ENABLING
AN ENERGY EFFICIENT
BUILT ENVIRONMENT IN BHUTAN

Enabling an Energy Efficient Built Environment in Bhutan

December 2018

Credits:

Citation: Bhutan Ecological Society (2018) Enabling an Energy Efficient Built Environment in Bhutan. Thimphu: Bhutan.

ISBN: 978-99980-847-0-4

The "Enabling an Energy Efficient Built Environment in Bhutan" report was compiled by the Bhutan Ecological Society with support from the Bhutan Foundation and the Karuna Foundation. Consultation services for the preparation of a preliminary draft were provided by Thinley Choden and Associates. We are grateful to Dr. Kuenga Wangmo for editing this report.

BHUTAN ECOLOGICAL SOCIETY

Bhutan FOUNDATION

KARUNA FOUNDATION

TABLE OF CONTENTS:

Executive Summary **1**

1. Introduction **5**

2. Energy & The Built Environment **12**

2.1 The Building Sector & Energy Consumption 12
2.2 Winter Energy Demand & Imports 16

3. Traditional Houses, Modern Constructions & Energy Efficiency **17**

3.1 Traditional Houses & Energy Efficiency 17
3.2 Modern Constructions & Energy Efficiency 22

4. The Building Sector Ecosystem **26**

4.1 Policy Frameworks 26
4.2 The Role of the Government 30
4.3 Financial & Fiscal Ecosystem 31
4.4 Labour 31
4.5 Supply Chain Ecosystem 31
4.6 Capacity 34
4.7 Motivation & Incentives 35
4.8 On-going Initiatives towards Energy Efficiency 35

5. Envisioning an Energy Efficient Built Environment **38**

5.1 Kickstart A Sustainable Building Initiative 38
5.2 Target Mega Buildings & New Townships 40
5.3 Build Capacity, Networks and Knowledge Sharing 41
5.4 Support Innovation and Technology Enhancement throughout the Supply Chain 42
5.5 Establish an Energy Endowment 43

6. Looking into the Future **44**

Sources and References **45**

Acronyms:

BLSS	:	Bhutan Living Standards Survey
BPC	:	Bhutan Power Corporation
BSB	:	Bhutan Standards Bureau
CAGR	:	Compound Annual Growth Rate
CDB	:	Construction Development Board
CGI	:	Corrugated Galvanized Iron Sheets
DES	:	Department of Engineering Services
DoFPS	:	Department of Forests and Park Services
DRE	:	Department of Renewable Energy
EE&C	:	Energy Efficiency & Conservation
EPS	:	Expanded Polystyrene
GHG	:	Greenhouse Gas
GNHC	:	Gross National Happiness Commission
kWh	:	Kilowatt hour
LDC	:	Least Developed Country
LPG	:	Liquid Petroleum Gas
Masl	:	Meters above sea level
MoF	:	Ministry of Finance
MoWHS	:	Ministry of Works & Human Settlement
NEC	:	National Environment Commission
NEECP	:	National Energy Efficiency & Conservation Policy
NHDCL	:	National Housing Development Corporation Limited
RCC	:	Reinforced Cement Concrete
RGoB	:	Royal Government of Bhutan
RMA	:	Royal Monetary Authority
tCO2e	:	Tonnes of carbon dioxide equivalent
TOE	:	Ton of oil equivalent
TTI	:	Technical Training Institutes

List of Figures, Tables & Plates:

Figure 1 : Revenue generated from 2008 to 2016, from five operational plants
Figure 2 : GDP contribution and growth rate of the hydropower and construction sector
Figure 3 : New constructions average over 150 buildings annually and a total of over 1000 constructions have been approved since 2011
Figure 4 : Number of applicants for subsidized timber to construct houses in rural areas of Wangdue, Thimphu, Punakha, Paro and Haa
Figure 5 : % monthly income spent on electricity as a function of monthly income
Figure 6 : Electrification rate increased from 36% to 99.5% within the last decade and half (2005 – 2016)
Figure 7 : Monthly domestic electricity consumption (2010 – 2016)
Figure 8 : Monthly electricity demand for buildings, industrial use and agriculture (July 2016 – June 2017)
Figure 9 : Monthly kerosene consumption for Thimphu, Paro, Haa, Wangdue, Punakha and Gasa (July 2016 till June 2017)
Figure 10 : Month wise electricity generation from Tala, Chukha and Basochu hydropower plants in 2016
Figure 11 : Annual electricity imports (in MU) and expenditure (Nu in millions)
Figure 12 : Schematic highlighting key roles of important actors within the building sector

Table 1 : Hydropower plants currently under construction
Table 2 : Electricity tariffs: Bhutan, India and China
Table 3 : Total energy consumption by major sectors in 2014

Plate 1 : Babesa area of Thimphu in the early 1990s and at present
Plate 2 : A traditional house in Paro, Bhutan
Plate 3 : An almost complete 6-storey residential complex in Kawajangsa, Thimphu

Executive Summary

Over the last two decades, the construction sector in Bhutan, along with the hydropower sector, has witnessed exponential growth. As of 2017, the construction sector employed over 3,866 contractors, generated 15.87% of Bhutan's GDP, and employed 3.2% of the labour force. Thimphu has trebled in size from only about 8 km^2 in 2002 to almost 26 km^2 at present, and over a thousand new buildings have been approved for construction since 2011. By 2018, Thimphu had an estimated total of 5295 houses. Similar growth in the number of buildings is also noted in rural areas; over 3500 applications were filed for subsidized timber allocation for new constructions in the five western Dzongkhags of Wangdue, Punakha, Thimphu, Paro and Haa between 2013 and 2017.

The building sector alone in Bhutan accounted for almost 42% of domestic electricity consumption in 2014. However, similar to the rest of the world, adoption rates of energy efficiency measures are not keeping pace with the growing number of buildings and floor size. Globally, buildings and construction together consume close to 36% of all energy use and generate nearly 39% of all energy related GHG emissions.

Modern constructions in Bhutan continue to be ill suited for the local environment. The lack of relevant smart designs, construction methods,

and materials has created a current building stock with sub-standard indoor quality of life, as homes are uncomfortably cold during winter months, particularly at higher elevations. Such poor quality homes drive up energy consumption, leading to significant economic, environmental, and social costs.

As per Bhutan's draft *National Energy Efficiency & Conservation Policy*, implementation of energy efficient measures can realize annual savings of up to Nu. 621 million (300 million kWh). Such measures, according to the draft *Energy Efficiency Roadmap* of 2018, will also save energy consumption to the tune of 0.4 million TOE and reduce GHG emissions of up to 2.3 Million tCO2e over the next 15 years.

Bhutan already has a number of policies which lay out the aspirations for improving energy efficiency within the built environment. These policies will need to be backed by institutional frameworks that allow for the execution and implementation of relevant policy tools, supported by a suite of financing options, and appropriate rules and regulations.

Effecting positive changes within the building sector remains challenging due to the involvement of many stakeholders. To achieve a future where a majority of buildings, towns, and cities in Bhutan are energy efficient, we propose to:

- **Kickstart A Sustainable Building Initiative**:

  The initiative will conduct research, keep track of progress, bring together stakeholders on a regular basis to discuss issues, serve as a center for innovation and advocacy, and build capacity to help bring focus and achieve synergies across different efforts.

- **Target Mega Buildings & New Townships**:

  Public buildings, such as the Jigme Dorji Wangchuck National Referral Hospital, consume significant amounts of energy. Targeting public buildings and retrofitting them will help reduce energy consumption and energy related expenses. An energy audit, followed by retrofitting plan, should be carried out on all major public buildings. Institutions such as the *National Housing Development Corporation Limited* and Government Ministries must be engaged and encouraged to consider green design elements in all their constructions. Bumthang and Haa towns, both located at high altitudes, are slated to be developed within the next few years. Providing information on green designs, insulation materials, and techniques will contribute significantly to achieving energy efficiency in these upcoming towns.

- **Build Capacity, Networks, and Knowledge Sharing**:

  Capacity, networks, and knowledge sharing mechanisms should be developed at four levels: 1) appreciation for energy efficient designs by policy and decision makers; 2) capability and skills to design energy efficient structures; 3) capability to supply and source energy efficient materials; and 4) capability to build such structures.

- **Support Innovation and Technology Enhancement throughout the Supply Chain**:

  A critical bottleneck to achieving energy efficient buildings is the lack of proper construction and insulation materials. To overcome this, information on sound and up-to-date construction and insulation technologies, best practices, materials, and suppliers should be provided through a dedicated web-based portal and a regular publication. To help upgrade technology and sustain businesses, manufacturers should be connected to potential investors and markets.

- **Establish an Energy Endowment**:

  Over the next 5 to 10 years, the Sustainable Building Initiative should work to establish an energy endowment to support fiscal incentives and provision of low interest loans for energy efficient constructions. It should also provide capital or grants for supporting innovative and entrepreneurial ideas which conventional financial institutions may perceive as risky.

  Aspirations within extant policy documents should be invoked to help initiate action and bring about positive transformation. Opportunities which exist to construct energy efficient buildings and towns should be tapped and emphasis should also be placed on sustained capacity building. This will help nurture a generation of energy conscious architects and builders, whose influence and contributions could spread well beyond Bhutan into the wider Himalayan region.

CHAPTER 1

Introduction

Bhutan has witnessed tremendous economic growth over the last two decades and is set to graduate out of the Least Developed Country bracket into the Mid-Level Income Country bracket by 2023[1], a little over half a century since it joined the UN in 1970. The rapid growth in the hydropower and construction sectors has contributed to this trajectory. Bhutan's economic model has been and is still guided by a deep appreciation for securing ecological balance and socio-cultural harmony, in what is now commonly and widely expressed as the development philosophy of Gross National Happiness (GNH).

The Bhutanese also continue to accord great importance to environmental conservation and sustainable development. Today, Bhutan has over 70% of its total land area under forested watersheds. This helps sustain the hydro-energy sector, which remains Bhutan's biggest revenue generator, contributing over 25% of the country's annual revenues (Figure 1).

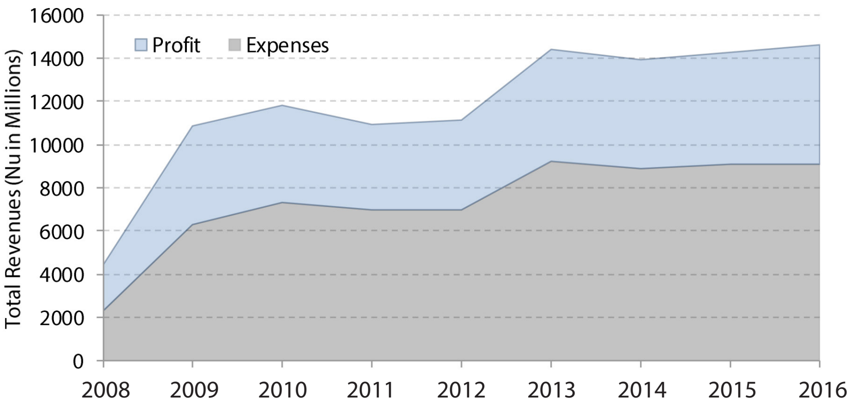

Figure 1: Revenue generated from 2008 to 2016, from five operational plants

The hydropower sector is poised to further grow (Table 1) and remains crucial to ensuring and sustaining Bhutan's economic growth.

Table 1: Hydropower plants currently under construction

Hydropower Plant	Capacity (MW)	Expected Completion Date
Punatsangchu I	1200	2019
Punatsangchu II	1020	2018
Mangdechu	720	2018
Nikachu	118	2019
Kholongchu	600	2022
TOTAL	**3658**	

Over the last two decades, along with the hydropower sector, the construction sector has also witnessed exponential growth (Figure 2). Construction activities employ over 3,866 contractors, make up 15.87% of Bhutan's GDP, and employ 3.2% of the labour force as of 2017[2].

Rapid economic growth, estimated at 7.5% for 2017, has led to Bhutan being ranked as one of the fastest growing economies in South-east Asia. Corresponding with this economic growth, urban centers such as Thimphu and Paro have also witnessed significant expansion in the last 2 decades. Thimphu in particular has almost trebled in size (Plate 1) from only about 8 km^2 in 2002 to almost 26 km^2 at present and over a thousand new building plans have been approved for construction since 2011 (Figure 3). As of 2018, Thimphu has an estimated total of 5295 houses. Similar growth in the number of buildings

> **Thimphu has almost trebled in size from only about 8 km^2 in 2002 to almost 26 km^2 at present and over a thousand new buildings have been approved for construction since 2011. As of 2018, Thimphu has an estimated total of about 5295 houses.**

[1] http://www.kuenselonline.com/bhutan-proposes-to-graduate-from-ldc-in-2023/

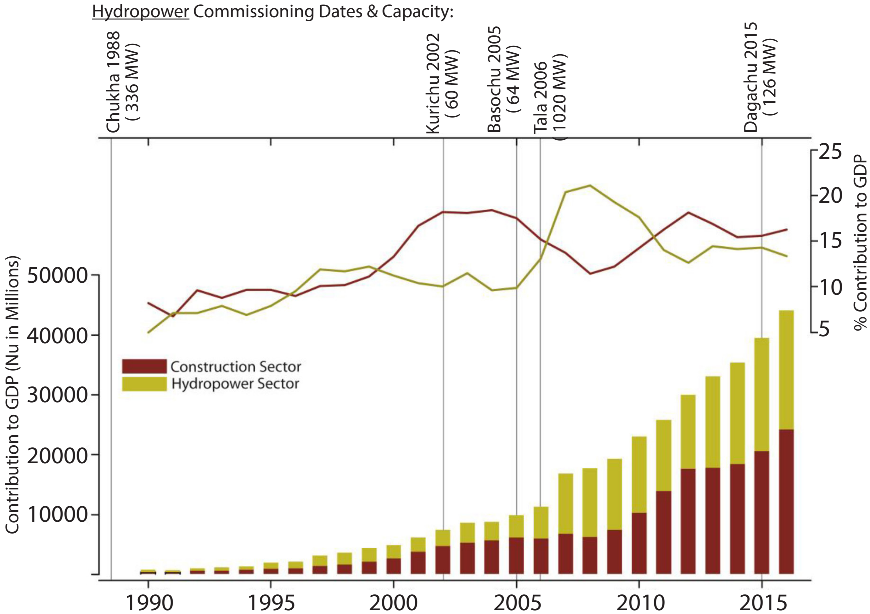

Figure 2: GDP contribution and growth rate of the hydropower and construction sectors. After the commissioning of Kurichu, Basochu, and Tala, the contribution to GDP from both the hydropower and construction sectors has grown exponentially.

are also noted in rural areas; with over 3500 applications for the allocation of subsidized timber for new constructions filed in the five western dzongkhags of Wangdue, Punakha, Thimphu, Paro, and Haa[5] from 2013 to 2017 (Figure 4).

The growing building sector in Bhutan accounted for almost 42% of domestic electricity consumption in 2014[6]. However, much like the rest of the world, adoption rates of energy efficiency measures are not keeping pace with the growing number of buildings and floor size.

---

[2] Statistical Yearbook of Bhutan 2018 (http://www.nsb.gov.bt/publication/files/SYB_2018.pdf)
[3] https://www.adb.org/countries/bhutan/economy
[4] https://www.reuters.com/article/us-climatechange-asia-cities/from-bangkok-to-bhutan-growing-cities-race-to-outrun-disasters-idUSKBN0LG1P020150212

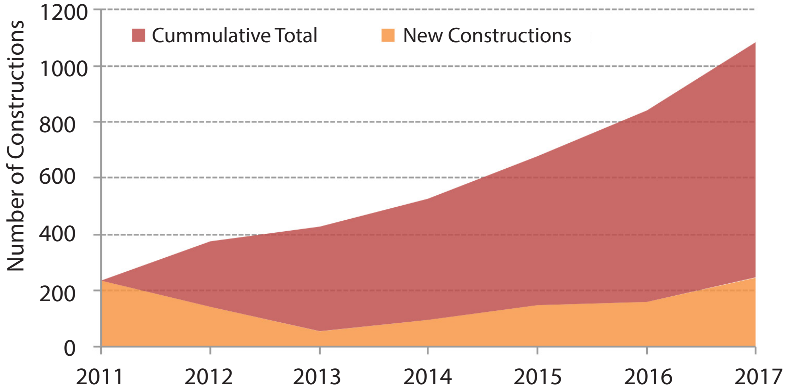

Figure 3: New constructions average over 150 buildings annually and a total of over 1000 constructions have been approved since 2011

Globally, buildings and construction together consume close to 36% of all energy use and generate almost 39% of all energy related greenhouse gas emissions.

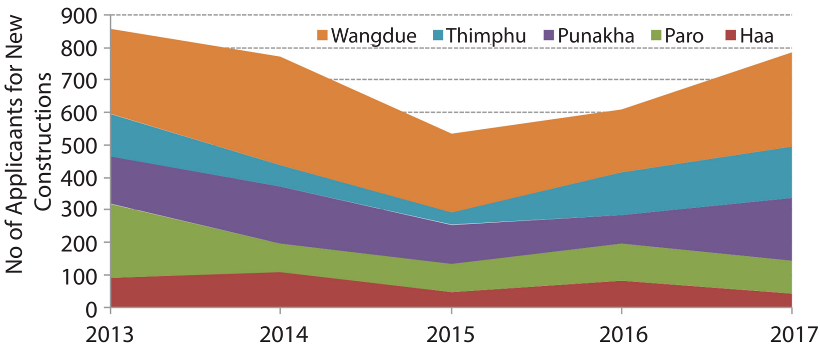

Figure 4: Number of applicants for subsidized timber to construct houses in rural areas of Wangdue, Thimphu, Punakha, Paro, and Haa

---

[4] Data for other dzongkhags could not be obtained at the time of compiling this report
[5] Bhutan Energy Data Directory 2015 (accessed from http://www.moea.gov.bt/wp-content/uploads/2018/07/Bhutan-Energy-Data-Directory-2015.pdf on 11.10.2018)
[6] Abergel, T., Dean, B., & Dulac, J. (2017). Towards a zero-emission, efficient, and resilient buildings and construction sector: Global Status Report 2017. UN Environment and International Energy Agency.

Modern constructions in Bhutan continue to be ill-suited for the local environment, with designs, technologies, and capabilities mostly imported from neighboring India. The lack of relevant smart designs, construction methods, and materials has created a current building stock (institutions, commercial, and homes) with sub-standard indoor quality of life, as homes are uncomfortably cold during winter months, particularly at higher elevations. Such poor quality homes drive up energy consumption and entail significant economic, environmental, and social costs (Figure 5).

Bhutan's draft National Energy Efficiency & Conservation Policy recognizes the need to promote energy efficiency and estimates that annual savings of up to Nu. 621 million (300 million kWh) can be realized from the implementation of energy efficient measures[9]. The draft *Energy Efficiency Roadmap*[10] of 2018 also contends that implementation of energy saving and conservation measures within the building sector will cumulatively save upto 0.4 million TOE and reduce GHG emissions to the tune of 2.3 million tCO2e over the next 15 years. Global carbon emissions continue to peak[11], and any effort to minimize and conserve energy use will help offset this rise.

> **Globally, buildings and construction together consume about 36% of all energy use and generate almost 39% of all energy related greenhouse gas emissions. The growing building sector in Bhutan accounted for almost 42% of domestic electricity consumption in 2014. Similar to the rest of the world, adoption rates of energy efficiency measures are not keeping pace with growth in the number of buildings and floor size.**

Building on previous efforts, this Report first notes that significant amounts of energy are consumed by the buildings sector. Second, the Report assesses traditional houses and modern buildings, and outlines challenges and issues faced by modern constructions. We next provide brief reviews of the policy, labour, financial, and material supply chain ecosystem for the building sector, with the aim to identify gaps and opportunities. We end by proposing 5 key recommendations to kickstart, catalyze, and scale up energy efficiency initiatives within the building sector.

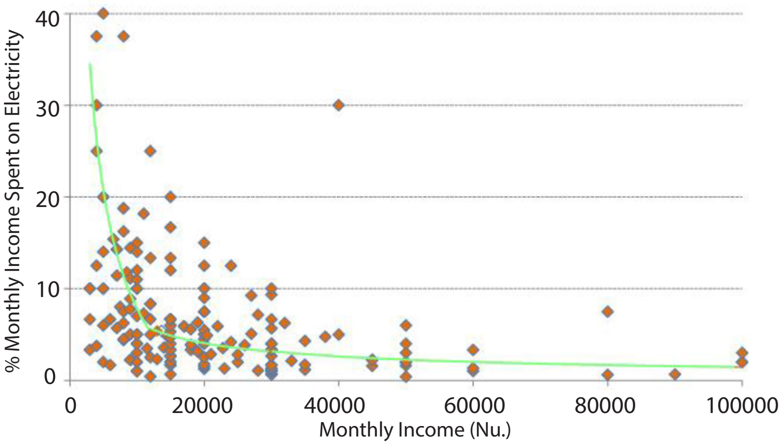

Figure 5: % monthly income spent on electricity during winter months (November to March) as a function of monthly income. Households, especially lower income households spend a substantive portion of their income to pay for electricity bills[8].

---

[8] This data is computed from 230 households surveyed from across Thimphu in early 2018
[9] https://www.gnhc.gov.bt/en/wp-content/uploads/2017/05/EEC-Final-Draft-Policy-2017- Final-1.pdf
[10] https://www.moea.gov.bt/wp-content/uploads/2018/07/EE-Roadmap-Draft.pdf
[11] https://www.unenvironment.org/resources/emissions-gap-report-2018

Plate 1: Babesa area of Thimphu in the early 1990s (top[12]) and at present (below)

[12] B&F Shaw Collection (1990) - http://www.bhutanstudies.org.bt/BhutanImage_Archive/

CHAPTER 2

Energy and The Built Environment

2.1 The Building Sector & Energy Consumption

With rapid economic development and growth in the construction sector, increase in the number of manufacturing and processing industries and completion of rural electrification plans, consumption of electricity has risen significantly. At the end of 2015, the Bhutan Power Corporation (BPC) managed to electrify an additional 45,408 rural homes taking electrification coverage to 99.95% (Figure 4). As of 2017, BPC has a total customer base of 184,227[13] .

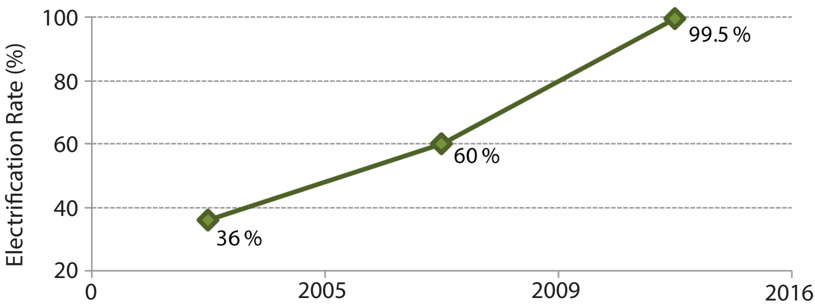

Figure 6: Electrification rate increased from 36% to 99.5% within the last decade and half (2005 – 2016)[14]

Table 3: Total energy consumption by major sectors in 2014

Sector	Total Energy Consumption (%)
Building	41.58
Industry	37.21
Transport	18.64
Agriculture	2.56

The building sector consumes more than a third of total energy consumed in Bhutan (estimated at 41.58% for 2014[15], Table 3).

Electricity consumption has increased at 10.1% CAGR for residential buildings between 2005 – 2014, while biomass and kerosene consumption has decreased by 1% and 6.9% respectively. During the same period, electricity consumption increased by 8.4% CAGR and biomass consumption increased by 5.5% CAGR for commercial and institutional buildings respectively.

In general, demand for electricity has grown due of increase in the number of consumers getting connected to the grid (Figure 6 and 7). Electricity consumption peaks during winter months (November – April) (Figure 7) and this peak can be attributed to increasing usage of electrical heating appliances.

[13] http://www.bpc.bt/wp-content/uploads/2017/05/Annual-Report-2016.pdf
[14] https://norad.no/en/toolspublications/publications/2017/norwegian-energy-cooperation-with-bhutan/
[15] Bhutan Energy Data Directory 2015 (accessed from http://www.moea.gov.bt/wp-content/uploads/2018/07/ Bhutan-Energy-Data-Directory-2015.pdf on 11.10.2018)

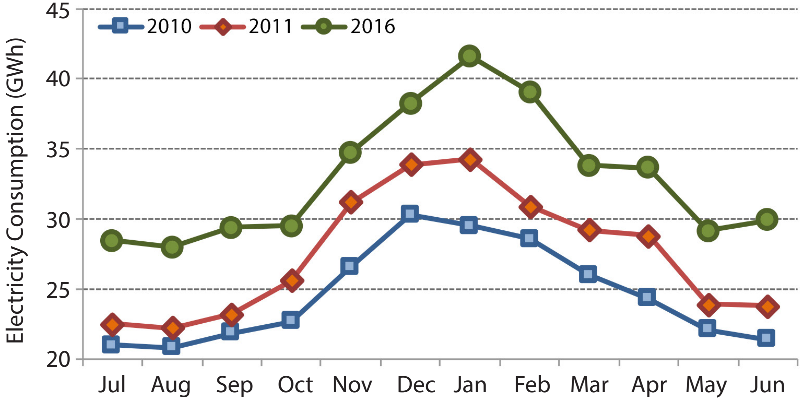

Figure 7: Monthly domestic electricity consumption (2010, 2011 & 2016). Electricity consumption has been rising over the years and consumption continues to spike during winter months starting from October and lasting till about April.

This rise in demand during winter months is primarily driven up by increase in energy usage from buildings (Figure 8). Industrial and agricultural energy demand, for Low Voltage lines, remains constant throughout the year.

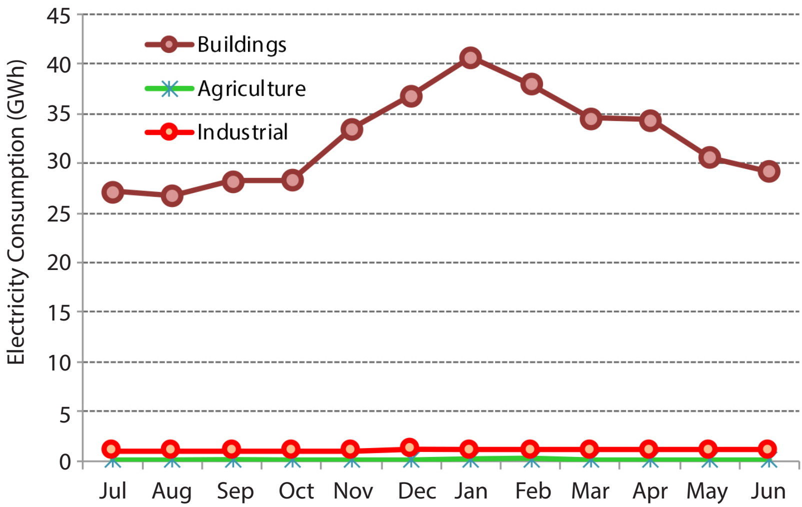

Figure 8: Monthly electricity demand for buildings, industrial use and agriculture (July 2016 – June 2017)

Furthermore, imports in kerosene also see a substantive rise during winter months to cater to heating requirements (Figure 9).

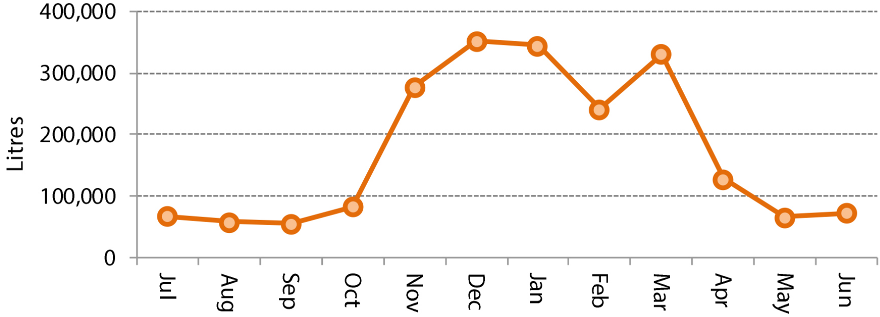

Figure 9: Monthly kerosene consumption for Thimphu, Paro, Haa, Wangdue, Punakha and Gasa (July 2016 till June 2017)

In addition to kerosene, fuelwood also supplements heating of residences and institutions. In 2016 alone, a total of over 150,000m^3 of fuelwood was consumed[16] .

[16] Forestry Facts & Figures 2016 (DoFPS)

2.2 Winter Energy Demand & Imports

While demand is highest during winter months, mainly due to increased consumption by the building sector, power generation slumps over the same period (Figure 10).

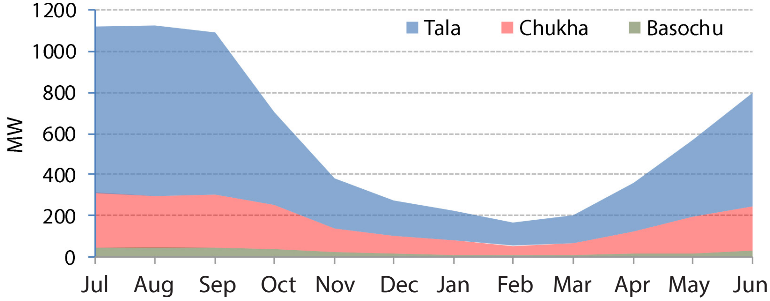

Figure 10: Month wise electricity generation from Tala, Chukha and Basochu hydropower plants in 2016. Power generation is lowest during winter months (November to April) when domestic demand is the highest.

Although Bhutan does not have a net deficit in electricity generation, imports continue to grow annually (Figure 11). As such, any initiative aimed at increasing energy efficiency within the building sector will result in significant cost savings, especially during winter months.

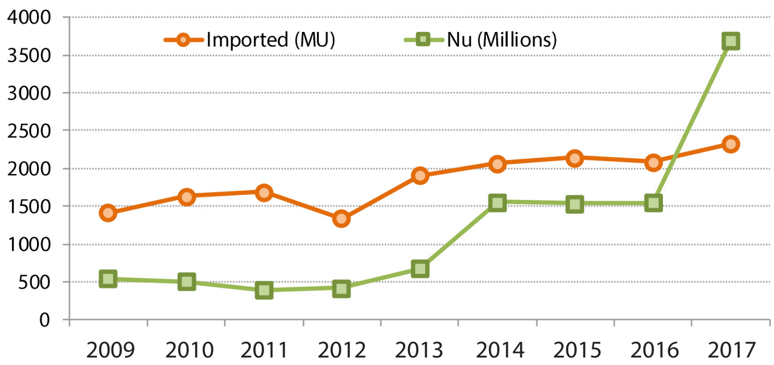

Figure 11: Annual electricity imports (in MU) and expenditure (Nu in millions)[17]

[17] Adapted from data obtained from BPC

CHAPTER 3

Traditional Houses, Modern Constructions and Energy Efficiency

3.1 Traditional Houses & Energy Efficiency

Traditional architecture in Bhutan has evolved over centuries to adapt to local environment, climate, available materials, and technology. Traditional Bhutanese architecture mainly consists of rammed earth walls, stone masonry, and intricate woodwork around windows and roofs built with locally available materials[18].

The box-shape of the houses provided a smaller surface area to volume ratio, resulting in lesser area of the building envelope being exposed to the cold climatic conditions and, therefore, allowing a lower amount of heat loss. Traditional Bhutanese buildings also demonstrate

Plate 2: A traditional house in Paro, Bhutan. Note the boundary wall and also the wall of the house which is made of rammed earth. All windows are wooden and the roof which would have been of wooden shingles has been replaced by corrugated galvanized iron (CGI) sheets.

[18] http://www.mowhs.gov.bt/wp-content/uploads/2010/11/Bhutan-Arch-Guidelines-final-2014.pdf

contemporary sustainability principles in their use of orientation to reduce heat loss and maximize passive solar gain. In many Bhutanese villages, houses and trees are often arranged to provide maximum wind shelter. Wind sheltering is deployed in the form of a boundary-type wall which helps create 'outdoor hot-zones', both between buildings in a cluster, and also around the building (Plate 2).

Individual buildings mostly follow a generic layout with a wall of rammed mud that runs along the back. This wall generally faces the north allowing maximum light to enter through south facing windows. Rammed earth is used on all four sides of all storeys, except the top floor, where the front wall and half of each side wall consist of a timber frame structure with a fill in of plastered bamboo weaving, known as 'ekra wall' in Bhutan. This type of walling enables greater structural freedom and allows for large south facing windows, a key element of passive solar design in climates where demand for winter heating exceeds that for summer cooling.

[17] http://www.mowhs.gov.bt/wp-content/uploads/2010/11/Bhutan-Arch-Guidelines- final-2014.pdf

The 2013 Green Building Guidelines of the MoWHS[19] advocate and encourage the use of rammed earth for the following reasons:

- Rammed earth does not require a lot of energy to process and apply
- Modern rammed earth, stabilized with rebar and a small percentage of cement, should easily last hundreds of years, eliminating the stream of waste as houses need repair and replacement
- Stabilized rammed earth is fire resistant, and if built correctly can withstand hurricanes, floods, and earthquakes
- Rammed earth buildings have low carbon emissions and are non-toxic
- The thick thermal mass of the walls absorb solar energy from south facing windows and will retain heat if properly insulated during winter

"Buildings using traditional materials and construction methods were found to be the worst performing buildings in terms of air tightness and thereby thermal performance. Joints between elements of the timber structure such as joists, floor boards, window casements, window frames, lintels with decorative elements and timber-frame members were identified as major causes for air leaks"

[18] http://www.mowhs.gov.bt/wp-content/uploads/2014/05/Bhutan-GREEN-Building-Design-Guidelines-PDF-for-website-FI.pdf

[19] As per consultations with officials from the Bank of Bhutan

[20] Jentsch, M.F., Kulle, C., Bode, T., Pauer, T., Osburg, A., Namgyel, K., Euthra, K., Dukjey, J. and Tenzin, K., 2017. Field study of the building physics properties of common building types in the Inner Himalayan valleys of Bhutan. Energy for Sustainable Development, 38, pp.48-66.

Despite these positive features, there has been a decline in the construction of homes and buildings using traditional methods. This is due to the lack of proper knowledge and guidance coupled with the Bhutanese's aspirational ideal for modern constructions which lean towards RCC buildings.

Additionally, banks do not extend construction loans to traditional buildings because they are considered semi-permanent structures[20]. Structural and engineering permits/codes also do not allow for traditional buildings to be constructed above 2 to 3 floors as it is not considered earthquake safe.

---

[19] http://www.mowhs.gov.bt/wp-content/uploads/2014/05/Bhutan-GREEN-Building-Design-Guidelines-PDF-for-website-FI.pdf

[20] As per consultations with officials from the Bank of Bhutan

[21] Jentsch, M.F., Kulle, C., Bode, T., Pauer, T., Osburg, A., Namgyel, K., Euthra, K., Dukjey, J. and Tenzin, K., 2017. Field study of the building physics properties of common building types in the Inner Himalayan valleys of Bhutan. Energy for Sustainable Development, 38, pp.48-66.

[22] (Bhutan Building Regulations of 2002) https://bhutan.eregulations.org/media/bhutan_building_rules_2002.pdf

On the negatives, buildings using traditional materials and construction methods were found to be the worst performing buildings in terms of air tightness and thermal performance[21]. Joints between elements of the timber structure such as joists, floor boards, window casements, window frames, lintels with decorative elements, and timber-frame members were identified as major causes for air leaks.

Plate 3: An almost complete 6-storey residential complex in Kawajangsa, Thimphu. The ground floor will be rented out as commercial space. The structure is RCC with brick walls and window frames are wood.

3.2 Modern Constructions & Energy Efficiency

Modern buildings and structures are dominantly reinforced concrete cement (RCC) construction with steel frame and bricks (Plate 3). This has come to be the standard across Bhutan. With earthquake resiliency as the highest priority, structural soundness is the key element considered in building designs, in addition to maintaining traditional aesthetics of the buildings[22] . The outcome is the current building stock where structures are designed to be earthquake resilient, but almost every building is energy inefficient.

> **Average energy loss of a building in Bhutan is estimated to be around 97 kWh per annum.**

The building sector is comprised of 3 categories: residential, commercial, and institutional. Residential buildings include self-owned bungalows/homes, apartments, and public housings, while commercial buildings include private offices, shops, hotels, restaurants, factories, and industrial structures. Institutional buildings include Government offices, schools, hospitals, and other public structures. As of 2016, almost 69.5% of all structures in urban areas and 21.4% in rural areas are made of bricks and concrete[23] .

Heat losses from modern buildings are significant, with loss of heat through walls being the highest at about 40 to 70%. In terms of U-values, a measure for thermal

[23] Bhutan Living Standards Survey 2017 (http://www.nsb.gov.bt/publication/files/pub2yo10667rb.pdf)

transmittance, the most common contemporary wall construction type with brick infill walls was found to perform the worst at 1.25 to 1.45 W/m^2 K, compared to traditional rammed earth walls at 1.1 to 1.2 W/m^2 K. Cement stabilized earth block construction technique derived from the traditional rammed earth walls had U-values at 1.05 to 1.25 W/m^2 K. Average energy loss of a building in Bhutan is estimated to be around 97 kWh per annum.

Loss of heat due to air infiltration through windows, roofs, and doors accounts for 20 to 25% of total loss. In most buildings in Bhutan, single glazed windows with wooden frames are used. All 230 residential flats surveyed in Thimphu had gaps between the internal and the external environment, allowing for significant air infiltration through gaps between doors and windows. Air infiltration loss was high largely due to the usage of non-seasoned wood for windows and doors. Typical air leaks in all buildings were found to be joints between materials, timber structure joints, and the joints of windows and doors made with wooden frames.

Households spend a considerable portion of their income, about 8% on average, to meet electrical and heating bills. Lower income households in particular spend a significantly higher portion of their income on electricity (Figure 5).

Buildings in Bhutan were classified as leaky[20] and basic measures recommended to improve air tightness included improving window designs using side hung casements with one rabbet each in the casement and the frame. Caulking of gaps between window frames and use of wood with moisture content below 15% were also suggested.

> **"Heat losses from modern buildings are significant, with loss of heat through walls being the highest at about 40 to 70%. Buildings in Bhutan are classified as leaky and basic measures to improve air tightness include improving window designs using side hung casements with one rabbet each in the casement and the frame. Caulking of gaps between window frames and usage of wood with moisture content below 15% were also suggested."**

CHAPTER 4

The Building Sector Ecosystem

"Despite the use of reinforced concrete, the manner in which houses are built is utterly pre-industrial. Power tools are few, and timber is typically dressed and joined with hand tools. Rebar is cut, bent, wired together, and raised manually. Limited manufactured products such as insulated windows, appliances, and electrical components can be sourced, but must be trucked over the southern mountains from India" (**Marcus Gleysteen Architects, http://mgaarchitects.com/blog/bhutan**)

Many actors have stakes in the built environment (Figure 9). The interests of private builders, companies, and state owned business entities are high. Engineers, builders, and masons also play an important role, as do contractors, private home builders, and various actors along the supply chain.

Constructions also impact Government appropriations, where past estimates reveal that almost 60% of the total annual budget outlays are allocated for procurement, of which 80% accounts for procurements related to construction works. There is also a huge outflow of money through payments for labour, specialized professional services, and procurement of materials. The Royal Monetary Authority of Bhutan remits about 7 Billion Indian Rupees as payments for foreign workers and 5.76 Billion for the construction industry alone.

Despite significant expenses, innovation to make Bhutanese constructions more energy efficient has been lacking. Currently there are no approved rules regulating the energy efficiency sector. The Bhutan Energy Efficiency Codes are being framed and the Green Building Design Guidelines (2013) are in place, but these are not mandatory for implementation, and there are no compliance monitoring frameworks in place.

In general, there is a reluctance to adopt and invest in energy efficient structures due to substantive initial investments. Most materials and appliances have to be imported from abroad with high transportation costs.

Bhutan does have a number of policies which lay out the aspirations for improving energy efficiency within the built environment. Some policies are already in place, some are awaiting approval by the Government, while a few others are being conceived and tabled. These policies, however, will need to be backed by institutional frameworks, which allow for the execution and implementation of the policies, supported by a suite of financing options. Appreciation for energy efficiency will have to be built and capacity enhanced to deliver on designs and actual constructions. Supply chains will have to be created and facilitated to allow for technology to be made economically attractive and scalable.

4.1 Policy Frameworks

4.1.1 National Energy Efficiency & Conservation Policy

As of June 2018, The *National Energy Efficiency and Conservation Policy*[24] is awaiting approval of the Government.

The Policy highlights the benefits of enhancing EE&C measures which includes significant reduction in GHG emissions with positive implications for poverty alleviation. Direct benefits to the economy such as additional revenues being generated through the export of saved electricity and reduced imports of petroleum products are also mentioned. The policy document estimates potential annual savings of about 621 million ngultrums (about USD 9 million) as a result of EE&C related interventions.

The Policy identifies the *Department of Renewable Energy* (DRE) as the Nodal Agency for implementation of the Policy. The Thromdes in collaboration with the Department of Engineering Services (DES) of the MoWHS and other relevant agencies are tasked with the implementation of the Policy as well as enforcement of the Energy Efficiency Building Codes which are being developed for both new building constructions and retrofits in existing buildings. It foresees the Department of Human Settlement (DoHS) within the MoWHS to exercise provisions under it to promote green urban planning. Private sector engagement is reflected through the mention of the Bhutan Chamber of Commerce and Industries (BCCI) and the Association of Bhutanese Industries (ABI) to promote and implement EE&C measures in the industry sector.

"The Bhutan Energy Efficiency Codes are being framed and the Green Building Design Guidelines (2013) are in place, but these are not mandatory for implementation, and there are no compliance monitoring frameworks in place."

The Policy further requires the MoWHS to make energy efficient materials easily available and promote the development of local value chains for manufacturing energy efficient building materials.

It requires the Gross National Happiness Commission, in coordination with the Ministry of Finance (MoF) and relevant agencies, to source funding from international development partners to support EE&C programs. All relevant information related to EE&C measures are to be compiled by the National Environment Commission (NEC) in collaboration with DRE to prepare the Country's position on climate change mitigation efforts and facilitate flow of climate finance through National Appropriate Mitigation Actions (NAMAs), Intended Nationally Determined Contributions (INDCs), and emerging international mechanisms.

The Policy tasks the Ministry of Finance (MoF) with designing fiscal and financial instruments, including sector-specific incentives and penalties to catalyze the adoption of energy efficient practices. It further requires the MoF to provide tax rebates for manufacture and/or import of energy efficient building materials as defined by the Energy Efficiency Building Codes.

The Policy recognizes the importance of capacity building of stakeholders (architects, engineers, planners, developers, artisans, masons, retailers, manufacturers, etc.) and calls for trainings, workshops, and seminars to enable the implementation of the Energy Efficiency Building Codes.

"The Policy further requires the MoWHS to make energy efficient materials easily available and promote the development of local value chains for manufacturing energy efficient building materials."

4.1.2 Construction Industry Policy

As of December 2018, the draft *National Construction Industry Policy*[25] is open for public comments on the GNHC website.

The objective of this Policy is to guide professional development of the construction sector, improve infrastructure quality, increase the construction industry's contribution to the GDP, and also increase employment opportunities. The Policy aims to secure sustainable financing, improve coordination, and collaboration among key players within the sector, and foster innovation. Certification and capacity building of engineers, plumbers, and contractors are also mentioned.

The policy document outlines measures to promote green growth and sustainable financing of the construction sector. It mentions incentives for constructions adopting energy efficiency standards and for local businesses that manufacture environmentally friendly and energy efficient construction materials. The Policy intends to promote the use of certified and locally manufactured materials like prefabricated and standardized components in all public and private constructions. And it encourages the use of locally grown timber species and alternatives such as bamboo in the construction industry.

> **"The Construction Development Policy mentions incentives for constructions adopting energy efficiency standards and for local businesses that manufacture environmentally friendly and energy efficient construction materials."**

4.1.3 National Human Settlement Policy

As of December 2018, the *Human Settlement Policy*[26] is awaiting the approval of the Government.

[24] https://www.gnhc.gov.bt/en/wp-content/uploads/2017/05/EEC-Final-Draft-Policy-2017-Final-1.pdf
[25] https://www.gnhc.gov.bt/en/wp-content/uploads/2018/07/NCIP-FINAL-DRAFT_25th-June-2018.pdf

This Policy's primary aim is to promote access to safe and affordable housing for all citizens of Bhutan. It also promotes home ownership. The Policy encourages the promotion of green building technologies alongside the preservation and promotion of vernacular architecture. It intends to create an enabling environment for a well-functioning housing market by promoting professional real estate developers, and by limiting the role of public agencies to providing subsidized public housing for lower income groups. Importantly, the Policy calls for better and easier access to finance for housing projects that focus on green building technologies using locally produced building materials.

4.1.4 Alternative Renewable Energy Policy 2013

While the *Alternative Renewable Energy Policy*[27] of 2013 does not mention the construction sector directly, it alludes to the promotion of renewables such as solar and integrating such systems within built environment to help diversify energy sources within Bhutan.

4.1.5 Energy Efficiency Roadmap

A draft *Energy Efficiency Roadmap* document has been compiled by the Department of Renewable Energy[28]. The document sets energy efficiency targets for the building, appliances, and industrial sectors and calls for the certification of EE&C programs to ensure the uptake and growth of energy efficient buildings in Bhutan.

---

[26] https://www.gnhc.gov.bt/en/wp-content/uploads/2017/05/Draft National_Human_Settlement_Policy_of_Bhutan.pdf
[27] http://img.teebweb.org/wp-content/uploads/2015/06/alternative-renewable-energy-policy-2013.pdf
[28] https://www.moea.gov.bt/wp-content/uploads/2018/07/EE-Roadmap-Draft.pdf

4.2 The Role of the Government

The primary role of the Government is to formulate relevant policies, rules, and regulations and allow for fiscal instruments to promote energy efficiency. As seen prior, multiple policies – both in the draft and approved form – aspire to and call for energy efficiency within the building sector.

However, both the 2002 Bhutan Building Rule[29] and the 2013 Rural Construction Rules[30] do not feature any clause to promote energy efficiency.

During the 12th Five Year Plan (2018 to 2023), only 60 million Ngultrums have been tentatively allocated for promotion of energy efficiency in the construction industry. The draft plan mentions the introduction of conducive policy to improve thermal performance of buildings. No significant plan of action has been tabled to genuinely bring about a transformation within the building sector.

4.3 Financial & Fiscal Ecosystem

Currently, there are no financial incentives from the RMA and banks for energy efficiency measures. For instance, loans cannot be availed for rammed-earth structures due to lack of codes and estimates. However, MoWHS is negotiating with banks to make loans available with fairer interest rates for construction of traditional buildings and structures aimed at improving energy efficiency. Policies awaiting Government approval call for instituting fiscal instruments to support energy efficient buildings.

> **"The draft 12th FYP mentions the introduction of conducive policy to improve thermal performance of buildings. No significant plan of action has been tabled to genuinely bring about a transformation within the building sector."**

[29] https://bhutan.eregulations.org/media/bhutan_building_rules_2002.pdf
[30] http://www.mowhs.gov.bt/wp-content/uploads/2010/11/Eng-Final-Rural-Construction-Rules.pdf

4.4 Labour

Construction labourers are mostly sourced from India. Indian labourers are familiar with building for sub/tropical climates and are not versed in energy efficiency concepts.

Bhutan has invested in training a professional labour force through the Technical Training Institutes (TTIs). Within these institutes, however, energy efficiency does not feature as a significant component of the curriculum. Most TTI graduates prefer to work with Government affiliated construction companies, such as the National Housing Development Corporation Limited (NHDCL). On-the-job training at NHDCL may offer opportunities for specialization and subsequent retention of talent pool.

4.5 Supply Chain Ecosystem

4.5.1 Bricks

Three main varieties of bricks are used in Bhutanese constructions: mud-bricks; hollow mud-bricks; and autoclaved aerated concrete (AAC) bricks. A study done by the Green Public Procurement project in Bhutan found that the quality of products by four local brick manufacturers were up to Bhutan Standards Bureau (BSB) standards and also included green and sustainability factors. Locally produced concrete bricks have high R-Values, which is the measure of a material's capacity to resist heat flow from one side of the wall to the other.

The Government also encourages the use of local bricks and has instructed the BSB to provide support to local manufacturers to standardize, certify, and develop product specifications.

4.5.2 Timber

Bhutanese constructions can acquire timber from sawmills as well as directly from the forest. In many instances, the timber are not seasoned and are directly used in constructions. Unseasoned timber crack and warp, leading to gaps allowing for significant heat loss via air infiltration through the wooden features of a building.

The draft National Construction Industry Policy encourages the use of locally grown timber and bamboo. Milling facilities and technologies related to timber seasoning will have to be promoted to increase the use and efficacy of timber.

4.5.3 Windows

Locally assembled glazed windows with imported glass from India (value-added) are available in Thimphu and Paro. Sliding aluminum frame windows were found to deliver better thermal performance than integrating locally produced wooden windows. Locally produced window frames can perform better if windows are sized correctly, have rabbet edges, and open inwards.

However, it is difficult to produce airtight windows without improving timber quality and craftsmanship in addition to some sealant being used. Improved double-glazed windows will also add significantly to construction costs. The economics of such interventions will need to be studied in further detail.

4.5.4 Insulation

Private homeowners are starting to invest in insulation. Gypsum, glass wool, rock wool, expanded polystyrene (EPS), polyurethane foam (PUF), and air sealants are being used to insulate ceilings, walls, and gaps between window joints.

Presently, no data on the properties of insulation materials are available for Bhutan. Guidance on use of such materials is required to avoid thermal bridges, as these could otherwise result in increased condensation risks. It may also be important to consider test efficacy and costs of environmentally sensitive insulating materials made from recycled materials such as cellulose or wool.

4.5.5 Heating

Private residences mostly use electric radiators, kerosene heaters, and wood stoves (*bhukaris*) for heating. Due to significant loss of heat through air leakages, heating costs can be substantive for homes during winter months (Figure 5).

A few hotels, institutions, and private home owners have also installed solar water heating systems while a few others have also installed under floor heating systems. However, these have led floors to crack and also creak due to constant contraction and expansion.

The Bhutan Green Building Guidelines of 2013 recommend adoption of passive solar building design, where windows, walls, and floors are designed to collect, store, and distribute solar energy in the form of heat in the winter and reject solar heat in the summer. However, the rate of adoption of such designs is not known and may be minimal at present.

4.5.6 Lighting

LED lighting is becoming popular and is being increasingly used. However, the extent and impact of such adoption is not known. Mass adoption and use has the potential to lead to substantial energy savings.

4.6 Capacity

As of June 2018, there are a total of 181 architects registered with the *Construction Development Board* (CDB) of Bhutan[31] (145 privately licensed and 36 government architects). There are a total of 81 registered architectural/engineering consultancy firms in the country.

It is not known how many architects and companies are interested in and proficient with energy efficient designs.

4.7 Motivation & Incentives

Energy efficiency improvements are not within the main interest of real estate builders or small homebuilders as it adds significantly to overall construction costs. Furthermore, access to designs and technology are limited which further limit the growth of energy efficient buildings. Overall, there is also ignorance on potential savings from energy efficiency measures. More importantly, home builders may not directly benefit from such energy savings, since most homes are built to be rented out. As such, there are no significant incentives for real estate and home builders to invest in energy efficiency.

"Furthermore, access to designs and technology are limited which further limit the growth of energy efficient buildings."

4.8 On-going Initiatives towards Energy Efficiency

4.8.1 Energy Efficient Buildings

There are a few ongoing building initiatives such as the library being built at the Jigme Singye Wangchuck School of Law in Paro. This library is being promoted as the first truly energy efficient building in Bhutan and will serve as a place to learn from and be inspired by.

---

[31] http://www.cdb.gov.bt/web/listofarchitects
[32] http://www.bbs.bt/news/?p=93015
[33] http://www.ebd.lth.se/

The Zhiwaling Ascent hotel in Thimphu is also supposed to have been constructed to be energy efficient. Such examples should be studied to assess constraints, performance, and replicability.

4.8.2 Gasa Floor Heating

The use of Gudeul, a traditional Korean room heating technology, has been successfully piloted in Gasa[32]. The system, which was invented in Korea, uses direct heat transferred from wood smoke to the underside of a thick masonry floor to heat up an entire room. The room is fully insulated using desho or traditional Bhutanese paper handmade from the bark of the daphne tree. A feasibility study conducted for Lunana Gewog by the pilot project showed that the use of Gudeul can save over 1.5 million pieces of wood, equivalent to about 3 million Ngultrums, annually.

4.8.3 Capacity Building for Engineers

Work is underway to offer a Masters in Energy Efficient Buildings at the College of Science and Technology in Gedu in collaboration with Lund University in Sweden[33] .

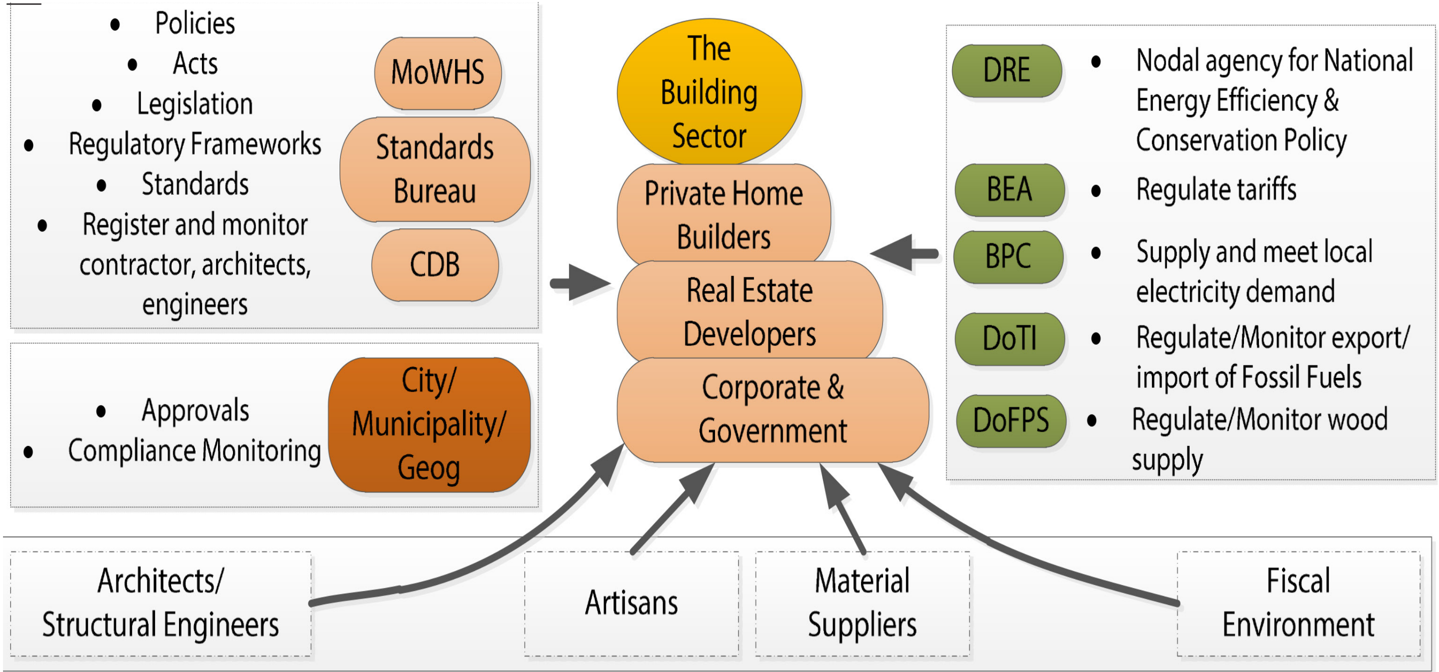

Figure 9*: Schematic highlighting key roles of important actors within the building sector. The building sector comprises of private home and real estate builders in addition to Corporate and Government Institutions which fund building of public spaces. The MoWHS and the BSB play key roles by taking a lead in proposing policies and developing standards. These standards are monitored by regional and local level authorities such as City/Municipal and Goeg authorities. DRE is identified as the nodal agency to coordinate energy efficiency activities.*

CHAPTER 5

Envisioning an Energy Efficient Built Environment

The building sector is complex with many actors, institutions, and layers. Making an impact in this sector will require engagement at multiple levels and across sectors spanning the Government, private sector, and educational institutes. We envision a future where a majority of buildings in Bhutan are energy efficient and thereby contribute to a low carbon development pathway.

We outline 5 key recommendations to promote energy efficient buildings. All of the recommendations and strategies feed into each other, and will have to be implemented in parallel.

5.1 Kickstart A Sustainable Building Initiative

Due to a wide range of stakeholders involved in the construction sector, the *Sustainable Building Initiative* (SBI) will coordinate efforts and aim to achieve synergies across different programs. It will keep track of progress, conduct research, and bring together stakeholders on a regular basis to discuss issues, build capacity, and serve as a space for innovation and advocacy.

Over the next five years, the SBI should:

- In collaboration and consultation with the Ministry of Works and Human Settlement, provide free advisory services on energy efficient constructions in partnership with Dzongkhag Engineers and Gewog Administrative Officers. This should be supplemented by establishing a web based platform for accessing free advice and design templates for interested individuals and builders. The website could also provide links to sources for procuring energy efficient building materials.

- Organize annual capacity building programs for architects, builders, and manufacturers. A portfolio of such programs aimed at manufacturers (sawmillers, brick builders, and windows manufacturers), architects, masons, and regulators should also be developed and delivered.
- Keep abreast of innovation and technology leaps within the energy efficiency movement, adapt best practices, and disseminate across Bhutan.
- In tandem with the GNHC certification scheme, work towards an energy efficiency certification scheme for buildings in Bhutan.
- Keep abreast of policy changes and development of building codes and standards. Assist agencies to disseminate such changes across actors and stakeholders.
- Commission studies to provide economic justifications to upscale efforts in promoting energy efficient buildings.

- Engage the Government, financial institutions, and private stakeholders to conceptualize and advocate for an Energy Endowment to support energy efficiency initiatives.

- Engage the Government and relevant stakeholders to incorporate energy efficiency and conservation measures within building rules and regulations.

5.2 Target Mega Buildings & New Townships

Buildings such as the Thimphu public hospital consume significant amounts of energy. Targeting these public buildings and retrofitting them will help save energy consumption and cut energy related expenses. An energy audit followed up by plans to retrofit major public buildings should be carried out.

The National Housing Development Corporation Limited (NHDCL)[34] is tasked with providing safe and affordable homes for Bhutanese and is responsible for constructing major public residences across Bhutan. The NHDCL should be engaged and influenced to consider green design elements in all their constructions. An immediate possibility would be to embed a green design expert within the NHDCL to train and mentor engineers and also to influence designs under consideration.

Most ministries have plans to construct office spaces in the near future. Engaging all such ministries to influence their design parameters to ensure energy efficiency will bear great dividends. Chief engineers should be engaged and consulted on designs and plans. Special training packages for all such engineers should be developed and delivered.

The Bumthang (2600 masl) and Haa (2720 masl) towns, both at high altitudes, will be constructed within the next few years. Providing information

[34] http://www.nhdcl.bt/

on green designs, insulation materials, and techniques to better insulate homes will contribute significantly to achieving energy efficiency in these upcoming towns.

5.3 Build Capacity, Networks, and Knowledge Sharing

Energy efficient buildings are still a fairly novel idea in Bhutan. This has partly to do with the lack of capacity within this field. Currently, capacity can be viewed at 4 levels: *1) appreciation for energy efficient designs by policy and decision makers; 2) capability and skills to design energy efficient structures; 3) capability to supply and source energy efficient materials; and 4) capability to build such structures.*

We propose that capacity be built at all 4 levels. High level advocacy campaigns in the form of international workshops and learning forums can be organized once a year.

Energy efficient design workshops for architects and engineers from across Bhutan and the Himalayas should be conducted on an annual basis. Energy efficiency principles should be embedded within the main curriculum of engineering degrees at the College of Science and Technology.

A portfolio of training materials and information packages should be developed to foster innovation and technology leaps within and across the supply chain targeting wood, bricks, and insulation product manufacturers.

Vocational Training Institutes should be engaged to incorporate elements of energy efficiency into their curriculum. Trainees should be made to appreciate design elements and basics of benefits which can be reaped from simple and proper insulation.

An online green design forum could be launched to exchange ideas and share experiences.

All the workshops and capacity building programs will also serve as a platform for networking, sharing of experiences, and learning.

Demonstration structures should be built which can be used as learning sites. The demonstration structures could be a portfolio structure which has a mix of different buildings, such as apartments and cottages. Public educational tours should be arranged to expose design elements and explain the benefits of energy efficient designs to a wider public.

5.4 Support Innovation and Technology Enhancement throughout the Supply Chain

A major bottleneck to the achievement of energy efficiency is the lack of proper building and insulation materials. Provision of information on technology and best practices to all building supply manufacturers could be done through a dedicated web based portal and regular publications.

Manufacturers could also be linked to potential investors with advanced technology from 3rd countries, thereby help upgrade technology and also expand their businesses. An example of such an initiative is the *Business 2 Business* partnerships promoted by Denmark in Bhutan[35] (page 32).

In particular, manufacturers of bricks, windows and door frames, and insulation products should be targeted.

5.5 Establish an Energy Endowment

Over the next 5 to 10 years, the SBI should work to establish an energy endowment, hereafter referred to as the Fund. This has the required policy backing in the Renewable Energy Policy document. The Bhutan Green Building Design Guidelines of 2013 also recommends a suite of incentives to promote green buildings in Bhutan[36] .

The Fund should support fiscal incentives and low interest loans for energy efficient constructions. It should also provide capital or grants for innovative and entrepreneurial ideas which conventional financial institutions may perceive as risky.

The Fund can be established as a Trust Fund, such as the Bhutan Trust Fund for Environmental Conservation[37], with an independent governance board. Mechanisms should be explored to enable a certain percentage of revenues generated from electricity to be ploughed back into this fund. Additional funds could also be sourced from multilateral donors, banks, and private philanthropists.

---

[35] www.netpublikationer.dk/um/14_bhutan_denmark/Pdf/bhutan_denmark_partnership.pdf

CHAPTER 6

Looking into the Future

Global carbon emissions continue to peak. And buildings and construction generate almost 39% of all energy related GHG emissions. Energy efficiency measures in the building sector will help offset GHG emissions significantly.

Bhutan is the only carbon negative country in the world. Innovations within the building sector to improve energy efficiency will not only realize significant monetary savings but will also allow for Bhutan to continue remaining carbon negative.

This Report has outlined key recommendations and strategies to kick start, catalyze, and scale up energy efficiency initiatives within the building sector. Aspirations within extant policy documents should be invoked to help initiate action and bring about positive transformation. Opportunities which exist to build entire towns which are energy efficient should be seized. Effective and sustained capacity building programs will also nurture a generation of energy conscious architects and builders whose influence and contributions could spread well beyond Bhutan into the wider Himalayan region.

All this will allow Bhutan to remain true to its philosophy of Gross National Happiness, where economic growth is balanced by ecological sensitivity and cultural maturity.

> **"Global carbon emissions continue to peak. Buildings and construction generate almost 39% of all energy related GHG emissions. As such, energy efficiency measures in the building sector will help offset GHG emissions significantly."**

[36] http://www.mowhs.gov.bt/wp-content/uploads/2014/05/Bhutan-GREEN-Building-Design-Guidelines-PDF-for website-FI.pdf
[37] http://www.bhutantrustfund.bt/

Sources and References

1. http://www.kuenselonline.com/bhutan-proposes-to-graduate-from-ldc-in-2023/
2. Statistical Yearbook of Bhutan 2018 (http://www.nsb.gov.bt/publication/files/SYB_2018.pdf)
3. https://www.adb.org/countries/bhutan/economy
4. Tang, A 2017 From Bangkok to Bhutan, Growing Cities Race to Outrun Disasters. Reuters, 12 February 2015, accessed November 2018 (https://www.reuters.com/article/us-climatechange-asia-cities/from-bangkok-to-bhutan-growing-cities-race-to-outrun-disasters-idUSKBN0LG1PO20150212)
5. Data on number of rural house building timber applicants for other dzongkhags could not be obtained at the time of compiling this report
6. Bhutan Energy Data Directory 2015 (accessed from http://www.moea.gov.bt/wp-content/uploads/2018/07/Bhutan-Energy-Data-Directory-2015.pdf on 11.10.2018)
7. Abergel, T., Dean, B., & Dulac, J. (2017). Towards a zero-emission, efficient, and resilient buildings and construction sector: Global Status Report 2017. UN Environment and International Energy Agency.
8. This data is computed from 230 households surveyed from across Thimphu in early 2018
9. https://www.gnhc.gov.bt/en/wp-content/uploads/2017/05/EEC-Final-Draft-Policy-2017-Final-1.pdf
10. https://www.moea.gov.bt/wp-content/uploads/2018/07/EE-Roadmap-Draft.pdf
11. https://www.unenvironment.org/resources/emissions-gap-report-201812.B&F Shaw Collection (1990) - http://www.bhutanstudies.org.bt/BhutanImage_Archive/
12. B&F Shaw Collection (1990) - http://www.bhutanstudies.org.bt/BhutanImage_Archive/
13. http://www.bpc.bt/wp-content/uploads/2017/05/Annual-Report-2016.pdf
14. https://norad.no/en/toolspublications/publications/2017/norwegian-energy-cooperation-with-bhutan/
15. Bhutan Energy Data Directory 2015 (accessed from http://www.moea.gov.bt/wp-content/uploads/2018/07/Bhutan-Energy-Data-Directory-2015.pdf on 11.10.2018)

16. Forestry Facts & Figures 2016 (DoFPS)
17. Adapted from data obtained from BPC
18. http://www.mowhs.gov.bt/wp-content/uploads/2010/11/Bhutan-Arch-Guidelines-final-2014.pdf
19. http://www.mowhs.gov.bt/wp-content/uploads/2014/05/Bhutan-GREEN-Building-Design-Guidelines-PDF-for-website-FI.pdf
20. As per consultations with officials from the Bank of Bhutan
21. Jentsch, M.F., Kulle, C., Bode, T., Pauer, T., Osburg, A., Namgyel, K., Euthra, K., Dukjey, J. and Tenzin, K., 2017. Field study of the building physics properties of common building types in the Inner Himalayan valleys of Bhutan. Energy for Sustainable Development, 38, pp.48-66.
22. (Bhutan Building Regulations of 2002) https://bhutan.eregulations.org/media/bhutan_building_rules_2002.pdf
23. Bhutan Living Standards Survey 2017 (http://www.nsb.gov.bt/publication/files/pub2yo10667rb.pdf)
24. https://www.gnhc.gov.bt/en/wp-content/uploads/2017/05/EEC-Final-Draft-Policy-2017-Final-1.pdf
25. https://www.gnhc.gov.bt/en/wp-content/uploads/2018/07/NCIP-FINAL-DRAFT_25th-June-2018.pdf
26. https://www.gnhc.gov.bt/en/wp-content/uploads/2017/05/Draft National_Human_Settlement_Policy_of_Bhutan.pdf
27. http://img.teebweb.org/wp-content/uploads/2015/06/alternative-renewable-energy-policy-2013.pdf
28. https://www.moea.gov.bt/wp-content/uploads/2018/07/EE-Roadmap-Draft.pdf
29. https://bhutan.eregulations.org/media/bhutan_building_rules_2002.pdf
30. http://www.mowhs.gov.bt/wp-content/uploads/2010/11/Eng-Final-Rural-Construction-Rules.pdf
31. http://www.cdb.gov.bt/web/listofarchitects
32. http://www.bbs.bt/news/?p=93015
33. http://www.ebd.lth.se/
34. http://www.nhdcl.bt/
35. www.netpublikationer.dk/um/14_bhutan_denmark/Pdf/bhutan_denmark_partnership.pdf
36. http://www.mowhs.gov.bt/wp-content/uploads/2014/05/Bhutan-GREEN-Building-Design-Guidelines-PDF-for website-FI.pdf
37. http://www.bhutantrustfund.bt/

BHUTAN ECOLOGICAL SOCIETY

Bhutan FOUNDATION

KARUNA FOUNDATION