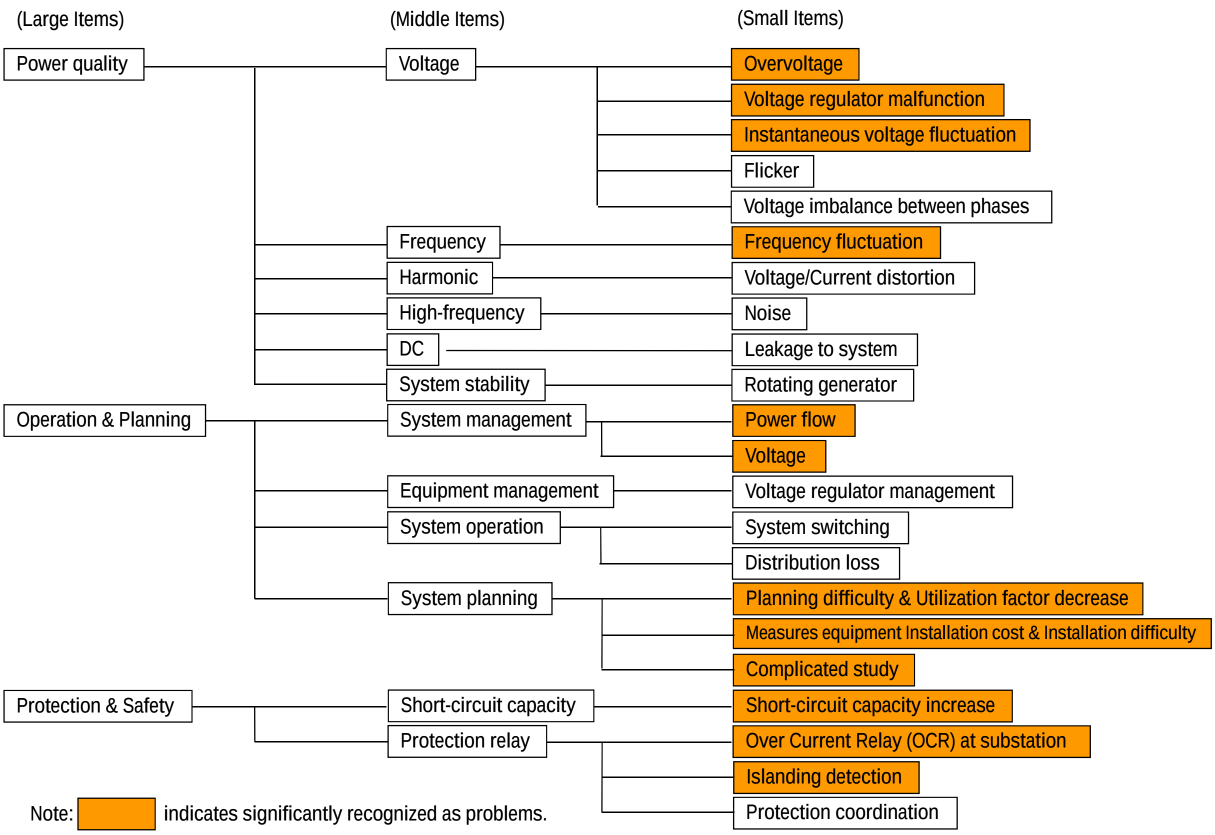


Figure 4-6 Relation between IRR and FIT

The value of FIT decreases when the value of IRR lowers. As for the level of the decrease, the case of the solar is the most remarkable.

4.5 Problems with Grid Connection

When a large-capacity distributed generator such as RE is connected to the distribution system, there are various problems for concern, as shown in Figure 4-7. Especially in the early stages, it is an over voltage along the distribution line by a reverse power flow within the distribution system. An example of countermeasures in Japan is shown in Figure 4-8 and Figure 4-9.



Source: JICA Survey Team (based on the website of the Institute of Applied Energy of Japan)

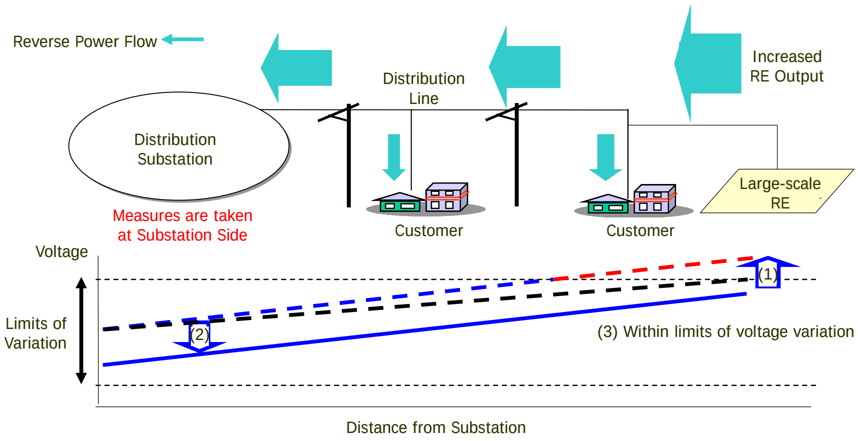
Figure 4-7 Problems for concern in Distribution System

Problems and examples of countermeasures are shown in Table 4-9.

Table 4-9 Problems and Examples of Countermeasures

Problems	Explanation	Examples of Countermeasures
Over voltage	Over voltage along the distribution line due to a reverse power flow	Installation of voltage regulator (SVR)
False operation of voltage regulator	Impossible voltage control in case of reverse power flow at SVR	Installation of highly-developed new type SVR
Instantaneous voltage fluctuation	Occurrence of instantaneous voltage fluctuation due to output change of short duration at connection/disconnection with grid	Installation of compensation device for instantaneous voltage fluctuation, effective utilization of storage battery
Flicker	Occurrence of flicker by voltage fluctuation around 10 Hz due to short duration and cyclic output fluctuation	Improvement of protective method for voltage regulator, and effective utilization of storage battery
Voltage imbalance between phases	Damage to generator by increase of negative-sequence current	Phase connection change of single phase load, adoption of current balancer system
Frequency fluctuation	Insufficiency of system output control against output fluctuation of RE resource	Increase of regulation ability at system side, effective utilization of storage battery
Harmonic (Voltage/Current distortion)	Damage to facilities due to increase of harmonic voltage distortion by occurrence of harmonic current	Installation of harmonic compensation device with active filter
Harmonic (Noise)	Occurrence of radio influence by increase of harmonic noise	Adoption of active or passive electromagnetic noise filter
DC Leakage to system	Influence on facilities such as transformer due to superimposed DC by increase of number of grid connation	Adoption of transformer less inverter
System stability (Rotary machine)	Large power swing in case of short-circuit fault	Installation of high speed circuit breaker at RE resource side
System management (Power flow/Voltage)	Difficulty in power flow and voltage management by system operator with large-scale RE resources	Adoption of monitoring system for distribution line
Voltage regulator management	High frequency maintenance by increase of voltage regulator operation	Sending voltage decision management to minimize tap change
System operation (System switching)	Difficulty in loop switching due to broadening voltage phase difference angle	Adoption of system information measuring sensor
System operation (Distribution loss)	Increase of distribution loss by increase of reactive power from voltage regulator	Loss reduction of interconnection inverter
System planning (Difficulty in planning & Decrease of utilization factor)	Difficulty in decision for timely system expansion due to difficulty in forecast of demand and load factor Decrease of facilities utilization factor by decrease of power flow of distribution line	Established system planning method with effective utilization of storage battery, etc. corresponding to uncertainty
System planning (Cost and difficulty in installation of voltage regulator)	Increase of Equipment cost by using a large number of voltage regulators Limitation of voltage regulator installation because there are few places which can bear capacity and weight	Downsizing of voltage regulator
System planning (Complicated review work)	Complicated review work for grid connection with increase of RE resources	Establishment of system access rule
Increase of short-circuit capacity	Damage to facilities due to insufficiency of short-circuit withstand capability of circuit breaker	Adoption of High speed and current-limiting circuit breaker
Protection relay detection (OCR at substation)	No detection of OCR due to decrease of short-circuit current at substation by shunt effect	High accuracy of relay setting
Protection relay detection (Island detection for dispersed sources)	Low sensitivity of island detection with several RE sources	Protection coordination setting taking into account overall system with several RE sources
Protection relay detection (Reverse power flow through transformer)	Effect on system protection coordination and voltage management at occurrence of reverse power through transformer	High accuracy of relay setting

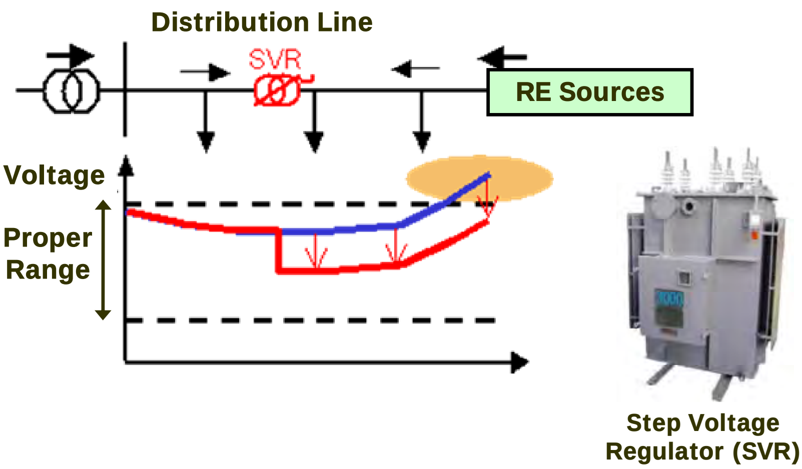
Source: JICA Survey Team



(1) When RE output increases, line voltage rises due to increase of reverse power flow.
(2) Sending voltage at substation will drop automatically after taking countermeasures to detect current change in case of reverse power flow.
(3) Line voltage can be controlled within the limits of variation.

Source: Website of TEPCO

Figure 4-8 Example of Countermeasure for Over voltage by Substation

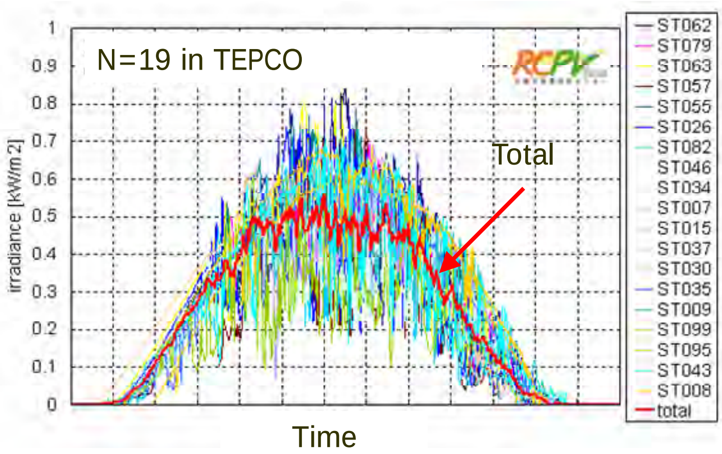


Distribution line voltage can be controlled within the limits of variation by installation of SVR.

Source: JICA Survey Team (based on the website of the Institute of Applied Energy of Japan)

Figure 4-9 Example of Countermeasure for Over voltage by Distribution Line

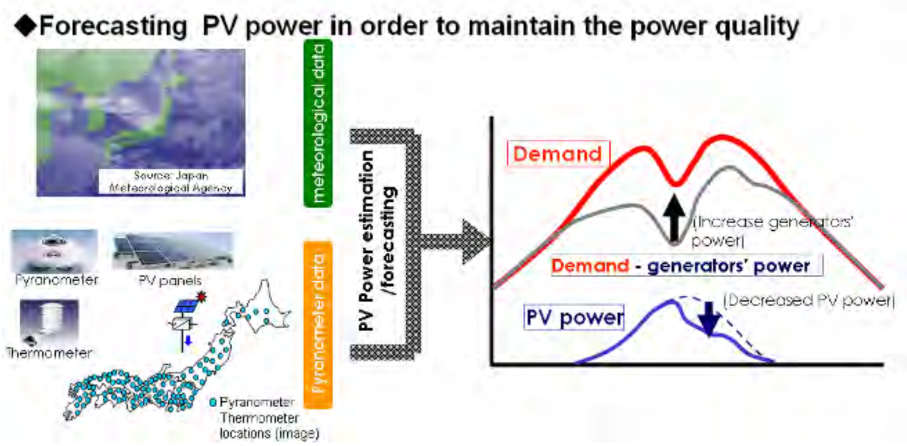
The output of PV and wind power generation is subject to weather conditions. If the output of PV and wind power generation distributed in some areas is totaled, in many cases, each change will offset each other and the rapid change with a small time scale (time width) will gradually become smaller. Therefore, so that the amount of RE introduction increases and as it is distributed in a large area, the effect which offsets change becomes larger, as shown in Figure 4-10. Although the many discussions about the issue that PV and wind power generation need to smooth output with a storage battery since generation output fluctuation is large are not a mistake, the equalization of the generation output in a power system should also recognize that increasing the amount of RE introduction can be realized. In Spain, where wind power generation occupies 20% of total installed capacity/power generation, it is considered that the reason why the power system does not collapse due to output fluctuation is that rapid output fluctuation as a whole is very small, by the offset of this change. Within a time scale of several hours or more, although output fluctuation is still large, if this can only be predicted, sufficient management is possible and this is actually practiced in Spain.



Source: Website of National Institute of Advanced Industrial Science and Technology of Japan

Figure 4-10 Smoothing Effect (Example of PV Generation Output)

Moreover, the adoption of battery energy storage which utilizes surplus power during off peak demand period, the development of methods to estimate the current PV power generation output from weather data or sunlight data, and forecast of the PV power generation output will be effective, as shown in Figure 4-11.



Source: JICA Survey Team

Figure 4-11 Forecast Technologies for PV Power Generation (Example in Japan)

However, if the power generation of large-capacity RE sources is exported to India, the amount of power may be expected to fluctuate. With regard to the export tariff, a power purchase agreement (PPA) is generally signed between Bhutan and India at the time of hydropower plant completion. Although it is due to be revised every five years (10% price increase), it has not been revised so far, and Bhutan is showing the intention to revise the tariff; however, India does not tend to accept Bhutan's proposals. In addition, even if the amount of exports is below or above the planned value, a penalty is not imposed, but the Indian side may impose a penalty by Unscheduled Interchange (UI) applied in India in the case of significant fluctuation in the amount of exports with large-capacity RE sources.

An isolated operation detector should be installed. The reasons are that electric shock of maintenance workers, facilities damage, and delay of power system restoration, etc. occur in the event of main system outage by factors such as work outage and failure. The distributed power source which should be tripped essentially continues operation independently under isolated operation separated from the main power system.

In addition, when a large amount of the power conditioner (PCS) which converts the DC power into the AC power generated by the solar cell is connected to the grid, there is some concern for system voltage distortion and anomalous overheating etc. of facilities connected around the PCS, due to the harmonic current. In order to mitigate the harmonic current, the adoption of a harmonic voltage synchronization system, which causes the harmonic current not to flow, is effective by making system harmonics voltage, and amplitude and harmonics voltage with an equal phase superimposed on the internal voltage of PCS.

Incidentally, as a reference, grid connection protection relay in the case of using PCS is shown in Table 4-10.

Table 4-10 Grid Connection Protection Relay in the case of using PCS

Contents of protection relay	Abbreviation	Intended fault for protection
Overcurrent	OCR-H	Short-circuit inside the premises
Ground fault overcurrent	OCGR	Ground fault inside the premises
Overvoltage	OVR	Generation facilities abnormality
Undervoltage	UVR	Generation facilities abnormality, System blackout, system short-circuit
Frequency increase	OFR	System frequency increase
Frequency decrease	UFR	System frequency decrease
Isolated operation	—	Isolated operation

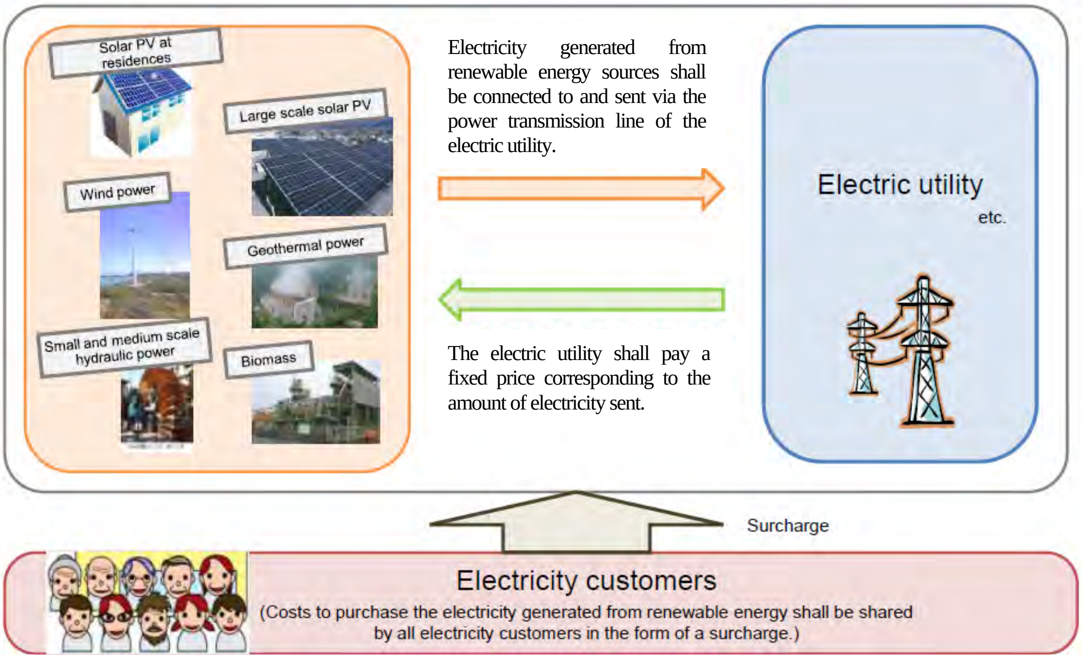
4.6 Design of FIT (in the Case of Japan)

In order to promote renewable energy, an attractive tariff system, namely design of Feed in Tariff (FIT), becomes important. A workshop was held during the second field survey to explain the structure of FIT in Japan as a preceding example.

4.6.1 FIT System

The electric utility is responsible for purchasing electric power generated from renewable energy vendors at a procurement cost within a predetermined period specified by the government. From the viewpoint that costs required in generating renewable energy are counted in the electricity bill and fairly born by all consumers, people should incur their cost according to the amount of power they used.

- This is a scheme to foster renewable energy in Japan with the help of all electricity customers.
- Electric utilities will be obliged to purchase electricity generated from renewable energy sources such as solar PV and wind power on a fixed-period contract at a fixed price. This will promote the introduction of renewable energy.
- Costs of purchased electricity generated from renewable energy shall be transferred to electricity customers all over Japan in the form of a nationwide equal surcharge. They shall pay the surcharge for renewable energy proportional to electricity usage.

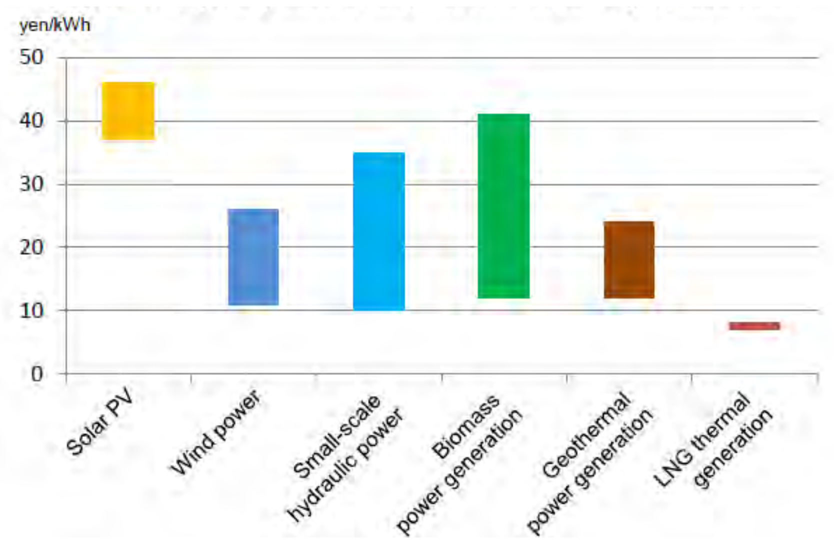


Source: Ministry of Economy, Trade and Industry (METI), in Japan

Figure 4-12 FIT System in Japan

4.6.2 Power Generation Cost

The power generation cost of renewable energy is more expensive than that of conventional thermal power generation and the like. The figure below shows the power generation cost of renewable energy in Japan; however, the value of cost greatly changes depending on the geographical conditions when the energy source was constructed, accessibility, and the technical differences even for the same energy source.



Source: Ministry of Economy, Trade and Industry (METI), in Japan

Figure 4-13 Generation cost for renewable energy in Japan

4.6.3 Logic for Determining FIT

(1) Necessary costs

The costs included in the FIT consist of following items.

- Construction cost
- Operating and maintenance costs
- Connection cost that should be born by renewable energy vendor side
- Land lease
- Corporate tax

(2) Appropriate profit

When assessing the business profitability of a project, internal rate of return (IRR) is generally used. Also when determining an appropriate profit, it is important to take the comprehensive comparison with other business into consideration, and every country including Japan uses “pre-tax IRR” as a project index relating to FIT design.

According to a document from the Ministry of Economy, Trade and Industry in Japan, Germany and Spain set IRR to about 7%, and about 8.5 to 10%, respectively. Considering the difference in interest rate (approximately 1% in Germany and 4% in Spain), typical IRR in Japan is set at 5 to 6% on pre-tax, and so the IRR should be set at 1 to 4% for a low risk project and 10 to 13% for a high risk project, according to the risk of the project. The document describes the reasons for setting these values

(3) Estimation of FIT

FIT is estimated by determining the size of each energy source, necessary costs for each fuel kind, appropriate profit (IRR) according to the degree of risk and durable years, and by converting the calculated total costs to the present values. The FIT for each energy source and size is as shown in the table below.

Table 4-11 FIT system in Japan (part-1)

Energy source		Solar PV		Wind power		Geothermal power		Small- and medium-scale hydraulic power		
Procurement category		10 kW or more	Less than 10 kW (purchase of excess electricity)	20 kW or more	Less than 20 kW	15MW or more	Less than 15MW	1MW or more but less than 3MW	200 kW or more but less than 1MW	Less than 200 kW
Cost	Installation cost	325,000 yen/kW	466,000 yen/kW	300,000 yen/kW	1,250,000 yen/kW	790,000 yen/kW	1,230,000 yen/kW	850,000 yen/kW	800,000 yen/kW	1,000,000 yen/kW
	Operating and maintenance costs (per year)	10,000 yen/kW	4,700 yen/kW	6,000 yen/kW	—	33,000 yen/kW	48,000 yen/kW	9,500 yen/kW	69,000 yen/kW	75,000 yen/kW
Pre-tax IRR (Internal Rate of Return)		6%	3.2%(*1)	8%	1.8%	13%(*2)		7%	7%	
Tariff (per kWh)	**Tax inclusive** (*3)	**42.00 yen**	**42 yen**(*1)	**23.10 yen**	**57.75 yen**	**27.30 yen**	**42.00 yen**	**25.20 yen**	**30.45 yen**	**35.70 yen**
	Tax exclusive	40 yen	42 yen	22 yen	55 yen	26 yen	40 yen	24 yen	29 yen	34 yen
Duration		20 years	10 years	20 years	20 years	15 years	15 years	20 years		

Source: Ministry of Economy, Trade and Industry (METI), in Japan

Table 4-12 FIT system in Japan (part-2)

Energy source		Biomass				
Biomass type		Biogas	Wood fired power plant (Timber from forest thinning)	Wood fired power plant (Other woody materials)	Wastes (excluding woody wastes)	Wood fired power plant (Recycled wood)
Cost	Installation cost	3,920,000 yen/kW	410,000 yen/kW	410,000 yen/kW	310,000 yen/kW	350,000 yen/kW
Cost	Operating and maintenance costs (per year)	184,000 yen/kW	27,000 yen/kW	27,000 yen/kW	22,000 yen/kW	27,000 yen/kW
Pre-tax IRR (Internal Rate of Return)		1%	8%	4%	4%	4%
Tariff (per kWh)	Tax inclusive	40.95 yen	33.60 yen	25.20 yen	17.85 yen	13.65 yen
Tariff (per kWh)	Tax exclusive	39 yen	32 yen	24 yen	17 yen	13 yen
Duration		20 years				

Source: Ministry of Economy, Trade and Industry (METI), in Japan

Chapter 5 Preparation of Renewable Energy Master Plan

In this chapter, the JICA Survey Team assesses the urgent necessity of energy diversification by renewable energies in Bhutan, and recommends the topics that should be paid attention to during the renewable energy master plan formulation.

5.1 Necessity of Renewable Energy Master Plan (REMP)

5.1.1 Assessment of Necessity of REMP

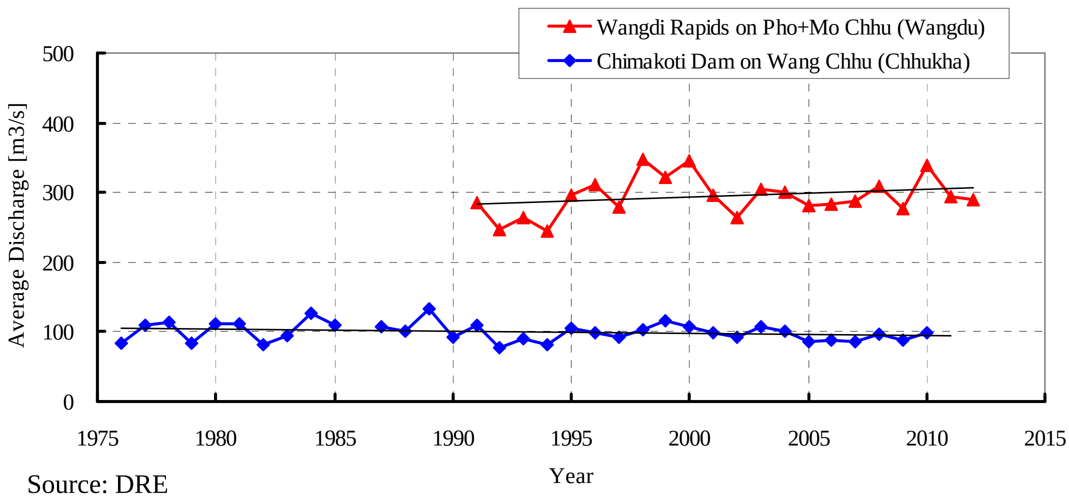
According to the Alternative Renewable Energy Policy 2013, it is expressed that the energy portfolio by renewable energy is necessary based on the following four points.

(1) Reliance on a single electricity source
(2) Rising energy demand
(3) Increasing fossil fuel imports
(4) Low hydropower production in winter months

On the other hand, the RGoB is developing very abundant water resources, and selling the surplus electricity to India except during the winter season. There is no problem for the electricity supply in other seasons. From the viewpoint of supplying electricity to the Bhutanese people, it is thought that enough supply power can be secured by developing large-scale hydro power plants gradually in the future.

(1) Reliance on a single electricity source (reduction of water flow by climate change)

As for the amount of power generation in the Chhukha hydroelectric power plant, substantial change is not seen, as shown in Figure 3.3. The following figure shows the trends of the big river flow in Bhutan. There is no substantial change.



Source: DRE

Figure 5-1 Trends of the Big River Flow in Bhutan

Thus, it is difficult to find grounds that the amount of river flow has decreased by the influence of climate change judging from the tendency of the past 30 years or so.

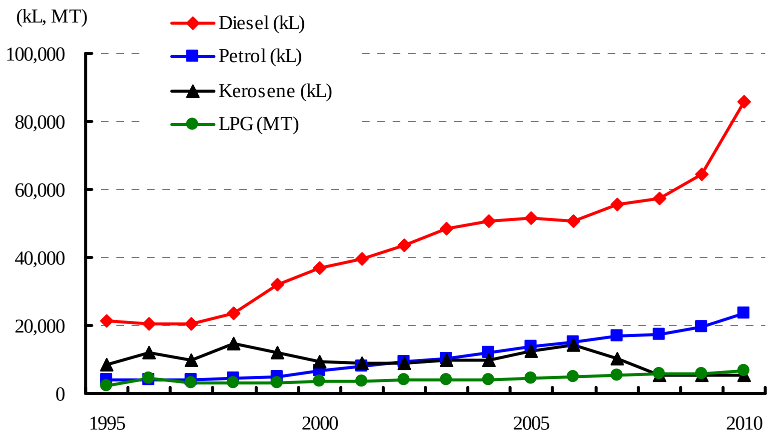
Recently, the global warming tendency is remarkable due to the influence of the human race's production activity. There are opinions that river flow will dry up in the future due to the influence of glaciers melting. According to the papers related to the relation between river flow and climate change, there are reports[12] that the river flow rate also may increase so that the amount of evaporation of seawater may increase by the influence of global warming and the rainfall may increase. And moreover, glacier melting occurs remarkably in the summer of the rainy season, and the river flow rate in winter of the dry season does not contain the amount of glaciers melting. Therefore, it is thought that the river flow rate in winter is hardly affected by global warming.

(2) Rising energy demand

The electric power demand is forecasted to increase steadily in the future as shown in Chapter 3.2.2. As for the expansion of these electric power demands, an increase in Bhutanese people's power consumption is included. However, RGoB will positively attract the electric power multi consumption type industry to the industrial zone in the southern part of Bhutan, exploiting the advantage of the cheap rate of electricity, and an increase in the electric power demand is largely dependent on an increase in the power consumption of those factories. If the electricity rate changes (cheap in summer, and high in winter) depending on the balance between demand and supply to the customers in the industrial zone as a condition of the contract at the attracting stage, the power consumption of the factory in winter can be controlled. And the increase of the electric power demand in winter will be controlled at a low level.

(3) Increasing fossil fuel imports

The transition of the amount of fossil fuel imports is shown below.



Source: DRE

Figure 5-2 Transition of Amount of Fossil Fuel Import

12 Rising river flows throughout the twenty-first century in two Himalayan glacierized watersheds (Nature geoscience letters, 4 August 2013)

The amount of imports of fossil fuels increases every year. This is mainly the amount of fuel for transportation, and it increases with an increase in vehicles. In order to control the amount of the imported fossil fuel, the introduction of the biotechnology fuel is effective. However, unused biomass residues do not exist too much in Bhutan. Therefore, it is necessary to produce new plants suitable for manufacturing large amounts of biotechnology fuel, and it is necessary to secure the cultivated acreage and the production farmers.

It is possible to use abundant electric power resources by large-scale hydro to promote the introduction of electric vehicles, though it is not renewable energy, and to control the amount of fossil fuel imports for vehicles. However, this idea is the reverse idea to the portfolio of energy.

(4) Low hydropower production in winter months

As shown in Chapter 3.2.2, the supply power from hydro power in winter drastically decreases and it cannot maintain enough electric power for supplying the whole country at present. As a result, electric power is imported from India, though imports are small. However, large-scale hydroelectric power plants (2,940MW of a total of three projects) are under construction now, and it is expected that the current power generating capacity will triple by 2017, and the supply power in winter will also increase to three times that of the current level.

Moreover, the construction of Bunakha hydro power project (180MW), which is a reservoir type power plant, is planned (commencement of commercial operation in 2020). At a reservoir type power plant, the supply power in winter can be better secured by storing a part of the river flow rate for summer in the dam. This power plant is located immediately upstream of the Chhukha hydro power. Increasing not only the output of the Bunakha hydro power in winter but also that of the Chhukha hydro power and the Tala hydro power, which are located downstream, becomes possible by using the water saved in summer. As a result, increasing the supply capacity in winter further becomes possible.

Thus, it is thought that the issue of supply power shortage due to the decrease in the amount of hydro-power in winter will be solved in the near future (around 2020).

(5) Complete stop of large-scale hydroelectric power plants

In Bhutan, almost all electric power is produced from hydroelectric power plants. If all large-scale hydroelectric power plants have to stop operation completely because of a big problem due to natural phenomena such as typhoons or glacier lake collapse, it is assumed that the electric power will become insufficient in Bhutan, and Bhutan will have to import electric power from India. However, large-scale hydroelectric power plants (including those under construction) are located on three big river basins, and it is thought that the probability that all power plants would stop operation at the same time is extremely low.

(6) Recommendations

As assessed above, JICA Survey Team concluded that it is difficult to find any basis for the urgent necessity of energy diversification by renewable energies, and the level of necessity of urgently developing renewable energies is not so high. However, proactively promoting the utilization of unused energy is of significance as this will lead to effective usage of the resources on earth and the mitigation of GHG emissions. In addition, according to the GNH policy that is the basic policy of Bhutan, there are 4 pillars, which are "promotion of sustainable development", "preservation and promotion of cultural values", "conservation of the natural environment", and "establishment of good governance". These four pillars have a trade-off relationship respectively, and it is thought that renewable energy is an excellent tool to satisfy "promotion of sustainable development" and "conservation of the natural environment" simultaneously.

On the other hand, the economic efficiency of renewable energy is greatly inferior to a large-scale hydroelectric power plant. Therefore, financial support by RGoB is needed in order to promote the development of renewable energy. It is thought that RGoB should discuss the rights and wrongs of promoting the development of renewable energy based on a relative comparison with another sector, with its large financial burden, at the creation process of the renewable energy master plan.

There are a lot of points under discussion in the development of renewable energy. In order to offer the materials for discussion, it is necessary to note the following points at the renewable energy master plan formulation.

5.2 Recommended Studies for the Renewable Energy Master Plan

According to AREP2013, the renewable energy master plan will be prepared in 3 years. However, because data reliability is very low, it is difficult to make the master plan now, and therefore it is necessary to accumulate reliable data through the entire area of Bhutan.

5.2.1 Recommended Studies for the Renewable Energy Master Plan

The work which should be approached first is to acquire and accumulate indispensable data continuously in order to execute the potential survey.

It is especially necessary to record meteorological data (wind velocity, wind direction, solar irradiation, and rainfall, etc.) at the representative places for solar power and wind power by established methods. A survey of one year or more is necessary when using it to evaluate potential. To obtain more reliable data, a continuous long-term survey is needed for three to ten years.

The preliminary research on the renewable energy potential of the whole country will be executed by DRE (supported by consultant) based on the GPS geographical features data and meteorological data in the near future. The whole country is divided into an extremely detailed mesh, and the amount of potential in each mesh is calculated by computer analysis, and the DRE (consultant) creates the potential map in Bhutan. However, this investigation is just desk research and no-one measures the potential on-site at all.

The method for collecting measurement data and estimating potential of each renewable energy sector based on these data is explained briefly here.

(1) Solar power

Meteorological data is collected online from the nine meteorological observation points in the whole country now. However, this weather data collection system has been gradually introduced since 2010, and the accumulation of continuous data is insufficient. In the MP survey, it is necessary to increase the number of similar meteorological observation points to grasp the amount of potential in each region, and to investigate potential with higher accuracy.

Example of study flow for formulation of solar power master plan is as follows.

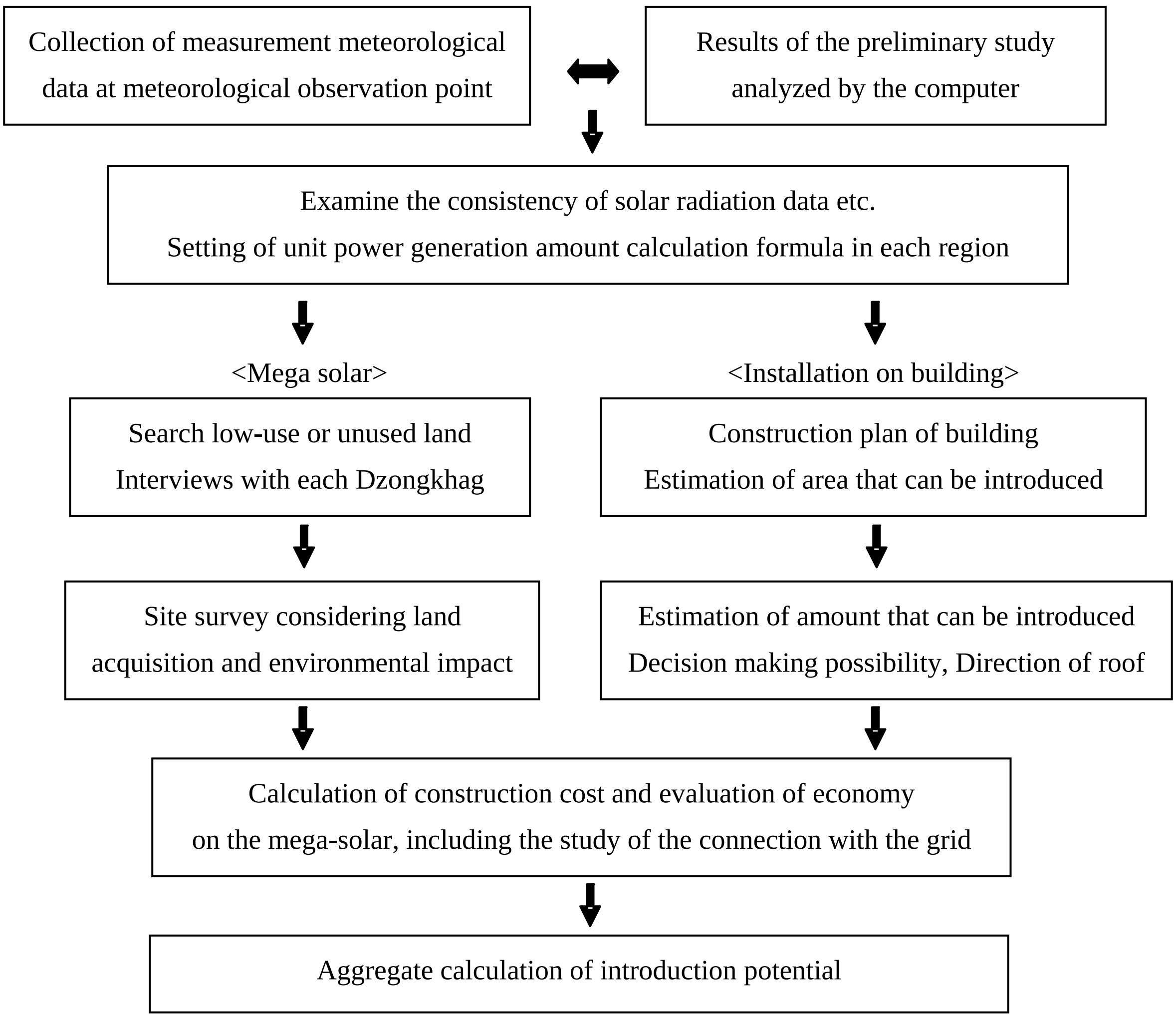


Figure 5-3 Example of Study Flow for Formulation of Solar Power Master Plan

(a) Setting of unit power generation amount calculation formula in each region

The result of the preliminary research data from the computer analysis and the measured data at the meteorological observation point in Bhutan is collated; DRE examines the consistency of each data, and the quantity of solar radiation of various places is estimated. Based on the quantity of solar radiation of various places, the unit power generation amount calculation formula that becomes the grounds of the potential calculation is set. The unit power generation amount calculation formula is a calculation formula with which everybody can easily calculate the amount of power generation according to the input of the conditions of installation place, such as installation space, installation angle, direction of the installation, highest temperature, and normal temperature, etc.

(b) Estimation of the installing potential of the mega solar system

First, the conditions for the candidate site are set up within DRE, and interviews are conducted with each Dzongkhag based on the conditions. Second, about the site chosen by the interview result, DRE carries out a rough study such as site survey and checks the possibility of land acquisition and the existence of environmental issues. Third, the area that can be introduced is totaled, and the introduction potential is estimated by the unit power generation amount calculation formula.

(c) Possibility of installation on building

Based on the sample building data of a public facility and factory, the area (roof, side wall) of the photovoltaic generation panel which can be installed, is calculated. The area and the number of public buildings and factories, which are obtained from statistical data, are multiplied, and the installing potential of the photovoltaic generation is estimated. In this calculation, because it is difficult to think that solar panels will be set up in all buildings, it is important to estimate the probability of doing the decision making that sets up the solar panel by using the technique of questionnaires etc. and to discount the number of installations. It is estimated by the same methodology as for a residential house.

(2) Small hydro power

Continuous long-term flow data in big rivers already exists. If the catchment area ratio of these data is used, a small-scale river flow around the measurement point can be guessed. In the potential survey of small hydro, it is thought that the rough potential can be calculated by using these data.

However, because the tendency of the river flow is thought to be somewhat different between the large river and the small river, a continuous flow measurement is necessary even in a small river, in order to investigate more detailed potential.

An example of study flow for formulation of the small hydro power master plan is as follows. In the development of small hydro power, because a great change in the basic parameters, such as the amount of water used, the head, and the output etc. becomes difficult afterwards if development is done in the place once, it is very important to select the development plan whose effect is the highest in each river.

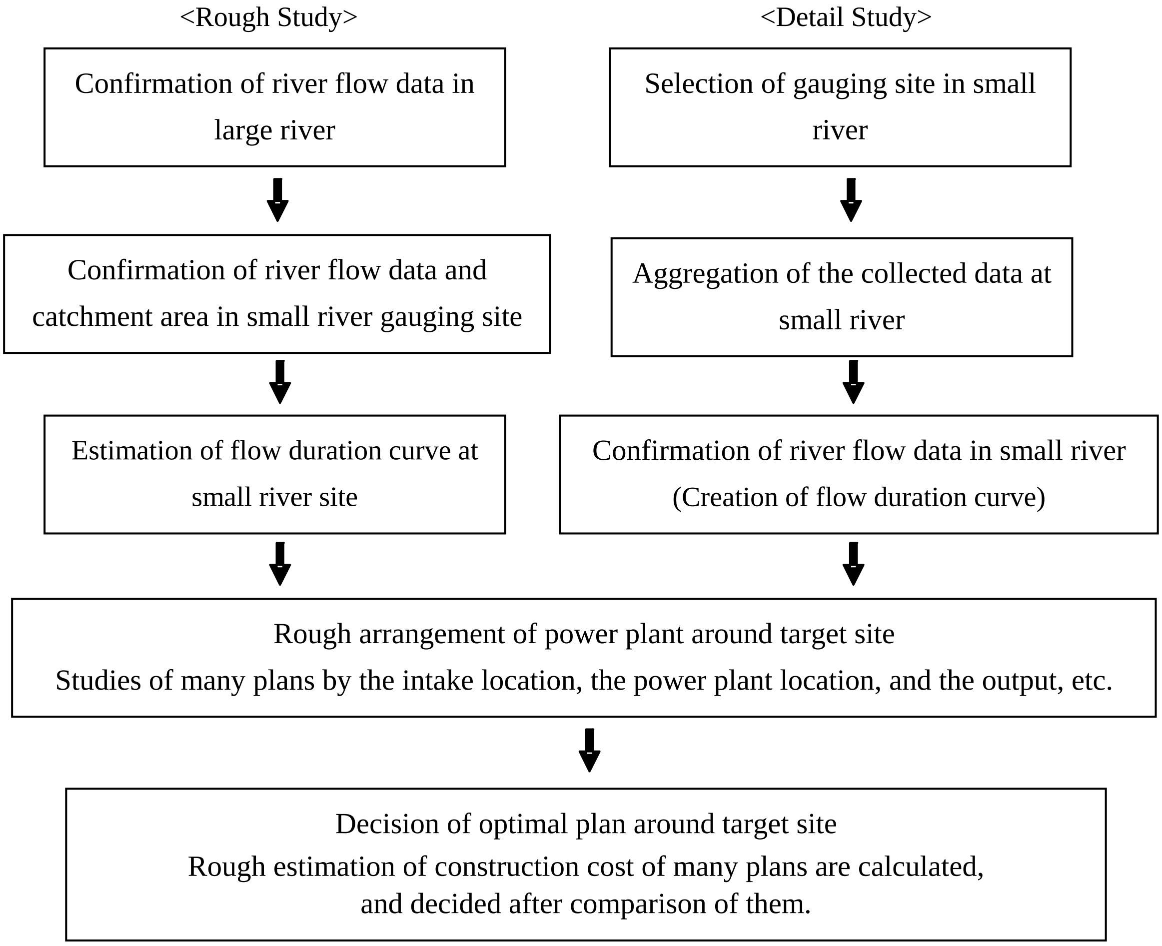


Figure 5-4 Example of Study Flow for Formulation of Small Hydro Power Master Plan

(a) Rough arrangement of power plant around target site

DRE obtains detailed maps (scale 1/50,000 or more) of a small river, and makes various plans that have different intake location, power plant location, and output, etc. As for each plan, various options with different maximum discharge (maximum output) are examined. The construction cost of equipment rises, though a large amount of power generation is obtained if the maximum discharge is increased and the maximum output is enlarged. It is efficient to select the maximum output that results in an annual utilization factor of about 40-60% as a general tendency, though it differs according to the flow-duration curve of the identified river.

(b) Rough estimation of construction cost

The rough estimations of the construction cost of various plans are calculated. However, because it is inefficient for DRE to calculate the construction cost of each point of all plans, DRE creates the calculation kit. Firstly, the hydro power plant is divided into various components, such as intake, waterway (including water tank, spill way), hydraulic pressure tubes, powerhouse, water turbine, generator, control system, tailrace, power lines, and access road. The calculation kit is the tool by which DRE can calculate the construction cost of equipment. DRE inputs just only basic parameters, such as maximum discharge, length of the waterway, effective head, maximum output, length of the transmission line, and the length of the access road.

(c) Decision of optimal plan

DRE carries out a comparative study of various plans, and settles on the optimal program in the small river. DRE compares cost (C: necessary annual cost for construction, operation and maintenance of power plant) and benefit (B: obtained benefit from the generated electric power), and selects the plan that is the biggest (B-C). There is another selection method by using IRR. However, it is not recommended to select the plan that is the biggest IRR because there is a possibility that a very small-scale plan will be selected.

(3) Wind power

It is recommended to select the survey region based on the results of preliminary study by computer analysis, information from local persons or vegetation features which indicate a strong wind direction. However, the air density decreases according to the altitude. Therefore the outputs of wind power become small in high altitude regions in the case of the same wind velocity, so it is recommended to select regions where the altitude is comparatively low. At the selection of survey location, it is actually important to avoid special influence from mountains.

An example of study flow for formulation of the wind power master plan is as follows.

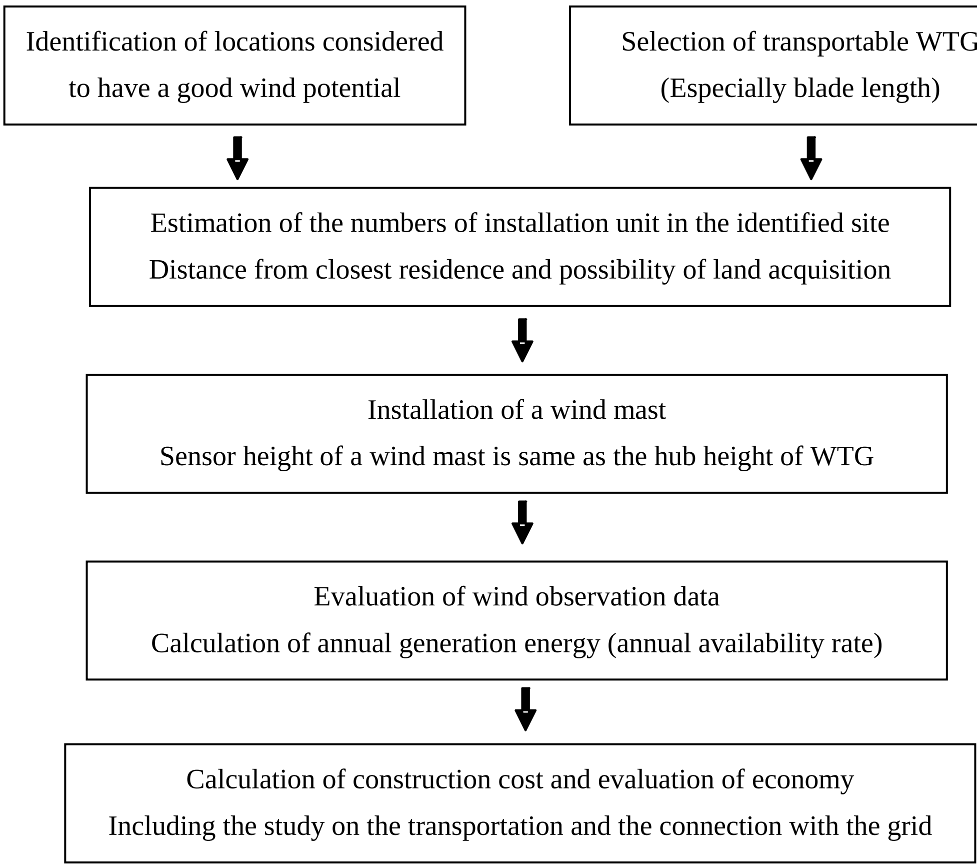


Figure 5-5 Example of Study Flow for Formulation of Wind Power Master Plan

(a) Selection of transportable WTG (Wind Turbine Generator)

When the wind synopsis is observed in a place where geographical features are as complex as in Bhutan, it is necessary to confirm the influence of the wind which WTG receives in as detailed a way as possible. Therefore, it becomes important to make the sensor height of a wind mast the same as the Hub height of WTG as much as possible. It is important to decide the model of WTG to some extent before wind observation. Because there is a limitation in conveyance of long blades in Bhutan, the selection on WTG is much influenced by the transportation possibility.

(b) Estimation of the numbers of installation units in the identified site

DRE carries out site survey at the point where it is assumed that the wind synopsis is good for the observation, and checks the possibility of land acquisition and the presence of environmental issues (especially influence on residences in the surrounding area from the noise), and estimates the number that can be installed in the identified site.

(c) Evaluation of wind observation data

The amount of the annual generation energy (annual availability rate) is estimated from the wind velocity data collected at each short interval (ten minutes or less) and the characteristics (relation between the velocity of the wind and the output) of the WTG that apply. At the estimation, it is necessary to compensate for the difference between the hub height of the applicable WTG and the measurement position height, and the influence of the reduction of air density due to the altitude.

(d) Calculation of construction cost and evaluation of economy

The cost of the road reinforcement and the cost of the grid connection in addition to the cost of construction of the WTG are added and the total construction cost is calculated. Adding the annual O&M expenses to the annual expenses of construction, the generation cost (economical index) is calculated from the estimated annual generation energy. When annual availability rate exceeds 20%, it is generally appreciable with an excellent and economical potential place though it depends on the level of the unit construction cost and the annual O&M cost.

(4) Biomass

Statistics for the production amounts of farm products and timber already exist. However, these products are not produced as renewable energy sources. It is necessary to survey usage of these products and to grasp the surplus amount.

An example of study flow for formulation of the biomass master plan is as follows.

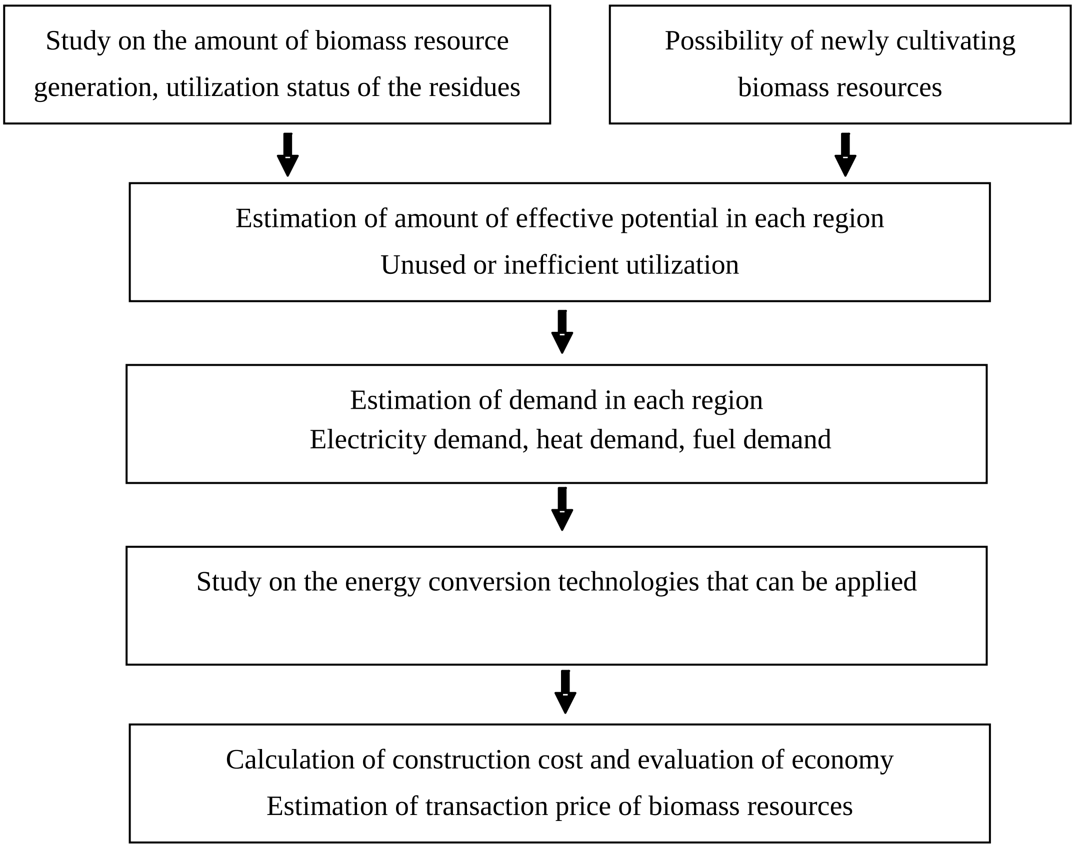


Figure 5-6 Example of Study Flow for Formulation of Biomass Master Plan

(a) Estimation of amount of effective potential in each region

Based on production statistics of agriculture, livestock, forestry, and the municipal waste that become biomass resources, DRE investigates how the residue generated by the process of production is used in each region. Unused or inefficient utilization from residues is identified. Moreover, the possibility of newly cultivated products to use as biomass resources is examined. And then, these are synthesized and the amount of effective potential in each region is estimated. At that time, DRE calculate average calorific value (Joule/kg) of each biomass resource from an average element ratio.

(b) Estimation of demand

The amount of energy of biomass resources can be converted into other energy, such as electric power, heat, and fuels. Therefore, DRE investigates the relation between the electric power demand, the heat demand, the fuel demand and the amount of the supply in various places where biomass resources are generated. And DRE examines what kinds of energy are the most efficient when converting biomass resources.

(c) Study on the energy conversion technologies that can be applied

As for biomass, there are many kinds of resources derived from agriculture, livestock, forestry, and municipal waste, and there are many energy conversion technologies, such as direct combustion, gasification, and creation of ethanol etc. The most efficient conversion technology is selected based on the result of the above-mentioned demand estimation in each region. Especially, because the transportation loss of heat is large, it is important that the heat production site is close to the demand site.

(d) Evaluation of economy

Information on the construction cost, the O&M cost, and the conversion efficiency of all applicable energy conversion technologies is collected. The amount of annual generated energy after the conversion is calculated in consideration of the amount of the biomass resource and the conversion efficiency. And the annual cost is calculated in consideration of the construction cost of the energy conversion equipment and the annual O&M cost, and the economy (production cost) is calculated.

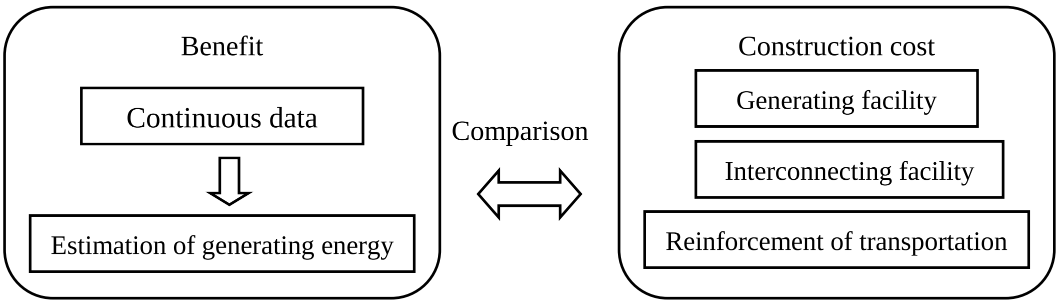
Biomass resources differ from other renewable resources and belong to individuals. Therefore, confirmation of the owner's intention is necessary for using the residues as a resource, and according to circumstances, it is considered to transact it for a fee. Moreover, it is necessary to consider the reflection in the economy if the applied technology uses fossil fuels for a combustion aid, and causes an increase the amount of CO_2 emissions.

5.2.2 Prioritization

At the prioritization of the projects or development areas, it is important to evaluate not only the economic point of view but also various factors overall.

(1) Economic potential surveys at various areas

At the stage where continuous data of one year or more in various places has been accumulated, the estimate of the rough potential of various places becomes possible. The estimate of the amount of electric power generation in various places becomes possible based on the results of this survey. The economical priority level of the development area for each renewable energy sector is decided as follows, based on the relation between the cost and the amount of electric power generation. It is thought that (construction cost) / (amount of electric power generation) is used for the comparison as a very simple index.



Source: JICA Survey Team

Figure 5-7 Decision Method of Economical Potential

In consideration of the level of FIT shown in the next paragraph, the appropriate level that can be economically developed is set about each renewable energy sector, and the potential that can be economically developed is calculated.

In the large-scale hydro power under construction now, the value of (construction cost) / (amount of electric power generation) is 10Nu/ kWh or less.

(2) Environmental and Social Considerations

JICA Environmental and Social Guideline states that JICA applies a Strategic Environmental Assessment (SEA)[13] at the time of preparation of the Master Plan. Since the Bhutanese Government also put emphasis on SEA hereafter, it may therefore be suggested to compile possible impacts and necessary points to be considered at the detailed design phase according to each project type, through examination of the existing information during preparation of the Master Plan.

The purpose of the SEA is, at the very beginning of the project formulation, to examine comprehensively the expected environmental and social impacts prior to the project's implementation. It aims to minimize the negative impacts through implementing mitigation and alleviation countermeasures by discussing such measures at the early stage of project formulation. In addition, in the case that positive impacts are predicted, it aims to verify and present those impacts and to consider the measures having such positive impacts for certain, or even methods to maximize them. Particularly in the case of renewable energy projects, comparative analysis focusing on positive impacts can be described.

As a method of SEA at the time of preparation of the Master Plan, according to the type of renewable energy project (small hydro, solar power, wind, biomass etc.), including information on scale and location if this is identified, primary scoping can be conducted for both negative and positive aspects. Possibility and magnitude of predicted impacts are examined in terms of natural environment (location in relation to national protection areas, existence of rare species of animals, etc.), social environment (necessity of resettlement, influence on residents around the project site, etc.) and pollution (ambient air, water, etc.) at construction and operation phases. The results of the predicted rating for each item are presented in the form of a matrix table. For each item at the respective phase of the project, impacts can be rated at "significant", "some extent", "almost no impact" or "unknown" etc. Rating of the scale of impacts can be discussed by a group of stakeholders, such as officers in the project executing agency, National Environment Committee, experts in natural and social research institutes and others so that it can be discussed in multi-dimensional aspects.

[13] Strategic Environmental Assessment is the one undertaken at early stage before the project implementation, that is, during the decision making phase before the project implementation. The early stage means the timing of drafting governmental policy, plan, program, namely, drafting the higher level of policy and plan.

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Above all, in discussions on alternative projects, it is important to examine whether or not more positive or negative impacts can predicted. Within the range of information available, specific numerical indicators can be calculated, such as the effect on reduction of CO2 emissions according to the type of project.

The results of analysis on environmental and social impacts can also be one criteria together with technical and financial ones to select the project, and they can also contribute to understanding and presenting the critical and appropriate points to conduct an environmental and social impact survey (if necessary) at the feasibility study phase for each project.

(3) Comprehensive evaluation

The following factors at various development areas and various project sites are quantitatively evaluated as much as possible. And, a final prioritization is decided by the overall evaluation based on the weighted value evaluated by the importance degree of each factor.

- Economy
- Existence of issues of environmental and social aspects
- Priority order of the regional development (necessity of area development in national policy)
- Correspondence with other development plans (for instance, road development plan and electric power equipment reinforcement plan, etc.)
- Contribution level to global environment (reduction of CO2 emissions)

5.2.3 Studies on the Promotion Scheme

(1) Establishment of FIT

Because the purpose of FIT is to promote the development of renewable energy, it is necessary to consider the following points when establishing FIT.

- To offer a level that the investor feels is attractive
- To be able to secure fiscal resources

These two are in a trade-off relation. If FIT at an attractive level is offered, it is necessary to prepare a lot of fiscal resources because of promoting the introduction of renewable energy. On the other hand, if FIT at an unattractive level is offered, the introduction of renewable energy doesn't advance at all.

(a) Appropriate IRR

The level of IRR is thought to be a return that corresponds to the investment from the investor's view. It is appropriate that the IRR is set at the level by which the investment risk premium is added to the deposit interest rate of the city bank. It is preferable to set low IRR for low risk business, and high IRR for high risk business according to the business characteristics. The present interest rate of Bhutanese banks is about 7% on deposits for one year or more, and if the risk corresponding to each renewable energy is added to the value and an appropriate IRR level calculated, it becomes as follows.

Table 5-1 Risk Evaluation of each Renewable Energy and appropriate IRR

	Biomass timber-fired	Wind	Solar PV	Small hydro
Risk due to delay of construction	low	medium	low	medium
Risk that expected amount of power generation is not obtained	medium	high	medium	low
Risk that electricity cannot be generated due to natural disaster	low	high	medium	high
Breakdown risk of equipment	high	medium	low	medium
Comprehensive evaluation of risk	medium	high	low	medium
Appropriate IRR	10%	12%	8%	10%

It is thought that the appropriate level of IRR is assumed to be about 8% for solar power with low risk, about 10% for biomass and small hydro power with medium risk, and about 12% for wind power with high risk. To be influenced by the interest rate of Bhutanese banks, it is necessary to survey a long-term interest rate forecast when deciding IRR level.

(b) Necessary fiscal resources

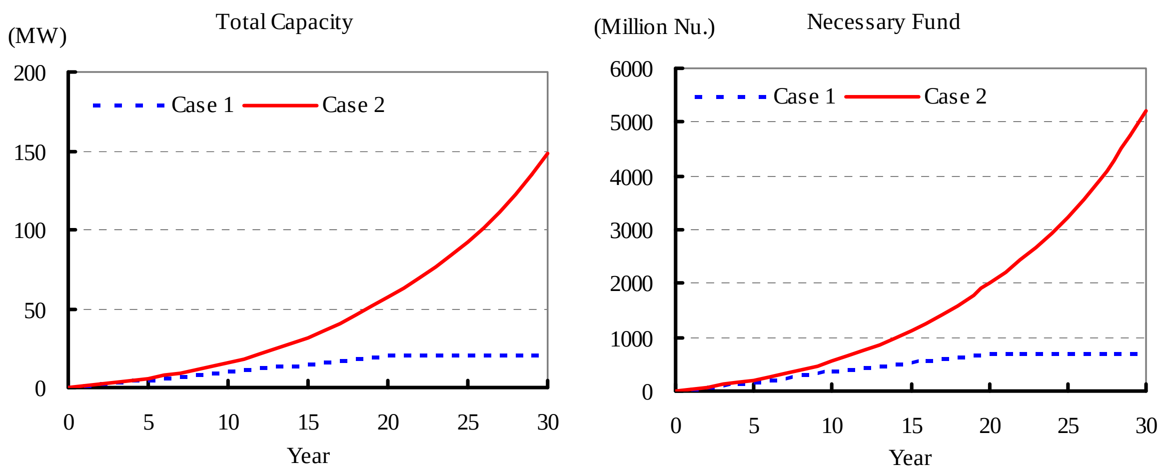
The JICA Survey Team carried out trial calculations for the necessary fiscal resources about the following two cases after introduction of the FIT.

- Case 1: the installation amount every year is 1MW (does not change)
- Case 2: the installation amount for the first year is 1MW and 10% of the installation amount increases every year afterwards
- Common condition

  FIT rate: 20 Nu./kWh

  Annual availability factor: 20%

  FIT supporting period: 20 years (to be retired after 20 years pass)



Source: JICA Survey Team

Figure 5-8 Trial Calculations for Necessary Fiscal Resources

In Case 2, the total installed capacity will increase to about 150MW in 30 years, and the necessary fiscal resources to cover FIT are 5,000 million Nu. Thus, it is necessary to assist FIT continuously, not as a temporary expense, but for a long term. It is necessary to consider an accumulation of the expense that should be assisted by FIT when the installation amount becomes bigger. If it relies on only Royalty for the fiscal resources, the introduction of FIT has a danger of failing sooner or later, though it doesn't cause problems at all at first.

(2) Establishment of PPA

It is hardly decided at the present stage except to receive the electric power generated from the renewable energy business as a priority. According to AREP 2013, it is written that "The NA shall develop model PPAs for different RE technologies to facilitate signing PPAs at lower transaction cost". Therefore, DRE should develop it in the near future. PPA is about a 20 year long-term contract and the most important risk hedging measure for the company who supplies the electric power and for the company who receives the electric power.

Therefore, it is important to describe the following items in addition to the general articles of the duration of contract and the transaction price.

- Guarantee of receipt for a long term
- Mechanism of clear pricing for a long term (method of considering inflation in the future)
- Compensation method in the event of an issue not attributed to either side etc.

(3) Promotion scheme for foreign investor's participation

As the promotion scheme for foreign investor's participation, great preferential taxation is written in AREP 2013, and it is seemingly attractive. Moreover, as described in Chapter 4.2.2 foreign investor participations are open, and participation by only foreign investors in the renewable energy field (except small hydro power) can be approved. However, because exchange to foreign currency of the dividends is not permitted, it is difficult to say that this is attractive for foreign investors. Therefore, DRE should request the Department of Industry (DOI) to change the article of FDI policy so that foreign investors can exchange dividends to foreign currency for businesses in the renewable energy field.

5.2.4 Executing Organization of Master Plan Formulation

It is very important that the DRE staff should act as a leader and make the master plan from Bhutanese people's viewpoints. However, the formulation of the renewable energy master plan is the first challenge in Bhutan, and the DRE staff doesn't have the experience or enough exclusive knowledge. Therefore, support from overseas specialists is necessary if required.

(1) The DRE staff's composition and necessity of enhancement

(a) Current status of DRE staff

The current staff composition and the job descriptions of DRE are shown below.

Table 5-2 Current Staff Composition and Job Descriptions of DRE

	Manager	Staff	Job description
Director	1	1	Overall control
Alternative Energy Division	1		Implementation of Renewable Energy programmes covering all Renewable Energy technologies including Policy Aspects
Solar Energy Section	1	2	
Wind Energy Section	1	1	
Bio-Energy Section	1	1	
Small Hydro Development Section	1	1	
Planning and Coordination Division	1		Coordination of on/off-grid rural electrification program. Review and provide technical sanction on RE projects. Preparation of fiscal budget
Rural Electrification Section	1	1	
Programme Coordination Section	1		
CMD Section	1		
Research and Development Division	1		Implementation of Renewable Energy programmes
Research Section	1	3	
Energy Conservation Section	1	2	
Pool Staff		9	Administration, accounts, drivers etc.
Total	13	21	

(Created by JICA Survey Team based on the DRE data, as of October 2013)

The overall number of DRE staff is 34, and Managers number 13 among these. Managers graduated from university or hold qualifications of an equal level. Three persons among these are away from duty for the long term because of study in foreign countries etc.

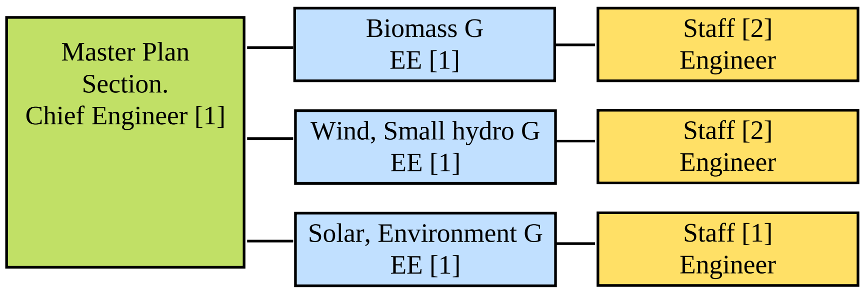
DRE mainly manages the execution plan of the projects (Solar Home Lighting System Project, Bhutan Biogas Project, Sustainable Rural Biomass Energy Project, and Wind Power Project, etc.) that each donor, such as ADB, is supporting.

(b) New organization at master plan formulation

Because a large amount of data processing and an analytical work are expected at the master plan formulation, it is difficult to execute master plan formulation work together with other routine work.

Because the data collection becomes the main work at the beginning stage, it is thought that present DRE staff can execute master plan formulation work together with other routine work. However, it is preferable to arrange the following specialized organization in the Alternative Energy Division of DRE after the measured data can be obtained to some degree and to execute work. (approximately half a year after work starts)

Advanced knowledge is necessary for the staff when executing MP formulation work. Therefore, persons who graduated from university and have some knowledge of the renewable energy field are correspondingly recruited, or present manager staff in DRE is relocated.



(Source: JICA Survey Team)

Figure 5-9 Specialized Organization for MP Formulation

(c) Training plan for the staff

Special skills are not required for the master plan formulation work. As described in the previous section, special training is not necessary and it is enough for the staff who graduated from university to undertake On the Job Training (OJT) by foreign specialists. However, because there are few renewable energy facilities in Bhutan, there is little chance for the staff to learn the renewable energy equipment at actual sites. Therefore, in order to improve the staff's skill level and to make a good MP, it is very important to visit the renewable energy facilities in foreign countries. It is effective to exchange opinions with related staff at the site visited about the issues which occur in the development stage and the operation stage and to share ideas for their solutions.

(2) Work responsibility schedule

The basic work responsibility schedule for making the REMP is shown in Table 5-3. The DRE officers have the responsibility to make the REMP and the overseas experts support the portions in which the DRE officers lack knowledge and capability and carry out capacity building of DRE officers.

Table 5-3 Work Responsibility Schedule for REMP

	DRE officers	Overseas experts
General	♦ Set the FIT ♦ Create the PPA form ♦ Prioritize each RE ♦ Examine the source of revenue in a preferential treatment policy	♦ Support the FIT setting ♦ Support the PPA form creation ♦ Support the prioritization of each RE ♦ Support the examination of the preferential treatment policy
Solar power (PV)	♦ Data collection of solar radiation ♦ Estimate the installing potential of the small-scale solar system ♦ Set the guideline for the installing of the small-scale solar system ♦ Estimate the installing potential of the mega solar system ♦ Feasibility study for the mega solar project ♦ Detail design for the mega solar project	♦ Support the estimation of the installing potential of the small-scale solar system ♦ Support the setting of the guideline for the small-scale solar system ♦ Support the condition for the mega solar potential site ♦ Support the detail design for the mega solar project
Small hydro	♦ Data collection of the river flow ♦ Make optimal planning for each site ♦ Study for environmental and social considerations ♦ Estimate the construction cost by the construction cost estimation sheet ♦ Prioritize each site	♦ Make and train the construction cost estimation sheet ♦ Support the optimal planning for each site ♦ Support the prioritization of each site
Wind power	♦ Select the potential site ♦ Data collection of the wind conditions ♦ Select the WTG in consideration of the transportation ♦ Study for environmental and social considerations （Possibility of land acquisition） ♦ Determine the layout ♦ Evaluate the wind conditions ♦ Estimate the construction cost ♦ Economical analysis	♦ Support the data collection of the wind conditions ♦ Support the selection of the WTG ♦ Support the determination of a layout ♦ Support the evaluation of the wind conditions ♦ Support the estimation of the construction cost ♦ Support the economical analysis
Biomass	♦ Potential survey and data collection ♦ Select the optimal facility ♦ Estimate the construction cost ♦ Economical analysis ♦ Set the guideline for operation and maintenance	♦ Support the selection of the optimal facility ♦ Support the estimation of the construction cost ♦ Support the economical analysis
Environmental & Social considerations	♦ Execute the Strategic environmental assessment ♦ Site survey	♦ Support the execution of the Strategic environmental assessment

Source: JICA Survey Team

5.2.5 Necessary Instruments at MP Formulation

For the master plan formulation, the preparation of some instruments is necessary as well as the establishment of the new organization. Because the potential originates in natural phenomena, it is important to measure the potential of the solar power, the wind power and small hydro power in various places.

Table 5-4 Necessary Instruments at MP Formulation

Renewable energy	Necessary instruments
Solar power	Pyranometer, Pyrheliometer (stationary type for fixed point observation)
Wind power	Anemometer (stationary type for fixed point observation)
Small hydro power	Weir type flow meter (stationary type for fixed point observation), propeller type flow meter (portable), distance meter (portable)
Others	GPS equipment (portable)

Source: JICA Survey Team

The necessary number of the stationary type measuring instruments for the fixed point observation is more than the number of measurement locations. In addition, data preservation devices for a long term and fixed structures that can endure some level of snowstorm are necessary. It is sufficient for the analysis at the master plan formulation stage to use spreadsheet (Excel) functions, though special software that analyzes the obtained information in detail is needed in the development stage.

5.2.6 Road Map for Formulation of RE Master Plan

If Bhutan were to create the RE Master Plan, then the recommended road map is as follows.

Table 5-5 Road Map for RE Master Plan

		Year 1	Year 2	Year 3
Potential Survey				
Accumulation of reliable data	DRE			
Estimation of RE potential	DRE			
Estimation of RE economical potential	DRE			
Prioritization of RE potential area	DRE			
Preparation of Promotion Scheme				
Check cost level of each RE	DRE			
Establishment of FIT	BEA			
Establishment of PPA	DRE			
Revision of FDI policy	DOI			
Arrangement of Study Structure				
Establishment of new organization	DRE			
Preparation of measurement instruments	DRE			
Training (Study tour)	DRE			

Source: JICA Survey Team

Chapter 6 Environmental and Social Considerations and Public Security

6.1 National Environmental Policies and Plans

RGoB has a development strategy, adopting a unique development principle "Gross National Happiness (hereinafter referred to as "GNH")" which aims to realize the nation's happiness not only through economic development and financial or physical prosperity, but also through considerations on social traditions, culture, and harmonization with the environment. Measures for environmental conservation are included in the four pillars of GNH; Pillar 1: Sustainable and Equitable Socio-Economic Development, Pillar 2: Conservation of the Environment, Pillar 3: Preservation and Promotion of Culture, and Pillar 4: Good Governance. In fact, environmental conservation has been described as one of the fundamental issues in any national development plan in the past.

According to "Bhutan 2020; A Vision for Peace, Prosperity and Happiness" (published in 1999), which states the long-term strategic development plans, "Environmental conservation" is one of the main development goals. Reflected in this is a target indicator of maintaining the forestry coverage ratio at a level of at least 60% of the total national land. "The Tenth Five-Year Plan (2008-2013)" adopted countermeasures for environmental conservation, such as prioritization of conserving the environment in land utilization plans, promotion to utilize cleaner energy, development of environmental policy and legal framework, and development of an environmental information management system. In "The Eleventh Five Year Plan" currently being drafted, natural resource conservation and sustainable use & management remain one of the main issues and renewable energy, with its lower environmental burden, is to be further promoted. In addition, according to the National Environment Commission (NEC), Strategic Environment Assessment (SEA) is emphasized in the next Five-Year Plan.

The following are the main documents established in the past as national policies and strategic plans on the environment. After the first one was established around 20 years ago, even the latest one was drafted in 2003. According to NEC, the latest version of national environmental strategies was published in 1998, and as of July 2013, a new version is currently being drafted, to be finalized by 2014.

<u>Under the jurisdiction of NEC</u>

- Conservation in Bhutan (enacted in 1994)
- The Middle Path, National Environment Strategy for Bhutan (enacted in 1998)

<u>Under the jurisdiction of the Ministry of Agriculture (as of 2013, MoAF)</u>

- Biodiversity Action Plan for Bhutan 2002 (enacted in 2003)
- Vision and Strategy for the Nature Conservation Division 2003 (enacted in 2003)

6.2 Laws, Regulations and Organizational Structure for Environmental and Social Considerations

6.2.1 Laws and Regulations for Environmental Impact of Development Projects

In Bhutan, "Environmental Assessment Act 2000" was enacted in 2000, and "Regulation for Environmental Clearance of Projects and Regulation in Strategic Environmental Assessment" was published in 2002. After that, the "National Environmental Act" was established in 2007.

As of July 2013, for application of environmental clearance in development projects, 8 kinds of environment assessment guidelines are established based on the regulations. Besides a General Guideline, there are guidelines for 7 sectors (mines and quarries, forestry activities, roads and highways, hydropower projects, power transmission and distribution line projects, tourism, urban development). For renewable energy projects that are the target of this survey, it is necessary to implement an environmental assessment (EA) for all hydropower projects with the Guideline for Hydropower Projects, regardless of the installed capacity of the power plant[14]. With regard to wind, PV and biomass projects, it is necessary to refer to the General Guideline, and also to consult with NEC to confirm the applicable environmental clearance for each project case.

In addition to the guidelines, Environmental Codes of Practice are established for overhead and underground facilities, water discharge and tourism.

6.2.2 Laws and Regulations in the Context of for Environmental and Social Consideration

Table 6-1 shows the main laws and regulations for conservation of the natural environment, countermeasures for environmental pollution, and social considerations such as land acquisition and resettlement. During the implementation period of the Tenth Five-Year Plan, detailed regulations for pollution - for example, revision of environmental standards for air and water pollution, and regulations for water management and waste management - have been developed. However, these regulations have just begun to be implemented and experience in applying the regulations is still to be accumulated.

[14] In interview to NEC, only submission of simple document appears to be required in case of very small-scale hydropower plants, such as micro and pico hydropower.

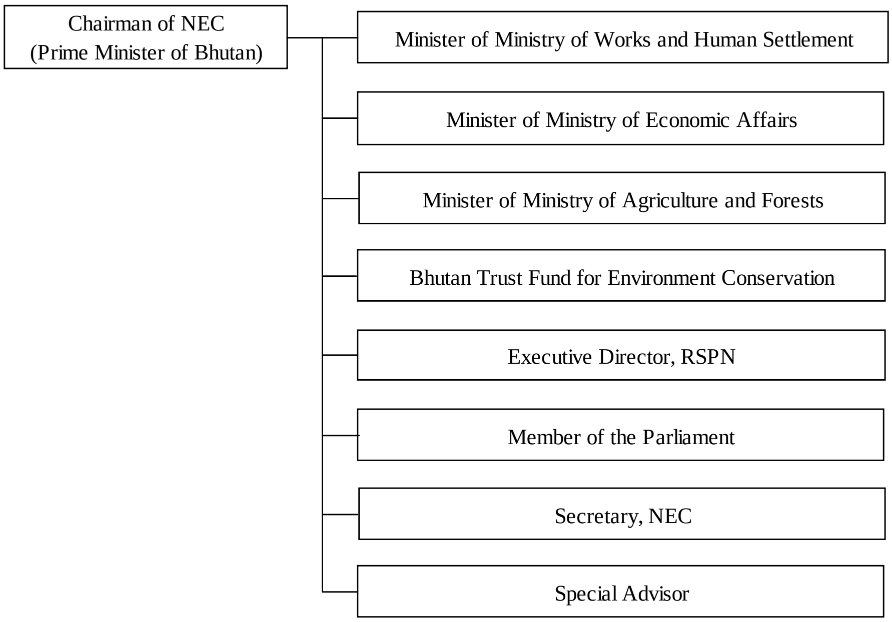
Table 6-1 Laws and Regulations in the Context of Environmental and Social Considerations

Sector	Laws and Regulations	Year Established	Jurisdiction (as of 2013)
Conservation of Natural Environment			
➢ Forest Conservation	Forest and Nature Conservation Act 1995	1995	Ministry of Agriculture and Forests (MoAF)MoAF
	Forest and Nature Conservation Rules, 2006	2006	MoAF
➢ Fauna and Flora	Biodiversity Act of Bhutan 2003	2003	MoAF
	Rules on Biological Corridor, 2006	2006	MoAF
Social Considerations			
➢ Land acquisition	The Land Act of Bhutan 2007	1979/2007/	National Land Commission (NLC) Secretariat
	Land Rules and Regulations	2007	NLC Secretariat
Pollution			
➢ Air, Water, Noise, Soil pollution, Vibration, Land Subsidence, Odor Nuisance, others	Environmental Codes of Practice for Sewage and Sanitation Management in Urban Area	2000	NEC
	Water Act of Bhutan 2011	2011	NEC
	Water Regulation	Drafted	NEC
	Environmental Standards 2010	2010	NEC
➢ Waste	Environment Codes of Practice for Hazardous Waste Management	2002	NEC
	Waste Prevention and Management Regulation 2012	2012	NEC

6.2.3 Organizational Structure for Environmental and Social Considerations

(1) National Environmental Commission, NEC

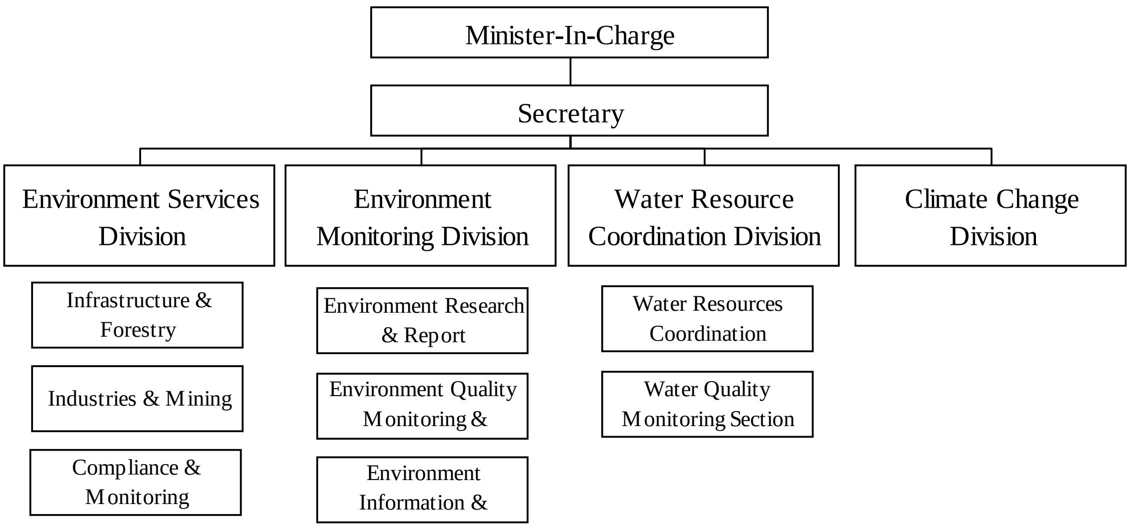
NEC is a high decision-making and coordinating body, which establishes environmental policies or laws and regulations, institutionalizes and examines Environmental Clearance, and governs the conservation/preservation/improvement of the natural environment, such as water resources and climate change. The below Figure describes the members of NEC, with the Prime Minister of RGoB as the Chairman of NEC. NEC is composed of 8 members, Ministers of related ministries, representatives of NGOs, a member of Parliament, the Secretary of NEC and a Special Advisor.



Source: NEC Website (as of July 2013)

Figure 6-1 Members of NEC in Bhutan

The following figure shows the organizational structure for the Secretariat of NEC. Under the Secretary, there are 4 divisions, Environment Services, Environment Monitoring, Water Resource Coordination and Climate Change. As of July 2013, the number of all officers in charge is 46.



Source: NEC Web Page (As of July 2013)

Figure 6-2 Organizational Structure of NEC in Bhutan

Environmental Clearance is managed under the Environmental Service, which consists of 7 full-time officers. As of 2013, the number of Environmental Clearances applied for was 150 per year. Currently, the human resource capacity is only those 7 and they take responsibility for all sectors. According to NEC, the examination work can be outsourced in future; however, at this moment it is not outsourced due to lack of human resources in the private sector and concerns of corruption.

NEC assigns one environmental officer in each Dzongkhag, called “Dzongkhag Environment Officers (DEO)”, who is in charge of environmental conservation for each Dzongkhag. Depending on the project, DEO can give the approval of Environmental Clearance in each Dzongkhag.

(2) Ministry of Agriculture and Forests, MoAF

To maintain forest conservation in Bhutan, protected areas are designated and administrated under MoAF, which is one of the important stakeholders for RE projects. The department in charge of conservation of the natural environment is the Department of Forest & Park Services Under this department, there are divisions which possess information on the natural environment, such as Forest Protection & Enforcement, Wild Life Conservation, National Parks, and also Ugyen Wangchuck Institute for Conservation and Environment (UWICE), an institute for environmental protection and research on fauna and flora.

In addition, the department in charge of biogas projects utilizing dung from livestock is the Department of Livestock.

(3) National Land Commission (NLC)

Land acquisition and compensation in development projects is under the jurisdiction of NLC. In practice, the land acquisition process is carried out in cooperation with stakeholders of the local government; in NLC, it is under the responsibility of the Land Record Officer of the respective region in the Land Registration Division.

6.3 Implementation of Environmental and Social Considerations relating to Development Projects

6.3.1 Environmental Clearance Procedure

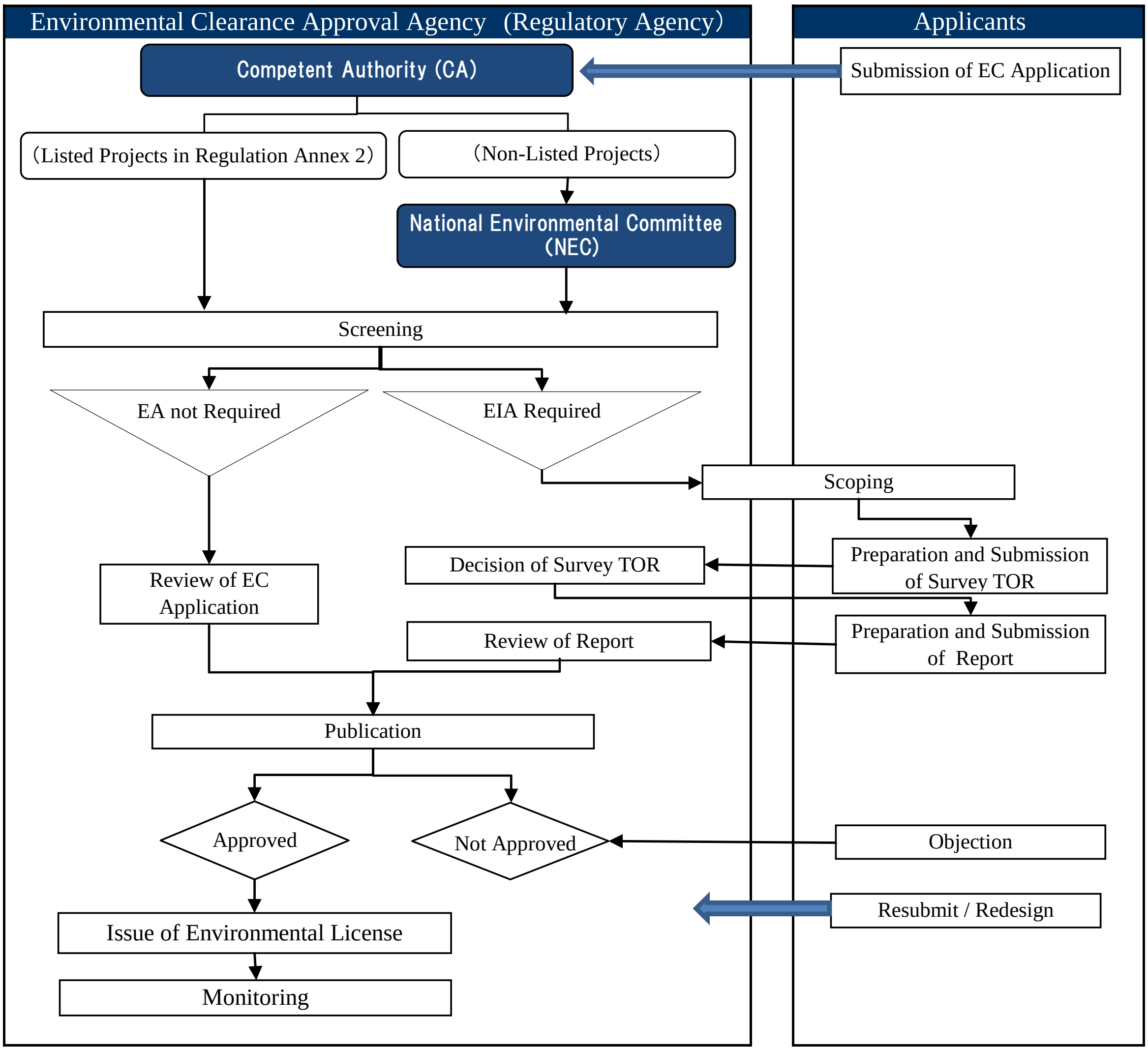
The following figure describes the procedure of environmental assessment.

Regarding Environmental Clearance (hereinafter referred to as "EC"), Annex 2 of "Regulation for Environmental Clearance (issued in 2002)" stipulates what kind of project is necessary/unnecessary to obtain Environmental Clearance and from which government organizations (Department in charge of ministry, public company, local administration authority, etc.) Applicants refer to this regulation and submit a document on the Environmental Information of the planned project to the Competent Authority (hereafter CA[15]). In the case that CA conducts the environmental assessment, it is done by the director or at division head level. EA regulation requires the establishment of an Environment Unit (EIU) within CA, however, according to NEC, at present the EIU is not always established constantly. In some cases, it is established upon discussing the project only.

In the case that there are guidelines for the sector of the project, the document on Environmental Information is prepared according to the guidelines. If the project is not described in the regulation and there are no applicable guidelines of EC, the document on Environment Information is submitted to NEC through CA. The submitted documents of EC require a certificate which has no objection to the project from all stakeholders (related governmental organizations and local government). CA and NEC review the content of the Environmental Information in the documents, and if they are adequate, the proposed project plan is published.

Depending on the project, the Environmental Assessment report is required for further details. In such case, if applicants submit Terms of Reference (TOR) for the Initial Environmental Examination (hereafter IEE) or EIA, they prepare reports after approval of TOR by NEC and submit to them. Finally, the report approval is through the examination by NEC and EC is issued by them.

Annex 1 of Regulation for Environmental Clearance indicates the time limit for each phase of EC. Notice of the receipt of application form should be made by EC or CA within 15 days. Examination of the Application document requires approximately 1-3 months in NEC. Then, in the case that further study is required, 1 to 3 months are indicated for screening to decide what details of Environmental Assessment are necessary. After that, approximately 1-3 months are indicated to examine IEE or EIA. The content of the Environmental Assessment is examined by Technical Committee, and then NEC, a high decision-making entity, finally approves or rejects it.



Source: Regulation for the Environmental Clearance of Projects, NEC

Figure 6-3 Procedure Flow of Environmental Clearance

6.3.2 Procedure of Environmental Clearance for Renewable Energy Project

In the case of renewable energy projects, Regulation for Environmental Clearance of Projects (2002) Annex 2[16] does not describe whether CA can approve the environmental clearance. In the case of all renewable energy projects, according to NEC, it is desired that the applicant submit the document through DRE. NEC then ultimately decides which organization can issue the clearance.

[15] According to NEC, this CA system is currently being reexamined. After 2014, there is a plan that Regional Environmental Office will be established and they may conduct environment clearance on all projects in their respective region.

[16] "Regulation for Environmental Clearance of Projects (2002) has not been amended or supplemented since its establishment. NEC is currently undertaking revisions, including re-examining the Annex 2, and a revised regulation will be completed. In those revisions, however, for environmental clearance on renewable energy projects such as solar power, wind power, and biomass, it is apparently not mentioned whether or not CA will conduct the environmental clearance at the moment.

6.3.3 Procedure for Land Acquisition and Compensation

Land acquisition is regulated under the Land Act (the latest version was issued in 2007). National Land Commission (hereafter NLC) has the responsibility for registration of land possession and management, approval of the application for development projects, and procedures on land acquisition. According to NLC, if land acquisition is required, the project implementation authority sends a letter to NLC, and NLC proceeds with the arrangements for land acquisition with consultation by the land record officer in the district. At the outset, the committee is formed, comprising Gup, who is a representative at the block level, the forestry officer of MOAF in the block, and Tshogpa, who is a representative of villages. This committee investigates the land ownership and current situation of the land and also reviews the content of compensation and discusses it. After the investigation at the block level, the district officer in charge submits the approval on the land acquisition to NLC and then the Chief or Director of the Land Registration Division in NLA will finally approve it.

With regard to compensation for land acquisition, there are two methods; 1) provides alternative land and 2) provide cash compensation. It is usual to provide alternative land for landless farmers, and to provide cash compensation in the case of small-scale land owners. For cash compensation for the acquired land, it is necessary to refer to the Land Compensation Rate, established by the Department of National Properties, the Property Assessment & Valuation Agency (PAVA), and the Ministry of Finance. Buildings and crops in the acquired land are also targets for compensation, and the value is calculated into cash based on the public standard Compensation Rate. According to PAVA, people generally prefer the provision of alternative land than cash compensation.

6.3.4 Comparison with JICA Guidelines for Environmental and Social Considerations

Regulations for Environmental Clearance in Bhutan mention specific projects for which the CA responsible for the project can issue the EC. Almost all projects are managed by small-scale industry, which rarely has any environmental impact. Road construction projects in urban areas and expansion/improvement of roads are included. While a judgment on environmental influence in the JICA Guidelines for Environmental and Social Considerations is based on sectors which tend to have environmental impact, or the impact scale of construction work of the project etc., the regulations in Bhutan do not describe such standards of judgment clearly at the first phase of screening. When it is difficult to make a judgment of environmental influence, the government authority in charge (CA) is supposed to entrust the judgment to NEC. In such cases, however, the first screening judgment depends on the capacity of the personnel in charge, and whether or not he or she can judge properly at the initial stage.

6.4 Information and Data for Environmental and Social Considerations

6.4.1 Natural Environment

Bhutan is one of the few countries where untouched natural resources yet remain. Biodiversity is affluent by geological conditions and climate, thus Bhutan is called a hotspot of prominent biodiversity in the world. In a description of “Protected Areas and Biodiversity of Bhutan” by Lhendup Tharchen, a biologist in Bhutan, although the survey on insects and reptiles has not yet progressed, approximately more than 5,500 species of vascular plants, 770 species of bird and 200 mammals are found as of August 2013. The Constitution stipulates maintaining a forestry coverage of 60% or more of the total land forever. The Land Cover Mapping Project (LCMP), implemented in 2010, shows that the forestry coverage ratio is 80.89% of the total land.

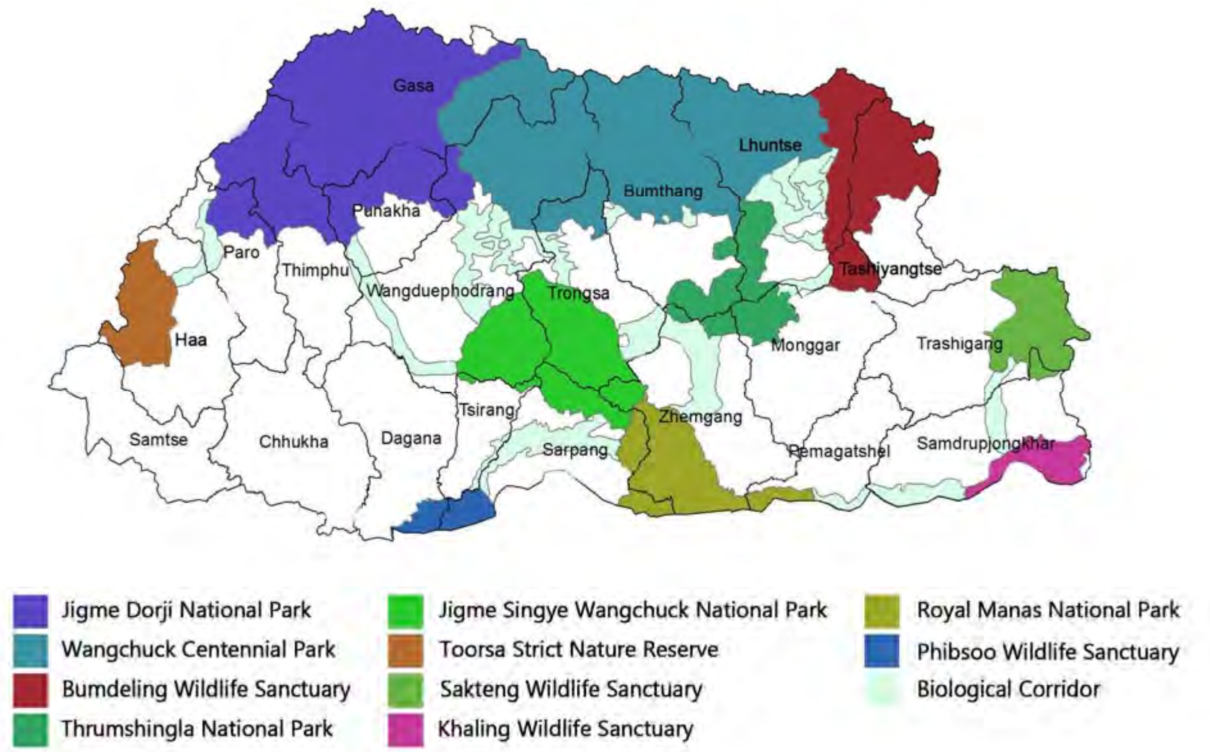
(1) Protected Areas

The following table shows a list of the protected areas in Bhutan. It is composed of a total of 12 areas, with 5 national parks, 4 wildlife sanctuaries, 1 nature reserve, 1 biological corridor and 1 royal botanical park. These protected areas account for approximately 50% of the national land. The location of each protected area is shown in the below Figure.

Table 6-2 List of Protected Areas in Bhutan

No.	Protected Area	Established Year	Dzongkhag	Land Scale (km²)
1	Wangchuck Centennial Park	2008	Gasa, Wangdue Phodrang, Bumthang, Trongsa, Lhuntse	4,914.00
2	Jigme Dorji National Park	1993	Punakha, Gasa, Thimphu, Paro	4,316.00
3	Jigme Singye Wangchuck National Park	1993	Trongsa, Wangdue Phodrang, Sarpang, Tsirang, Zhemgang	1,730.00
4	Royal Manas National Park	1993	Sarpang, Zhemgang, Pemagatshel	1,057.00
5	Thrumshingla National Park	1993	Bumthang, Lhuntse, Mongar, Zhemgang	905.05
6	Sakten Wildlife Sanctuary	1993	Trashigang, Samdrup Jongkhar	740.60
7	Bumdelling Wildlife Sanctuary	1993	Trashiyangtse, Lhuntse, Mongar	1,520.61
8	Phibsoo Wildlife Sanctuary	1993	Sarpang, Dagana	268.93
9	Khaling Wildlife Sanctuary	1993	Samdrupjongkhar	334.73
10	Toorsa Strict Nature Reserve	1993	Haa, Samtse	609.51
11	Biological Corridors	1999	Haa, Paro, Thimphu, Punakha, Wangdue Phodrang, Sarpang, Tsirang, Trongsa, Zhemgang, Bumthang, Mongar, Lhuntse, Trashigang, Samdrupjongkhar	2,685.61
12	Royal Botanical Park	2004	Punakha	47.00

Source: Department of Forest & Park Services（DoFPS）, MoFA



Source: Edited by JICA Survey Team, based on the map provided by Department of Forest & Park Services（DoFPS）, MOFA

Figure 6-4 National Protected Areas and Biological Corridors of Bhutan

(2) Information on Endangered Species

MoFA undertakes information collection on fauna and flora. Under this ministry, the Department of Forest & Park Services (DoFPS) manages the natural environment information in each national park and other protected areas and the National Biodiversity Center (NBC) deals with the data on the species of animals and plants that are relevant to the Red List Category of the International Union for Conservation of Nature (IUCN). Data on Endangered Species and others is implemented by the Information Management Division of NBC.

In Bhutan, the main research institutes on fauna and flora are: NBC (mainly research on plants), DoFP (mainly on plants and mammals), Ugyen Wanchuk Institute of Conservation of Environment (UWICE, Experts on birds and insects belong to this organization), College of Natural Resource (Experts on fish in this organization). Other than these institutions, park managers and rangers who are in charge of respective national parks and other protected areas are familiar with the information on the fauna and flora in the region.

A list of Endangered Species and others obtained through this survey is, according to NBC, drafted based mainly on literature review and field survey will be conducted hereafter. There are uncategorized species.

The Red List of plants is 6 “Critically Endangered” species, 6 “Endangered” species, 5 “Vulnerable” species and 52 “Near-threatened” species (Refer to Table 6-3). There is a category called “Local decline[17]” which lists 8 species.

Table 6-3 Endangered Plants in Bhutan

Category	No.of Species	Example (Family)
Critically Endangered	6	Boeica fulva (Gesneriaceae), Cupressus corneyana (Cupressaceae), Embelia ribes (Myrsinaceae), Podocarpus neriifolius (Podocaepaceae) and others
Endangered	6	Lobelia nubigena (Campanulaceae), Meconopsis superba (Papaverpraceae), Nardostachys jtamansi (Valerianaceae) and others
Vulnerable	5	Aglaia perviridis (Meliaceae), Cupressus cashmeriana Cycas pectinata (Cuppresaceae), Gastodia elata (Cycadaceae) and others
Near Threatened	52	Calamus acanthospathus (Areceaceae), Arenaria desissima (Caryophyllaceae), Coremathodium humile (Compositae） and others

Source: NBC, DoFPS and MoAF

Regarding mammals, the latest Red List shows 1 “Critically Endangered” species (Pygmy Hog), 10 “Endangered” species (Red Panda, Bengal Tiger, Snow Leopard), 14 “Vulnerable” species (Sloth Bear, Himalayan Black Bear, Himalayan Musk Deer) (Refer to Table 6-4). The following table shows the current version of the list of endangered species.

Table 6-4 Endangered Mammals in Bhutan

Category	No.of Species	Example (Family)
Critically Endangered	1	Pygmy Hog (Sus salvanius)
Endangered	10	Golden Langur (Trachupithecus geei), Capped Langur (Trachypithecus pileatus), Wild Dog (Cuon alpinus), Red Panda (Ailurus fulgens), Bengal Tiger (Panthera tigris tigris) and others
Vulnerable	14	Assamese Macaque (Macaca assamensis), Sloth Bear (Melusus ursinus), Himalayan Black Bear (Ursus thibetanus laniger), Himalayan Musk Deer (Moschus chrysogaster) and others

Source: Lhendup Tharchen, “Protected Areas and Biodiversity of Bhutan”, 2013

[17] According to NBC, “Local decline” is a species which local people feel the number of has declined year by year.

Regarding birds, the latest Red List lists 4 “Critically Endangered” species (White-bellied Heron, Baer’s Rochard, White-rumped Vulture, Red-headed Vulture), 13 “Vulnerable” species (Black-neck Crane, Rufous-necked Hornbill, Chestnut-breasted Partridge), 15 “Near-threatened” species (Ward’s Trogon, Rufous-throated Wren Babbler, Japanese Quail) (Refer to Table 6-5). In addition, it lists 7 “Local decline” species.

Table 6-5 Endangered Birds in Bhutan

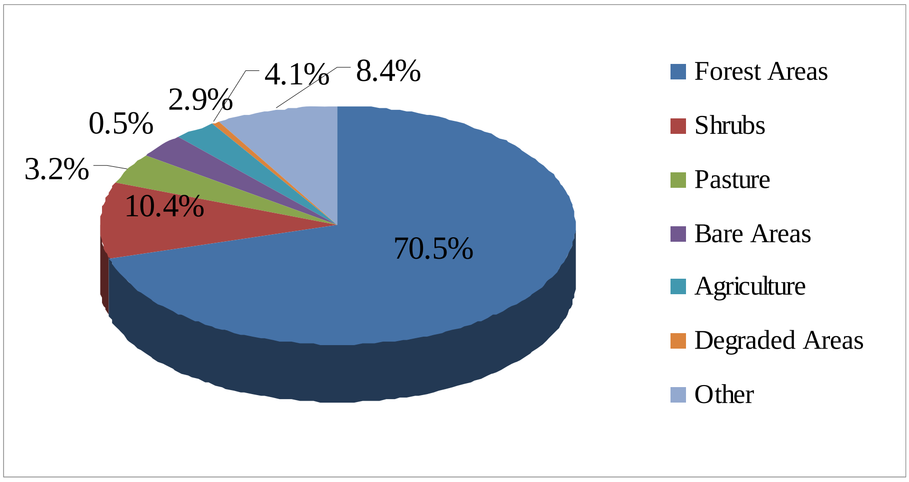
Category	No.of Species	Example (Family)
Critically Endangered	4	White-bellied Heron (Ardea insignis), Baer’s Rochard (Aythya baeri), White-rumped Vulture (Gyps bengalensis), Red-headed Vulture (Sarcopyps calvus)
Vulnerable	13	Black-necked Crane (Grus nigricollis), Rufous-necked Hornbill (Aceros nipalensis), Chestnut-breasted Partridge (Arborophila mandellii), Palla’s Fish Eagle (Hailaeetus leucoryphus) and others
Near-threatened	15	Ward’s Trogon (Harpactes wardi), Rufous-throated Wren Babbler (Spelaeornis caudatus), Cinereous Vulture (Aegypius monachus), Blyth’s Kingfisher (Alcedo Hercules) and others

Source: DoFPS, MoAF

6.4.2 Social Environment

The following figure shows the share of land by use and vegetation compared to the total in Bhutan. Approximately 81% of the country’s land is covered with forest or shrub, and approximately 3% is farm and grassland.

In Bhutan, ethnic minorities exist: for example there are nomads who wear particular ethnic clothes in Laya and Lunana in the north and also one called “Brokpa” in the east. However, there is no group designated as an ethnic minority to be protected or taken into legal consideration.



Source: NSB “Bhutan Statistical Year Book 2012”

Figure 6-5 Share of Land by Use and Vegetation

6.5 Possibility of CDM Registration Project

(1) Countermeasures for Climate Change in RGoB

RGoB ratified UNFCCC on August 15 1995, and the Secretariat of NEC became the focal institution for climate change issues. Then, NEC was designated to host the National Climate Change Committee (NCCC) and assigned as the Designated National Authority (DNA) responsible for CDM registration. RGoB submitted the Initial National Communication on 21st October 2000 and the Second National Communication on 23rd November 2011. RGoB signed the Kyoto Protocol on 26th August 2002. In 2009, the Multi-sectoral Technical Committee on Climate Change (MSTCCC) was established.

(2) Current Status of CDM Projects

8 CDM projects were submitted from RGoB to the United Nations, and among them, host country approval was issued to 4 projects. The following table gives a list of CDM projects submitted to UNFCCC.

Table 6-6 CDM Projects Submitted to UNFCCC

Project Name	Type	Status	Host Country Approval	CER/Year
Rural Electrification Project for Clean Energy, Better Living and Sustainable Growth in Bhutan	Electrification of rural communities by grid extension	Validation	○	19,259
Solar LED Lamp Project in Developing Asia	Improvement of energy efficiency	Validation		7,772.85
Heat Retention Cooking in Less Developed Countries	Improvement of energy efficiency	Validation		57,190.42
Substitution of Grid Power Generation through Transmission of Renewable Electricity Generated in a Hydro Power Generating Station	Hydropower	Validation		3,279,253
Punatsangchhu-I Hydroelectric Project, Bhutan	Hydropower	Validation	○	4,159,630
Carbon Soft Open Source PoA, LED Lighting Disturb	Improvement of energy efficiency	Validation		29,321.42
Dagachhu Hydropower Project, Bhutan	Hydropower (126MW)	Registered (2010/2/26)	○	498,998
e7 Bhutan Micro Hydro Power CDM Project	Hydropower (70kW)	Registered (2005/5/23)	○	524

Source: UNFCCC website[18]

[18] As of September 2013.

(3) Registration Procedure for CDM Projects

As of July 2013, there is no specific process for host country approval. Applicants prepare PDD and submit to NEC. Whenever the PDD is submitted, MSTCCC is held to discuss the project[19]. According to NEC, upon the examination of a candidate CDM registration project, the obtaining of environmental clearance inside the country is a minimum prerequisite.

(4) Registration Procedure for CDM Projects

<CDM of Large-scale hydropower plant projects>

RGoB is willing to promote the registration of all large-scale hydropower plant projects as CDM projects. The objective is long-term income from the sales of CER (Certified Emission Reductions) through hydropower which do not use fossil fuel such as coal, oil and gas.

The baseline is calculated by quantifying the trading amount of the host countries. For example, in the case of Dagachuu Hydropower Plant Project, which was the first CDM project in the world beyond the borders, the advantage for India is that India, depending on coal-fired power, can import clean electricity and gain CER if India registers as a host country.

<CDM of rural electrification>

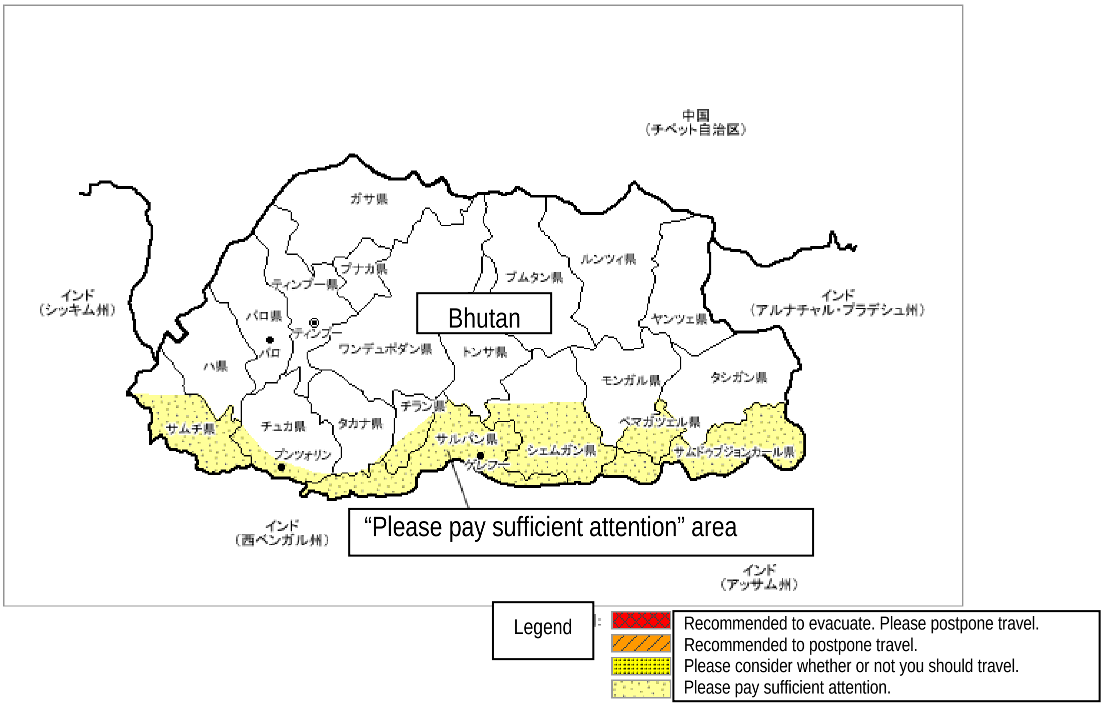
The figures of baseline scenario of rural electrification CDM projects are the new services (newly distributed though rural electrification project) by the technology which is introduced for the project and the consumption of fossil fuels caused by the provided service (electricity). If the project is not conducted, the fossil fuel would be consumed in rural areas, so that can be the project baseline scenario.

[19] Mitsubishi UFJ Morgan Stanley Securities, Co., Ltd. “Rural Electrification by Grid Extension of Electric Grid Mainly composed of Hydropower” (2013), p.28.

6.6 Public Security

6.6.1 Areas which Require Attention in Public Security

As of July 2013, attention should be paid in particular to the southern area (near the border along the States of Arunachal Pradesh, Assam and West Bengal in India) with regard to public security. According to the Overseas Safety homepage of the Ministry of Foreign Affairs in Japan, safety level is divided into four categories, as risk information when traveling to a foreign country (refer to the legend in Figure 6-6). For Bhutan, it is the first level of risk, “Please pay sufficient attention”. The specific areas are marked in Figure 6-6. The whole southern border area requires sufficient attention with regard to public security.



Source: Website of Ministry of Foreign Affairs in Japan[20]

Figure 6-6 Areas to be Noted in Terms of Public Security

20 http://www2.anzen.mofa.go.jp/info/pcmap.asp?id=039&infocode=2012T033&filetype=1&fileno=1, as of 17th July 2013

The background of insecurity in these areas is described in following points.

1) Activities of Extremist Organizations in India

Since the 1990s, extremist organizations for separation and independence movements in Assam state, such as the United Liberation Front of Assam (ULFA) and National Democratic Front of Bodoland (NDFB), invaded these areas while being chased by the Indian Army. The RGoB implemented a clean-up operation against the extremists in 2003.

2) Nepali-origin Bhutanese Refugees

RGoB established measures for strengthening national identity at the beginning of the 1990s. With this turning point, it was reported that approximately 60,000 Nepali-origin Bhutanese Refugees moved away from the southern area of Bhutan. With the refugees as a core part, three anti-government forces, the Bhutan Communist Party, Bhutan Tiger Force and United Revolutionary Front of Bhutan, have emerged and conducted anti-government movements.

In relation to the above-mentioned activities, although there are not many incidents to injure the general public, terrorist bombings occurred near the border in the southern area, at Phuentsholing and Gelephu in May 2011, and Phuentsholing in October 2011.

6.6.2 Number of Crimes

Except for the southern area, the general conditions of public security are good, particularly in tourist places. According to the Bhutan Statistical Yearbook, the total number of crimes in the whole of Bhutan was 2,371 in 2007; however, this increased to 4,697 in 2011 - over twice that of 2007. The breakdown shows that the number of thefts, robberies and murders doubled. In recent years, the number of young people who have migrated from rural to urban areas has increased remarkably. Crimes such as theft, sneak-thievery and assault show an increasing trend, caused by such young people who cannot obtain a job in urban areas turning to crime. Compared with the situation in the past, it has become necessary to pay more attention to general crime in urban areas.

Chapter 7　Study for Use of Renewable Energy

In this chapter, the JICA Survey Team carries out an overview of the findings concerning renewable energy in Bhutan and examines the possibility of renewable energy use in Bhutan based on the obtained information.

According to “Alternative Renewable Energy Policy 2013”, the preliminary minimum target of renewable energy is 20MW by 2025 through a mix of renewable energy technologies as shown in Table 7-1. In view of the rising energy demand and the reliance on a single electricity source, the AREP states that it is critical to diversify the energy mix by harnessing renewable energies other than hydropower to ensure energy security, economic development, and protection of the environment.

The target minimum of development of renewable energy was set against this background. It is expected that regulations and promotions related to renewable energy will be developed and that the development of renewable energy will be promoted.

Table 7-1　Minimum Target of Development of Renewable Energy

Type of Renewable Energy	Minimum Installation Capacity（MW）	Remark
(1) Electricity Generation		
Solar	5	
Wind	5	
Biomass	5	
(2) Energy Generation		
Biomass Energy System	3	3 MW equivalent
Solar Thermal System	3	3 MW equivalent
Total	21	

Source:　Alternative Renewable Energy Policy 2013

Present situation of renewable energy in Bhutan is shown in this chapter.

7.1　Photovoltaic Generation

7.1.1　Features of Photovoltaic Generation

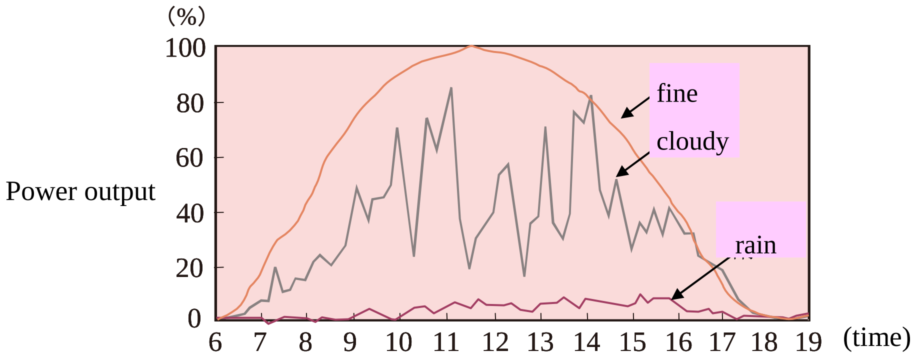
Solar energy can be exploited in various ways; two major ways to use solar energy are as follows.

1. Solar energy is directly used as heat or light, such as in a solar home lighting system, water heating system and solar cooking system.

2. Solar energy is transformed into electrical energy, such as solar thermal power generation, photovoltaic generation and solar lanterns.

However, the target of this study is only photovoltaic generation; therefore, the features of photovoltaic generation are described as follows.

Photovoltaic generation is a power generation system which transforms photon energy from the sun into electrical energy via a photovoltaic cell, to obtain an electrical power output. A technical feature of photovoltaic generation is that output fluctuates with time and weather, because power output is strongly influenced by the amount of solar radiation. As shown in the following figure, power output fluctuation during cloudy weather is especially large.



Source: The Federation of Electric Power Companies of Japan

Figure 7-1 Power Output Fluctuation of Photovoltaic Generation

Photovoltaic generation can be classified into independent systems, and power grid connected systems, in terms of forms of use. An independent system is a system which is not connected to an external commercial power grid; the generated power is stored in a rechargeable battery and used. It is used for portable or backup power systems, and also for electrification of an area distant from the commercial power grid. In Bhutan, it is currently used as a power supply in un-electrified areas.

On the other hand, a system connected to the commercial power grid of an electric power company is a power grid connected system. It connects with the commercial power grid through a power conditioner. In recent years, the price of photovoltaic generation modules has been falling. If a policy such as a “Feed-in Tariff (hereafter FIT)” is introduced, the installation of photovoltaic generation may progress even in Bhutan.

Furthermore, it can be classified into mega solar systems and small-scale solar systems in terms of the generation capacity of the photovoltaic generation system. Generally, the mega solar system is a large-scale photovoltaic generation system with more than one megawatt power generation capacity. The small-scale solar system is a small and medium scale photovoltaic generation system, with less than one mega watt power generation capacity. In Bhutan, the mega solar system may be installed in unused land and the small-scale solar system may be installed on a roof top of a building, or a small unused space.

7.1.2 Present Situation of Photovoltaic Generation Installation in Bhutan

In Bhutan, photovoltaic generation systems are installed for rural electrification. The installed capacity of the photovoltaic generation systems is shown in the following table. The ABD (currently installing) shown in Table 7-2 is the on-going electrification project, which targets 100% electrification by fiscal year 2013. Since the purpose is rural electrification, all are independent/standalone systems, called Solar Home System (hereafter, SHS), equipped with a small battery. Therefore, so far there are no power grid connected systems in Bhutan.

Table 7-2 Installed Capacity of Photovoltaic Generation Systems

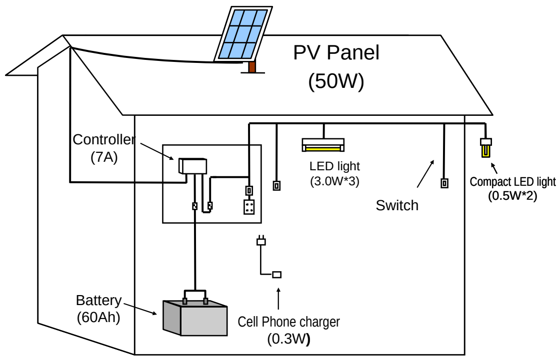
Sl	Dzongkhag	RGOB No of sets	RGOB WP	RGOB Total wp	ADB No of sets	ADB WP	ADB Total wp	ADB (currently installing) No of sets	ADB (currently installing) WP	ADB (currently installing) Total wp	JICA No of sets	JICA WP	JICA Total wp	Other No of sets	Total wp
1	Tsirang				20	50	**1,000**				63	46	**2,898**		**3,898**
2	Chhukha				8	50	**400**	39	50	**1,950**	11	50	**550**	23	**2,900**
3	Dagana				31	50	**1,550**	18	50	**900**	53	40	**2,120**		**4,570**
4	Gasa				175	50	**8,750**				5	50	**250**		**9,000**
											18	40	**720**		**720**
5	Haa				42	50	**2,100**				3	50	**150**		**2,250**
											13	40	**520**		**520**
6	Paro				37	50	**1,850**				24	50	**1,200**		**3,050**
7	Punakha				10	50	**500**				6	50	**300**		**800**
8	Samtse				98	50	**4,900**				71	40	**2,840**		**7,740**
9	Sarpang				78	50	**3,900**	12	50	**600**	29	40	**1,160**		**5,660**
								20	50	**1,000**	47	40	**1,880**		**2,880**
10	Trongsa				4	50	**200**				7	50	**350**		**550**
	Wangdue										34	40	**1,360**	87	**1,360**
11	phodrang				94	50	**4,700**				9	50	**450**		**5,150**
12	Bumthang				16	80	**1,280**	25	50	**1,250**	6	50	**300**		**2,830**
13	Zhamgang	238	80	**19,040**				53	50	**2,650**	49	40	**1,960**		**23,650**
								25	50	**1,250**	62	40	**2,480**	157	**3,730**
14	Mongar	282	80	**22,560**							18	50	**900**		**23,460**
15	Lhuntse	120	80	**9,600**				2	50	**100**	61	40	**2,440**		**12,140**
16	Tashigang				80	80	**6,400**				1	50	**50**		**6,450**
17	Tashiyangtse				30	80	**2,400**	20	50	**1,000**	6	50	**300**		**3,700**
	Samdrup							26	50	**1,300**	15	40	**600**		**1,900**
18	Jongkhar				307	80	**24,560**				3	50	**150**		**24,710**
		23	80	**1,840**							43	40	**1,720**		**3,560**
19	Pemagytshel										2	50	**100**		**100**
		24	80	**1,920**				108	50	**5,400**	9	40	**360**		**7,680**
20	Thimphu	14	80	**1,120**											**1,120**
	Total	701		**56,080**	1,030		64,490	348		**17,400**	668		**28,108**	267	
	Grand Total														**166,078**

Source: DRE

The typical SHS, with capacity of 50W, is shown in Figure 7-2.

Solar Panel

Source: JICA Survey Team



System Diagram of SHS

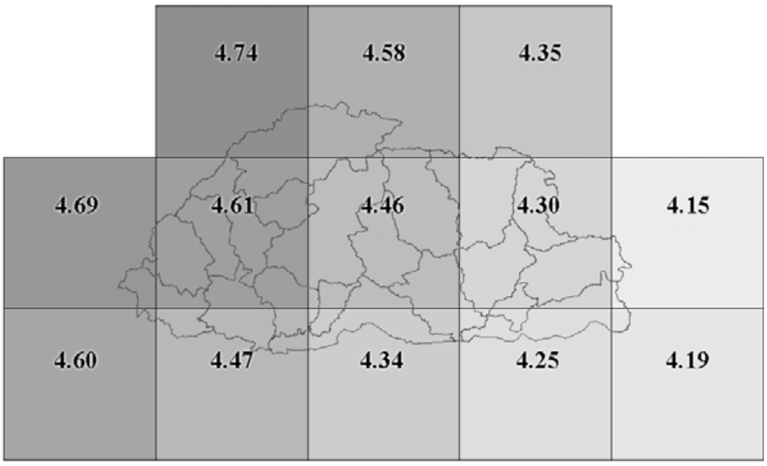
Figure 7-2 Solar Home System

7.1.3 Potential for Development of Photovoltaic Generation System in Areas

The following two reports exist as reports about the potential of photovoltaic generation systems.

- The Integrated Master Plan Study for Dzongkhag-wise Electrification in Bhutan (Japan International Cooperation Agency 2005/10)
- Potential for Development of Solar and Wind Resource in Bhutan (National Renewable Energy Laboratory 2009/9)

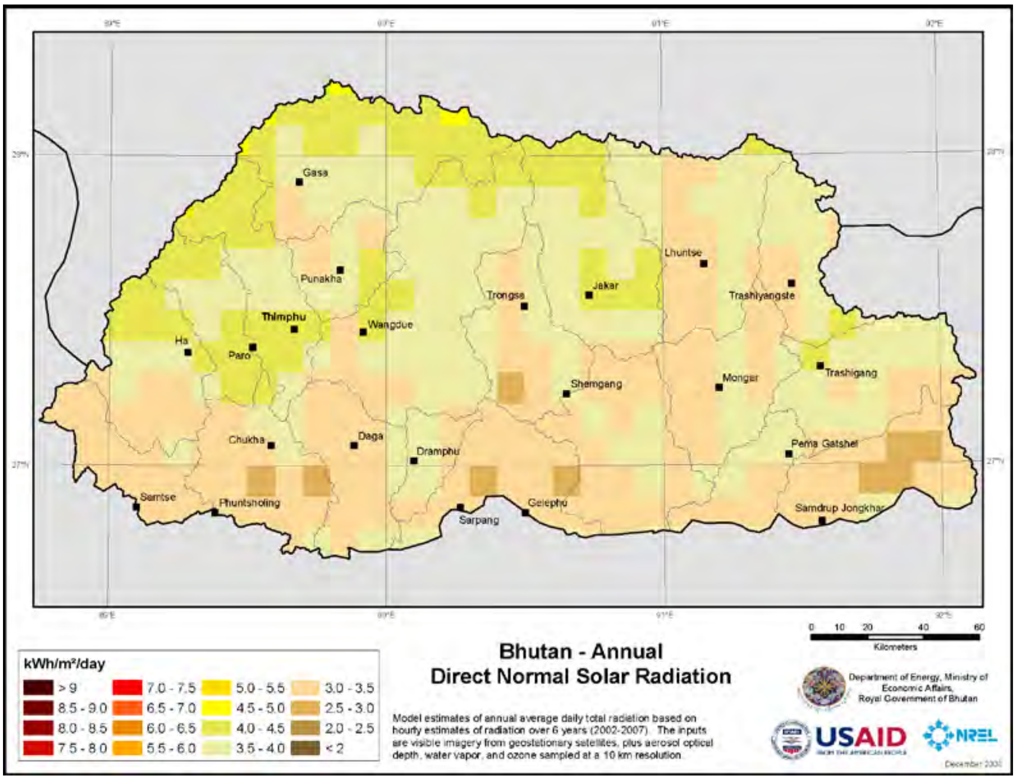
In "The Integrated Master Plan Study for Dzongkhag-wise Electrification in Bhutan", the potential of photovoltaic generation systems has been reported from the viewpoint of rural electrification; the map of the "Estimated Annual Average Horizontal Solar Irradiation" created from satellite data of NASA is shown. The report concludes that Bhutan has high solar potential in the northern part and in the western part, and there is not a lot of difference from the average between each area.



Source: The Integrated Master Plan Study for Dzongkhag-wise Electrification in Bhutan

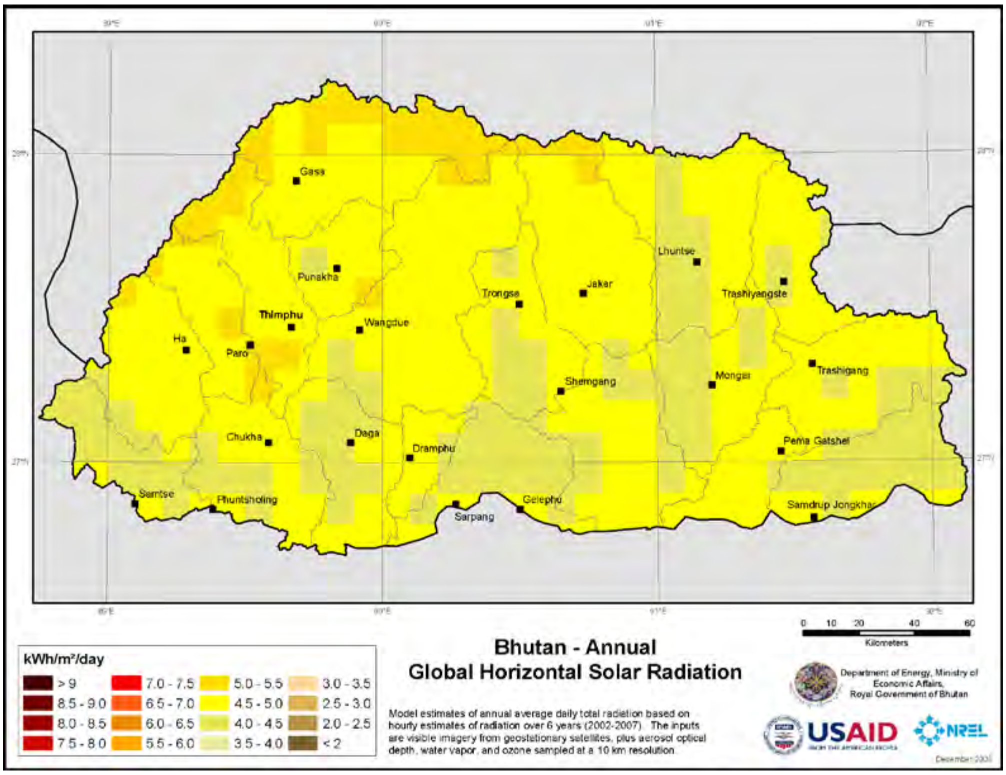
Figure 7-3 Estimated Annual Average Horizontal Solar Irradiation (kWh/m2/day)

In "Potential for Development of Solar and Wind Resource in Bhutan", by the National Renewable Energy Laboratory (hereafter "NREL data"), the potential of photovoltaic generation systems has been reported by a simulation based on meteorological data. The report concludes that Bhutan has a moderate amount of available solar light energy. The direct normal solar radiation and global horizontal solar radiation are shown in Figure 7-4 and Figure 7-5.



Source: Development of Solar and Wind Resource in Bhutan

Figure 7-4 Direct Normal Solar Radiation



Source: Development of Solar and Wind Resource in Bhutan

Figure 7-5 Global Horizontal Solar Radiation

The amount of available solar light energy in each district is shown in Table 7-3. There is a tendency that the northern area has a large amount of insolation and the southern area has a small amount of insolation.

Table 7-3 Annual Average Global Solar Resource of Each District

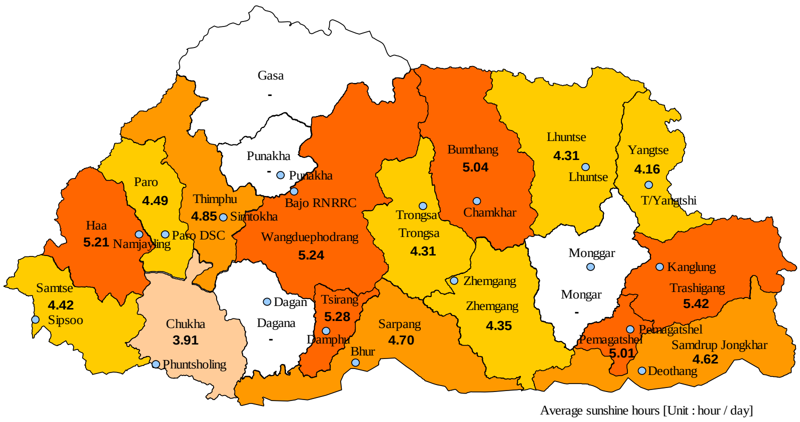
	District	Total Land Area (km^2)	Range of Annual Solar Resource at Tilt (kWh/m^2–day)		
1	Bumthang	2,718	4.5	to	5.6
2	Chukha	1,880	4.4	to	5.6
3	Dagana	1,723	4.4	to	5.1
4	Gasa	3,135	4.8	to	6
5	Haa	1,905	4.5	to	5.7
6	Luentse	2,859	4.5	to	5.5
7	Mongar	1,945	4.6	to	5.3
8	Paro	1,287	4.7	to	5.3
9	Pemagatshel	1,022	4.7	to	5.8
10	Punakha	1,110	4.6	to	5.2
11	Samdrupjongkhar	1,877	4.4	to	5.1
12	Samtse	1,305	4.5	to	5.1
13	Sarpang	1,656	4.4	to	5.1
14	Thimphu	1,796	4.8	to	6.1
15	Trashigang	2,204	4.5	to	5.4
16	Trashiyangtse	1,449	4.6	to	5.4
17	Trongsa	1,814	4.5	to	5.2
18	Tsirang	638	4.5	to	5.1
19	Wangdue	4,036	4.5	to	5.6
20	Zhemgang	2,417	4.5	to	5.1
	Total	38,776			

Source: Development of Solar and Wind Resource in Bhutan

From a study of the existing reports, the Survey Team makes an assumption that Bhutan has a moderate amount of available solar light energy. But the NREL data is not actual measurement data; it is calculated by a simulation based on meteorological data. Therefore it can be used for grasping the tendency of an amount of solar radiation, but it cannot be used for designing and constructing a photovoltaic generation plant.

In order to understand the actual amount of solar radiation, the JICA survey team obtained the meteorological data, which are sunshine hours data and solar radiation data, from the Meteorology Section; Hydro met Services Division, Department of Energy (hereafter “Hydromet Services”).

The summary of the average sunshine hours for four years from 2009 to 2012 is shown in Figure 7-6.



Source: Hydromet Services

Figure 7-6　Average Sunshine Hours

About the solar radiation data, measurement of the amount of global horizontal solar radiation has been started from 2004 by Hydromet Services, Department of Hydromet Services at 14 points. However, because of an equipment failure, a battery shutdown and other trouble, the data of solar radiation has a lot of missing data; therefore it is not suitable for using as an estimation of the potential of photovoltaic generation systems.

Therefore, in Hydromet Services, in order to collect accurate data, new on-line systems have been operated one by one since 2010. In the new on-line system, the measurement data of the amount of global horizontal solar radiation has been collected from nine meteorological observation points. Photos of the meteorological observation points are shown in Figure 7-7, and the location of the meteorological observation points are shown in Table 7-4 and Figure 7-8. Moreover, the monthly amount of solar radiation in 2012 at 9 points is shown in Figure 7-9.

Simtokha meteorological observation points

Chamkhar meteorological observation points

Source: JICA Survey Team

Figure 7-7　Observation Points

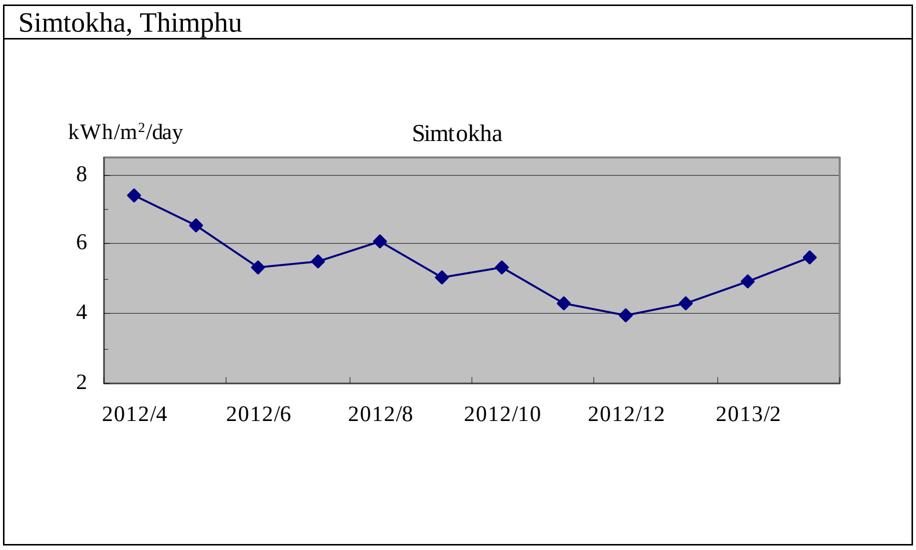
Table 7-4 New On-line observation points

Sl#	Dzongkhag	Station Name	Altitude (m)	Latitude	Longititude
1	Thimphu	Simtokha	2310	27:26:18	89:40:31
2	Paro	Paro DCS	2406	27:22:59	89:25:12
3	Wangdue	Bajo, RNRRC	1180	27:29:12	89:54:03
4	Bumthang	Chamkhar	2470	27:32:43	90:45:13
5	Zhemgang	Zhemgang	1820	27:12:58	90:39:20
6	Monggar	Monggar	1580	27:16:45	91:14:84
7	Chukha	Malbase	394	26:51:29	89:26:40
8	Dagana	Dagana	1865	27:57:25	89:51:34
9	Trashigang	Kanglung	1980	27:16:40	91:30:56

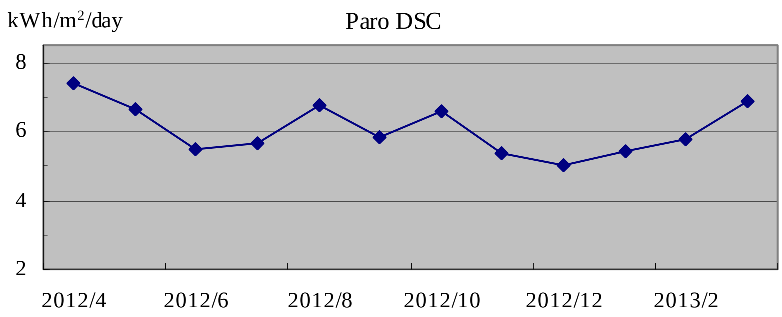
Source: Hydromet Services

Source: JICA Survey Team

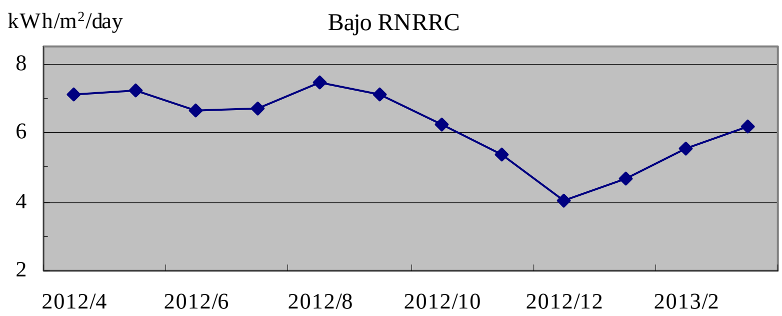
Figure 7-8 Location of New On-line Meteorological Observation Points



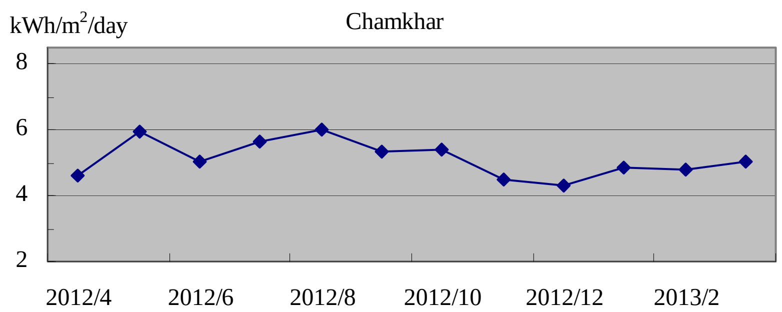
Paro DCS, Paro



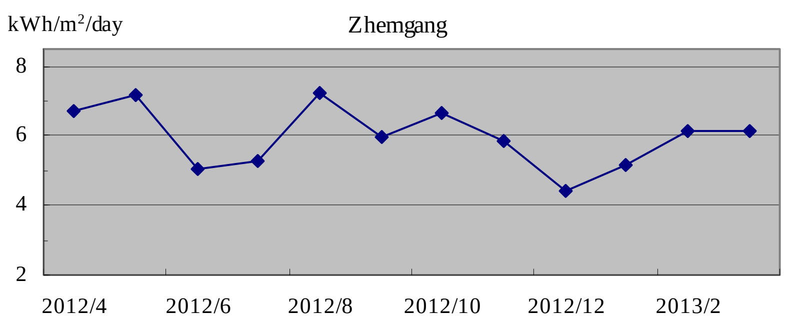
Bajo, RNRRC, Wangdue



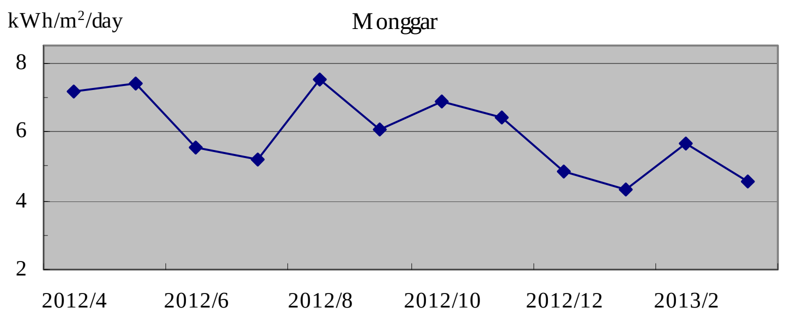
Chamkhar, Bumthang



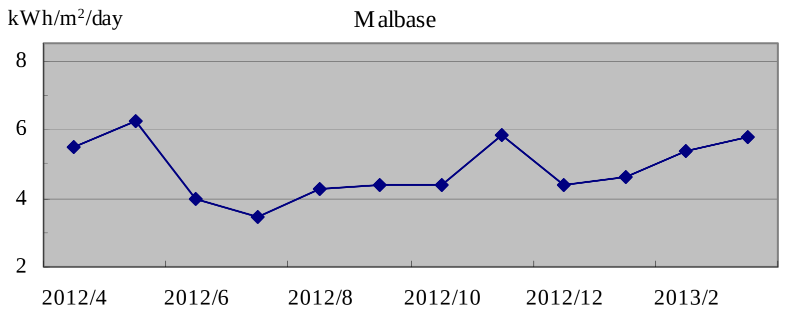
Zhemgang, Zhemgang



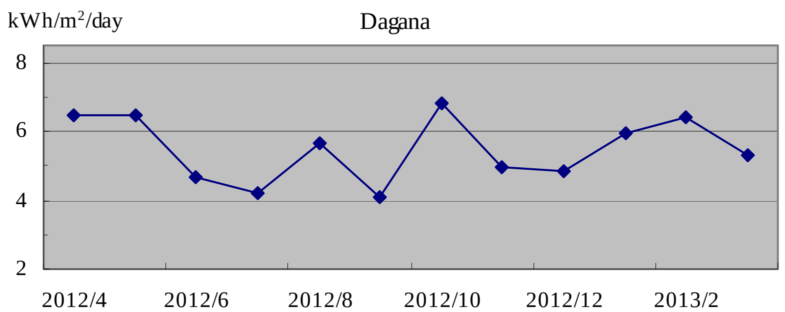
Monggar, Monggar



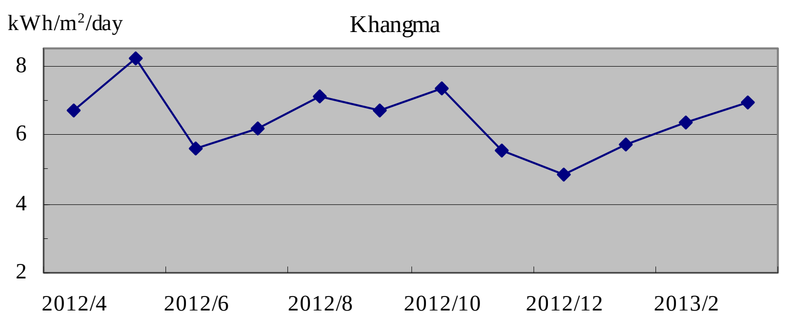
Malbase, Chukha



Dagana, Dagana



Kanglung, Trashigang



Source: Hydromet Services

Figure 7-9 Amount of Solar Radiation in 2012

The following points can be made from the measurement data results of the amount of solar radiation from the new on-line observation points.

- Bhutan has a high amount of solar radiation across the whole country.
- Paro, Wangdue Phodrang, and Trashigang have a particularly high amount of solar radiation.
- Although the amount of solar radiation in the southern part is high, the temperature in the southern part is high; therefore the conversion efficiency of photovoltaic generation becomes low.
- Although the amount of solar radiation in the northern part is not measured, installation of a mega solar system is difficult in the northern part because of difficulties in the transportation of equipment and materials.

However, since there is data for only one year, this has been greatly affected by the influence of the weather situation of that particular year. Therefore, in order to increase the reliability of the data, it is necessary to continue solar radiation data collection at the same points.

Moreover, in order to estimate the potential of the photovoltaic generation system throughout Bhutan, it is necessary to measure the solar radiation at each Dzongkhag. Therefore, the JICA Survey Team recommends the installation of meteorological observation points at each Dzongkhag.

7.1.4 Organization Chart for Promotion of Photovoltaic Generation Systems

DRE is the Department responsible for the promotion of renewable energy technologies. The “Solar Energy Section” is the division responsible for the promotion of photovoltaic generation system installation. In the Department, there are four staff members who have had training in Japan for the promotion of photovoltaic generation systems.

Moreover, the Ministry of Economic Affairs (MoE) formulates policies, such as FIT, and the Bhutan Electric Authority (BEA) sets concrete rules and guidelines. DRE also works with BEA to formulate policies and set concrete rules and guidelines, and strives to promote the installation of renewable energy.

7.1.5 Present Situation of the Promotion of Photovoltaic Generation Systems

"Alternative Renewable Energy Policy 2013" was adopted on 5th February and released in April, 2013 by the RGoB. Based on this policy, DRE is planning to make an incentive system such as FIT and revise the electrical tariff system. The creation of a national renewable energy master plan is also considered. As a target of "Alternative Renewable Energy Policy 2013", DRE is planning to install a minimum of 5MW photovoltaic generation systems by 2025.

Moreover, the draft of the “11th Five Year Plan of the DRE”, there is a plan for the installation of 1MW photovoltaic generation system by 2015 as a pilot mega solar power plant in the country. In cooperation with BPC and MoF, the installation of SHS for rural electrification is also continued. Furthermore, although there will be no numerical target by 2018, installation of additional photovoltaic generation systems by private sector capital is also set as a target.

7.1.6 Rules and Guidelines on the Installation of Photovoltaic Generation

Small-scale solar systems and SHS can be considered for cases where they are installed on a house site or roof top. When it is not a protected area, the supervisors of regulations for installation in an individual’s land or property are the Department of Human Settlement, Ministry of Works and Human Settlement. In addition, the private sector organization "Thromde", which has approval from the government, is performing the business of regulation and supervision for institution construction.

The guidelines on building regulations are follows;

- Bhutan Building Rules 2002 (BBR2002)
- Thimphu Municipal Development Control Regulations 2004 (DCR2004)

And construction standards follow the following Indian standards.

- IS 875 (loading)
- IS 1873 (earthquake)
- IS 13920 (detail design)

There are no regulations regarding installation on a building with a photovoltaic panel at present. Therefore the JICA Survey Team recommends creating guidelines or specifications on the installation to buildings of photovoltaic panels in DRE from now on.

7.1.7 Economic Aspects

Table 7-5 shows the base price of photovoltaic generation system installation in several countries, as reported by the International Energy Agency (IEA) in 2012. The prices shown in Table 7-5 are the past record of photovoltaic generation system installation projects, with consumption tax not included. The price contains the subsidy of each country. There is variation by each country.

Table 7-5　Base Price of Photovoltaic Generation System Installation in Several Countries

Country	Off-grid (USD/W)		Grid-connected (USD/W)	
	<1kW	>1kW	<10kW	>10kW
AUS	6.2-15.5	7.2-20.6	3.1-4.1	2.6-4.1
AUT	<13.9	<13.9	3.5	<3.5
CAN		13.1	6.9	3.5-5.3
CHE			5.6-6.7	3.4-4.5
CHN			2.7	2.7
DEU			2.8-3.5	2.5
DNK	3.7-6.5	6.5-11.2	3.4-5.6	1.9-7.5
FRA			5.4	2.8-3.6
ISR	7.0	7.0	3.5	3.0
ITA	6.9-9.7		4.2-4.7	2.8-4.2
JPN			6.5	6.5
KOR			3.6	2.8
MYS			3.7	3.7
NLD			2.6-3.9	2.6-3.9
SWE	6.9	4.9	4.3	3.9
USA			6.1	3.6-4.8

Source:Report IEA-PVPS T1-21:2012

The price trend is decreasing every year, as shown in the following figure.

Source:Report IEA-PVPS T1-21:2012

Figure 7-10　Trend of Small-Scale Photovoltaic Generation System

Next, an economic evaluation study is conducted for mega solar systems, small-scale solar systems and SHS. First, the unit price per kW (SHS for a unit price per W) is shown in the Table 7-6.

The unit price of a mega solar system and small-scale solar system is quoted from the mean value of the price of a solar system installed in European countries, as reported by the European Photovoltaic Industry Association in 2011. The unit price of SHS is quoted from the average of the price of the rural electrification project contract in Bhutan in 2013. Since the price of solar systems is decreasing, a price fall at the time of the installation must be considered, as shown in Figure 7-10.

Table 7-6 Unit Price of each Solar System

System type	Price (USD)
Ground-mounted mega solar system (kW)	3114.26
Small-scale solar system (kW)	5154.64
SHS (W)	6.83

Source: European Photovoltaic Industry Association and DRE

An economic evaluation of SHS is not conducted because the purpose of SHS installation is rural electrification. The economic evaluation of a mega solar system is conducted in Chapter 8. Here, the economic evaluation of a small-scale solar system is described follows.

In Bhutan there are no photovoltaic panel manufacture companies, so all equipment for photovoltaic generation systems must be supplied from overseas. And a house or building has the necessity of being reinforced. Therefore, actual installation prices may become comparatively higher than the prices shown in Table 7-6. For the case where a 3 kW photovoltaic panel is installed in Thimphu, a trial calculation is made using a calculation method of the Japan Photovoltaic Energy Association (JPEA), which is an incorporated association for technical standardization and the promotion of photovoltaic systems.

Power generation by photovoltaic panels is calculated by the following formula.

$$E_p = P \times H_m \times K_t \times \eta_{ino} \times K'$$

P: Capacity of photovoltaic panels (kWp)
E_p: Monthly power generation (kWh/month)
H_m: Average monthly solar radiation (kWh/m2/month)
K_t: Modification coefficients of temperature
η_{ino}: Power conditioner efficiency
K': Other efficiency

The conditions for trial calculation are shown in Table 7-7. In addition, each element of data is referred to from the following data and report.

- Solar radiation data: average solar radiation data at new on-line observation points in Thimphu in 2012
- Modification coefficients of temperature: JPEA reports
- Efficiency of power conditioner: JPEA reports
- Material cost of small-scale solar system: "COMPETING IN THE ENERGY SECTOR ON THE ROAD TO COMPETITIVENESS", EPIA
- Transportation, installation and other services: 10% of material cost, past record in "Project for upgradation of 220/66/11kV Semtokha Substation"
- Operation and maintenance: 1% of material cost, "Technology Roadmap, Solar photovoltaic energy", IEA

Table 7-7 Conditions for Trial Calculation

Item	Value
Photovoltaic capacity (kW) : P	3.00
Modification coefficients of temperature : Kt	0.90
Efficiency of power conditioner : ηino	0.90
Amount of solar radiation per month (kW・h/month) : Hm	166
Other efficiency : K'	0.99
Material cost of small schele solar system (USD/kW)	5,150
Transportation, installtion and other services (USD/kW)	515
Operation and maintenance (USD/kW/year)	51.5

Source: JICA Survey Team

The result of the trial calculation is shown in Table 7-8. From the trial calculation, monthly power generation is about 400 kWh / month, so the yearly power generation is about 4,800 kWh / year. Since the electric rate of low voltage in Bhutan is 2.14 Nu / kWh, the annual electricity bill saving which can be produced by photovoltaic generation is 10,300 Nu (158 USD).

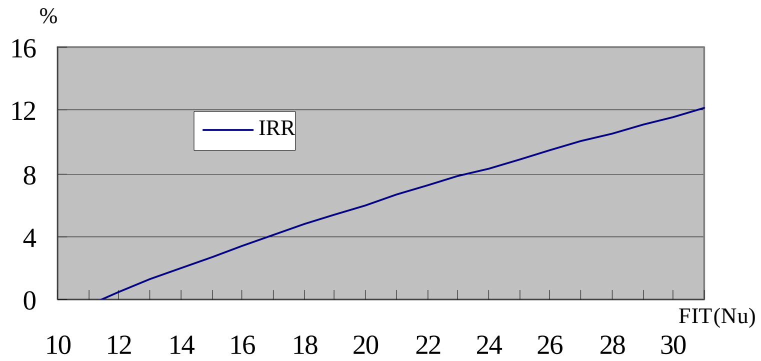
Since the initial investment of the 3 kW small-scale solar system is 17,000 USD, the initial investment is unrecoverable within the durable period of the solar system. In the present situation where FIT has not been introduced, the small-scale solar system does not have economic efficiency. Next, when the FIT of 11.46 Nu is introduced, it will take 20 years to recover the initial investment. When FIT of 11.46 Nu or more is introduced, considering the 20-year life of the solar system, the total project benefit becomes positive.

Table 7-8 Result of Trial Calculation

Item	Value
Power Generation per month (kWh)	400
Power genaration per year (kWh)	4,800
Electricity rate for LV (Nu/kWh)	2.14
Saving amount of money per year (Nu)	10,300
Saving amount of money per year (USD)	158
Pay back period without FIT (year)	4,290
FIT(Nu)	11.46
Pay back period with FIT (year)	20

Source: JICA Survey Team

Furthermore, the relationship between the FIT and the internal rate of return for 20 years is shown in the following figure. It is necessary to determine the amount of suitable FIT within DRE.



Source: JICA Survey Team

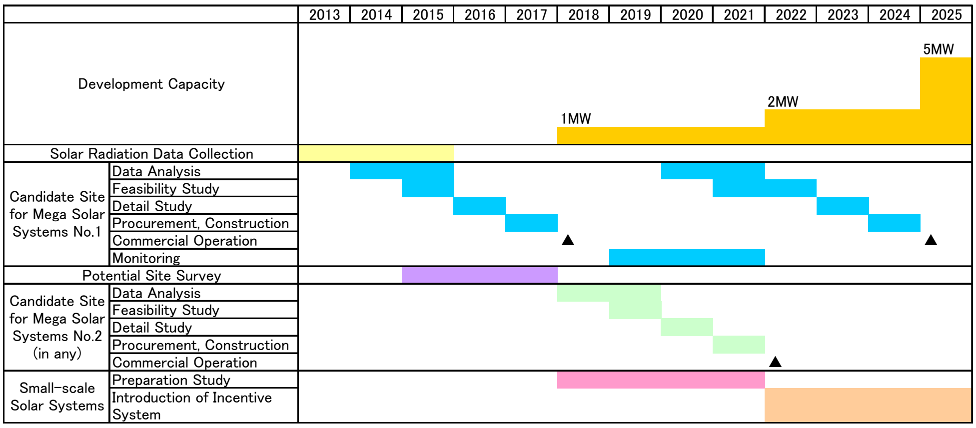
Figure 7-11 Relationship between FIT and IRR

7.1.8 Possibility of Target Achievement and Road map towards Target Achievement

According to “Alternative Renewable Energy Policy 2013”, the minimum target of photovoltaic generation systems is 5MW by 2025, and according to “Draft of the 11th Five-Year Plan in Bhutan”, the minimum target of photovoltaic generation systems is 1MW by 2015.

As a method for achieving the development targets, there are mega solar systems, small-scale solar systems and SHS. For SHS, since the purpose of its installation is rural electrification, it is not suitable as a method for achieving the development targets. For a small-scale solar system, since there are no regulations regarding installation on a building with a photovoltaic panel at present, it is not suitable as a method for achieving the development targets. Therefore, as a method for achieving the development targets, the mega solar system is promising.

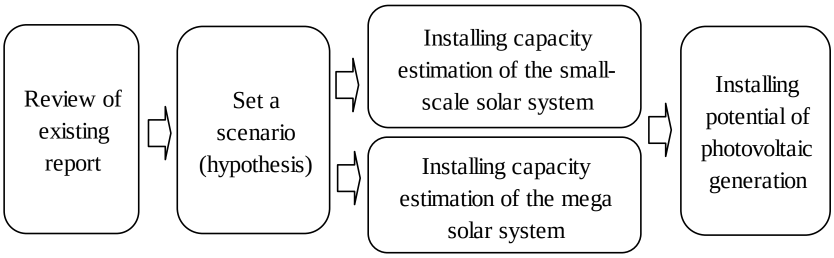
A promising candidate site for the mega solar system exists and is shown in Chapter 8 in detail. It is necessary to conduct a detailed study from now on. The road map towards achievement of the development target for photovoltaic generation system is shown in Figure 7-12.



Source: JICA Survey Team

Figure 7-12 Road Map towards Target Achievement

Moreover, it is necessary to conduct the installing potential study for the photovoltaic generation system in parallel. The procedure of study for the installing potential estimation of the photovoltaic generation system is shown in Figure 7-13.



Source: JICA Survey Team

Figure 7-13 Procedure of Study for Installing Potential Estimation

A review of the existing report is described in this report.

Next, a scenario (hypothesis) is discussed and set in DRE. The theoretically estimable amount of energy resources is discussed, disregarding the various constraining factors, such as land type and the technology used, defined as "the amount of available solar light energy". The amount of energy resources estimated after setting up the scenario, with consideration of the various constraining factors concerning the exploitation and utilization of energy, and which can be used, is defined as "the installing potential". Re-examination such as resetting the FIT is needed periodically because the constraining factors, such as economic efficiency, may change.

Third, the installing potential is estimated. Small-scale solar systems, such as a residential photovoltaic generation system and mega solar system, are given as candidate sites.

a) Estimation of the Installing Potential of the Small-scale Solar System

Based on the sample building data of a public facility and factory, the area (roof, side wall) of the photovoltaic generation panel which can be installed, is calculated. The area and the number of public buildings and factories, which are obtained from statistical data, are multiplied, and the installing potential of the photovoltaic generation is estimated. It is estimated by the same methodology as for a residential house.

And it is necessary to create guidelines or specifications on the installation to buildings of photovoltaic panels, and to set up a solar radiation database for opening to the public.

b) Estimation of the Installing Potential of the Mega Solar System

First, the conditions for the candidate site are set up within DRE, and interviews are conducted with each Dzongkhag based on the condition. Second, about the site chosen by the interview result, a rough study such as site survey is conducted and the area which can be installed is totaled. Third, a priority is given and the installing potential according to scenario is estimated.

Finally, the installing potential of the small-scale solar system and the mega solar system is summarized.

The above is the procedure of study for the installing potential estimation of photovoltaic generation system.

7.2 Small Hydropower

7.2.1 Characteristics

Hydropower generation is a system to make electricity by using energy in lakes and rivers at high elevation. Hydropower is rarely affected by the weather, unlike Photovoltaic power and Windpower generation. Therefore, it is easier to secure stable power, compared to Photovoltaic power and Windpower generation. The principle of small hydropower is equivalent to that of large hydropower. However, small hydropower plants do not include large civil structures, such as a large dam. As per AREP 2013, the hydropower projects are classified as shown below;

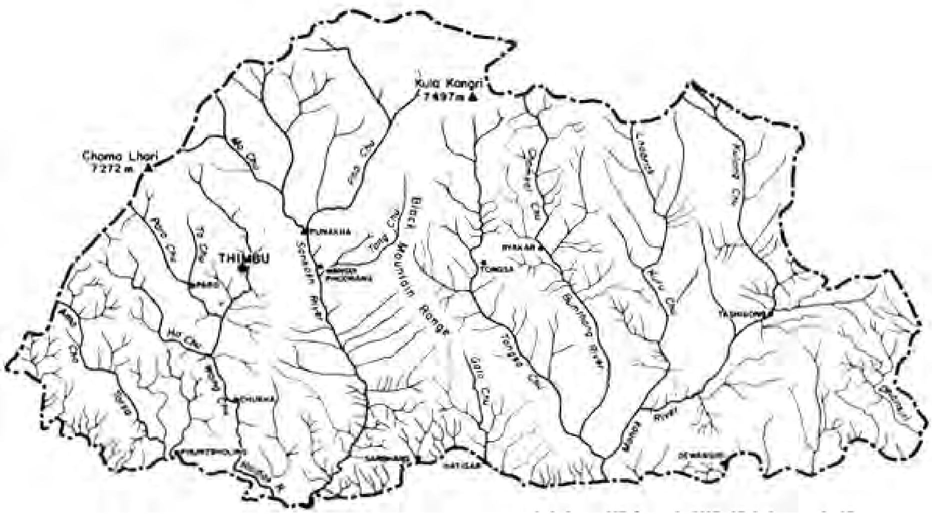
Pico – 1 kW to 10 kW
Micro – above 10 kW to 100 kW
Mini – above 100 kW to 1,000 kW
Small – above 1,000 kW to 25,000 kW

There are abundant water resources in Bhutan. Therefore, many hydropower plants have already been constructed and feasibility studies for new small hydropower plants are in progress. Small hydropower plants are planned to be constructed at the foot of the 7,000m class Himalayan Mountains. Site investigation is being carried out; however equipment transportation is a problem.

In Bhutan, there are many micro & mini hydropower plants which are older than 20 years. It is probable that power output can be restored with proper maintenance of deteriorated equipment.

7.2.2 Examination of Potential Sites in a Large River

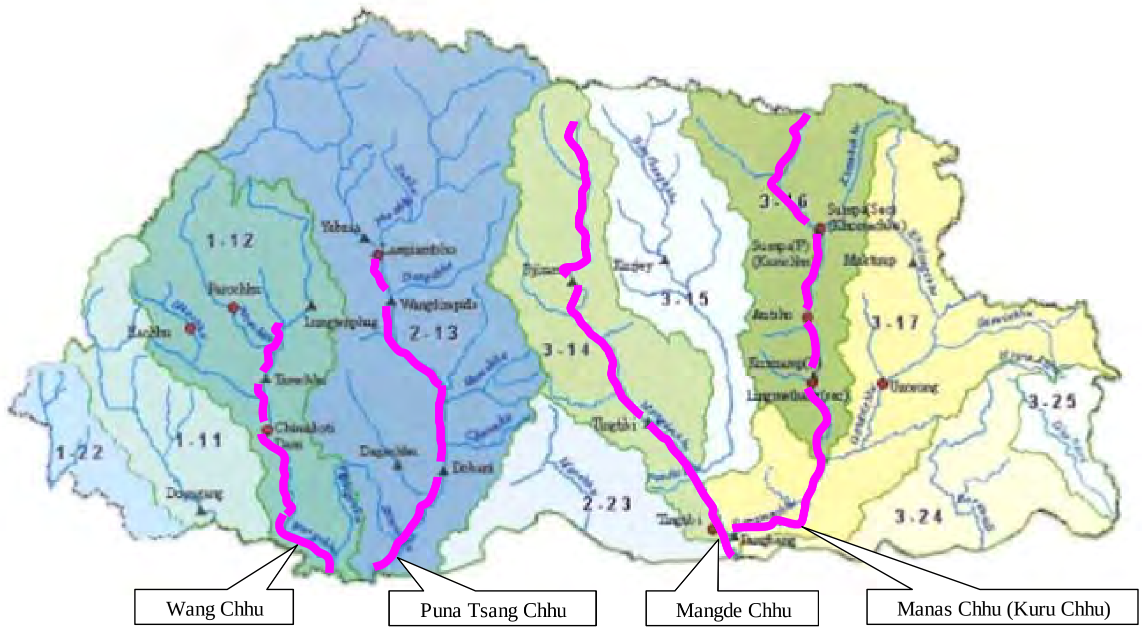
Discharge at rivers and the difference in elevation are important factors in examining potential sites for hydropower. Bhutan is situated in the Himalayan mountain range. There are several peaks exceeding 7,000m in the northern part of Bhutan and lowland under 1,000m in the southern part. Therefore, there is difference in elevation in the north and south. As shown below, there are many torrential rivers which flow from north to south. Almost all rivers flow into India and merge with the Brahmaputra River. In addition, many river systems are distributed evenly all over Bhutan. There are many districts which are suitable for Hydropower in Bhutan.



Source: Traced by architecture & planning cell Thimphu, Bhutan

Figure 7-14 River system in Bhutan

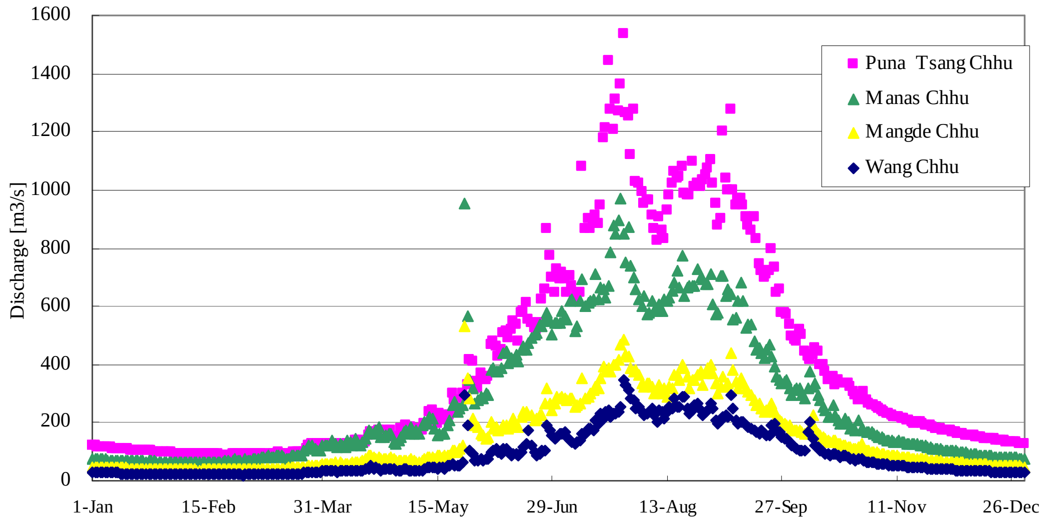
There are some gauging stations in river systems under the control of the Department of Hydro-met Services. The gauging stations observe discharge of major river daily.



Source: Surface Hydrological data of Bhutan (Year book)

Figure 7-15 Location of gauging station in Large river

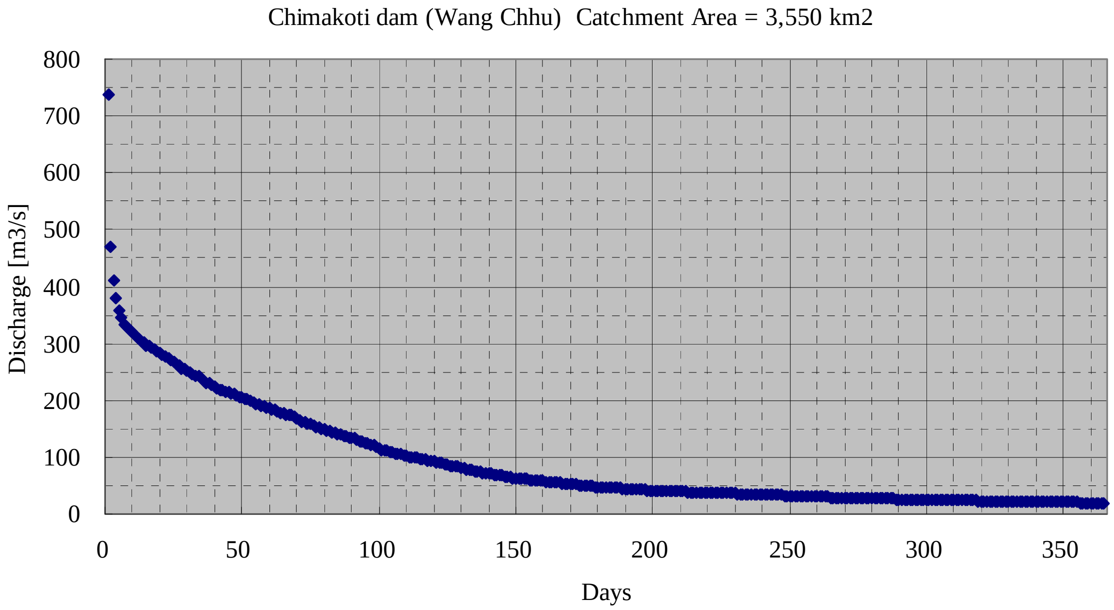
Annual river flow of large river "Wang Chhu, Puna Tsang Chhu, Mangde Chhu and Manas Chhu" in 2006-2010 is analyzed. According to river flow data of these large rivers, river flow increases from around May and there is a lot of river flow between June and September. There is around 1,400 m³/s river flow during the rainy season in Puna Tsang Chhu. The river flow gradually decreases after the rainy season.



Source: Surface Hydrological data of Bhutan (Year book)

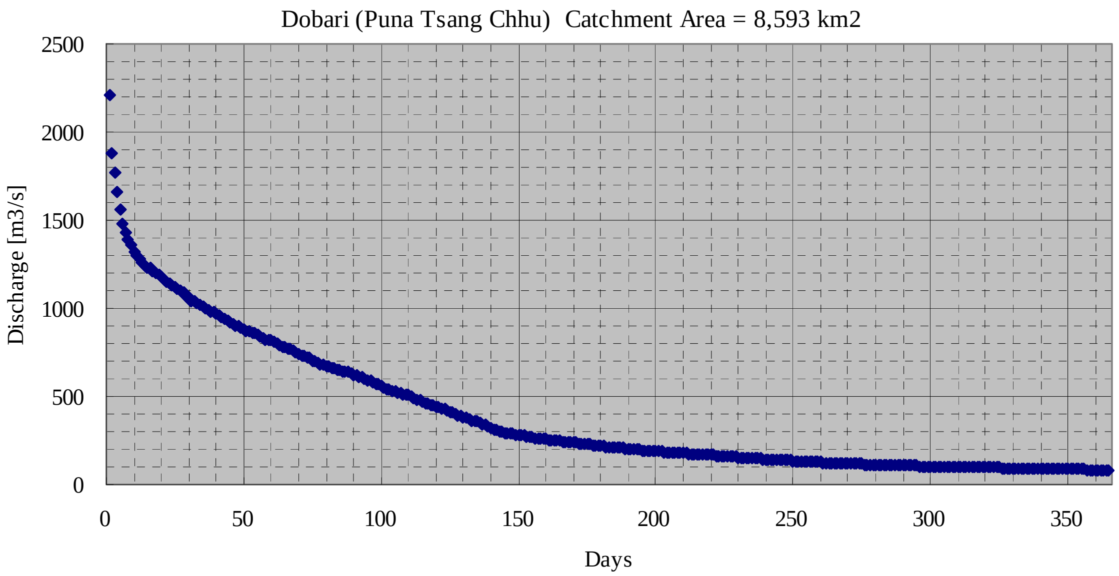
Figure 7-16 Annual river flow data in Large river

Duration curves of "Wang Chhu, Puna Tsang Chhu, Mangde Chhu and Manas Chhu" are made based on river flow data observed from 2006 to 2010. Duration curve is a curve which sorts daily average flow data from high discharge to low one. The duration curve is used to confirm the characteristics of the river.



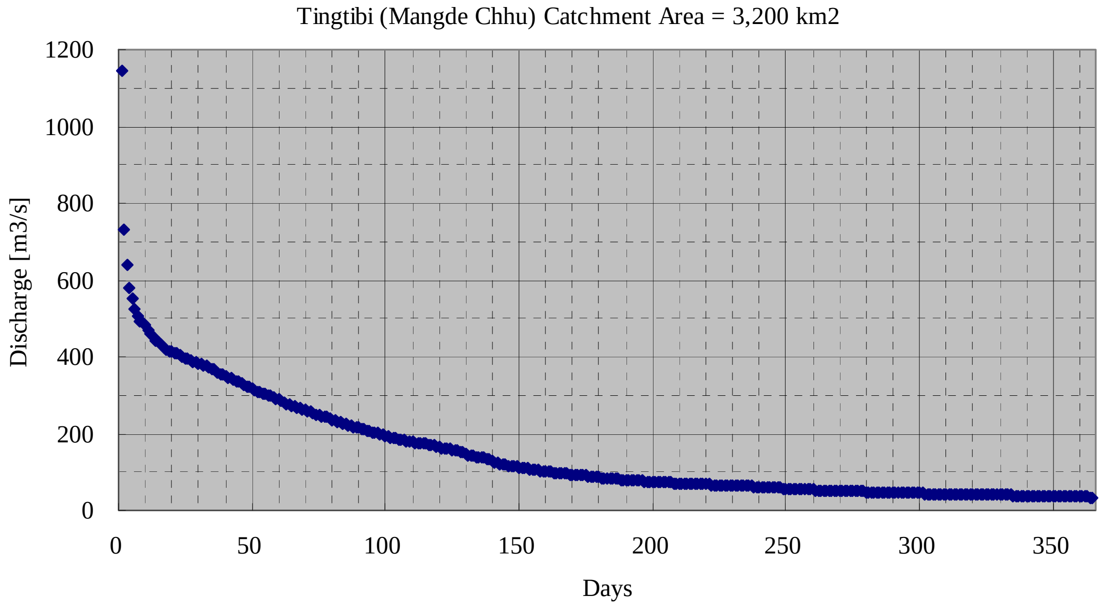
Source: Surface Hydrological data of Bhutan (Year book)

Figure 7-17 Duration curve of Wang chhu



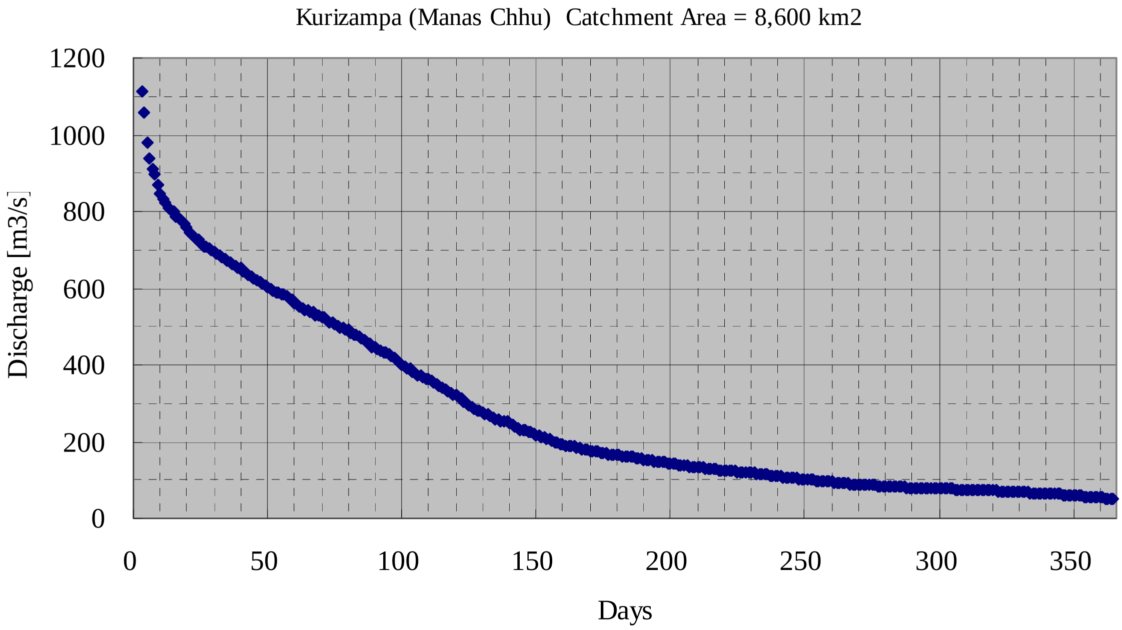
Source: Surface Hydrological data of Bhutan (Year book)

Figure 7-18 Duration curve of Puna Tsang chhu



Source: Surface Hydrological data of Bhutan (Year book)

Figure 7-19 Duration curve of Mangde chhu

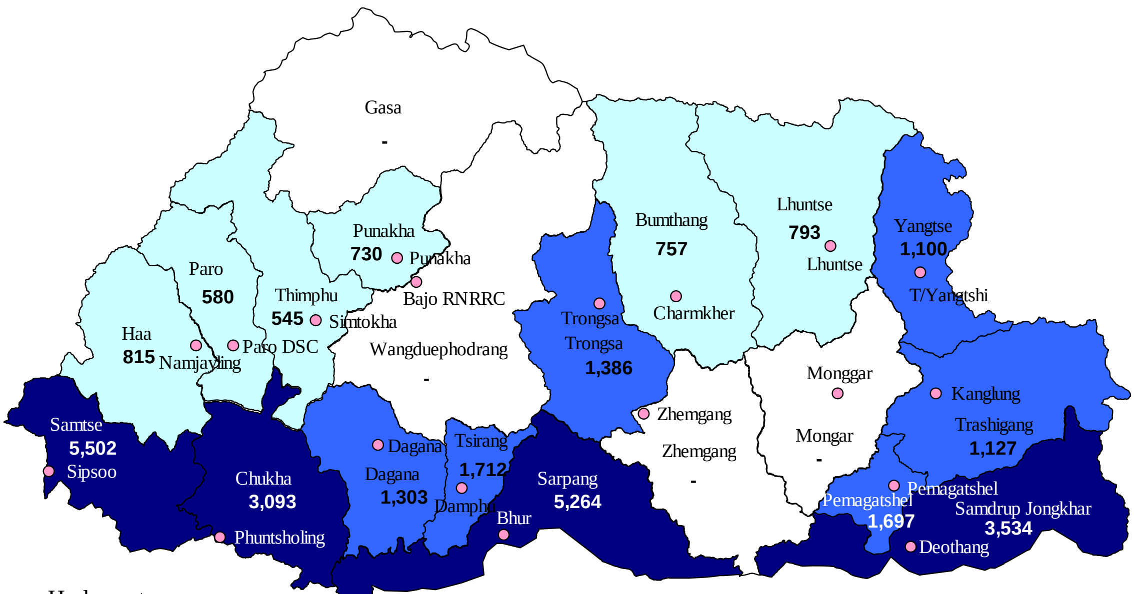


Source: Surface Hydrological data of Bhutan (Year book)

Figure 7-20 Duration curve of Manas chhu

For instance, there are 40 days with more than 1,000 m³/s in one year in Puna Tsang Chhu and about 90 m³/s river flow is flowing throughout one year. Punatsangchhu-I, Punatsangchhu-II, Sankosh, and Dagachhu hydropower plants are being constructed or planned in Puna Tsang Chhu.

The following map shows the annual average rainfall in Bhutan, which is based on rainfall data Hydromet collected from 2007 to 2011. The average rainfall data is not shown in some districts which have no data for rainfall.



Source: Hydromet

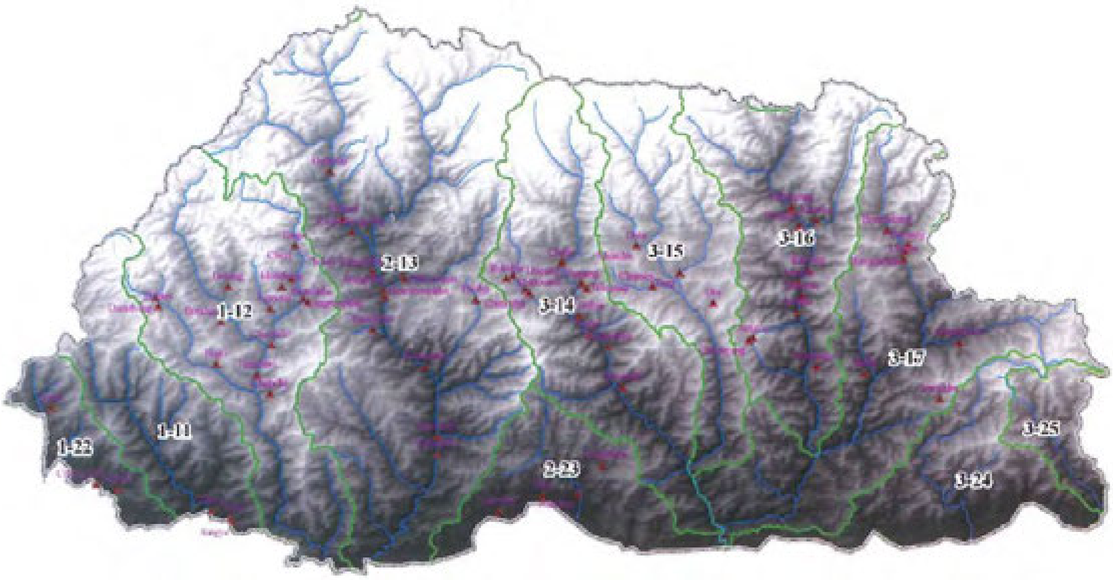
Average annual precipitation [Unit : mm / year]

Figure 7-21 Annual amount of rainfall in Bhutan

According to these data, there is much rainfall in southern Bhutan. It can be said that there are many potential sites for small hydropower by securing difference in elevation.

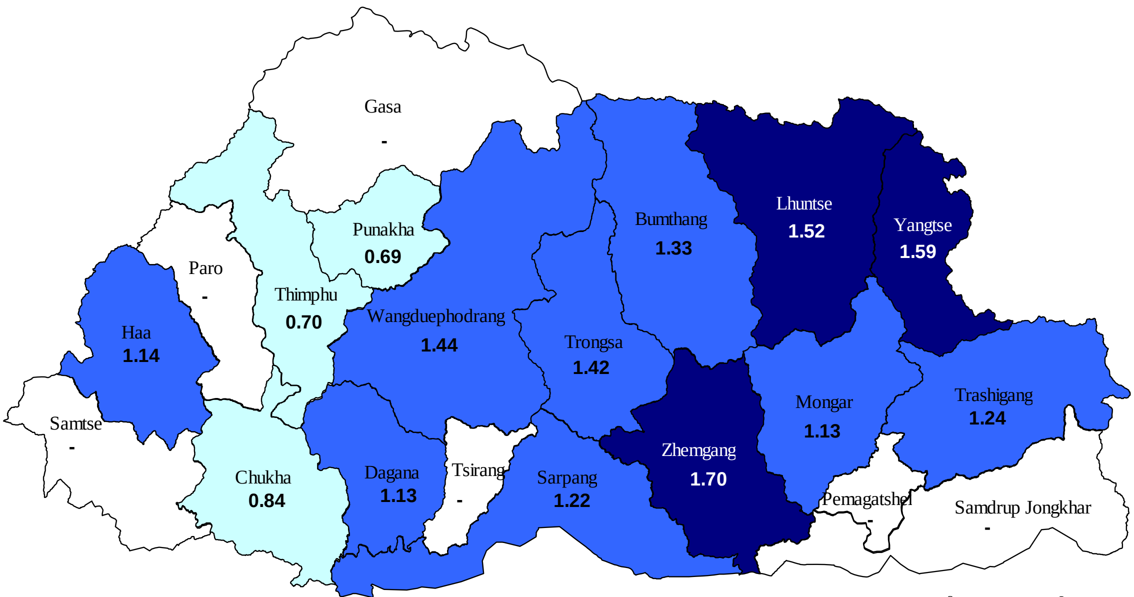
7.2.3 Examination of potential sites in Small River

There are many gauging stations in small rivers, however river flow is measured once a year during the dry season. Therefore, it is difficult to know the characteristics of small rivers throughout the year. There are gauging stations for small rivers as follows.



Source: Surface Hydrological data of Bhutan (Year book) ▲: Gauging Station

Figure 7-22 Location of gauging station in Small river



Source: Surface Hydrological data of Bhutan (Year book)

Average Specific Discharge [Unit : m^3 / sec / $100km^2$]

Figure 7-23 Average specific discharge (District-wise)

Discharge data in a small river is analyzed to calculate the average specific discharge (district-wise). The average specific discharge is not shown in some districts which have no data for flow and catchment area. The average specific discharge is large in the east (Lhuntse, Yangtse and Zhemgang). It is thought that discharge in these areas is affluent. Average specific discharge slightly differs according to area. It can be said that there are many potential sites for small hydropower by securing difference in elevation.
River flow in small rivers is analyzed and the trend of small hydropower potential will be estimated. Small hydropower potential will be estimated according to the following flows.

At first, the duration curve of large rivers, “Wang Chhu, Puna Tsang Chhu, Mangde Chhu and Manas Chhu” and river flow data from a small river which is supplied from HMSD is examined.

Next, three points with large specific discharge will be selected for each of the 4 rivers (Wang Chhu, Puna Tsang Chhu, Mangde Chhu and Manas Chhu). 12 points will be selected in total.
Duration curves for the 12 points in small rivers will be made by referring to duration curves in large rivers. River flow will be estimated by using the duration curves in small rivers. Equipment arrangement (including intake, waterway and powerhouse) will be examined and head will be estimated by using a topographic map. In this estimation, it is assumed that all hydropower plants are run-of river hydropower plants.

Then, the hydropower plant output and the construction cost will be estimated. Finally, the potential trend of the small hydropower plant (river-wise) will be estimated.

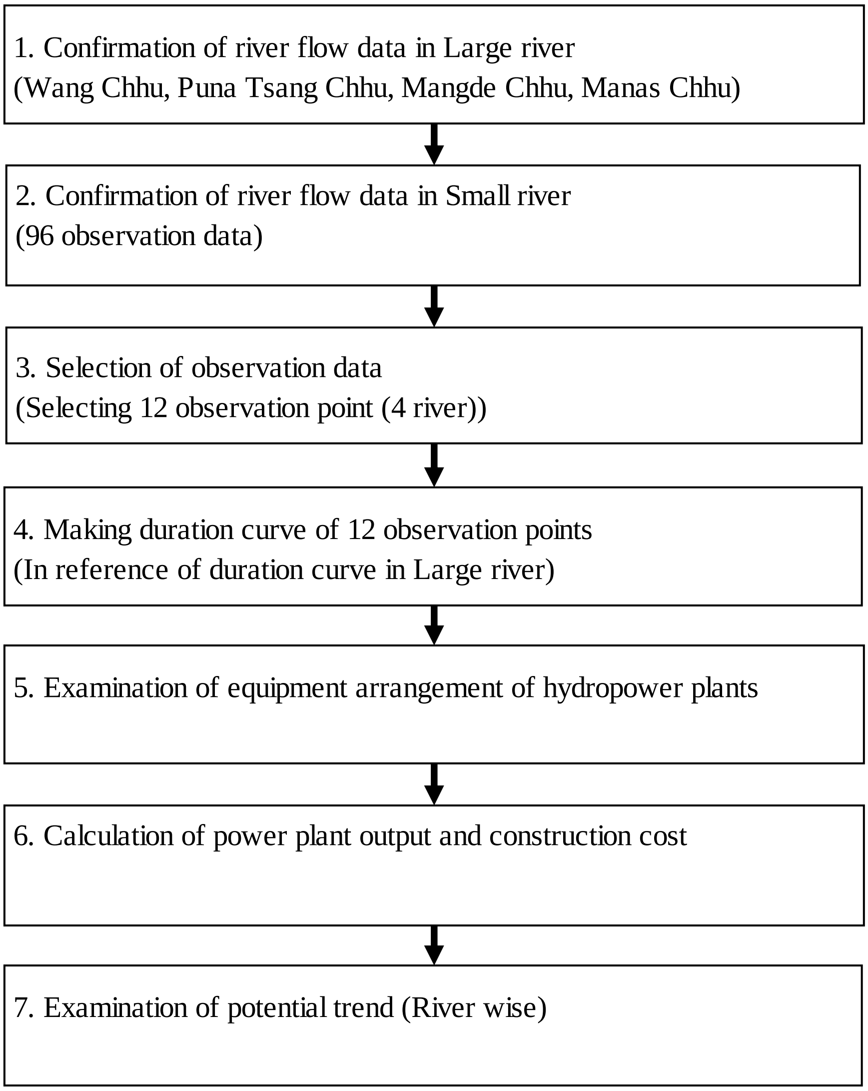


Figure 7-24　Flow of calculating small hydro potential

<u>1. Confirmation of river flow data in large rivers (Duration curves are made)</u>

Duration curves in large rivers (Wang chhu, Puna Tsang chhu, Manas chhu) were already made in "7.2.2 Examination of potential sites in a large river".

<u>2. Confirmation of river flow data in small rivers.</u>

Observation data in small rivers is shown below. River flow in small rivers is measured at each gauging station once a year. Most of the observation data is classified into a tributary of a large river, "Wang Chhu, Puna Tsang Chhu, Mangde Chhu and Manas Chhu".

Table 7-9 Observation data in Small river

No.	District	Small River	Main River	Location	Latitude	Longitude	Altitude(m)	Catchment area [km2]	Date	Q[m3/s]
1	Trashiyangtse	Dongdhichhu	Kulong Chhu	Leechen	27:35:06	91:29:35	1,774	91.86	17.3.92	1.821
2	Trashiyangtse	Birzamchhu	Kulong Chhu	T/Yangtse	27:36:20	91:29:56	1,782	15.8	17.3.92	0.214
3	Trashiyangtse	Nagpolachhu	Kulong Chhu	Bomdelling	27:39:51	91:26:31	1,914	-	12.02.02	1.293
4	Trashigang	Sarkang Chhu	Kulong Chhu	Balling	27:37:23	91:30:26	2,021	-	04.03.05	0.146
5	Trashigang	Kharthichhu	Gamri Chhu	Rangjung	27:21:30	91:40:02	1,048	67.3	12.02.94	0.914
6	Trashigang	Jirichhu	Drangme Chhu	Khaling	27:12:20	91:36:25	2,126	27.04	22.3.92	0.479
7	Trashigang	Bamrichhu	Drangme Chhu	Chenary	27:18:33	91:32:03	935	48.85	12.02.94	0.531
8	Trashigang	Rolongchhu	Drangme Chhu	Rolong	27:18:37	91:29:52	654	42.53	03.02.94	0.358
9	S/Jonkar	Charkelo	-	Darangri	-	-	-	−	02.03.07	0.158
10	Lhuntse	Ungerchhu	Manas Chhu	Gorgen	27:30:59	91:10:18	977	262.00	29.01.94	4.115
11	Lhuntse	Yonglachhu	Manas Chhu	Khoma	27:41:16	91:13:27	1,341	55.63	15.03.92	1.356
12	Lhuntse	Tangkerchhu	Manas Chhu	Gangzor	27:40:24	91:10:23	1,367	17.88	16.03.92	0.404
13	Lhuntse	Rongchhu	Manas Chhu	Thrimjung	27:43:21	91:08:55	1,329	67.70	13.01.98	1.183
14	Lhuntse	Kelongchhu	Manas Chhu	Thrimjung	27:42:53	91:09:00	1,280		07.02.02	1.098
15	Mongar	Rewanchhu	Manas Chhu	Rewan	27:33:01	91:12:08	806	52.4	13.02.01	0.562
16	Lhuntse	Shongmanchhu	Manas Chhu	Autsho	27:26:10	91:10:10	860		17.02.03	1.650
17	Lhuntse	Phawanchhu	Manas Chhu	Phawan	27:28:45	91:11:00	948	60.46	13.02.01	0.644
18	Mongar	Gangulhachhu	Manas Chhu	Kahlanzi	27:17:18	91:13:49	1,098	49.98	13.03.92	0.227
19	Mongar	Padangchhu	Drangme Chhu	Yadhi	27:16:19	91:22:35	993	18.17	03.02.96	0.215
20	Mongar	Sherichhu	Drangme Chhu	Sherichhu	27:15:15	91:24:36	542	437		
21	Mongar	Maurichhu	Manas Chhu	Lingmethang	27:15:11	91:11:15	536	284.05	28.01.94	4.908
22	Mongar	Chudigangchhu	Manas Chhu	Sengor	27:21:25	91:01:22	3,079	13.35	27.01.94	0.213
23	Mongar	Sengor Chhu	Manas Chhu	Sengor	27:21:49	91:02:05	2,994		28.02.03	0.089
24	Bumthang	Khagangchhu	Mangde Chhu	Chumey	27:30:01	90:43:34	2,752	181.00	23.02.92	1.590
25	Bumthang	Urachhu	Mangde Chhu	Ura	27:27:29	90:54:42	3,073	43.20	05.01.95	0.260
26	Bumthang	Yangbrachhu	Mangde Chhu	Ura	-	-	3,085	2.6	11.01.01	0.092
27	Bumthang	Tangchhu	Mangde Chhu	Tang	27:32:17	90:48:29	2,583	555.40	22.02.92	4.681
28	Bumthang	Dhurchhu	Mangde Chhu	Dhur	27:86:40	90:40:29	2,730	179.20	27.01.99	1.924
29	Bumthang	Menchhu	Mangde Chhu	Dhur	27:36:40	90:40:29	2,730	113.70	27.01.99	1.275
30	Trongsa	Chendibjichhu	Mangde Chhu	Chendibji	27:28:31	90:20:53	2,417	278	21.02.92	2.994
31	Trongsa	Khebichhu	Mangde Chhu	Chendibji	27:29:07	90:20:05	2,494	-	20.02.02	0.253
32	Trongsa	Nagnichhu	Mangde Chhu	Tangsibi	27:26:59	90:26:19	2,413	8.23	25.01.94	0.149
33	Trongsa	Durgangchhu	Mangde Chhu	Bamji	27:33:59	90:27:01	1,999	127.5	07.02.01	1.731
34	Trongsa	Dongirongchhu	Mangde Chhu	Chella	27:33:33	90:26:41	1,923	41.98	07.02.01	0.729
35	Trongsa	Thripangchhu	Mangde Chhu	Trongsa	27:30:15	90:30:29	2,139	17.70	25.01.94	0.221
36	Trongsa	Telegangchhu	Mangde Chhu	Trongsa	27:29:25	90:31:27	1,214	44.53	01.02.99	0.573
37	Trongsa	Bubjiachhu	Mangde Chhu	Bubjia	27:25:00	90:30:08	1,816	-	09.02.03	0.188
38	Trongsa	Yurmochhu	Mangde Chhu	Refee	27:22:00	90:32:04	1,071	80.20	22.01.96	1.587
39	Trongsa	Krishachhu/Dunddungchhu	Mangde Chhu	Langthel	27:20:05	90:35:30	1,020	133.00	23.01.96	2.958
40	Zhemgang	Wangdigangchhu	Mangde Chhu	Rewotala	27:13:27	90:38:17	952	-	26.02.02	0.998
41	Zhemgang	Kelkhorchhu	Mangde Chhu	Kelkhor	-	-	-	-	27.02.02	0.184
42	Zhemgang	Dakpichhu	Mangde Chhu	Tingtibi	27:50:30	90:57:30	580	122.00	24.01.94	2.397
43	Sarpang	Rongchhu	-	Surey	27:00:36	90:34:52	945	97.18	25.01.95	1.357
44	Sarpang	Rongchhu	-	Tatopani (Gelephug)	27:00:36	90:34:52	945	207.81	04.03.96	2.506
45	Sarpang	Gongchhu	-	Tatopani (Gelephug)	-	-	-	536.82	04.03.96	7.147
47	Sarpang	Bhurchhu	-	Jigmeling	26:55:21	90:23:55	378	81.00	23.01.95	1.272
48	Sarpang	Sarpangchhu	-	Sarpang	26:52:43	90:16:05	313	135.25	06.04.93	1.379
49	Dagana	Budeychhu	Puna Tsang Chhu	Sankosh	-	-	-	31.49	27.03.93	0.325
50	Dagana	Darachhu	Puna Tsang Chhu	Dagana	-	-	-	-	04.03.02	1.396

No.	District	Small River	Main River	Location	Latitude	Longitude	Altitude(m)	Catchment area [km2]	Date	Q[m3/s]
51	Dagana	Dagachhu	Puna Tsang Chhu	Trashiding	26:56:46	90:01:06	260	891.15	26.03.93	14.025
52	Dagana	Daga Chhu	Puna Tsang Chhu	Gewathang/dam site	-	-	-	-	2005/10/4	8.660
53	Tsirang	Changchaychhu	Puna Tsang Chhu	Tsirang	27:01:55	90:04:31	341	-	06.03.02	1.107
54	Tsirang	Bureychhu	Puna Tsang Chhu	Tsirang	27:04:47	90:04:35	416	-	07.03.02	2.797
56	Wangdue	Phobjikhachhu	Puna Tsang Chhu	Phobjikha	27:27:18	90:11:05	2,843	-	21.02.02	0.806
57	Wangdue	Nikkachhu	Puna Tsang Chhu	Chazam	27:31:26	90:17:50	2,601	-	05.02.03	1.556
58	Wangdue	Basochhu	Puna Tsang Chhu	Mazafall	27:22:09	89:52:24	1,789	167.00	02.03.01	2.078
59	Wangdue	Rurichhu	Puna Tsang Chhu	Rurichhu	-	-	-	77.3	02.03.01	0.967
60	Wangdue	Kamichhu	Puna Tsang Chhu	Kamichhu	27:16:11	90:02:09	659	-	08.03.02	0.839
61	Wangdue	Nahichhu	Puna Tsang Chhu	Hesothangkha	27:27:23	89:54:19	1,205	73.04	04.03.01	0.374
62	Wangdue	Bechu	Puna Tsang Chhu	Chuzomsa	27:30:35	89:57:51	1,374	145.2	21.0.1.94	2.386
63	Wangdue	Dangchhu	Puna Tsang Chhu	Wangdue	27:28:38	89:54:02	1,218	632.70	21.02.92	6.678
64	Punakha	Toebayrongchhu	Puna Tsang Chhu	Chhimi Lhakhang	27:31:31	89:52:03	1,256	125.94	04.02.98	0.760
65	Punakha	Rimchhu	Puna Tsang Chhu	Yebesa	27:40:07	89:46:25	1,324	-	11.03.02	2.173
66	Punakha	Kbjirongchhu	Puna Tsang Chhu	Yebesa	27:38:03	89:48:04	1,324	-	11.03.02	0.757
67	Gasa	Gathanachhu	Puna Tsang Chhu	Gathana	27:47:47	89:43:52	1,812	-	12.03.02	0.310
68	Thimphu	Thinleygangchhu	-	Thinleygang	-	-	-	18.28	06.03.01	0.126
69	Thimphu	Chubachhu	-	Kawajansa	27:00:00	89:00:00	-	13.72	25.02.94	0.122
70	Thimphu	Phajoding	Wang Chhu	Motithang	-	-	-	-	12.03.07	0.065
71	Thimphu	Dechephu	-	DechephuChhu	-	-	-	-	13.03.07	0.157
72	Thimphu	Taba rongchhu	-	Taba	-	-	-	-	13.03.07	0.112
73	Thimphu	Motithangchhu	Wang Chhu	Motithang	27:28:45	89:35:30	2,909	-	18.03.03	0.051
74	Thimphu	Samtellingchhu	Wang Chhu	Jungsina	27:30:06	89:37:11	2,495	49.28	07.03.01	0.106
75	Thimphu	Olarongchhu	Wang Chhu	Simtokha	27:26:19	89:40:20	2,327	100.22	22.03.93	0.610
76	Thimphu	Dodichhu	-	Chamgang	-	-	-	-	15.03.07	0.046
77	Thimphu	Bodichhu	-	Chamgang	-	-	-	-	15.03.07	0.063
78	Thimphu	Cherichhu	Wang Chhu	Dodayna	27:35:37	89:37:43	2,598	-	16.03.02	0.929
79	Thimphu	Tangochhu	Wang Chhu	Dodayna	27:35:37	89:37:43	2,598	-	16.03.02	1.972
80	Thimphu	Chumdoromchhu	Wang Chhu	Charkelo	27:19:15	89:33:50	2,137	137.1	23.03.93	0.831
81	Thimphu	Bjeemenachhu	Wang Chhu	Gidakom/Jimena	27:25:08	89:33:26	2,427	122.83	05.02.92	0.978
82	Thimphu	Dodi-darkchhu	Wang Chhu	Begana	-	-	-	-	28.06.93	0.057
83	Paro	Gabja rongchhu	Wang Chhu	Bonday	27:22:48	89:24:30	2,388	-	20.03.03	0.104
84	Paro	Dhotichhu	Wang Chhu	Dhoti	27:28:33	89:25:38	2,339	-	24.03.04	2.193
85	Haa	Nahuchhu	Wang Chhu	Nagu	27:15:50	89:23:51	2,679	17.13	05.03.92	0.202
86	Haa	Damthang Chhu	Wang Chhu	Damthang	27:26:25	89:12:21	3,014	-	19.03.05	1.088
87	Haa	Haatoey Chhu	Wang Chhu	Haatoey/yakchhu	27:25:00	89:12:55	3,003	-	19.03.05	0.219
88	Chhukha	Damchhu	Wang Chhu	Tamchhu	27:14:13	89:31:21	2,030	31.13	31.12.94	0.214
89	Chhukha	Tachogchhu	Wang Chhu	Chapcha	27:11:15	89:33:45	2,159	92.18	26.01.97	0.656
90	Chhukha	Dhotikhola	Amo Chhu	P/ling	26:51:52	89:23:39	240	21.50	16.02.98	0.061
91	Chhukha	Barsachhu	-	P/ling/Pasakha	26:50:42	89:27:14	310	51.70	28.02.00	0.658
92	Chhukha	Ammochu/Toorsa river	-	Doyagang	-	-	-	3600.00	15.03.01	32.439
93	Chhukha	Singyechhu	-	Pasakha	26:50:07	89:27:44	355	-	26.03.03	0.276
94	Samtse	Dhaina Chhu	-	Samtse	26:55:42	89:02:31	314	-	25.03.05	4.325
95	Samtse	Bindu Khola	-	Sibsu	27:07:58	88:53:53	914	-	26.03.05	2.044
96	Samtse	Chermerichi Chhu	-	Samtse	26:54:52	89:06:34	384	-	27.03.05	2.052

Source: Surface Hydrological data of Bhutan (Year book)

3. Selection of observation data

Three gauging stations in small rivers are selected for every large river system, “Wang Chhu, Puna Tsang Chhu, Mangde Chhu, Manas Chhu”. There are observation data at one gauging station for several years. Average specific discharge is calculated at every gauging station and three gauging stations with large specific discharges are selected. A gauging station is excluded for selection if the data of the gauging station is not sufficient. The results of the selection of gauging stations are shown below.

Table 7-10 Observation data in Tributary of Wang chhu

No.	District	Location	Annual Average Discharge [m³/s]	Average Specific Discharge[m³/s/100km²]	Catchment Area [km²]
1-1	Haa	Nagu	0.20	1.17	17.13
1-2	Chhukha	Chapcha	0.76	0.82	92.18
1-3	Chhukha	Tamachhu	0.25	0.80	31.13

Table 7-11 Observation data in Tributary of Puna Tsang chhu

No.	District	Location	Annual Average Discharge [m³/s]	Average Specific Discharge[m³/s/100km²]	Catchment Area [km²]
2-1	Wangdue	Chuzomsa	1.97	1.36	145.2
2-2	Wangdue	Wangdue	8.44	1.33	632.7
2-3	Wangdue	Trashiding	11.2	1.26	891.2

Table 7-12 Observation data in Tributary of Mangde chhu

No.	District	Location	Annual Average Discharge [m³/s]	Average Specific Discharge[m³/s/100km²]	Catchment Area [km²]
3-1	Zhemgang	Tingtibi	2.08	1.70	122.0
3-2	Trongsa	Chella	0.67	1.60	41.98
3-3	Trongsa	Langthel	1.98	1.49	133.0

Table 7-13 Observation data in Tributary of Manas chhu

No.	District	Location	Annual Average Discharge [m³/s]	Average Specific Discharge[m³/s/100km²]	Catchment Area [km²]
4-1	Lhuntse	Khoma	1.28	2.30	55.63
4-2	Mongar	Lingmethang	4.95	1.74	284.1
4-3	Mongar	Sengor	0.22	1.65	13.35

4. Duration curves are made at 12 observation points

River flow in a small river is measured once a year. Therefore, duration curves in small rivers are estimated by using duration curves in the large rivers, “Wang Chhu, Puna Tsang Chhu, Mangde Chhu and Manas Chhu”. The procedure to estimate the duration curves in small rivers is shown as follows. According to the annual flow date in large rivers, discharge observed from January to March is almost constant and is about 10-20 % of peak discharge during rainy seasons. Discharge observed from January to March is located at 300 days in duration curve.

A small river is a tributary of the large river, and it is assumed that the shape of the duration curve of a large river is equivalent to the shape of the duration curve of a small river, that river flow data is observed at 300 days of duration curve. The duration curve of the small river will be estimated based on this assumption.

In this chapter, the observation point “Nagu” is explained as an example for estimating hydropower potential. River flow is observed at Nagu in the small river, Nachu chhu, which is a tributary of Wang chhu. It is assumed that the shape of the duration curve of Nachu chhu is equivalent to the shape of the duration curve of Wang chhu, and that discharge at Nagu is observed at 300 days of the duration curve.

Discharge ratio (discharge at 300 days of Wang chhu/Nachi chhu) is 0.20/24.69. The duration curve of Nachu chhu is estimated by multiplying the discharge of Wang chhu by “0.20/24.69”. The duration curve of Nachu chhu, which is estimated from that of Wang Chhu, is shown below.

Using the same procedure, the duration curves of the other 11 observation points will be estimated from duration curves of the large rivers, “Wang Chhu, Puna Tsang Chhu, Mangde Chhu and Manas Chhu”.

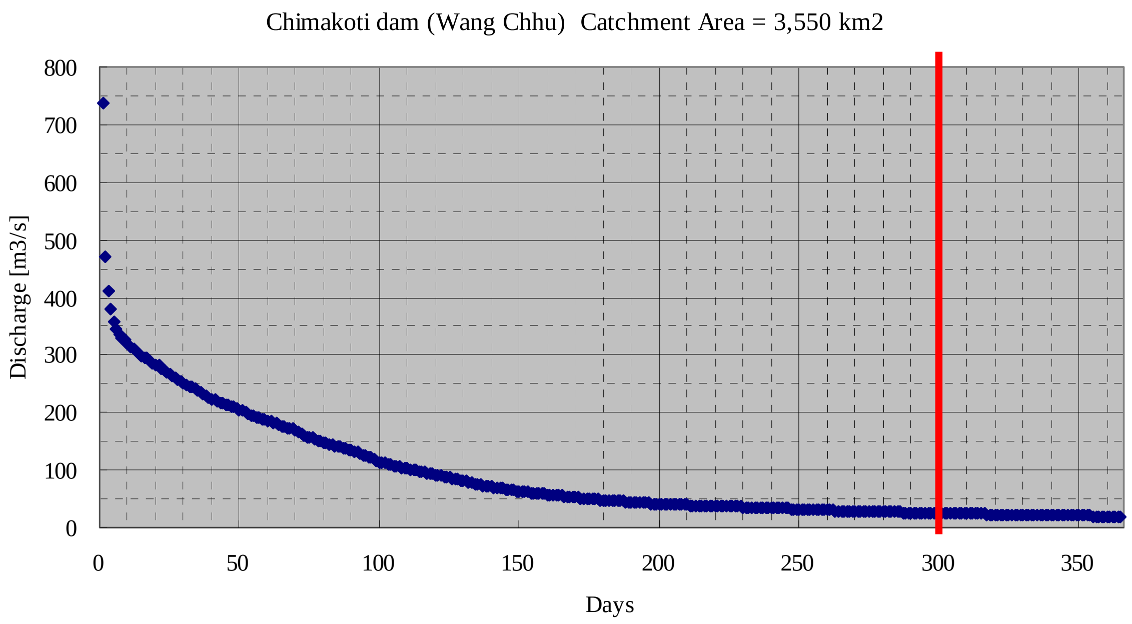


Figure 7-25 Duration curve in Wang chhu

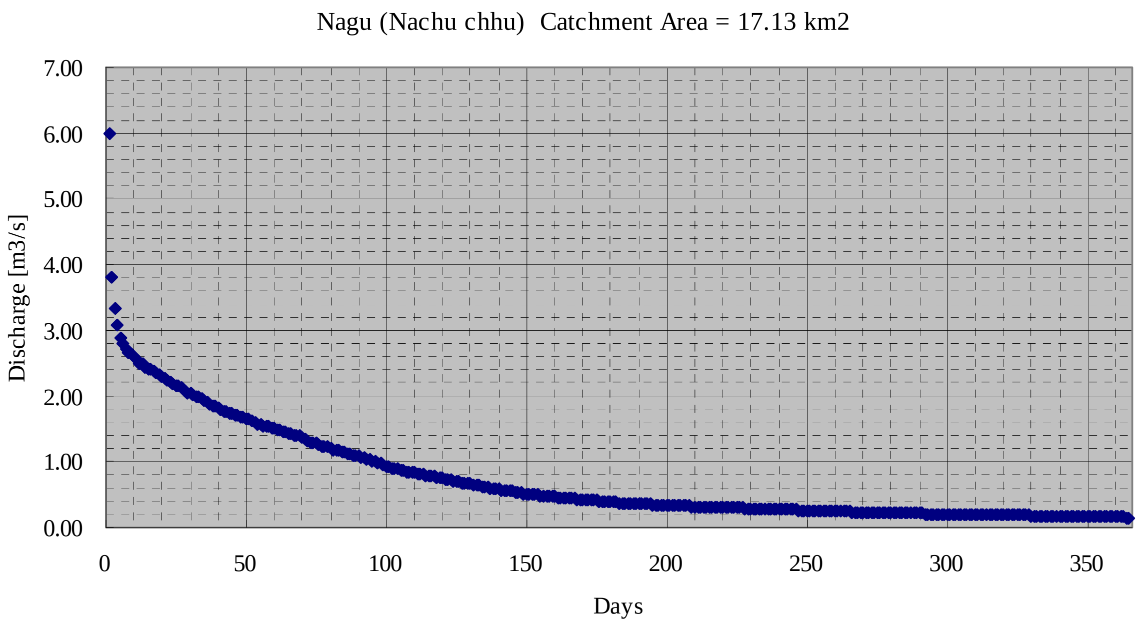


Figure 7-26 Duration curve in Nachhu chhu

<u>5. Examination of equipment arrangement of hydropower plants</u>

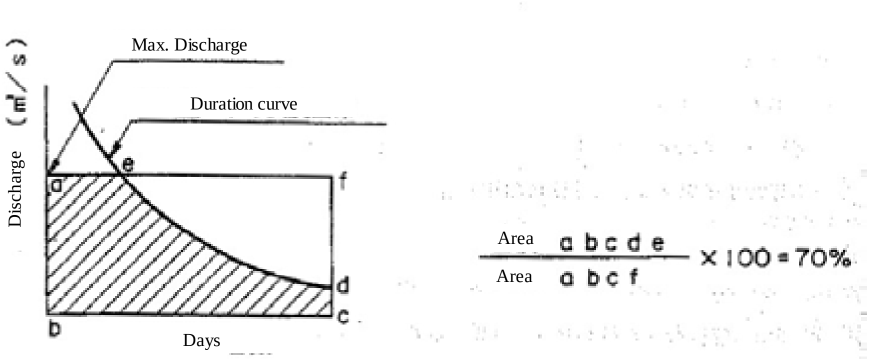
Equipment arrangement of hydropower plants for 12 observation points is examined by using a topographic map of Bhutan. Intake, waterway, penstock and powerhouse are examined at each of the 12 observation points in small rivers and head is estimated roughly from the topographic map.

<u>6. Calculation of power plant output and construction cost</u>

Power plant output is calculated from the above result. In the calculation, power plant output is calculated based on the following assumption.

- Hydropower plant: Run of river type
- Number of turbines: One
- Turbine efficiency: 80 %
- Generator efficiency: 90 %

Maximum discharge is decided so that capacity factor of discharge becomes 70% as shown below.



Source: Guide Manual for Development Aid Programs and Studies of Hydro Electric Power Projects (New Energy Foundation (NEF))

Figure 7-27 Calculation of Maximum discharge

The existing documents regarding the construction cost of small hydropower plants are analyzed and the formula for the construction cost is made. Length of headrace, length of penstock and power output are set as parameter, because the headrace, penstock and output affects the construction cost. However, the transmission equipment and transportation cost are excluded from this formula.

Construction cost = Civil equipment cost + Electrical and mechanical equipment cost + others
= (Length of headrace (m) * 290USD/m + Length of penstock (m) * 320 USD/m + Output (kW) * 910 USD/kW + others (Output (kW) * 860 USD/kW

Construction cost at each observation point is calculated by using this formula. Specification of hydropower plants and the construction cost are shown below.

Table 7-14 Specification of hydropower plants and Construction cost

No.	Location	Output [kW]	Head [m]	Max. Discharge [m3/s]	Annual energy [MWh]	Construction cost [1,000 USD]	Unit Construction cost [USD/kW]
1-1	Nagu	610	150	0.58	3,741	1,524	2,499
1-2	Chapcha	3,720	240	2.20	22,811	7,620	2,049
1-3	Tamchhu	1,620	320	0.72	9,934	3,765	2,325
2-1	Chuzomsa	9,080	210	6.13	55,679	16,949	1,867
2-2	Wangdue	11,130	60	26.3	68,249	20,089	1,805
2-3	Trashiding	39,400	160	34.9	241,601	70,332	1,785
3-1	Tingtibi	3,310	80	5.88	20,297	6,039	1,825
3-2	Chella	1,060	80	1.89	6,500	2,173	2,050
3-3	Langthel	4,740	120	5.60	29,066	8,661	1,827
4-1	Khoma	4,170	150	3.94	25,570	7,709	1,849
4-2	Lingmethang	12,870	120	15.2	78,919	22,979	1,785
4-3	Sengor	380	80	0.68	2,330	955	2,514

7. Examination of potential trend (River wise)

The trends of hydropower potential are examined at tributaries of Wang Chhu, Puna Tsang Chhu, Mangde Chhu and Manas Chhu. Powerhouse output and the construction cost of river wise are shown below. Power house output is large compared with that of other observation points. There is a large amount of discharge in the tributary of Puna Tsang Chhu and hydropower potential at the tributary of Puna Tsang Chhu. Powerhouse output in the western place is larger than that of the eastern place of Bhutan. If the same number of hydropower plants is constructed at these tributaries, there is great potential for small hydropower plants in the tributary of Puna Tsang Chhu. In addition, there is potential for small hydropower plants in the tributary of the eastern rivers compared with the western rivers. Regarding the construction cost, it is thought that there is not large a difference among Wang Chhu, Puna Tsang Chhu, Mangde Chhu and Manas Chhu.

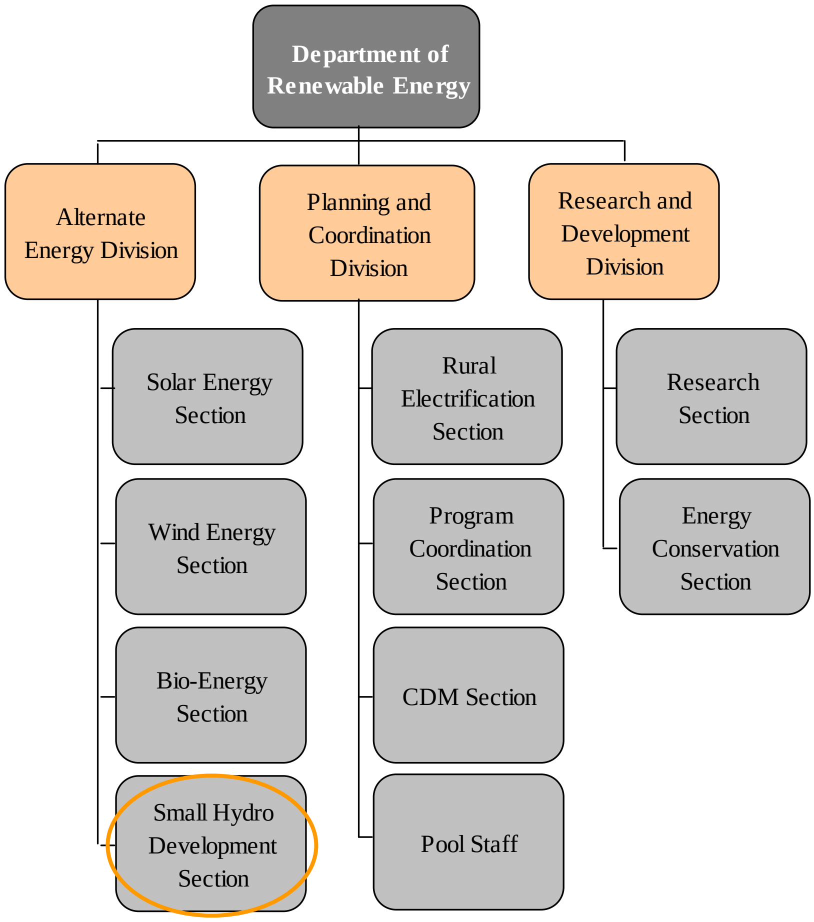
The hydropower potential and the construction cost are roughly estimated based on the existing documents. It is recommended that there are many data to estimate the potential of small hydropower. Discharge data of small rivers throughout many years is especially necessary. When the powerhouses are constructed, the site survey should be carried out to grasp transmission/distribution route, transportation cost, environmental impact, etc.

Table 7-15 Potential of small hydropower plants and Construction cost

No.	River System	Average Output [kW/plant]	Average Construction cost [USD/kW]
1	Wang Chhu	1,980	2,290
2	Puna Tsang Chhu	19,870	1,810
3	Mangde Chhu	3,030	1,900
4	Manas Chhu	5,800	2,040

7.2.4 Organization Chart

DRE promotes small hydropower development. The Small Hydropower Development Section in particular plays a key role in the planning of small hydropower development. The Small Hydropower Development Section is located in the Alternative Energy Division, DRE, as shown below.



Source: DRE

Figure 7-28 Organization Chart of DRE

In addition, as organizations for small hydropower development, there are NEC, which evaluates environmental impact, and BEA, which approves small hydropower development.

The general procedure for small hydropower development and the relationship between DRE and the other organizations are shown below.

(1) Plan for small hydropower development

AED plans small hydropower development in consideration of the relationship between demand and supply. If necessary, DRE discusses the development with BPC, which administers transmission/distribution lines.

(2) Feasibility Study

AED (or Consultants) carries out a Feasibility Study for small hydropower and examines the feasibility technically and economically.

(3) Detailed Project Report (DPR)

AED (or Consultants) performs a detailed site survey for small hydropower development and makes a DPR.

(4) Environment Impact Assessment (EIA)

AED makes EIA reports and submits them to NEC. Then, NEC evaluates EIA reports. DRE receives clearance for small hydropower after approval.

(5) Development permission

AED applies to BEA for development permission. AED receives development permission after BEA approves.

(6) Tender

AED solicits tender for small hydropower development and decides the developer.

(7) Design and construction

The developer designs and constructs the small hydropower plant according to the tender specification. AED supervises the design and construction.

(8) Operation and maintenance

The developer carries out O&M after the commencement of the small hydropower plant.

Remarks: DGPC or BPC sometimes develops small hydropower plant with their own funds. All developers need to obtain clearance (4) and permission (5).

7.2.5 Present situation of the Promotion

Some small hydropower plants were constructed by grant aid provided by Japan in 1980-1990s. Site survey was carried out by Swedish technical aid in 1999, and then a survey was also carried out by UNDP/GEF in 2000. A small hydropower plant was constructed in Chendebji to reduce GHG and to contribute to sustainable development of the community as “e7 Bhutan small hydropower CDM project”. At present, DRE is in charge of the Chendebji and Sengor Micro hydropower plants. BPC is in charge of the other micro/mini hydropower plants.

Some small hydropower projects have been planned, but all projects are being delayed due to certain problems as shown in Table 7-16.

Table 7-16　New small Hydropower Projects

No.	Projects	District	Output ［kW］	Present status
1	Bindu	Samtse	12,000	Development priority is high, but Project is being delayed.
2	Begana	Thimphu	20,000	Development priority is high, but Project is being delayed.
3	Soe	Thimphu	50	The development of these micro Hydropower Plants were dropped since it was techno-economically not feasible.
4	Lingzhi	Thimphu	100	

The existing small hydropower plants are shown below. BPC has plans to synchronize all small hydropower plants to the grid. Grid connection work for small hydropower plants that have comparatively large output, are preferentially in progress. Darachhu, Changchey and Tingtibi small hydropower plants were connected to the grid from 2012 to 2013. At present, there are nine small hydropower plants which have not yet been connected to the grid.

Some old and damaged small hydropower plants have been renovated. In addition, some small hydropower plants were abandoned since they were economically inefficient.

Table 7-17　Present Status of the Existing Small Hydropower Plants

No.	Plant	District	Output [kW]	Grid connection	Fund	Commencement year	Present status
1	Chumey	Bumthang	500 x 3	○	India	1988	Renovation work and grid connection was carried out in 2000.
2	Ura	Bumthang	50 x 1	×	Japan	1987	
3	Tamzhing	Bumthang	30 x 1	×	Japan	1987	
4	Darachhu	Dagana	100 x 2	○	Japan	1992	It was connected to the grid in 2012 -2013.
5	Rongchu	Lhuntse	100 x 2	○	Japan	2001	
6	Gangzur	Lhuntse	60 x 2	○	India	1986 *2000 (Partially renovated)	Equipment is old and made in India. It is connected with the grid manually when it starts operation.
7	Khalanzi	Mongar	130 x 3	○	India	1976	It was connected to the grid in 2013.
8	Sengor	Mongar	100 x 1	×	-	-	DRE is in charge.
9	Rangjung	Trashigang	1,000 x 2	○	Austria	1995	
10	Chenary	Trashigang	250 x 3	○	India	1972	It has been stopped due to flood.
11	Gidakom	Thimphu	250 x 5	○	India	1973 *2001 (Renovated)	It is connected with the grid manually when it starts operation.
12	Thimphu mini	Thimphu	100 x 4	○	India	1967 *1998 (Renovated)	It was connected to the grid in 2001.

13	Lingzhi	Thimphu	8 x 1	○	EU	1999	Pelton turbine made in England is used.
14	Chendebji	Trongsa	70 x 1	×	Japan	2004	It was constructed by e7 project. DRE is in charge.
15	Sherabling	Trongsa	50 x 1	×	-	-	
16	Tangsibji	Trongsa	30 x 1	×	Japan	1987	
17	Bubja	Trongsa	30 x 1	×	Japan	1987	It has been stopped due to land and sand.
18	Changchey	Tsirang	100 x 2	○	Japan	1991	It was connected to the grid in 2012-2013.
19	Basochu.I	Wangdue	12,000 x 2	○	Austria	2002	
20	Hesothangkha	Wangdue	100 x 3	○	India	1972	It will be stopped due to sediment.
21	Rukubji	Wangdue	40 x 1	×	Japan	1987	
22	Tingtibi	Zhemgang	100 x 2	○	Japan	1992	It was connected to the grid in 2012-2013.
23	Kekhar	Zhemgang	20 x 1	×	Japan	1987	Output is not stable due to water leakage from penstock. Output is usually 5-8 kW. It will be stopped due to rehabilitation work for penstock.
24	Thinleygang	Thimphu	30 x 1	-	Japan	1987	Shut down
25	Surey	Sarpang	70 x 1	-	Japan	1987	Shut down

Remarks: ○ (Grid connection), × (Isolated)

7.2.6 Economic Aspects

The economic efficiency of small hydropower plants depends on power generation, construction cost, O&M cost, etc. Selecting a site with a secure annual stable discharge leads to high power generation and economic efficiency. Small hydropower plant equipment consists of transmission/distribution line, turbine/generator and civil structures. With the object of economic efficiency, it is preferable that the equipment should be simplified in consideration of O&M after commissioning. In addition, spare parts can be shared by adopting the same equipment in several small hydropower plants and therefore economic efficiency will be enhanced.

When equipment is procured from countries other than Bhutan and India, it is often transported from the country to Kolkata port by ship, and then to Phuentsholing in Bhutan from Kolkata port by road. Small hydropower equipment can be transported without difficulty, because many large hydropower plants have already been constructed in Bhutan.

7.2.7 Possibility of Target Achievement and Road map towards Target Achievement

According to "Alternative Renewable Energy Policy 2013", a target of small hydropower generation system is not described, and according to "Draft of the 11th Five-Year Plan in Bhutan", the minimum target of small hydropower generation system is 12,150 kW by 2018.

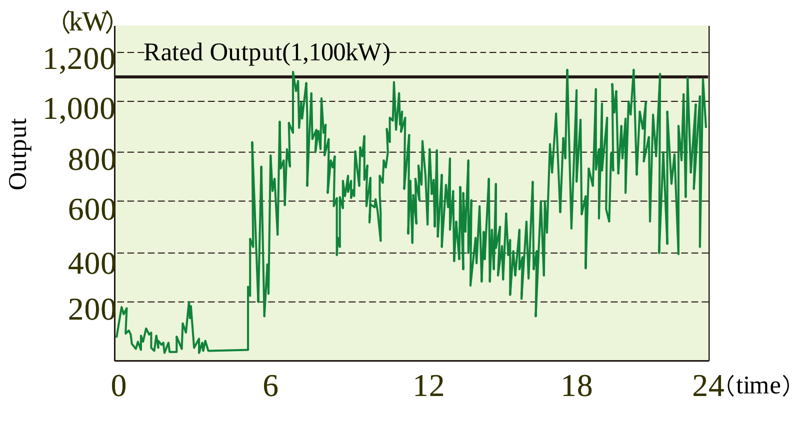
There seem to be many sites with hydropower potential in Bhutan. It is necessary to review the existing documents and plans from the past. There are many small hydropower plants in Bhutan. It is recommended that the knowledge gained from the experiences of hydropower plants in the past is used for the future hydropower development. In addition, it is recommended that unused energy in the treatment plant and agricultural zone should be utilized.

7.3 Windpower

7.3.1 Characteristics

Windpower generation is a generation system to make electricity by rotating a propeller using windpower. Horizontal Propeller types are often used for electric power.

In terms of the characteristics of windpower, the power is inexhaustible, but it is unstable. Therefore, it is difficult to secure a stable power output. When the air density decreases, the output decreases proportionately. Power output decreases at high elevations, even at the same velocity. (The power output at 2,000m elevation will drop to 82% of rated output.)



Source: The Federation of Electric Power Companies of Japan

Figure 7-29 Output Fluctuation of Windpower Generation

Recently, large Wind Turbine Generator (WTG) of more than 2,000 kW has mainly been manufactured. In contrast, small ones have not been manufactured much. The blade length of large wind turbines exceeds 40m, so equipment transportation is one of the key issues in developing windpower plants. Bhutan has extensive mountainous areas; therefore, ports to unload equipment and roads for transportation are limited. It appears difficult to develop large windpower plants due to these limitations.

7.3.2 Examination of Potential Site

Potential windpower sites have already been reported in the NREL report[21]. This is not actual measured data, but simulation results based on meteorological data, as described in the NREL report. Therefore, it is difficult to use this data in the NREL report for windpower construction.

It is necessary to search for potential sites in consideration of land acquisition and transportation, and to evaluate the wind conditions observed at the site for more than one year.

DRE has taken windpower data from several observation masts, which are installed at several points in Bhutan. However, the windpower data is not sufficient to confirm the potential sites all over Bhutan.

Wind conditions are confirmed based on the meteorological data of DRE, to examine the potential sites in 20 districts. The location of observation points is shown in the following Table.

This meteorological data is a comparison of 17 districts, because there are two observation points in Thimphu and no observation points in Mongar in the meteorological data of DRE. In addition, there are no wind velocity data or wind direction data in Dagana, Gasakhatey and MOEA.
Observation periods differ according to observation points. Therefore, potential sites are evaluated with meteorological data for three years (2009-2011, the observation point where effective data was not obtained utilized different data of the period).

Table 7-18 Meteorological Observation Points

No.	Observation point	District	Position		
			Latitude	Longitude	Elevation
1	Bhur	Sarpang	26:54:14N	90:26:02E	375m
2	Chamkher	Bumthang	27:32:25N	90:45:18E	2,470m
	Dagana(*)	Dagana	27:04:16N	89:52:29E	1,460m
3	Damphu	Tsirang	27:00:00N	90:07:18E	1,520m
4	Deothang	Samdrupjongkhar	26:51:21N	91:28:00E	300m
	Gasakhatey	Gasa	27:54:00N	89:42:59E	2,760m
5	Haa, Namjeyling	Haa	27:23:17N	89:16:55E	2,720m
6	Kanglung	Trashigang	27:16:06N	91:31:20E	1,930m
7	Lhuentse Dzong	Lhuentse	27:39:50N	91:11:50E	1,465m

21 'Potential for Development of Solar and Wind Resource in Bhutan'
Technical Report. NREL/TP-6A2-46547. September 2009. Paul Gilman. National Renewable Energy Laboratory

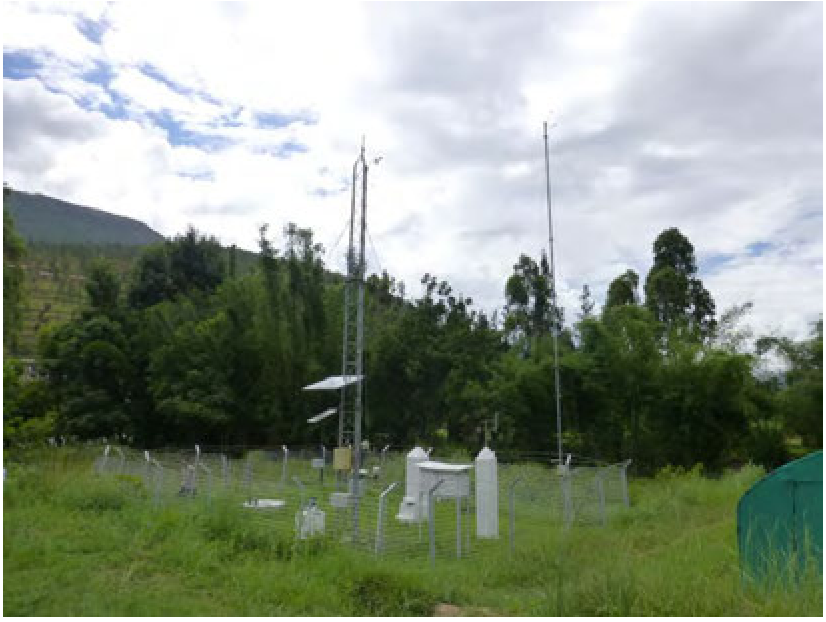
	MOEA, Complex	Thimphu	27:28:16N	89:38:14E	2,380m
8	Paro, DSC	Paro	27:22:59N	89:25:12E	2,406m
9	Pema Gatshel	Pema Gatshel	27:01:30N	91:25:27E	1,618m
10	Phuentsholing	Chukha	26:51:35N	89:22:29E	220m
11	Punakha	Punakha	27:34:54N	89:51:59E	1,236m
12	Simtokha	Thimphu	27:26:18N	89:40:31E	2,310m
13	Sibsoo	Samtse	27:01:00N	88:51:59E	550m
14	T/Yangtshi	Trashi Yangtse	27:36:00N	91:30:00E	1,830m
15	Trongsa	Trongsa	27:30:07N	90:30:18E	2,120m
16	Wangdue	Wangdue	27:29:12N	89:54:03E	1,180m
17	Zhemgang	Zhemgang	27:12:30N	90:39:19E	1,905m

(*) Wind velocity and wind direction are not observed at observation points in Dagana, Gasakhatey and MOEA.

Source: JICA Survey Team

Source: JICA Survey Team (based on Google earth)

Figure 7-30 Meteorological Observation Points



Source: Photo taken by JICA Survey Team

Figure 7-31 Meteorological Observation Point (Wangdue)

The wind direction and speed data specification of a meteorological observation point are as follows.

・Wind speed Average wind velocity of a day

・Wind direction Average wind direction of a day, 16 compass point.
（However, most data is octal.）

The analysis result of wind velocity distribution and wind direction of 17 points obtained from wind direction wind speed data is shown in Table 7-19.

Since the above data cannot be used for trial calculation of a production of electricity, a potential site cannot be selected from this result, but it will become a key for looking for the area which can expect the potential in Bhutan.

Data shows the following:,

- Probably, Bhur, Deothang, Pema Gatshel and Phuentsholing, located in the southern part, have low potential for wind.
- A location where more than 4m/s wind speed is observed may be able to be found as a potential site by investigating further.
  Above all, conditions may be good because Sibsoo, where the wind velocity is distributed over around 3m/s, and mainly 2m/s in wide areas, has low altitude.
- Kanglung, Lhuentse Dzong and Simtokha may have potential, but it is necessary for Kanglung and Simtokha to consider that wind energy will decrease by 20%, as the altitude is approximately 2000-2500m.
- Wangdue is the neighboring site where DRE is planning a pilot plant. Therefore, it was thought that the wind velocity is distributed into the high velocity range, but the wind velocity is

distributed into the low velocity range. Judging from the velocity data, it is not considered that Wangdue is a high potential site. It is thought that the reason is the location of the observation point, which is not suitable.

The observation point of Wangdue is in the agricultural experimental station of the bottom of a valley near the river. In addition, it is thought that the reason for the low data points is due to the fact that the observation point is surrounded with trees and thus wind is shut out. It is thought that the installed condition of each observation point influences observation data.

Source: JICA Survey Team (based on Google earth)

Figure 7-32 Install condition of Observation Point of Wangdue

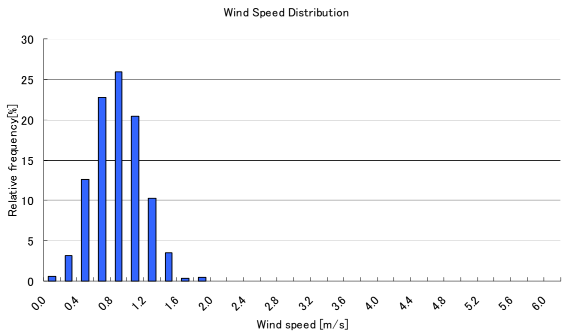
Because the exact coordinate of the weather observation point was provided by DRE, the JICA Survey Team confirmed setting environment by Google Earth.

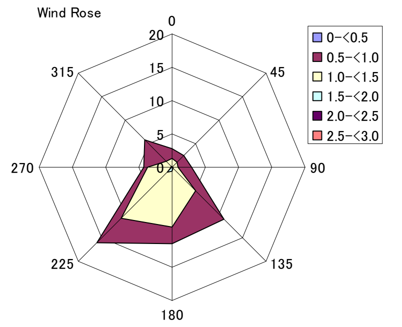
Deothang, Kanglung, Phuentsholing and Trongsa include trees or buildings in the environment. Pema Gatshel and Wangdue are installed in the mountain side of a steep incline, or has the direction where the installation part is interrupted with the inclined plane. These observation points may not express the wind of all the directions of the area correctly.

From such an uncertain element, for the wind power generation, the data of the weather observation point can be used only as a reference.

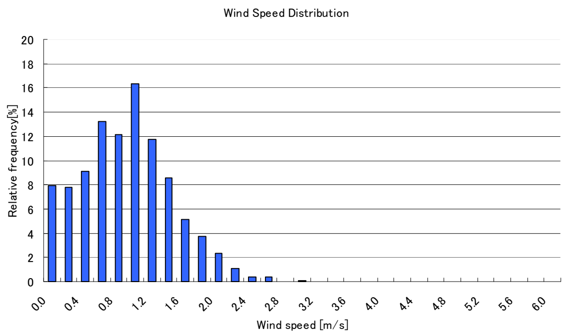
Table 7-19 Analysis of wind velocity distribution and the wind direction from Meteorological weather observation data

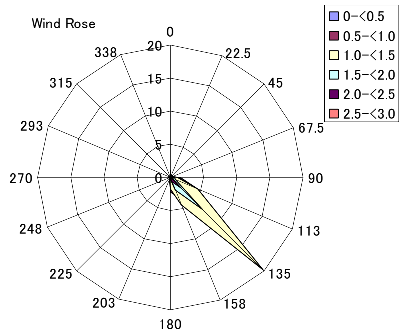
1. Bhur



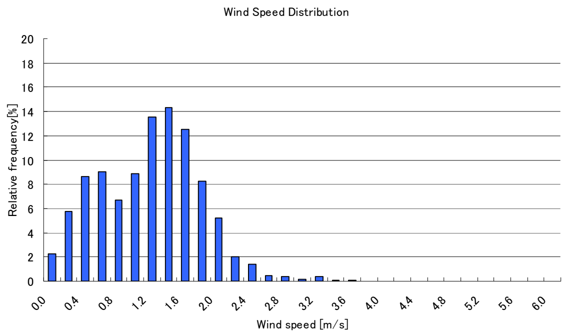


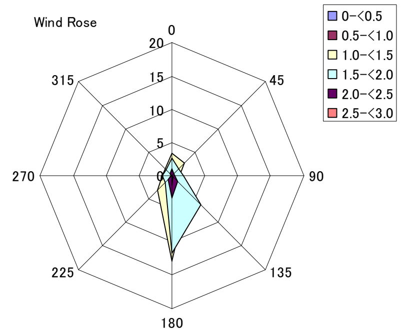
2. Chamkher



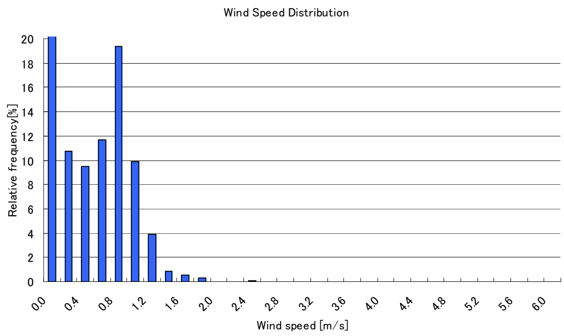


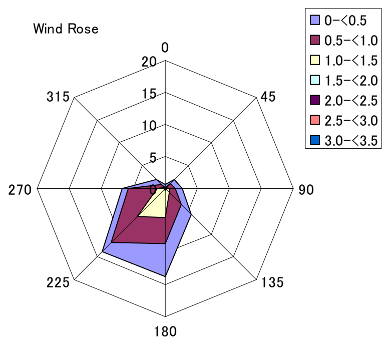
3. Damphu



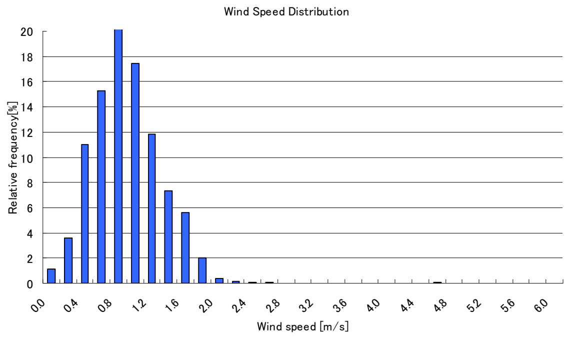


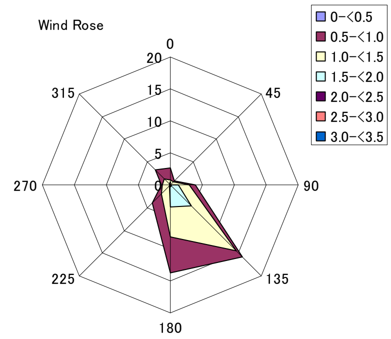
4. Deothang (*1)



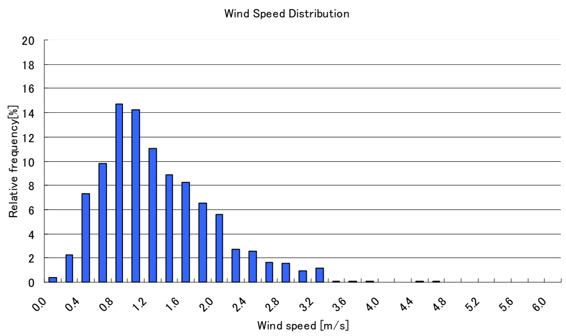


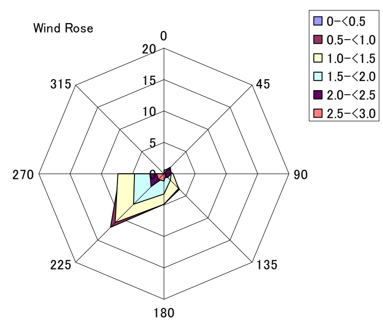
5. Haa, Namjeyling



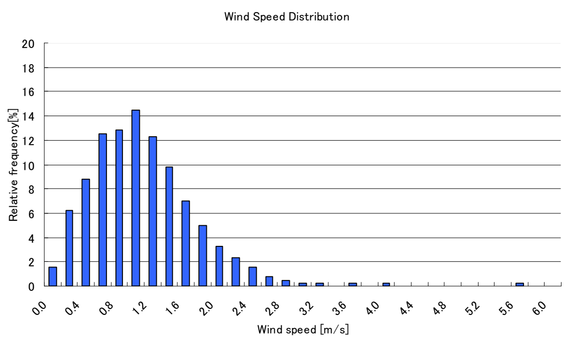


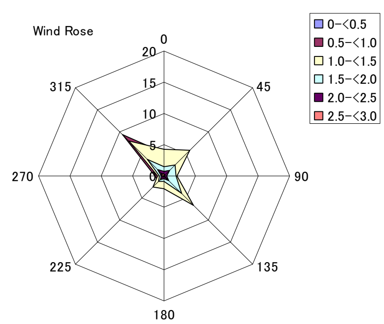
6. Kanglung



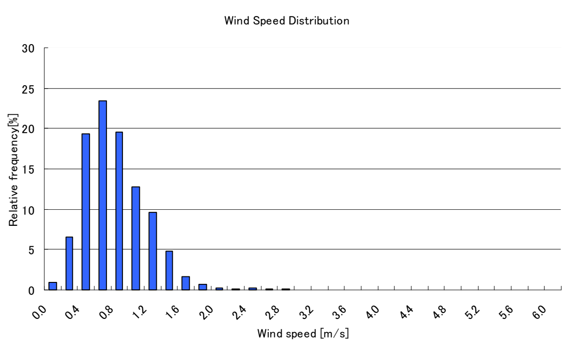


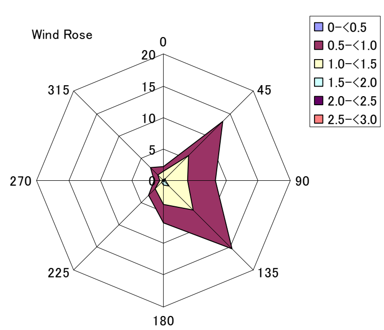
7. Lhuentse Dzong



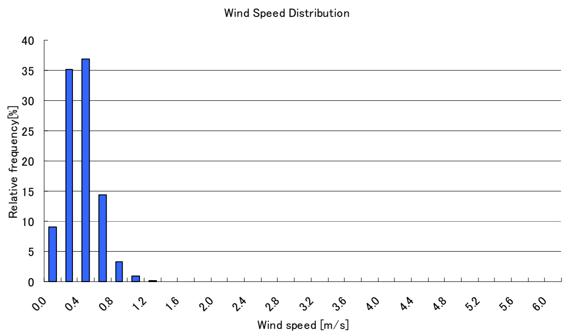


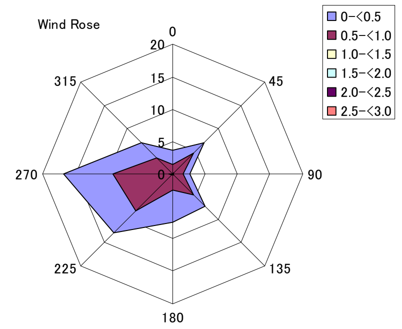
8. Paro, DSC



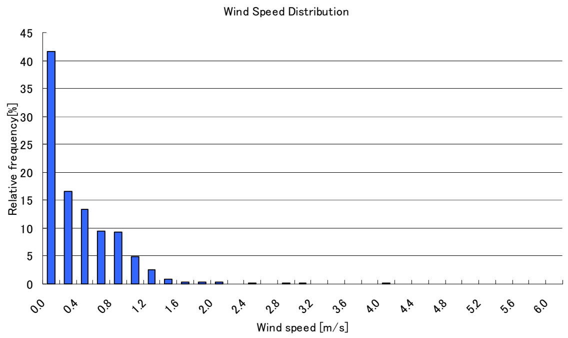


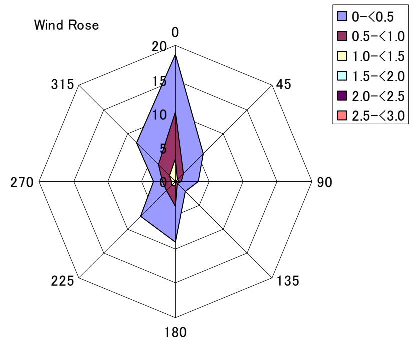
9. Pema Gatshel



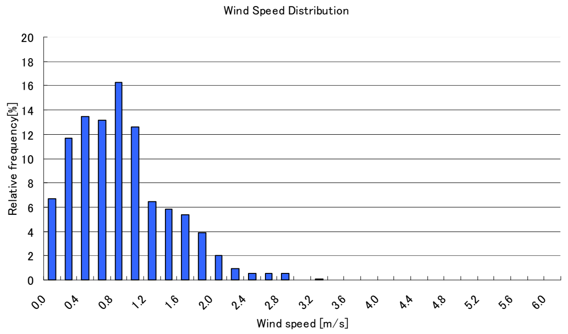


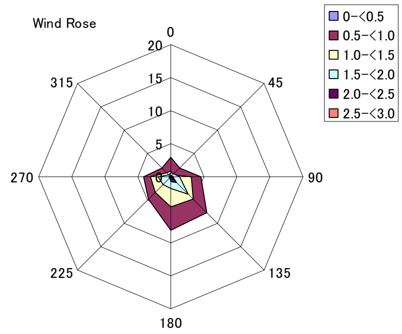
10. Phuentsholing



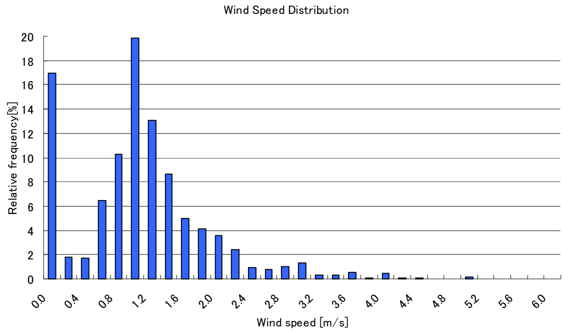


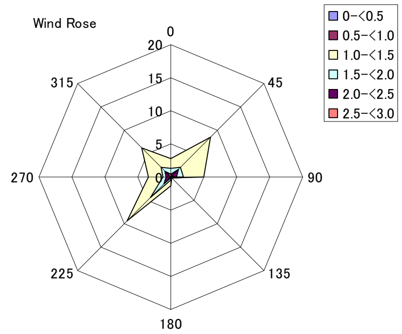
11. Punakha



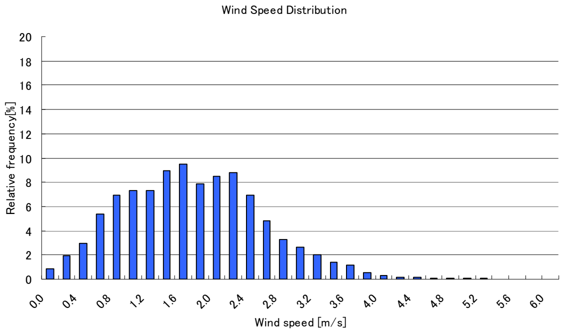


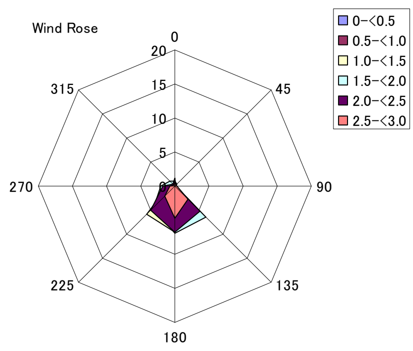
12. Simtokha (*1)



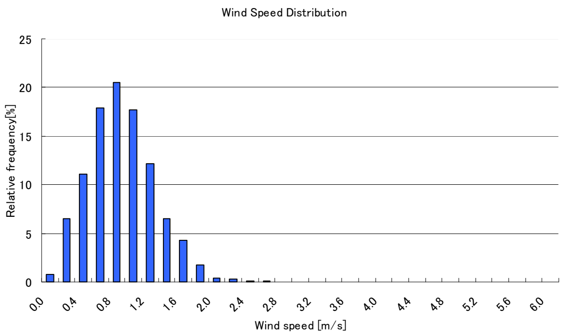


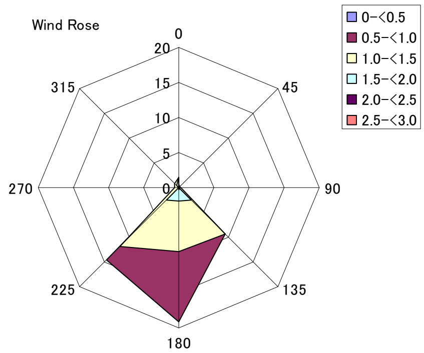
13. Sibsoo



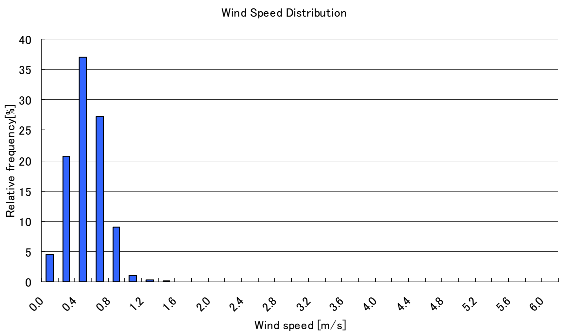


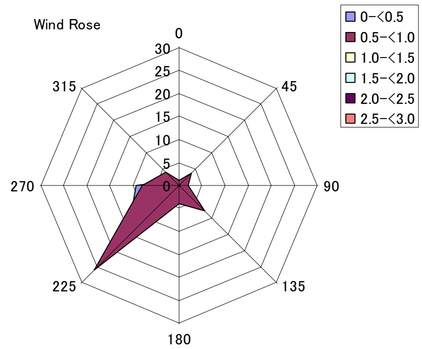
14. T/Yangtshi



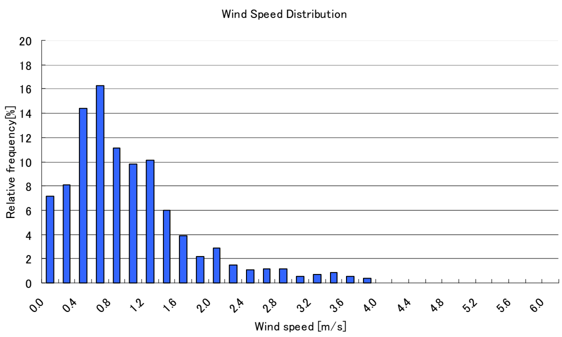


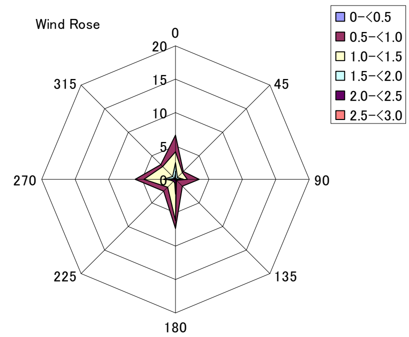
15. Trongsa



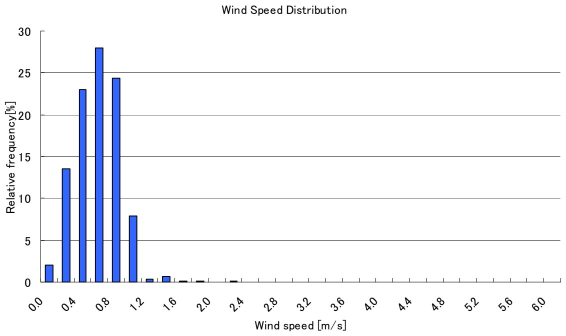


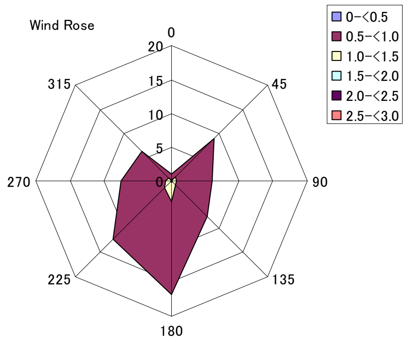
16. Wangdue





17. Zhemgang





(*1) It is thought that a lot of missing data are included for distribution of the wind speed because there are a great many data of 0m/s.

Then, the JICA Survey Team carried out an evaluation of the potential of Bhutan by wind observation survey data for the wind-power plant development that DRE measured.

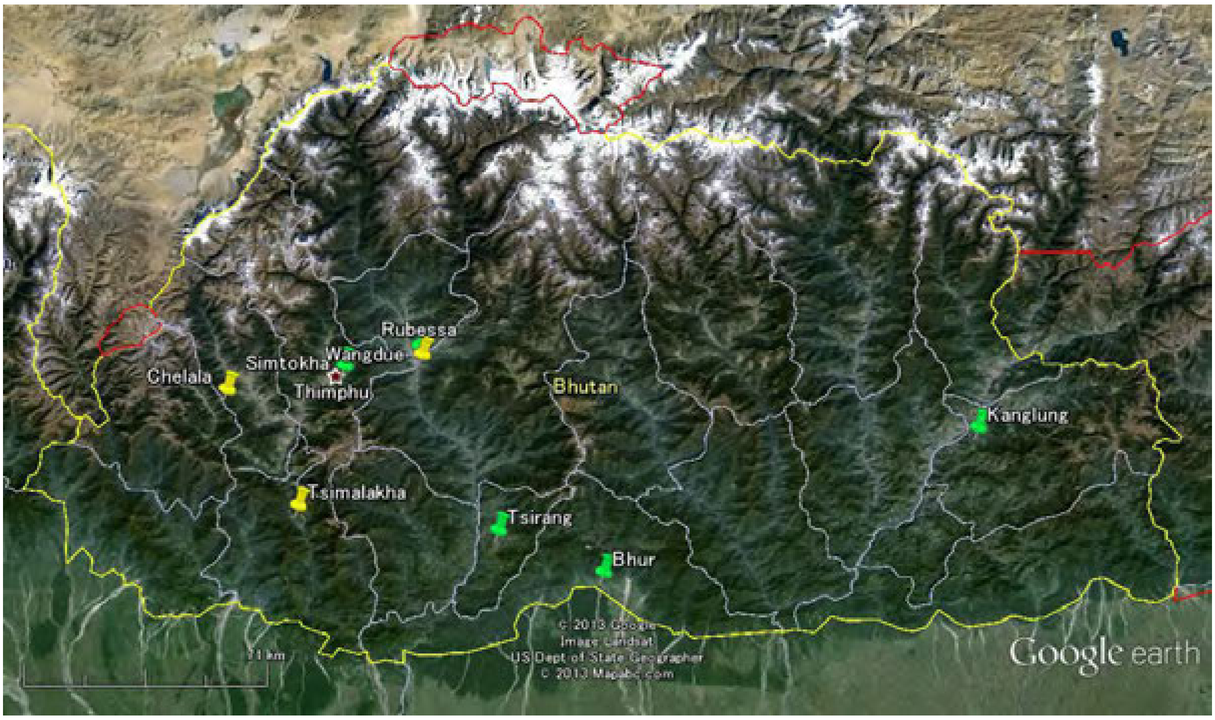
DRE installed wind observation masts in five places from about 2007 and three more places from about 2010, and collects wind speed and direction data for wind power generation study and development.

Data of observation masts to measure wind conditions of DRE is shown in Table 7-20.

Table 7-20 Observation Masts to Measure Windpower Conditions

Observation point	District	Position			Height of Mast	Height of Sensor	Observation period
		Latitude	Longitude	Elevation			
Bhur	Sarpang	26:54:25	90:25:51	377m	20m	20m	2007.5～
Kanglung	Trashigang	27:16:40	91:30:56	2,003m	20m	20m	2007.8～
Simtokha	Thimphu	27:26:18	89:40:31	2,310m	20m	20m	2007.5～
Tsirang	Tsirang	27:00:57	90:07:32	1,564m	20m	20m	2007.2～
Wangdue	Wangdue	27:29:26	89:53:53	1,219m	20m	20m	2007.6～
Chelela	Haa	27:22:27.32	89:20:29.03	3,881m	20m	10, 20m	2010.8～
Rubessa	Wangdue	27:85:05.05	89:54:10.29	1,320m	20m	10, 20m	2010.8～
Tsimalakha	Chukha	27:04:44.06	89:33.02.06	2,165m	20m	20m	2011.7～

Source: JICA Survey Team



Source: JICA Survey Team (based on Google earth)

Figure 7-33 Position of Observation Masts

Source: Photo taken by JICA Survey Team

Figure 7-34 Observation Mast to Measure Windpower Conditions (Rubessa site)

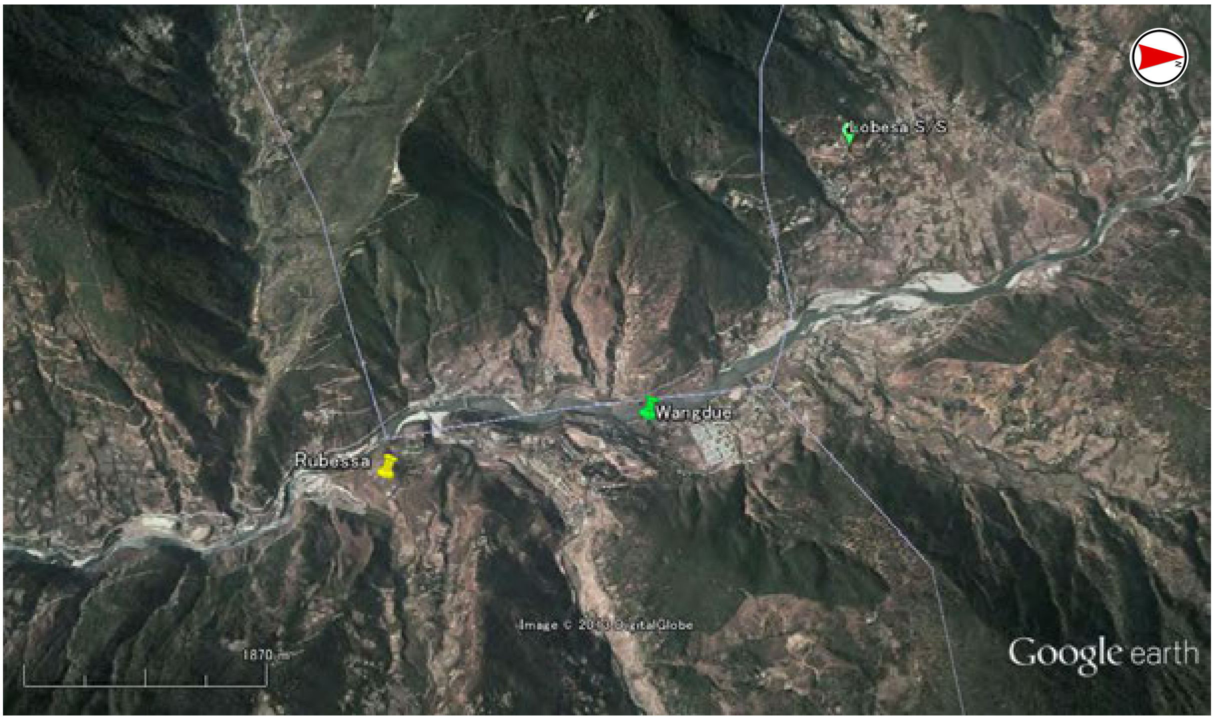
A potential site for windpower is affected by geography and the site status often changes. Therefore, even if the candidate site has good potential, the wind conditions should be observed for more than one year and the observation data needs to be evaluated.

In many cases, the observation result at a site is completely different from that of a neighboring site in mountainous regions and complex topography, such as in Bhutan.

Wind conditions taken from DRE are observed at the Rubessa site and the Wangdue site, which are located close to each other. There is a meteorological observation point which is very near the Rubessa and Wangdue sites. The effect of topography and difference in data between site and meteorological observation point will be confirmed by using these data.

In addition, “quality of wind” will be evaluated from the observation data of the Rubessa site.
Complex topography can cause turbulence and shorten the life of windpower equipment significantly.

As shown in Figure 7-35, 7-37 and 7-38, the Rubessa site is located on a hill which rises from a river, and is surrounded with high mountains. Such complex topography is likely to cause turbulence. At present, the wind at the Rubessa site is being analyzed to determine whether it is suitable for windpower turbines.



Source: JICA Survey Team (based on Google earth)

Figure 7-35 Observation Points for Comparison between Rubessa and Wangdue

Source: JICA Survey Team (based on Google earth)

Figure 7-36 Topography of Rubessa.

Source: Photo taken by JICA Survey Team

Figure 7-37 Wind mast installation conditions of Rubessa (taken from the opposite side of a river)

- The comparison of the wind velocity distribution.
  The wind velocity distributions of the Rubessa point and Wangdue point are shown in Figure 7-38 and Figure 7-39.

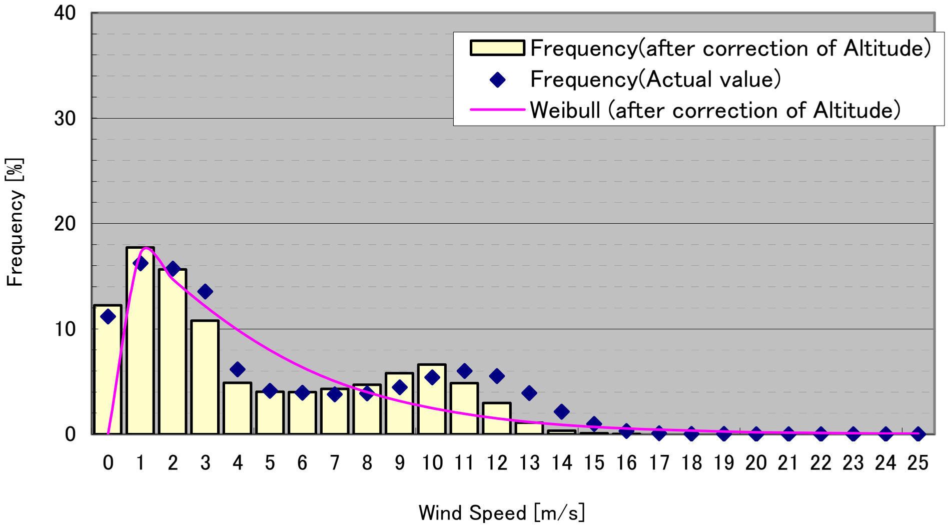
  Since the air density of the Rubessa point is considered approximately 12% lower in comparison with the sea level due to its altitude of approximately 1,300m, wind velocity should be evaluated 12% lower than the actual value.

  Similarly, since the air density of the Wangdue point is considered approximately 11% lower in comparison with the sea level due to its altitude of approximately 1,200m, wind velocity should be evaluated 11% lower than the actual value.

  Both wind masts are 20m in height, and the two masts are installed nearby, but the wind speed of Wangdue is much lower than Rubessa.

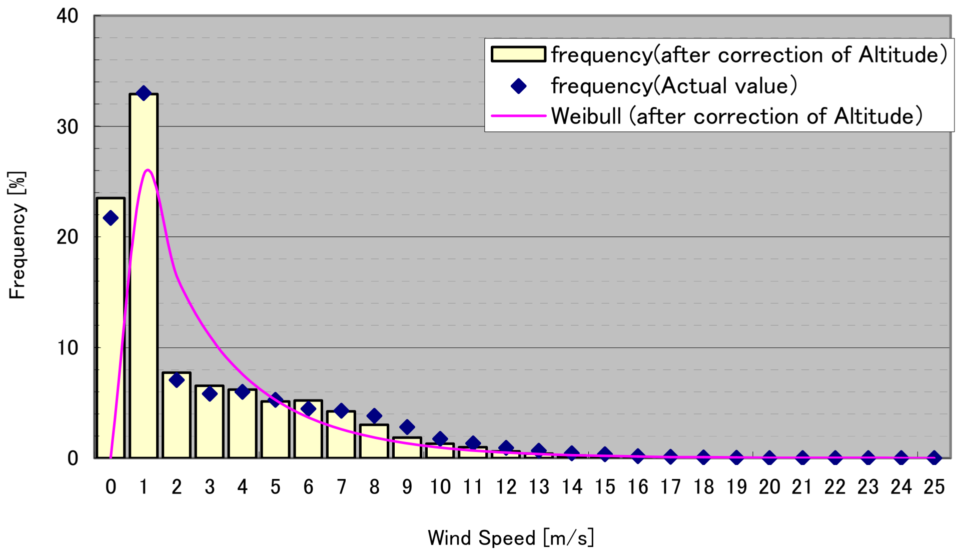
  It is thought that this cause was affected by the installation place. Because the Rubessa mast is installed on a hill where the surroundings are open, and there are no obstacles, the mast can receive strong valley winds.

  The Wangdue mast is installed in the weather survey point. Since wind is interrupted by trees or the steep slopes as shown in Figure 7-33, it is thought that the wind mast cannot fully receive wind.



Source: JICA Survey Team

Figure 7-38 Wind speed distribution of Rubessa



Source: JICA Survey Team

Figure 7-39 Wind speed distribution of Wangdue

- Comparison of wind direction

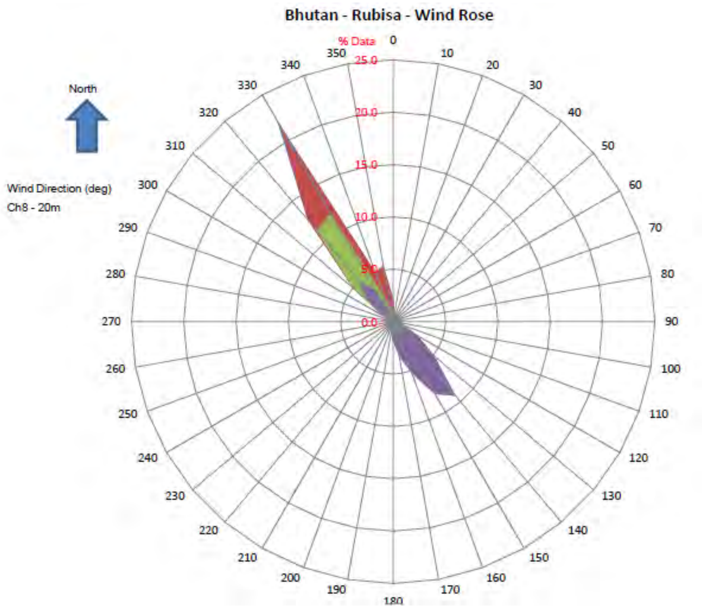
  The wind direction distribution (wind rose) of the Rubessa point and Wangdue point are shown in Figure 7-40 and Figure 7-41.

  Both points indicate a very sharp prevailing wind direction.

  However, the wind direction of the two points shows excellent characteristics in a slightly different direction, respectively.

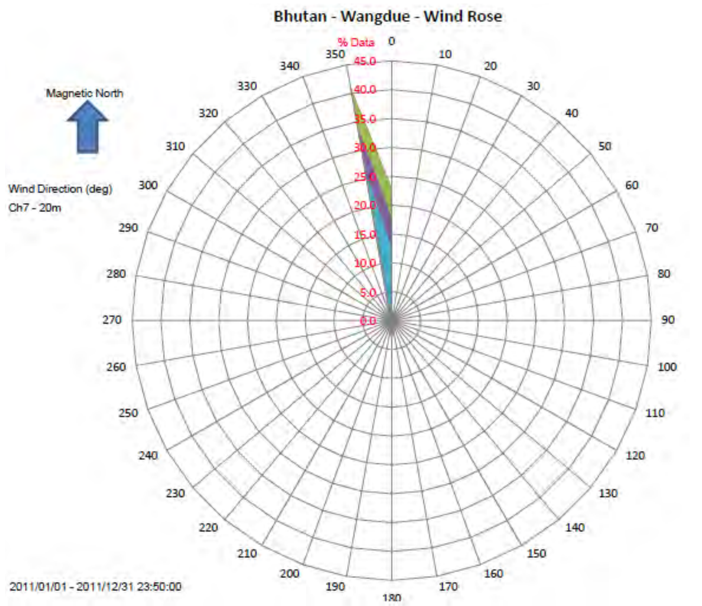
  The wind blows along the river, and the wind direction of Wangdue is concentrated northward. It is thought that the reason the wind direction characteristics of the two points differ greatly, though they are located nearby, is because they are strongly affected by the effect of the geography of the setting position of the wind direction sensors.

  When the Survey Team conducted a site survey, the direction of the wind was different from the data of Rubessa. And the data do not accord with the direction of the wind that local trees indicate. Because direction of wind data is important information for examination of turbulence intensity, it should be confirmed that the sensor does not have any errors.



Source: JICA Survey Team

Figure 7-40 Wind rose of Rubessa



Source: JICA Survey Team

Figure 7-41 Wind rose of Wangdue

a. Relation of location

b. Conditions of trees

Figure 7-42 Tree of the neighborhood of Rubessa

The production of electricity calculated from the wind speed of Rubessa is shown in Table 7-21. A production of electricity changes with the power curve characteristics of the selected WTG.

A trial calculation of the production of electricity was calculated by G58, which DRE chose, and KWT300, from which detailed data was obtained.

A trial calculation of the production of electricity was performed by G58 of Gamesa, which DRE chose for assessment of a pilot plant, and KWT300 of Komai Haltech, from which detailed data was obtained.

Table 7-21 Annual production and PLF of Rubessa (per unit)

WTG type	Manufacturer	production of electricity [MWh/year]	PLF [%]	Note
G58 (850kW)	Gamesa (Spain)	(ND)	23.2	DRE calculated
		1,520	20.4	JICA Survey Team calculated
KWT300 (300kW)	KOMAI Haltech (Japan)	433	16.5	

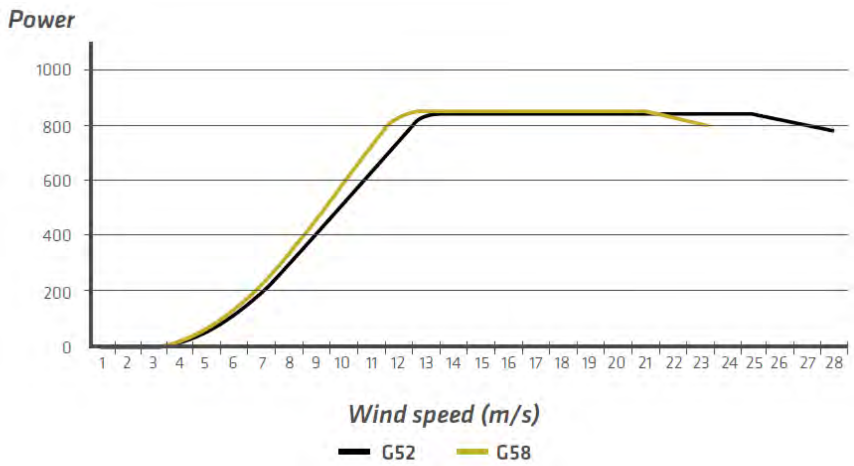
Source: JICA Survey Team

As for the trial calculation of the pilot plant of DRE, PLF is 23.2%. However, the trial calculation of the JICA Survey Team is 21.9% and the trial calculation of the JICA Survey Team decreased compared with the result of DRE.(In the trial calculation, the Survey Team believes that the following difference exists: The trial calculation of the loss resulting from the reliability of a grid, the availability of WTG, a turbulent flow loss, a Yaw mistake, etc. was made at 10%. The sensor height of the wind observation mast is not revised in the Hub height of WTG.)

G58 is a PLF of more than 20% also at the Rubessa point of low wind for the model for low wind velocity areas of G5X series.

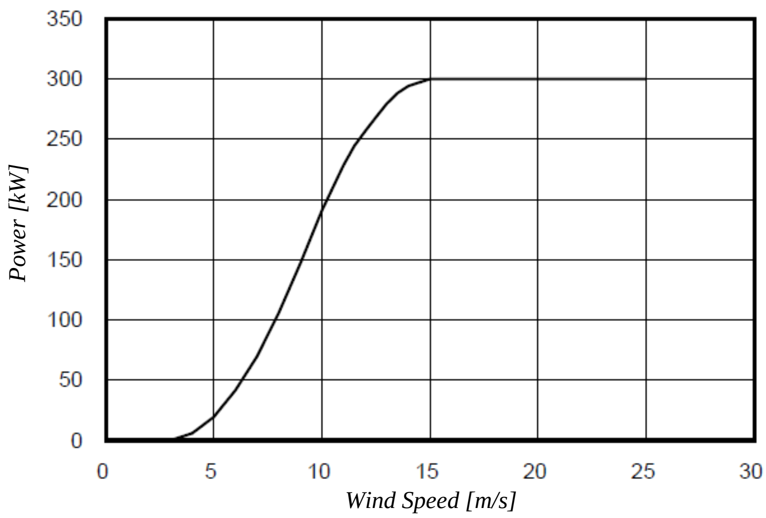
However, since it will be impossible to transport G58 to the Rubessa point, in reality, generation capacity is limited to a maximum of 300kW class.

If a trial calculation is made by KWT300, which has obtained detailed power curve characteristics, the PLF of Rubessa will be about 17%, but in reality, the PLF of Rubessa is below 20%.



Source: Gamesa catalog

Figure 7-43 Power curve for G5X series



Source: Offer of KOMAI Haltec Co.,

Figure 7-44 Power curve for KWT300

Then, the turbulence of the wind (turbulence intensity) of the Rubessa point was estimated.

The tolerance of WTG to turbulence intensity is specified by IEC61400-1, 'WTG design requirements', and it is indicated by the class of A-C.

The user and the maker have to analyze turbulence intensity and choose to install WTG which can be used from the wind data of the location.

The class of WTG by IEC is shown in Figure 7-45 (see IEC for details).

Table 1 – Basic parameters for wind turbine classes[1]

Wind turbine class		I	II	III	S
V_{ref}	(m/s)	50	42,5	37,5	Values
A	I_{ref} (-)	0,16			specified
B	I_{ref} (-)	0,14			by the
C	I_{ref} (-)	0,12			designer

In Table 1, the parameter values apply at hub height and

V_{ref} is the reference wind speed average over 10 min,

A designates the category for higher turbulence characteristics,

B designates the category for medium turbulence characteristics,

C designates the category for lower turbulence characteristics and

I_{ref} is the expected value of the turbulence intensity[2] at 15 m/s.

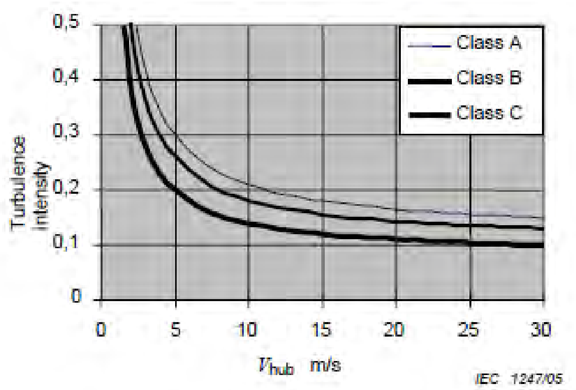
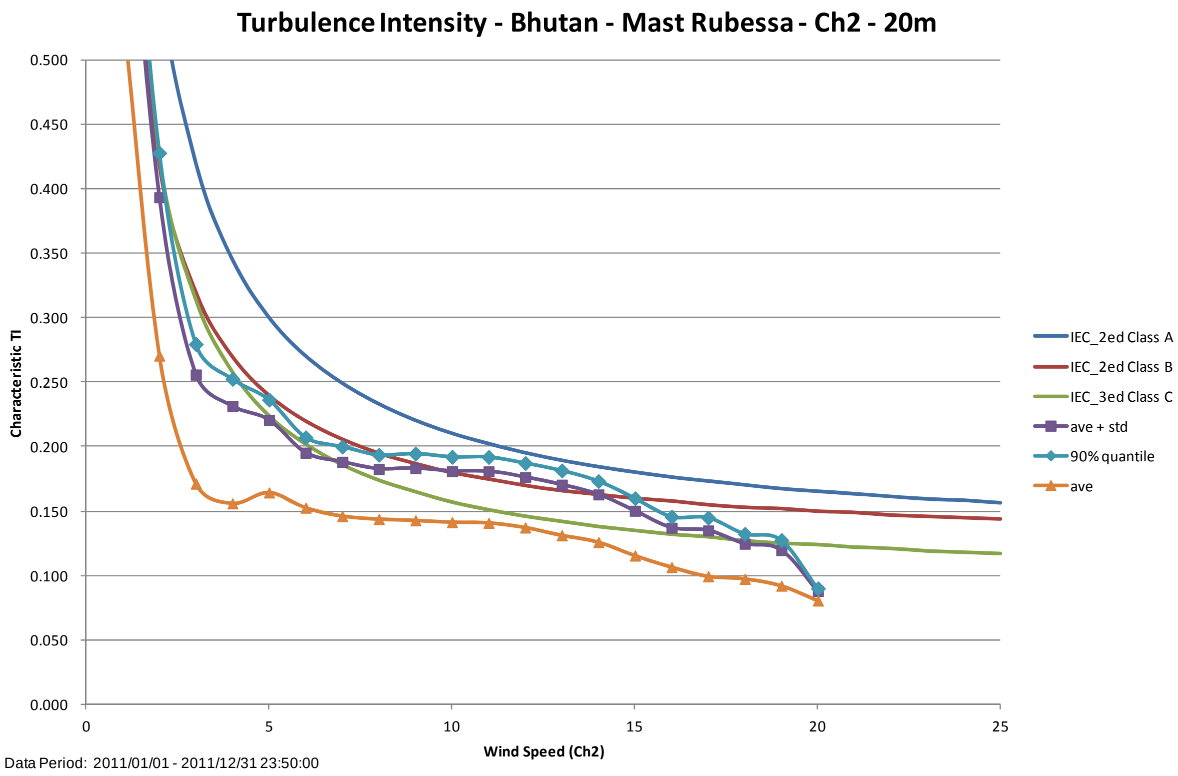


Figure 1b – Turbulence intensity for the normal turbulence model (NTM)

Figure 7-45 The class of WTG specified to IEC61400-1

The analysis result of the turbulence intensity by the wind data of Rubessa offered from DRE is shown in Figure 7-46.



Source: JICA Survey Team

Figure 7-46 Turbulence intensity of Rubessa

From Figure 7-46, although the turbulence intensity of Rubessa was over the reference value of the class B, it was in the reference value of the class A. From this result, it is recommended to choose the class A for WTG installed in Rubessa.

In addition, the 3rd Edition is used for the evaluation method of the turbulence intensity of IEC; a few changes are seen from the 2nd Edition. Since many of the WTG(s) which can be chosen in the market are models which received certification of the 2nd Edition, note that the curve of the classes A and B of Figure 7-46 is written by 2nd Edition.

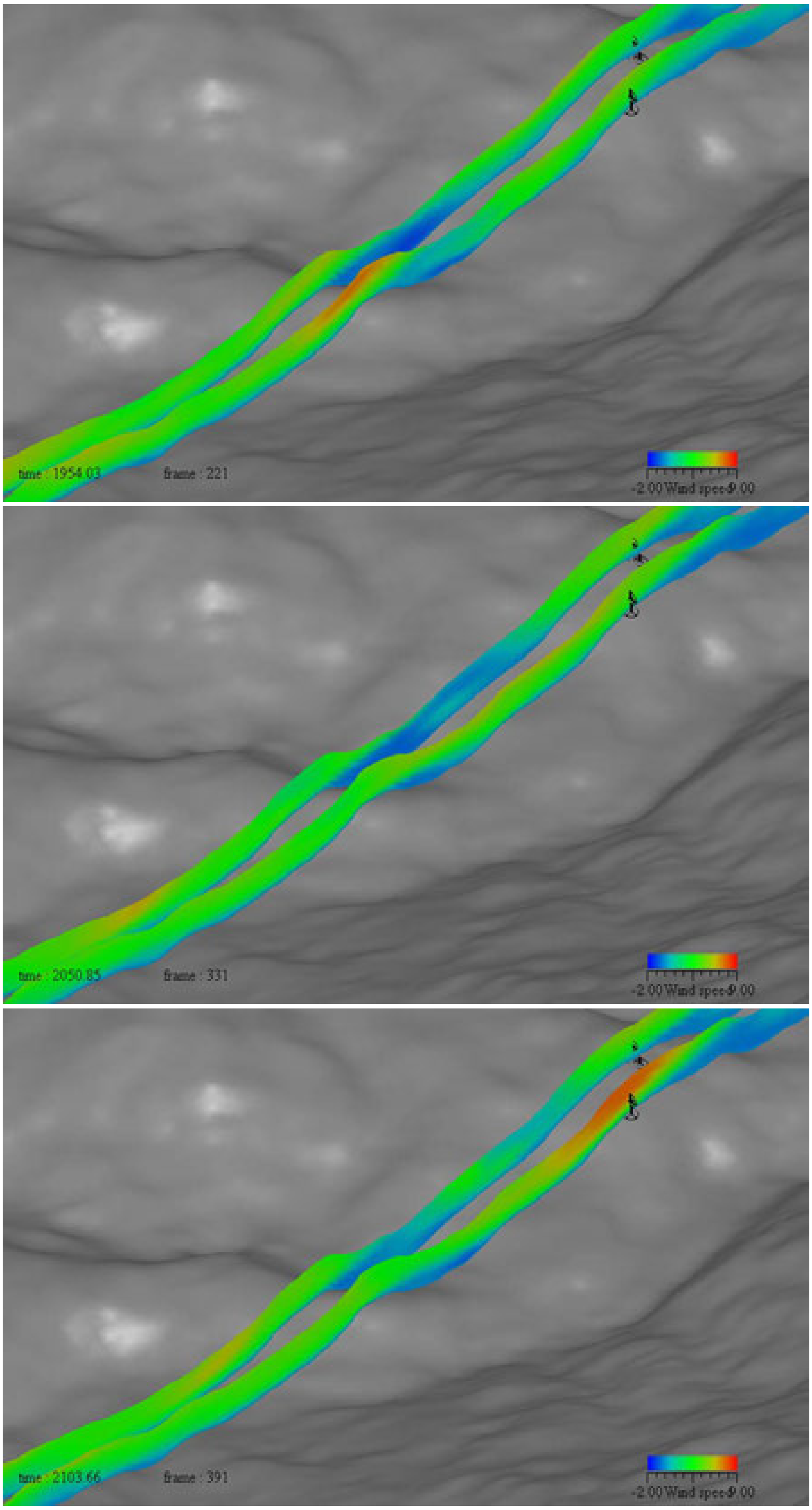
Moreover, since the complex terrain assumed in IEC is a comparatively easy model, the Survey Team have to understand that complex terrain like Bhutan is not assumed. An accident which is considered to be a result of WTG breakage due to turbulence of wind by complex terrain occurred in Japan in March 2013. This example of an accident shows that careful study is essential when installing WTG in a location of complex terrain.

When considering installation of WTG at a location of complex terrain, several wind masts (to all WTG installation locations, if possible) should be installed, and the wind should be confirmed.

However, since installation of wind masts is costly and time-consuming, CFD (Computational Fluid Dynamics) Analysis has been introduced in recent years as a technique of complementing the cost and time issue.

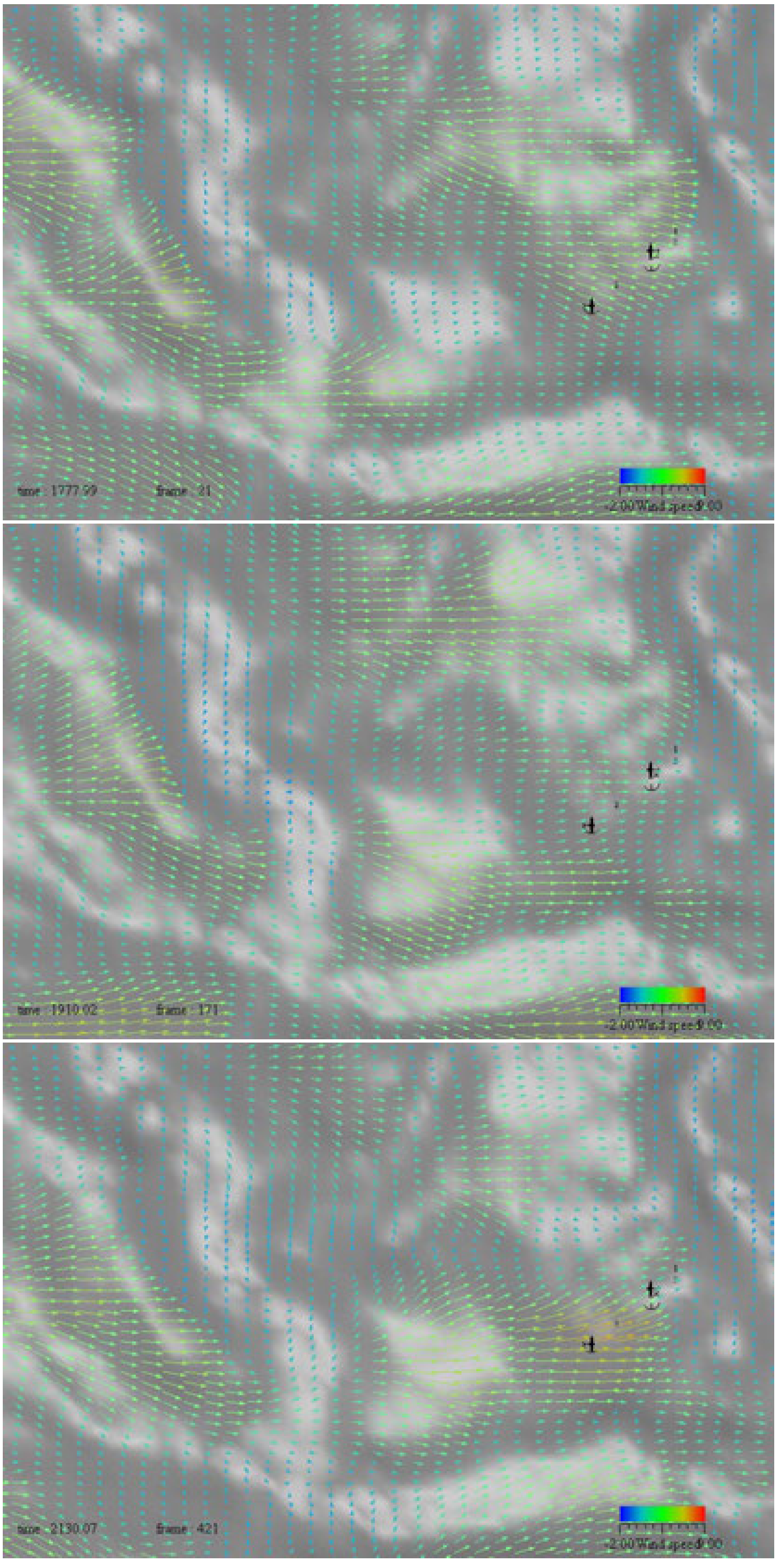
The example of the CFD analysis in Rubessa using software developed in Japan is shown. Figure 7-47 shows an example that vertically analyzes how the wind from a prevailing wind direction would change in the WTG installation location of the pilot plant. This analysis result shows that the wind is confused by a windward valley and an unstable wind is inputted into the WTG. However, it can confirm that the change width is not large. Figure 7-48 analyzes turbulence of the horizontal wind of the same place. Analysis was set as 40 m of ground height, which is the standard Hub height of the 300 kW class WTG. If in a field, the wind changed to the right and left slowly under the effect of geography, and has produced changes of wind velocity.

Confirming whether there is any change of extreme wind in the installation area of the WTG by using such analysis technology, while examining the installation location of the WTG and carrying out wind observation for backing, are the procedures which should be carried out by wind plant development at locations of complicated geographical features.



Source: JICA Survey Team (Supported by Eurus Energy Japan Co,.)

Figure 7-47 Example of the CFD Analysis in a Rubessa (vertical direction)



Source: JICA Survey Team (Supported by Eurus Energy Japan Co,.)

Figure 7-48 Example of the CFD Analysis in a Rubessa (horizontal direction, H-40m)

Although analysis for potential confirmation of wind power has been conducted, limitations of transportation of WTG, which is another key point of wind power development in Bhutan, are shown below.

As stated previously, it is thought that the southern part of Bhutan, which probably has little limitations of transportation, has few existing potential sites. The point with the possibility of leading development is an extension of the Rubessa point where DRE is planning the pilot project.

Transportation of goods to Rubessa follows a route which goes along an overland route via Phuentsholing and Thimphu from India. The JICA Survey Team ran all the routes twice and confirmed the road conditions. Figure 7-49 shows the route confirmed by the JICA Survey Team.

Source: The Survey Team based on Google earth

Figure 7-49 Confirmation of a Transportation Route (Phuentsholing- Rubessa)

There are many curves from Phuentsholing to Chukha, and although the slope is large, road width is fixed comparatively widely.

However, several sharp curves impose limitations on the transportation of long cargo.

In the transportation route, it is the narrowest from Chukha to Chapcha, and it is a section of a sharp curve. A 10-m trailer could barely make the turn which was confirmed during survey.

Moreover, there is a location where rocks have pushed out to the road side, and the Survey Team concluded that detailed survey is required before transportation of large-sized cargo takes place.

According to a newspaper report, construction of a bypass road is to be begun in 2015. Although the pavement condition of the road between Thimphu and Rubessa is not good, it is comparatively wide.
Detailed confirmation will be required for several of Kant's deep, sharp curves.

From the conditions of the whole transportation route in Bhutan, the Survey team assessed that a vehicle with approximately 12m of full length could transport materials in Bhutan. With this transportation limitation, the longest blade which is part of the component parts of WTG would be approximately 15m (equivalent to 300kW/unit).

However, since the conditions would vary by the vehicle in use, locus study of curves will be required after which vehicle to be used is decided in consideration of transit possibility. Although in Japan, with restrictions in place, there is a case in which exclusive use is applied to transport a blade in a sharp curve etc. For instance, with the exclusive use in place, one blade will be carried at a time, and the running speed is set very slow.

Since the narrow sections in Bhutan are very long and transportation will be prolonged if a special vehicle is used, it is not realistic to apply the above example from Japan.

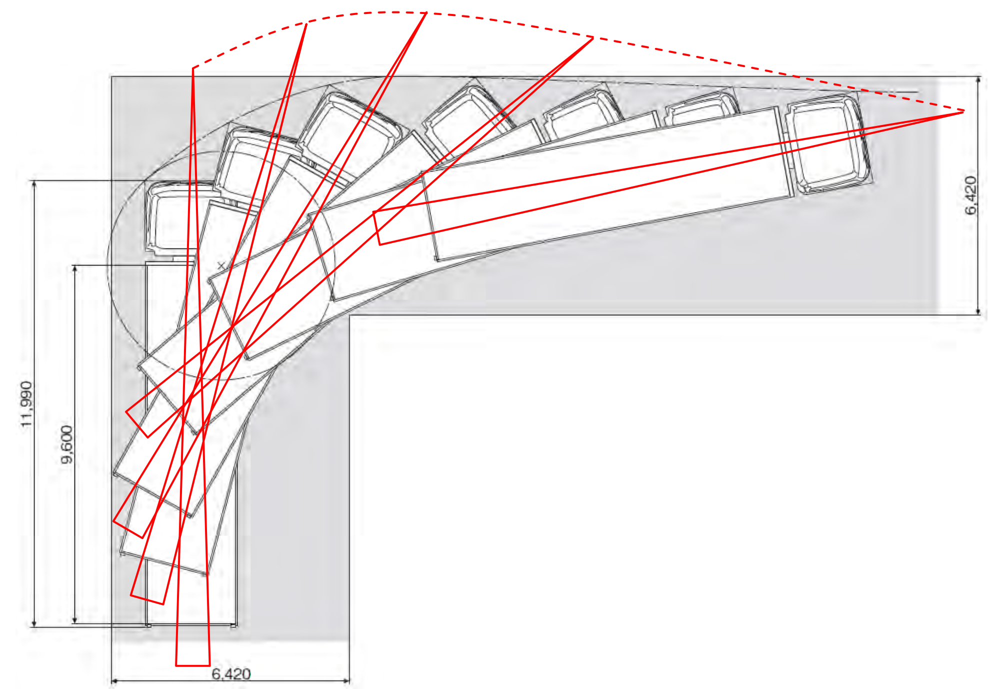


Figure 7-50　Locus Study Image of Transportation Vehicles

Moreover, a section where the width is remarkably narrow from a landslide, and a closed section, were also in the route.

Although traffic stop was canceled comparatively early, earth and sand had to avoided to such an extent that only one vehicle could pass.

Since transportation trouble by large-sized cargo can affect the project schedule, it is necessary to plan transportation programming carefully and take seasonal conditions into consideration. As for the rainy season, landslides by rain can happen, and during the winter, snowfall and frost could be an issue.

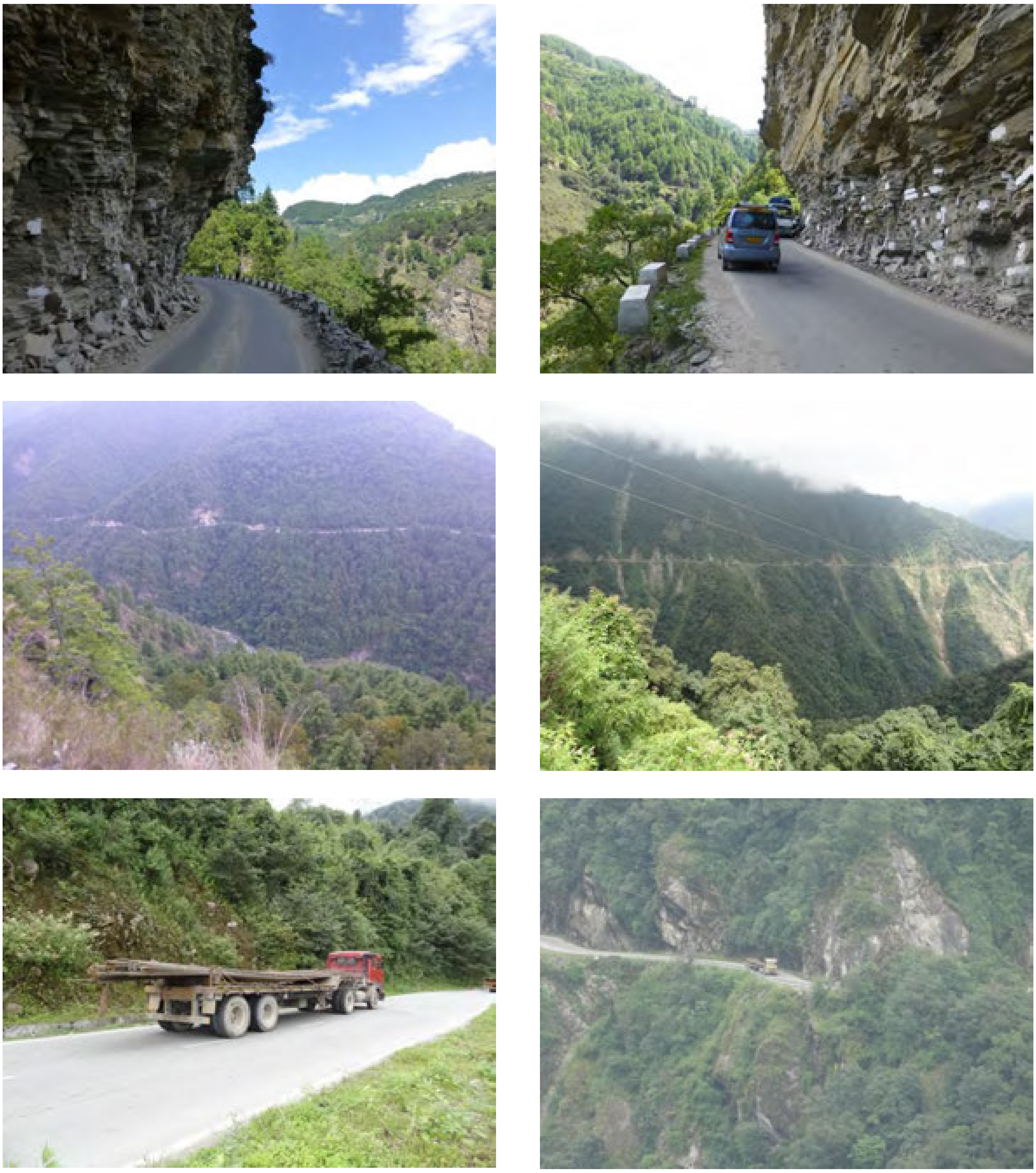


Figure 7-51　Road Condition of Transportation Routes

7.3.3 Organization Chart and Present Situation of the Promotion

In Bhutan, a large windpower project has not yet been carried out. DRE is promoting a pilot project at Rubessa using ADB's fund.

The organization chart for the pilot project is shown in Figure 7-52.

BPC is in charge of the Tender of EPC Contractor and Construction works. However, DRE obtains this from ADB. Therefore, BPC and DRE are in charge of the supervision of construction works.

DRE	BPC
- Contract with ADB - Windpower planning - Making tender documents	- Tender - O&M (After commissioning)
Supervision of construction works	

Figure 7-52 Organization Chart for the Pilot Project

According to information from DRE, at present, no windpower projects except this pilot project have been planned.

7.3.4 Economic Aspects

The economic efficiency of windpower plants is calculated from the relationship between wind conditions and construction cost. Therefore, it is necessary to evaluate a windpower project by predicting the windpower generation calculated from observation data of the wind conditions at each site, and by the construction cost, because windpower conditions differ from site to site.
The construction costs of standard WTG in Europe are shown in Table 7-22.

Table 7-22 Construction Costs of Standard 2MW WTG in Europe (2006- €)

	Investment [€1000/MW]	Share [%]
Turbine	928	75.6
Foundation	80	6.5
Electric Installation	18	1.5
Grid connection	109	8.9
Control systems	4	0.3
Consultancy	15	1.2
Land	48	3.9
Financial costs	15	1.2
Road	11	0.9
Total	1228	100.0

Source: Risø DTU

It is considered that transportation conditions and cost worsen the economic aspect in Bhutan. It is thought that long blades of more than 15m cannot be carried to the Rubessa site due to transportation limits. Under this condition, the maximum output of a windpower plant seems to be approximately 300kW.

Since Hub height will go down if the size of WTG becomes small, the capacity factor of WTG worsens. And many WTG(s) will be installed in order to obtain the same production of electricity. Since economical efficiency gets worse as a result, construction costs become comparatively high-priced than the value shown in Table 7-22.

In addition, equipment is unloaded from Kolkata port, India, when it is imported from a foreign country other than India. The equipment is transported over more than 900km by road after ship transportation.

When carrying out large-scale development in Bhutan, it is thought that it is necessary to construct WTG on a mountain, but for the purpose, development of the road for construction is needed.

Wind power generation development of Europe is usually performed near the coastline. Therefore, it is necessary to take into consideration in Bhutan that the cost of a road increases very much. Since wind power plant development in Bhutan has many special conditions as mentioned above, it is thought that it is necessary to perform economical assessment for every individual matter.

JICA Survey Team (based on Google earth)

Figure 7-53 Cargo Transportation Route from Overseas

7.4 Biomass Generation

7.4.1 Features of Biomass

The word “Biomass,” which consists of the words “Biology” and “Mass,” means biological resources for energy usage. Biomass is an organic substance, for which it is deemed that no carbon dioxide is created through combustion (“Carbon Neutral”), therefore the usage of an alternative to fossil fuels leads to a reduction in CO_2 emissions.

In Bhutan, since early times, biomass energy was used mainly in people’s lives, for example, firewood was used for cooking and livestock waste mixed with straw was used as fuel after drying. The types of biomass in Bhutan are (1) agricultural residues, (2) forest resources, (3) livestock waste and (4) general waste (organic waste from the city). The following table shows the major amounts of biomass in Bhutan.

Table 7-23 Biomass Energy Potential in Bhutan (2005)

Type of Biomass	Potential biomass production (tonne/year)	Maximum energy value (GJ/year)	%
(1) Fuel wood	1,565,540	20,974,729	**76.9**
(2) Crop residues	(390,639)	(5,754,424)	**21.1**
Paddy straw	97,787	1,410,281	
Rice husk	14,668	211,219	
Maize stalk	190,193	2,795,834	
Maize cob	43,473	669,479	
Maize husk	24,453	352,128	
Wheat straw	6,120	93,029	
Barley straw	2,191	33,309	
Millet stalk	3,669	53,932	
Buck wheat straw	3,665	55,702	
Mustard sticks	4,420	79,511	
(3) Animal dung	253,052	203,707	**0.7**
(4) MSW	81,119	358,608	**1.3**
Total	2,290,350	27,291,468	

Source: Bhutan Energy Data Directory 2005

For biomass resources in Bhutan, 76.9 % of the total is forest resources, amounting to 1.56 million t/ year, which is equal to 20.97 million GJ/ year. Second highest, at 21.1 %, is agricultural resources, amounting to 0.39 million t/year, which is equal to 5.75 million GJ/year. Forest resources and agricultural resources make up 99 % of the total amount.

(1) Agricultural sector

The agricultural and livestock industries occupy an important position in Bhutan, with 18.5 % of GDP (in 2008). Around 69 % of the population (in 2008) is engaged in these industries. As the country is almost entirely covered by mountainous land, both gradual slopes and mountainous land are used, therefore small scale farm houses are scattered over a wide area. The main harvests are paddies in the western area, wheat and buckwheat in the central area, and maize in the eastern area. Fruits such as oranges and apples etc. are also produced.

Table 7-24 Annual Yield in Bhutan

Type	Annual Yield (MT)
Paddy	71,637
Maize	57,663
Wheat	4,873
Millets	4,066
Buckwheat	3,950
Barley	1,445

Source: Agriculture Statistics 2010

As a typical example, the yield from paddies is high at Punakha and Paro in the western area. In the western area, single cropping is adopted at elevations of between 1,000 m and 2000 m, and double cropping is adopted at low elevations and in the warm climate of the southern area.

Table 7-25 Annual Paddy Yield for each Dzongkhag

Dzongkhag	Annual Yield (MT)
Punakha	12,425
Paro	12,403
Wangdue	7,645
Samtse	7,126
Sarpang	4,512
Tsirang	4,218
Dagana	4,085
Samdrup Jongkhar	3,032
Lhuentse	2,861
Chukha	2,760
Trashigang	2,410
Trongsa	1,807
Zhemgang	1,767
Thimphu	1,499
Trashiyangtse	1,443
Mongar	868
Gasa	308
Total	71,637

Source: Agriculture Statistics 2010

Currently, almost all agricultural residues, such as rice husk, straw, and corn haulm, are used efficiently. Rice husk and straw are used independently or in a mixture with wheat bran used for livestock feed, and straw and corn haulm are used as carpeted straw for livestock. Carpeted straw is also used as compost, after resolution by natural fermentation in the temporary stock after mixing with livestock waste. Agriculture in Bhutan uses most of these organic fertilizers.

With regard to agricultural residues, as the scale is small and the points are scattered, and usage ratios such as livestock feed and organic fertilizer are high, it is currently difficult to use them as biomass resources.

Upon interviewing agriculture-related persons, such as DRE and MoAF, equable comments regarding the difficulty of the usage of agricultural residues were encountered.

(2) Livestock sector

The varieties of livestock in Bhutan include cow, buffalo, horse, yak, mule etc. Livestock is determined as part of agriculture. Not only the usability of products such as butter and cheese, which are made of meat and milk, but also the working energy of livestock such as cows and horses are holding back agricultural technology. People are heavily dependent on livestock.

The amount of organic waste from livestock is 0.25 million t/year, equal to 2.03 million GJ/year. This is around 0.7% of total biomass resources, so the potential is low.

In rural areas, 90% of households have livestock, and the total number of livestock is assumed to be about 4,000,000. As the livestock sector is scattered like the agriculture sector, consideration is needed for intensive type biomass resources.

(3) Forest sector

The consumption of firewood per capita in Bhutan is 1.3 t/year, which is relatively large compared to the rest of the world[22].

The following table shows the annual amount of forest resources according to Dzongkhag.

Table 7-26 Annual Amount of Forest Resources According to Dzongkhag

	Dzongkhag	Growing Stock (Million m^3)	Yield (ton/year)	Fuel wood (ton/year)
1	Thimphu	10.46	65,890	26,356
2	Paro	7.62	47,140	18,856
3	Haa	17.58	118,070	47,228
4	Chukha	35.65	273,610	109,444
5	Samtse	29.1	233,290	93,316
6	Punakha	15.05	110,920	44,368
7	Gasa	16.85	100,910	40,364
8	Wangdue Phodrang	46.04	328,680	131,472
9	Tsirang	10.68	85,730	34,292
10	Dagana	24.84	188,410	75,364
11	Bumthang	17.8	102,850	41,140
12	Trongsa	34.02	255,280	102,112
13	Zhemgang	42.45	334,290	133,716

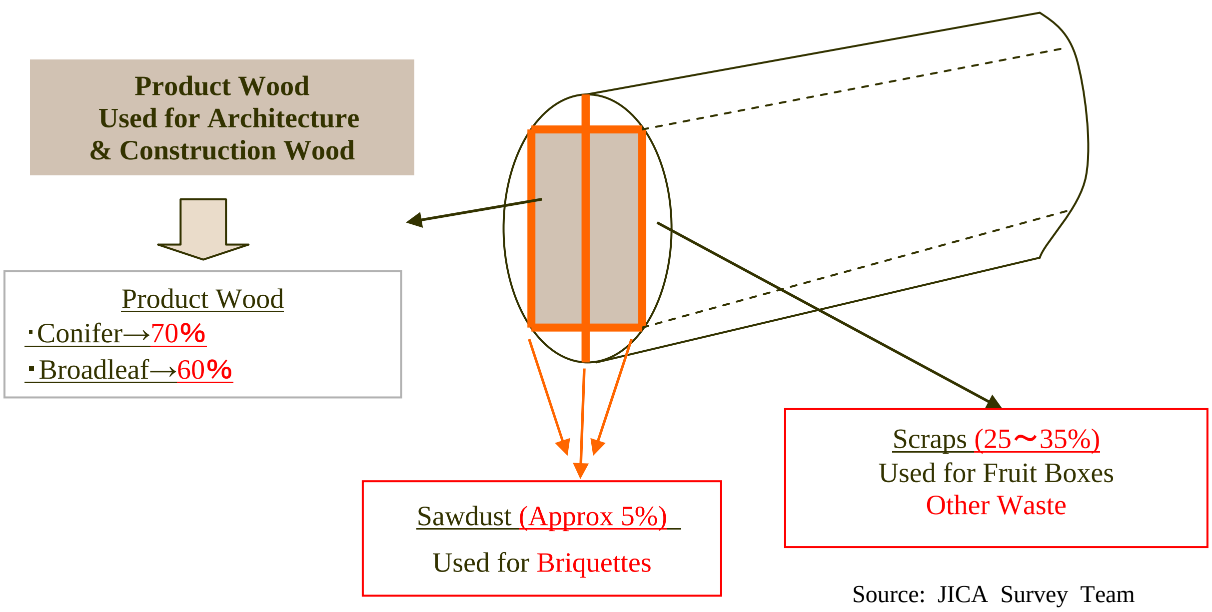
[22] Consumption of forest biomass 73,861t/634,982 people (official Census Commissioner 2006)

14	Sarpang	41.87	341,120	136,448
15	Lhuentse	39.36	279,970	111,988
16	Mongar	37	282,830	113,132
17	Trashigang	32.17	232,300	92,920
18	Trashi Yangtse	23.78	167,500	67,000
19	Pema Gatshel	5.99	48,380	19,352
20	S/Jongkhar	39.1	316,690	126,676
	Total	527.31	3,913,860	1,565,544

Source: Bhutan Energy Data Directory 2005

The major usage of timber in Bhutan is as material for architecture and construction, in production of poles, beams and boards using lumber. During lumbering, sawdust is produced to around 5% of the amount of timber. At some sawmilling factories near urban areas like Thimphu, the sawdust is used for heating fuel as briquettes via pressing; however most of the sawdust is not used and is dumped as waste. Odd pieces which are produced during lumbering are partly used for fruit packing boxes; however the rest becomes waste. This waste part could be considered useful for biomass resources. The amount of odd pieces is around 25% for broad-leaved trees and around 35% for needle-leaved trees.

As mentioned later, an FS for effective usage of wood-based biomass is being conducted by UNDP funding. This means that the potential for wood-based biomass is assumed to be high in Bhutan even by other donors. In this survey, wood-based biomass should be focused on for biomass resources.



Source: JICA Survey Team

Figure 7-54 Possibility as Wood-based Biomass Resources

Source: Photo by JICA Survey Team

Figure 7-55 Collection Site of Sawdust

Source: Photo by JICA Survey Team

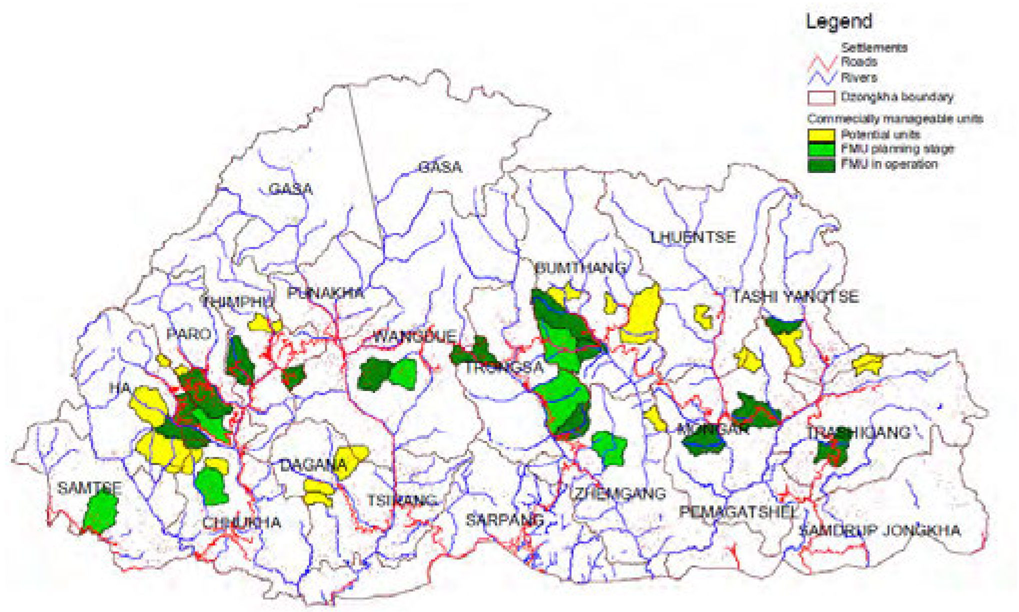
Figure 7-56 Briquette from Sawdust

7.4.2 Potential for Development of Biomass Generation System in Bhutan

During the first mission, the conclusion through discussions with DRE was that a potential survey focusing on wood-based resources is necessary. The areas where wood-based resources could be used consist of two types, community areas and commercial areas. Community areas exist all across the country; the local public can use them, but usage is restricted within 1.5 km from rural communities. The major use is as firewood for cooking, and branch wood or deadwood is mainly used. Deforestation and aggregation of trees was conducted by human effort.

With regard to commercial areas, the Forest Management Unit (FMU), which is managed by DoFA, is set for each area and it manages the deforestation, aggregation, export, transportation and planting according to a 10 year plan.

The amount of deforestation is 2 million cft for commercial areas and 5 million cft for community areas (2010 actual data). In this study, residues from commercial areas are the target.



Source: Department of Agriculture, MOAF, Bhutan

Figure 7-57 Location of FMUs

Table 7-27 Basic Data of FMUs

Manageable areas	Total area (ha)	Forest Area (ha)	Total Forest Area	Gross operable (ha)	Total Forest Area	Net operable (ha)	Total Forest Area
FMU in operation	145,852	127,362	4.3%	71,937	**2.5%**	**58,684**	**2.0 %**
FMU in planning stage	80,802	68,642	2.3%	45,345	**1.5%**	**28,152**	**1.0 %**
Potential units > 1000 ha	110,932	104,086	2.1%	71,801	**2.4%**	**44,577**	**1.5 %**
Area 100-1000 ha	51,379	51,379	1.8%	51,379	**1.8%**	**31,854**	**1.0 %**
Total	**388,965**	**351,469**	**12,0%**	**240,463**	**8.2%**	**163,267**	**6.5 %**

Source: Bhutan Energy Data Directory 2005

In the commercial areas, the National Resources Development Corporation., Ltd. (NRDCL), which is the lower organization of DoFA, conducts deforestation, aggregation and transportation.

(1) Operation of commercial areas

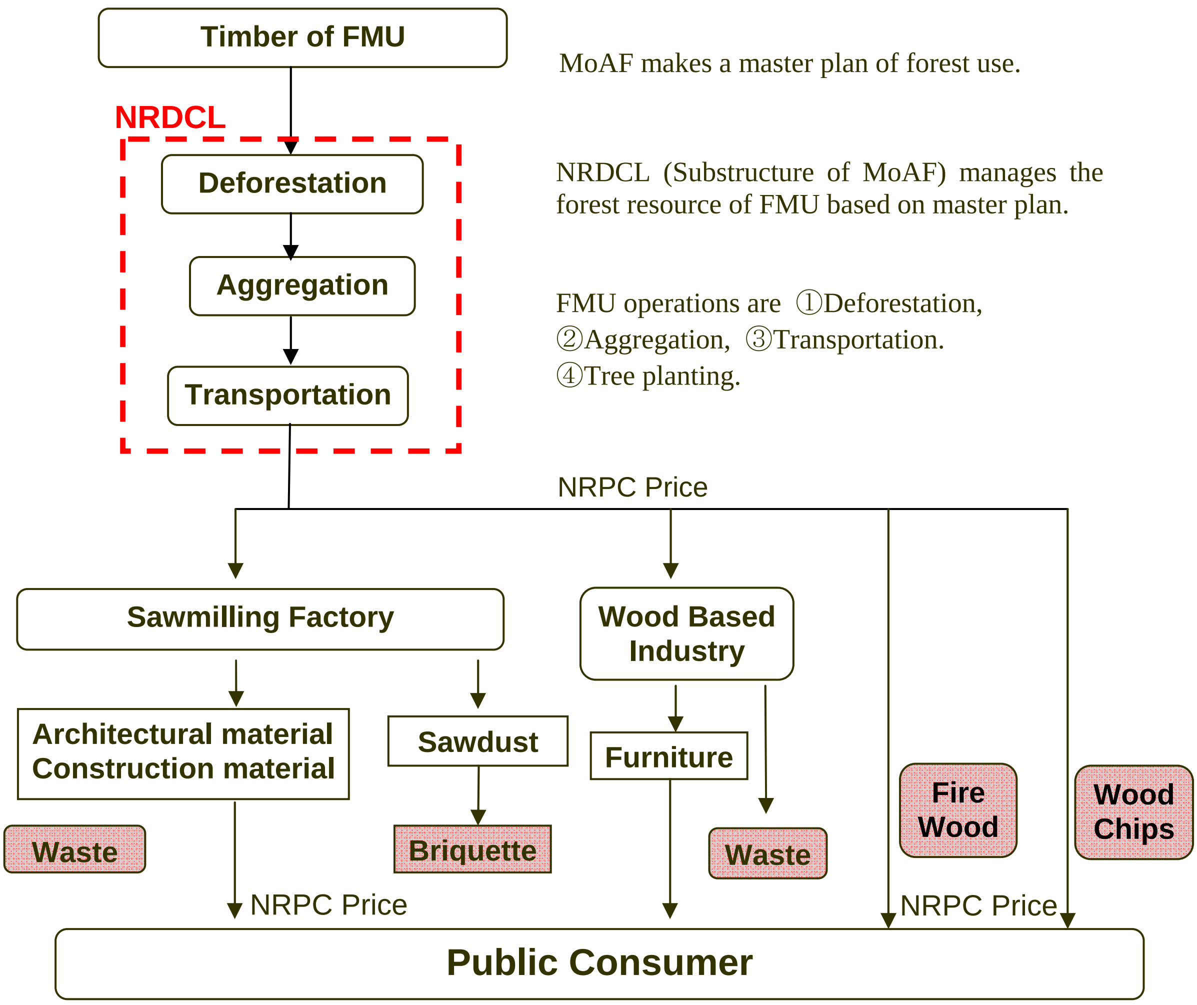
Based on the master plan of forest use that the forest station (DoFA) devises, NRDCL manages the forest resources of the commercial area units.

The following figure shows the operative organizational chart of the commercial areas. NRDCL headquarters are in Thimphu, and there are local offices in Wang, Rinpung, Zhonggar, Sha, Zhemgang, P/ling Jakar; administration manages FMUs in 20 places. NRDCL carries out deforestation, aggregation and transportation. The main use of wood is as material for buildings and construction, and the quantity of handling is around 70%. The quality of wood tip for a furniture factory or a smithy is 30%.

NRDCL manages the sale of the wood in each FMU. NRPC decides every area of the price, and sells it on a first-come-first-served basis. NRPC performs pricing; the price is high in places with much demand, and low in places where demand is small. The supplier buying wood from NRDCL signs a 5-year contract.

NRDCL performs deforestation, aggregation and transportation. NRDCL selects a trust supplier by a bid once a year. The consumers can purchase directly from NRDCL.

The following require attention with regard to biomass fuel. ① Residual substance of the quality of wood system from the lumber mill, ② Briquettes made from sawdust, ③ Residual substance of the quality of wood system from the furniture factory, ④ Fire Wood , ⑤ Wood Chips.



Source: JICA Survey Team

Figure 7-58 Operative Organizational Chart of Commercial Areas

The track record from 2008 to 2012 is shown in the following table, with the amounts of annual handling of wood produced from commercial areas.

In the past several years, the amount handled was about 2 million CFT.

Table 7-28 The Amount of Annual Handling of Forest Wood Product from Commercial Areas

	2008	2009	2010	2011	2012	
Timber	1,712,183	2,068,852	1,999,407	1,971,564	2,173,826	Volume in cft
Briquette	453,060	470,795	529,915	306,015	344,250	Volume in kg
Woodchips	10,510	21,539	16,641	20,517	23,406	Volume in M3
Fire Wood	4,222	5,077	4,253	4,232	4,478	1 Truck Load = 8 m3

Source: NRDCL

Next, the amount of annual handling classified by NRDCL Local Office of Timber produced from commercial areas is shown in the following table, for Timber, and the relation of the local office of NRDCL and Dzongkhag which is the control range, are shown in the following table.

Table 7-29 The Amount of Annual Handling Classified by NRDCL Local Office of Timber Produced from Commercial Areas

NRDCL Regional Office	2008	2009	2010	2011	2012	Location
Wang	246,098	271,613	188,863	208,191	290,610	Western
Rinpung	419,678	436,790	433,773	389,275	577,184	
Zhonggar	148,708	215,423	321,960	374,714	269,999	Eastern
Sha	281,527	391,054	501,842	462,090	467,990	Central
Zhemgang	95,755	120,225	108,111	155,721	207,138	
P/ling	190,714	163,214	60,727	61,269	79,963	Western
Jakar	329,702	470,531	384,132	320,305	280,943	Central
Total	1,712,183	2,068,852	1,999,407	1,971,564	2,173,826	

Source: NRDCL

Table 7-30 Correlation between NRDCL Local Office and Dzongkhag

No.	Regional Office	Dzongkhag	Location
1	Wang	Thimphu	Western
2	Rinpung	Paro	
		Haa	
3	Zhonggar	Trashigang	Eastern
		Mongar	
		Lhuentse	
		Yangtse	
		Pema Gatshel	
		S/Jongkhar	
		Pema Gatshel	
4	Sha	Wangdue Punakha	Central
5	Zhemgang	Zhemgang	
		Bumthang	

6	P/ling	Chukha	Western-South
7	Jakar	Bumthang	Central

Source： NRDCL

Timber is the main resource of forest biomass. The amount of handling in 2012 per year is classified into three areas, (western area, central area and eastern area). 43.7% of the amount of handling is in Thimphu, Paro, Haa, and Chukha, which are western areas. 43.9% of the amount of handling is in Wangdue Punakha, Zhemgang, and Bumthang, which are central areas and comparable to the western area. 12.4% of the amount of handling is in Trashigang of the eastern area, Mongar, Lhuentse, Yangtse, Pema Gatshel, S/Jongkhar, and Pema Gatshel.

Biomass resources in the western and central area are promising, since it is desirable to judge the amount of actual handling more than potential quantity.

(2) Unit Price of Timber Resource

The unit price of timber, at which NRDCL, a substructure of MoAF sells, is decided and controlled by the National Resource Pricing Committee (NRPC), which is a substructure of DoA. The unit price is classified as ①Timber, ②fire wood, ③wood chips. In Bhutan, wood is classified by added value. In addition, as the cost of work (deforestation/aggregation/transportation) is different in every FMU, the price varies according to the area in which it is sold.
The following table shows the unit price of the timber in Thimphu.

Table 7-31 Unit Price of Timber (Thimphu)

Type	Timber	Sawmilling	Fire Wood
Needle-leaved (Class A)	137.68 Nu/cft	286.76 Nu/truck	Needle-leaved 5,967Nu/truck Special high quality type 6,177Nu/truck
Needle-leaved (Class B)	132.48 Nu/cft	279.00 Nu/truck	
Broad-leaved (Class A)	115.68 Nu/cft	281.45 Nu/truck	
Broad-leaved (Class B)	110.48 Nu/cft	272.78 Nu/truck	

※cft (cubic feet) = 0.028 m³、1 truck = 8 m³

Source: NRDCL

(3) Current Situation of Sawmilling Factories

In Bhutan, there are 105 sawmilling factories in 17 Dzongkhag. The following table shows the number of factories in each Dzongkhag.

Table 7-32 Number of Sawmilling Factories in each Dzongkhag

No.	Dzongkhag (District)	No. of Sawmills	Location
1	Haa	19	West
2	Paro	20	West
3	Thimphu	12	West
4	Wangdue	5	West
	West Total	56	
5	Chukha	5	West-South
6	Samtse	1	West-South
	West-South Total	6	
7	Bumthang	13	Central
8	Trongsa	1	Central
9	Zhemgang	3	Central
	Central Total	17	
10	Sarpang	7	Central South
11	Tsirang	1	Central South
	Central South Total	8	
12	Mongar	6	East
13	P/Gatshel	2	East
14	S/jongkhar	3	East
15	T/gang	5	East
16	T/Yangtse	2	East
17	Lhuentse	1	East
	East Total	19	
	OVERALL TOTAL	105	

Source: NRDCL

In this survey, a business model according to the scale of representative sawmilling factory would be formulated and proposed; afterwards, enlargement to other areas would be considered by pursuing productivity and economic efficiency. Continuous discussion with DRE would be needed, together with determination of the proposed area. Through discussion in the first survey, the western part is promising based on the demand of DRE.

(4) A Pilot Project of Biomass Power

The Survey Team suggest the biomass pilot plant in consideration of the following items.

① A stable supply of biofuel to the plant is ensured.

② Can perform accumulation of a biofuel easily.

③ The land for the plant can be secured.

④ The organization and capable persons to perform operation and maintenance are secured after pilot plant installation etc.

Installation of a pilot plant has been agreed on deliberations of DRE in the western area until now. It is from the potential quantity of biofuel, and the advantage in handling after installation. This pilot plant, if it succeeds, will be scheduled for development all over the country. In judging the biomass-resources potential of the western area, the amount of timber production of FMU is as shown in the following table. When Thimphu, Paro, and Haa are compared, Haa is the highest.

In the quantity-of-production plan, which was turned in the future according to the plan of the future quantity of production of NRDCL, Thimphu will begin to decrease from now on, and Haa will if it becomes a production increase trend.

Table 7-33 The amount of timber production at Thimphu, Paro and Haa

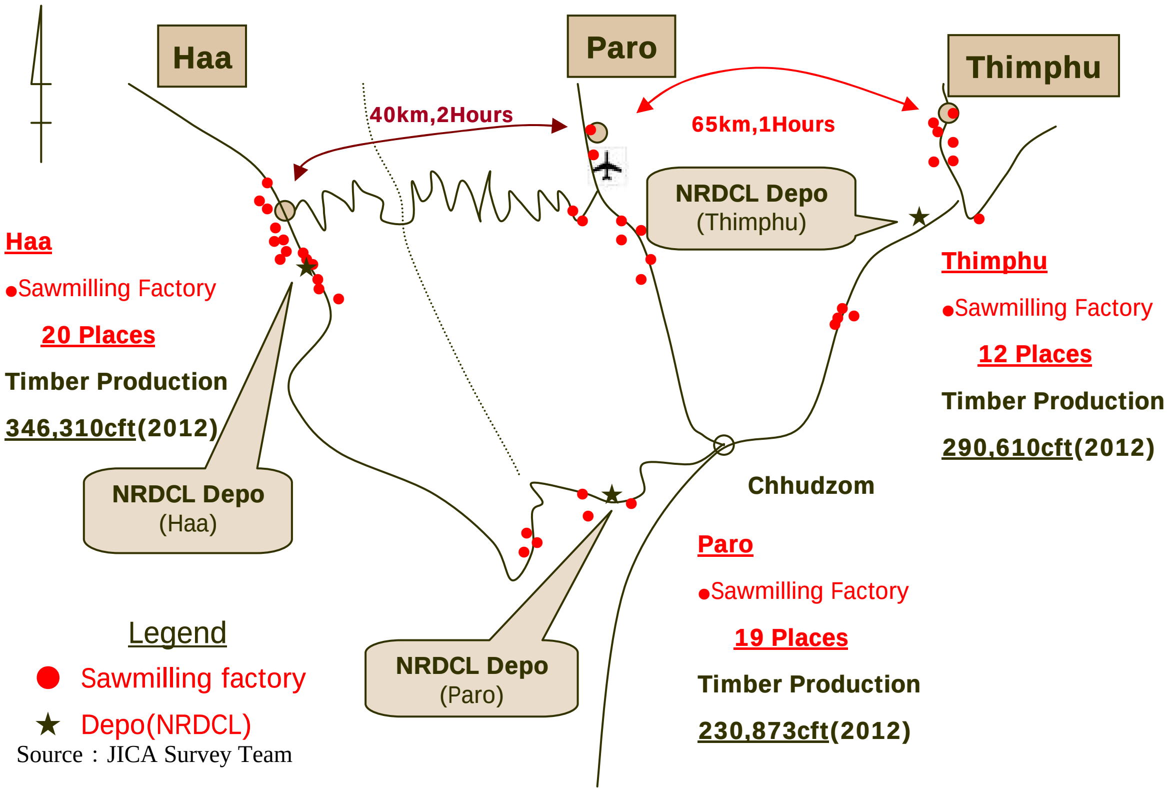
NRDCL	Dzongkhag (District)	2008	2009	2010	2011	2012	2013
		Volume in cft					
Wang office	Thimphu	246,098	271,613	188,863	208,191	290,610	338,000
Rinpung office	Paro	167,871	174,716	173,509	155,710	230,873	135,000
	Haa	251,807	262,074	260,264	233,565	346,310	503,000

source：NRDCL

The positions of the sawmilling factories in the western area are shown in the following figure. The distance between Thimphu and Paro is 65 km. It is about 40 km in distance from the bridge at which the direct lower stream of the airport in Paro branches up to the central part of Haa. In this section, a winding passage continues and travel time is about 2 hours.

In terms of road conditions, although there is a difference in elevation, the route passes through a comparatively stable loose slope, and danger is not felt. The geographical feature of Haa is rows of houses formed in flat land compactly along the Haa river. The sawmilling factories are also concentrated on this narrow range (refer to the following figure).

There are sawmilling factories in 20 places and working factories in 17 places. Government management factory is in one place, and other factories are all privately managed. The timber yard (Depo) is in the central part of Haa and Depo’s stock of timber is performed on a large scale.



Source：JICA Survey Team

Figure 7-59 The Position Figure of the Western side of the Sawmilling Factory

Western area

Source：JICA Survey Team

Figure 7-60 The Photograph of the Sawmill in Haa

Source：JICA Survey Team

Figure 7-61　Timber yard of Haa (Depo)

(5) Possibility of Expansion of Utilization of Biomass Resources

Scraps of timber which can be used as biofuel are about 25 to 35%. The aim is to use the eccrisis of this part of the timber scraps as biomass resources. In addition, the Survey Team considered the effective use of timber branches, fallow timber and fallen timber, which have not been used until now.

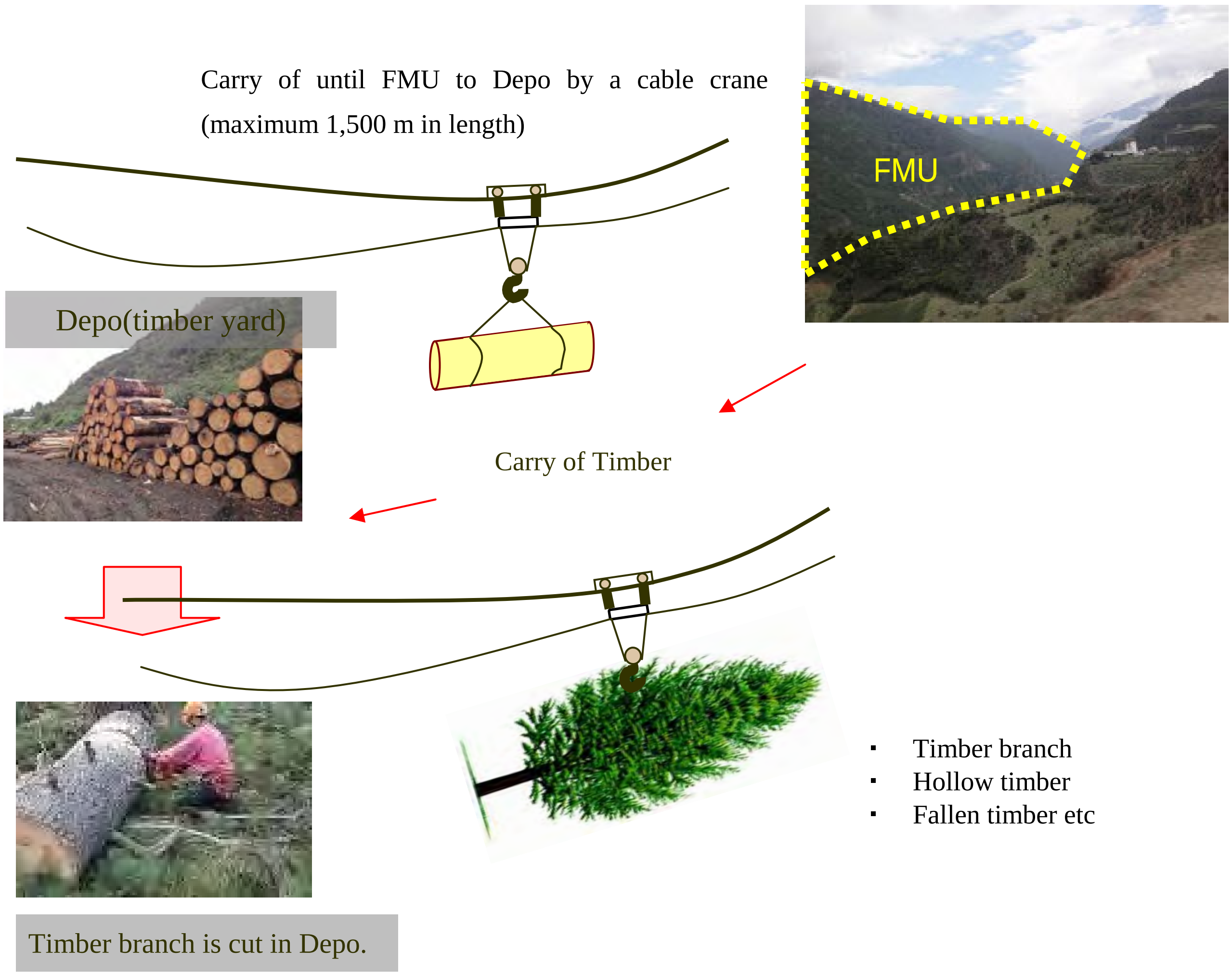
First, the volume of timber branches is estimated to be about 10 to 20% of the whole trees by conifer. Next, the vegetation of FMU is a natural forest mainly composed of conifers of over 300 years, and the part into which a limb broke and the core of trees rotted by high winds etc., and the thing which is called “hollow timber”. Hollow timber does not become a product processed within FMU. Moreover, although the existence of fallen timber was also checked, since neither served as a product until now, it was being processed in FMU at the time of felling.

Management of the old FMU divided management into several areas, shifted the stages of afforestation and felling, and aimed at timber growth. In one area, felling is advanced at intervals of one row of up-and-down direction. First, the timber log cuts away a branch at the time of felling, and carries out skidding of the material wood to Depo at the foot of the mountain with a cable crane. Afterwards, the trees are planted about the range after the end of felling.

In discussion with NRDCL, compared with other areas, since FMU and the timber yard (Depo) were comparatively near, Haa was not used until now. Timber branches, hollow timber and fallen timber, by carrying out skidding from FMU, may be able to be used as biomass resources. If this is

utilized, it is possible for it to be free or to be cheap and to trade, but transport costs cannot pay NRDCL, so it serves as a company burden.
The present condition is that NRDCL have paid the felling company an average of 40 Nu(s) per 1cft of logs as transport costs between FMU and Depo (FMU lower stream) including the felling fee and transport by cable crane.

The transport cost is a half grade of whole expense, and the transport cost of the timber branches to a timber yard (Depo) is estimated at about 20 Nu/cft. There is no cost, since the comment of NRDCL can keep the mountain clean, if it is good. The work image of the forest resources which are not exploited for the following figure until now is expressed.



Source: JICA Survey Team

Figure 7-62 The Use Expansion procedure of forest resources

(6) Special Feature of Sawmilling Factory in Haa

The schema of "Meriphensum Sawmilling factory" and "Ricky Sawmilling factory" which are the general sawmills in Haa is shown in the following table.

Table 7-34 Outline of sawmilling factories in Haa (Meriphensum Sawmill, Ricky Sawmill)

Item	Content
The quantity of production of a sawmill	App 5,000cft /month
The kind of timber	Blue Pine&Mix conifer (Conifer)
The operate situation of a sawmill	3～4 hour/ day
Electric tariff	3,000 Nu/month
Employee	5 persons
Use of sawdust	All Sawdust(s) have discarded in Haa.
Use of scraps	Product of Fruit Box

Source: JICA Survey Team

All sawdust have dumping in Haa.

Making a Fruit Box

Horizontal sawmilling machine

Vertical sawmilling machine

Source: JICA Survey Team

Figure 7-63 Current Situation of the Sawmilling Factory in Haa

(7) Selection of a Pilot Project Site

Selection of the pilot project compared three Dzongkhags of Thimphu, Paro, Haa in the western area (Refer to Table 7-35).

In view of the quantity of production in recent years, the potential quantity of forest biomass fuel resources is large in Haa, and shows predominance also in future plans.

Although sawdust generated in a sawmilling factory is estimated at about 5% from material timber, by Thimphu, it is used as briquettes and used for heating in winter. However, all are discarded in Paro and Haa. The Survey Team checked illegal dumping in the river by this survey. Therefore, there are also promising advantages for the environment, through using sawdust generated in Paro and Haa as biomass fuel resources.

Moreover, in Haa, handling is possible as mentioned above, with branches and leaves attached, since FMU and Depo were near. Timber branches and hollow timber were being dumped in FMU, and may have been able to be used as biomass resources until now.

Haa is about 17-18 km in a straight line from Paro. Although the altitude of Paro is 2,200 m, the altitude of Haa is 2,700 m and winter heating demand due to the low air temperature is high.

Table 7-35 Comparison of Pilot Project Sites (Thimphu, Paro and Haa)

Item	Thimphu	Paro	Haa
Production amount (cft/y on 2013)	Middle (135,000)	Small (338,000)	Large (503,000)
Location of Factories, Depo etc.	Factories are scattered.	Factories are scattered.	Factories, Depo, FMU are closed.
Potential of waste	Sawdust is utilized as briquettes	Sawdust is not utilized	Sawdust is not utilized
Demand of heating	High	High	Very High (coldest)

Source: JICA Survey Team

Based on the results of the survey, the potential quantity of biomass resources, supply of biofuel, and the point of effective utilization were considered, and it became clear that a Haa point was advantageous. Agreement was reached for making a comprehensive judgment that Haa is promising for a pilot project, as a result of repeated deliberations between DRE, MoAF, and NRDCL based on the results of this survey.

7.4.3 Organization Chart for Promotion of Biomass Generation Systems

The planning and proposal of projects regarding biomass energy are mainly conducted by the Bio Energy Section in the Alternative Energy Division of DRE. Existing pilot projects and donor projects like ADB are handled by the Research and Development Division. In the case that a project is proposed in this survey, Mr. Mewang of DRE would be the final decision maker who has the authority to implement a budget for each verification project regarding renewable energy. At the implementation stage of the project, the Bio Energy Section in the Alternative Energy Division would possibly be an agent for implementation.

7.4.4 Current Situation of the Promotion of Biomass Generation Systems

(1)RGoB and international aid organization's activity

The RGoB has set a target to install 5MW biomass generators by 2025 in its "Alternative Renewable Energy Policy 2013". To achieve the target, a biomass gasification generation project is examined in the "Bhutan Sustainable Rural Biomass Energy (SRBE)", via a United Nations Development Programme fund. (The project is planned to be tendered and to be installed and operated in 2014.)

MRE and MOE have been exceeding SRBE with 4 million dollars funded by UNDF, GEF and ADB. This program period is set at 3 years (2011-2013) and the aim of SRBE is to acquire the effective utilization of forest resources. Therefore, this program is composed of 3 issues, 1) establishment of basic policy related to the effective utilization of biomass, 2) exceeding alternative practice, 3) capacity building.

With regard to 2) above, the following 3 projects have been examined, ① 20,000 energy-efficient stoves in rural households for space institutions for space heating and cooking, ② wood briquetting technology for production fuels, ③ Biomass gasification for electricity services.

(2) Current status and trends of foreign companies' movements

Recently, Indian manufacturers have advanced remarkably into Bhutan in the area of power generators, agricultural machines and briquetting machines etc. In the JICA Survey Team's interview for DRE and the Agricultural Machinery Center (AMC*), they explained the situation whereby local manufacturers have not grown enough in Bhutan, and whereby Indian manufacturers have an advantage geographically when supplying machinery parts and maintenance systems as the background of Indian manufacturers' remarkable progress. In addition to that, Indian manufacturers have received high acclaim by RGoB, due to their full support systems from facility installation and O&M to capacity building, as they dispatch their instructors to Bhutan for teaching local staff directly.

As RGoB has observed some cases where local Bhutanese staff experienced difficulties in repairing advanced systems implemented by international aid organizations. RGoB has a strong will to implement systems that can be operated on their own for sure, and this could mean implementing "low technology".

The following table shows the companies nominated by SRBE as biomass gasification manufacturers.

*AMC is MoAF's branch, which deals with and leases agricultural machines, and provides machine parts to farmers.

Table 7-36 Gasification Manufacturers

No.	Name of Gasifier Manufacturer	Location/Country
1	AHT Pyrogas Vertriebs GmbH	Germany
2	Ankur Scientific Energy Technology Pvt. Ltd.	Vadodara, India
3	Associated Engineering Works	Tanuku, India
4	B9 Energy Biomass Ltd.	United Kingdom
5	Babcock Borsig Power, Austrian Energy	Austria
6	Babcock Wilcox Volund	Denmark
7	Battelle Columbus Laboratories, BCL	United States
8	Beijing Green Globe Energy Co. Ltd.	Beijing, China
9	BG Technologies, LLC	United States
10	Bioflame Ltd	United Kingdom
11	Biomass Engineering Ltd	United Kingdom
12	C.C.T. SPA	Italy
13	Carbona Corp. USA	United States
14	Carbona Inc.	Finland
15	Chevet	France
16	Condens Oy	Finland
17	Cosmo Products	Raipur, India
18	Costich Company	United States
19	Chugai Ro Co.	Japan
20	Danieli Ambiente S.R.L.	Italy
21	Electrotech	Mohali, India
22	Ensofor SA	Switzerland
23	FERCO	United States
24	Foster Wheeler Energia Oy	Finland
25	Future Energy GmbH	Germany
26	Gas Energietechnik	Germany
27	Girnar Chemicals and Gas Industries Pvt. Ltd.	Ahmedabad, India
28	Grain Processing Industries (India) Pvt. Ltd.	Kolkata, India
29	Grubl	Austria
30	Huairou Gasification Equipment Manufacturer	Beijing, China
31	Imbert GmbH fur Energie und Umwelt	Germany
32	Janata Refractory and Steel Rolling Mills	Ghaziabad, India
33	Jiangxi Peako Biomass Energy Co. Ltd.	Jiangxi, China
34	KARA Energy Systems BV	Netherlands
35	Kemestrie's Inc -BIOSYN	Canada
36	KN Consult ApS	Denmark
37	Krupp Uhde GmbH	Germany
38	Liaoning Energy Resources Co. Ltd.	Liaoning, China
39	Lurgi Energie und Umwelt GmbH	Germany
40	Martezo	France
41	MELIMA	Switzerland
42	M/S Chanderpur Works	Yamuna Nagar, India
43	Netpro Renewable Energy (India) Ltd.	Bangalore, India
44	NOELL-KRC Energie und Umwelttechnik GmbH	Germany
45	PRIMENERGY, Inc	United States
46	PRM Energy Systems Inc	United States
47	Procone Vergasungssysteme GmbH	Switzerland
48	Puhdas Energia Oy	Finland
49	rgr ambiente srl	Italy
50	Rheinbraun	Germany
51	Robb Walt	United Sates
52	Shijiazhuang Huadu Energy and Equipment Co. Ltd.	Hebei, China
53	Shunsheng Gasifier & Heat Supply Equipment Factory	Beijing, China
54	The Energy Resource Institute	New Delhi, India
55	Thermochem Inc (MTCI)	United States
56	Thermogenics Inc.	United States
57	Third Generation, Ltd	United Kingdom
58	TK Energi AS	Denmark
59	TPS Termiska Processer AB	Sweden
60	Ventec Waste to Energy Ltd	United Kingdom
61	VER GmbH	Germany
62	Wellman Process Engineering Ltd	United Kingdom
63	Xylowatt SA	Switzerland

Source: SRBE Report

7.4.5 Economic Aspects

(1) Economic evaluation

Related to the biomass gasification generation project, an economic evaluation has been delivered by SRBE to secure subsidies to reserve the benefit of the private sector, such as sawmill factory owners. In this evaluation, it is assumed that a 40kW gasification generation system will be installed in the sawmill factory (600cft/day timber production) and all electricity from the system will be used on this site. (The system's waste thermal usage is not assumed.) The conclusion of this evaluation shows that the simple payout period is 15 years and the PIRR is -4.02% in the case that the sawmill owner invests in all of the system cost. Due to this conclusion, SRBE suggests that financial support as an incentive for the sawmill owner is necessary to install biomass. There will be several support measures for the sawmill owner such as 1) Grant for capital expenditure, 2) Subsidy on interest rate, 3) Partial guarantee on loan, 4) Technical assistance, 5) Combination of the above. Among the above measures, SRBE have selected 1) and have assumed a 50% subsidy for investment in the system. Due to such subsidies, the simple payout period and PIRR will be improved to 11.93 years and 3.71% in SRBE's evaluation.

Table 7-37 Financial Analysis of the Gasification Plant (SRBE)

- Wood waste (for energy use) : 25 tonnes/month (not all of amount is used)
- Operating hours/day, days/week : 8 hours/day, 6 days/week
- Annual electricity generation : 78,000kWh

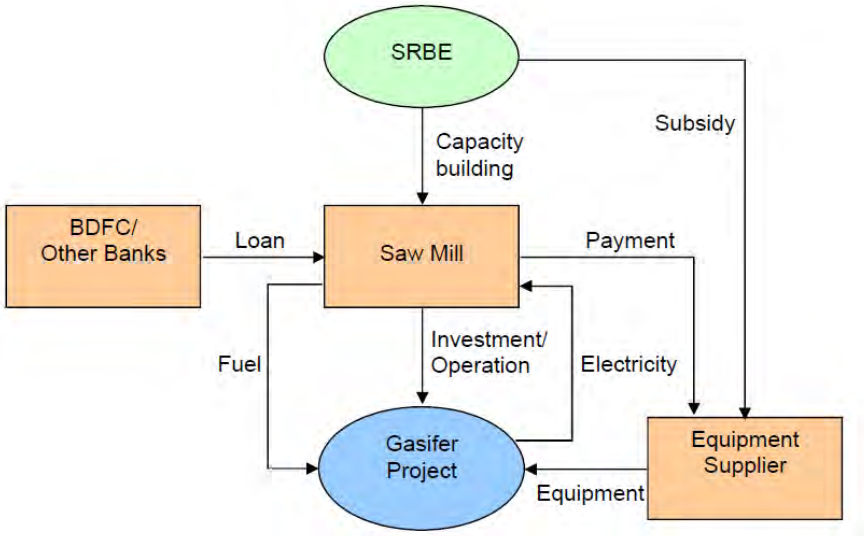
Unit: USD

Item	No grant	With 50% grant
Investment for the Gasification and Power Generation Plant		
Development and permits	1,500	750
System (Gas Engine, Generator, etc.)	37,000	18,500
Balance of Plant, Excavation and Civil works	3,700	1,850
Site Preparation and Offices	500	250
Design, Engineering, Supervision etc.	4,000	2,000
Mobilization and Start-up Costs	1,000	500
Import Duty (1% of Foreign EPC cost)	259	120
Construction time insurance (0.5% of EPC cost)	205	104
Contingency (10% of Total Investment cost)	4,816	2,408
Total Investment Costs (USD)	52,979	26,489
Operating costs for the Gasification and Power Generation Plant		
Administration	600	
Operation and Maintenance	814	
Insurance (0.25% of EPC cost)	112	
Total Operating Costs (USD)	1,526	
Cost Savings for Gasification and Power Generation Plant		
Purchased electricity from Grid	3,203	
Total Cost Savings (USD)	3,203	
Nominal Pre-Tax Project IRR (%) – 17yrs	-4.02%	3.71%
NPV – Cash Flow Before Interest and Tax	36,124	9,634
Simple Pay-back Period (yrs)	15	11.93

Source: JICA Survey Team from SRBE Report

(2) Procurement

It is assumed by DRE that international tendering for turnkey (EPC) contracts including design/procurement /construction will be held where biomass gasification generation projects should be done. DRE will examine technical and economic feasibility of this project in the specific site this year, and will set the selection standard of EPC supplier after they decide the rate of subsidy.



Source: SRBE Report

Figure 7-64 Business Model of the Gasification Plant (SRBE)

7.4.6 Application Possibility and Environmental Advantage

Based on the above potential survey, the possibility of biomass energy application and effects for solving environmental issues are considered as follows.

(1) Possibility of biomass energy usage

From the potential survey, it is clear that the possibility of wood biomass usage is high. There are various options of usage.

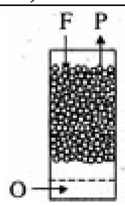
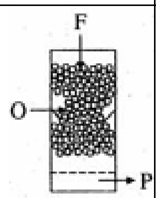
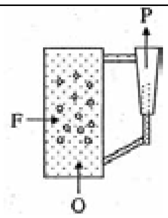
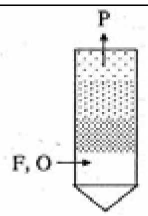
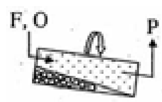
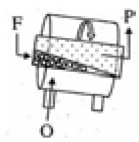
(a) Electricity Generation

Wood biomass generation technologies are mainly divided into 2 types, ① Gasification generation systems, and ② Direct fired systems. ① has complex system components compared with ②, but ① can be set in a compact space and can achieve high output in spite of small capacity. Therefore, ① can be applied in small scale projects which can not collect enough resources.

There are various types of furnace in ①. For wood biomass utilization, 4 types of gasification furnace (fixed bed, fluid bed, entrained bed, rotary kiln) are adopted. Nevertheless, the gasification reaction period is relatively long and ① will generate much tar due to the low temperature of the furnace (600℃).

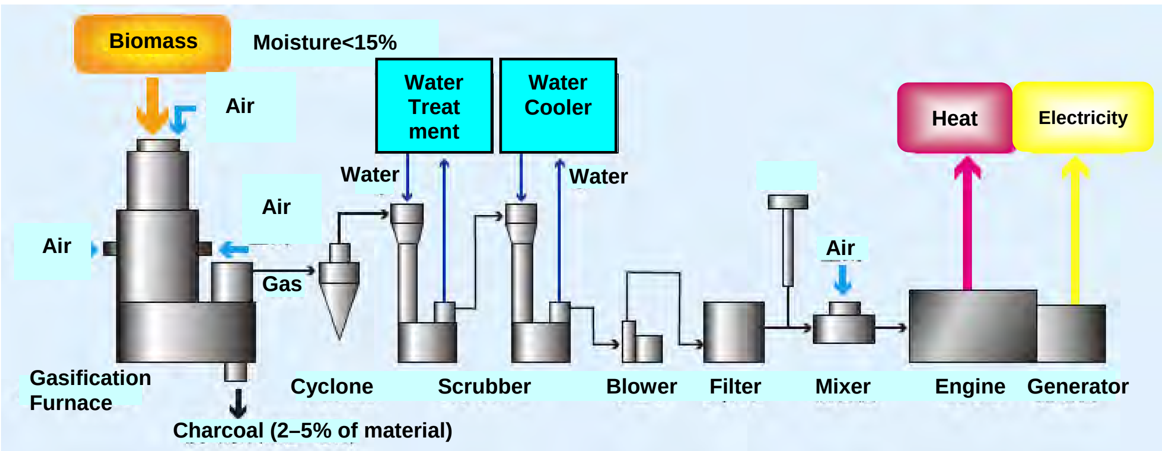
In the case of this small project, there is a high possibility that the downdraft type of fixed bed will be adopted, due to the compact size and lower tar generation among the fixed bed. The JICA Survey Team will examine eligible technology through domestic seminars and interviews of domestic manufacturers.

Table 7-38 Gasification Furnace

Type	Fixed Bed		Fluidized Bed	Entrained Bed	Rotary Kiln	
	Updraft	Downdraft			Internal heating	External heating
Gas heat	100-300 ℃	600-800℃	500-900℃	1,000-1,200 ℃	800-950℃	650-800℃
Fuel detention period	Long	Long	Middle	Short	Long	Long
Calory of generated gas	Low	Low	Middle	Middle	High	High
Generated tar	10-30g/m3	0.5-3g/m3	1-10g/m3	＜0.1g/m3	1-10g/m3	1-10g/m3
Difficulty of operation	Easy	Easy	Average	Difficult	Average	Easy
Scale	＜2,000kW	＜500kW	200kW＜	1,000kW＜		＜600kW
Image						

Source: NEDO Biomass energy installation guidebook

The biomass generation system manufactured by SATAKE Corporation (Higashi Hiroshima city, Hiroshima Pref.) is an example. This system includes a down-draft type gasification furnace, and syngas is used by the engine with the generator. Actual plants from 20kW to 1,500kW are in operation. Various types of biomass could be used.



Source: SATAKE Corporation

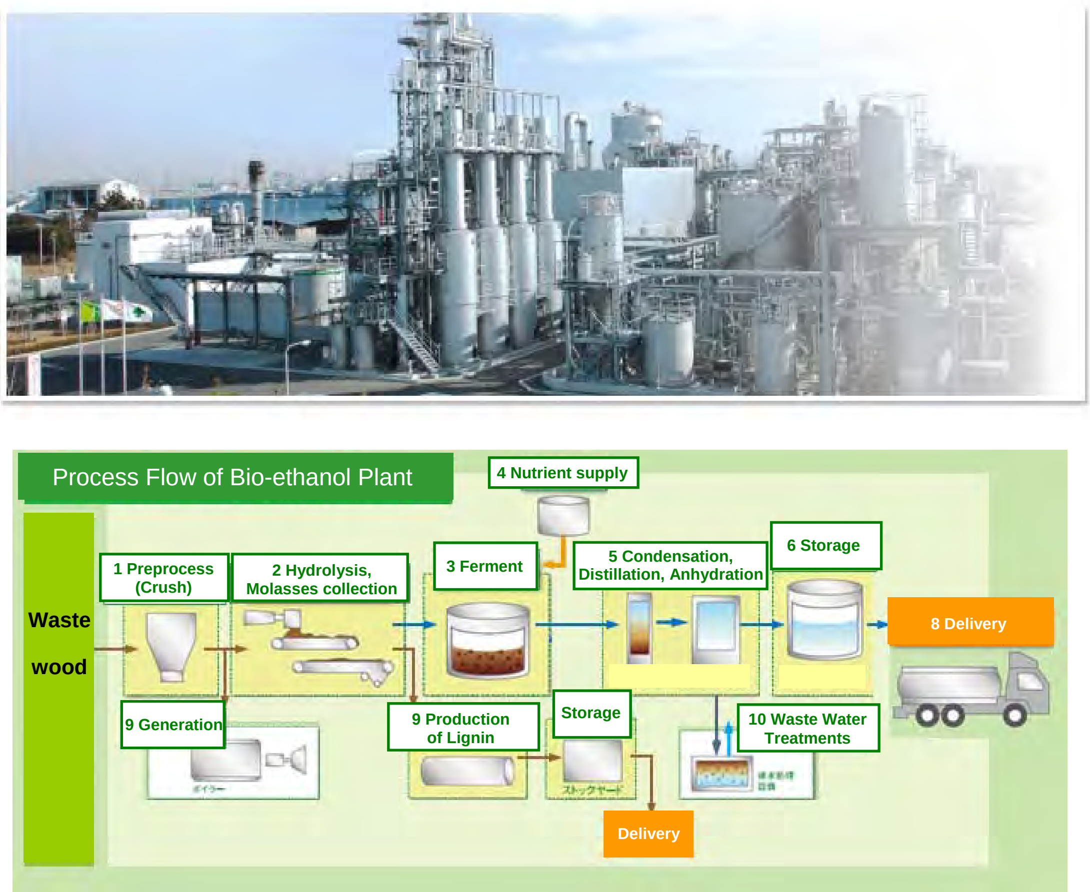
Figure 7-65 Example Diagram of Biomass Gasification Generation System

(b) Fuel

In Bhutan, the electricity tariff is low, and most of the sawmill factories are of a small scale with a small amount of electricity consumption. This means that the usage of biomass for electricity is not the best option. On the contrary, the price of fossil fuels, like petrol for vehicles, is high because it depends on imports, so that it is more effective than the biomass materials for alternative fuel. Practically, there is a technology to produce alcohol fuel (bio-ethanol) by fermenting biomass materials, and currently there exists not only a laboratory scale but also a commercial level plant.

Compared with other biomass materials, it is difficult to ferment wood biomass to produce bio-ethanol. However, as a result of development by gene recombination, it has recently become possible to produce bio-ethanol from wood biomass, and a middle scale plant is in operation in Japan. Produced bio-ethanol could be used directly as an alternative fuel to petrol for vehicles and lead to lower consumption of fossil fuel.

An example plant producing bio-ethanol is in operation by DINS SAKAI Corporation (Sakai city, Osaka) with a capacity of around 180 t/day of wood biomass.



Source: DINS SAKAI Corporation

Figure 7-66 Example Bio-ethanol Production Plant from Wood Biomass

It could be worth studying to apply this wood bio-ethanol production plant in Bhutan. The issues which should be solved are the application of suitable scale with the amount of biomass production, and the capacity building (strengthen the technical level of the operation and maintenance engineers) etc.

By just a simple calculation, assuming that this facility could produce 30 liter of bio-ethanol from 1 ton of wood biomass, according to current production from Table 7-29, around 500,000 cft of biomass could be produced from 2,000,000 cft of timber production annually, and it means over 200 kl/year of bio-ethanol could be produced which could achieve around 20% of the target value in AREP2013 (refer to P.3-3). The issues should be solved are, the application of suitable scale with the amount of biomass production, the capacity building (strengthen the technical level of the operation and maintenance engineers) etc.

(2) Possibility of improvement in environmental problems by using biomass energy

According to the potential study, it is clear that in the agricultural and livestock sectors, the waste is effectively utilized, and therefore there is no major environmental problem regarding waste treatment. On the contrary, wood biomass is not effectively utilized, except for sawdust in Thimphu, which is utilized in making briquettes. It is clear from the survey that there are piles of sawdust and residue in every sawmill factory and it makes a worse labor environment. Some factories dispose of them illegally in rivers. In such a situation, the application of the effective use of biomass materials leads not only to effective utilization of energy but also to an improvement in the labor environment and inhibition of illegal action, so it helps to solve environmental problems. In order to realize this in a harmonious way, application of low cost and simple facilities will be needed.

7.4.7 Necessity of Future Study for the Project Implementation

In this survey, mainly the study by data collection is conducted in order to grasp rough potential. In the future, for more accurate study such as formulation of master plan, the detail study for each step is needed. The following figure shows the example of study flow for the project implementation.

1. Potential Study for All of Biomass

<Agriculture, Livestock, Forest, Municipal Waste>

- Waste generation
- Current situation of waste utilization
- Needs of operator (Trouble in disposal etc.)

2. Detail Potential Study for Specific Biomass

<For forest sector (wood biomass)>

- Detail study about ratio of timber and waste from raw log
- Detail study about ratio of product log and non-product log in the forest
- Quality study of sawdust and residual wood (constituent, water contain etc.)

3. Study of Aggregation and Transportation of Biomass

<Formulation of base condition for biomass utilization>

- Study of optimum aggregation method of sawdust and residual wood in the sawmill factories
- Study of aggregation and transportation method of timber branches, non-product log from forest
- Study of transportation method between sawmill factories

4. Demand Study

<Actual demand and forecast study of biomass energy>

- Electricity demand
- Heat demand
- Fuel demand

5. Optimum Equipment Selection, Development Plan Formulation

<Selection and Scheduling with reliability and sustainability>

- Selection of optimum equipment according to biomass amount of securement and requisite
- Study of incidental equipment (transmission line between sawmill factories etc.
- Formulation of specific development plan according to demand scenario

6. Study of Cost and Economic Analysis

<Evaluation of business operation>

- Data collection about equipment cost
- Formulation of cost calculation method according to the type and size
- Economic analysis for the business

7. Study of Operation and Maintenance

<Formulation of O&M method for guiltless equipment>

- Study of necessary technology for operation and maintenance
- Study of technical learning method and human resource development

Figure 7-67 Example of Study Flow for the Project Implementation

Chapter 8 Study for Specific Project

In this chapter, the JICA Survey Team identifies the concrete projects in order to verify the possibility of the renewable energy use studied in the preceding chapter and to indicate the cost level and issues in renewable energy development. It is needless to say that detailed study is necessary when an actual project is executed because the study is very rough in this report.

8.1 Photovoltaic Generation Project

The plan of a rural electrification project by SHS is the only ongoing project, which is described in Chapter 7.1.2. At present, other plans for rural electrification projects by SHS do not exist. Only the study for grasping the exact situation of the already installed solar panels for achievement of 100% electrification is planned.

The mega solar project is described in this chapter.

8.1.1 Outline of the Project

Based on the draft of the Eleventh Five Year Plan in Bhutan, a mega solar system, with an installed capacity of 1 MW, is planned to be installed in Bumthang by DRE.

Source: Google Earth

Figure 8-1 Candidate Site of Photovoltaic Generation project

8.1.2 Outline of the Candidate Site

The candidate site is Shingkhar, which is about 20 km in a straight line and 40 km along the road from Jakar in Bumthang to east-northeast. The coordinates are 27 30'15" N and 90 57'25" E, and the altitude is about 3,500m. It is an unused slope area of about 7.7% facing south-southwest, a wetland area with huge patches of marshes across the area. There is a land assessment report by MoAF in 2011, titled “FIELD ASSESSEMENT REPORT, Shingkhar, Ura, Bumthang”. According to this report, the area is highland, with a minimum temperature from -1.5 to 10 ℃, maximum temperature from 7 to 15 ℃ and annual rainfall of 1,100mm. And an on-site survey has already been conducted by DRE. The candidate site is shown in Figure 8-1. Square shading on Figure 8-1 is the proposed area, measuring 125,000 m^2.

The proposed area is government land and the buffer area of a protected area, and there are no residents.

The proposed area is located near an unpaved road and about 1.3 km away from the closest 33 kV distribution lines, with a line size of about 50mm^2. Moreover, Bumthang is an area where the amount of solar radiation is relatively high, so the proposed area can be considered as an appropriate choice for the installation of a mega solar system in Bhutan.

North side of Candidate Site

South side of Candidate Site

Candidate Area

Access Road for Candidate Site

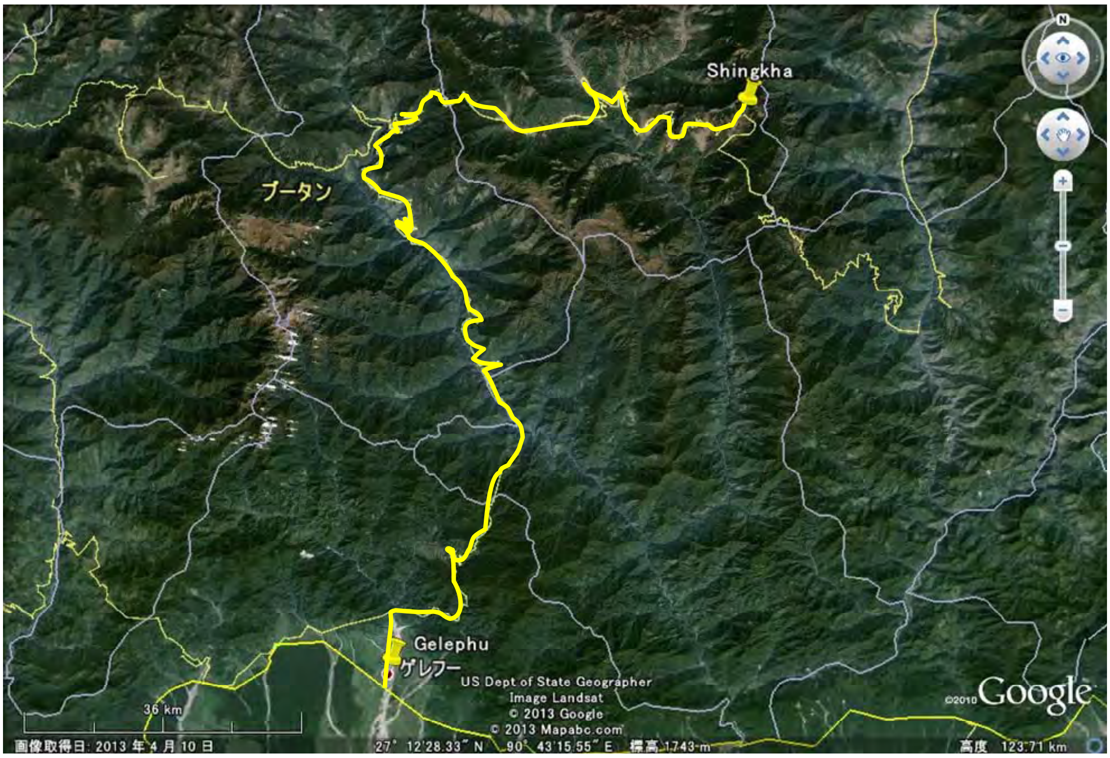
Access Road for Candidate Site

33 kV distribution line

Source: JICA Survey Team

Figure 8-2 Photo of Candidate Site

Since equipment and materials need to be transported via Trongsa and Jakar from Gelephu, they are carried by track.



Source: Google Earth

Figure 8-3 Photo of Candidate Site

Main Road **Main Road** **Entrance of Unpaved Road**

Source: JICA Survey Team

Figure 8-4 Photo of Access Road

8.1.3 Need for Development

First, this candidate site is an important and suitable area for achievement of the target of the draft Eleventh Five Year Plan. Moreover, since an on-site survey has already been conducted by DRE, the Bhutan administration officials' concern is high and the possibility of realization is high. The budget for implementation of this project is not yet proposed, but assistance from the Energy+ is expected.

Furthermore BPC has begun to study the grid connection with the mega solar system, but this project is the first mega solar project in Bhutan, so they need the assistance for this study.

It can be said that all conditions except the source of funds are ready. However, since there is little actual measurement data in order to design the photovoltaic generation plant, it is necessary to acquire actual measurements of solar radiation data for at least one year.

8.1.4 Feasibility of the Technical and Economic Aspects

The total system output and total array area of a mega solar system can be calculated via the rated output per photovoltaic panel, photovoltaic panel size and installation number of photovoltaic panels. The formula is shown below.

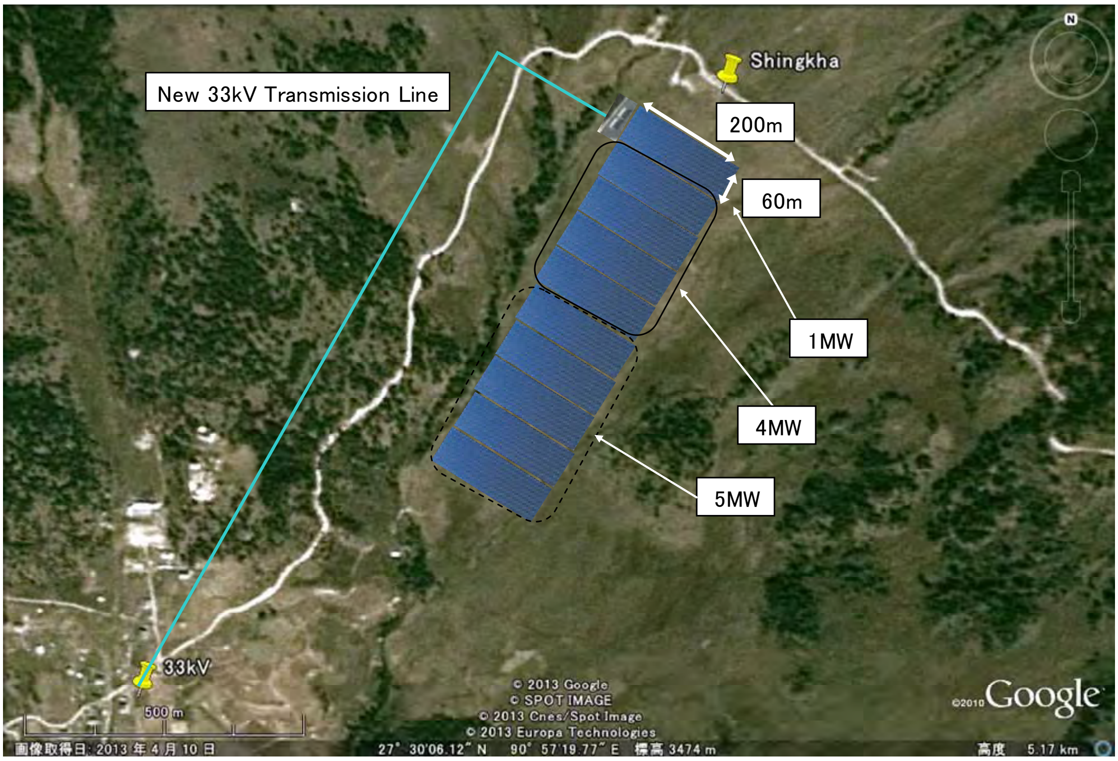
Total system output (kW) = Rated output per photovoltaic panel
× installation number of photovoltaic panel

Total array area (m^2) = photovoltaic panel size × installation number of photovoltaic panel

However, the area required for the mega solar system not only acquires an array area but also other facilities such as PCS, transformer and an administration building. Since the distance between arrays is set up in consideration of the inclines of the array and the shadows by a front array in the actual installation, the necessary area is about 10 - 15 m^2 / kW, so 10,000 to 15,000 m^2 is needed for one MW mega solar system. The proposed area is 125,000 m^2, which is enough space for installation of one MW mega solar system.

When a required area of one MW is calculated on condition of the following, Total array area is needed for about 12,000m^2. An image of a mega solar system arrangement is shown in Figure 8-5, including other equipment such as PCS, transformer and an administration building. And a 5 MW mega solar system, which is the minimum installation target by 2025, can also be installed in the area in the future. Moreover more than a 10 MW mega solar system can also be installed in the area.

- Transportation, installation and other services: 10% of material cost, past record in “Project for up gradation of 220/66/11kV Semtokha Substation”
- Operation and maintenance: 1% of material cost, “Technology Roadmap, Solar photovoltaic energy”, IEA
- Photovoltaic array direction and angle: South, 20 degrees
- Photovoltaic panel maximum nominal output: 190W
- Photovoltaic panel operating voltage: 35V
- Photovoltaic panel size: 1,600mm×800mm
- Photovoltaic panel arrangement: 3 rows×10 columns
- Photovoltaic array height: 1,500mm



Source: Google Earth

Figure 8-5 Image of Mega Solar System Arrangement

The power generation by photovoltaic panels is calculated by the following formula.

$E_p = P \times H_m \times K_t \times \eta_{ino} \times K'$

P: Capacity of photovoltaic panels (kWp)

E_p: Monthly power generation (kWh/month)

H_m: Average monthly solar radiation (kWh/m2/month)

K_t: Modification coefficients of temperature

η_{ino}: Power conditioner efficiency

K’: Other efficiency

The conditions for the trial calculation are shown in Table 8-1. In addition, each data is referred to from the following data and report.

- Solar radiation data: average solar radiation data at new on-line observation points in Thimphu in 2012
- Modification coefficients of temperature: JPEA reports
- Efficiency of power conditioner: JPEA reports
- Material cost of small-scale solar system: “COMPETING IN THE ENERGY SECTOR ON THE ROAD TO COMPETITIVENESS”, EPIA
- Transportation, installation and other services: 10% of material cost, past record in “Project for up gradation of 220/66/11kV Semtokha Substation”
- Operation and maintenance: 1% of material cost, “Technology Roadmap, Solar photovoltaic energy”, IEA

Table 8-1　Conditions for Trial Calculation

Item	Value
Photovoltaic capacity (kW) : P	1,000
Modification coefficients of temperature : Kt	0.90
Efficiency of power conditioner : ηino	0.90
Amount of solar radiation per month (kW・h/month) : Hm	165
Other efficiency : K’	0.99
Material cost of small schele solar system (USD/kW)	3,110
Transportation, installtion and other services (USD/kW)	311
Operation and maintenance (USD/kW/year)	31.1

Source: JICA Survey Team

From the calculation, the monthly power generation is about 134,719 kWh / month, so the yearly power generation is about 1,616,630 kWh / year. Since the electric rate of medium voltage in Bhutan is 1.79 Nu/kWh, the annual electricity bill saving which can be produced by photovoltaic generation is 2,893,768 Nu (48,402 USD).

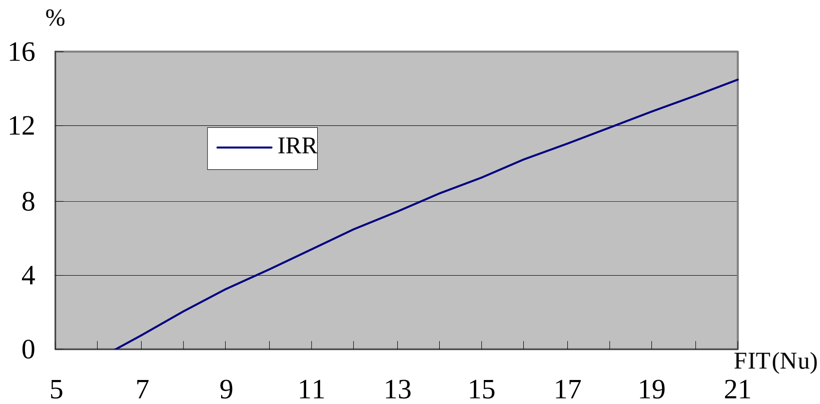
Since the initial investment of the one MW mega solar system is 3,421,000 USD, the initial investment is unrecoverable within the durable period of the solar system. In the present situation where FIT has not been introduced, the mega solar system does not have economic efficiency.
Next, when the FIT of 6.42 Nu is introduced, it will take 20 years to recover the initial investment. When FIT of 6.42 Nu or more is introduced, considering the 20-year life of the solar system, the total project benefit becomes positive.

Table 8-2 Result of Trial Calculation

Item	Value
Power Generation per month (kWh)	133,000
Power genaration per year (kWh)	1,600,000
Electricity rate for MV (Nu/kWh)	1.79
Saving amount of money per year (Nu)	2,870,000
Saving amount of money per year (USD)	44,200
Pay back period without FIT	261
FIT(Nu)	6.42
Pay back period with FIT	20

Source: JICA Survey Team

Furthermore, the relationship between the FIT and the internal rate of return for 20 years is shown in Figure 8-6. It is necessary to determine the amount of suitable FIT within DRE.



Source: JICA Survey Team

Figure 8-6 Relationship between FIT and IRR

Regarding the CDM, if it can use the same methodology which is applied to large-scale hydraulic power generation in Bhutan, the application to CDM might be possible.

It is thought that BPC operates and maintains the mega solar photovoltaic generation plant after commercial operation. However, since BPC does not own photovoltaic generation plants, it does not have the know-how for the operation and maintenance of a photovoltaic generation plant. Therefore it is necessary to train the BPC staff in the operation and maintenance of a photovoltaic generation plant.

8.1.5 Grid Connection

A connecting point is located at the end of the existing 33 kV distribution line (Tang/Ura feeder of Garpang substation, line length: approximately 33 km), and approximately 1 km away from the candidate site. Since it becomes a double-ended source from the aspect of the power system, it might be effective in respect of voltage drop mitigation of the end of the distribution line. For a “Mega Solar”, however, since a large-scale PV power plant is intensively connected to a power system, the influence of voltage fluctuations on stable system operation will be of particular concern. Therefore, the maximum voltage fluctuation, which means that output is changed from the maximum to zero or is changed from zero to the maximum, is roughly estimated in the case of grid connection with a “Mega Solar” of 1 MW at the initial project stage, 5 MW and 10MW at the expanded project stage to the end of this distribution line. Then, the amount of voltage fluctuation (ΔV) is approximately calculated by the following formula, if power flow change is set to ΔP and ΔQ.

$$\Delta V \cong -(R\Delta P + X\Delta Q)$$

where R is the line resistance and X is the line reactance.

The result of the estimation is shown in Table 8-3. The maximum voltage fluctuations for a PV power generation output of 5 MW is 9%, which is within the limits of voltage variation (±10%) regulated in “DISTRIBUTION CODE 2008”. In addition, as a reference, the maximum voltage fluctuation can be reduced if a large-sized (from Rabbit to Dog) conductor is adopted.

Moreover, when the maximum voltage fluctuations for a PV power generation output of 10 MW is 18%, which is out of the limits of voltage variation, since it is difficult to connect the grid in respect of line capacity, adoption of a large-sized conductor will be necessary in respect of line capacity. In addition, the voltage fluctuation is 10%, which is within the outer limits of voltage variation.

Table 8-3 Rough Estimation Result of Maximum Voltage Fluctuation at Connecting Point

		Existing	(As reference) Large-sized conductor
Type of conductor		Rabbit (ACSR 50mm^2)	Dog (ACSR 100mm^2)
Line capacity		10.5MW	16.3MW
Capacity of “Mega Solar”	1MW	2%	1%
	5MW	9%	5%
	10MW	18%	10%

Note: Current rating is 193A for Rabbit and 300A for Dog.
Line resistance is 0.54Ω/km for Rabbit and 0.27Ω/km for Dog.
Line reactance is 0.35Ω/km for Rabbit and 0.32Ω/km for Dog.
Q is assumed to be 0.2P.

Source: JICA Survey Team

In order to mitigate the voltage fluctuations from a "Mega Solar", there exist methods of absorbing and evacuating rippling power with a storage battery or restricting power generation output, etc. In the former, the facility cost becomes high, and it becomes impossible to use energy effectively in the latter. In recent years, for the latter, a function of controlling voltage fluctuation resulting from the power generation output of a solar cell has been developed, by evacuating the appropriate reactive power, which can be automatically controlled from the inverter for grid connection, with an effective power by generation according to the state of a power system.

8.1.6 Potential for Utilizing Japanese Technology and Partnering with Japanese Companies

If the grant aid from JICA becomes the source of this project fund, Japanese companies can join this project. Moreover, DRE plans to extend this mega solar photovoltaic generation plant from 1 MW to 13MW in the future. Therefore if Japanese companies join this 1 MW project as a pilot project, it is expected that they will have an advantage at the time of expansion.

8.1.7 Information on Environmental and Social Considerations

(1) General Information

The candidate site for mega solar is located in Shingkhar Village Ura Geog, Bumthang Dzongkhag, 10 km away from the downtown Ura District. Also, since the site falls in the buffer zone of Thrumshingla National Park, development projects are not restricted in this area[23]. Every winter from October to March, the area is covered with snow. The project site is situated in the northeast side from Shingkhar village (Refer to Figure 8-7). Near the site, there is a feeding station for cattle which MoAF manages to study feeding cattle with mineral-containing food.

Source: MOAF "Field Assessment Report (Shingkhar, Ura, Bumthang)"

Figure 8-7 Mega solar Candidate Project Site Map in Shingkhar

[23] In the survey, another site in Pangkhar, proposed by Gup of Ura Geog, which is near Gup's office, was investigated for comparison, but this site could not be reviewed as a candidate one due to the following reasons. According to the Park Ranger of Thrumshingla National Park, local people would be strongly against development projects because there are sacred rocks inside the site which are respected by local people. In addition, the site does not have much technical potential.

According to local stakeholders[24], around 2011 there used to be a golf course construction project. However, the project was cancelled due to objection from villagers in Shingkhar and wetland conservation. As a result of the study, the site is watershed, and pesticide spraying for lawn maintenance on the golf course makes an influence on fauna, flora and soil.

(2) Natural Environment

The site is categorized into wetland and 5 streams run though the site as shown in Figure 8-8. Local people call the land "Mercy Land" because there are rich water resources. According to "Field Assessment Report (Shingkhar, Ura, Bumthang)" (2011) by Watershed Management of MoAF, at the time of examining the golf course development project, the site was the water source of three main rivers, Phawjan chhu, Bungtawa chhu and Jarotpa chhu, which join downstream with Liri chhu, where there is a mini-hydro power plant in Ura Geog.

Figure 8-8 Stream in the candidate site in Shingkhar

Therefore, especially during the construction of a mega solar plant, it is necessary to consider avoiding causing impact on those rivers, especially at the construction stage.

In the range of the candidate site, there is grassland but no forest. The current situation of the fauna and the flora is described as follows, based on the interview with the Park Ranger and the survey report of MoAF.

- Birds: migratory birds rarely come to stay around the site. Tragopan, Himalayan monal and Blood Pheasant have been seen in winter and those birds come to drink water and take a rest, not to settle their nests. The MoAF report states that 26 birds have been seen around the site,
- Mammals: Not many mammals are seen except for wild yaks. The MoAF report describes that there are bears and wild boars,
- Flora: shrub, bamboos, pines, Halenia elliptica, Dorsera peltata and others have been found. There are some flora categorized into medical herbs,
- Insects: regarding butterflies, Indian Cabbage White has been found.

(3) Issues for Environmental and Social Considerations at the Project Implementation Stage

As a result of rapid investigation for this moment, the survey team did not find any serious issues to reconsider the project development.

From the viewpoint of the natural environment, it is assumed that there are few effects caused by the equipment of the mega solar project. While mammals have not been seen so much, birds will need

[24] Several interviews with Gup of Ura Geog, former Assistant Gup, Park Manager and the Park Rangers of Thrumshingla National Park were conducted.

to be surveyed in terms of further details by local experts. In addition, it is necessary to consider at the construction stage that there are streams as water resources.

Regarding social considerations, although the land is owned by the government, it is required that land utilization is discussed carefully with local people in the case of project implementations which require occupying a certain large scale of the land, since the land has been used for grazing of livestock as support for villagers' livelihoods. If the discussion with local people is focused on the land for 1MW class, which is in the first target, it would be relatively easy for them to understand and agree with. Therefore, the capacity of expansion will be decided through discussion and review with local people after the 1MW pilot project.

It is better to take into consideration the benefit for local people in a feasible context, because the candidate site has been used for local people's activities even though it is a part of this. For instance, there are some measures such as prioritized employment of local people on the construction stage and any arrangements that a part of the revenue from electric power sales or a part of the electricity for gratis can be utilized for local development[25]. Since there are a school, a health clinic, and also a milk processing facility constructed by the village, it can be considered to use them for operation costs for such facilities which benefit the whole village. If the project is conducted as a grant assistance project, that could implement such arrangements more easily.

8.2 Small Hydropower Project

8.2.1 Outline of Small Hydropower Project

There are new development projects and rehabilitation projects for a small hydropower project.

(1) New development project

There are many potential hydropower sites in Bhutan. Small hydropower plants can be introduced to a number of potential areas if there are sufficient funds for the hydropower development.

(2) Rehabilitation project

About 20 small hydropower plants are in operation. However, some of the equipment in these hydropower plants is old and rehabilitation work is planned to be carried out. Some hydropower plants will be abolished in consideration of economics. BPC, which has the existing small hydropower plants, decides the priority of rehabilitation projects in consideration of the following points.

- Power plant output
- Back-up (when the power plant stops, other plants or methods can supply electricity instead)
- Importance (for example, the power plant is near important national facilities)

[25] This was also the opinion of the Alternative Energy Division, MOEA.

The priority to rehabilitate the Thimphu mini and Chenary hydropower plants is high for BPC in consideration of the above points. In this chapter, the rehabilitation work for Thimphu mini hydropower plants is described from the point of view of using unused energy.

8.2.2 Outline of the Candidate Site

(1) New development project

It is possible to develop small hydropower in any districts in Bhutan because there are many hydropower potential. In this chapter, Khoma site is described as candidate site which was selected from the 12 sites in Table 7-14.

(a) Rationale to select and specification of hydropower plants

- Output: 4,170kW
- Head: 150m
- Maximum discharge: 3.94m3/s
- Construction cost: USD 7.7 million (1,849 USD/kW) (not including transportation and transmission equipment cost)

Power output is more than 1,000kW. Foreign companies can take part in a project for hydropower development which has an output of more than 1,000kW. Compared with other candidate sites, the construction cost of this site is not expensive.

(b) Outline of hydropower plant

Khoma site is located at Khoma Chhu, which is a tributary of Kuri Chhu (Manas Chhu). Arrangement of the powerhouse, intake facility, headrace and penstock is examined in reference of a topography map on a scale of 1:50,000. Water is taken from an intake facility located approximately 3km upstream of the point where Khoma Chhu meets Kuri Chhu. The water runs through the headrace which is approximately 900m long and is located along Khoma Chhu. Next, the water flows within the penstock and hydro turbine in the powerhouse. Turbine and generator make electricity by hydropower. Finally, the used water returns to Khoma Chhu.

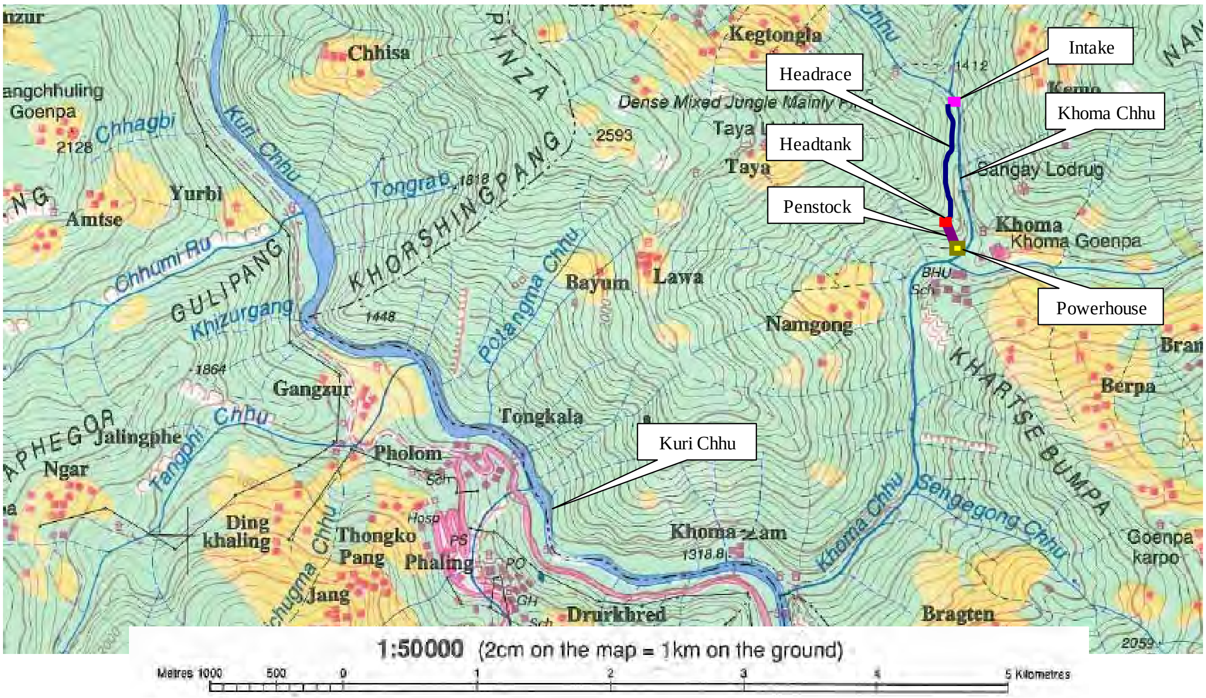


Figure 8-9 Candidate site (Khoma site)

According to the map study, headrace length is estimated as follows. Effective head is calculated to 150m.

Headrace length: 900m

Penstock length: 212m

(c) Estimation of construction cost.

Catchment area at intake is 55.63km2 and discharge of 1.356m3/s can be estimated during the dry season. When it is assumed that maximum discharge is 3.94m3/s and effective head is 150m, it is expected that maximum output is approximately 4,170kW.

According to the above specification, it is estimated that the construction cost will be approximately USD 7.7 million.

(d) Others

It is considered that the Chapcha, Chuzomsa, Tingtibi, Chella, Langthel and Lingmethang sites seem to be economically equivalent to the Khoma site. There seem to be a high priority of development in these candidate sites. However, it is important that several arrangement patterns regarding the powerhouse and intake facility be examined and that the most economical plan be selected from among several patterns when actual hydropower development is planned. The following points should also be considered when the actual development plan is examined.

- To plan and develop hydropower so as not to give rise to social and environmental problems
- To consider the construction cost of transmission equipment between candidate site and the nearby substation, and the construction cost of the access road for construction

- To give such benefits as a drinking water supply, which accompany hydropower development, to local residents as much as possible

(2) Rehabilitation project

Thimphu mini hydropower plant is located in the northern part, which is 4km from the center of Thimphu city. Part of the civil structure is located at the palace in which the fourth king lives. Part of the water discharged from Thimphu mini flows into Jungshina water treatment plant. At Jungshina water treatment plant, water is treated and supplied to Thimphu city as drinking water.

Source: JICA Survey Team based on Google map

Figure 8-10 Candidate Site of Rehabilitation Project

8.2.3 Need for Development

(1) New development project

There seems to be a great deal of hydropower potential in Bhutan. It is preferable that new hydropower plants should be developed to earn money and supply electricity if there are sufficient funds and proper land.

(2) Rehabilitation project

The main specifications of Thimphu mini hydropower plant are described below.

Table 8-4 Specification of Thimphu mini hydropower plant

Name	Thimphu mini
Commissioning year	1967
Output [kW]	400 (100 x 4)
Number of unit	4
Turbine type	Turgo impulse
Head [m]	100.5
Discharge [m3/s]	0.5

Rotation speed [min-1]	1,500
Generator capacity	112.5 kVA
Manufacturer of Turbine & Generator	Jyoti Ltd. (India)

There are 4 units of turbine and generator in Thimphu mini hydropower plant. At present, the generator of No.4 unit is broken and No.4 unit cannot operate. Maximum output is about 240 kW during peak load. It is thought that the reason is due to a decrease in discharge because the water at the waterway and head tank is supplied to the people of the palace and around hydropower plants.

Turbine and Generator

Penstock

Figure 8-11 Photos of Thimphu mini hydropower plant (1)

Head tank

Pipes for drinking water

Figure 8-12 Photos of Thimphu mini hydropower plant (2)

Pipes for drinking water are installed at the middle of the waterway and head tank. The water in the channel near the head tank seems to be much lower than the channel near the intake. Some water is leaked from the penstock, waterway and head tank, but it is thought that usage for drinking water is related much to decrease of discharge.

There are no duration curves, generation data or detailed drawings at present, so it is necessary to carry out a detailed survey when the rehabilitation work is conducted. The rehabilitation plan is proposed based on the survey results in view of the point of using unused energy.

It seems that the water level is constant and the head is unchanged because the water of the head tank is used for drinking water. It is assumed that the head is 100.5m, total efficiency is 72% (turbine efficiency is 80%, generator efficiency is 90%) and that three units (No.1-3) are available to operate, because No.4 unit was broken. Power output is 240kW during peak load, and discharge is calculated to 0.33 m3/s (0.11m3/s per unit).

0.33m3/s is under the rated discharge of 3 units, even during peak load. It is recommended that the number of units is changed from 4 to 2 to use water efficiently and rated discharge is changed to 0.165m3/s. It is possible to reduce operation & maintenance work and the maintenance cost by decreasing the number of units.

Turbines and generators cannot generate during rehabilitation work. It is preferable to carry out the rehabilitation work of the turbine and generator, as well as any civil structure which is worsening, at the same time. It is estimated that the rehabilitation cost of turbine, generator, penstock and head tank is USD 800,000, but it is necessary to conduct a detailed survey before the rehabilitation work.

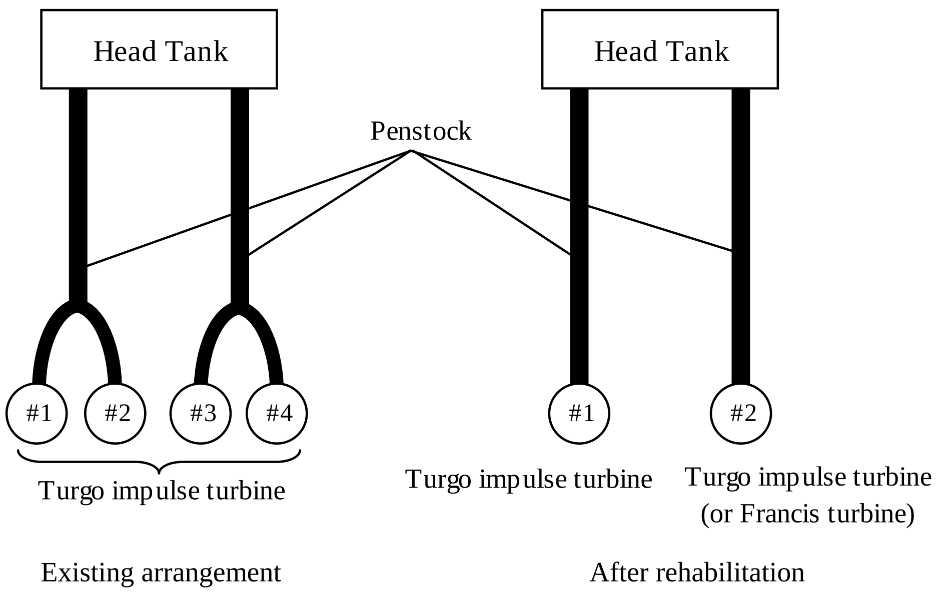


Figure 8-13 Equipment arrangement of Thimphu mini hydropower plant

An alternative rehabilitation plan is to install one Turgo impulse turbine and one Francis turbine, though turbine types are different. It is estimated that power generation will be increased, but there are some disadvantages regarding spare parts and operation and maintenance.

The efficiency of the Turgo impulse turbine does not decrease too much, but the efficiency at maximum discharge is lower than that of Francis turbine. On the other hand, the efficiency of Francis turbine drops during partial operation.

The disadvantages of each of the Francis and Turgo impulse turbines cover each other and it is expected that power generation will increase compared with the present situation.
The operation and maintenance method is different because turbine type is different. In addition, the operation method is more complicated than before because it is necessary to change the number of operating units according to the discharge condition. The maintenance method is not easy because the inspection method and spare parts are different. There is the disadvantage that spare parts are not shared between Francis and Turgo impulse turbines. The operator should keep spare parts for both units. In addition, it is necessary for the operator to take operation & maintenance training for the new Francis turbine. The rehabilitation plan should be determined in consideration of an increase in power generation as well as the operation and maintenance method.

8.2.4 Feasibility of the Technical and Economic Aspects

(1) New development project

It is necessary to examine the site survey including the environment around the site depending on the site condition. There is no technical problem because many hydropower plants have been built up to now. Regarding the economic aspects, several candidate sites are proposed and the most economically viable site will be selected for new construction of them.

(2) Rehabilitation project

A part of the penstock and turbine and generator are renewed in the case of the Thimphu mini rehabilitation plan. There seem to be no technical matters in this rehabilitation project, but it is necessary to consider the effect upon Jungshina water treatment plant when the Thimphu mini hydropower station stops.

8.2.5 Grid Connection

Since the power generation by small hydropower has few problems concerning the power system stability, a big problem does not occur regarding a grid connection. There exists 11 kV distribution line (Rabbit) from Tangmachu substation (33/11 kV) near the candidate site. However, line capacity is only approximately 3.5 MW, therefore, it is impossible to connect to the 11 kV distribution line. Moreover, though the line capacity can be secured only to 5 MW at most if a large-sized conductor (Dog) is adopted, it is also difficult to connect the 11 kV system taking into account from the aspect of large capacity. Therefore, a new 33 kV distribution line construction of approximately 15 km will be necessary from Tangmachu substation to the candidate site. In addition, BPC has the intention to carry out grid connection for the existing small hydropower plants without grid connection. However, BPC considers it to be low priority compared to the construction of the renewal facilities.

8.2.6 Potential for Utilizing Japanese Technology and Partnering with Japanese Companies

(1) New development project

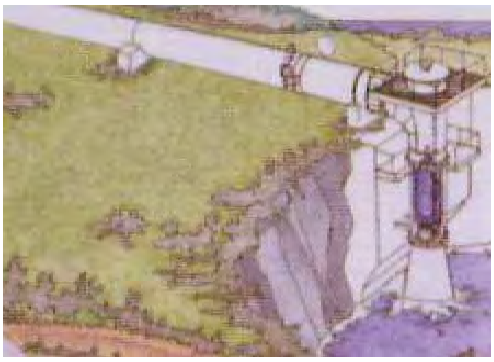
There are small hydropower manufacturers which handle package types of hydropower equipment. The package type of hydropower equipment has a simple structure and is not as expensive as general hydropower equipment. In addition, the package type is easy to connect with general civil structures and easy to maintain.

Equipment and spare parts are shared between hydropower plants when the same types of hydropower equipment are installed in the same regions and river systems. It is possible to operate and maintain the hydropower equipment in an efficient way.

Therefore, the possibility of utilizing Japanese technology would be enhanced if many package types of hydropower plants can be introduced into Bhutan.

Tubular turbine

Source: Brochure of Toshiba corporation

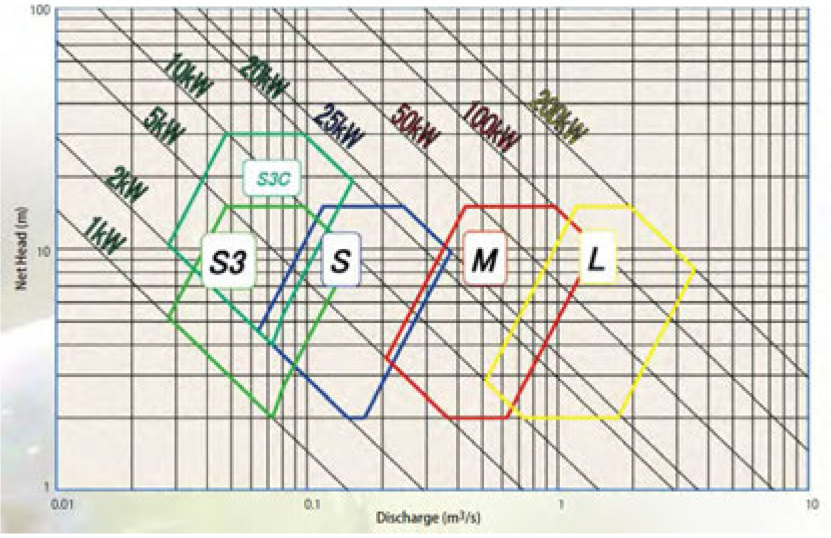


Submersible turbine

Source: Brochure of Eaml engineering Co, .Ltd

Figure 8-14 Example of Small Hydropower Plant

A selection chart for package type small turbine is shown as an example. Normally turbines are manufactured from the beginning depending on the discharge, head and other parameters. However, package type turbines are standardized and the turbines are selected according to the site condition (Head and discharge). Therefore, the equipment cost is inexpensive compared with normal turbines.



Source: Brochure of Toshiba Corporation

Figure 8-15 Selection chart for package type small turbine (Example)

(2) Rehabilitation project

The possibility of utilizing Japanese technology and partnering with Japanese companies would be explored if the electrical and mechanical equipment is replaced in the Chenary hydropower plant. It is necessary to confirm the present condition.

8.2.7 Indications for Environmental and Social Consideration

(1) Necessary Information for Environmental Clearance

As described in Chapter 6, in the case of Bhutan, for any hydro power plant project, regardless of its generating capacity, the project executor or owner must submit an EIA report. According to "Application for Environmental Clearance: Guideline for Hydropower" (2004), the EIA report requires the information indicated in Table 8-5. While the items are those that are generally required for EIA, it entails items relating to the natural environment in Bhutan, such as the impact of glacial outburst flood.

Table 8-5 Summary of Necessary Information Items for EC of Hydropower Projects

Category	Item	Contents
Contents of the project	➢ Details of Applicant ➢ Project objectives ➢ Site location ➢ Details of the Project	・ Type of project, project costs, facility details
Examination of the project	➢ Alternative measures ➢ Public consultation	・ Alternative measures include project alternatives and project site alternatives ・ Details of public consultation held with PAP (Project Affected People)
Environmental information for the project site	Physical environment details	・ Topography, hydrology, impact from glacial outburst flood (GLOF), sediment yield, mining and mineral resources and others
	Biological environment	・ Land use, vegetation, location in relation to the protected

Category	Item	Contents
		areas, fish species, wildlife and others
	Social environment	・ Land tenure, houses, infrastructure, cultural and heritage sites, right of water use
Environmental impacts and countermeasures	➢ Project impacts(positive and negative) and mitigation measures ➢ Monitoring program	・ Project positive impacts (if possible, quantification of the impact), adverse impacts upon the site selection phase, the project design phase and the construction phase and mitigation measures for them. ・ Environmental management plan and monitoring plan by applicant/Holder and Contractor
Approval document from stakeholders	・ No objection certificate with sign from stakeholders(central and local governments)	

Source: NEC "Application for Environmental Clearance : Guideline for Hydropower" (2004)

For example, the following items are written as a result of the comparison of alternative measures in the environmental assessment report for Chendebji Power Station (70kW) constructed by Kansai Electric Power Company, as the micro hydropower project funded by e7[26].

① In with project case comparing to without project case, benefit for local people would be large scale. Without project case, the people would lose such great benefit.
② Difference in environmental impacts, decreasing emissions of CO_2, NOx and SOx in comparison to the case of electrification by diesel power generation

In the aspect of the natural environment, the information source on wildlife is mainly the officials of national parks. Regarding positive/negative impact, the description is not that detailed, for example, categorizing direct and indirect impacts, showing the evidence in each accordingly and a range of impacts. In the case of a run-of-river type small-hydropower plant, if the site selection is conducted carefully, the environmental impact tends to be not that large compared with other types of hydropower plants, therefore the information details appear to be equivalent to the contents of the general Initial Environmental Examination (IEE).

(2) Maximization of Socioeconomic Impact

In the case that a small-hydropower plant is an independent source of electricity constructed in remote village areas, there are many good practices supported by donors in the world that the project components include that the beneficiary villagers can be involved in O&M and bill collection and the social and economic activities utilizing electricity can increase. In Bhutan as well, local people conduct the bill collection and simple O&M in Chendebji Power Station, and that scheme has been also introduced to the Sengor Micro-hydropower Station constructed by UNDP/ GEF fund.

In the village areas, when small-hydropower stations are developed, it is recommended that the projects are designed and implemented to make local people gain as much benefit as possible.

[26] e7 was established as a Non-Profit Organization by the main electric power companies from the G7 countries in 1992. The objective of e7 is to play an active role on global issues to promote sustainable development. As of 2013, e7 has been changed to e8.

8.3 Windpower Project

8.3.1 Outline of Windpower Project

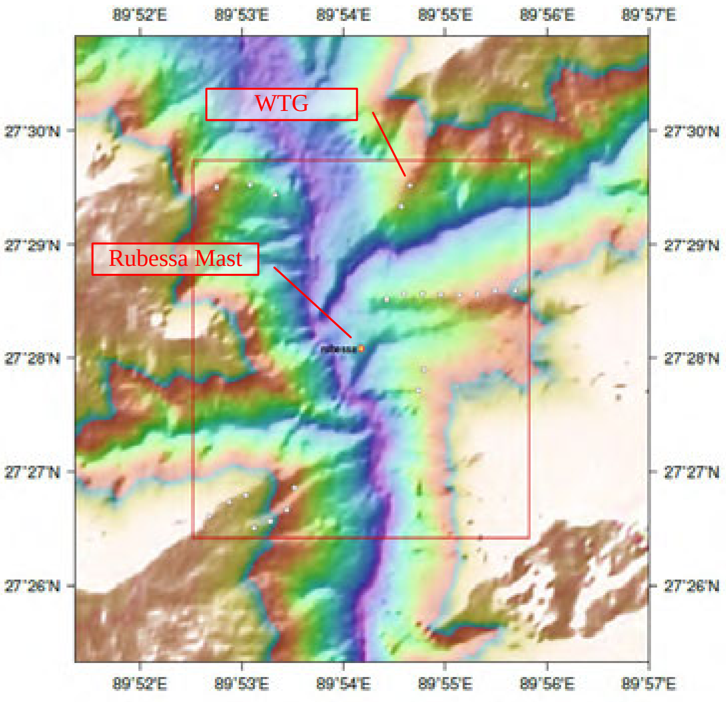
It is difficult to evaluate potential sites all over Bhutan from the existing data. It is necessary to examine the feasibility by investigating wind conditions.

However, it seems to be possible to develop an extension to the ongoing windpower pilot project supported by ADB at the Rubessa (Wangdue) site according to the information given by DRE.

8.3.2 Outline of the Candidate Site

In Bhutan, Rubessa is a constantly windy location, and since population density is low, further development could be possible.

The U.S. consultant (3TIER) is studying installation of WTG at the surrounding mountain top in a study of the pilot plant which DRE is promoting.



Source: 3TIER Report of DRE offer

Figure 8-16 WTG Layout Proposed in the Preliminary Report of the U.S. Consultant

When acceleration at height by wind shear etc. is taken into consideration, the wind velocity of the summit of the mountain is stronger than the point of a wind mast. Since improvement in utilized capacity is expected even taking the fall of air density into consideration, a layout to the summit of the mountain of the mast circumference is proposed.

However, judgment is impossible unless it actually measures the potential of the wind of the summit of the mountain.

Moreover, since it is possible that turbulence intensity also rises if it is windy, there is a concern that an applicable WTG does not exist.

In addition, the road development expense for transporting WTG to the construction place, etc. is needed, and the cost increases significantly.

In considering an extension, it is necessary to examine first whether acquisition of land and development of the road for construction are possible, and narrow down the places in which WTG can be installed. Then, it is necessary to carry out wind observation anew and to make a potential judgment.

There is also the Sibsoo (Samtse) area, which the Survey Team feels could be a potential site besides Rubessa. Sibsoo is the only potential site out of 17 Meteorological weather observation data points in Bhutan.

The altitude of Sibsoo is low at 550 m, and the Survey Team assumes that there are few transportation problems. Sibsoo is a point at which measurement by wind mast should be carried out and the possibility of development of wind power generation should be examined.

As Chapter 7.3 and the above described, the construction of a wind plant must be assessed from the wind observation results and construction conditions for every site in order to determine suitability. When studying construction at a location of especially complicated geography like Bhutan, there is a case where the study method generally enforced cannot estimate the trouble which will occur after commencement of commercial operation.

The study procedure for the plant construction which should be carried out is as follows.

The procedure of wind plant development study

(Development procedure in consideration of complex topography)

1) Extraction of a location considered to have good wind.

   Although it is not easy to look for a location that is windy throughout the year, in a windy place, information is obtained from talking to local residents etc. in many cases. The Survey Team was able to obtain information during the site survey that the Wangdue area, which encompasses the Rubessa point, is also a location famous for being windy from ancient times.

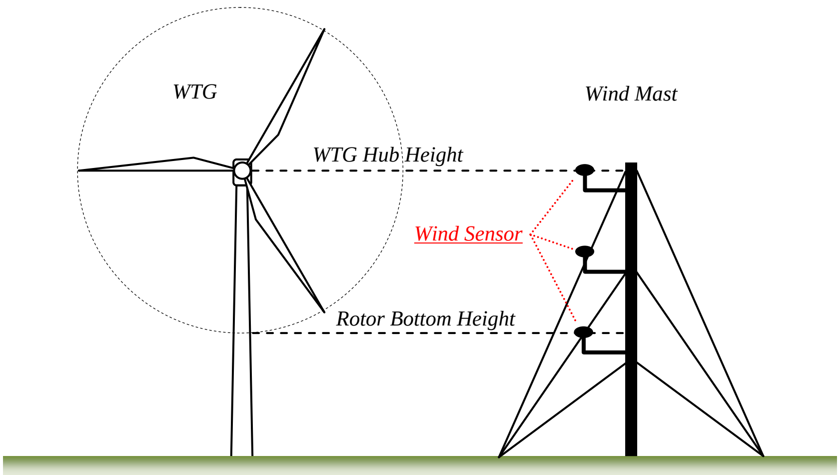
   Moreover, windy places are often indicated by trees. As shown in Figure 7-42, whether unbalance by wind is visible in tree branches or not becomes information which can be used to judge the potential of wind power generation.

2) Selection of carriable WTG

When geography is used for wind observation at a complicated location like Bhutan, the Survey Team should confirm in detail the effect of the wind which the WTG receives. It becomes important to make the sensor height of the wind mast the same as the Hub height of the WTG as much as possible for that purpose.

Therefore, it is important to decide the model of WTG to some extent before wind observation.

In Bhutan, which has limitations in conveyance, the selection conditions for WTG depend on the transportation possibilities.



Source: JICA Survey Team

Figure 8-17 Height of Mast Sensor for Wind Observation

3) Possibility of land acquisition including development of the site access road

Observation of wind will be useless if acquisition or development of land cannot be done. Before carrying out wind observation, it is recommended to confirm whether acquisition of land required for plant construction is possible.

4) Study of the WTG layout

The layout of WTG is temporarily decided based on WTG selected by 2). And the position of wind masts is determined based on the confirmed layout.

Wind observation needs to be performed at both ends of the area, and in at least three places in the center of the area.

Moreover, CFD should be utilized in the stage of concluding the layout of WTG, as it decides wind observation location.

- The layout is planned so that WTG may not be installed in a location where the risk of a turbulent flow is assumed.
- Since there is a risk of turbulence at the location to install WTG, additional measurement is planned.

In addition, when there are demands on the environmental side, they are taken into consideration at the time of layout determination.

5) Installation of a wind mast.

After examining 2) - 4), a wind mast is installed and wind observation is performed. First, observation is performed for one year and potential and intensity of turbulence will be analyzed.

Since there is an anemometer, which can record observational data not only on average but per several seconds for 10 minutes, finer data should be used to analyze wind turbulence.

6) Assessment of wind observational data, and implementation of additional observation.

Further observation will be studied if there is potential by observation of 5). If a result with strong turbulence is obtained, in order to obtain the turbulent flow characteristics of the whole site as much as possible, the observation point should be changed and additional observation should be performed.

7) Calculation of construction cost

If potential is confirmed, a trial calculation of construction cost will be studied.

Since construction cost changes with WTG(s), it is desirable to prepare all the data for a candidate model.

8) Assessment of economic efficiency.

First, electric power production is calculated for each model selected from wind observational data. And economic efficiency is examined based on the construction cost etc. for which it asked by 7). Economic efficiency may be good if the power generation characteristics are excellent, even if the construction cost is high.

In addition, economic efficiency including the promise of availability, O&M support conditions, etc. is examined.

9) Suitability judgment of construction implementation.

Implementation of wind plant construction is judged based on the above procedure.

8.3.3 Need for Development

It is meaningful for diversification of energy to introduce wind power generation, in order to promote introduction of renewable energy.

In AREP2013, the introductory desired value of wind power in 2025 is 5MW. Since equipment of the schedule carried out now and supported by ADB is about 500 kW, in order to attain this aim, it will need development of around an additional 4.5 MW over ten years.

Although points where potential for wind power generation exist in Bhutan, considering the below development issues, economic efficiency will worsen. Therefore, it is necessary to carry out a sufficient economic efficiency assessment during actual development.

- The energy of wind drops at points where altitude is high.
- If road conditions are taken into consideration, because of limitations of WTG transportation, large-scale machines which are in use across the world cannot be chosen.
- Since there are many locations with complex topography, the possibility of turbulent flow generation is high.

8.3.4 Feasibility of the Technical and Economic Aspects

Bhutan has little area where the potential of wind power generation is high. Moreover, since most land is at a high altitude, wind energy will drop.

WTG transportation also has limitations, since transportation on mountains is required, and thus, only small machines of 300kW class have the possibility of being constructed. And, because the number introduced is limited, there is no scale merit.
When importing from overseas, over-the-road hauling of 900km or more is required. And construction which cuts through mountains, such as site road construction, is required. Therefore, construction cost will become still higher.

Economic efficiency is not so high, since Bhutan cannot be assumed as an appropriate place for wind power generation from the above conditions. If there is no considerably high-priced tariff, it will be very difficult to obtain investments for wind power generation.

8.3.5 Grid Connection

There exists an 11 kV distribution line near the candidate site, and also a 33 kV distribution line a few hundred meters away. The BPC is planning to integrate the wind power source from the wind farm to the existing 33 kV distribution line. However, the system reliability of the 33 kV distribution line in question is lower than that of the 11 kV distribution line, as shown in Table 8-6, because the 33 kV distribution line is a long distance and Lobesa substation has only one 5 MVA, 66/33 kV transformer. However, the 33 kV distribution line has a huge advantage in respect of voltage fluctuations, and if it is a grid connection with several hundred kW of this wind capacity, there will be almost no voltage fluctuation problems. When the project is extended to this candidate site in future, while aiming at improvement in power supply reliability of a 33 kV distribution line, such as an installation of additional transformer at Lobesa substation and interconnection with other distribution line, the same countermeasures against voltage fluctuations should be taken as the PV Project. In addition, the area of the connecting point of the 33 kV distribution line is private land, and since it is difficult to construct a substation, it will be constructed near the wind power plant.

Table 8-6 Interruption Frequency of Distribution Line to be connected (February 2013)

	Interruption frequency	Average interruption duration
33kVdistribution line （Lobesa substation 33kV feeder 2）	13	1h10m27s
11kVdistribution line （Lobesa substation 11kV feeder 4）	2	11m30s

Source: BPC

8.3.6 Potential for Utilizing Japanese Technology and Partnering with Japanese Companies

There are five manufacturers for large windpower equipment in Japan. However, the unit output standard of windpower equipment is the 2,000kW class at present, and it seems to be very difficult to import this class into Bhutan due to transportation limits. Therefore, the possibility for Japanese manufacturers supplying their own equipment is low at present.

Table 8-7 Japanese Windpower Manufacturers

Manufacturer	Products	Blade length	Remarks
Komaihaltec Inc.	KWT300(300kW)	16m	
Toshiba Co. Ltd	U50,U54,U57(750kW) U88,U93(2,000kW)	24.3- 27.8m 42.7- 45.5m	Manufactured by Unison Co., Ltd (Korea) Toshiba equipment is in preparation
Japan Steel Works, Ltd	J80-2.0(2,000kW)	40m	
Hitachi	HTW2.0-80(2,000kW)	39m	
Mitsubishi Heavy Industries, Ltd	MWT102A/2.5(2,500kW) MWT95A/2.5(2,500kW) MWT92A/2.5(2,500kW)	49.7m 46.2m 44.7m	

(Product information as of July 2013)

An EPC contract is required for windpower manufacturers as bidding qualification for a pilot project in Bhutan. However, it is difficult for a Japanese company to conclude an EPC contract. Other issues include organization in charge of maintenance after commencement.

8.3.7 Information on Environmental and Social Consideration

The following section describes the results of the site survey of the ADB pilot project and interviews with local stakeholders[27] and the general information from “Project Report for the Pilot Wind Power Project at Rubessa, Wangdue Phodrang” (DRE, 2013).

(1) Site Location

The ADB wind power project is located in Sangrupgang Chiwog, Rubessa Geog.

(2) Natural Environment

The project site is not surrounded by national parks and protected areas. The land consists of hard rock or semi-hard rock and is dry. There is no water resource. It sometimes happens that the local people have to stop cultivation due to water shortage.

- General information of the fauna and flora: wild boar and fawn are seen sometimes around the project site, but there are almost no other wild animals. Regarding fauna, shrubs are found dispersed around the project site, but there is no information that there are rare species.

- Birds and insects: according to local stakeholders, the wind is very strong around the project site, thus birds and insects (butterflies) have rarely been seen. The DRE report describes, based on the results of RSPN survey, that 14 species among 21 migratory birds have found sometimes or often around Rubessa Geog.

(3) Social Environment

<Land Tenure and Use>

The project site falls into the government land owned by the Regional Livestock Department Center, MoAF. Inside the project site, there is a MoAF building, but there are no residents and no farming activities by local people. The surrounding land of the project site (50m and more distant from the construction of the wind power system) is owned by 5 households. Some people among them obtained the land as alternative land for compensation upon construction of the Punatsangchhu Hydropower Station in the neighborhood. Not all households settle around the project site. Two households live in downtown Rubessa Gewog, and the others live in the village far from the project site. Besides the MoAF building, around the site there are a privately-owned sawmill factory (furniture factory), a house (for rent, still under construction), and a guest house (under construction) (Refer to Figure 8-18). There are no cultural or traditional heritages near the project site.

[27] Local stakeholders are Tshogpa of Rubessa Geog and Environment Officer of District.

		
Sawmill Factory (Furniture Factory)	**House (for rent, still under construction),**	**Guest House (under construction)**

Source: JICA Survey Team

Figure 8-18 Private-owned Buildings around the Project Site

<Social and Economic Activities of villagers in Sangrupgang>

There are 150 households in Sangrupgang Village. People make their livelihoods from rice farming and agriculture (beans, tomatoes, spinach and others). People mainly work on rice farming and producing rice cakes. There is no irrigation system and people depend on rain-fed water. Moreover, since no water resource exists around the village, people abandon farming due to water shortages. They keep livestock (2-3 cattle/ household). Their products are mainly for their own consumption and are sometimes sold in the market if there is anything left over. The farmland is located near to their house, and while the size of farmland is 9-10 acres for rich households, the average size per household is 2-3 acre, as the land was inherited by generations.

(4) Issues for Environmental and Social Considerations at the Project Implementation Stage

During the survey for this time, the survey team examines the items that tend to be pointed out after the commercial operation of wind power plants. In the natural environment aspect, it is often pointed out about bird strike. According to the DRE report, it is described that there are few effects from birds because there is no forest and birds fly beyond 100-150m in the air from the land, while the wind power system is below 100m in height. Local people explain that there are few birds around the site, hence the chance of bird strikes is slim.

In the social aspect, noise problems tend to be revealed after commencement of the project. Based on the information from NEC and DRE, “Environmental Standards 2010” stipulate that the limitation of noise is 55dB in the daytime and 45dB at night (the standard of the noise level depends on area categories such as Industry, Sensitive and Mixed Areas, and the project site is Mixed Area) and this standard is applied to the project. The DRE report refers to the graph which shows the relation of noise level and distance in the case of a wind power system of 250kW, by a Danish consulting company in an energy-related sector. The graph shows that in locations of 50m and more from the system, the noise level becomes less than 55dB and, therefore, the report states that there is no problem, since houses are located 50m or further from the system.

5 households who have land around the project site have already accepted and signed for the agreement of no objection to the project implementation. Regarding the landscape, the representative of the village is convinced that no people care about the landscape with a wind power system, and the DRE report states that the clearance of the landscape was approved by the District government.

In the current situation, the influence of noise and landscape seems to be minimal, because people around the site are supposed to be only travelers staying in the guest house temporarily, and the scale of the system is relatively small in the case of 2 units of 250kW class rated output. However, regarding noise, this should be noted in the monitoring after commencement of commercial operation, since the wind direction and the location of buildings cause a change in the sense of hearing the noise, and the Rubessa wind power would be the first experience of a wind power project in Bhutan.

Apart from these issues, considering the lack of water sources surrounding the project area, a new water source development plan is being prepared by the block office and the ADB pilot project plans to include part of the finance for this project within the project component. Therefore, the benefit for the local area is already being considered on this point.

8.4 Biomass Generation Project

As mentioned in Chapter 7 , a wood biomass system using wood waste produced in sawmill factories would be set as the model biomass project, and it would be set at Haa with the highest potential. While the main study of this survey is the usage for electricity power, there is a high demand for heating, such as drying timber in sawmill factories (currently there is no drying system other than natural drying), or house heating in the winter season, therefore a co-generation system (with electricity and heating) is studied.

8.4.1 Outline of the Project

(1) Basic policy

In this survey, the JICA Survey Team assumes to commence the biomass gasification generation project on the basis of DRE's policy for biomass promotion. DRE has not finished the technical and economic examination on a specific business model yet. Therefore, the examination of a specific site and business model should be held back.

Currently, DRE expects that sawmill owners' investment and UNDP's fund will be applied to biomass gasification generation, but there is the possibility that Japanese companies' technical support and systems will be adopted with the Japanese government's aid and yen loan, depending on the project size and technology. In this case, capacity building should also be commenced for sustainable operation.

(2) Abstract of business model

In the JICA survey team's assumption, a biomass gasification generation plant is assumed to be installed in a sawmill factory. The assumed potential site would be Meriphensum Sawmill in Haa. The outline of this sawmill is shown in 7.4.2 (2).

Assuming that the amount of biomass material (sawdust, residue etc.) produced is around 20% of raw wood, the biomass material production of one sawmill factory is around 1,250 cft/month from 5,000 cft/month of the product wood. Generally, 1kg of biomass material should be needed for 1kWh generation by a biomass gasification generation system; the amount of production means around 500kWh of electricity generation considering around 0.5 of density, meaning that a system with 20 to 30kW should be suitable.

Considering cost reduction by enlarging scale, a system with around 100kW also could be applied by collecting material from 3 or 4 sawmill factories. In this case, there are many issues to be solved, such as how to compensate for the material provided, who should pay the transportation cost of the material, and who should construct the electricity supply network in the case that the electricity is delivered to these sawmill factories.

As an example, the following table shows an outline of the business model with a 100kW project. In the case of one sawmill factory, it is the same, except the capacity is 20 to 30kW.

Table 8-8 Outline of Assumed Project (Example)

Item	Abstract
1) Installation site	Sawmill factory (such as Meriphensum factory in Haa)
2) Operator	Private
3) Operation system	Sawmill factory's staff (Staff concurrent duties on saw miller and system operator.)
5) Available waste resource	Around 1 t/day (from Meriphesum factory and neighboring factories)
6) Technology	① Gasification generation system or ② Direct fired system
7) System efficiency	Generation capacity：Around 100kW Electricity efficiency：10～20% Thermal efficiency：30～40%
8) Operation time	8 hours/day, 20days/month (System operation should be adjusted to the operation time of the factory)
9) Electricity utilization	Self-consumption
10) Thermal utilization	Thermal utilization should be examined hereafter

8.4.2 Outline of the Candidate Site

In the case that the system is installed in a sawmill factory in Haa, there is no need for land acquisition or resettlement because the land of the sawmill factory is used..

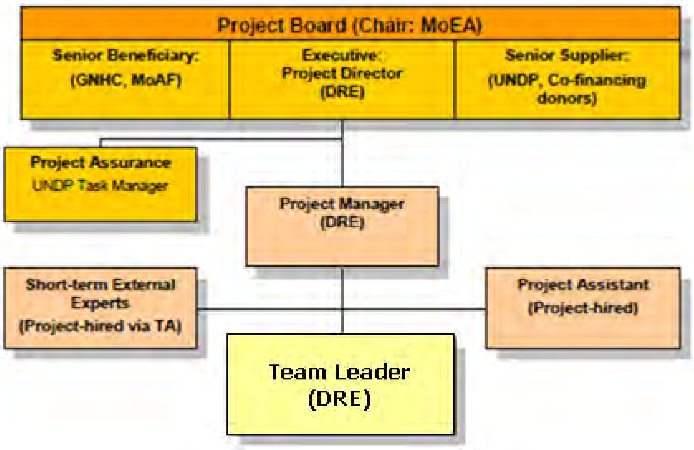
8.4.3 Need for Development

(1) Expectation and concern of counterparts in RGoB

RGoB is concerned about reckless deforestation due to the wood consumption increase with a focus on fire wood. Therefore, they expect to 1) prevent immoderate deforestation from efficiency wood material usage of biomass generation system. In addition, 2) GHG emission reduction is expected according to the avoidance of methane gas generation from the dump yard. In addition, in areas other than Thimphu, sawdust is not utilized effectively, and not only residue but also sawdust is waste which is difficult to treat, therefore effective usage should contribute to the environment.

(2) Identification of decision maker and their intentions

Mr. Mewang of DRE (Alternative Energy Division) is the final decision maker for renewable energy project budget implementation. If the above project actually commences, the Bio Energy Section of DRE will be the promotion entity.



Source: SRBE report

Figure 8-19 Project Organization Structure

8.4.4 Feasibility of the Technical and Economic Aspects

(1) Economic aspects

In the case of operation on the preconditions of 8.4.1, annual electricity generated from a 100kW generator is about 192,000kWh by simple calculation, and in the case that all of the electricity is used for self-consumption, the sawmill factory can avoid about USD 6,000/year payment of electricity fees (calculated using house use tariff.)

Regarding equipment cost, according to SRBE report, a 40kW plant needs around USD 50,000 investment. If a 100kW biomass generation plant needs USD 120,000, the simple payout period will be 20 years. In addition, in the case that a Japanese manufacturer provides equipment, the cost would be much higher, as shown later. Any support systems, such as subsidies which can prepare the sawmill factory owner’s incentives and advance payout periods for systems, should be paid for those who will invest in the biomass generation system.

Practically, there are several factors excluded in the above evaluation which will cause deterioration in the balance of payments, such as the resource aggregation cost from several saw millers. Conversely, the balance of payments will be improved from several factors such as scale merit, when this project can collect resources with low cost.

Table 8-9 Factors Causing Economic Effect

Good factor	Bad factor
(In the case that wood waste can be aggregated from several sawmill factories:) Construction cost unit reduction from scale merit Fuel consumption reduction due to heat waste utilization from biomass generation system (If CDM will be applied to this project:) Return increase from CER sales	Aggregation cost and Logistics cost of wood waste Labor cost of O&M Consumption of kerosene and diesel for support of combustion (depending on types of generation system)

(2) Technical aspects

Considering the gasification system, a syngas-fired engine generator should be used for generation. A normal diesel engine cannot be operated only by syngas and should be mixed with diesel oil. In that case, procurement of diesel oil would be needed with a high unit price in Bhutan and that would have an impact on economic feasibility. Therefore, the equipment cost according to the possibility of single fuel firing should be should be compared.

(3) Other

Biomass generation systems bring the following two GHG reduction effects, 1) Reduction of methane gas generated from wood waste dump yard, and 2) Substitution electricity from biomass power plant on behalf of grid power. With regard to 2), the GHG reduction effect is negligible because almost all electricity is generated from hydropower in Bhutan. SRBE expects only the effect of 2) as 171tCO_2/year equivalent.

8.4.5 Grid Connection

When the grid connection is carried out to a nearby 11 kV distribution line, it is assumed that a certain amount of PV power generation output as surplus power will flow into a power system. However, at most at about 100 kW, since the power generation by biomass also has few problems concerning the power system stability, a big problem does not occur regarding a grid connection.

8.4.6 Potential for Utilizing Japanese Technology and Partnering with Japanese Companies

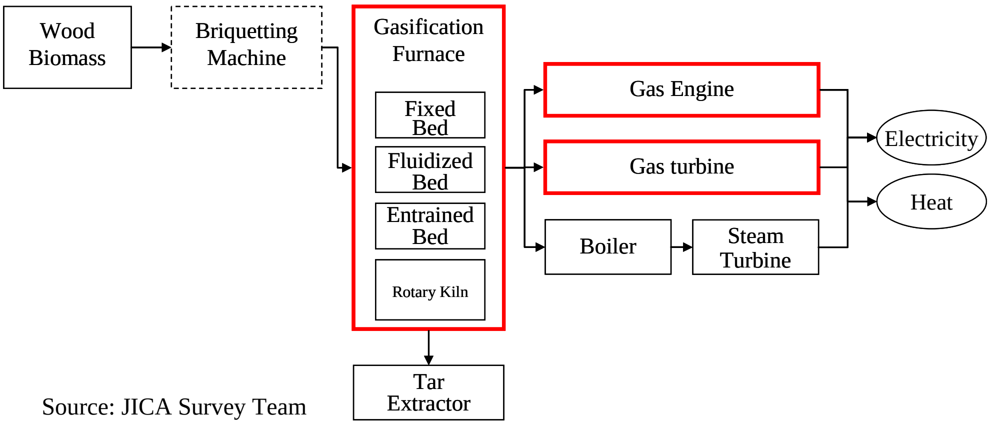
The RGoB intends to install facilities which can be operated by local systems rather than advanced technology. Moreover, if the commencement of the project is decided, the turnkey contract (ICB) including design/procurement/construction is assumed by DRE. If Japanese companies provide technology to Bhutan, it is necessary to explain about the quantitative merits of their technical advantage and at the same to establish a system to secure the sustainability of projects.

(1) Technical aspects

In the area of biomass power generation, various technologies and combinations of them are included. For the wood biomass generation system, the following system flows are considered.

① Gasification generation system

The key components are the gasification furnace and the generator.

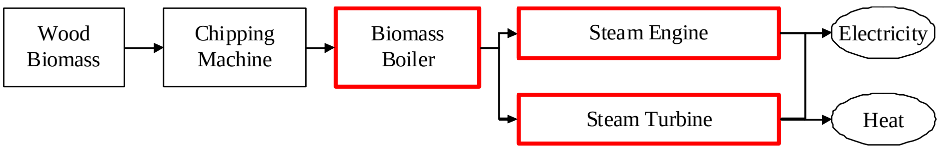


Source: JICA Survey Team

Figure 8-20 System Flow (Gasification Generation System)

② Direct fired system

The key components are the biomass boiler and the generator.



Source: JICA Survey Team

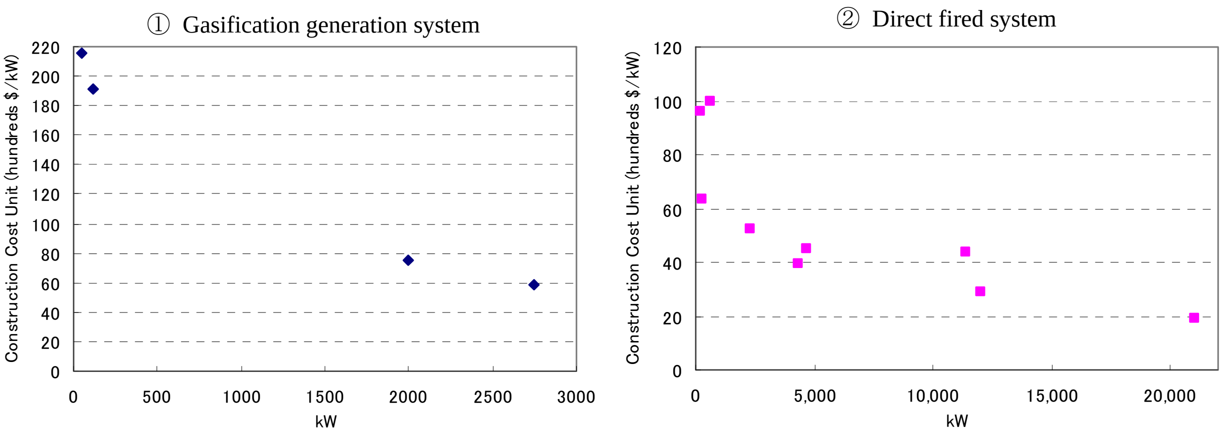
Figure 8-21 System Flow (Direct Fired System)

From a technical point of view, for all of these components, Japanese manufacturers have high level technology. For example, SATAKE Corporation has great experience in gasification generation systems and has the ability to manufacture equipment for various type of biomass. UBE Machinery Corporation has the ability to manufacture biomass-fired small size boilers, and KOBELCO has a line-up of screw-type small size steam turbine generators which are suitable for biomass generation. As above, there exist Japanese manufacturers who could install high performance and reliable equipment.

(2) Cost competitiveness

The cost of Japanese equipment in the area of biomass power generation is higher compared with international standards. It is extremely difficult to install them in Bhutan via market mechanisms. For example, a 300kW biomass boiler is set at a price of USD 100,000-150,000 (USD 400-500/kw) in Germany and England, but USD 700,000-1,200,000 (USD 2,000-4,000/kw) in Japan. This means that the price of a Japanese boiler is 4-8 times that of one from Germany or England.

In SRBE's economic evaluation's precondition, a 40kW biomass generation system's initial investment is about USD 50,000. According to a NEDO report, the unit by capacity of a 40kW generation system's initial investment is ① Around USD 20,000/kW(-2,000kW)/Less than USD 10,000/kW (2,000kW-) in the case of gasification generation system; ② Around USD 10,000/kW(-5,000kW)/ Less than USD 5,000/kW (5,000kW-) in the case of direct fired system. The Japanese system's price is 4-8 times that of SRBE's price. (The above "Initial investment" includes system/balance of plant/construction/start-up cost.)



Source: JICA Survey Team

Figure 8-22 Initial Investment of Biomass Generation System in Japanese Biomass Business

For the economic calculation in Chapter 4, the initial investment costs for biomass would be set as follows: as the lowest level, 1,300 USD/kW from SRBE report is used, and as the highest level, 5,000 USD/kW, which is the lowest level of Japanese actual installation according to NEDO report, is used.

(3) Operation aspect（O&M system）

The shape and moisture content of sawmill waste are relatively stable compared with other biomass resources. Therefore, making a plant operation plan is easier than for other renewable resources. Nevertheless, different shaped resources cause imperfect combustion and increase the frequency of exchanging parts in the long-term due to tar and soot. Therefore, eligible system operation is very important in order to control maintenance and inspection costs within a certain range. According to such specific reasons, it is indispensable to commence eligible capacity building (establishment of O&M system, instruction for operation staff etc.) when foreign companies try to install their manufacturers.

8.4.7 Review from Environmental and Social Aspect

Assuming the case that the biomass power plant can be constructed in the sawmill factory, the following section describes the results of the site survey and the interviews with local stakeholders, such as the sawmill factory owner, and the Environment Officer of Haa.

The utilization of sawdust and residues for a biomass electric power plant is effective in making use of waste, however, concerns remain for private sawmill factories in terms of the comparison among investment cost, the current/future energy demand, and the current electricity tariff. The environmental considerations for biomass power plants, and the disposal of ash and tar after combustion are concerns. For example, the ash can be utilized as fertilizer, thus, it is better to consider promoting such measures of waste management to reduce the residue as much as possible.

(1) Environmental Considerations in Operation of Sawmill Factories

According to the District Environment Officer (DEO) in Haa, there are 21 sawmilling factories, and 17 of these are in operation. All factories use wood resources under FMU below the regulation of forest conservation. The DEO in Haa mentioned that the owners of sawmilling factories are profit-oriented and less conscious of environmental pollution. Based on the interview with the factory owner, sawdust waste is left inside the factories and then thrown out on the mountain nearby when it reaches a certain amount. The sawmill factory that the Survey Team visited had left a large amount of sawdust behind the factory and part of the sawdust waste seems to flow into the river.

The DEO recognizes that the sawdust can cause air pollution, however, the regulation for sawdust waste disposal has not been established; therefore, instructions for owners on how to deal with it are not conducted. Some people complain about the sawdust disposal and in such cases, the DEO asks the factory owner to take countermeasures for the complaints. One of the factory owners said, on the other hand, that they had never received any complaints so far because the people living around the factories are all relatives or the sawmill owner knows the neighbors well.

(2) Utilization of Sawdust Remains and Energy Demand

The factory owner seems to willingly accept the idea of utilizing the sawdust for the biomass power plant since that waste is left and accumulates as it is. According to one of the factory owners, currently, the electricity tariff of operating expense accounts for not that high a cost (Nu 3,000-3,500/ month), the owner is interested in biomass plants with sawdust waste if there is some financial support scheme. It can be assumed that other sawmilling factories could have the same opinion.

In the DEO in Haa’s opinion, he thinks the best way to utilize the waste is to sell it to briquette factories, however, there are no briquette factories in Haa. In Thimphu, there are some briquette factories, but no sawdust has been sold to Thimphu until the present because of high transportation costs. In Haa, there is a plan to construct a briquette factory by a private company, which would be the first briquette factory in Haa.

The number of workers at sawmill factories is 3-4 and many of them are from India and live in the residence inside the factory. The energy demand of the sawmilling factory consists of equipment and lighting for factories, and the residence of workers. The factory has only a sawing machine and no drying machine or others. As another use for the biomass energy, the DEO refers the use of energy for heating purposes, because there is a high demand for heating during winter time.

8.5 Comprehensive Evaluation

The comprehensive evaluation of proposed projects for each renewable energy sector is as follows.

(1) Position of each project

The position of each project is shown below.

Source: create by JICA Survey Team based on the Google earth

Figure 8-23 Position of each Project

(2) Power generating facility data

The facility data of the concrete renewable energy projects that have been described up to now is as follows.

Table 8-10 Facility Data of the concrete Renewable Energy Projects

	Site	Dzongkhag	Capacity (kW)	Annual generation (MWh)	Unit construction cost (USD/kW)	Construction cost (million USD)
Solar	Shingkhar	Bumthang	1,000	1,600	3,400	3.40
Small hydro	Khoma	Lhuentse	4,170	25,600	2,500	10.40
Wind	Rubessa	Wangdue	300	433	2,000	0.60
Biomass	Haa	Haa	100	192	1,300	0.13

- The cost of interconnection to the grid and the construction work expense of the road for construction are added to numerical value 1,850USD/kW described in Chapter 8 , and the unit construction cost of small hydro power is assumed to be 2,500USD/kW.
- The cost of interconnection to the grid and the cost increase due to scale disadvantage are added to numerical value 1,228Euro/kW (cost of 2MW machine, 1.35Euro/USD) described in Chapter 7 , and the unit construction cost of wind power is assumed to be 2,000USD/kW.

Source: JICA Survey Team

(3) Generation cost

The calculation result of the generation costs of the projects that have been proposed in this report is as follows based on the above-mentioned facility data and the following preconditions.

- Discount rate = 12%, Salvage value = 10%
- Exchange rate = 65 Nu./USD

Table 8-11 Generation Costs of the concrete Renewable Energy Projects

	Site	Capacity (kW)	Unit construction cost (USD/kW)	Life (years)	O&M cost to construction cost	Generation cost (Nu/kWh)
Solar	Shingkhar	1,000	3,400	25	1.0%	18.9
Small hydro	Khoma	4,170	2,500	30	0.6%	3.4
Wind	Rubessa	300	2,000	20	2.5%	14.2
Biomass	Haa	100	1,300	20	3.1%	7.2

- In the calculation of the biomass, it is estimated that the fuel expenses is unnecessary at all.

(Source: JICA Survey Team)

The availability of small hydro power is high compared with other renewable energy even if the supply power decreases in winter, thus a lot of electric power is expected to be generated and the power generation cost is the cheapest. However, the generation cost is higher than the large-scale hydroelectric power plants and is about twice the electric tariff rate. Some support measures such as FIT is still necessary though the economical possibility is the highest and there are a number of project sites at an equal level besides the proposed projects.

As for biomass, wind power, and solar, annual availability rate is low with 20% or less, and the power generation cost is greatly higher than the electric tariff rate. Therefore, great support measures, such as high FIT, subsidy by REDF, are necessary for executing a concrete project.

Chapter 9 Study on Future Cooperation

9.1 Potential for Utilizing Japanese Technology and Partnering with Japanese Companies

9.1.1 Possibility of Partnering with Japanese Companies

As described in Chapter 4.2.2, because the exchange to foreign currency of dividends is not permitted, the possibility of partnering with Japanese companies in the renewable energy field is extremely low at the present stage.

9.1.2 Potential for Utilizing Japanese Technology

The general evaluation of Japanese products' quality and durability is high although the initial cost is also high. Therefore, there is a possibility of selecting Japanese companies' products if the economic calculation is carried out in consideration of the long-term maintenance cost during their life time. If Japanese companies participate in the renewable energy business, the possibility of utilizing Japanese products is high because the high quality of the Japanese products is likely to be recognized. However, because the foreign currency exchange of dividends is not permitted as described in the above, the possibility of partnering with Japanese companies is extremely low at the present stage.

Moreover, because the initial cost is generally high, generating companies tend to control the initial cost for all the renewable energy sectors. Therefore, the possibility that generating companies select Japanese products is considered low due to a relatively high initial cost. However there is a possibility that a JV enterprise of a Japanese company and a company in the surrounding countries such as India can provide cost-attractive products with high quality.

Table 9-1 Japanese Companies' Products which may be Installed in Bhutan

Product	Company	Product
Hydro power equipment	TPSC (INDIA)	Subsidiary of Toshiba Plant Systems & Services Corporation, Japan (TPSC). Hydro-eKIDS™, for low head and small scale hydroelectric power plants
Hydro power equipment	EAML Engineering Company Limited	Small scale cross flow turbine, submersible turbine generator
Wind turbine	Komaihaltec Inc	Small scale wind turbine (300kW)
Solar PV (Cell)	Fuji Electric Systems Co.,Ltd	Flexible amorphous solar module (portable)
Biomass	KANSAI corp.	Briquetting machinery which can solidify grain material (for example, sawdust and rice husk etc.) and gasification plant
	SATAKE corp.	Biomass gasification plant and generator (30-1,500kW) (SATAKE has their factory in Thailand.)

(1) Hydropower equipment

In Bhutan, small hydropower plants which are constructed by Japan's grant aid are under operation. Bhutanese engineers recognize that Japanese technologies are very high compared with Indian technologies. In general, turbine type and rotation speed are different depending on the effective head and discharge. Therefore, the hydropower equipment is manufactured every time the project is implemented. Equipment cost can be reduced by standardizing the hydropower equipment. In addition, TPSC(I) (Toshiba Plant Systems & Services Corporation (India)) manufactures hydropower equipment in India and has cost competitiveness against Indian products.

(2) Wind turbine

At present, large wind turbines with 2MW or over are manufactured in most cases in the world. In Bhutan, transportation to carry blades is limited because the road is not in good condition. Therefore, windpower capacity in Bhutan is limited to approximately 300kW. There are not many companies to manufacture 300kW-class wind turbines in the world. It is possible that 300kW-class wind turbines manufactured by Komaihaltec Inc. are used. However, technologies to install wind turbines are not sufficient and full turn key contract is required in Bhutan. It is necessary for wind turbine manufacturer like Komaihaltec Inc. to take part in this windpower project with the civil and electrical engineering companies.

(3) Photovoltaic panel

In the supply amount of the photovoltaic cell module and the photovoltaic panel, the market share of a cheap Chinese-made and Taiwanese-made product is high. For this reason, a possibility that the Japanese products in this field will be chosen is very low. The portable type photovoltaic cell module which can roll round is produced by some Japanese manufacturer. It is thought that the portable type photovoltaic cell module can be used as a power supply for mountain climbing in a mountain area and for emergency disaster.

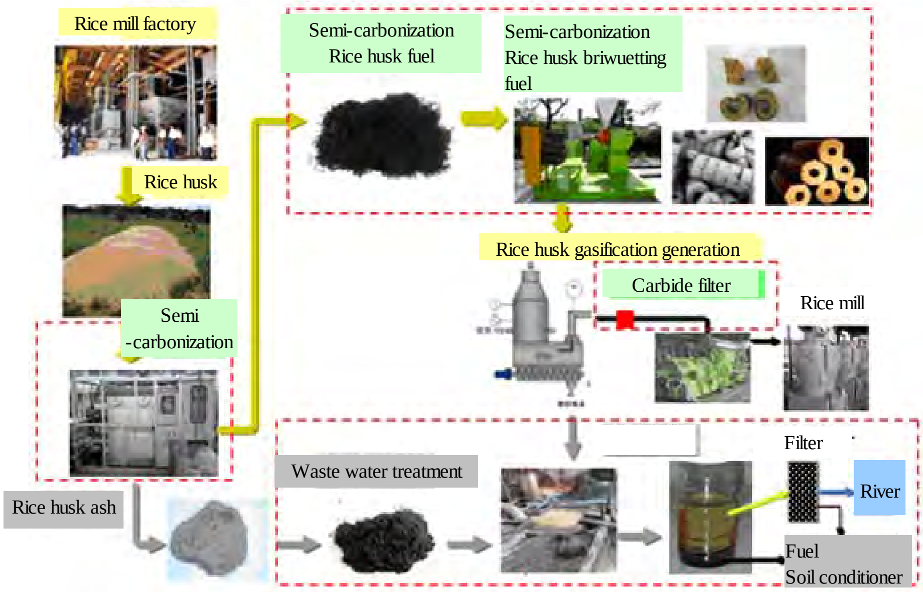
(4) Biomass equipment

KANSAI corp. and SATAKE corp. have commenced a renewable energy (biomass) project abroad. KANSAI corp. is examining their business possibility of rice husk gasification generation in NEDO's (New Energy and Industrial Technology Development Organization) project in Myanmar. In this project, KANSAI corp. is planning to install briquetting facilities in 30,000 rice centers of Myanmar and to install gasification plants and generators in several rice centers in which they can achieve eligible profitability.

In present, the gasification plants are made by Myanmar’s company, but the suitable size and form of material is limited to small grains by those plants, therefore, there is a possibility that SATAKE’s technology will be adapted to that project in Myanmar.

On the other hand, it is difficult for Japanese products to be adopted in Myanmar from a financial view, therefore SATAKE estimates that they should transfer their skill to local companies or install products from their local factories in neighboring countries such as Thailand. In the case of SATAKE, they have their local factory, which is a joint venture operated by SATAKE and a Thai company, and they have their trading subsidiary, which has transported agricultural machinery made in Thailand. In addition to that, SATAKE has a partnership company which can support maintenance service for SATAKE's products.

In the above project, Bio Fuel Co., Inc. plays a leading role to examine the feasibility of the business model, arrangement of the counterparts, capacity building measures, and resolve the technical issues. The role of a facilitator such as Bio Fuel is especially important for sustainable business to establish the business model including collecting materials measures and operational systems in the biomass area.



* The items in the dotted lines indicate technology Japanese companies.

Source：NEDO Homepage

Figure 9-1 Rice Husk Gasification Generation Project in Myanmar

As described in Chapter 7, Japanese technology to produce bio fuel (ethanol) from the resources of woods is considered most advanced, and therefore Japanese companies may contribute to this field in Bhutan from the technological aspect.

9.2 Proposal for Direction of Future Cooperation

(1) Technical cooperation for renewable energy master plan

According to AREP2013, the renewable energy master plan will be prepared in 3 years. In this report, the JICA Survey Team proposes that the DRE staff act as a leader and make the master plan. However, the creation of the renewable energy master plan is the first challenge in Bhutan, and the DRE staff does not have the experience or enough exclusive knowledge. Therefore, support from overseas specialists should be considered, if required. As a support scheme of JICA in this field, there is a possibility of establishing a technical cooperation project or dispatching of short-term/long-term experts.

(2) Support for pilot project

In this report, the JICA Survey Team proposes the possibility of a concrete pilot project for solar PV, wind power, and biomass. These projects are under the assumption to be connected to the existing electric power grid, and from the economic viability's point of view, renewable energy is inferior compared with the development of a large-scale hydroelectric power plant. DRE (BEA) will decide the FIT level in consideration of these circumstances, and after introduction of FIT, investment by private companies, including Japanese companies, will advance. However, development by private companies does not advance at once because it takes time for the decision of FIT. In addition, in Bhutan, there is no investment by Japanese companies in the energy field, and the renewable energy field in Bhutan is an unknown world for Japanese companies. In consideration of such circumstances, it is one option that JICA supports the pilot project which DRE (or BPC) will implement using ODA loan or grant aid as a means to secure the bridgehead of the participation of Japanese companies in the renewable energy business of Bhutan.

However, the electric power supply to the people of Bhutan is sufficient by constructing large-scale hydroelectric power plants through the grid. It is difficult to say that development of renewable energy is an urgent issue. Therefore, it is difficult for JICA to support it if RGoB does not give priority to renewable energy development in Bhutan.

(3) Production of bio-fuel

In this report, the JICA Survey Team proposes a project that produces electric power from woody biomass, but there is also another option of a project that produces bio-fuel from the same woody biomass. Because of the very low electricity tariff rate in Bhutan, the investor in the project cannot obtain a great amount of sales in the case of electric power production, and in the case of low FIT, profit will not be obtained. On the other hand, because all the fuel is imported from India, and bio-fuel has a high worth in Bhutan, it is expected that the economy of the project would improve if the project produces bio-fuel. There is significance to support this project from the viewpoint of a reduction in the amount of fuel imported from India.

As a support scheme in this field, JICA offers a scheme called "Small and Medium-Sized Enterprise Partnership Promotion Survey" and supports information gathering and the making of a business plan. Because a reduction in the amount of CO2 emissions can be expected by introducing this project, it is possible to establish a small-scale pilot project by grant aid (for environment and climate change) and to have advanced Japanese technology in a positive way.