Norad

Norwegian Energy Cooperation with Bhutan

A summary report

CONTENT

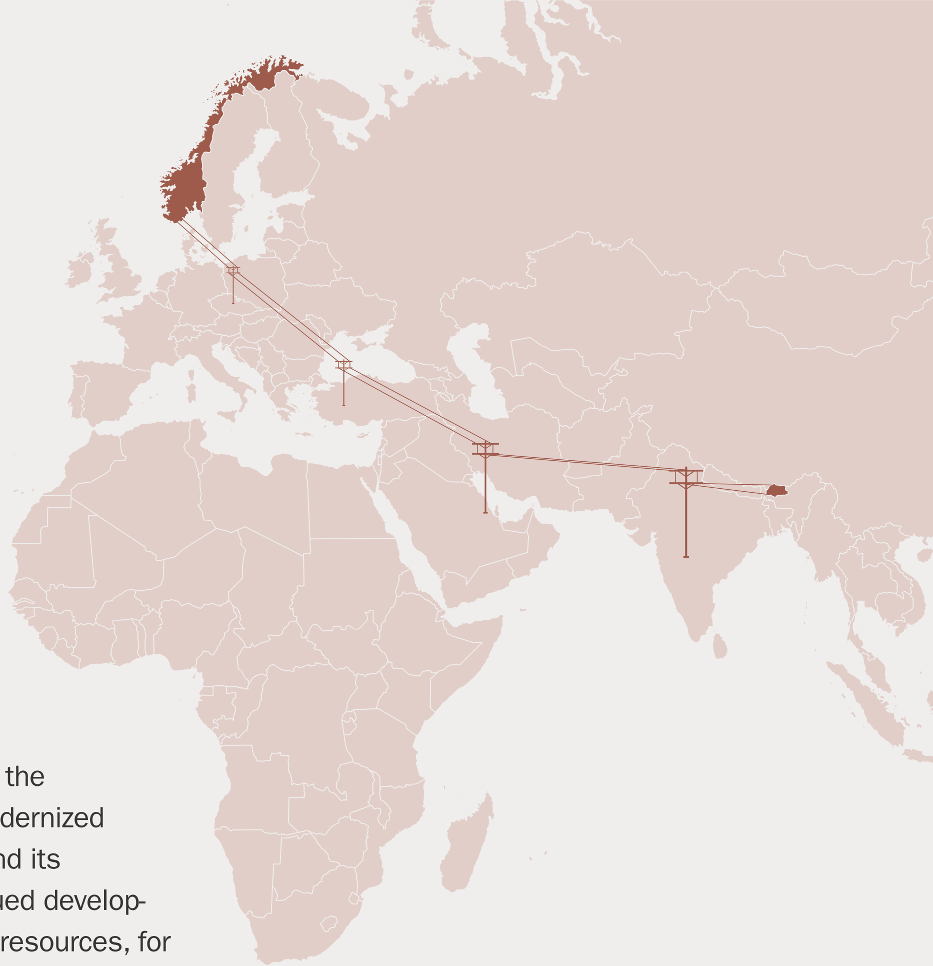
Foreword

In 1967 the cooperation between Bhutan and Norway started, when Norwegian missionaries were invited by His Majesty King Jigme Dorji Wangchuck of Bhutan to establish a hospital in Riserboo, Trashigang, in eastern Bhutan. In February 1967 the missionaries laid down the foundation stone for the hospital, built to combat leprosy. Today the hospital is owned by the Bhutanese government, and leprosy is virtually eliminated in Bhutan.

Later the cooperation between Norway and Bhutan gradually broadened to include initiatives concerning environment, health, gender equality, forest conservation and industrial activities, coordinated through the Norwegian Embassy in New Delhi.

During the latter part of the 1980s, the World Bank initiated a major study on electrification challenges in Bhutan. Norway, given the century-long hydropower experience found a natural interest in the water resource potential in Bhutan. The World Bank project was supported by Norway, initiating the Norwegian energy cooperation with Bhutan.

Over the course of the cooperation period, the ambition of Bhutan to reach electricity access for the entire population has been achieved almost 100 %, an achievement given the challenging geography of Bhutan. With the Norwegian support the modernized energy sector of Bhutan and its entities ensure the continued development of renewable energy resources, for the benefit of the Bhutanese population. The export of electricity from Bhutan will continue to create large revenues for the years to come.



This report is a made to provide a summary of the Norwegian energy cooperation with Bhutan, and to communicate the main results and experiences thereof.

Executive Summary

PHOTO: KEN OPPRANN

The Royal Bhutanese Embassy in New Delhi August 9th 1988 sent a letter to the Royal Norwegian Embassy in New Delhi, proposing the establishment of a hydrological network and preparation of a hydropower development master plan for Bhutan. This proposal was well received by Norway, given the Norwegian century-long experience in hydropower. Our nations soon found a common interest in overcoming the challenges of utilizing the water resource potential in Bhutan in the most sustainable way, as a sound basis for the energy cooperation thereafter.

For almost three decades the energy co-operation between Bhutan and Norway has had four main pillars, respectively 1) hydropower, 2) geohazards, 3) renewable energy and energy efficiency and 4) capacity building through training initiatives across all topics of the cooperation.

During this period the energy supply capacity in Bhutan has increased substantially. Electricity supply to all inhabitants has been almost fully achieved, an impressive achievement given the challenging geography and the rather low population density. The revenue from electricity export is about 25 % of the total revenues of Bhutan, and this share will remain large when the planned projects are completed.

The total Norwegian energy related grants to Bhutan have been 194 million Norwegian Kroner. Close to 70 % of the funds have been allocated to hydropower initiatives, 18 % to other renewable energy and energy efficiency, and 12 % to cooperation on geohazards. The Norwegian support has been directed at various elements of capacity building and creation of the legal framework conditions to support hydropower development. It is thus not possible to measure directly the impact of the Norwegian support, as this has been funding initiatives contributing to aspects of planning and preparatory works. Other donors have also supported the energy sector of Bhutan during these years, particularly Japan, Austria, Netherlands and the Asian Development Bank (ADB).

HYDROPOWER

A major study on electrification challenges in Bhutan, the "Power System Master Plan" (PSMP) was initiated in 1989 in cooperation with the World Bank. The purpose of the PSMP was to develop a twenty-year hydropower development plan to ensure electricity export, and to meet the growing domestic power demand. The PSMP should ensure that hydropower development was done in a safe, cost efficient and environmentally friendly way. It was imperative to integrate the power system master plan into the overall national development plans of Bhutan.

The development of the PSMP was done by Norconsult in cooperation with local stakeholders, and completed in 1993. It summarized the hydropower potential, and provided guidance on future hydropower developments. The PSMP included energy forecasts, grid analyses, as well as prefeasibility studies of a range of possible hydropower plants, ranked in order of attractiveness.

KEY ACHIEVEMENTS OF THE ENERGY COOPERATION

Hydropower

- Power System Master Plan
- Planning of 27 hydropower projects
- Regulations and guidelines on electricity, water and dam safety
- Support to reforms of the energy sector
- Energy regulator strengthened
- 10 hydrological & meteorological stations
- Hydrological modelling & glacier measurements

PHOTO: KEN OPPRANN

Geohazards

- Capacity to gather and process field data for infrastructure development
- State–of–the–art equipment available for field investigations
- Early warning systems for landslides at vulnerable sites
- Detailed feasibility study for the Thimphu–Wangdue tunnel

PHOTO: HARALD BIRKELAND

Renewable energy and energy efficiency

- Plans and strategies for renewable energy & energy efficiency
- Recommendations for a national energy efficiency policy
- 2 hydropower prefeasibility studies
- Guidelines for independent power producers
- National scheme for measuring, reporting and verification

PHOTO: HARALD BIRKELAND

Capacity building

- 23 master's degrees and postgraduate diplomas
- 467 participants in short term training sessions
- Integrated on–the job training
- Ad-hoc advisory support

PHOTO: ENDRE OTTOSEN

The next step of the cooperation (1996-99) was the completion of the feasibility study of the Mangdechhu hydropower project, identified as one of the projects in the PSMP. Norwegian advisers cooperated with the Department of Energy during the early stages of this planning process. A Bhutanese-Indian partnership for this project was established in 2010, the Mangdechhu Hydroelectric Project Authority (MHPA). The project capacity is 720 MW and the electricity production will be 2,925 GWh/year, increasing Bhutan's total electricity production by 27 %.

In 2000 it was proposed to involve the Norwegian Water Resources and Energy Directorate (NVE) more systematically in the work in Bhutan, related to improving the regulatory framework for energy projects in Bhutan. Phase I of the institutional cooperation program including NVE started in 2001, with capacity building to the Department of Energy, with an update of the PSMP and support to the Water Resources Management Plan. Phases II, III *and IV of the cooperation continued to 2017. The assistance from NVE was related to

PHOTO: HARALD BIRKELAND

capacity building, support to power sector reforms and accelerated development of hydropower projects.

Before 2001, the power sector was organized under the Ministry of Trade and Industry. During the cooperation with NVE, the power sector has been unbundled. Separate power sector entities have been created, such as Bhutan Electricity Authority (BEA), Bhutan Power Corporation Ltd. (BPC) and Druk Green Power Corporation (DGPC). Today, these entities together with the Ministry of Economic Affairs

PHOTO: KEN OPPRANN

ensure the best utilization of renewable energy resources for the benefit of Bhutan.

GEOHAZARDS

Bhutan, being a part of the Himalayas, has a young geology. A combination of steep hills, weak rock formations and flash floods after heavy rainfall causes frequent landslides, especially in the monsoon season. Human activities as road construction, mining, urbanization and poor water management also contribute to landslides.

The highway between Thimphu and Phuentsholing has the heaviest traffic in Bhutan. Due to heavy rains in 2000, landslides and floods struck this road, causing a huge roadblock. After this tragedy, the worst landslide in modern history of Bhutan, the cooperation on geohazards was initiated, with capacity building and technology transfer. The cooperation has involved the Ministry of Economic Affairs' Department of Geology and Mines (DGM) and the Norwegian Geotechnical Institute (NGI).

RENEWABLE ENERGY AND ENERGY EFFICIENCY

In 2012, Bhutan joined the Energy+ program. The aim was to electrify the entire country, utilize more renewable energy sources in addition to hydropower, and to improve energy efficiency. The program was defined in 3 phases. Phase 1 consisted of preparatory work in terms of baseline studies, feasibility studies, formulation of energy efficiency policy, renewable energy resource assessments, and policy recommendations to support achieving the goals. For reasons beyond the Bhutanese partnership the Energy+ program was terminated in 2016, and thus Phases 2 and 3 of the Energy+ program were never completed. The analyses completed under Energy+ should still be useful to Bhutan as a basis for further developments.

CAPACITY BUILDING

The Bhutanese eagerness for knowledge and professional training has been supported across all the elements of the cooperation. The programs have provided long and short term training opportunities with altogether close to 500 course seats. This includes both extensive long-term education to obtain master's degrees and short-term trainings in Bhutan, Norway and elsewhere. Together the personnel of the energy sector of Bhutan represent a strong culture, especially needed in perspective of the hydropower potential to be developed. This human capacity is crucial to ensure the right balance between technology, economy and environment in the utilization of energy resources.

1 Introduction

Bridge crossing Punatshangchhu. PHOTO: HARALD BIRKELAND

Dagachhu hydropower plant. PHOTOS: HARALD BIRKELAND

This report has been prepared on behalf of the Norwegian Ministry of Foreign Affairs. The purpose is to provide a summarized overview of the Norwegian energy cooperation with Bhutan, to communicate the main results and experience, and to serve as historical documentation. This report is not a formal review nor an evaluation. It presents a summary of the entire energy-related cooperation between Bhutan and Norway, covering many separate agreements.

Endre Ottosen and Harald Birkeland, senior advisers of Norwegian Agency for Development Cooperation (Norad) are authors of this report. The key learnings, interpretations and other views in this report represent the perspectives of the authors, and do not necessarily reflect the views of the Directors of Norad. Any errors herein are the sole responsibility of the authors, and should not be attributed to the individuals or institutions referred to.

The report is based on a combination of findings during a field visit to Bhutan in September 2016, on a desk study of program deliverables, previous reviews, and a range of interviews with involved contributors, as listed in the annex.

The authors are grateful to all contributors, and especially to the focal point in Bhutan, Jambay Lhundup, Executive Engineer in Department of Hydropower & Power Systems, Ministry of Economic Affairs, for the supporting work to this report.

2 Timeline, Key Components and Stakeholders

PHOTO: KEN OPPRANN

THE NORWEGIAN ENERGY COOPERATION WITH BHUTAN **SUMMARIZED**

Hydropower

1990-2016

135,5 MNOK

Hydropower

- Power System Master Plan
- Planning of 27 hydropower projects
- Regulations and guidelines on electricity, water and dam safety
- Support to energy sector reforms
- Energy regulator strengthened
- 10 hydrological & meteorological stations
- Hydrological modelling & glacier measurements

Geohazards

2002-2016

22,5 MNOK

Geohazards

- Capacity to gather and process field data for infrastructure development
- State–of–the–art equipment available for field investigations
- Early warning systems for landslides at vulnerable sites
- Detailed feasibility study for the Thimphu–Wangdue tunnel

Renewable energy and energy efficiency Energy+ Phase 1

2012-2016

36,5 MNOK

Renewable energy, energy efficiency

- Plans and strategies for renewable energy & energy efficiency
- Recommendations for a national energy efficiency policy
- 2 hydropower prefeasibility studies
- Guidelines for independent power producers
- National scheme for measuring, reporting and verification

Capacity building

1990-2016

Funding integrated in the other pillars

Capacity building

- 23 master's degrees and postgraduate diplomas
- 467 participants in short term training sessions
- Integrated on–the job training
- Ad-hoc advisory support

The key components of the energy-related cooperation between Bhutan and Norway illustrated. In each of the key pillars there is a range of separate activities described, in respective chapters of this report.

TABLE 1 // OVERVIEW OF THE MAIN COMPONENTS OF THE ENERGY COOPERATION BETWEEN NORWAY AND BHUTAN, 1990 – 2016, NOMINAL VALUES. 1 USD = 8.5 NOK

	Key elements	Norwegian funding, MNOK	Approximate equivalent MUSD
1990-93	Power System Master Plan	20	2.4
1996 -99	Mangdechhu Feasibility Study	21	2.5
2001-04	Institutional Strengthening of the Energy Sector, Water Resource Management and Planning and Geohazards, phase I	23	2.7
2004-07	Institutional Strengthening of the Energy Sector and Geohazards, phase II	20	2.4
2008-11	Strengthening of the Energy Sector and Support to Accelerated Hydropower Development Program of Bhutan and Geohazards, phase III	36	4.2
2012-16	Institutional Strengthening of the Energy Sector and Geohazards, phase IV	38	4.5
2012-16	Renewable Energy and Energy Efficiency, Energy+ phase I	36.5	4.3
	Total	**194.5 MNOK**	**23 MUSD**

During this cooperation, a restructuring of the energy sector in Bhutan has taken placed, as it has previously done in Norway and most other countries in transition. A typical (though not universal) development path is to structure and de-bundle the authorities related to power plant planning, licensing and other needed approvals. In figure 1 is shown the current listing of the most important public energy stakeholders in Bhutan.

Separate power sector entities have been created in Bhutan since 2000. The most important are Bhutan Power Corporation Ltd. (BPC), Druk Green Power Corporation (DGPC) and Bhutan Electricity Authority (BEA). BPC was formed as a transmission and distribution company. Druk Green Power Corporation (DGPC) is the main state owned generation company, formed in 2008 through a merger of national hydropower corporations. BEA is the national electricity regulator, and was granted full autonomy by the Royal Government of Bhutan from 2010. BEA has developed from being a unit of 4-5 staff within the Department of Power within the Ministry, to an independent regulator with more than 30 employees.

FIGURE 1 // BHUTANESE ENERGY STAKEHOLDERS, AS ORGANIZED AFTER 2010. PRIOR TO THIS, MOEA WAS MINISTRY OF TRADE AND INDUSTRY, AND DHPS WAS DEPARTMENT OF ENERGY (DOE) AND DEPARTMENT OF POWER (DOP)

MoEA – Ministry of Economic Affairs

- **DHPS – Department of Hydropower & Power Systems**
- **DHMS – Department of Hydro-Met Services**
- **DGM – Department of Geology and Mines**
- **DRE – Department of Renewable Energy**

BPC – Bhutan Power Corporation Ltd. (Transmission & Distribution)

BEA – Bhutan Electricity Authority (Independent regulator)

DGPC – Druk Green Power Corporation (Genco)

NEC – National Environment Commission

GNHC – Gross National Happiness Commission

DHPS-colleagues, from left, Jamyang Namgyal, Dy. Executive Engineer, Jambay Lhundup, Project Manager and Wangmo, Assistant Engineer. PHOTO: ENDRE OTTOSEN

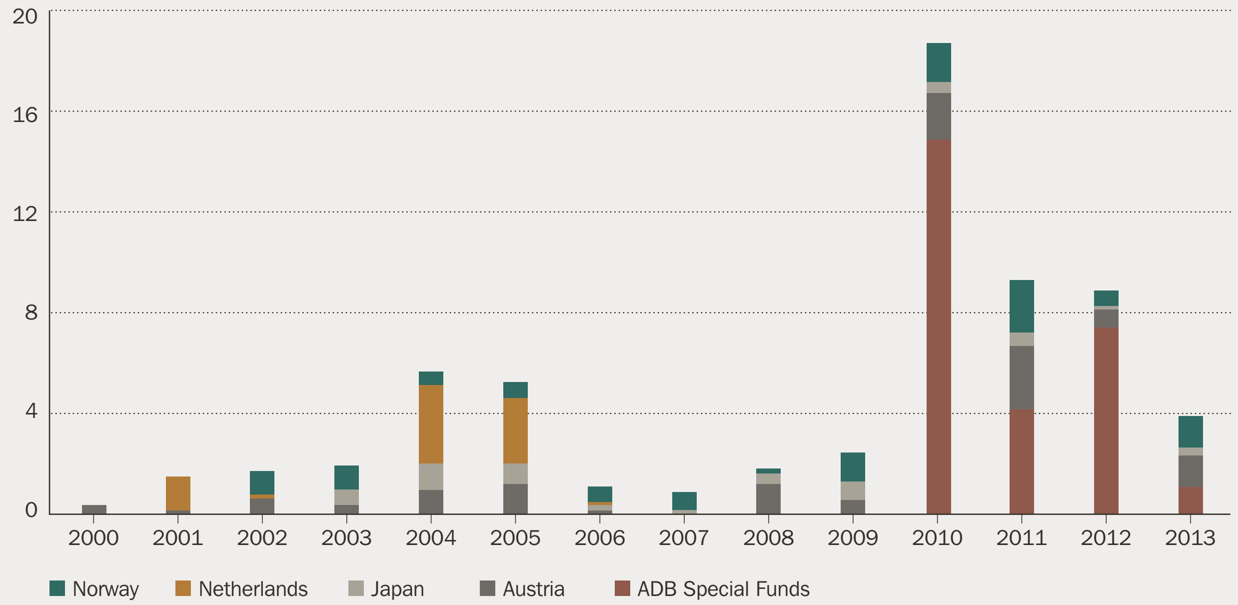
NVE has since 2001 been providing advice to BEA, as on-the-job training and practical regulatory support. This has supported the strengthening of BEA, to be able to fill its role as a fully independent regulator.

The above mentioned power sector entities together with of the Ministry of Economic Affairs today ensure the continued development of renewable energy resources for the benefit of the Bhutanese population.

The main stakeholders in the Norwegian energy cooperation with Bhutan have been:

- The Royal Norwegian Embassy (RNE) to Bhutan, New Delhi
- Norwegian Ministry of Foreign Affairs (MFA)
- Norwegian Water Resources and Energy Directorate (NVE), on behalf of Norad and MFA
- Norwegian Geotechnical Institute (NGI), on behalf of Norad and MFA
- Norwegian Agency for Development Cooperation (Norad)
- Multiconsult/NORPLAN, consultants on hydropower
- Norconsult, consultant on hydropower and PSMP
- Asian Development Bank (ADB), responsible for program management of the Energy+ cooperation on behalf of MFA.

FIGURE 2 // OVERVIEW OF ENERGY GRANTS TO BHUTAN, PER DONOR AND YEAR, 2000-2013, (EXCLUDING INDIA) (MUSD)



SOURCE: OPENAIDDATA.ORG

Other countries have contributed significantly to the energy sector of Bhutan, particularly India as an investor in the largest hydropower projects, and as a provider of grants and loans. Donors of energy grants have been Japan (mainly electricity grid related), Austria (hydropower and energy efficiency), Netherlands and the Asian Development Bank (ADB), as illustrated in figure 2. The Norwegian energy grants to Bhutan in the period 2000-2013 are about 18% of the total energy grants from all donors (excluding India). Japanese contributions to rural electrification were also large before 2000.

3 Power System of Bhutan

PHOTO: HARALD BIRKELAND

Hydropower is important to the development of Bhutan for two main reasons:

- It is a way of providing provide safe, reliable, sufficient and affordable electricity for domestic and industrial use.
- It is a large source of revenue based on electricity export, that can provide monetary strength to finance social projects and to achieve economic self-reliance.

In 2003, Bhutan set a target to provide “electricity for all by 2020”. To achieve this goal, the then Department of Energy made a Rural Electrification Master Plan, a road map on how to fulfill the ambition. Full electrification is very challenging as it is capital intensive to reach every household. It is also practically difficult in a mountainous country, where transport is challenging, and with a low population density. Through a range of concerted actions across the Bhutanese society, involving planners, engineers and many others, the grid expansion plans were realized at an amazing pace.

FIGURE 3 // SHARE OF BHUTANESE POPULATION WITH ACCESS TO ELECTRICITY HAS INCREASED RAPIDLY

TARGET: «ELECTRICITY FOR ALL BY 2020»	**NEW TARGET:** «ELECTRICITY FOR ALL BY 2013»	
2005 Electrification rate: 36%	**2009** Electrification rate: 60%	**2016** Electrification rate: 99,5%

SOURCE: BPC

Today, about of 99.5 % of the total Bhutanese population have access to electricity. The per capita gross consumption of electricity is 2,742 kWh per annum (2015). The revenue from electricity export is about 25 % of total national revenues, and this share will remain large or increase even more when the planned projects are completed.

The rural electrification process has positive impacts. Electric lights have improved the quality of lives of students and women in rural households. Further it has improved the quality of services of basic health units as well as other services like telephones. Once electricity is made available to a rural home, it enhances income activities. With better light the population enjoy more productive time than with the kerosene lamps. Rice cookers and water boilers have become handy for use in the kitchen, and exposure to hazardous fuel wood smoke has been greatly reduced. The overall quality of life has improved with the electrification [1].

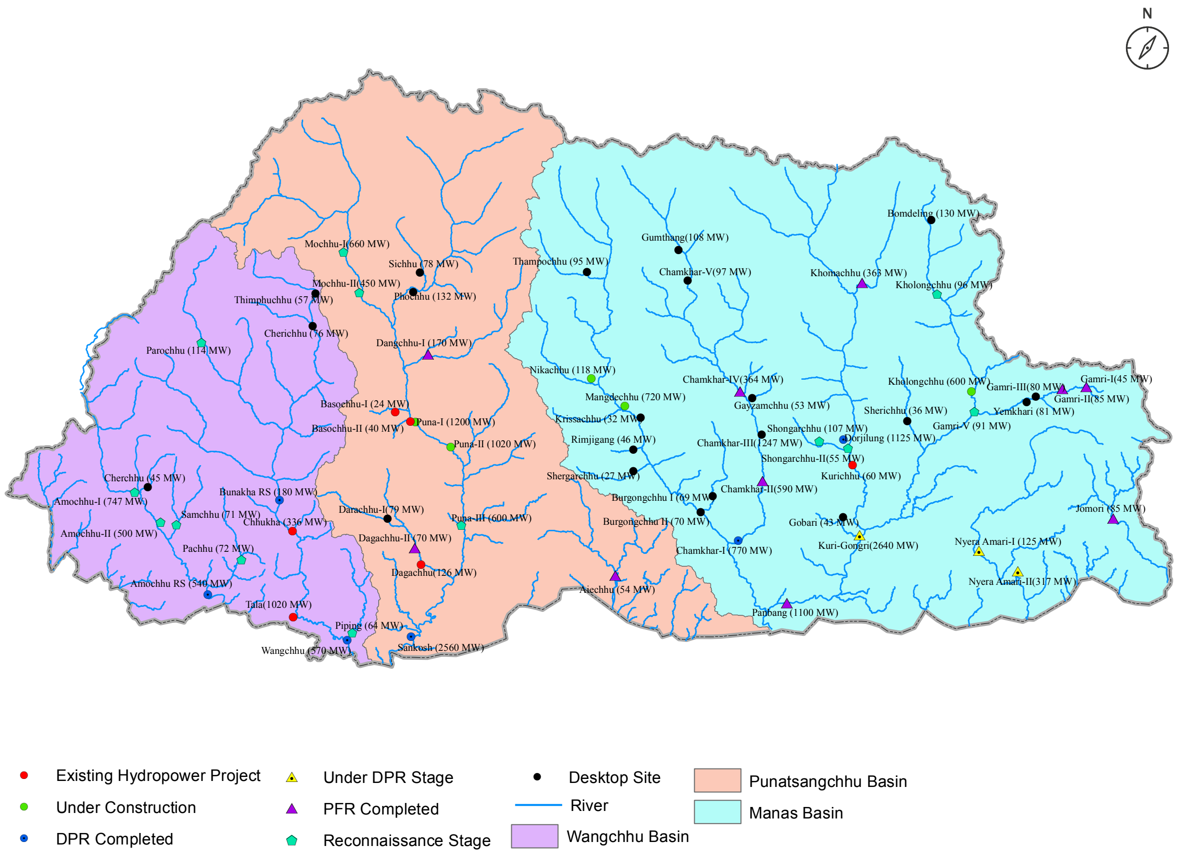
1 S.Tshering & B.Tamang, “Hydropower - Key to sustainable, socio-economic development of Bhutan” presented to UN Symposium on Hydropower & Sustainable Development, 2004, China

ENERGY SUPPLY

Bhutan meets its energy needs to a large extent from renewable energy, with hydropower being the source of virtually all electricity. Fuelwood is still important for cooking and partially for heating. Fossil fuels are widely used in the transport sector. The potential for hydropower in Bhutan is estimated to be around 30,000 MW, of which approximately 23,760 MW is estimated by DGPC to be techno-economically feasible for development. According to a 2009 protocol to a Bhutan-India agreement, India will provide grants and soft loans to Bhutan with the aim to produce 10,000 MW by 2020, and import all the surplus electricity.

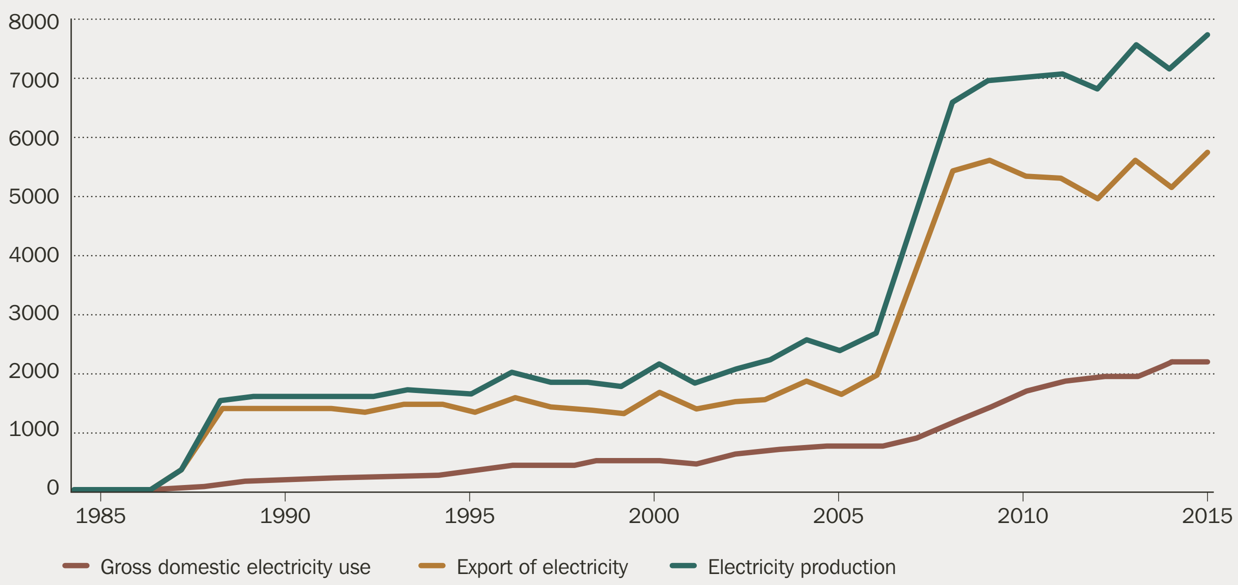
Currently there are five operating large scale Hydroelectric Power Plants (HEPs) in Bhutan with a total installed capacity of 1,606 MW. In addition there are 21 mini-/micro HEPs with a total of about 16 MW installed capacity. The location of existing and planned HEPs > 25 MW are shown in figure 4.

FIGURE 4 // EXISTING AND PLANNED HYDROELECTRIC POWER PLANTS IN BHUTAN > 25 MW



PREPARED BY: SURVEY AND MAPPING CELL, DEPARTMENT OF HYDROPOWER & POWER SYSTEMS, MOEA

FIGURE 5 // ELECTRICITY PRODUCTION, EXPORT AND DEMAND, 1984-2015 (GWH/YEAR)



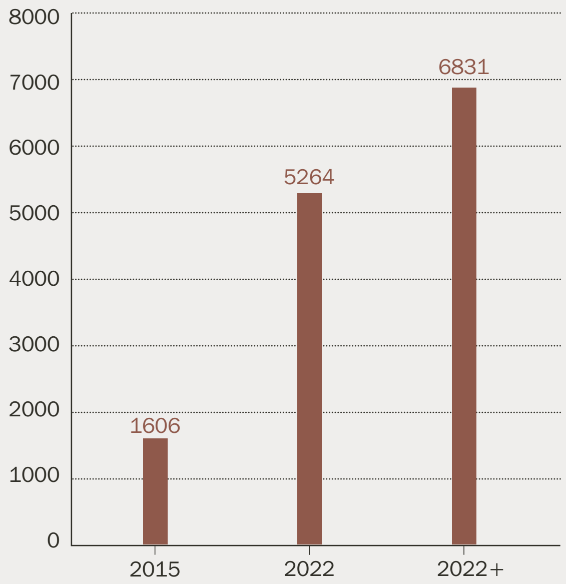
SOURCE: STATISTICAL YEARBOOK OF BHUTAN, (SYB)

Figure 5 illustrates the great increase in electricity production in Bhutan 1984-2015. In 1988 the 336 MW Chhukha project was established as the first major HEP, representing the start of the major electricity export to India. Kurichhu and Basochhu HEPs were completed in 2002-2005, with in total 124 MW installed capacity. The Tala project of 1,020 MW was completed in 2007 after 10 years of construction time. The Dagachhu 126 MW HEP from 2015 is so far the last of the commissioned plants.

The untapped hydropower potential is still very large, given the country size, and five main projects are now under development. These have a total of 3,658 MW additional capacity, and are expected to be completed by 2022. In addition there are six more projects in various planning stages, with an additional 1,567 MW, planned for development beyond 2022. The mid-term future increase in total installed capacity is shown in figure 6.

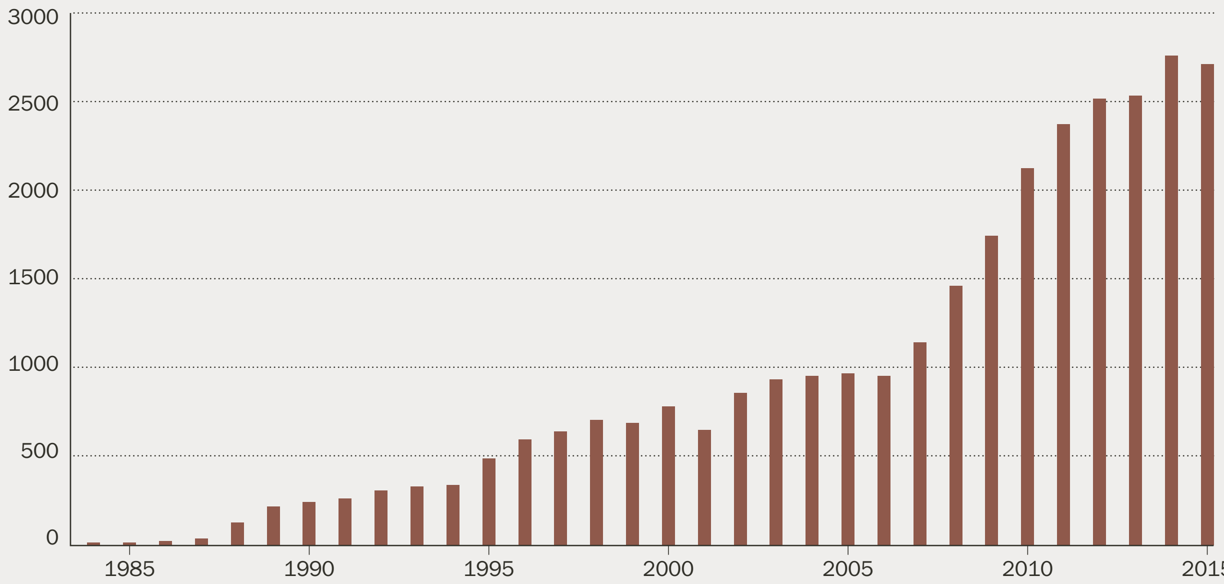
Despite huge efforts by Bhutan and partners over the last decade to implement hydropower projects, the target of 10,000 MW will not be reached by 2020. The reason for the delay in the progress is a combination of challenges related to unforeseen geotechnical difficulties, which in turn result in huge cost overruns. The future hydropower projects will most likely be an important cause of increasing national debt to Bhutan. In the first project developments with India the cost of a hydropower plant used to be 60 % grants and 40% loans. Since 2005 the Indian investment financing of hydropower has shifted to be 70% loan, at typically 10% interest rate, and 30% grant funding.

FIGURE 6 // TOTAL ACCUMULATED CAPACITY FORECAST 2015-2022+, (MW)



SOURCE: ADAPTED FROM WB-REPORT "MANAGING ENVIRONMENTAL AND SOCIAL IMPACTS OF HYDROPOWER IN BHUTAN"

FIGURE 7 // BHUTAN GROSS ELECTRICITY USE PER CAPITA 1984-2015 (KWH/YEAR)



SOURCE: SYB

ELECTRICITY DEMAND

According to the Bhutan Energy Directory of 2014, the industry consumes about 83 % of the electricity in Bhutan, the residential households consume about 11%, and commercial and institutional buildings consume around 6 % of the total electricity consumption.

The development of the annual gross electricity use per capita in the period 1984-2015 is shown in figure 7. With the gradual increase in electricity consumption there is also an associated potential for energy efficiency, both in the industry and in buildings. The options for energy efficiency improvements were specifically elaborated in the Energy+ program, work package 3.

FIGURE 8 // BHUTAN ELECTRICITY USE PER CAPITA, COMPARED TO SELECTED OTHER COUNTRIES, 2013 (KWH/PERSON)

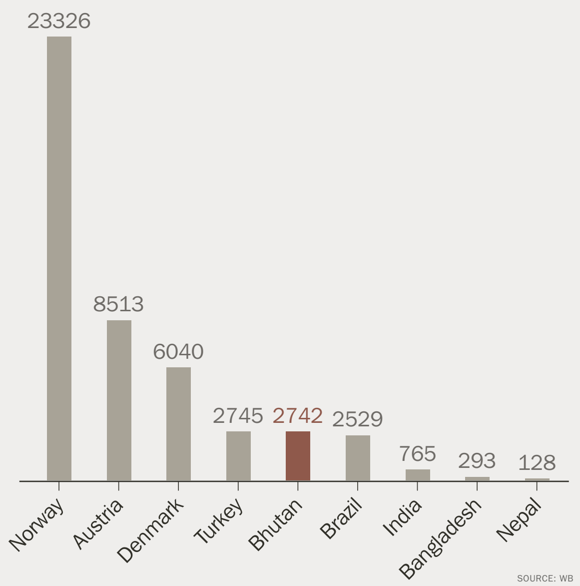
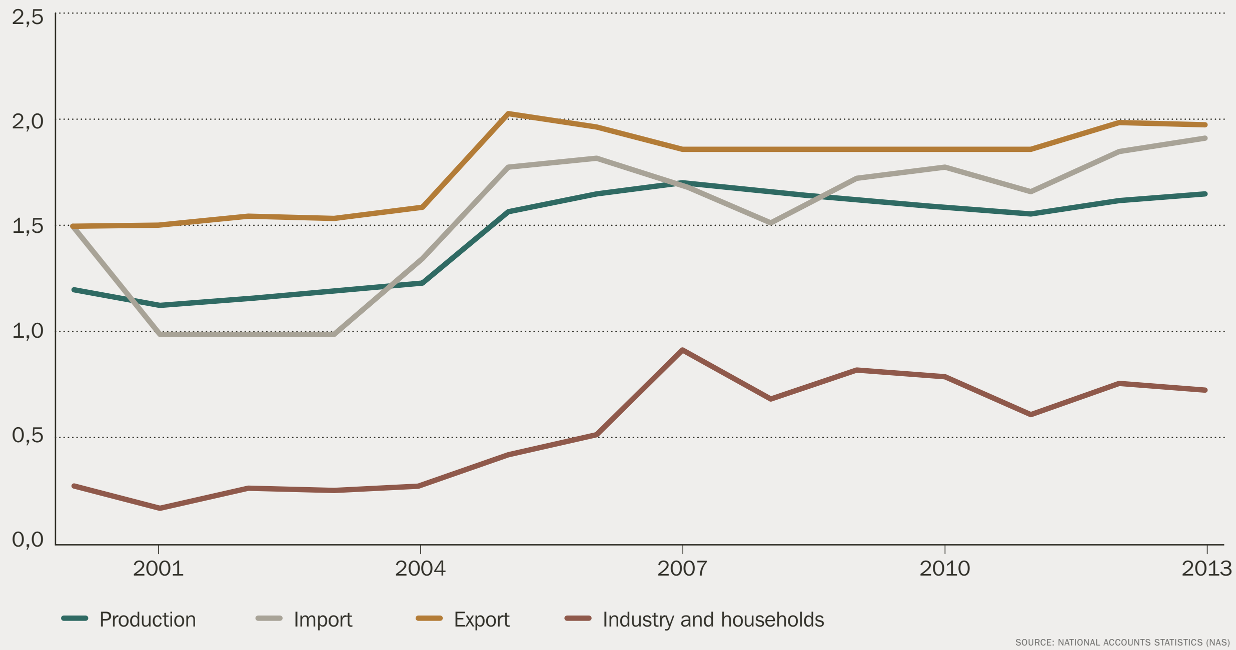


FIGURE 9 // THE AVERAGE ELECTRICITY PRICES 2000-2013, (NU/KWH) DERIVED FROM NAS 2014

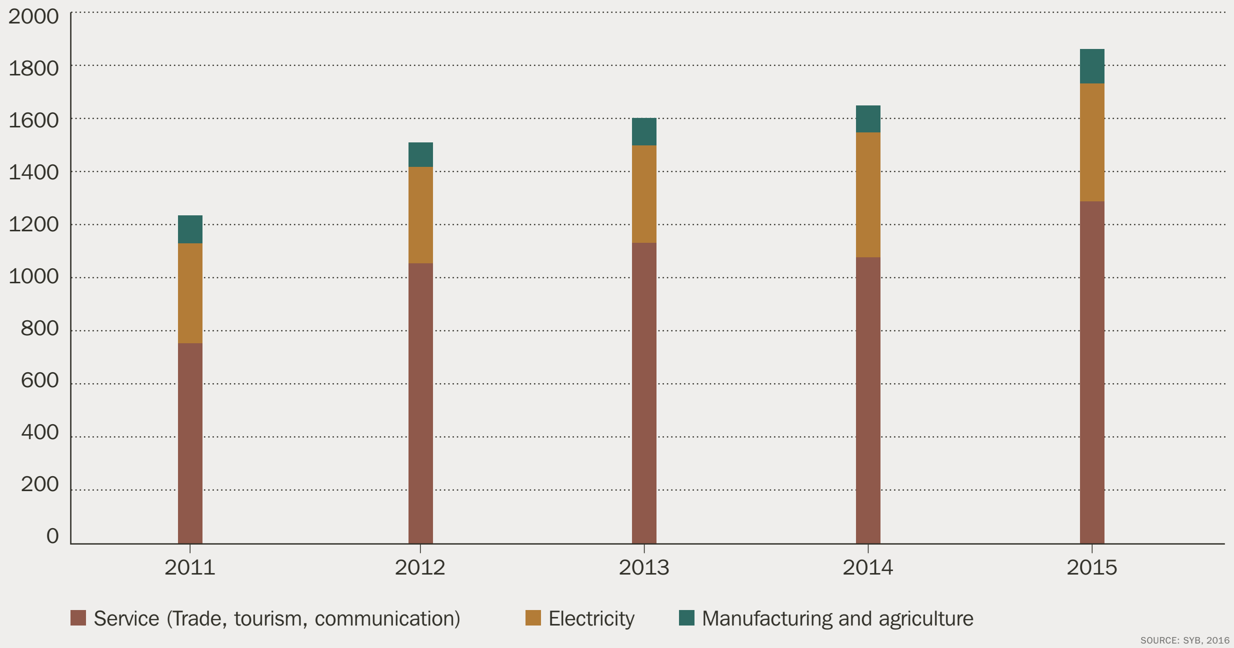


As seen in figure 8, electricity use per person in Bhutan is close to that of Turkey and Brazil.

ECONOMIC IMPACT OF HYDROPOWER

Since 1988 Bhutan has exported electricity at ever increasing amounts. The revenues from electricity sales strongly support the socio-economic development and standard of living in Bhutan. The electricity prices of respectively production, export, import and domestic use of electricity have been fairly stable since 2000, as illustrated in figure 9.

FIGURE 10 // BHUTANESE STATE REVENUES PER MAIN SECTORS 2011-2015 (MILL. NU)



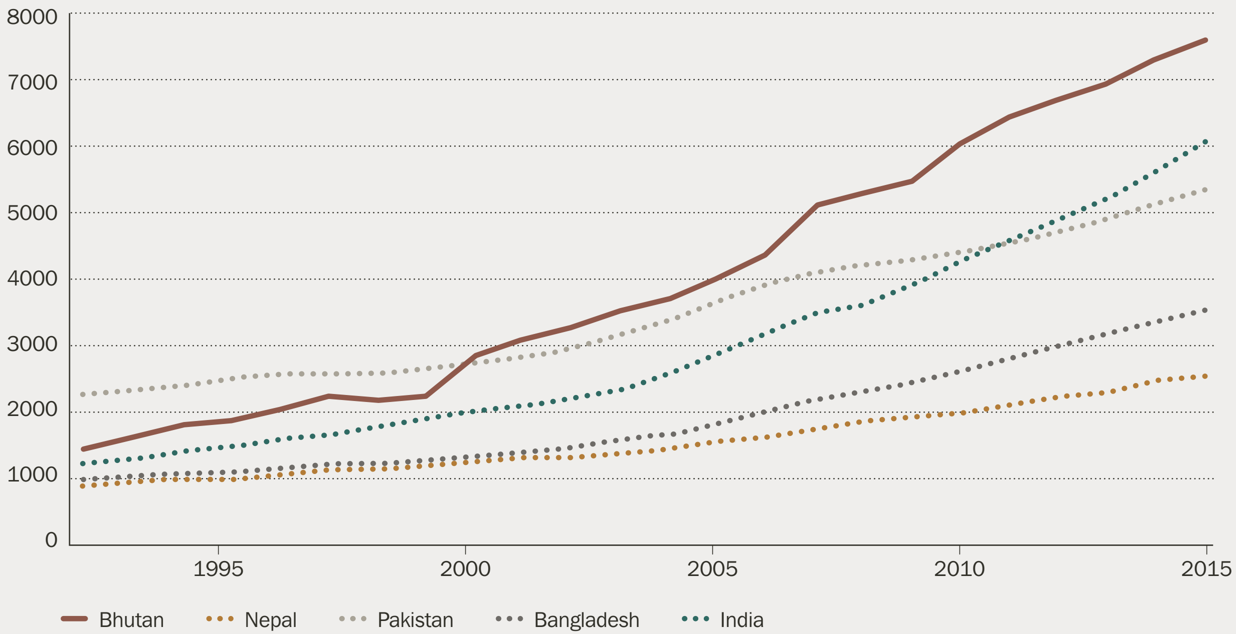
Street scene from Thimphu, capital of Bhutan. PHOTO: HARALD BIRKELAND

The electricity revenues have since 2011 been around 25-30% of total state revenues, with trade, tourism and communication being the dominant element of more than 60% of revenues, ref. figure 10.

Hydropower developments are characterized by the need for large upfront investments, long planning and construction time, as well as a long lifetime. Depending on the financing options for these large investments, the economic impact of hydropower is very important. The Ministry of Finance together with the World Bank have made forecasts for the financial impacts of hydropower. The estimated national perspectives up to 2033 show that the hydropower support to economic growth will be substantial. Another World Bank publication

Tala hydropower plant. PHOTO: KEN OPPRANN

FIGURE 11 // GNI PER CAPITA DEVELOPMENT SINCE 1992 (USD$)

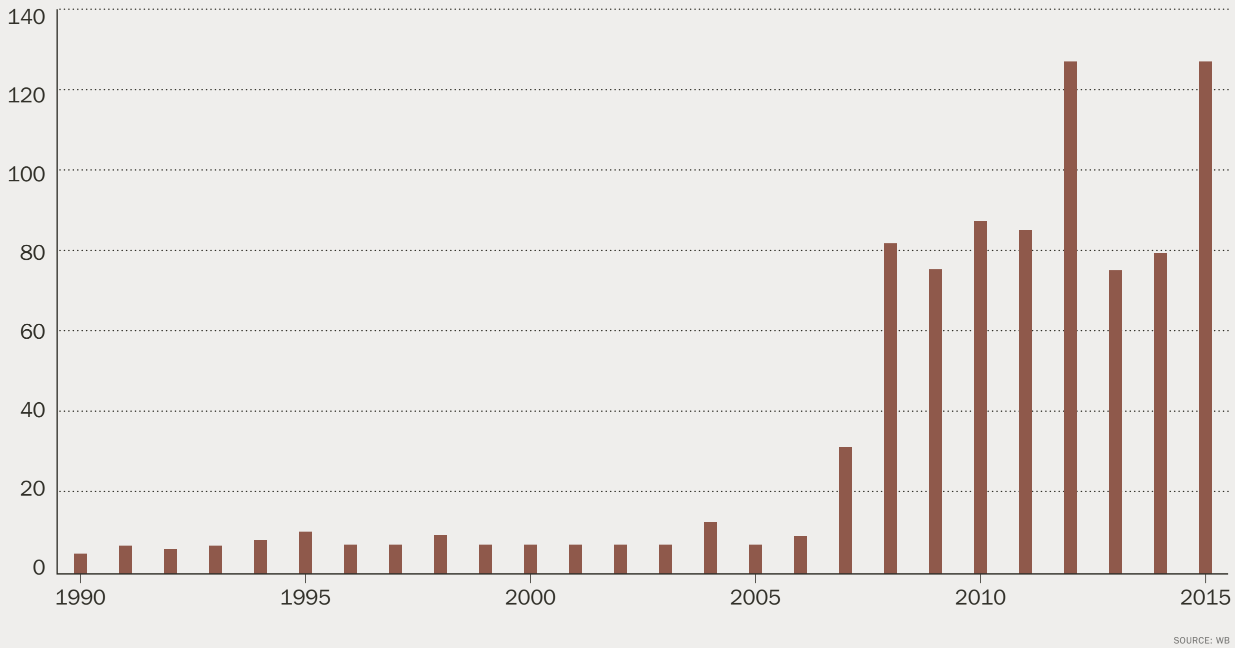


SOURCE: WORLD BANK, INTERNATIONAL COMPARISON PROGRAM DATABASE

"Bhutan – Macroeconomic and Public Finance Policy Note on Hydropower impact and Public Finance Reforms towards Economic Self-Reliance" of 2015 also highlights the need to diversify the Bhutanese economy. Initiatives are needed to increase tax revenues, and to consider ways to reduce the debt burden from the huge investments in the hydropower sector. The World Bank note further suggests a possible strategy supporting of macro-economic stability, fiscal self-reliance and private sector development.

In perspective of the time of this cooperation, the gross national income (GNI) per capita for Bhutan has had a very strong growth, especially compared to countries in the region, as shown in figure 11.

FIGURE 12 // BHUTAN DEBT SERVICE ON EXTERNAL DEBT, PUBLIC AND PUBLICLY GUARANTEED (MUSD)



Bhutan's public and publicly guaranteed external debt was 99 percent of GDP by end of June 2015. Two thirds of the debt is from commercially profitable hydro projects. Figure 12 shows the debt service of Bhutan since 1990, with the rapid increase since 2007, due to the first large hydropower investments.

CLIMATE AND ENVIRONMENT

The nature of Bhutan is diverse and fragile, and the tradition to protect nature remains strong. In order to protect the beauty of the nature in Bhutan there is a separate chapter on environment in the Constitution, declared in 2008. About 52% of the area of Bhutan is protected. Despite being known as a mountainous country, the forest cover is as high as 72 %. The forest is viewed as crucial to future protection of the environment, flora, fauna and biodiversity. The article 5 of the Constitution therefore states that minimum 60 % of forest coverage shall remain at all times to come. There are many protected areas and biological corridors across Bhutan, as shown in the figure 13.

In perspective of the planned large-scale hydropower developments, including needs for transmission and distribution lines, there are some of environmental challenges. Specifically related to hydropower the main environmental concern is aquatic biodiversity, according to the 2016 World Bank study, "Managing Environmental and Social Impacts of Hydropower in Bhutan".

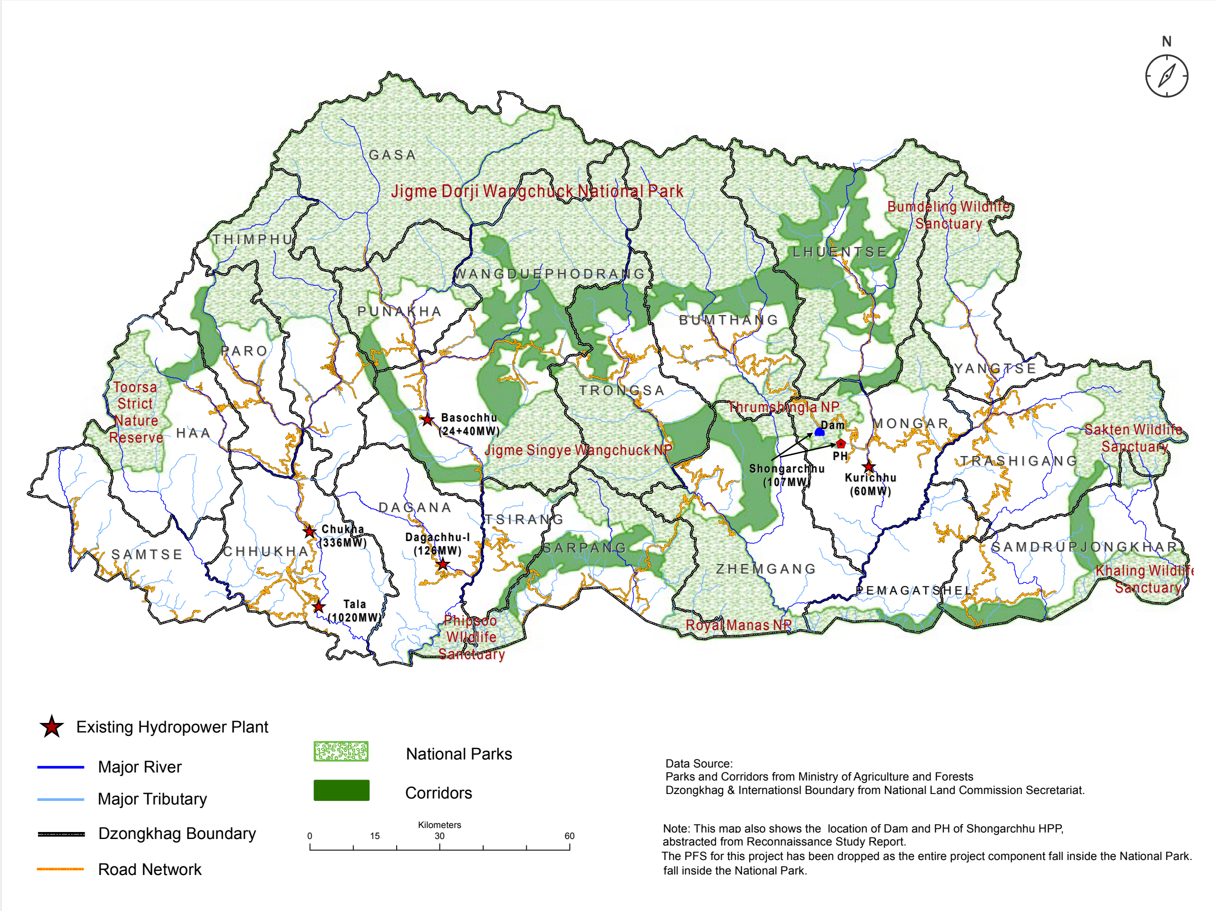
Across nations with hydropower developments, protests against the projects are common.

During the last years some more protests against the mega-projects in Bhutan have been raised. The World Bank has in 2016 initiated a major program with Bhutan to address challenges both related to social and environmental aspects of hydropower developments.

RGOB in 2009 made a declaration to be carbon neutral, to ensure that emissions do not exceed forest sink capacity. Bhutan reported in its 2011 communication to the UNFCCC to be a net sink for GHG emissions, amounting to 4.7 million tons of CO_2-equivalents.

In its Intended Nationally Determined Contribution (INDC) submitted to UNFCCC Secretariat in 2015, Bhutan emphasizes the continued efforts to keep emissions as low as possible. The most challenging sectors with respect to increasing emissions are agriculture, industry and transport.

FIGURE 13 // LOCATION OF EXISTING HEPS WITH NATIONAL PARKS AND CORRIDORS



SOURCE: HYDROPOWER DEVELOPMENT DIVISION, DEPARTMENT OF HYDROPOWER & POWER SYSTEMS, MOEA

4 Hydropower Cooperation

Tala hydropower plant. PHOTO: KEN OPPRANN

KEY ACHIEVEMENTS OF THE HYDROPOWER COOPERATION

Support to unbundling the energy sector and to development of an independent energy regulator	Power System Master Plan and planning of 27 hydropower projects	Regulations and guidelines on electricity, water and dam safety	10 hydrological and meteorological stations, hydrological modelling & glacier measurements

Time period: 1990-2016 / Key Partners: DHPS, DHMS, NVE, Norconsult, NORPLAN / Budget: 135.2 MNOK

This chapter describes the components of the hydropower cooperation between Bhutan and Norway.

Summarized key achievements of the hydropower cooperation are shown in the figure to the left.

The main share of this cooperation has been related to creation of a sound framework for hydropower development, including supporting regulatory reforms, the capacity building of the energy authorities in Bhutan, as well as early-phase planning of separate hydropower projects. Through this support Norway has thus indirectly contributed to the development of the energy sector of Bhutan. However as Norway has not been directly involved in investments in infrastructure, such as hydropower plants or power lines, it is not possible to quantify the effects of this cooperation in terms of megawatts, energy production or financial investments. Nevertheless all the planning works conducted during this cooperation form a solid basis for the continued development of the hydropower sector of Bhutan.

The sequence of the main elements of this cooperation is shown in figure 14.

FIGURE 14 // THE SEQUENCE OF THE MAIN COMPONENTS OF THE HYDROPOWER COOPERATION

SOURCE: NORAD

POWER SYSTEM MASTER PLAN

Through cooperation with the World Bank, a major assessment of the electrification challenges in Bhutan was initiated in 1989, called the “Power System Master Plan” (PSMP). The purpose of the PSMP was to investigate the possibilities for electricity export, and to cover the growing domestic power demand. The PSMP entailed identification of the most promising hydropower sites, and plans for how to develop these in a systematic and safe way. It had a twenty-year perspective, and ensured that the power system developments were integrated into Bhutan's national development plans.

The PSMP was completed by Norconsult in 1993. It was a first major achievement of the energy cooperation, summarizing the hydropower potential, and providing long-term guidance on future hydropower developments. It also included energy forecasts, transmission grid analyses, as well as prefeasibility studies of a range of possible hydropower plants, ranked in order of attractiveness.

MANGDECHHU HYDROPOWER PLANT

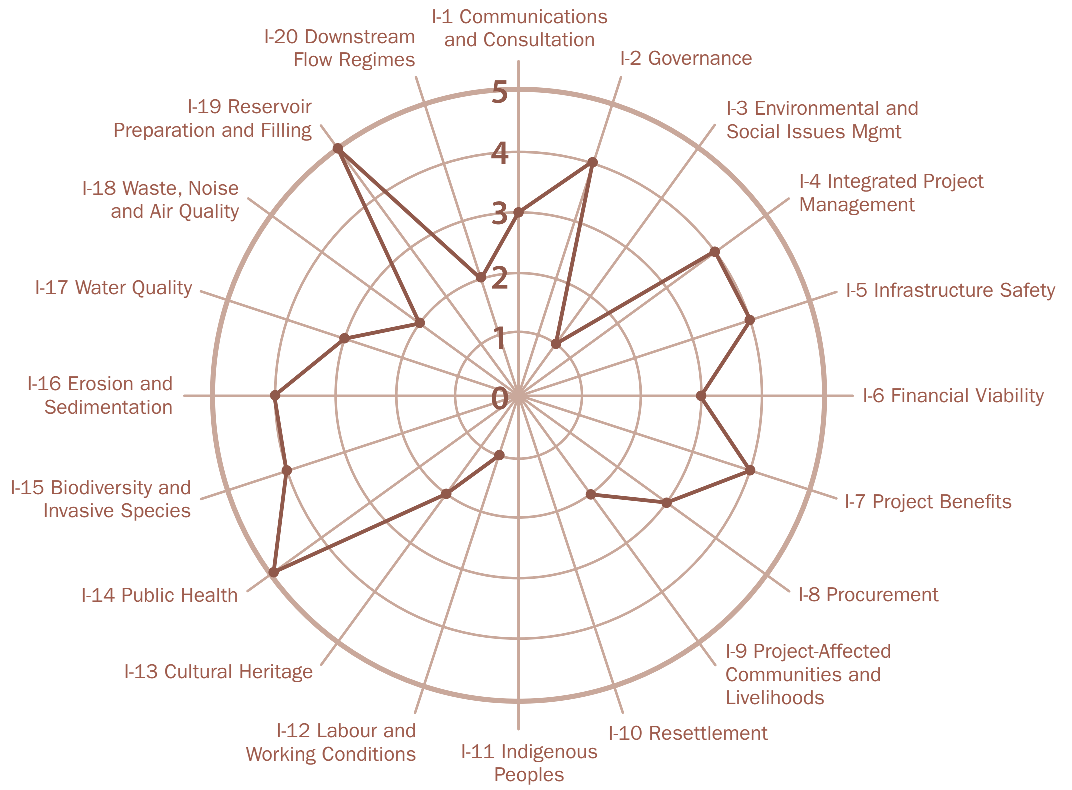
After the completion of the PSMP, the next main step of the cooperation was the completion of the full feasibility study of the Mangdechhu hydropower project, in the period 1996 to 1999. This project, located in Trongsa district was one of several possible sites in the Mangdechhu river. The 265 MW alternative was among the identified projects in the PSMP. Norwegian consultants from Norconsult, NORPLAN and Statkraft Engineering cooperated closely with the Department of Energy during the early stages of this planning process. During the Mangdechhu feasibility study, NVE was an advisor to Department of Energy, providing facilitation and quality control, as well as contractual support.

The feasibility study in 1999 described an increased capacity solution of 360 MW, estimated to produce 2,000 GWh/yr. A special purpose vehicle for the project was established in 2010, the Mangdechhu Hydroelectric Project Authority (MHPA), as a Bhutanese-Indian partnership. The project capacity has been further increased to 720 MW and is now (2017) in the construction phase. About

4,000 employees are involved, in both MHPA and its contractors. The estimated time for completion is 2018, and the electricity production will be 2,925 GWh/yr. This will increase the annual electricity production of Bhutan by almost 38% relative to the 2015 electricity generation.

The World Bank in 2016 performed an assessment of Mangdechhu Hydroelectric Project in accordance with the Hydropower Sustainability Assessment Protocol (The Protocol). The Protocol's Implementation tool contains 20 topics relevant to governance, finance, technical, social, and environmental considerations. 12 out of 18 relevant topics performed at or better than the basic good practice level (score 3 or better of maximum 5 for each topic). Meeting the basic good practice provisions of the Protocol is a highly commendable performance, and proven best practice is quite difficult to achieve. The assessment shows that the project demonstrates competent standards in its sustainability management. The summarized scoring is shown in figure 15.

FIGURE 15 // SUSTAINABILITY PROFILE OF THE MANGDECHHU PROJECT



SOURCE: WORLD BANK 2016 "MANAGING ENVIRONMENTAL AND SOCIAL IMPACTS OF HYDROPOWER IN BHUTAN"

INSTITUTIONAL COOPERATION ON HYDROPOWER

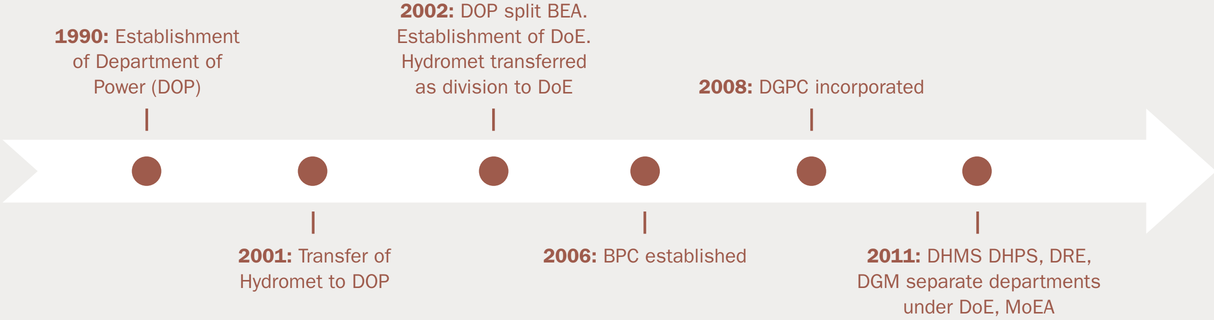
In 2000 it was proposed to involve NVE more systematically in improving the regulatory framework for energy projects in Bhutan. Norway entered into an agreement with Bhutan in 2001 on institutional strengthening of the energy sector. The cooperation has since then involved NVE as the main Norwegian counterpart, during four phases, as summarized in table 2. The total work by NVE has been approximately 25,000 hours (15 man-years) and involved around 50 persons. The funding channeled through NVE also includes fees of consultants and travelling costs.

The management of power system planning, hydro-meteorological services and electricity regulation in Bhutan have gone through several structural changes and reforms over the past 15 years. Some of these changes were direct or indirect results of the collaboration between Norway and Bhutan, such as the establishment of Bhutan Electricity Authority.

TABLE 2 // SUMMARIZED INSTITUTIONAL COOPERATION ON HYDROPOWER 2001-2016

Phase no.		Overall Aim	Funding, MNOK (nominal value)	Approximate equivalent, MUSD
I	2001-2004	Institutional Strengthening of the Energy Sector and Water Resources Management and Planning	20	2.4
II	2004-2007		15	1.8
III	2008-2011		29.8	3.5
IV	2012-2016		29.4	3.5
Total			**94.2 MNOK**	**11.2 MUSD**

FIGURE 16 // TIMELINE ILLUSTRATING KEY CHANGES IN THE BHUTANESE ENERGY ADMINISTRATION



The Norwegian energy directorate (NVE) started out working mainly with Department of Power (DOP), but as structural reforms divided DOP into different entities, the cooperation was adapted into work streams accordingly. Towards the end of this collaboration, there were parallel programs working with DHPS, DHMS, DRE, and BEA.

The key elements of the cooperation between NVE and Bhutan authorities have been:

- Hydropower systems (DHPS)
- Regulatory support (BEA)
- Hydrometeorology and Glaciers (DHMS)

Capacity building was carried out within all topics, and is further described in chapter 7.

Hydropower systems

Technical assistance to hydropower administration and management was a key element in the institutional collaboration, already from the start. The first priority of the cooperation involving NVE was to update the PSMP from 1993. The update was done in 2001-2003 by Norconsult, with technical assistance from NVE. The updated PSMP included listings of prospective hydropower plants, transmission grid upgradings, and a description and forecast of the regional power market.

The update included more detailed information and management aspects on hydrology, environment and social aspects. The updated plan was more realistic, and synchronized with the requirements of the present and the future needs. The plan details the revised hydropower potential and availability of 23,503 MW from 72 sites across three main river basins, as listed on page 63 in the annex. It further provides a ranked list of six major hydropower projects for possible development in the next 20 years. The selection of projects was done using Multi Criteria Analysis (MCA) on 11 top ranking projects. The report also includes the national transmission grid development plan for domestic supply of electricity, and for export of surplus electricity to connecting delivery points in India.

Another important topic for consideration was dam safety. Between 2004 and 2007, critical safety aspects of hydropower dam development in Bhutan were identified and assessed. Later, further modifications to Bhutanese conditions were applied to the guidelines. A draft national Dam Safety Guideline was developed in 2011-2012, including dam classifications and inspection requirements.

Building on the PSMP, more efforts were put into development of specific project preparation studies.

Between 2008 and 2016, 20 reconnaissance study reports were developed for projects ranging from small-scale (in the range of 20 MW) to large-scale projects up to 1,900 MW.

Pre-feasibility studies were prepared for six projects between 85 to 1,230 MW. Some of these reports were developed in-house by the DHPS, with guidance and/or quality assurance from foreign experts. Other reports were prepared by contracted international consultants, often with local sub-consultants. Having a good feasibility report is one of several important elements in order to attract investments in hydropower.

Most of the studies included extensive on-the-job training. NORPLAN, Norconsult, Lahmeyer, Energy Infratech, Fichtner and Mott MacDonald have been the main involved international consultants. The project reports have over time been conducted with gradually more involvement of the professionals of MoEA, in order to transfer as much knowledge as possible. In some of the projects, local employees were working as team members to the consultants, with specific task responsibilities.

DGPC in 2016 completed a Detailed Project Report (DPR) of the 1,125 MW Dorjilung project, located in the Monggar district, with Norwegian funding support.

The main part of the Norwegian hydropower support has since 2008 been related to the above mentioned studies of specific projects. Parallel to this, various ownership arrangements in the hydropower sector have been considered. In 2009, a protocol agreement with India aimed for bilateral joint governmental development of 10,000 MW by 2020. Considering the heavy upfront investments needed to develop the large hydropower plants, the financial challenges have remained substantial. Bhutan also considers other financial models, with a mix of ownership, grants and loans. The Basochhu and Dagachhu projects, commissioned in 2005 and 2015 respectively, are examples of alternative development models. There are also recent considerations on how to secure financing of the mega-projects to come, including possible trilateral investments with India and Bangladesh. Based on the preparation of hydropower projects DHPS in 2012 developed a long-term transmission grid master plan which serves as a roadmap for development of transmission grid in the country.

Regulatory support

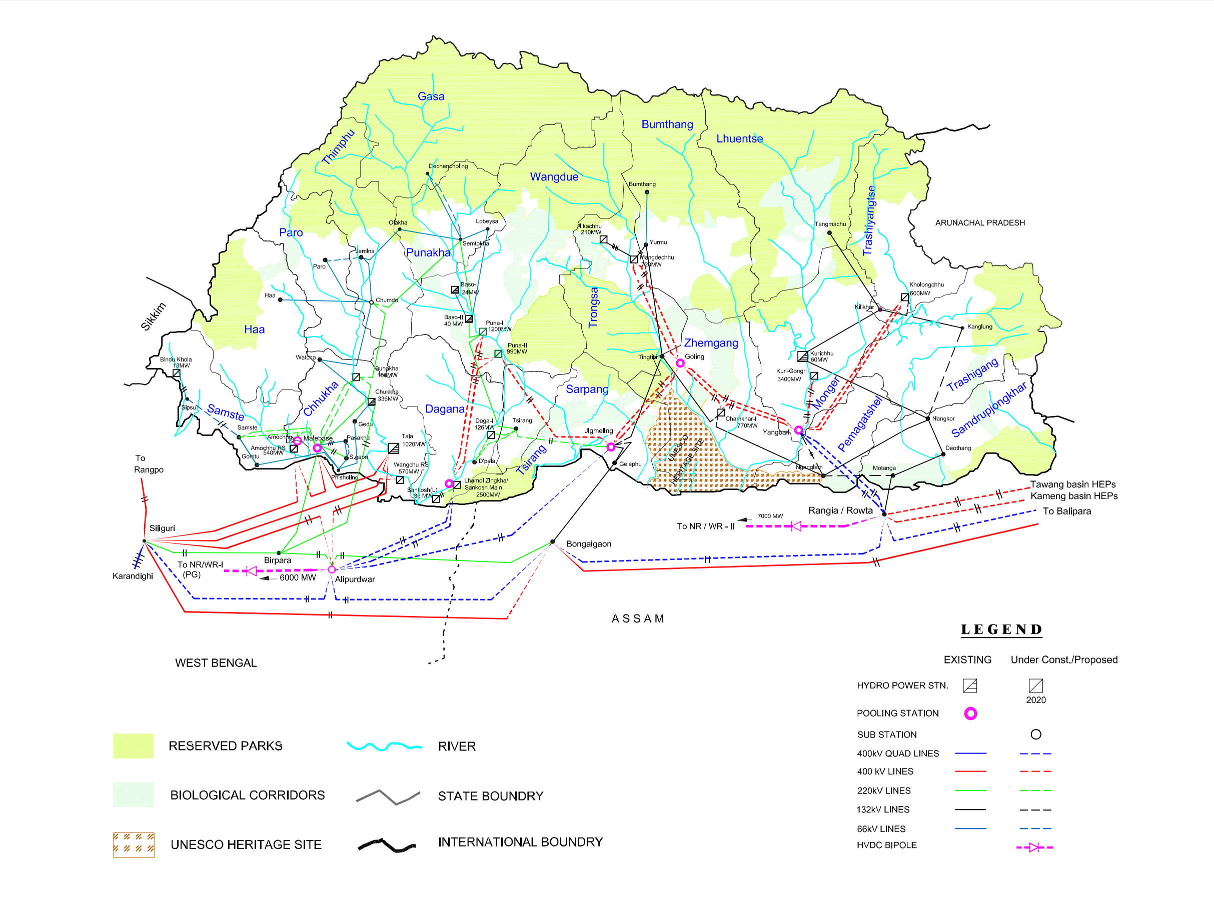
The hydropower collaboration program was initially set up to assist Bhutan in adopting a system for managing its vast hydro resources in a sustainable and efficient manner. This implied establishing the required legislation and regulations, as well as establishing a professional administration of the sector. Between 2001 and 2004, Norway assisted Bhutan in drafting plans to organize a "Ministry of Energy and Water Resources" and a "Department of Energy". In 2002, the Department of Power was split in Bhutan Power Corporation (BPC) and Bhutan Electricity Authority (BEA), and the Department of Energy was established. Norway

Jamyang Namgyal, Dy. Executive Engineer, DHPS, Assistant Project Manager for phase IV of the institutional cooperation, showing a range of the prefeasibility studies of hydropower projects PHOTO: ENDRE OTTOSEN helped draft early inputs to what later became Bhutan Water Policy and Bhutan Water Act, as well as Regulations to the Electricity Act of 2001.

Since 2005, much effort was put into development of BEA. A well-functioning and independent regulating authority is crucial for modern energy sector management. A tariff model and a Tariff Determination Regulation were designed, as well as the principles and procedures for tariff determination. Guidelines were developed for licensing, tariff applications and reviews, fines and penalties.

Norway supported BEA in evaluation of several license applications, such as a 400 kV transmission line, two large scale hydropower plants, as well as the license for a 600 kW Wind Power Plant. In the last phase of the collaboration (2012-2016), an amendment to the Electricity Act of 2001 was initiated with the support of NVE, and a Right Of Way (ROW) regulation was developed. In 2014 BEA, again with assistance from NVE, licensed BPC as the System Operator in Bhutan.

FIGURE 17 // POWER TRANSMISSION MASTER PLAN BY 2020



SOURCE: DHPS

Hydro-meteorology and Glaciers
Systematic collection and processing of hydro-meteorological data is needed to ensure efficient and sustainable management of hydro power resources. It is also relevant for the agriculture sector and from a safety perspective. A hydro-meteorological network was designed and established already in 1991 to fulfill data requirements for these sectors.

In the first phase of the institutional collaboration, Norway supported Bhutan (then Hydromet Services Division) with procurement of hydro-meteorological and sediment laboratory equipment. Technical elements such as updates of hardware, software and databases were included. Input to the Water Resources Management Plan was provided in this phase.

The second phase included work to strengthen the system for hydro-meteorological data collection. During the years 2004-2007, 10 hydrological and meteorological stations were established, and existing stations were upgraded. Many of the hydrological stations were destroyed in a cyclone in 2009. These stations were later restored with Norwegian support. Three new sediment sampling stations were established in eastern Bhutan.

After 2008 hydrological models suitable for the Himalaya region have been evaluated. An existing model was modified in order to take into account mass balance of glaciers and glacier dynamics relevant to Bhutan. The results from the modelling is used to describe hydrological regimes of Bhutan, which in turn is a basis for evaluating hydropower production capacity. One key output from this work was the report *"Climate Change Impacts on the Flow Regimes of Rivers in Bhutan and Possible Consequences for Hydropower Development"*. This report describes the long-term perspectives on hydropower challenges in Bhutan. The work on hydrological modelling continued into the final phase. DHMS now has a fully operational model of the Mochhu sub-basin.

A glacier mass balance measurement network and high altitude meteorological station was established on Thana Glacier in Chamkharchhu basin, and potential Glacier Lake Outburst Flood

The control center of Bhutan Power Corporation. PHOTO: ENDRE OTTOSEN

(GLOF) sites were investigated. The increased knowledge about GLOF and associated risks is closely coordinated with the work on flood warning systems.

The increased knowledge on melting of glaciers is very important to Bhutan, and to the entire Himalaya region. Bhutan therefore cooperates with the International Centre for Integrated Mountain Development (ICIMOD) in scientifically documenting the cause, process and effects of the GLOFs.

The Department of Hydro-Met Services (DHMS) is now designated as the National Centre for Hydrology and Meteorology (NCHM), an independent agency in Bhutan responsible for weather, climate and water resources. NCHM intends to collaborate internationally on the following topics:

- Improved hydro-met services related to weather, climate and water resources, seasonal short-term inflow forecasting, flood forecasting and warnings
- Improved understanding of snow and Himalayan glaciers
- Research within hydrology, water resources, glaciers and impact of climate change
- Capacity building and training to enhance the professional capacity

High altitude glaciers pose challenges to measure and predict. PHOTO: MIRIAM JACKSON

5 Geohazards Cooperation

PHOTO: HARALD BIRKELAND

KEY ACHIEVEMENTS OF THE GEOHAZARDS COOPERATION

Capacity to gather and process field data for infrastructure development	State-of-the-art equipment available for field investigations	Early Warning Systems for landslides at vulnerable sites	Detailed feasibility study for the Thimphu-Wangdue tunnel

Time period: 2002-2016 / Key Partners: DGM and NGI / Budget: 22.5 MNOK

In Bhutan, landslides occur naturally and frequently. This is due to a combination of steep hills, weak rock formations and flash floodings from heavy rainfall, especially during the monsoon season. Human activities such as road construction, mining, urbanization and poor water management also contribute to landslides.

The highway between Thimphu and Phuentsholing has the heaviest traffic in Bhutan. Due to unusually heavy rains in July 2000, landslides and floods struck several areas in south Bhutan, and caused an 18-km long roadblock of this highway. The disaster is the worst landslide in modern history in Bhutan.
After this tragedy the geohazards cooperation between Bhutan and Norway was initiated.

The first agreement was signed in 2002, and the program has been implemented in four phases. During these years, the overall aim of the geohazard cooperation has shifted slightly, from landslide prevention, to road tunnel preparations, and lately more specifically targeting infrastructure developments, specifically related to hydropower. The key involved entities have been Department of Geology and Mines (DGM) and the Norwegian Geotechnical Institute, NGI. The total work by NGI has been approximately 15 000 hours and involved around 20 persons. The funding channeled through NGI, shown in table 3, also includes fees of consultants and travelling costs.

LANDSLIDE PREVENTION

The first phase of cooperation involved geological mapping, registration of landslides, and estimation of slope instabilities. Samples were collected from landslide prone areas and lab-tested, and monitoring of landslide behavior was conducted with instruments acquired for this purpose. The first phase also included development of geohazard maps and plans for landslide prevention.

TABLE 3 // SUMMARIZED COOPERATION ON GEOHAZARDS

Phase no.		Overall Aim	Funding, MNOK (nominal value)	Approximate equivalent, MUSD
I	2002-2004	Institutional strengthening related to geohazards	3	0.4
II	2004-2007		5	0.6
III	2008-2011		6	0.7
IV	2012-2016		8.5	1.0
		Total	**22.5 MNOK**	**2.7 MUSD**

Typical road challenges PHOTO: ENDRE OTTOSEN

ROAD TUNNEL PREPARATIONS

In the second phase of cooperation, the partners developed detailed plans for selected road tunnel options, and conducted further investigations of two critical sites. To support these investigations a ground penetrating radar (GPR) was procured, equipment that is still with DGM and represents a source of revenue when such services are requested. Efforts were made to facilitate dialogue on geohazards with other relevant institutions both in Bhutan, India and Nepal.

INFRASTRUCTURE DEVELOPMENT

In the third phase, risk reduction measures for infrastructure developments in Phuentsholing area were initiated. Early warning systems were developed for an urban settlement (Thimphu) and a hydropower site (Tala). Installation of automatic rainfall measuring stations were included. Software for analyzing slope stability was also acquired.

The DGM/NGI team conducted sub-surface geological investigations and data collection at the planned Nikachhu hydropower project (118 MW), which will reduce the risk associated with

Site investigations are important preparations prior to dam establishment. PHOTO: NGI the project. Publications were prepared, such as a handbook for rock mass characterization, and design guidelines for construction of safe and cost efficient underground structures.

The Thimphu-Wangdue tunnel

Road tunneling technologies are of great interest to Bhutan, as the travelling times between the cities could be greatly reduced by use of tunnels. Two major hydropower projects (Punatsangchhu I and II) are being constructed near Wangdue. Several thousand people are residing in the area, and many others are commuting. A pre-feasibility study for the Thimphu-Wangdue tunnel was prepared as a part of the third phase of the cooperation.

The planning of this tunnel continued in the fourth phase, with completion of a full feasibility study. Data collection for the study included airborne geophysical surveys and field investigations along the tunnel alignment. The study was done by NGI in cooperation with DGM and Department of Roads (DOR). Alternative tunnel designs were including proposals of a longer tunnel with lower inclination.

Airborne geophysical survey along Thimphu-Wangdi tunnel PHOTO: NGI

Drone used for low-cost surveys in complex terrain PHOTO: NGI

The quality of the rock mass varies along the tunnel alignment. It is estimated that 60-65 % of the tunnel will pass poor to fair quality rock, requiring systematic bolting and at some weakness zones more rock support is needed. The total tunnel cost is estimated to be 1200 MNOK (140 MUSD or 9,2 Billion Nu) for the 14 km long alternative, excluding connecting roads. The new road link will reduce the road length to less than half, and the travelling time to one third of today. More detailed mapping of geological structures and better cost estimates must be made prior to investment decisions. Still the studies have paved the way for construction of Bhutan's first major road tunnel.

Capacity building has been an integral part of all phases of the collaboration on geohazards, including on-the-job training. Training has been provided through field visits in Bhutan and a range of study tours to Norwegian projects. DGM representatives have been trained by NGI experts through participation in field investigations, data collection and use of modern equipment and software, as well as attending short-term trainings in Norway and Bhutan.

6 Renewable Energy and Energy Efficiency

300 kW wind turbine at Rubesa. PHOTO: HARALD BIRKELAND

KEY ACHIEVEMENTS OF ENERGY + PHASE 1

Plans and strategies for renewable energy and energy efficiency	Recommendation for a national energy efficiency policy & guidelines for independent power producers	Two hydropower prefeasibility studies, one feasibility study of a 30 MW PV solar power plant	National scheme for measuring, reporting and verification of GHG emissions

Time period: 2012-2016 / Key Partners: DRE, DHPS, ADB / Budget: 36.5 MNOK

Energy+ was a partnership program established in 2011, supporting increased access to sustainable energy and reduced greenhouse gas emissions through deployment of renewable energy and energy efficiency.

In 2012, the Norwegian Minister of International Development announced a pledge of up to NOK 100 million (results-based) (11,8 MUSD) to the Prime Minister of Bhutan with the intention of entering into an Energy+ Cooperation Partnership (Cooperation). The Governments of Bhutan and Norway, and Asian Development Bank (ADB) signed a cooperation framework document in 2013 which provided details on the implementation of the Cooperation.

The focus of Energy+ on renewable energy and energy efficiency was complementing the previous Norwegian initiatives within hydropower and geohazards in Bhutan. The cooperation was also supporting the Sustainable Energy For All initiatives in Bhutan. Energy+ was in line with national policies such as the Alternative Renewable Energy Policy and the Sustainable Hydropower Development Policy. Energy+

activities were integrated in Bhutan's 11th five year plan.

In Energy+ the budget allocation was 36.5 MNOK (4,3 MUSD) to Phase 1, and 63.5 MNOK (7,5MUSD) to Phases 2 and 3. During Phases 2 and 3 funding would be provided as "Payment-By-Results". The results would be measured as access to sustainable energy and reduced emissions of greenhouse gases (GHG) relative to baselines, and with payments in proportion to the progress.

The implementation of the partnership was guided by the Energy+ Cooperation Framework, Memorandum of Understanding, Joint Implementation Note, Partnership Agreement, Contribution Agreement and Joint Consultation Group Meetings, representing all the stakeholders.

Due to reasons beyond activities taking place in Bhutan, the Energy+ program was terminated in 2016. For Bhutan it was decided to complete the Phase 1 activities, but to abandon Phases 2 and 3.

FIGURE 18 // ENERGY+ PARTNERSHIP THREE-PHASED APPROACH

Phase 1 Readiness → **Phase 2** Implementation → **Phase 3** Scaling up

ENERGY+ PHASE 1
The first phase of Energy+ aimed to enhance clean and sustainable energy development in Bhutan, through conducting the following readiness actitivies

- Support to increase access to energy services like electricity connections, heating and cooking
- Support use of renewable energy by training, institutional development and legal reforms
- Support the development of renewable energy master plan
- Support energy efficiency programs to enhance the energy security
- Identify national appropriate mitigation action (NAMA) opportunities in the energy sector
- Develop a measurement, reporting, and verification (MRV) system

Organization of Energy+ in Bhutan
Department of Renewable Energy (DRE) was the executing agency. ADB was in charge of program management on behalf of Norwegian Ministry of Foreign Affairs, MFA. The Department of Hydropower & Power System (DHPS) and The National Environment Commission (NEC) were implementing agencies responsible for specific sub-projects of the program, as summarized below:

DRE was responsible for:

- Conducting a feasibility study for the 30 MW Shingkhar solar power plant
- Financing a pilot project to encourage the use of higher energy efficiency lamps
- Conducting reconnaissance studies for four mini or small hydropower projects
- Formulating renewable energy master plan
- Formulating national energy efficiency and conservation policy
- Formulating feed-in-tariff framework for renewable energy technologies
- Conducting a study for the deployment of solar water heating system in Bhutan
- Formulating rules and guidelines of the alternative renewable energy policy
- Assessment of resource requirements for minimum energy performance standards
- Updating Bhutan Energy Data Directory 2005

DHPS was responsible for:

- Conducting prefeasibility studies for three hydroelectric power projects (HEP)
  - *Shongarchhu HEP, estimated capacity 107 MW*

Modern houses in Wangdue Phodrang. PHOTO: HARALD BIRKELAND

- *Dagachhu-II HEP, estimated capacity 135 MW*
- *Manas HEP, estimated capacity 1800 MW*
- Making guidelines and manuals for private sector participation in the hydropower sector
- Participating in training programs to strengthen institutional capacity

NEC was responsible for:
- Preparing environmental and social safeguards and standards for energy sector
- Identifying national appropriate mitigation action (NAMA) opportunities in the energy sector in Bhutan
- Developing a Measurement, Reporting, and Verification (MRV) system
- Developing national energy registry system

Key outputs:
In order to provide the range of outputs in phase 1 as described above, four different consulting firms were contracted for implementation of project activities in four work packages, as listed below.

- Work Package 1: Feasibility studies of hydropower projects and preparation of guidelines
- Work Package 2: Renewable Energy Master Plan
- Work Package 3: Energy Efficiency Program
- Work Package 4: MRV System

Complete listing of the work package outputs is shown in the annex 9.2.

Assessment
All the reports of work packages 1 to 4 were prepared according to the ToR developed jointly by ADB, the executing agency (DRE) and the implementing agencies (DHPS & NEC). The reports covered all the issues both technical and financial that need attention in the next level of study and to minimize risk and make the projects attractive to investors. During the implementation period some adjustments were to the original scope, e.g. two instead of three HEP prefeasibility studies were carried out.

The final reports have been endorsed by the implementing and executing agencies. According to DRE and ADB, the overall quality of the reports presented was acceptable, considering the time and resources allocated to the consultants. The deliverables should form a useful basis for continuation of work within the energy sector of Bhutan.

Traditional houses, and chili peppers drying on the roof. PHOTO: HARALD BIRKELAND

7 Capacity Building

Librarian Kuenga in the DHPS hydropower library. PHOTO: ENDRE OTTOSEN

KEY ACHIEVEMENTS OF CAPACITY BUILDING

23 master's degrees and postgraduate diplomas	467 short term trainings*	Integrated on-the job training	Ad-hoc advisory and gap-filling

Time period: 2001-2016 / Cross-cutting, funding incorporated in all programs

*Less number of individuals participated

Capacity building has since the early 1990s been an important element of the energy cooperation between Norway and Bhutan. Transfer of knowledge has been done in different ways and on several levels throughout the cooperation.

ON-THE JOB TRAINING

Transfer of knowledge between Norwegian and Bhutanese colleagues has been an integral part of the work in all programs and activities of the energy cooperation. This has been done through on-the-job training while working on specific deliverables, and through more ad-hoc advisory services, mentoring and quality assurance.

On-the-job training was integrated already in the early phases of collaboration. During the development of the PSMP (1990-1993), advisors from Norconsult spent many months of fieldwork across Bhutan, collecting data and information, together with Bhutanese colleagues.

During the Mangdechhu Feasibility Study, NVE acted as an advisor to Bhutan Department of Energy, on contractual issues and quality assurance, while Norwegian advisers from Norconsult, NORPLAN and Statkraft Engineering worked closely with the design teams.

When NVE, and later NGI, were more systematically involved in improving regulatory framework and resource management in Bhutan, training was an important part of the programs. During the years NVE has been working in Bhutan, around 50 experts have been involved. From NGI, around 20 experts have been directly involved in Bhutan, and a similar number as supporting staff. Most of these have contributed to on-the-job training while working over shorter or longer periods of time in Bhutan, and have been available as support after return to Norway. The combination of frequent visits, long-time presence and professional relations between Norwegian and Bhutanese partners has made it possible to maintain contact and exchange advice and knowledge, also at a distance.

Field visit to Punatsangchhu, Martin Brittain, NVE and Nima Tshering, BEA PHOTO: JENS AABEL

The effects of the training have been evident as the cooperation has progressed over the years, and the Bhutanese partners have gradually become more in charge of the management of the program. In the last phase the pre-feasibility study for Jomori-I (85 MW) and six Reconnaissance Study Reports (RSR) were handled in-house by the Department for Hydropower & Power Systems.

Glacier mass balance monitoring with Bhutanese colleagues. PHOTO: MIRIAM JACKSON

Although on-the-job-training is practical and useful to the ones participating, it might be challenging to keep the momentum in-between the availability of the trainers.

Much of the hydropower related training has been development of prefeasibility reports, and thus quite project specific. The advantage of this approach has been the direct relevance to bring more projects faster forwards towards investment decisions.

HIGHER EDUCATION AND SHORT-TERM TRAINING

In addition to the on-the-job training, the programs have provided support to more formal capacity building, both through full master degrees, and as short-term trainings. During the hydropower cooperation the capacity building components have included 23 master degrees and around 467 short term training course seats for Bhutanese professionals. Some individuals have joined several trainings over the years, hence number of people trained is significantly less. The short term courses include ICH trainings, as described in the adjoining text box.

The master degree scholarships have made it possible for Bhutanese students to get degrees both in Norway and other countries. Many of these former students today work in the hydropower sector in Bhutan, such as in MoEA, BPC, BEA and DGPC.

The International Centre for Hydropower (ICH) is an international association of companies and organizations active in all aspects of hydropower generation and supply. ICH delivers training courses in more than 20 countries in Asia, Africa and Latin America, as well as in Norway.

ICH offers a comprehensive course portfolio, on topics ranging from development and management of hydropower projects; technical training related to operation and maintenance, turbine technology, sediments and dam safety, economic topics such as power trading, and environmental and social impacts and conflicts. ICH courses are from one to three weeks in duration, and normally with participants from many countries.
In some cases, ICH also delivers tailored courses on demand.

Since 2008, Norway has sponsored 316 seats at ICH courses, for candidates from the partnering institutions in Bhutan. These courses have been in Norway, South-East Asia, and in some cases tailor-made courses in Bhutan. The ICH courses have been an important part of the Norwegian capacity building offered to Bhutan.

ICH regional power trade course, Thimphu 2015. PHOTO: TOM SOLBERG

The short-term trainings have typically been one- to three-week courses. Some have been organized in Bhutan, specifically adapted to the local needs. In many cases Bhutanese professionals have attended international courses in other countries, including Norway.

Dorji Namgay, CEO DHI-Infra

Mr. Dorji Namgay was involved in the early stages of cooperation with Norway. He went to Norway on a scholarship to do his Master's Degree in Trondheim in 1995. When he returned he joined then Department of Power, where he was involved in the Mangdechhu feasibility study and other parts of the cooperation. Mr Namgay recalls that the Bhutanese requested that most of the design on Mangdechhu was done in Bhutan, for maximum learning effect.

"The key to success in the Bhutan-Norway cooperation has been that the Norwegian advisers have developed solutions together with the Bhutanese counterparts, while at the same time documenting the process and the results. This has ensured maximum learning effect for the beneficiary, and enabling them to pass the know-how on to the next generation"

Dorji Namgay, one of the first Bhutanese exchange students to Norway

PHOTO: ENDRE OTTOSEN

Sagar Ghimirey and Choten Duba received their Master's Degree at the 2-year "Hydropower Development Master Program" at NTNU in Trondheim (2014-2016), with scholarships from the institutional collaboration program, funded by Norway. Representing the Department of Hydropower Systems and Department of Renewable Energy, Mr. Ghimirey and Mr. Duba bring back knowledge and experience that benefit both the large-scale hydropower development in Bhutan, as well as development of alternative renewable energy, following the Energy+ program.

The two Bhutanese engineers describe a tailored master's program with committed professors and well-planned courses. Fieldwork and practical assignments were included in the curriculum. The tradition of leaving students to brainstorm and find solutions to academic problems amongst themselves was much appreciated. "The cross-disciplinary courses where students from different master programs collaborate on projects was particularly enriching", Mr. Choten recalls.

Both got summer internships with Statkraft SF in Oslo. This included deployment at the Devoll Hydropower Project in Albania, where they worked alongside consultants from Sweco and Multiconsult on dam slope stabilization. This experience is highly relevant to Bhutan, where they have huge challenges with weak rock formations and frequent landslides.

Left: Mr. Sagar Ghimirey, Dy Executive Engineer, DHPS. Right: Mr. Choten Duba, Dy Executive Engineer, DRE.
PHOTO: ENDRE OTTOSEN

It took some time for the Bhutanese friends to adapt to the Norwegian weather. However, they came to appreciate the snow in winter, and the long summer days. They took on cycling in the summer, and even tried skating and skiing during winter. "But, just as important, discovering the Asian grocery shops, with ingredients to spice up the traditional, mild Norwegian cuisine, also helped us get through the long winters", Mr. Choten says with a smile.

8 Program Reviews and Key Learnings

Thimphu. PHOTO: HARALD BIRKELAND

This chapter first summarizes findings from two reviews of the program, conducted in 2007 and 2011 respectively.

Key learnings from the cooperation are thereafter summarized, and these represent the view of the authors.

PROGRAM REVIEWS

Two reviews were conducted during the cooperation, covering the programs related to the hydropower sector and geohazards. The first review was conducted by NORPLAN in 2007, covering Phase I and II of both programs, including recommendations for Phase III. The second review was conducted by Scanteam in 2011, covering Phase III of both programs and included recommendations for continuation into Phase IV.

The NORPLAN review (2007) concluded that most targets from the first two phases were reached, and that the cooperation should be continued until the energy sector has become more self-reliant. The review pointed to possible improvements in the programs. An important observation was that the coordination of the two programs, and the communication between the governmental entities in Bhutan, should be strengthened. Another recommendation from 2007 was to use a more systematic approach to capacity building, to maximize gains for the whole sector, and avoid too much dependence on individuals. The review team also suggested to define the planned outputs more clearly, to ensure that all stakeholders would be better coordinated.

The review by Scanteam (2011) also concluded that the programs were successful, and increasingly complementing each other, and recommended to extend the cooperation into a fourth phase. The review repeated the recommendation to strengthen the communication and coordination across sectors and programs, to avoid overlap and enhance impacts of the collaboration. The recommendation to further improve the result chain and result based management and reporting was also reiterated. Executing responsibilities should increasingly be transferred to the Bhutanese counterparts, to ensure sustainability. The review team expressed concern related to the accumulated environmental impact of the accelerated hydropower program, and recommended Strategic Environmental Assessments (SEA) to be applied as a tool on an overall level, in addition to the project based Environmental Impact Assessments (EIA).

KEY LEARNINGS

There are numerous interesting experiences and positive references from this long-standing energy cooperation between Bhutan and Norway.

The good relations and common attitudes between Bhutanese and Norwegian energy professionals are by some described as a matching “personal chemistry”. The cultural background and similarities between our countries supporting this, could be summarized as being two small nations, living close to nature and mountains, and sharing the sincere interest in developing the valuable water resources in a sustainable manner.

A positive feature of the cooperation has been the long duration and stability, supporting deeper and more thorough knowledge transfer, as well as allowing stronger relationships to develop.

One key challenge related to the cooperation, across topics, is the physical distance between Bhutan and Norway, and that none of the countries have a local embassy. Despite improved connectivity with broadband and internet, the availability of the right expertise over a period of time is a constant challenge. Once the visiting expert is available, it might be challenging to involve the local staff, if daily routines and interruptions impair continuity of the work.

From an administrative viewpoint it is noted that over time the awareness and attention from Norad, RNE and MFA to the Bhutan cooperation seems to have been moderate in terms of professional involvement. The cooperation could have been further improved through a stronger and more continuous involvement of the same staff members.

Norad, RNE and MFA have only been moderately involved into strategic professional discussions with the respective implementing partners on both hydropower and geohazards. This has especially been lacking in the transition between phases of the cooperation. It seems that some of the review recommendations have not been fully followed when entering into new phases of cooperation.

The cooperation on hydropower could have addressed environmental challenges more clearly, especially during the last two phases of cooperation, where the large-scale project developments were emerging.

More focus on gender and equality could have been integrated in the various parts of the program, though numerous female participants have joined the training programs.

The issues of anti-corruption are seriously addressed by RGoB. Given the very high monetary impact of the electricity sector to the country it is important to continue to keep a very high standard when it comes to financial and contractual aspects related to energy project developments in Bhutan.

Tashi Pem, project manager of DHPS, explains the capacity building experience.
PHOTO: ENDRE OTTOSEN

The ambitions of the program to attract private sector investments in hydropower have not yet been fulfilled. In retrospect it might be considered that the expectations of private sector attraction were somewhat too simplified and optimistic, especially related to the speed of project development.

More strategic business-development advice to RGOB related to attracting investments in the energy sector could have been included in the program.

The regulatory basis of the energy sector and the wide range of completed project-specific preparatory studies, established with Norwegian support, in total should be a solid basis for attracting more private sector investments. As the challenges of developing financial models to attract investments are overcome, Bhutan should be well prepared for the future.

So far there are few business-based relations between Norway and Bhutan. Some positive examples of (rather small-scale) cooperation involve consultancy, technology advice and energy forecasting. NGI has recently (2017) been awarded a commercial contract to conduct an assessment of the strengthening works on two major hydropower plants under construction. The projects suffered from both a landslide and a weak shear zone, causing structural collapse and other damages.

SOME SECTOR-SPECIFIC OUTPUTS AND LEARNINGS:

Hydropower

Positive elements of the hydropower cooperation, noted by numerous stakeholders, have been

- Flexibility and long duration of the program, ensuring in-depth knowledge transfer, and with options to modify when needed
- Involvement of dedicated professionals, with personal commitment and enabled partners to cooperate closely also between and after missions
- The combination of theory and practice in engineering topics
- On-the-job-training both during field visits and study tours, both to Norway and elsewhere
- Availability of scholarships for master's degrees abroad have benefited a generation of hydropower engineers, today working across the energy sector in Bhutan

Challenges related to the hydropower cooperation have been

- Lack of funding to do additional tasks
- Strategic discussions between the program phases could have involved the parties more
- Recommendations from reviews (2007 and 2011) were not clearly addressed in the subsequent work plans, such as environmental and social concerns, and strengthened coordination between government entities
- The amount of travelling abroad and associated costs in the program have been substantial
- A higher degree of medium/long-term advisors could have increased the net benefit
- Frequent replacements of Norad and RNE officers have reduced the degree of involvement

Geohazards

Positive elements of the geohazards cooperation have been

- Involvement of dedicated professionals, both from NGI and also other entities
- The program and its focus has been adapted to Bhutanese interest
- The long-term program has ensured continuity of work on rather complex matters
- Combination of theory and practice, including demonstration of modern-type technologies both for surveys and engineering
- NGI provided on-the-job-training, both as field visits in Bhutan as well as through a range of study tours to Norwegian projects

Challenges related to the cooperation on geohazards have been

- Strategic discussions between the program phases could have involved all parties more
- Lack of funding to do additional tasks
- Some geohazards of interest to Bhutan are not related directly to energy (landslide-protection and tunneling technology) hence other funding sources are needed
- A higher degree of medium/long-term advisors could have increased the net benefit
- The geotechnical knowledge of NGI could have been used more directly to develop relevant legislation, related to construction of hydro-power plants and other infrastructure

Tunnel drilling and blasting. PHOTO: KEN OPPRANN

Renewable Energy and Energy Efficiency

Energy+ was terminated after Phase 1 of the program.

Positive elements of the Energy + initiative

- Emphasis on other renewable energy sources (in addition to hydropower) potential and usage, and demand side energy efficiency, supplementing the long term hydropower cooperation
- Supporting local capacity in Bhutan related to renewable energy and energy efficiency
- Involvement of dedicated professionals from a range of international consultancies
- Proposed new elements into the Bhutanese legislation, to enhance energy efficiency
- Project development of a 30 MW solar PV power plant and of two hydropower projects

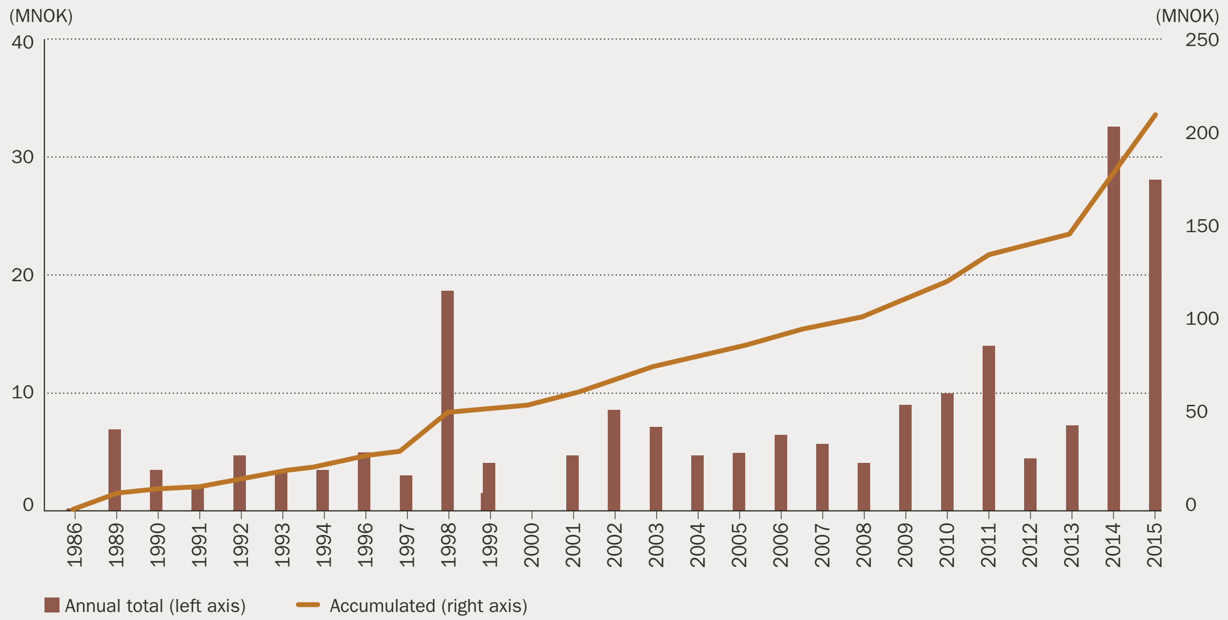
Challenges related to the Energy+ cooperation

- Seemingly too high budget for Phase 1, covering many consultancy reports
- The value of some of the reports is questioned, as some of these are quite generic and not very specific to Bhutanese conditions
- The limited capacity in Bhutan to absorb the potential knowledge of so much consulting work in a short period of time is a challenge
- The management of the consultant-contracts was done by ADB, but the beneficiary was DRE. The Phase 1 summary report of ADB for some of the work packages describes challenges related to the time spent to interpret the ToR for the assignment.

9 Annex

Ugyen Dorji (left) and Jambay Lhundup of DHPS share views on operational experiences. PHOTO: KEN OPPRANN

FIGURE 19 // OVERVIEW OF NORWEGIAN ENERGY* GRANTS TO BHUTAN, PER YEAR AND ACCUMULATED



*Due to statistical definitions this figure also includes 14 MNOK to environmental projects in Bhutan since 1986

SOURCE: NORAD

Power lines crossing rice fields in Daga district. PHOTO: ENDRE OTTOSEN

Some facts on ODA funding to energy projects in Bhutan are summarized in the figures below. All values are NOK, in nominal values (per year of the respective agreement).

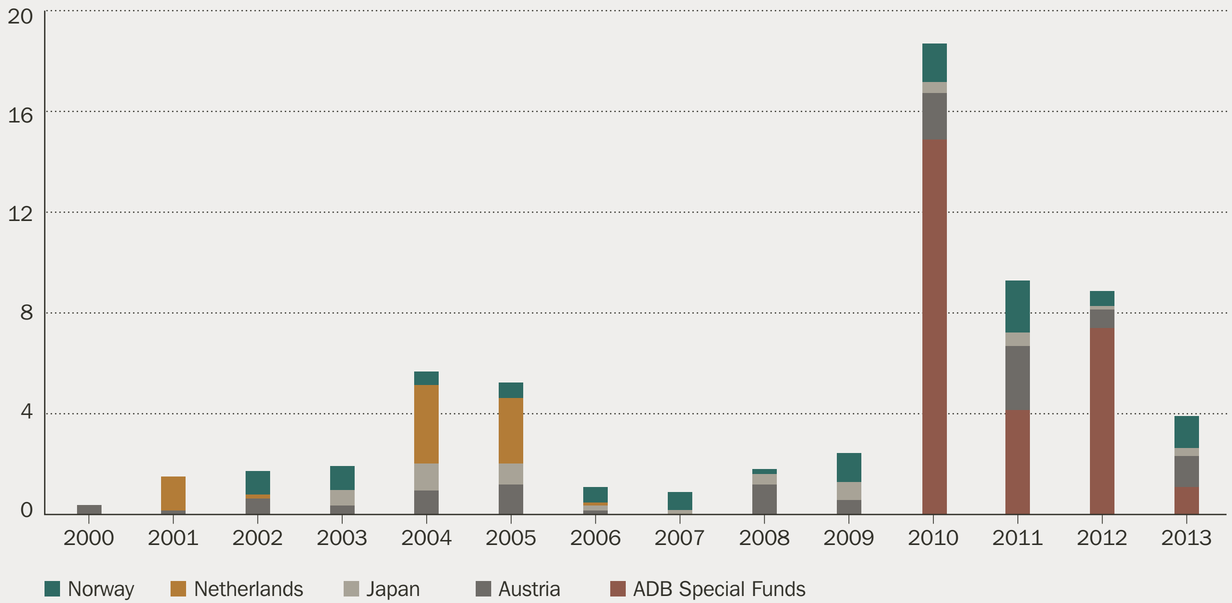
For the use of comparison, the following exchange rates have been used in this report

1 USD = 8,5 NOK
1 NOK = 7,66 Nu (BTN)

ENERGY FUNDING

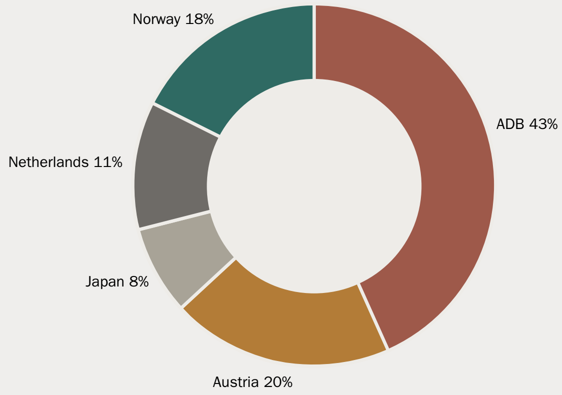
Figure 19 shows the bilateral Norwegian energy and environmental funding to Bhutan since 1986. Due to varying reporting definitions over time the overview includes 14 MNOK support to environmental projects.

FIGURE 20 // OVERVIEW OF ENERGY GRANTS TO BHUTAN, PER DONOR AND YEAR, 2000-2013, EXCLUDING INDIAN CONTRIBUTIONS



SOURCE: OPENAIDDATA.ORG

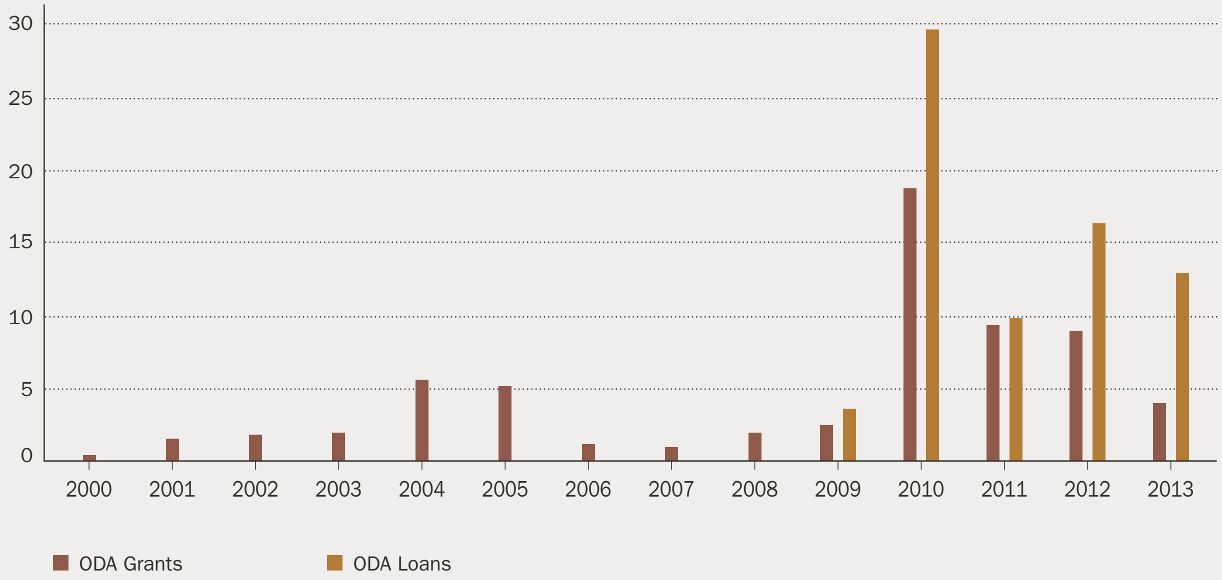
FIGURE 21 // OVERVIEW OF ENERGY GRANTS TO BHUTAN, % SHARE PER DONOR 2000-2013, EXCLUDING INDIAN CONTRIBUTIONS



SOURCE: OPENAIDDATA.ORG

For the years 2000-2013 the figures 20-22 also include reported grants and loans from other energy donors to Bhutan, however excluding India, which investment contributions are not classified as aid. Over this period the share of the Norwegian energy grants to Bhutan was 18%. The Energy+ Phase 1 contribution was provided after 2013 and is thus not reflected in the figures including other donors.

FIGURE 22 // OVERVIEW OF ENERGY LOANS AND GRANTS TO BHUTAN, 2000-2013, EXCLUDING INDIAN CONTRIBUTIONS

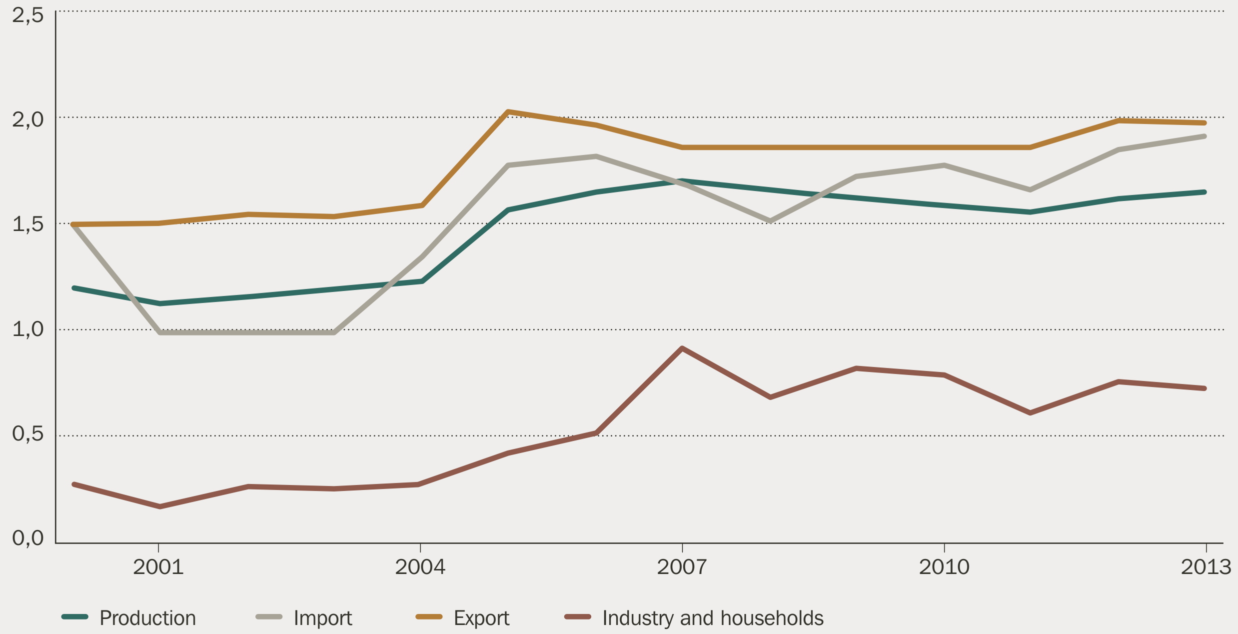


SOURCE: OPENAIDDATA.ORG

Tala dam. PHOTO: KEN OPPRANN

Since 2009 there has been a major donor shift from grants to loans to Bhutan, as shown in the figure 22. The main loans to Bhutan energy infrastructure during 2000-2013 have been provided by Japan (67%) and ADB (33%).

FIGURE 23 // THE AVERAGE ELECTRICITY PRICES 2000-2013 (NU/KWH)



SOURCE: NATIONAL ACCOUNTS STATISTICS

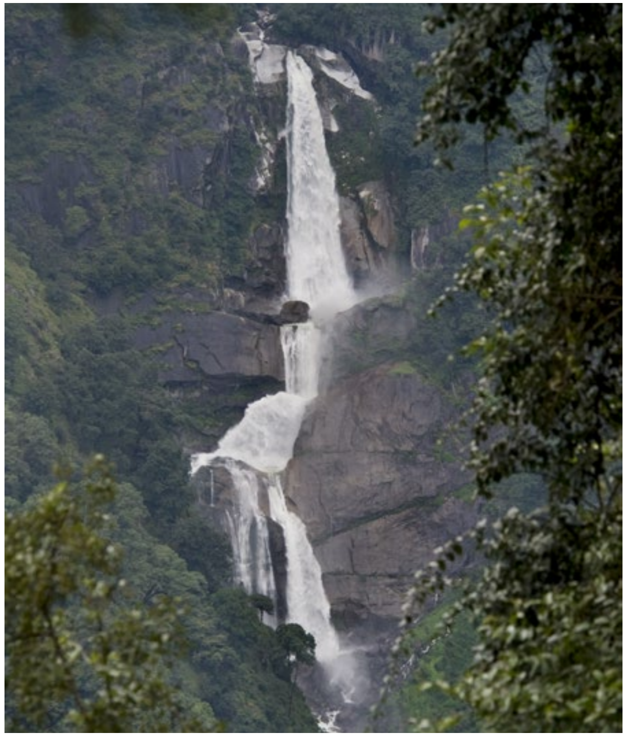


PHOTO: KEN OPPRANN

Since 1988 Bhutan has been exporting electricity at ever increasing amounts. These revenues strongly support the socio-economic development and standard of living in Bhutan.

The electricity prices of respectively production, export, import and domestic use of electricity provide the net economic benefit.

ENERGY+ PHASE 1 OUTPUTS

In order to provide the range of outputs in phase 1, as described in chapter 6, four consulting firms were contracted for project activities.

Work Package 1: Feasibility studies of hydropower projects and preparation of guidelines

Mott Macdonald Limited (UK) with partners were contracted to

- Prepare prefeasibility studies of the hydropower sites Dagachhu II, Shongarchhu, and Manas
- Prepare guidelines and bidding documents for hydropower projects by independent power producers, (IPPs)

These deliverables are considered by DRE to be of high importance to accelerate the priority hydropower projects.

Work Package 2: Renewable Energy Master Plan

Fichtner Gmbh & Co (Germany) with partners were contracted to

- Develop renewable energy implementation guidelines and regulations in line with the Alternate Renewable Energy Policy (2013)
- Conduct resource mapping, prepare a renewable energy master plan, and propose regulatory framework to promote renewable energy
- Formulate a renewable energy feed-in-tariff framework
- Pre-studies of four hydropower plants and the 30 MW Shingkhar solar power plant
- Standards and implementation strategy for solar water heating
- Requirements to implement minimum energy performance standards for appliances

DRE considers the above deliverables as important elements of the strategy for the diversification of the energy supply mix. The deliverables have rendered DRE its preparedness to implement and scale-up the range of energy projects proposed.

Work Package 3: Energy Efficiency Program

Ernst & Young LLP India was contracted to

- Formulate a national energy efficiency policy
- Improve energy efficiency through the use of energy efficient light bulbs (LED)
- Update Bhutan Energy Data Directory of 2005

Work Package 4: MRV System

NIRAS (Denmark) and partners were contracted to

- Identify NAMA related to the energy sector
- Help NEC implement low-emission capacity building
- Develop MRV system and a national energy registry
- Prepare environmental and social standards and safeguards for the energy sector

The above deliverables have enabled Bhutan to develop a framework for the preparation of NAMA, to maintain its commitment to remain carbon neutral, while pursuing prosperity and gross national happiness.

SUMMARY OF HYDROPOWER PROJECTS IN BHUTAN IDENTIFIED IN PSMP, AND THEIR CURRENT STATUS PER MARCH 2017, SOURCE DHPS

Sl. No.	Name of the Project	Installed Capacity (MW)	Annual Energy (GWh)	Gross Head	Project Cost (Nu in million)	Status	Remarks
1	Basochhu-I HPP	24	105	356	1440	Operation	Under operation
2	Basochhu-II HPP	40	186	483	1821	Operation	-do-
3	Chukha HPP	336			2465	Operation	-do-
4	Dagachhu HPP	126	360	304	8208	Operation	-do-
5	Kurichhu HPP	60		35	5600	Operation	-do-
6	Tala HPP	1020	3962	820	41240	Operation	-do-
7	Kholongchhu HEP	600	2599	800	33050	Construction	Under construction. Estimated COD 2022
8	Mangdechhu HEP	720	2984	733	40756	Construction	Under construction. Estimated COD 2018
9	Nikachhu HEP (Tangsebji)	118	492	536	8829	Construction	Under construction. Estimated COD 2019
10	Punatsangchhu-I HEP	1200	5234	336	93961	Construction	Under construction. Estimated COD 2019
11	Punatsangchhu-II HEP	1020	4215	243	70264	Construction	Under construction. Estimated COD 2018
12	Amochu reservoir	540	1883	197	37384	DPR Completed	DPR completed
13	Bunakha reservoir	180	719	162	29528	DPR Completed	-do-
14	Chamkharchhu-I HEP	770	3344	576	64714	DPR Completed	-do-
15	Dorjiluing HEP	1125	4558	306	89244	DPR Completed	-do-
16	Sankosh HEP	2560	6215	177	114720	DPR Completed	-do-

Sl. No.	Name of the Project	Installed Capacity (MW)	Annual Energy (GWh)	Gross Head	Project Cost (Nu in million)	Status	Remarks
17	Wangchhu HEP	570	2011	306	40608	DPR Completed	-do-
18	Kuri-Gongri HEP	2640	4621	222	207189	DPR Preparation	DPR under preparation
19	Druk Bindu	18				DPR Preparation	-do-
20	Nyera-Amari I & II HEP Integrated	442	1700	889	37383	DPR Preparation	-do-
21	Aiechhu (Mau Basin)	54				PFR Completed	PFR completed
22	Chamkharchhu-II HEP	590	2420	419	39841	PFR Completed	-do-
23	Chamkharchhu-IV	364	1492	305	29471	PFR Completed	-do-
24	Dagachhu-II HEP	70	261	334	9594	PFR Completed	-do-
25	Dangchhu HEP	170	685	451	15263	PFR Completed	-do-
26	Gamri-I HEP	45	165	607	3132	PFR Completed	-do-
27	Gamri-II HEP	85	303	532	4686	PFR Completed	-do-
28	Jomori HEP	85	362	365	6826	PFR Completed	-do-
29	Khomachhu HEP	363	1415	785	30784	PFR Completed	-do-
30	Manas RS	1100	4640	125	110500	PFR Completed	-do-
31	Bemengchhu	14	60	257		Reconnaissance Completed	Recon.
32	Gamrichhu-5	90	376	200	72	Reconnaissance Completed	-do-
33	Mochhu - 1	660	2630	490	854	Reconnaissance Completed	-do-
34	Mochhu - 2	450	1835	290	749	Reconnaissance Completed	-do-
35	Pachhu	72	290	405	7240	Reconnaissance Earmarked	Recon (DHPS-2016)
36	Parochhu	114	432	605	278	Reconnaissance Completed	Recon

Sl. No.	Name of the Project	Installed Capacity (MW)	Annual Energy (GWh)	Gross Head	Project Cost (Nu in million)	Status	Remarks
37	Pipingchhu	64	261	313	5394	Reconnaissance Completed	Recon (DHPS-2016)
38	Punatsangchhu-III	600	2840	165	1324	Reconnaissance Completed	Recon
39	Shongarchu-1	107	417	1250	179	Reconnaissance Completed	-do-
40	Shongarchu-2	55	220	325		Reconnaissance Completed	-do-
41	Yangtse/Kholong	96	406	208	9044	Reconnaissance Completed	Recon by DHPS, 2016
42	Amochu-1	747	3317	505		Reconnaissance Preparation	Undergoing RS (DHPS)
43	Amochu-2	500	2210	288		Reconnaissance Preparation	Undergoing RS (DHPS)
44	Samchu	71	277	362		Reconnaissance Preparation	Undergoing RS (DHPS)
45	Bambichhu	22	85	436		Desktop	Desktop
46	Bomdeling/Kholong	130	583	621		Desktop	-do-
47	Burgangchu-1	69	336	455		Desktop	-do-
48	Burgangchu-2	70	340	366		Desktop	-do-
49	Chamkharchhu-3	1247				Desktop	Desktop by LII
50	Chamkharchhu-5	97	423	225		Desktop	Desktop
51	Cherchhu	25	98	377		Desktop	-do-
52	Cherchu (Churchhu/Chechhu)	45	177	300		Desktop	-do-
53	Cherichhu	76	312	381		Desktop	-do-
54	Darachhu-1	79	418	235		Desktop	Desktop
55	Gamri-4/Yamkhari	81	398	291		Desktop	-do-
56	Gamrichu-3	80	392	382		Desktop	-do-

Sl. No.	Name of the Project	Installed Capacity (MW)	Annual Energy (GWh)	Gross Head	Project Cost (Nu in million)	Status	Remarks
57	Ghijam/Lirigang/ Gayzamchhu	53	241	1017		Desktop	-do-
58	Gobarichu	43	170	334		Desktop	-do-
59	Gumthang	108	520	339		Desktop	-do-
60	Haachhu	17	69	63		Desktop	-do-
61	Jaldhaka	19	79	65		Desktop	-do-
62	Krissa	32	160	403		Desktop	-do-
63	Ngargangchhu	24	94	258		Desktop	-do-
64	Phochhu	132	620	125		Desktop	-do-
65	Rimjigangchhu	46	226	632		Desktop	-do-
66	Samachhu	16	62	73		Desktop	-do-
67	Shergarchhu	27	131	200		Desktop	-do-
68	Sherichu	36	175	567		Desktop	-do-
69	Sichhu	78	335	709		Desktop	-do-
70	Thampochhu	95	470	541		Desktop	-do-
71	Thimphuchhu	57	479	235		Desktop	-do-
72	Wachi	24	118	258		Desktop	-do-
	Total	**23503 MW**	**80014 GWh**	**Average head 396m**			

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Acronyms

ADB	Asian Development Bank
BEA	Bhutan Electricity Authority
BPC	Bhutan Power Corporation Ltd.
DGM	Department of Geology and Mines
DGPC	Druk Green Power Corporation
DHPS	Department of Hydropower & Power Systems
DHMS	Department of Hydro-Met Services
DoE	Department of Energy (former)
DOP	Department of Power(former)
DOR	Department of Roads
DPR	Detailed Project Report
DRE	Department of Renewable Energy
DSM	Demand Side Management (end-user energy efficiency)
EIA	Environmental Impact Assessments
E&S	Environmental and Social
FS	Feasibility Study
GHG	Greenhouse Gas
GNH	Gross National Happiness
GNHC	Gross National Happiness Commission
GPR	Ground Penetrating Radar
GWh	GigaWatthour (1 million kWh or 1 million units of energy or electricity)
HEP	Hydroelectric Power Plant – hydropower plant
ICH	International Centre for Hydropower
kWh	KiloWatthour (1000 Watthours), unit of energy amount
LED	Light Emitting Diodes (efficient lighting system)
MCA	Multi-criteria Analysis
MFA	Norwegian Ministry of Foreign Affairs
MHPA	Mangdechhu Hydroelectric Project Authority
MOEA	Ministry of Economic Affairs
MRV	Measurement, Reporting and Verification
MSC	Master of Science
MW	Megawatt (one million watts)
NAMA	National Appropriate Mitigation Action
NAS	National Accounts Statistics
NCHM	National Centre for Hydrology and Meteorology
NEC	National Environment Commission
NGI	Norwegian Geotechnical Institute
NOK	Norwegian Krone (currency of Norway)
NSB	National Statistics Bureau
NTNU	Norwegian University of Science and Technology
NU	Bhutanese Ngultrum (currency of Bhutan, currency code BTN)
NVE	Norwegian Water Resources and Energy Directorate
PFS	Pre-feasibility Study
PSMP	Power System Master Plan
PV	Photovoltaic Systems (solar cells)
RE	Rural Electrification
RGOB	Royal Government of Bhutan
RNE	Royal Norwegian Embassy
ROW	Right of Way
RSR	Reconnaissance Study Report
SEA	Strategic Environmental Assessments
SYB	Statistical Year Book, published by NSB
TA	Technical Assistance
TOR	Terms of Reference
USD	US Dollar
WB	World Bank

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Cover photo: Harald Birkeland
Punakha Dzong in the Punakha–Wangdue valley, at the confluence of rivers Phochhu (male) and Mochhu (female), known downstream as the Punatsangchhu.
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