IRENA
International Renewable Energy Agency

RENEWABLES
READINESS ASSESSMENT

KINGDOM OF BHUTAN

December 2019

About IRENA

The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that serves as the principal platform for co-operation, a centre of excellence, a repository of policy, technology, resource and financial knowledge, and a driver of action on the ground to advance the transformation of the global energy system. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy, in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity. **www.irena.org**

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About the RRA

A Renewables Readiness Assessment (RRA) is a holistic evaluation of a country's conditions that helps to identify the actions needed to overcome barriers to renewable energy deployment. This is a country-led process, with IRENA primarily providing technical support and expertise to facilitate consultations among different national stakeholders. While the RRA helps to shape appropriate policy and regulatory choices, each country determines the best mix of renewable energy sources and technologies to achieve national priorities. The RRA is a dynamic process that can be adapted to each country's circumstances and needs. IRENA has continually refined its methodology for the RRA process based on experience in a growing range of countries and regions.

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Acknowledgement

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RENEWABLES
READINESS ASSESSMENT

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BHUTAN

FOREWORD

Minister of Economic Affairs

This Renewables Readiness Assessment (RRA) brings Bhutan one step closer to achieving energy security through a diversified and sustainable supply mix. The report – prepared by the Department of Renewable Energy under the Ministry of Economic Affairs in collaboration with the International Renewable Energy Agency (IRENA) – demonstrates the highest motivation to scale up renewables and energy efficiency through plans guided by the philosophy of Gross National Happiness.

About 30% of the country's energy consumption today is met through electricity, mainly via hydropower plants. Other energy demand is met mostly through fuelwood (traditional biomass), which adds to pressure on the environment, and imported fossil fuels, which hurt the balance of payments. Hydropower, along with being renewable, is the nation's top revenue earner. However, our current plants are run-of-river, with no water storage, so their electricity output dwindles during the lean season. In addition, we must take cognizance of the impact of global warming on glaciers, which are the main source of water feeding into our rivers.

Given rising demand for electricity, we need to explore other clean and renewable energy sources to broaden our energy mix. Solar, wind, modern bioenergy and small hydro installations could all play a role as the nation strives to create a sustainable energy system. These other renewables, apart from covering intermittent hydropower shortages, could also complement our electricity exports during the monsoon season.

Despite the mountainous terrain, the country is blessed with good solar and wind resources in several regions. As per the Renewable Energy Management Master Plan (2016), Bhutan could produce 12 gigawatts (GW) of solar and 760 megawatts (MW) of wind energy in technical terms. Yet the country's current installed capacity for renewables, apart from large hydro plants, only amounts to 9 MW.

The Alternative Renewable Energy Policy in place since 2013 envisions boosting this to 20 MW, including 5 MW from solar photovoltaics, 5 MW from wind and 3 MW for solar water heating, by 2025. Still, rapid investments are needed to reach these levels by the target date.

Balancing the objectives of growth, well-being and conservation remains a key challenge for the country. As the economy grows and living standards improve, energy consumption will also rise, along with related environmental, resource and economic challenges.

I hope the RRA enables the Royal Government of Bhutan to navigate this transitional phase smoothly. The country-led consultation process has suggested appropriate policy and regulatory choices in a way that will, I hope, ensure the broadest possible buy-in. Dialogue with multiple stakeholders has highlighted challenges, but also solutions, for renewable energy deployment.

The Royal Government and particularly the Ministry of Economic Affairs greatly appreciate the insights arising from the RRA process. The recommendations made in this report are sure to be considered in decisions about any future course of action in the energy sector. We look forward to long and fruitful collaboration in the future.

H.E. Lyonpo Loknath Sharma
Minister of Economic Affairs
Royal Government of Bhutan

FOREWORD
from the IRENA Director-General

The Kingdom of Bhutan has long sought to preserve its natural resource wealth at the same time as building a reliable energy system and viable modern economy. Global leadership in environmental protection has helped the country achieve impressive economic growth rates that serve the well-being of citizens without compromising Bhutan's pristine Himalayan ecosystems. The innovative Gross National Happiness indicator exemplifies the country's unique approach to national development.

Rapid economic growth rates over the last decade – among the fastest in the region – are linked closely to investments in hydropower, a sector that now accounts for one-fifth of Bhutan's domestic revenue. Yet as the country keeps developing, the environmental, resource and climate concerns linked to energy consumption are set to become more complex. Other renewable energy technologies, including solar photovoltaics, wind, bioenergy and small hydropower, offer ways to diversity the electricity mix while helping to meet growing energy demand.

This Renewable Readiness Assessment (RRA) proposes ten concrete actions through which the Royal Government of Bhutan could address ongoing energy challenges, foster a more diverse mix of renewables, and further improve people's livelihoods. The Department of Renewable Energy, part of Bhutan's Ministry of Economic Affairs, undertook the study in collaboration with IRENA to explore options in both the electricity and end-use sectors.

With power-generation costs falling steadily and technologies maturing, the business case for a diverse mix of renewables has never been stronger. The Alternative Renewable Energy Policy in place since 2013 underlines the value of distributed renewables to make electricity consistently available in Bhutan's rural areas. Scaling up renewables for heating, transport, industrial and other direct applications would also boost quality of life, create jobs and help to reduce dependence on fuel imports.

I sincerely appreciate the leadership and support provided by the Ministry of Economic Affairs in the preparation of this study. Input from other stakeholders and international partners has broadened the perspective of the assessment and added further insights. IRENA looks forward to continued collaboration, both with the Royal Government of Bhutan and with other partners, in the pursuit of a sustainable energy future.

Francesco La Camera
Director-General
International Renewable Energy Agency

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ABBREVIATIONS

ADB	Asian Development Bank
AEPC	Alternative Energy Promotion Centre
AREP	Alternative renewable energy policy
BPC	Bhutan Power Corporation
BTN	Bhutanese ngultrum
CAGR	compound annual growth rate
DGPC	Druk Green Power Corporation Limited
DHPS	Department of Hydropower and Power Systems
DOE	Department of Energy
DRE	Department of Renewable Energy
EV	electric vehicle
FIT	feed-in tariff
FYP	five-year plan
GDP	gross domestic product
GLOF	glacial lake outburst flood
GNH	Gross National Happiness
GW	gigawatt
GWh	gigawatt-hour
ICIMOD	International Centre for Integrated Mountain Development
IEMMP	Integrated energy management master plan for Bhutan
IRENA	International Renewable Energy Agency
kWh	kilowatt-hour
ktoe	thousand tonnes of oil equivalent
LCOE	levelised cost of electricity
LPG	liquid petroleum gas
MJ	megajoule
MOAF	Ministry of Agriculture and Forests
MOEA	Ministry of Economic Affairs
MW	megawatt
MWh	megawatt-hour
MWth	megawatt-thermal
NEC	National Environment Commission
ORC	organic Rankine cycle
PV	photovoltaic
REDF	Renewable Energy Development Fund
ROR	run-of-river
RRA	Renewable Readiness Assessment
SEDA	Sustainable Energy Development Authority
SME	small- to medium-sized enterprise
TERI	The Energy and Resources Institute
toe	tonnes of oil equivalent
TW	terawatt
USD	US dollars


Photograph: Shutterstock

EXECUTIVE SUMMARY

The Kingdom of Bhutan has long aspired to grow in a sustainable manner and today prioritises both the wellbeing of its citizens and the conservation of the environment, as indicated in the country's "Gross National Happiness" (GNH) approach. The four pillars of GNH are: sustainable and equitable socio-economic development; environmental conservation; preservation and promotion of culture; and good governance. The Kingdom of Bhutan is an environmental leader and a net-carbon-negative country, as it sequesters much more carbon than it emits, thanks to substantial hydropower capacity and forests that cover 70% of the country.

Hydropower represents a significant share of the national economy and provided one-fifth of domestic revenue and one-third of export earnings in 2016. Overall energy consumption in the country has been growing rapidly. Industry and transport are the fastest growing sectors in terms of energy consumption, with demand doubling in the 2005–2014 period. Rapid electrification in the last decade has helped shift fuel consumption away from biomass (mainly fuelwood) to electricity, which satisfies around one third of total energy demand and is primarily produced from hydropower.

The renewable energy landscape in Bhutan is dominated by hydropower; domestic electricity demand and electricity exports are almost exclusively supplied by this technology. Other renewable energy technologies such as solar, wind and bioenergy are in their initial stages of deployment – often limited to pilot projects and small applications. As Bhutan continues to strive towards a modern, secure and sustainable energy system, renewable energy can play a key role in this transition.

As Bhutan's economy continues to grow and living standards improve, its energy consumption and related environmental, resource and economic challenges are set to increase. Balancing the objectives for growth and the aspirations for wellbeing and conservation will be an important challenge for Bhutan's decision makers. A diversification of the energy sector towards renewable energy in all applications can help address energy demand while creating economic opportunities and position Bhutan as a global example for sustainable growth and wellbeing.

A strong rationale for diversification

While hydropower is likely to remain an important component of the energy sector and economy of Bhutan, renewable energy technologies such as solar PV, wind, bioenergy and small hydropower could offer opportunities to diversify the country's energy mix and help address rising energy demand. The Kingdom of Bhutan stands at a crossroads where several social, economic and environmental factors present a clear rationale for greater diversification of the energy sector towards renewable energy.

Renewable energy deployment can catalyse economic growth, industrial development and job creation. Technologies such as solar PV and wind create more jobs than fossil fuel technologies per unit of electricity generation. Bhutan's entrepreneurs can both contribute to, and benefit from, such deployment by providing services and equipment to all segments of the value chain. Access to energy through renewables can also provide socio-economic benefits including income through productive uses, improvements in living conditions, and reduced indoor pollution and deforestation.

Renewable energy technologies can help strengthen grid supply while reducing dependence on fuel wood and kerosene for cooking and heating. In doing so, they can complement hydropower, which has been central to providing electricity access in rural areas of Bhutan.

Renewables can also complement hydropower in forming a more diversified electricity generation portfolio, which is resilient to changes in seasonal weather patterns and weather extremes that can adversely affect supply. Rainfall in Bhutan tends to decline in the winter months, which – coupled with reduced melting – results in reduced river flow and hydroelectricity generation. Low river flows during the winter are already an issue, leading to imports of electricity from India (which amounted to 4% of total domestic electricity demand in 2017). Renewable energy technologies such as solar PV, wind, hydropower and bioenergy have different generation profiles during the year that can be complementary in a diversified system.

A diversified energy system that constitutes several renewable energy technologies can be more resilient to the impacts of climate change. Bhutan's dependency on hydropower to meet its electricity demand could make the country vulnerable to long-term climate change impacts, thereby raising energy security concerns. Climate change can have negative impacts on river flows, including seasonal reductions in flow and generally more erratic flow patterns. Climate change is also expected to result in increasingly frequent and intense extreme weather events, resulting in flooding due to extreme precipitation and glacial lake outburst floods (GLOF). These impacts of climate change could pose significant risks to existing and future hydropower developments. A diversified electricity generation system could help reduce the vulnerability to such risks.

Deployment of renewable energy technologies can also help further Bhutan's environmental stewardship. The reliance on run-of-river (ROR) hydropower has helped the country to establish its leadership in environmentalism and climate change mitigation. That said, ROR hydropower installations can produce their own environmental and ecological impacts.

The advent of dams with reservoirs can have even more severe environmental impacts, such as displacement, habitat destruction and methane emissions. Small hydropower plants can mitigate some of the environmental impacts associated with larger projects. Other renewable energy technologies such as solar PV, wind and bioenergy, when implemented in a sustainable way, can also help to reduce environmental impacts.

Greater penetration of renewable energy, coupled with increased energy efficiency, can help address rising domestic energy demand in an environmentally and economically sustainable manner. Energy consumption in Bhutan has been growing rapidly (with a CAGR of 5.49% since 2005). Most of this demand – especially in the transport and industrial sectors – is met through imported fossil fuels, which represent a significant and growing economic burden. Comparison with historical data suggests that imports are increasingly cutting into export revenue. In this regard, renewable energy solutions can help cater to the demand for electricity and heating, whilst the transport sector can be made more sustainable through the introduction of electric vehicles.

The rationale for renewable energy deployment in Bhutan is further strengthened by the increasing competitiveness of renewables. Falling prices are especially evident for solar PV and wind. Global weighted-average levelised costs of utility-scale solar PV fell by 77% between 2010 and 2018, and levelised costs for wind energy have declined by around 34% over the same period. Declining renewable energy costs are benefiting from a conducive financing environment and innovative financing schemes. A comprehensive evaluation of the costs of renewables in Bhutan can assess the current and future cost competitiveness of renewable energy technologies, allowing for better planning of the power system to achieve a more diverse and distributed technology mix.

Recommendations for the deployment of renewable energy

A smooth transition towards renewable energy that optimises its multiple benefits requires strategies, policies and regulations that are well-designed and -implemented. The Renewable Readiness Assessment presents a set of recommended actions to help Bhutan move towards a more diversified energy system through accelerated development of renewable energy resources.

Strengthen the renewable energy policy framework

An updated National Renewable Energy Policy, which accounts for the rapid fall in renewable energy costs and updated resource assessments, could serve as an overarching guide for accelerated deployment and indicate the political commitment of the government. This policy could offer opportunities to adopt more ambitious renewable energy targets based on evolving market conditions and resource potential, and could also cover the transport and heating sectors.

Operationalise the Renewable Energy Development Fund (REDF)

Making the REDF operational could have a transformational effect on the deployment of renewables in the country. The funding can come from a variety of avenues including international, national, public and private sources. Depending upon the specific circumstances, Bhutan may choose to access one or a combination of such sources. REDF may focus on direct lending, grants and subsidies for renewable energy projects, and may also play a pivotal role by issuing instruments that de-risk investments and mobilise private investors.

Promote renewables for productive use

Renewable energy applications should be tailored to different productive end-uses in different segments of the value chain in relevant sectors (e.g., textiles, agriculture, food processing, animal husbandry, cottage industries, service and retail). The selection of renewable energy technologies must be based on the demands of local communities and should be complemented by adequate training to ensure that projects are well operated and maintained.

Set up enabling conditions for prosumers

The government could encourage individual consumer- and community-owned mini-grids through incentive schemes to feed low cost generation to the grid. This could be achieved through consumer-centric tariffs, benchmarked against the location-specific cost of delivery of electricity. To ensure direct income for populations in remote regions, the contracts could be given directly to the residents of those communities.

Stimulate electric mobility for public and private transport

Public procurement of electric vehicles (EVs) can help stimulate their roll-out in Bhutan by increasing their visibility in the public space and stimulating the emergence of charging infrastructure, related expertise and businesses. Public buses, government vehicles and taxi fleets are attractive early targets. The penetration of EVs in private transport demands a broader set of policies, including financial incentives to facilitate their acquisition and cut their usage costs.

Incentivise renewable applications for heating

Financial incentives can be an important near-term option to support the switch to solar water heaters in buildings and the uptake of heat pumps for space heating. These incentives may include a range of grants, low-interest loans and tax incentives. Mandates for solar water heating could also be an option.

Promote energy efficiency in conjunction with renewables

The shift towards renewable energy should be coupled with improved energy efficiency in all sectors of the economy including industry, buildings, transport and appliances. Energy efficiency and conservation measures can play a significant role in shaping and reducing energy consumption in these sectors, resulting in massive fuel and emissions savings.

Enhance the capacity of government officials

There is a need to improve the technical and co-ordination capacities of energy-related institutions. Capacity-building initiatives should aim to strengthen capacities at all levels, including for policy makers, government officials, private sector actors and consumers.

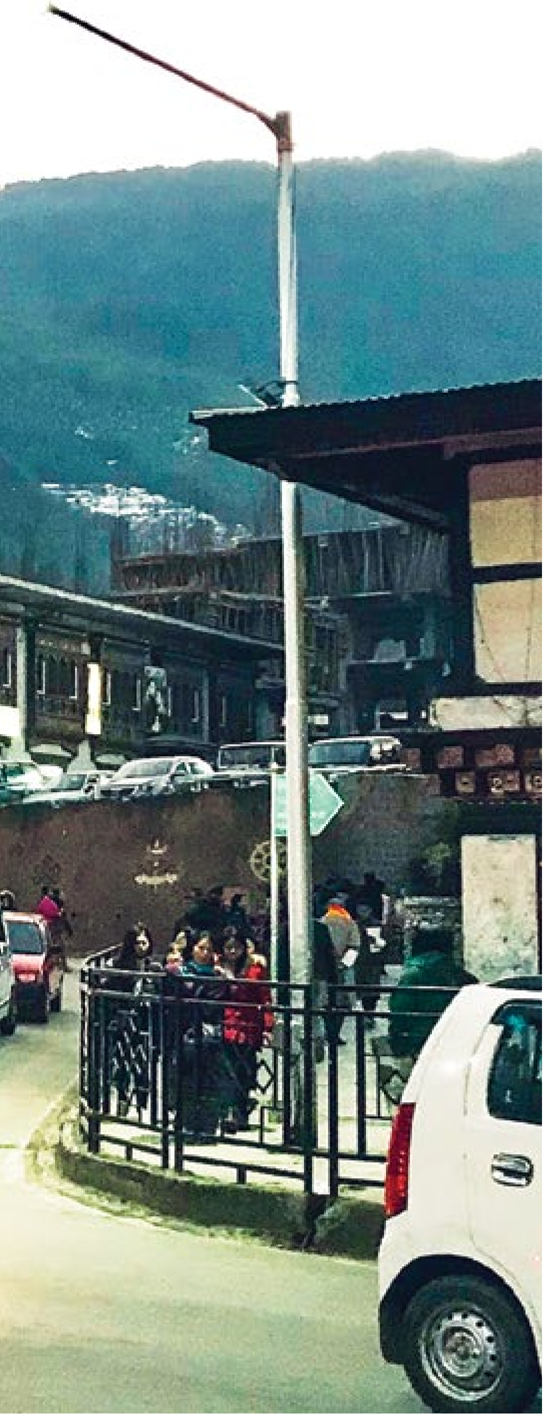
Foster entrepreneurship through skills development and other interventions

Supporting local entrepreneurs demands a comprehensive approach that develops skills and strengthens local capabilities. This approach should entail close co-ordination between policies focusing on renewable energy deployment, education, trade, regional development, industry and labour.

Increase public awareness through pilot projects in social sectors

In the initial stages of deployment in Bhutan, demonstration projects could have significant outreach impacts, especially when implemented in government buildings, schools or places of worship. These projects should be complemented by a broader national communication strategy aimed at raising public awareness, boosting understanding of the benefits of renewable energy and establishing an intrinsic link with Bhutan’s legacy of environmental stewardship.

Bhutan's capital, Thimphu
Photograph: IRENA / Prasoon Agarwal



I. INTRODUCTION

1.1. Country Background

The Kingdom of Bhutan is a landlocked country in South Asia located in the Eastern Himalayas. It is bordered by China to the north and west, and India to the south and east. The country's landscape ranges from sub-alpine Himalayan mountains in the north to subtropical plains in the south. The climate in Bhutan varies with elevation, from subtropical in the south to temperate in the highlands, with year-round snow in the north.

Bhutan currently has a population of 754 394, with an annual population growth rate of 1.2% (World Bank, 2018). The overall literacy rate stands at 59.5%. The unemployment rate has been relatively constant at around 2.4% during 2013–2017 and is significantly higher in urban areas (4.6%) and among young people (15–24 years; 10%) (World Bank, 2018). Thimphu is the capital and largest city, with a population of around 114 500, and Phuntsholing is the financial hub.

Bhutan is one of the smallest economies among the eight South Asian countries but is also among the fastest-growing economies in the world. The Kingdom's GDP has grown steadily at an average rate of around 6.5% per year between 2008 and 2017. Economic growth has been accompanied by rising living standards. Within the same period (2008–2017), GDP per capita has increased, with an annual growth rate of 5.6% (World Bank, 2018), whilst the poverty rate fell from 12% in 2012 to 8.2% in 2017 (National Statistics Bureau [NSB], 2017a).

Hydropower, cement, wood and food products constitute the primary industries of Bhutan. Agriculture, construction, and electricity and water supply are also major economic activities in the country and accounted for 17%, 16% and 12% of GDP, respectively, in 2012. Bhutan's main exports include electricity, cardamom, gypsum, timber, handicrafts, cement, fruit, precious stones and spices. India is by far the largest trading partner, while Bangladesh, Japan, Singapore and China are also key trading partners.

Historically, Bhutan has aspired to grow in a sustainable manner that prioritises the wellbeing of citizens and the conservation of the environment – as identified in the country's "Gross National Happiness" (GNH) approach. The four pillars of GNH are: 1) sustainable and equitable socio-economic development; 2) environmental conservation; 3) preservation and promotion of culture; and 4) good governance.

As Bhutan's economy continues to grow and living standards improve, energy consumption and related environmental, resource and economic challenges are set to increase. Balancing the objectives for growth and the aspirations for wellbeing and conservation will be an important challenge for the decision makers of the country.


Photograph: Shutterstock

1.2. Renewables Readiness Assessment (RRA)

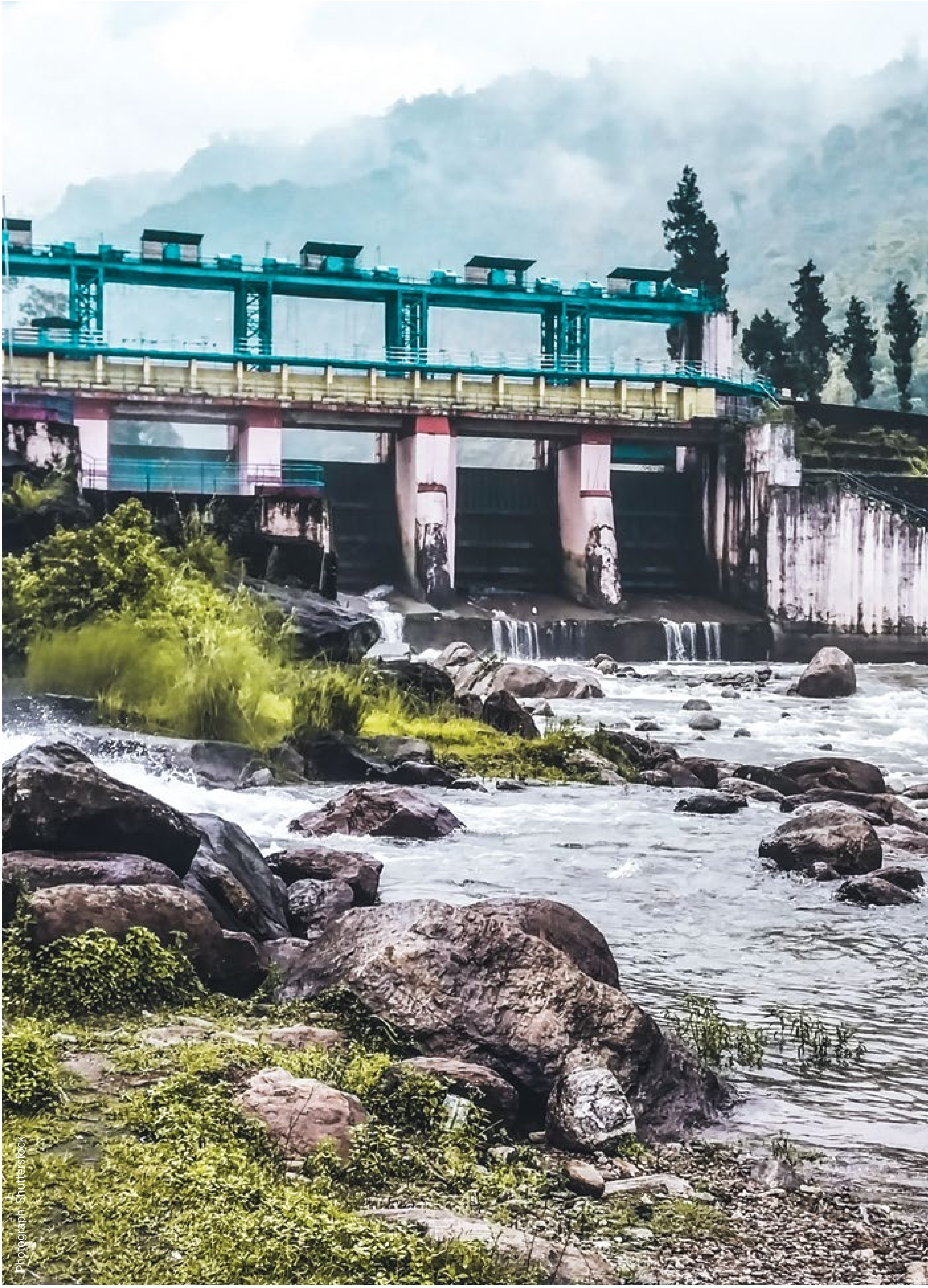
A transition towards renewable energy in all energy sector applications can help address energy demand while creating economic opportunities and position Bhutan as a global example for sustainable growth and wellbeing. The Renewables Readiness Assessment (RRA) aims to support the Royal Government of Bhutan in this transition. The RRA has been initiated by the Department of Renewable Energy (DRE) within the Ministry of Economic Affairs (MOEA) in co-operation with the International Renewable Energy Agency (IRENA), with a view to supporting the country's efforts in enabling the wider penetration of various renewable energy technologies.

IRENA developed the RRA as a tool for carrying out a comprehensive evaluation of the conditions for renewable energy deployment in a particular country. The RRA is a country-led, consultative process. It provides a venue for multi-stakeholder dialogue to identify challenges to renewable energy deployment and to devise solutions to existing barriers.

Short - and medium - term recommendations are presented to governments to guide the formation of new policies or the reform of existing policies to establish a more conducive enabling environment for renewable energy. The RRA also consolidates existing efforts and mobilises resources for priority action. Since 2011, the RRA methodology has been used to conduct more than 30 country assessments, often resulting in extensive stakeholder engagement and improvements in policies and institutional frameworks.

In the specific context of Bhutan, the RRA provides a comprehensive assessment of conditions on the ground, including the existing enabling environment and the potential for growth of the renewable energy market. In Bhutan's case, the assessment indicates a strong case for diversification towards more non-hydropower renewables in the power sector and towards renewables in end-use energy sectors (namely transport and heating). Finally, it provides a portfolio of recommendations including policy measures and initiatives, based on analysis and inputs from numerous stakeholders, to help Bhutan realise its renewable energy potential.

The Bhutan RRA has benefitted from the valuable guidance of the Department of Renewable Energy and other relevant public and private sector entities. An initial 'expert consultation workshop', co-organised by IRENA and the DRE in December 2018, was instrumental in laying the foundations for the findings and recommendations of the RRA.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2. ENERGY SECTOR CONTEXT

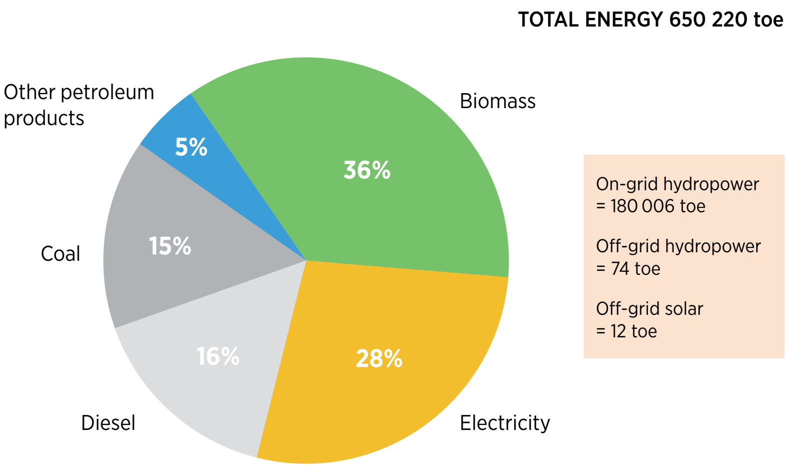
Bhutan's power sector provides a significant contribution to its national economy, 19.45% of domestic revenue, 34.15% of total export earnings and 8% of GDP in 2016 (RMA, 2017) (Poindexter, 2018). The country generates surplus power during the monsoon season from its run-of-river hydropower infrastructure and the surplus power is exported. When facing power shortages during the lean months (November–March) owing to reduced flow in the rivers, the country relies on energy imports. Energy consumption in the country has been growing rapidly and stood at 650 220 tonnes of oil equivalent (toe) in 2014, representing a steady increase at a compound annual growth rate (CAGR) of 5.49% since 2005 (DRE–MOEA, 2016a; SE4All, 2012).

Energy demand in industry and transport doubled in the period 2005–2014, making them the fastest growing sectors in terms of energy consumption. Over this period, per capita energy consumption increased from 0.6 toe per capita in 2010 to 0.69 toe per capita in 2017, which is indicative of rising industrialisation and improving living conditions. Notably, while per capita energy consumption is increasing, the energy intensity of the economy – as measured by energy consumption per unit of GDP – has declined from 3.7 toe/Bhutanese ngultrum (BTN) to 3.1 toe/BTN (NSB, 2018).

2.1 Energy consumption by fuel

Bhutan's energy demand is dominated by thermal energy (72%), with only 28% of demand being serviced by electricity (Figure 1). Biomass in the form of fuelwood, biogas and briquettes is the largest source of thermal energy, satisfying 36% of total energy demand. It is followed by diesel, coal and other petroleum products (petrol, kerosene and LPG), which satisfy 16%, 15% and 5% of demand, respectively (DRE–MOEA, 2016a). The supply of electricity is dominated by hydropower.

Figure 1. Fuel mix in the economy (toe)



Source: DRE–MOEA (2016a).

2.2 Electricity sector

The government has aggressively pursued electrification through both off-grid and grid connected solutions, achieving a current electrification rate of 99% overall and 98.4% in rural areas. Virtually all electrification is through the grid (99% of households), with solar home systems and stand-alone generators together accounting for 1%. The significant increase in electrification in the last decade has helped shift fuel consumption away from biomass (mainly fuelwood) to electricity, which caters to 28% of total energy demand and is produced primarily from hydropower. Off-grid hydropower and solar home lighting systems accounted for a very small percentage of electricity generation in 2014 (Figure 1).

Bhutan's installed power generation capacity in 2017 was 1.6 gigawatts (GW), representing only 6% of its techno-economic feasible hydropower potential. Total electricity generation in 2017 was estimated at 7 729 gigawatt-hours (GWh), which far exceeds the domestic electricity requirement of 2 243 GWh/year (DRE–MOEA, 2016a). Hourly electricity demand varies by region and season (Figure 2) and electricity demand generally begins increasing in the early morning and declines after 9:00 pm.

While the country has achieved near universal electricity access, reliability remains an issue. According to the Bhutan Living Standards Survey (NSB 2017b), 58% of households had faced one or more electric power failures/interruptions lasting at least one hour during the preceding seven days. The proportion of households that faced more frequent power interruptions is higher in rural areas (64.3%) than in urban areas (46.6%).

2.3 Imports and exports of energy

Currently, Bhutan's power generation is mostly dependent on run-of-river (RoR) type hydropower plants, which are more susceptible to variation in rainfall patterns and the impacts of climate change.

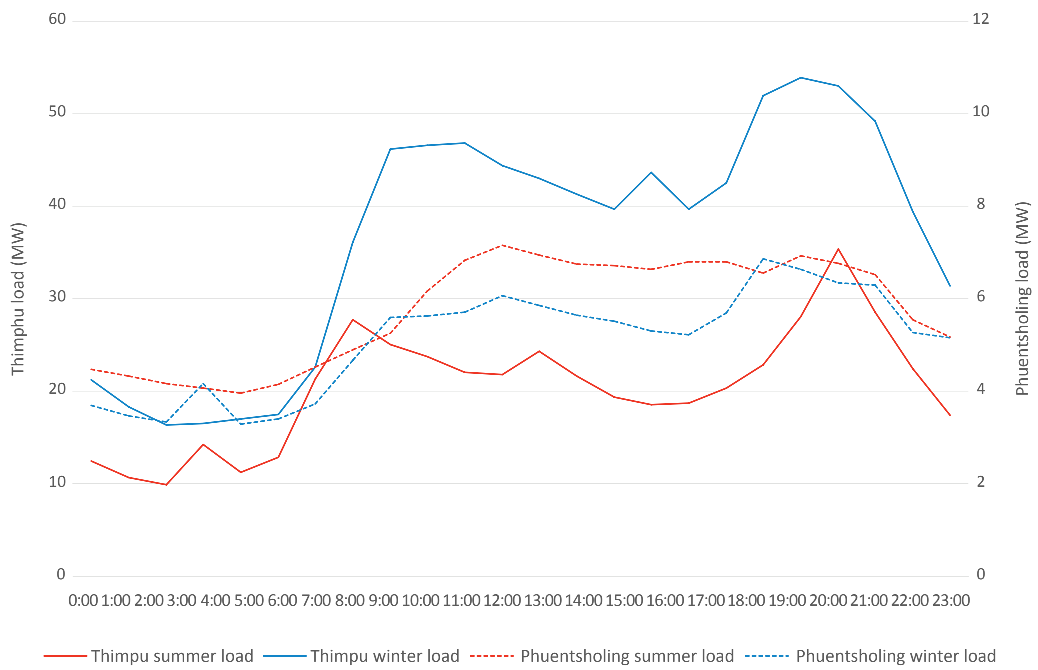
The winter season in Bhutan is drier than summer, due to lower average rain fall, which leads to reduced flow volume in the rivers and hence reduced hydropower generation (SARI/EI and IRADe, 2016). Furthermore, with Bhutan located in the cold Himalaya mountain range, the demand for electricity for heating is also high during the winter months.

A significant portion of total electricity generation is exported to India, which has increased from 1 460.5 GWh in 2000 to 5 700 GWh in 2017; i.e. 74% of total generation (DHPS, 2018). With the construction of several projects in progress and the strengthening of the transmission network, there is more potential for electricity exports. By 2017, the net revenue from cross-border electricity exchanges had reached BTN 11 908 million (USD 171 million).

As electricity demand outstrips supply in winter, the country resorts to imports from India. Overall, electricity imports from India were around 92 GWh in 2017, increasing from just 34 GWh in 2006 (SARI/EI and IRADe, 2016; DHPS, 2018). These imports, although currently much smaller than exports, are increasing on an annual basis.

Bhutan relies on imports for coal, diesel and other petroleum products. Generally, petroleum reserves have not been explored in Bhutan and there are no refineries for crude oil processing in the country.

Figure 2. Hourly electricity demand



Source: BPC (2018)

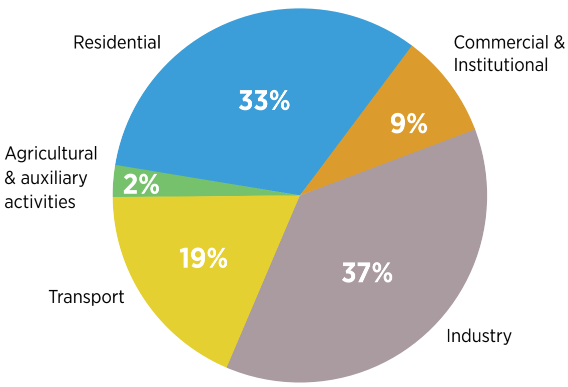
Imports of fossil fuels including coal, diesel, kerosene, petrol and LPG totalled 205 784 toe in 2014, with diesel accounting for more than half of this. These imports carry significant economic value; the bill for the import of all petroleum products, for instance, was estimated at BTN 9 984 million (USD 144 million) in 2017, i.e. 84% of the export revenue from hydroelectricity (DRE–MOEA, 2016a).

2.4 Energy consumption by economic sector

The highest energy consumption was noted in the buildings sector (which includes the residential and commercial/institutional segments), accounting for 41.6% of total consumption. Most of the energy consumption in the buildings sector can be attributed to the residential segment, which accounts for 33% of the total energy consumption of the Bhutanese economy. The industrial sector accounts for 37% of total energy consumption, while transport accounts for a smaller share (19%), followed by a much smaller share for agricultural and auxiliary activities (2.6%). See Figure 3 for a detailed breakdown.

Energy demand in the residential sector is dominated by fuelwood, although its use has declined from 91% of the total residential fuel mix in 2005 to 87% in 2014. The main energy end-uses are heating, cooking and lighting. In cooking, fuelwood is being replaced by LPG, electricity and biogas, whereas the fuelwood for space heating is primarily being replaced by electricity. Similarly, the institutional and commercial sectors are also dominated by biomass (DRE–MOEA, 2016a).

Figure 3. Energy consumption by economic sector



Source: DRE–MOEA (2016a).

Going forward, the integration of renewables in the buildings sector (residential, institutional and commercial) will be aided by continued electrification. Biogas and more efficient cooking stoves can increase the use of sustainable biomass for cooking.

Improved biomass space heaters can help replace kerosene and LPG in heating applications. Renewable energy technologies such as solar water heating can also offer viable solutions for water heating in buildings (DRE–MOEA, 2016a).

Of the total energy demand from the industrial sector, large industries (which include the ferro-alloys, ceramics and cement industries) account for around 78%, with the remaining demand coming from various small enterprises in handicrafts, food processing, construction, wood, saw-mills, poly-products and paper production.

Electricity is the dominant fuel for the industrial sector and caters for 57% (137 ktoe) of total industrial energy demand, followed by coal and other conventional energy sources at 40%.

The industrial sector experienced a sharp decline in the use of fuelwood (biomass) and kerosene (-24% and -20% CAGR, respectively) and an increase in the consumption of electricity, diesel and coal (15%, 15% and 12%, respectively) during the period 2005–2014 (DRE–MOEA, 2016a).

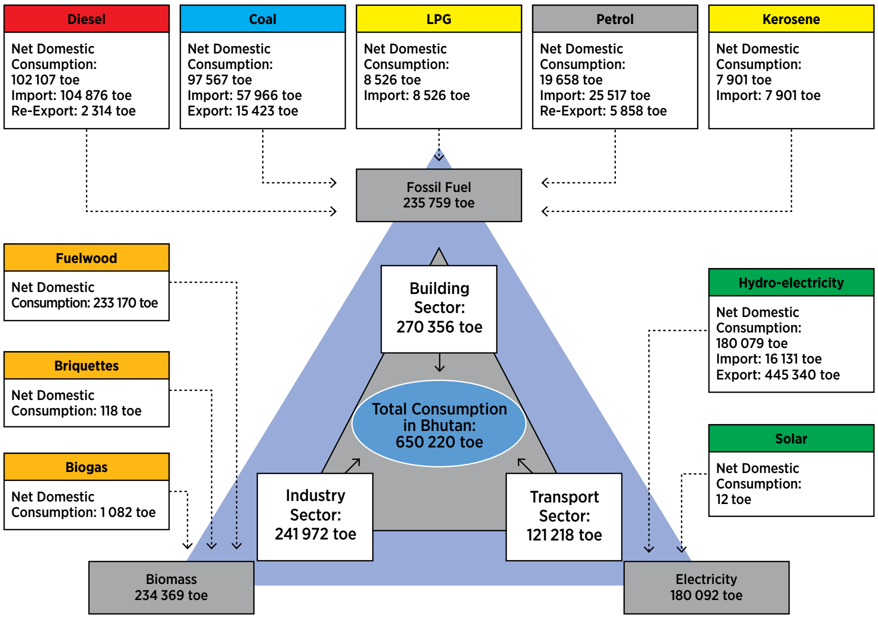
Transport sector energy consumption is also on the rise, with demand for all fuels doubling between 2005 and 2014. Diesel accounts for 81% of fuel consumption, with petrol and kerosene (aviation) accounting for 16% and 3%, respectively. Trucks and buses are the largest consumers of diesel, with taxis accounting for the largest share of petrol. Electric buses could offer a solution for public transport and electric vehicles could satisfy demand for taxis and private vehicles in a sustainable manner (DRE–MOEA, 2016a).

Overall, the energy intensity[1] of Bhutan's economy was reported at 10.4 megajoules per USD (MJ/USD) in 2015, which was much higher than neighbouring China (6.9 MJ/USD), India (4.7 MJ/USD) and Nepal (7.4 MJ/USD) (World Bank, 2019). The industrial sector is a major consumer of energy. Energy audits in large- and medium-scale industries have revealed significant opportunities for improvement in the energy efficiencies of processes and equipment (DRE–MOEA, 2016a).

The quantitative flows of energy production and consumption in Bhutan are summarised in Figure 4.

[1] Energy intensity level of primary energy (MJ/USD 2011 PPP GDP).

Figure 4. Summary of energy forms and flows in 2014



Source: DRE–MOEA, 2016a.

2.5 Energy demand outlook

Several studies have investigated the outlook for the future development of the energy sector in Bhutan, including the "Integrated energy management master plan for Bhutan" (2010) and "Bhutan: A national strategy and action plan for low carbon development", produced by Energy Analysis in 2012.

Integrated energy management master plan for Bhutan (IEMMP) (2010)

The "Integrated energy management master plan for Bhutan" (IEMMP) was developed by the Department of Energy at the Ministry of Economic Affairs in collaboration with The Energy and Resources Institute (TERI) to give a holistic overview of future energy demand and supply until the year 2020. Four different scenarios were analysed (DOE–MOEA, 2010):

- The business as usual scenario incorporates existing government plans and policies. GDP is set to grow at 7% and the energy intensity of the economy remains unchanged.

- The energy efficient scenario incorporates existing government plans and policies (i.e. BAU), and couples them with a shift towards modern and efficient technologies.

- The high growth scenario assumes a GDP growth rate of 10%, with unchanged energy intensity for the economy; the growth is led by the industrial and service sectors.

- The high growth coupled with energy efficiency scenario combines high growth rates with high energy efficiency scenarios.

All scenarios in the IEMMP result in a sharp rise in demand. Electricity demand increases at least four-fold in all scenarios within the 2005–2020 period, with a six-fold increase in the high growth scenario over the same period. The scenarios focus on energy efficiency and do not specify exact contributions from non-hydro renewable energy.

"Bhutan: A national strategy and action plan for low carbon development"

The Energy Analysis report, "Bhutan: A national strategy and action plan for low carbon development", was developed to make recommendations to the Royal Government of Bhutan on options for pursuing green growth by the Danish Ministry of Foreign Affairs. Referred to as the NSAP, it contains four different scenarios for future energy consumption until the year 2040: a baseline scenario; an energy efficiency (EE) scenario; a renewable energy (RE) scenario; and an EE+RE scenario.

Energy demand growth rates in all scenarios in the NSAP are much lower than in the IEMMP. Electricity demand, for instance, increases three-fold in the 2005–2020 period (EA and COWI, 2012). The actual growth in energy demand in past years is reported to be lower than the projection in the IEMMP and higher than the projections of the NSAP (DRE–MOEA, 2016b).

2.6 Institutional structure

The energy sector of Bhutan is governed, planned and co-ordinated by two key ministries: the Ministry of Economic Affairs (MOEA) and the Ministry of Agriculture and Forests (MoAF). The MOEA focuses on conventional and renewable energy production, consumption and exports; the MOAF is responsible for planning and governance of biomass and forest resources.

Policy making

The Ministry of Economic Affairs plays a central role in the formulation of energy sector policies through its three departments: 1) the Department of Hydropower and Power Systems (DHPS); 2) the Department of Renewable Energy; and 3) the Department of Hydromet Services (ADB, n.d.).

The Department of Renewable Energy is the nodal agency for the implementation of the renewable energy policy within the Ministry of Economic Affairs (MOEA). Its responsibilities, among others, include: the development of the renewable energy master plan; supporting the Renewable Energy Development Fund (REDF); co-ordination of the action plans of different organisations and agencies; facilitation of project developers in all phases of project development; and development of policy directives related to renewable energy.

The National Environment Commission (NEC), is the national body concerned with the environment. It is also charged with responsibility for ensuring expedient, efficient and high priority processing and issuance of clearances/permits to promote the development of renewable energy projects.

Thromdes are the municipal authorities responsible for providing policy and other support towards the substitution of fossil fuels by green energy sources in urban transport, street lighting and district heating systems, including the conversion of waste to energy and the promotion of green buildings.

Utilities

There are two major power utility companies in Bhutan: the Druk Green Power Corporation Limited (DGPC), and the Bhutan Power Corporation (BPC). The state-owned Bhutan Power Corporation (BPC) holds the main responsibility for transmitting and distributing electricity (ADB, n.d.). BPC owns and operates plants below 5 MW, which include micro/mini-hydro and diesel power plants. BPC also manages the transmission and distribution system and retails electricity to customers in the country (SARI/EI and IRADe, 2016).

The Druk Green Power Corporation (DGPC), also state-owned, is responsible for power generation. DGPC owns and operates the large hydro power plants in the country. It is the holding company for all existing hydropower companies. Before power exports, DGPC gives 15% of the power it generates as an energy royalty to the government, which sells it to BPC at discounted prices. Electricity is supplied to domestic consumers at affordable tariffs that are substantially cross-subsidised by power exports (ADB, n.d.).

Regulator

As the power sector regulator, the Bhutan Electricity Authority is responsible for setting tariffs; establishing and enforcing technical, safety and operational standards; issuing licenses; and monitoring other regulatory functions. While the electricity tariffs are regulated by the Bhutan Electricity Authority on a cost-reflective tariff structure, actual retail prices are cross-subsidised in the value chain of the power sector in a transparent manner (ADB, n.d.).

Financing

Hydropower projects form the bulk of investments in the energy sector. Large hydropower projects are usually funded by a mixture of debt and grants by partner governments. Some of the largest hydropower projects – such as Tala (1020 MW), Chukha (336 MW) and Kurichhu (60 MW) – have been funded by the government of India with a mix of grants (60%) and loans (40%). The Basochhu hydropower plant (64 MW) has been financed by the government of Austria.

As Bhutan moves forward with the deployment of medium and large hydropower, new models of project financing are being employed. The joint venture model, wherein part of the funding is raised as company debt and the remainder is covered by government entities (national and foreign) is being used for as many as ten hydropower projects at different stages of deployment. Bhutan's DGPC entered a joint venture with India's Tata Power for the development of the 126 MW Dagachu Hydropower Plant under a public–private partnership (PPP) model. The project was financed by the Asian Development Bank (ADB), Austria's Raiffeisen Bank and the National Pension and Provident Fund of Bhutan (NPPF) (Roychoudhury and Srinivasan, 2016).

Smaller power projects, including for distributed generation, are often funded by support from partner governments and development banks. The pilot 600 kW wind turbines in Wangdue, for instance, were funded by ADB.

Wangdiphodrang, Bhutan
Photograph: Shutterstock

3. RENEWABLE ENERGY SECTOR OVERVIEW

The renewable energy landscape in Bhutan is dominated by hydropower. Domestic electricity demand and electricity exports are almost exclusively met by hydropower. Other renewable energy technologies such as solar, wind and bioenergy are at initial stages of deployment – often limited to pilot projects and small applications. As Bhutan continues to strive towards a modern, secure and sustainable energy system, renewable energy can play a key role in this transition.

3.1. Resource potential

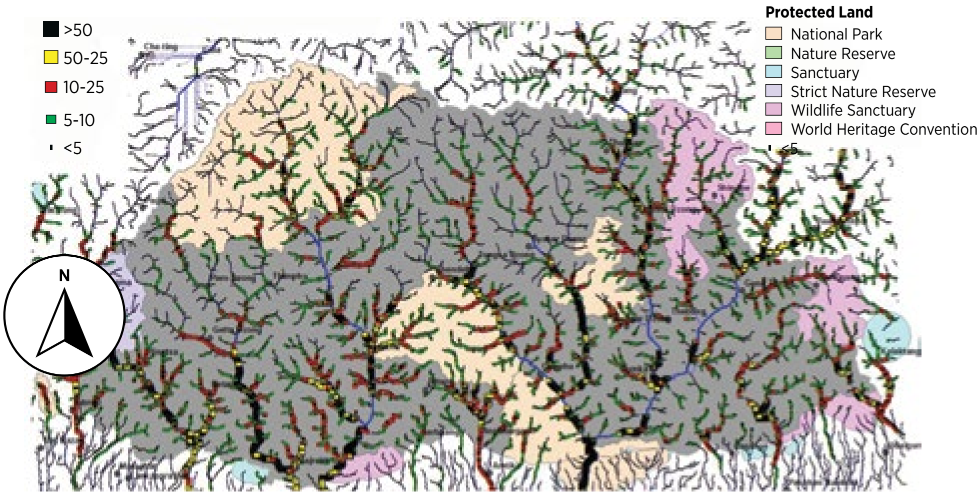
Bhutan is endowed with several different renewable energy types, with a particular abundance of resources for micro/mini, small, medium, large and mega hydropower.[2] In addition to fast flowing rivers and streams, the country is also endowed with resources for solar, wind and biomass.

Hydropower

Hydropower remains the chief resource for renewable energy in Bhutan. The Lhuntse, Mongar and Wangdue dzongkhags (districts) are considered to have excellent hydropower power potential (Figure 5). The theoretical potential of hydropower is estimated at more than 41 GW, whereas the restricted technical potential is estimated at 26.6 GW (DRE–MOEA 2016b).

Figure 5. Hydropower resource of the river network in Bhutan

Power Potential in 2km in successive River cells [MW]



Source: DRE–MOEA, 2016c.
Disclaimer: Boundaries and names shown on this map do not imply any official endorsement or acceptance by IRENA.

2 The Sustainable Hydropower Development Policy, 2008 defines these as: micro/mini (less than 1 MW); small (1 MW to 25 MW); medium (25 MW to 150 MW); large (150 MW to 1 000 MW); and mega (more than 1 000 MW) hydropower.

Solar

Despite its mountainous terrain, the country enjoys good solar resources in several regions. The high altitude, combined with the terrain of the country, mean that satellite measurements are not as reliable as in other regions of the world. Satellite maps, such as that shown in Figure 6, show that solar radiation can vary from 1 600 to 2 700 kWh/m^2/yr. Other datasets suggest a range of 1 000 to 2 000 kWh/m^2/yr. Regardless, the irradiation is better than many regions in the world, such as Germany and the UK, which have already achieved a sizeable share of power generation from solar energy.

More focused ground-measured readings can help provide the bankable resource data required for solar projects. The orientation and slope of solar panels are two key limitations in Bhutan. Both determine the accessibility of the area and decide the technology used for supporting structures. In addition, areas already in use for agriculture, as well as forestry and protected areas, limit deployment. The DRE–MOEA (2016b) estimates theoretical solar potential at 6 terawatts (TW) and restricted technical potential at 12 GW.

Wind

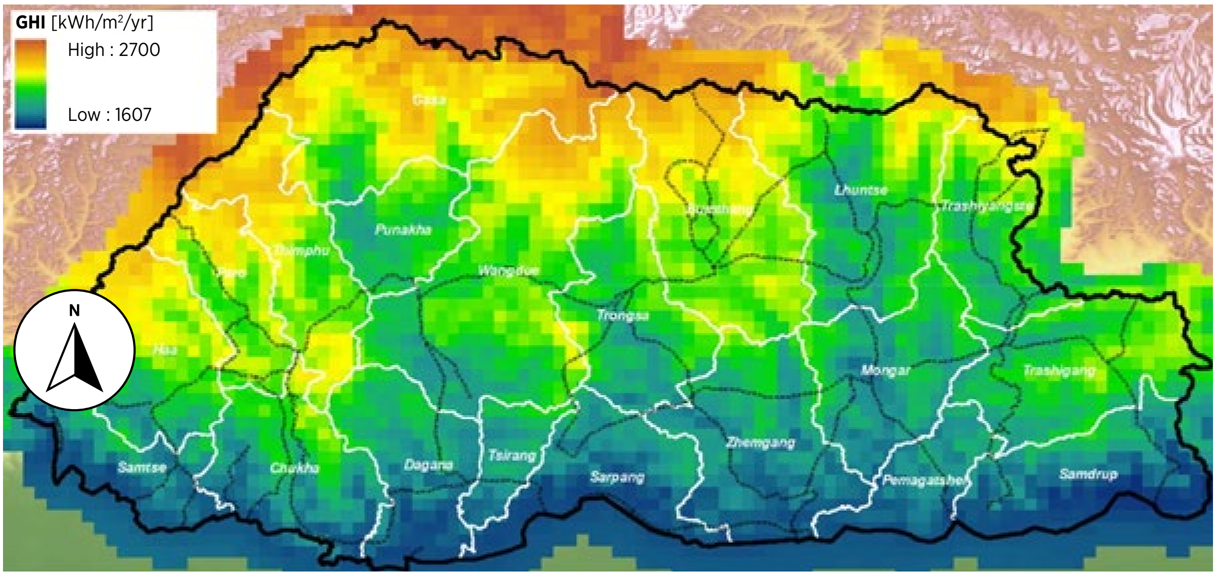
Bhutan's overall wind regime is heavily influenced by the seasonal monsoon, which means that wind speeds are high from November to April and low in the remaining months. This coincides with the periods when hydro resources are short, and offers an opportunity for diversifying the supply of power by leveraging the seasonal complementarity between wind and hydro resources (DRE–MOEA, 2016c).

As Figure 7 shows, areas with high wind speeds are often located in high-altitude mountain tops and ridges above 3 000 metres. These areas are particularly inaccessible when transporting large modern wind turbine nacelles, blades and towers, restricting installations to small wind turbines in distributed applications (DRE–MOEA, 2016c).

Therefore, the country's promising wind resources tend to be concentrated in the so-called 'valley wind systems', which tend to be in accessible regions, and are both regular and predictable. These local wind systems emerge from local thermal differences and result in winds that flow through valleys in a regular manner.

The wind energy resources translate into actual potential when supported by research that accounts for limitations such as slope and elevation levels; distance to roads, built up areas and airports; restricted areas (e.g. agricultural land, forest, protected area); and technological limitations. A DRE–MOEA (2016b) study that accounts for these limitations found that Bhutan can easily deploy close to 760 MW of wind energy, with the northern dzongkhag (district) of Wangdue accounting for close to 19% of this potential, followed by the southern dzongkhags of Chukka (12%) and Dagana (10%) (DRE–MOEA, 2016c).

Figure 6. Solar map

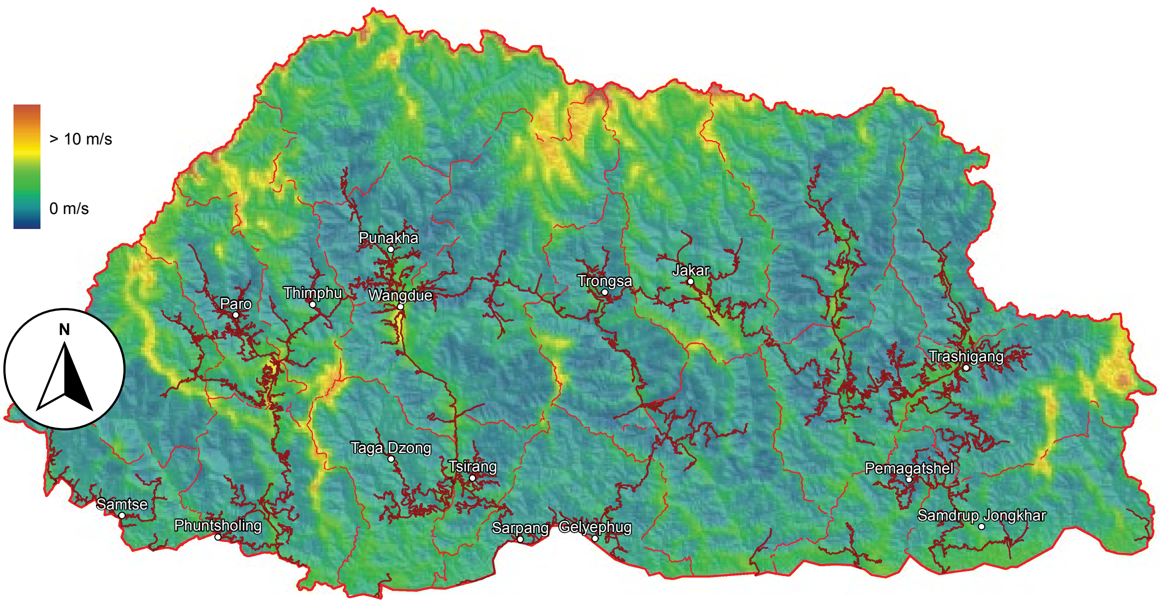


Notes: map from 3Tier in original resolution, values in kWh/m^2 including districts and major national road network.

Source: DRE–MOEA, 2016c.

Disclaimer: Boundaries and names shown on this map do not imply any official endorsement or acceptance by IRENA.

Figure 7. Map of annual average wind speeds (60m height; 1x1 km model)



Source: DRE–MOEA (2016b).

Disclaimer: Boundaries and names shown on this map do not imply any official endorsement or acceptance by IRENA.

3.2. Renewable energy policies and regulations

The Bhutan Sustainable Hydropower Development Policy 2008 captures most aspects of hydropower development, such as the institutional structure of the hydropower sector, project solicitation, project investment, fiscal incentives, etc. The policy aims to mobilise funds and attract investment for accelerated hydropower development. It offers several fiscal incentives to encourage investors and developers – including an exemption from income tax for ten years – and waives sales tax and duties on imported equipment and exported electricity. The policy encourages public and private investments from local and foreign entities in medium (25 MW to 150 MW) and large projects (150 MW to 1 GW). Investments in mega hydropower projects (more than 1 GW) are undertaken in collaboration with the governments of partner countries. The policy is currently under review by the Department of Hydropower and Power Systems.

The Alternative Renewable Energy Policy, 2013 (AREP), aims to help promote and develop renewable energy in the country. The policy strives to ensure adequate provision and extensive use of modern energy services in rural areas through distributed renewable energy projects in locations that have been largely dependent on firewood and kerosene for cooking, heating and lighting. In urban areas, the policy strives to optimise and conserve the usage of grid-based power through the promotion of dispersed energy generation options. It also aims to encourage renewables in both rural and urban settings through measures including technical and financial support and direct funding for small scale projects. It envisions supporting project developers, manufacturers and system integrators through income tax exemptions for 10 years (extendable to 15 years for strategic or poverty alleviation related reasons) as well as exemption from custom duties and sales tax on equipment. The tariffs for distributed and grid-connected projects could be determined by the Bhutan Electricity Authority (BEA) and may include subsidies to cover lifetime project costs. Large hydro projects are not covered under this policy.

The AREP also includes provisions for a Renewable Energy Development Fund (REDF), which aims to provide financial assistance to create a favourable investment climate for renewable energy in Bhutan. The REDF is envisioned to be the central financing instrument for the development of renewable energy projects in Bhutan, and it is supposed to be funded through contributions form hydropower plant owners and through royalties. However, so far, the funds have not been put in place.

Targets for renewable electricity generation capacity for 2025 are defined in the AREP. The policy envisions a combined renewable energy (excluding hydropower) target of 20 MW. This includes technology-specific targets of: 5 MW of solar PV, 5 MW of wind and 5 MW of biomass by 2025.

While the AREP focuses on small hydropower (<25 MW), it does not define a target for the technology. It does define targets for renewable heat generation technologies, however, foreseeing 3 MW_{th} for biomass and 3 MW_{th} for solar water heater systems.

A comparison of the country's renewable energy resources (Section 3.1) on offer shows that the targets in the AREP may be conservative. The renewable energy master plan (DRE–MOEA, 2016b) provides alternative scenarios which tend to be more ambitious. These scenarios are compared in Table 1, and show that the country can potentially exceed the targets adopted in the AREP.

Renewable energy policies and regulations, just like other forms of legislation, are implemented through the 'five-year plans' (FYP) – a series of national economic development plans created by the government of Bhutan.

The 11th FYP 2013–2018 sought to support hydropower and other renewable energy technologies through the development of institutional capacities, human capabilities, and concrete sectoral policies including a renewable energy master plan. The 12th FYP 2018–2023 continues to strengthen relevant regulatory and institutional frameworks and emphasise the deployment of pilot renewable energy projects.

3.3. Installed renewable energy capacity and generation

The installed capacity of Bhutan is dominated by hydropower power plants, accounting for 1 614 MW of the country's total capacity of 1 623 MW in 2018. Medium, large and mega hydropower plants provide 98% of total hydropower capacity, with the Tala Hydropower Plant alone accounting for more than 1 GW (DHPS, 2019).

The remaining capacity is provided by diesel generators, wind turbines and small solar plants. Diesel generators account for 8 MW, and wind energy for a further 0.6 MW (DHPS, 2019). Solar PV has been implemented in both on- and off-grid settings, often at a small scale. The number of operating solar PV systems in 2014 was assessed at roughly 2 400 and estimated to contribute around 143 MWh of electricity.

Table 1: Renewable energy scenarios proposed by the "Renewable energy master plan"

	Capacity by 2025 (MW)			
	AREP targets	Low case	Base case	High case
Small hydropower	*	37.2	67.5	110
Wind	5	2.4	5.1	7.8
Solar PV	5	2	6.1	11.9
Biomass	5	0.6	1	8.1
Others	5			
Total	**20**	**42.2**	**79.7**	**137.8**

*The AREP does not indicate a target for small hydropower.

Source: DRE-MOEA, 2016b


Photograph: Shutterstock

4. RATIONALE FOR RENEWABLE ENERGY

While hydropower is likely to remain an important component of the energy sector of Bhutan, renewable energy technologies such as solar PV, wind, bioenergy and small hydropower could offer opportunities for diversifying the country's energy mix and addressing rising energy demand. This section analyses the key rationale for a shift towards a more diversified energy system.

4.1. Socio-economic benefits of renewable energy

Renewable energy deployment can be an engine for economic growth, industrial development and job creation. The Royal Government of Bhutan recognises these socio-economic benefits and the importance of providing access to energy to support income generation. Although Bhutan has achieved near universal electricity access, households continue to depend on fuel wood (and kerosene) to meet cooking and heating energy needs.

The use of renewable energy and more efficient cooking and heating technologies could help reduce deforestation and indoor emissions, bringing significant health benefits. Renewables can also help to enhance living conditions by freeing up time and effort spent gathering fuelwood, which can be utilised for other productive or leisure activities. Women often benefit the most from such interventions as they are most affected by indoor emissions and the drudgery associated with gathering fuelwood.

Off-grid renewable energy technologies offer a cost-effective, rapidly deployable and modular tool to speed up the process of electrification, especially in remote regions. Globally, development of community-based micro-hydro and biomass technologies has an established track record. The growing deployment of small wind and solar PV-based technologies has enabled further diversification of this technology mix.

Electricity generation from solar PV applications could include lanterns, solar home systems and village-powering mini-grids. Similarly, bioenergy could be used for improved cooking stoves, space heating and steam production for commercial and industrial processes. Applications for motive power may include the use of water mills for food processing or other commercial and industrial processes (grinding, woodwork, etc.). Windmills can also be used to energise water pumping.

4.2. Seasonal variation in hydro-electricity generation

Hydropower is sensitive to changes in seasonal weather patterns and weather extremes that can adversely affect the supply of energy. Rainfall in Bhutan tends to decline in the winter months (Figure 8), which, coupled with reduced meltwater from snow and ice, results in reduced river flows. Bhutan's dams are run-of-river and power generation fluctuates with these seasonal river flows. Low river flows during the winter are already an issue, leading to imports of electricity from India to satisfy 4% of total domestic electricity demand in 2017.

Renewable energy technologies such as solar PV, wind, hydropower and bioenergy have different generation profiles during the year, which can complement each other in a diversified system. Wind, for example, can potentially complement hydropower during the winter months. An energy system that constitutes a healthy mix of renewable energy technologies including hydropower, solar PV, wind and bioenergy can therefore be more resilient to seasonal variations in rainfall.

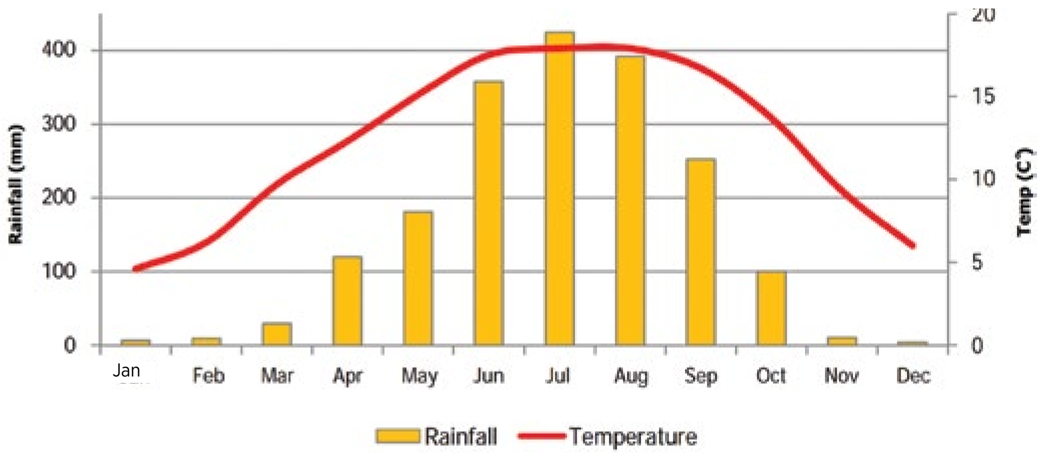
4.3. The impact of climate change on hydropower

Bhutan's dependency on hydropower to meet electricity demand renders the country vulnerable to long-term climate change impacts, thereby raising energy security concerns. Climate change and the potential resulting changes in hydrological patterns (rainfall, snow and melting of ice) may pose risks to future and existing hydropower developments. Climate change may affect the hydropower driven power system in two key ways:

Changes in flow patterns: Climate change can have negative impacts on river flows, including a seasonal reduction in flow and overall more erratic flow patterns, which can pose an energy security risk (Walker, 2016). While the river flow may decrease as the glaciers recede, increased monsoon rains may result in increased inflows, both of which are detrimental to hydropower production; i.e., generation further dips during lean seasons while increased flows during monsoons will mean more silts impacting hydro plant structures.

A study with a time span stretching from 2000 to 2100 shows that the river flow in Bhutan could increase by 7% or decrease by 13%. Such concerns are already pushing decision makers to think about hydropower with reservoirs, as opposed to the run-of-river type currently used in Bhutan (Gyelmo, 2016). A move towards reservoirs may lead to an increase in costs and environmental impacts.

Figure 8: Average annual rainfall and temperature for the Kingdom of Bhutan



Source: SARI/EI and IRADe, 2016

Extreme events: Climate change is expected to result in the increasing frequency and intensity of extreme weather events, including flooding due to extreme precipitation and glacial lake outburst floods (GLOFs). So far, around 5 GLOFs have been reported in Bhutan and 25 glacial lakes have been identified as potential sources of GLOFs. In Nepal, GLOFs have been associated with the destruction of the Namche/Thame hydropower plant (ICIMOD, 2007; Lutz, et al., 2015).

A diversified energy system comprising several renewable energy technologies, including hydropower, solar PV, wind and bioenergy, can be more resilient to the impacts of climate change. Such a system can better withstand variations in climatic patterns (irradiation, precipitation, seasons and wind flow) and extreme events (floods and storms).

4.4. Environmental impacts of hydropower

Bhutan is recognised for its environmental stewardship, which is built on a high-level commitment to environmental conservation. Environmental conservation is recognised as one of the four key pillars and nine key domains of the GNH approach, which guides planning and development in the Kingdom. The country has been recognised internationally by the Worldwide Fund for Nature (WWF) and the Champions of the Earth awards for the active environmental role played by its leadership.

Bhutan's constitution guarantees 60% forest-cover and, accordingly, the current forest cover is more than 70%. This thick forest cover harbours a rich biodiversity that places the country as one of the top ten biological hotspots of the world (Chhopel, 2014). The country is also one of the most 'carbon negative' in the world, as its forests absorb three times more CO_2 than its population creates (Neslen, 2015). The reliance on run-of-river hydropower has, so far, helped the country to establish its environmental leadership and successful record of climate change mitigation.

While ROR hydropower installations can curb some of the environmental and climate impacts associated with installations featuring reservoirs, other impacts remain unavoidable. ROR hydropower installations divert water towards tunnels, which could result in the drying up of riverbeds, causing potentially irrevocable damage to riverine ecosystems. To address this issue, environmental regulations in Bhutan require a specified minimum flow. Other potential impacts include loss of forest; disturbance to wildlife; heavy dust pollution and equipment noise pollution; damage to water bodies such as streams and ponds; and stress on water resources in the region.

The advent of dams with reservoirs can have more severe environmental impacts. Most of the hydropower projects implemented in Bhutan are ROR schemes, with the 60 MW Kurichhu HEP being the only reservoir scheme. That said, the trend is shifting towards dams with reservoirs. Four planned mega projects – the 180 MW Bunakha HEP, 2 585 MW Sunkosh HEP, 2 640 MW Kuri-Gongri HEP and 540 MW Amochhu HEP – are reservoir-based hydropower projects (Premkumar, 2016). Compared to the existing fleet of ROR projects, the impacts of the implementation of these projects carry risks such as habitat destruction and increased methane emissions.

Small hydropower plants (<25 MW) can help mitigate some of the environmental impacts associated with large projects. They are usually run-of-river installations and avoid most impacts associated with reservoirs. However, deployment should still consider, and try to minimise, environmental implications for land use, water flow and ecosystems. Furthermore, small hydropower plants are advantageous in terms of their short gestation period, enhanced firm power and low investment requirements; they can also be developed under local community ownership. Overall, small hydropower plants can have substantial socio-economic benefits with minimal impacts on the environment when implemented in a sustainable way.

4.5. Rising domestic demand and fuel imports

Energy consumption in the country has been growing rapidly at a CAGR of 5.49% since 2005 (DRE–MOEA, 2016; SE4All, 2012). Most of this energy demand – especially from the transport and industrial sectors – is met through imported fossil fuels, which represent a significant and growing economic burden. Comparisons with historical data suggest that imports are increasingly cutting into export revenues.

Dependence on imports of fossil fuels can be an energy security issue. Excessive reliance on imported fuels introduces risks related to regulation and political climate in the exporting country. Furthermore, excessive reliance on imported fossil fuels also exposes the country to volatility in international fuel markets. Renewable energy solutions can help cater to demand for electricity and heating.

The transport sector can be made more sustainable through the introduction of electric vehicles. The Government of Bhutan is partnering with the United Nations Development Programme (UNDP) and the Global Environment Facility (GEF) to introduce electric vehicles in the taxi fleet of its capital, Thimphu (See Box 1).

Box 1: **Electric vehicles**

The government of Bhutan, under the Bhutan Sustainable Low-emission Urban Transport Systems project, is rolling out a program to electrify the taxi fleet of the capital, Thimphu. The plan was launched in early 2018 with 26 electric taxis. The city has 535 taxis, 500 of which are envisioned to become electric over the course of three years.

The project extends beyond electric taxis and includes designing and implementing an innovative financial mechanism to support the introduction of electric vehicles. It also aims to support the expansion of charging network infrastructure and the establishment of a sustainable and viable related business model.

Charging stations are also being installed in various dzongkhags – Thimphu, Paro, Haa, Wangdue Phodrang, Punakha and in the city of Phuentsholing.

The introduction of electric taxis can be an essential first step toward the broader introduction of electric vehicles. This can allow for a fast and economical pathway to the electrification of Bhutan's transport sector, thereby opening opportunities for reductions in gasoline and diesel imports. Electric vehicles can play a pivotal role in the energy transition by both lowering vehicle emissions and allowing for the broader introduction of renewables to the transport sector. Furthermore, EVs are more efficient than internal-combustion-engine vehicles.

Source: UNDP, 2018; and Tshomo, 2019

4.6. Favourable renewable energy technology and market developments

Globally, the increasing competitiveness of renewables has become evident in recent years. Declining renewable energy costs are benefiting from a conducive financing environment and innovative financing schemes. While public sector financing is playing a vital enabling role, the private sector accounted for over 90% of global renewable energy investments in 2016 (IRENA and CPI, 2018).

DRE–MOEA (2016c) presents an analysis of the LCOE of different renewable energy technologies. According to this analysis, small hydropower has the lowest LCOE, ranging from 4.2 BTN/kWh to 8.8 BTN/kWh, followed by biomass gasification and steam. Wind energy, PV and biomass ORC (organic Rankine cycle) have the highest LCOE (DRE–MOEA, 2016b).

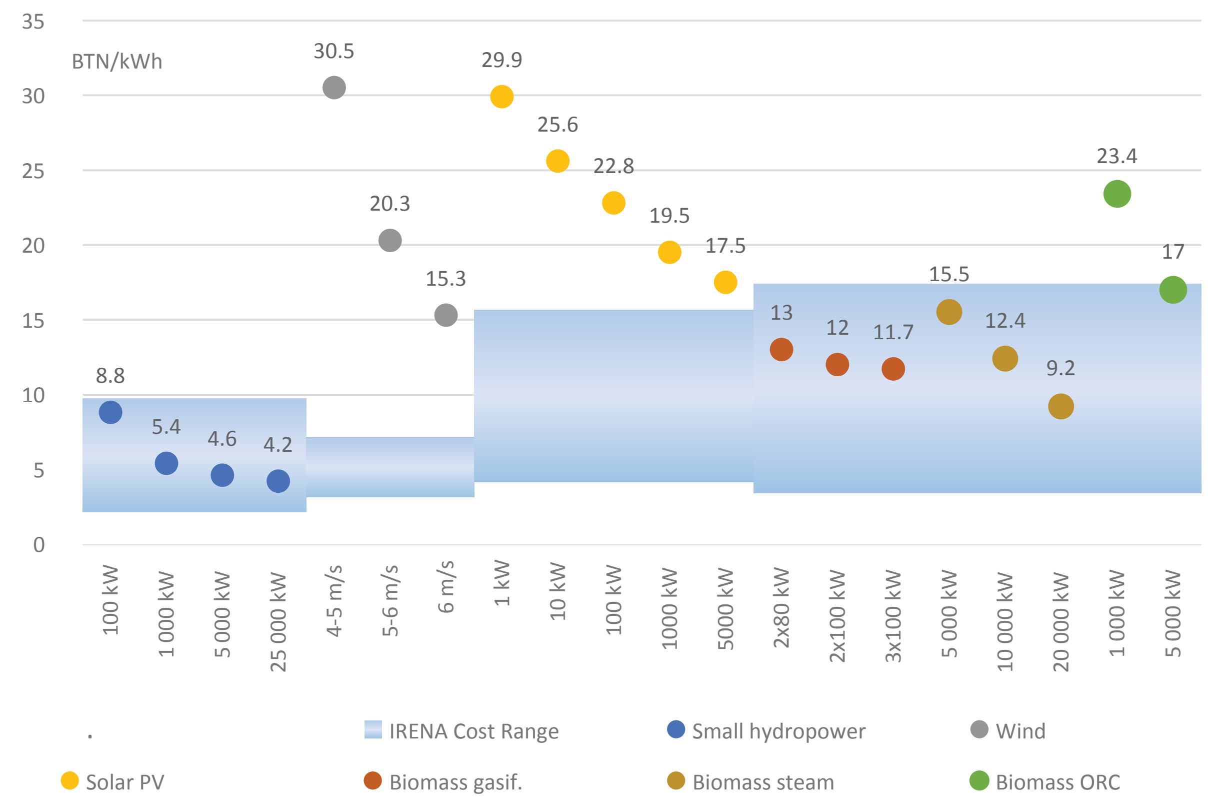
A comparison with IRENA's global costing database (IRENA, 2019a) suggests that due to the rapid cost reductions in solar PV and onshore wind in recent years, current costs are already lower than the estimates used for these LCOE calculations (DRE–MOEA, 2016b). The shaded area in Figure 9 shows IRENA's cost ranges for these technologies[3].

- For solar PV, for instance, IRENA's data shows that project costs ranged from 4 BTN/kWh to 16 BTN/ kWh in 2018. This makes small scale solar PV a viable alternative to replace or support off-grid diesel and petrol gen-sets that have typical generation costs of around 17.4 BTN/kWh.

- IRENA's wind costs database shows that onshore projects are being developed at prices ranging from 3 BTN/kWh to 7 BTN/kWh. The wind LCOEs in Bhutan are likely to be higher due to the lack of accessible locations and lower wind speeds in those locations that are easily accessible.

[3]The IRENA cost ranges are based on the 5th and 95th percentile of projects in IRENA's costing database for 2018.

Figure 9: Levelised costs from renewables in Bhutan (BTN/kWh) compared with global tariffs



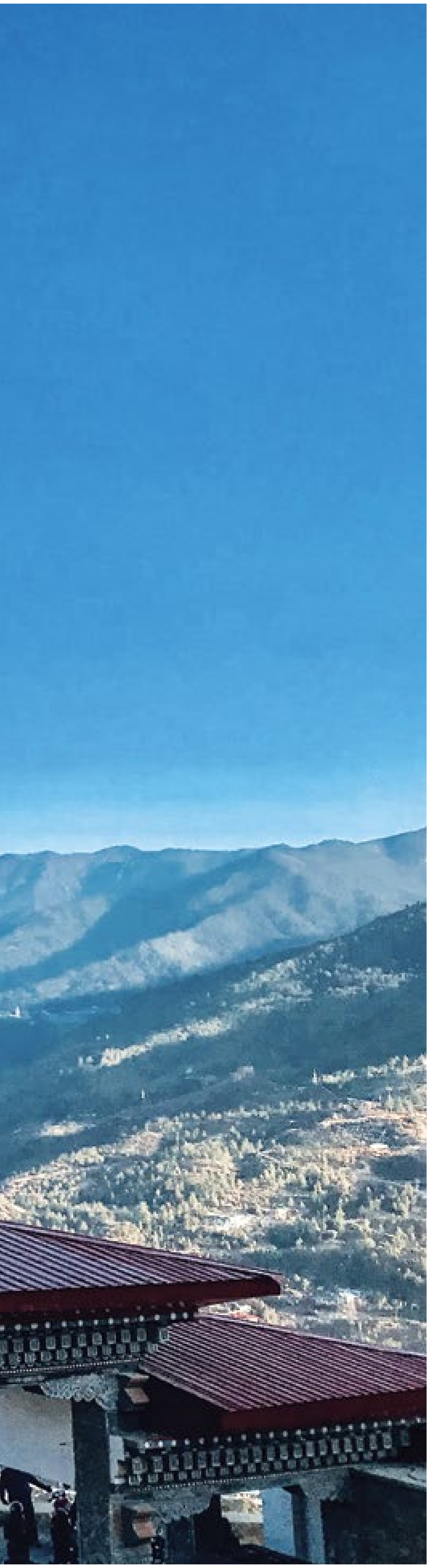
Source: Data included in DRE–MOEA (2016c) and IRENA (2019b).

Note: IRENA cost range is shown in blue background colour and represents the 5th and 95th percentiles of projects in IRENA's costing database for 2018.

In remote areas without reliable connections to the electricity transmission network, renewable energy technologies can easily compete with alternatives – typically diesel or petrol gen-sets – that have a LCOE of about 17.4 BTN/kWh. In such settings, small hydro, solar PV and biomass, as well as hybrid mini-grids, can provide reliable electricity at much competitive costs (DRE–MOEA, 2016b).

As financing models are improving and being tailored to a broader pool of project developers ranging from small-scale communities to large institutions, the cost of capital is falling and renewable energy finance is becoming more accessible. Thus, a re-evaluation of the costs of renewables in Bhutan can assess the current and future cost competitiveness of these technologies, allowing for better planning of the power system and progress towards a more diverse and distributed technology mix.

Gate to Buddha Dordenma
Credit: IRENA/Prasoon Agarwal



5. KEY CHALLENGES AND RECOMMENDATIONS

A smooth transition towards renewable energy that simultaneously optimises its multiple benefits requires policies that are well designed and implemented. This chapter presents the recommended actions to help Bhutan move towards a more diversified energy system through accelerated development of renewable energy resources.

5.1. Policy and regulatory framework

Scaling up the deployment of non-hydropower renewables requires the establishment of a dedicated policy and regulatory framework. Given that Bhutan is still at the very early deployment stage, renewable energy projects are being implemented on an ad hoc, project-by-project basis. Realising the true renewable energy potential of the country demands a gradual paradigm shift towards overarching policy frameworks, complemented by strong institutions, laws and regulations. With a wider deployment of non-hydro renewables, potential challenges may arise associated with their integration into the grid and accommodating for variability.

The AREP 2013 already provides a comprehensive set of guidelines on suitable policy instruments, deployment pathways and capacity developments. It could form the basis for a revised National Renewable Energy Policy that accounts for evolving market conditions, declining costs, updated resource assessments and changing global and national priorities. Subsequently, renewable energy policy instruments and regulations can be developed to support and implement the guidelines stipulated in this updated national policy.

The AREP 2013 also laid the foundations for establishing a Renewable Energy Development Fund (REDF) as the central financing instrument for renewable energy projects in Bhutan. Considering the nascent renewable energy market in the country, the effective introduction of a dedicated funding mechanism is highly important. The REDF was expected to be funded by up-front premiums from the large hydropower project developers, energy royalties from the generating companies and renewable energy grants from international development institutions and other donors. Despite its formulation in AREP, REDF is yet to be implemented (DRE–MOEA 2016a).

Action 1: **Strengthen the renewable energy policy framework**

A well-designed policy framework should be attuned to specific national and local contexts. The long-term stability of policies and targets is key to ensuring investor confidence and sustained growth. While stability is key, policies must continuously adapt to changing market conditions to facilitate cost-competitiveness; such a framework does not need to be developed from scratch.

In the context of Bhutan, an updated National Renewable Energy Policy, which accounts for the rapid fall in renewable energy costs and updated resources assessments, could serve as the overarching guideline for accelerated deployment. Declining costs could result in substantial reductions in the requirement for subsidies for renewable energy technologies. As the market matures, further reductions in local deployment costs can contribute to a gradual shift from a government support-driven model to a more market-driven approach. Policies must be augmented to support such a market transformation.

An updated National Renewable Energy Policy can also offer an opportunity to adopt more ambitious renewable energy targets than the existing 2025 targets set in the AREP 2013. The existing targets may not be consistent with Bhutan's legacy of environmental stewardship and do not reflect either declining renewable energy technology costs or the promising resource potential of the country. The renewable energy targets could be re-evaluated based on several factors, including: resource potentials; impact of climate change on hydro resources; technology costs; suitability of technologies to local context; and the aspirations of the country to develop a local industry (IRENA, 2015a).

The updated renewable energy targets should also cover the transport and heating sectors. While challenging from a technical and administrative standpoint, they can influence around 70% of the energy consumption in Bhutan, which is currently served by imported fossil fuels and traditional biomass. Such targets would require deep engagement and strong co-ordination among involved government departments. Globally, targets for renewable heating and cooling remain limited, but there are several examples that can help guide target setting in Bhutan (IRENA, IEA and REN21, 2018). South Africa, for instance, has targeted five million homes for solar thermal water heating by 2030. Thailand's 2015 Alternative Energy Development Plan includes heat targets for solar thermal, biomass, biogas and municipal waste by 2036 (IEA, 2016).

A strong and well-designed renewable energy policy framework that is guided by clear targets and supported by robust institutions, laws and regulations, can signal the political commitment of the Royal Government of Bhutan to the public, investors, international institutions and other relevant stakeholders – thus enabling a meaningful introduction of non-hydro renewables in the country. Long-term energy planning and associated grid assessments are also crucial to facilitate deployment and integration of variable renewable energy into the power system.

Action 2: **Operationalise the renewable energy development fund**

Making the Renewable Energy Development Fund operational could have a transformational effect on renewable energy deployment in Bhutan. Identifying potential sources of funding is a critical starting point in the operationalisation of the REDF. The funding can come from a wide variety of avenues including international, national, public and private sources. Depending upon the specific circumstances, Bhutan may choose to access one or a combination of these sources.

While dedicated public financing facilities can focus on directly lending and issuing grants/subsidies to renewable energy projects, they can also play a pivotal role by issuing instruments that de-risk investments and mobilise private investors. Such instruments include guarantees, derivative instruments, liquidity facilities and other innovative structures that can help overcome challenges to private sector investment (IRENA, 2016b). Hence, as the REDF matures, the focus can shift towards such de-risking mechanisms, with the potential for leveraging larger pools of private sector investment.

Renewable energy and energy efficiency projects can be funded through taxation on fossil fuel-based technologies. These taxes help account for the social and economic costs of fossil fuel consumption and can contribute to creating a level playing field for renewables. Several countries rely on a combination of government and donor funding to capitalise national renewable energy funds (Annex 1).

Together with an enabling policy environment and ambitious renewable energy targets, the REDF can demonstrate the long-term commitment and support of the government by sending strong and positive signals to donors, multilateral development banks, local and foreign project developers, and other industrial stakeholders.

5.2. Livelihood enhancement through renewable energy

Increasing access to cost-effective and environmentally sustainable energy services can also help improve livelihoods through better health, enhanced education and greater gender equality. Renewable energy applications for productive uses, especially in distributed applications, can enhance opportunities for job creation and income generation. Bhutan's approach to development, enshrined in the GNH, prioritises human wellbeing over material growth, considering factors such as the spiritual, physical, social and environmental health of people. Renewable energy deployment can complement and contribute to this approach in Bhutan by improving the lives of its citizens.

Encouraged by declining solar PV technology costs and regulatory support such as feed-in tariffs, electricity consumers in many markets are installing solar PV systems to produce electricity for self-consumption and feeding to the grid (giving rise to the term 'prosumer'; i.e. one who both consumes and produces a product). The unsubsidised average tariff (or average cost of delivery) of low voltage electricity in Bhutan is estimated at 5.81 BTN/kWh.

The cost of delivery of electricity is likely to be much higher in regions that are remote and/or sparsely populated. Thus, utilities may be interested in purchasing renewable energy from prosumers (or simply generators) in these areas. At the same time, a decentralised renewable energy system – especially comprising grid-connected rooftop solar PV – can complement the grid by supplying the excess electricity generation from individual homes.

Action 3: **Promote renewables for productive use**

Renewable energy applications could be tailored to different productive end-uses in different segments of the value chain in relevant sectors (e.g., textiles, agriculture, food processing, animal husbandry, cottage industries, service and retail, etc.). However, the successful use of renewable energy solutions for productive uses in Bhutan will depend on the availability of an ecosystem that includes viable technology, adequate training, conducive policies, affordable financing and access to a market for products and services. (SELCO Foundation, n.d.)

The selection of appropriate technologies must be based on the demands of local communities and should be accompanied by adequate training to ensure that projects are properly operated and maintained. Renewable energy for greenhouses could be an interesting application for increasing food security in the face of climate change. In China, biogas from organic domestic and animal waste is used to provide heat for greenhouse production of fruit and vegetables (FAO, 2011).

Renewable energy can also contribute to other parts of the food supply chain at the post-harvest, storage, transportation and distribution stages. Renewables-based storage can help in increasing the shelf-life of food items and keep them in good condition, resulting in increased incomes. Simple solar dryers built using woodworking tools and basic skills can be used to dry fruits and other foods. Improved water mills in Nepal use the mechanical energy produced by water flow to process food items, while also generating electricity (IRENA, 2016a).

Box 2: **Opportunities for productive uses of renewable energy in Bhutan**

Renewable energy can be used in agricultural, industrial and commercial processes that provide goods and services and generate income. Market adoption of renewables in these processes can depend on several factors, such as suitable technologies, adequate training, conducive policies, affordable financing and access to a market for products and services.

The upfront costs of renewable energy projects can be an important issue for cash-strapped entrepreneurs and small business owners, which means that grants and/or financing models are key to kickstarting the market. The financial model must be context specific and could include credit from national banks, micro finance institutions and co-operatives. Designing appropriate and sustainable financing models, however, may require a thorough understanding of the financial circumstances of the entrepreneurs. For instance, the monthly payment to the lender should be lower than expected profits to allow for sustainable debt servicing.

In many cases, small business owners may not have bank accounts or a credit history with financial institutions and therefore may require guidance and support in securing and servicing loans.

Capacity building for different stakeholders is another important enabler. For example, training of installers and technicians was an important component of Vietnam's biogas programme, which resulted in more than 150 000 biogas digesters in the country. Around 1 700 masons were trained to construct different biogas digester designs.

More than 1 000 government sector technicians were trained to perform duties such as outreach for biogas technology, identification of suitable households and inspection and verification of biogas digesters. End users were also trained in proper operation and maintenance of digesters.

Source: IRENA (2016a); SELCO Foundation (n.d.)

Action 4: **Establish enabling conditions for prosumers**

The government could encourage individual consumer- and community-owned mini-grids through incentive schemes to feed low cost generation to the grid. This could be achieved through consumer-centric tariffs, benchmarked against the location specific cost of delivery of electricity (on average 5.81 BTN/ kWh in 2019). Such efforts could help scale up renewable distributed generation in remote regions, which would cater to rising electricity demand and reduce requirements for upgrades in transmission infrastructure, resulting in a reduction in overall system costs. This would also provide a source of income to rural and remote communities, with potential livelihood benefits.

In locations with rich hydropower resources, community-owned small hydropower can offer an alternative to large hydropower with lower investments and gestation periods. Community ownership of such projects can help ensure that benefits are adequately shared with the local population of Bhutan. The hydropower community ownership model in Nepal provides an interesting example. The subsidies for hydropower from the Alternative Energy Promotion Centre (AEPC) were initially only focused on projects owned by communities and co-operatives, before later being opened to the private sector. Furthermore, project-affected communities in Nepal are given a constitutional right to invest in hydropower in order to help build project ownership and support among communities. In practice, the government of Nepal requires hydropower developers to offer up to 10% of their shares to communities affected by the project.

To ensure that remuneration can help generate valuable direct incomes for populations in remote regions, contracts should be given to the residents of those communities. This can encourage residents, as well as people with second homes in rural areas, to invest in renewables. The tariff should not exceed the location-specific cost of delivery of electricity but should nonetheless compensate renewable generation by local consumers and communities.

These projects can be further supported by other financial incentives such as grants, subsidies, tax breaks and duty exemptions. For instance, Malaysia offers feed-in tariffs (FITs) for community level solar PV projects, with more attractive rates for smaller units to account for the higher costs per unit of production. There are also special bonuses for projects integrated with buildings and using locally manufactured/assembled solar PV modules (SEDA, 2019).

5.3. End-use sector interventions

Diversification of the energy industry of Bhutan requires a significant uptake of renewable energy in end-use sectors and an overarching improvement in energy efficiency. Heating and transportation are two major arenas with tremendous potential for the adoption of renewable energy within their end-use sectors. Increases in energy efficiency can help shape and decrease energy demand, thus facilitating renewable energy uptake.

Heating is a major source of energy consumption in Bhutan and efforts have been made to encourage the uptake of solar water heaters. Although heat-pumps[4] are popular in developed countries, they are still a new concept in Bhutan, and only recently have incentives such as tax exemptions been considered to promote them. Powered by the hydroelectricity-based grid, these heat pumps offer a viable opportunity for increasing the penetration of renewable energy in heating end-uses in Bhutan. Air- and ground-sourced heat pumps, both of which run on electricity, are both viable options for space heating in Bhutan (DRE–MOEA, 2018).

Hot water is often produced using inefficient electric immersion heaters or fossil fuel burning, which can contribute to inefficient consumption. Solar thermal water heaters offer a viable alternative. Renewable-powered solar water heating costs have declined rapidly and are expected to continue falling (IEA, 2016).

Electric mobility offers an ideal solution for integrating renewable energy in the transport sector – which is particularly important in a country like Bhutan, given that it imports petroleum products and has surplus renewable electricity generation. Bhutan has levied zero customs duty on the import of electric vehicles (EVs); however, their use remains limited.

This indicates that the integration of EVs in public and private transport fleets requires additional policy incentives. Globally, sales of EVs have been increasing rapidly in countries such as China and United States, which have ambitious plans for EV integration. After China and the US, the next largest markets are in Europe, with considerable growth in EV sales from 2012 to 2017 in Germany (CAGR of 75%), Norway (70%) and the UK (68%) (IRENA, 2019b).

The pursuit of renewable energy in Bhutan should also be accompanied by a systematic focus on energy efficiency and conservation in the energy sector, as well as in other sectors of the economy such as industry, building, transport and appliances.

[4] Heat pumps are an energy efficient form of heating, which are accepted as a renewable energy technology in some regions and jurisdictions such as the European Union Renewable Energy Directive, which recognises that heat pumps use renewable energy sources from the air, water and ground, subject to a minimum performance factor. Global energy statistics do not presently capture the renewable heat produced by heat pumps.

Improved energy efficiency and energy productivity can offer a host of benefits including decreased hydrocarbon imports, increased electricity exports, reduced spending on power generation, greater competitiveness of industrial firms, enhanced disposable incomes for residents and businesses, and reduced budgetary stress on government. This could also lead to environmental benefits such as reductions in air pollution and greenhouse gas emissions, and increased forest area and carbon sequestration (IRENA, 2015b).

Action 5: **Stimulate electric mobility for public and private transport**

Public procurement of EVs can help stimulate the roll-out of EVs in Bhutan by increasing their visibility in the public space, building charging infrastructure, and encouraging the emergence of related expertise and businesses. Public buses, government vehicles and taxi fleets are attractive early targets. Neighbouring countries are already implementing measures to accelerate the adoption of EVs in public fleets:

- In India, the central government provides up to 60% of the purchase cost of electric buses, which has encouraged public procurement of EVs in multiple cities, including those in hilly terrains such as Shimla and Dharamsala (Shah, 2018; UITP, 2018).

- In China, subsidised procurement and operation helped to bring the cost of electric buses closer to conventional buses. As a result, Shenzhen completely converted its city bus fleet of 16 000 buses to all-electric models by the end of 2017. Also, around 21 000 taxis had been electrified by 2019 (Dixon, 2018; Plautz, 2019).

- In Nepal, funding from ADB has enabled the inauguration of five electric buses in Kathmandu (Rai, 2018).

The penetration of EVs in private transport demands a broader set of policies, including financial incentives to facilitate the acquisition of EVs and cut their usage costs. In Norway, for instance, value-added tax and vehicle registration tax exemptions, free access to toll roads and circulation tax rebates were the most important drivers for EV ownership, according to a survey of EV owners (IEA, 2018).

In the United States, the federal government and several states offer financial incentives, including tax credits, to lower the up-front costs of EVs. The federal tax credit ranges from USD 2 500 to USD 7 500 per vehicle, depending upon its size and battery capacity (US DOE, n.d.).

The government could also prioritise the establishment of a robust charging network. While a lot of charging for EVs, taxis and buses takes place at private premises, publicly accessible charging locations can be a very attractive driver for accelerated uptake.

The European Union Alternative Fuels Infrastructure Directive suggests one publicly accessible charger for every ten electric cars, but this can change with each market. In Norway, the country with the highest share of EV sales, there is one charger for every 19 EVs, which is partly due to strong Norwegian consumer preference of home charging (IEA, 2018). Bhutan plans to unveil 23 charging stations for the initial roll out of 300 EVs (Lhamo 2018).

In the long term, EVs can offer an opportunity for fundamental transformation of the transport and power sectors and can help support greater grid penetration by renewable energies through technologies such as time-variable ‘smart charging’ and vehicle-to-grid electricity supply. The batteries of grid connected cars can potentially help regulate voltage and frequency, or supply electricity to meet spikes in demand. Investing in EVs and relevant infrastructure now can help develop local know-how and potentially provide the basis to ‘leap-frog’ towards a smarter, more flexible and efficient grid in the not-so-distant future.

Action 6: **Incentivise renewable applications for heating**

Financial and fiscal incentives can be important near-term options to support the switch to solar water heaters in buildings and the uptake of heat pumps for space heating. These incentives may include a range of grants, low-interest loans and tax incentives. Solar water heaters and heat pumps (HS Code 84.19 and HS Code 84.15) are currently subject to a duty of 20% and a sales tax of 5% in Bhutan (DRC–MOF 2017). The removal of these duties (and potentially the sales tax) could speed up their deployment.

Grants, subsidies and low interest loans can also help accelerate the adoption of heat pumps and solar water heaters, especially in the near term. For instance, Tunisia’s Prosol solar water heating programme includes an innovative financing model that offers capital grants combined with a value-added-tax exemption, reduction of customs duties and reduced interest loans paid back through electricity bills (IRENA, IEA and REN21, 2018). Subsidies and lower electricity tariffs, especially during the initial stages of technology introduction, will help to reduce the ownership costs of heat pumps.

Mandates for solar water heaters could also be a promising option for Bhutan. Several countries have mandated solar water heating in new buildings, often through building codes at either the national or local level. The first country to do this was Israel in the 1980s, which now has one of the highest levels of penetration of solar water heating in the world. Numerous Brazilian cities have also established solar mandates; in 2007, Sao Paulo mandated that, for new construction (residential and commercial), 40% of the energy to heat water had to come from solar (IRENA, IEA and REN21, 2018).

Action 7: **Promote energy efficiency in conjunction with renewables**

The shift towards renewable energy should be coupled with improved energy efficiency in all sectors of the economy including industry, buildings, transport and appliances. Energy efficiency and conservation measures can play a significant role in shaping and reducing energy consumption in these sectors, resulting in massive fuel and emissions savings.

Bhutan's "National energy efficiency and conservation policy" delineates a comprehensive set of energy efficiency and energy conservation measures for all sectors (DRE–MOEA, 2017). A concerted effort toward comprehensive implementation of these measures is an essential first step towards a sustainable energy system.

The building sector offers several opportunities for energy saving through improvements in appliance efficiency, building envelopes and equipment operation. Electrical appliance efficiency can be improved through measures such as minimum energy performance standards, green public procurement and fiscal incentives for efficient equipment. Better building insulation is necessary for the efficient operation of heat pumps. Single glazed windows with wooden frames are used in most buildings in Bhutan and lead to heat losses in the range of 20–25%. The use of double glazing with air gap sealing weather strips can help cut down such losses (DRE–MOEA, 2015). Renewable-based heating technologies in Bhutan remain in the initial stages of development.

At this stage, certification is important to promote public awareness and confidence. Equipment certification and labelling programmes are being used in several neighbouring countries (e.g. India and Thailand) for renewable heating equipment such as water heaters, and can form the basis for similar certifications in Bhutan.

Energy efficiency measures in the industrial sector can lead to significant fuel savings, often in a financially profitable manner. The implementation of the recommendation in the "National energy efficiency and conservation policy" will be key; the policy aims to introduce several measures including energy audits, industry-specific consumption targets, capacity building activities, and appropriate upgrades through retrofit, refurbishment or process modifications (DRE–MOEA, 2017).

Improved energy efficiency is a vital component of an integrated national energy strategy and supports the advancement of renewable energy. Reducing energy demand can make it easier to achieve a given target for a share of renewables. Shaping demand using measures such as peak shaving and demand response can support better integration of variable renewables into the grid. This is particularly important given the evening peak demand in the country (Figure 2), and the limited availability of solar energy at that time. Reforms to energy pricing can help level the playing field for renewable energy technologies, thus incentivising their uptake in both on-grid and off-grid settings. In the specific case of Bhutan, improving energy efficiency is a fundamental and cost-effective first step towards integration of renewables in all sectors. For example, biomass boilers become more cost-effective if heat demand is reduced through improvements in energy efficiency.

5.4. Capacity, skills and awareness

The successful adoption of renewable energy technologies in Bhutan requires the formulation and implementation of strategies for capacity building. There is a need to improve the technical and co-ordination capacities of the institutions concerned with energy, as well as broader public-sector institutions, with respect to renewable energy. Furthermore, the deployment capabilities of the private sector, which is the driving force for renewable energy industry growth globally, also remains limited in Bhutan. From the consumer's perspective, the high upfront costs of renewable energy and energy efficiency projects, together with a lack of awareness concerning payback periods, are hindering their deployment.

Action 8: **Enhance the capacity of government officials**

Capacity building initiatives should aim to strengthen capacities at all levels, including among policy makers, government officials, private sector actors and consumers. Government staff could receive on-the-job training and short courses on specific topics. For the DRE, the recommendations of the Training Needs Assessment Report 2016 could be implemented to ensure that the Department is sufficiently equipped to spearhead the implementation of renewable energy in the country.

In the medium term, the strengthening of existing units and establishment of new units specialising in renewable energy could increase efficiencies and reduce costs. Potential key units may include those focusing on planning, policy formulation and monitoring; bidding and procurement processes; research and development; socio-economic benefits and community impacts; and public awareness. Improved collaboration with relevant national and international institutions in the renewable energy sector – encompassing its applications across other important sectors such as agriculture, buildings, industry and tourism etc. – could help to close the capacity gap.

Bhutan's neighbouring countries, such as Bangladesh, China, India and Nepal, have extensive public-sector experience in renewable energy deployment. By leveraging their strengths and experience, Bhutan can improve its national institutional capacities.

Action 9: **Foster entrepreneurship through skills development and other interventions**

Local entrepreneurship in renewable energy can help reduce unemployment and increase incomes whilst ensuring that renewable energy projects are developed and maintained in a sustainable manner. Fostering local entrepreneurs demands a comprehensive approach that develops skills and strengthens local capabilities while ensuring demand for renewable-energy-related goods and services. This can be achieved through a tailored policy mix that entails close co-ordination between policies focusing on renewable energy deployment, education, trade, regional development, industry and labour.

Renewable energy entrepreneurs require a wide array of skills depending on the technology, maturity of the industry, project size and the segment of the value chain. In the initial stages, while Bhutan augments renewable energy capacity, installation and O&M skills and know-how could be most important. Local entrepreneurs with adequate skills can help to ensure the proper operation and maintenance of installed projects, while reducing faulty installations, cost overruns, project delays and performance issues – all of which can contribute to a negative public perception of renewable energy.

As the industry matures and some of the equipment manufacturing is localised, the demand for skills required for manufacturing may also increase. Potential strategies for developing a skilled workforce include the introduction of renewable energy courses in curricula, on-the-job training, workshops, internships and mentorships, and collaboration between industry and academia or with international public and private market players (IRENA, 2013; 2012).

Potential measures include: direct investments and soft loans for entrepreneurs; joint ventures; research collaborations; supplier development programmes; and development of business linkages aimed at fostering technology transfer and licensing (IRENA, 2014). For example, in Morocco, the Moussanada programme offers financial support for modernising SMEs and improving their competitiveness.

Action 10: **Increase public awareness through pilot projects in social sectors**

Public awareness is critical to inform the public discourse on the energy sector and renewable energy. With the industry still going through its initial stages in Bhutan, demonstration projects could have a tremendous outreach impact, helping to increase public knowledge concerning renewable energy technologies, especially when implemented in government buildings, schools or places of worship. The implementation of such projects in schools could be coupled with the introduction of renewable energy in curricula, which can have long-term impacts. These projects could potentially source their funds from international donors and partners.

In addition to raising awareness, pilot projects in social sectors have the additional benefit of ensuring staff retention and improving the quality of public services in rural areas. The use of renewable energy technologies could be considered in meeting the heating and electrification requirements of social infrastructure, especially in rural and remote locations. Heat pumps powered by solar PV, for example, could present a flexible option for pilot projects in hospitals and schools, as the electricity from PV can also be used for lighting.

Renewable energy technologies have been used to heat and power social sector facilities around the world. In the Indian state of Chhattisgarh, solar PV has been used to power over 900 health centres and district hospitals, resulting in a 50% increase in patient admissions, more successful births and better day to day operation (IRENA, 2019a). Any such initiative in Bhutan would require close co-operation between the relevant implementing agencies in several areas including planning, policy formulation, budgeting, procurement and implementation.

Pilot projects should be complemented by a broader national communication strategy aimed at raising public awareness, boosting understanding of renewable energy benefits and establishing their intrinsic link with Bhutan's legacy of environmental stewardship. As a result, these efforts could lead to citizens making more informed decisions regarding participation in renewable energy programmes. Government communication efforts should also highlight extant regulatory frameworks that could be beneficial for stakeholders.

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Annex: Dedicated renewable energy funds in other countries

Bangladesh: Infrastructure Development Company Limited (IDCOL)

IDCOL is a government-owned financial institution that supports the development of medium- to large-scale infrastructure and renewable energy projects in Bangladesh. The institution is funded and supported by a variety of organisations including the World Bank, ADB, JICA, SNV, KfW, GIZ, IDB, USAID, GPOBA, DFID and the government of Bangladesh. By investing around USD 700 million, IDCOL has leveraged an estimated USD 1.5 billion from end-users through upfront payments and loans.

The Solar Home Systems (SHS) initiative is a key program administered and financed by IDCOL. The institution is supported by the World Bank and the International Development Association (IDA) under the umbrella of the Rural Electrification and Renewable Energy Development Project (RERED). The cumulative funding from the World Bank and IDA in the project is estimated at USD 573 million. IDCOL provides grants and soft loans as well as technical assistance. Local partner organisations – usually microfinance institutions – work with local private vendors to select customers, extend loans, install systems, and provide after-sales services.

The SHS initiative has resulted in the installation of more than 4 million systems, resulting in savings of around USD 400 million in spending on kerosene. The initiative has had a positive impact on the local manufacturing industry. Initially, batteries were the only locally manufactured component. Gradually, all components, including solar panels, began to be produced locally. The SHS industry was a major contributor to the estimated 130 000 solar PV jobs in Bangladesh in 2018 (IRENA, 2018).

Thailand: Power Development Fund

Thailand's Power Development Fund was established to provide capital to: enhance extensive electrification; decentralise development in provincial areas; rehabilitate localities affected by faulty power plant operation; and promote the use of renewable energy and other environmentally friendly technologies. The fund is capitalised through a levy on fossil fuel generation with rates that vary according to the amount of emitted pollution and fuels used. The specific sources of funding include license fees, fines, donations and accumulated interest.

The Energy Regulatory Commission (ERC) manages policy making, regulation, operation, grant approval and fund allocation. The ERC is supported by several sub-committees focusing on operations, fund management, renewable energy, public relations and evaluation. Thailand uses similar mechanisms to support biofuels and energy efficiency projects. Thailand's national biofuels committees are supported by approximately USD 3 million in palm oil taxes. The country's Energy Conservation Promotion (ENCON) Fund is supported by a levy on petroleum products that raises about USD 50 million per year.

Nepal: Central Renewable Energy Fund (CREF)

The Central Renewable Energy Fund (CREF) of Nepal is contributing to the growth of renewable energy, especially in rural settings. It was designed to receive funding from multiple donors alongside the government of Nepal. The CREF is administered by the Global IME Bank (GIBL), with funds disbursed through seven partner banks (BOK, CEDB, CIVIL, NIBL, SBL, HBL & TDBL) selected through Nepal's Public Procurement Act and Rules.

The GIBL has already processed around 75 000 subsidy application forms valued at NPR 2 billion (USD 18 million) and partner banks have started releasing funds for projects including the Urban Solar Program. As of March 2016, NPR 8 million had been loaned at a 0% interest rate for the Urban Solar Programme through CREF (Bhushal, 2016; Winrock International, 2016).

Historically, investment in renewable energy systems has been funded through heavy subsidies. However, with the CREF, Nepal intends to move towards a loan-based approach to increase the financial sustainability of renewable energy deployment. Before the establishment of the CREF, the technical evaluation and funding of renewable energy projects used to be disbursed through the Alternative Energy Promotion Centre (AEPC). The establishment of CREF helped separate the technical and financial evaluation of projects, while increasing transparency and donor confidence.

The CREF is reported to receive funding from multiple donors as well as the government of Nepal. While the exact contributions are not known, indicative budget information shows that the government of Nepal contributes half of the funding (Table 2).

Table 2: Indicative budget for CREF, 2012–17

Budget Commitment	USD (million)
Danida (Denmark)	11.4
Norway	10.5
DFID (UK)	7.6
KfW (Germany)	2.9
SREP (World Bank)	20
Government of Nepal	63.9
Total	**116.3**

Source: AEPC, 2013.

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