ICIMOD

WORKING PAPER

Renewable energy solutions for enterprise development in the Hindu Kush Himalaya: A needs assessment

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Executive summary

The Hindu Kush Himalaya (HKH) region has a fragile ecosystem, which is being exacerbated by climate change, posing challenges for the livelihoods and the socio-economic development of over 240 million people living in the region and close to two billion living downstream. They are all dependent on the ecosystem services and natural resources of the HKH region, including water, hydropower, timber, biodiversity, niche products, mineral resources, and flood management. However, with a higher incidence of poverty compared to the plains, growing climate risks, and the significant socio-economic disruption caused by the COVID–19 pandemic, mountain-specific recovery plans need to be devised that are guided by the principles of inclusiveness and green and resilient development that can underpin global and national sustainable development and climate change agendas.

In the mountains, various units of enterprises – individuals, community organisations, and micro, small and medium enterprises – are engaged across mountains value chains. Strengthening their competitiveness and resilience has several pre-requisites, including access to technologies and markets, skills and know-how, financing, and infrastructure. Affordable, sufficient, and reliable energy supply is a crucial input that enables enterprises to drastically improve their productivity and resilience, reduce losses throughout the supply chain, diversify products and services, enable value-generating activities, and enhance access to markets and information.

However, energy poverty is a fundamental challenge in the HKH mountains, characterised by a strong dependence on biomass, suppressed productive demands, and poor

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energy efficiency. Renewable energy technologies, which offer cost-effective, reliable, distributed, and adaptable solutions, have the potential to meet diverse energy needs for productive and consumption uses in mountain areas. There is already growing evidence across the HKH of the role distributed renewable energy solutions are playing to improve energy access in remote mountain areas presently unconnected or underserved by centralised infrastructure. Yet, an overall understanding of the potential of renewables, their application in the mountain context, and in strengthening economic value chains is limited. Data and information on existing and potential (suppressed) productive demand and know-how to address the gaps are urgently required to design and support adequate programmes and energy supply systems that support local enterprises.

Towards this end, ICIMOD and the International Renewable Energy Agency (IRENA) have partnered to advance a regional initiative to facilitate action and cooperation to scale up the use of renewable energy towards resilient enterprise development in the HKH. This needs assessment represents the first phase of cooperation. It aims to contribute to filling the knowledge gap regarding energy flows and gaps in selected economic value chains, opportunities for renewable energy solutions, and challenges in scaling up renewable energy deployment. The work further advances the objectives of the Renewable Energy and Energy Efficiency Capability for the Hindu Kush Himalaya (REEECH), a platform to advance regional cooperation to address mountain-specific energy challenges, specifically focusing on nexus solutions.

The comprehensive needs assessment analysed select economic value chains in the HKH region – yak milk in Bhutan and China, bamboo in Bangladesh and Myanmar, and tourism in Nepal and India – from an energy perspective. These three value chains have been selected for their prevalence in the mountain economy in the region, and for access to country-wise case studies based on primary data.

The analysis provides insights into the energy flows along each segment of these value chains, related challenges and missed opportunities, and potential entry points for renewable energy solutions to be integrated to improve the competitiveness, profitability, and the entrepreneurial orientation of mountain enterprises. It finds that local enterprises across the value chains face a lack of access to affordable, reliable, and sufficient modern forms of energy, resulting in the use of traditional fuels at the expense of the environment, missed opportunities for value-creation, and drudgery that disproportionately affects women.

The primary data presented suggests that whereas there is a growing adoption of distributed renewable energy solutions to meet diverse energy needs, these generally focus on consumption uses and are often not tailored towards productive end-uses across value chains. It shows that where an enabling ecosystem exists, renewable energy can indeed enhance livelihoods, offer opportunities for value addition, improve the resilience of enterprises, and support several development objectives related to gender, food security, health, and employment.

This working paper proposes a regional action plan with key action areas based on the needs assessment conducted by IRENA and ICIMOD and stakeholder consultations. The key proposals include the following:

1. Adopt an ecosystems approach to shape renewable energy's contribution to enterprise development.
2. Integrate sustainable energy in dedicated policy and planning measures focused on mountain development.
3. Catalyse accessible finance for end-users and enterprises that covers energy infrastructure as well as productive appliances, training, and capacity-building.
4. Support technology innovation and adaptation processes with a focus on energy efficiency.
5. Build capacities across value chains of mountain products and services to enhance the sustainability of distributed renewables and to maximise enterprise value from improved energy supply.
6. Improve the data and information base regarding energy flows in mountain value chains.
7. Leverage regional partnerships, such as REEECH, to facilitate the exchange of best practices and lessons learnt, the harmonization of efforts, and improved access to markets.

In advancing the above actions, REEECH can play a central role by leveraging its regional convening power and close collaboration with regional member states and focal agencies. The recommended actions are well aligned with REEECH's four thematic areas – knowledge management and awareness; inputs to policy development and implementation; promotion of investment, entrepreneurship, and innovation; and capacity development.

Contents

SECTION I

Introduction

The Hindu Kush Himalaya (HKH) region extends into eight countries – Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan – and covers an area of more than 4 million square kilometres (Bajracharya and Shrestha 2011). The region is characterised by a rich diversity in terms of cultures, languages, weather systems, biodiversity, socio-economic conditions, and livelihoods. Over 240 million people live in the region and directly derive their livelihoods from the ecosystem services, such as water, food and energy, provided by the mountains and hills (ICIMOD et al. 2019). The HKH ecosystem supports livelihoods here, largely based on agriculture and nature-based goods and services, including non-timber forest products from the region's forests (Joshi et al. 2016). In addition, nearly 2 billion people living in ten river basins benefit directly and indirectly from the region's resources. For almost one-third of the world's population, the mountains are a source of goods and services of tremendous significance, including water, hydropower, timber, biodiversity, niche products, mineral resources, and flood management (Sharma at al. 2019).

The mountains and hills of the HKH also constitute a fragile ecosystem undergoing rapid change as a result of infrastructure development, urbanization, migration, and tourism, and where the impacts of climate change are most evident. Poverty is widespread in the HKH region, and higher than the plains due to biophysical and socio-economic specificities of mountain areas (Gioli et al. 2019).

There exist numerous goods and services being produced and consumed in the region with income-generating potential via value chains. There are innumerable units of enterprises in the region, in various forms and sizes, such as individuals, community organisations, and micro, small, and medium enterprises (MSMEs). These enterprises support the livelihoods of a majority of the population in mountain areas and are a major source of local employment. Strengthening the resilience, capabilities, and the potential for local value creation of the enterprises across economic value chains is critical to meeting several of the sustainable development goals related to poverty alleviation, decent work, economic growth, climate action, health and well-being, and gender, among others in the mountain context.

The social and economic impacts of the COVID–19 pandemic on mountain communities here, although yet to be fully understood, have been, and are likely to be, immense. Key pillars of the mountain economy, such as tourism, remittances, and the demand for goods and services, have been severely disrupted, and this has resulted in a significant loss of income and shock for vulnerable communities without adequate social protection.

As governments consider COVID–19 recovery packages, it is crucially important to ensure that the immediate support for vulnerable communities is tailored to, and accessible for, the mountain populations. Further, the recovery plans should be guided by the principles of inclusiveness and a green recovery that advance the development of resilient livelihoods and infrastructure and which can underpin global and national development goals and climate change agendas.

Part of such support includes strengthening mountain enterprises. This has several pre-requisites, ranging from access to technologies and markets, skills and know-how, to finance and energy. With affordable, adequate, and reliable energy supplies, enterprises

could drastically improve their productivity and resilience, reduce losses throughout the supply chain, diversify products and services, expand value-generating activities, and enhance access to markets and information.

However, energy poverty is a fundamental challenge in the HKH mountains, characterised by a strong dependence on biomass, suppressed demand for productive activities, and poor energy efficiency (ICIMOD et al. 2019). The reliance on traditional sources of energy and fossil fuels, such as diesel, for meeting energy needs – primarily due to limited or unreliable access to most modern forms of energy, a consequence of the remote locations of mountain communities – is environmentally unsustainable, constrains value chain development, and contributes to climate change (Dhakal et al. 2019).

Renewable energy technologies offer cost-effective, reliable, and adaptable solutions to these challenges in a growing number of geographical and socio-economic contexts. These technologies rely on locally available energy resources, and have the potential to be deployed rapidly and at scale to meet different energy needs across various economic value chains in the mountain context. Deploying renewable energy as part of strategies to develop and strengthen value chains in the HKH could offer substantial benefits in terms of energy security, climate resilience and mitigation, and enhanced socio-economic outcomes for mountain communities (IRENA 2016). A resilient and sustainable development trajectory for the HKH region would also benefit the billions of people downstream relying on secure and clean water supply, and other products and services.

Although renewables continue to be deployed across all countries of the HKH, an understanding of their potential and application in the mountain context and capacity to strengthen economic value chains is limited. Data and information regarding existing and potential (suppressed) production demands and know-how to address the knowledge gap are urgently required to design and support suitable programmes and energy supply systems that foster local enterprises (ICIMOD et al. 2019). The primary focus of this analysis is to contribute towards bridging this knowledge gap.

1.1 About the needs assessment

Energy flows and needs in different segments of the economic value chains of goods and services of mountain communities are not well understood or documented enough to inform effective decision-making. To this end, the International Renewable Energy Agency (IRENA) and ICIMOD conducted a comprehensive needs assessment to analyse selected economic value chains in the HKH region from an energy perspective. Value chains for yak, bamboo, and tourism were chosen. As further outlined in Chapter 3, these three value chains were selected for their prevalence in the mountain economy in the HKH region, as well as for access to country-wise case studies based on primary data.

Through a comprehensive review of the academic and grey literature, and primary data covering the three value chains, the analysis provides insights into the energy flows along each segment of the value chain, related challenges and 'missed opportunities', and potential entry points for renewable energy solutions. It also assesses how access to renewable energy solutions can improve the competitiveness, profitability, sustainability, and entrepreneurial orientation of mountain enterprises.

An in-depth analysis of the contextual and mechanistic factors – such as the degree of job specialization and layers of management control – that influence specific outcomes of renewable energy development for enterprise growth was also conducted for the three value chains studied. A portfolio of projects that have integrated renewable energy supply with productive end-uses[1] in mountain and non-mountain contexts was also generated from the literature. This informs the identification of key priority areas to feature in the regional action agenda, a key outcome of the initiative.[2]

This working paper is organised into four chapters. Chapter 1 presents the context, purpose, and methodology of this study. Chapter 2 provides an overview of the HKH region, in terms of the mountain economy and energy landscape. Chapter 3 presents evidence from a systematic review of the literature and case studies on current energy flows in selected mountain value chains and the contextual and

[1] Productive end-uses refers to the use of energy for income-generating activities undertaken by various units of enterprises in diverse sectors such as agriculture, cottage industry, and dairy. Consumption end-uses refers to the use of energy that does not directly support income-generation, including activities in households, community centres, and public buildings.

[2] The work will also be a contribution to ICIMOD's Renewable Energy and Energy Efficiency Capability for the Hindu Kush Himalaya (REEECH). In 2016, the United Nations Industrial Development Organisation (UNIDO) and ICIMOD launched a process that led to the establishment of REEECH, which was formally activated in November 2018. The REEECH initiative, in the long term, envisions to be the Regional Sustainable Energy Centre in Asia, part of the Global Network of Regional Sustainable Energy Centres across the world.

mechanistic factors that shape these flows. Finally, Chapter 4, building on the outcomes of the assessment, proposes an action agenda for stakeholders in the region to scale up the adoption of renewable energy to support livelihoods and enterprise development.

Through this assessment and future work, IRENA and ICIMOD aim to advance regional action and cooperation regarding renewable energy for resilient livelihoods and mountain economies in the HKH region. The assessment further advances REEECH's objective as a platform to advance regional cooperation to tackle mountain-specific energy challenges, focusing on nexus solutions (ICIMOD et al. 2018). The approach adopted to analyse energy flows and opportunities for deploying renewables in the three selected value chains has a high potential to be replicated in other value chains relevant to the region. The analysis provides a blueprint for stakeholders to advance a joint vision for renewable energy, livelihoods, and enterprise development in the HKH region.

The findings of the assessment can provide a basis to replicate the scale and speed of the global energy transition in the mountain context, and contribute to ensuring inclusiveness, a key pillar of the 2030 Agenda for Sustainable Development. Speed is of the essence as mountain communities face the brunt of climate change impacts on fragile ecosystems and the livelihoods they support.

1.2 Methodology

The systematic review for this report was based on literature from business and investment, ecology, and sustainability studies for a comprehensive view of relevant concepts. These include resilience, particularly in the context of enterprise development, and key characteristics or enablers (strategies, policies, infrastructure, techniques, and technologies) that contribute to the sustainability and competitiveness of enterprises.

A literature search was performed using the following keywords: 'business model innovation', 'MSME and resilience', 'resilient enterprises', 'green enterprise growth', 'organisational resilience' and 'sustainable business model/strategy'. Since resilience is a metaphor closely related to the concept of sustainability, a database search was also done for 'sustainable business model/strategy'. Articles were reviewed from both within and outside of the HKH region because of their paucity from within the HKH. The list of articles eligible for inclusion was shortlisted based on an article's citation score, the use of novel definitions of resilience/resilient enterprises, or on the discussion of different enablers and obstacles to resilience in the context of small businesses. In addition, as part of the primary data-gathering effort, key informant interviews (KIIs) and focus group discussions (FGDs) were conducted with a wide range of stakeholders to understand key opportunities and existing challenges for renewable energy integration in enterprises.

SECTION II

The Hindu Kush Himalaya: A primer

The HKH region stands at an important crossroads in its development trajectory. The fragility of its ecosystem, further exacerbated by climate change, poses challenges for the livelihoods and potential for socio-economic development of over 240 million people living in the region, many of them poor. At the same time, the uniqueness and diversity of the mountains and digital connectivity offer tremendous opportunities to strengthen value chains for various products and services with comparative advantage.

Tailored efforts to improve the capacities and entrepreneurial orientation of local units of enterprises – households, community organisations, or MSMEs – could bring substantial benefits in terms of their resilience and promoting sustainable development goals. Among other infrastructural needs, access to modern, adequate, reliable, and affordable energy is a critical input and enabler in this process. This chapter offers a primer to the linkages between mountain livelihoods, poverty, and energy in the HKH region.

2.1 Mountain livelihoods and challenges faced

Poverty is widespread in the HKH region. Over a quarter of the estimated 240 million people in the region live in poverty. Bangladesh has the highest incidence of poverty in the mountain areas (46 per cent), followed by Afghanistan, Nepal, India, Pakistan, and Bhutan (Gioli et al. 2019).

Besides India, the poverty rates in all countries in this region are higher in the mountain and hill areas than the respective countries as a whole (Hunzai et al. 2011). Several factors are responsible for this, including the remote locations of mountain communities, poor social and physical infrastructure, limited access to markets, and a high dependence on natural resources. People's livelihoods are supported by a fragile ecosystem that has been further impacted by climate change, rapid infrastructural development, tourism, and urbanization (Joshi et al. 2016).

National-level poverty alleviation programmes and initiatives are likely to have limited impacts on mountain communities; the sub-national and local manifestations of poverty are simply too profound. Addressing poverty in mountain communities requires focused programmes and interventions that support inclusive livelihood opportunities.

The majority of the population in the HKH relies on subsistence agriculture and livestock rearing as sources of livelihood. There are more than 200 million smallholder farmers in the region, and agriculture contributes 40 per cent of the region's GDP. It also generates the bulk of the livestock products — 75 per cent of the milk and 60 per cent of the meat — and employs millions of people on farms.

Depending on local context and mountain conditions, the livelihoods also vary. In high-altitude areas, livestock-based livelihoods, such as yak-rearing, are common and access to common-pool resources, such as pasture lands and water, is key to sustenance (Gioli et al. 2019). In the mid-hills of the HKH, the combined practice of mainly subsistence agriculture and extensive livestock-rearing is common. Meanwhile, in the lower hill tracts, traditional, sedentary agricultural practices, such as multiple cropping and crop diversification, are prevalent (Wu et al. 2016).

However, traditional agriculture alone is insufficient to meet all needs of the people and offer a long-term pathway out of poverty. In recent decades, farmers

have been gradually shifting from subsistence to high-value agriculture, involving the growing of fruits, vegetables, and spices such as ginger, turmeric, and cardamom (Gioli et al. 2019). This is especially the case in areas where access to markets, know-how, and finance has improved.

Mountain livelihoods in the HKH are also evolving. Over the past three decades, there has been a shift from the agro-pastoral to several off-farm activities. Households in the mountains increasingly rely on livelihoods that combine farming work with non-farm activities (Gioli et al. 2019), including wage labour, tourism, and rural industries such as that based on bamboo products. Diversity is a central determinant of livelihood security and non-farm livelihoods are pivotal to the sustainable future of mountain people and communities (ICIMOD n.d.).

Appropriately designed livelihood diversification can increase economic opportunities and add value to local economies. For example, milk and meat processing, niche high-value crops, or the sustainable harvesting of herbal and medicinal plants can significantly provide or complement livelihood options for the people of the HKH (ICIMOD n.d.). The unique conditions in the high mountains and mid-hills offer a comparative advantage for developing various niche products and services for both local consumption and export. However, to tap into these opportunities, a number of challenges need to be overcome. These include access to financial resources, farm inputs, technology, training, research, and advisory services, poor linkages between the actors in the value chain, as well as poor basic infrastructure such as roads, transport, markets, and communication (Joshi et al. 2016).

Mountain value chains are long, are scattered across a wide geographical area, transportation is costly, and the advantages inherent in HKH's mountain products and services remain largely unexplored. Even though there may be good demand in national and international markets for mountain products, the value is mostly captured by those at the far end of the value chain as a number of value-addition measures, such as processing, packaging, and branding, take place in urban areas and the plains.

A key, often less understood ingredient in the development of mountain value chains is access to reliable, affordable, and sustainable energy. Bringing value forward in the supply chain and closer to mountain communities requires processes that are energy-intensive, such as running agro-processing equipment, producing dairy products from milk, or improving services offered by tourist lodges and homestays in the mountains. MSMEs that operate within these value chains, and constitute about 95 per cent of the private sector in the HKH region, could either depend on unreliable or expensive energy (for example, diesel, coal, or grid electricity) to meet their energy needs, or not have access to modern energy sources at all and rely on manual forms of energy use (for example, in preparing land for agriculture, or milking cattle). Both conditions – the lack of access to, or the reliance on expensive and unreliable energy sources – limit the growth potential of MSMEs in the HKH region.

With most centralised infrastructure, the challenge of accessibility to modern forms of energy is particularly high in the mountain context. However, the growing competitiveness of distributed renewable energy (DRE) solutions shows promise. The next subsection will discuss, broadly, the energy landscape in the HKH, specifically focusing on new technology solutions that are emerging and which improve energy access in remote, mountain areas of the region.

2.2 Energy in the HKH region

With a strong population growth, rising consumption, and industrialization, energy consumption in countries of the HKH has risen rapidly. Between 2010 and 2017, final energy consumption in all countries of the HKH barring Afghanistan witnessed double-digit growth. For instance, during this period, energy use in Bhutan and Nepal rose 18 per cent and 23 per cent respectively (UNSD 2020).

Disaggregated data related to energy production and consumption in the mountain context is limited. National-level energy data tends to hide important disparities in energy use between the plains and the mountains. Mountain-specific characteristics such as inaccessibility, fragility, and marginality, combined with the 'isolated enclave' nature of mountain economies and communities lead to different patterns and trends in energy demand (Papola 2002). In Pakistan, for instance, household access to clean fuels for cooking, lighting, and heating is generally found to be lower in the mountain areas compared to the national average. Whereas at the national level, 74 per cent of the households report the use of clean fuels in urban and 12 per cent in rural areas respectively, the corresponding rates are lower in the mountain provinces of Khyber Pakhtunkhwa and Balochistan (PBS 2020). Households in mountain areas also spend more on fuels for lighting and cooking than those in the plains.

The populations in Bhutan and Nepal fall entirely in the HKH region and an analysis of energy consumption in these countries yields important insights for the mountain context (Dhakal et al. 2019).

In both these countries, households represent the largest energy consumer, accounting for over three-quarters of total final energy consumption. This trend is also evident in other countries of the HKH such as Bangladesh, Myanmar, and Pakistan, although their shares of household consumption as a percentage of total energy consumption are lower. In Afghanistan, India, and China, the industrial sector is the largest energy consumer. However, a different picture might emerge when considering the mountain and hill areas of these countries.

Within households, traditional biofuels (for example, fuelwood and briquettes) constitute the largest source of energy supply in all countries in the HKH barring China, and are used for cooking, water and space heating, and other applications (for example, process heating). Due to the generally cool-to-cold weather throughout the HKH, space and water heating acquires prominence, and fuel is needed for cooking as well. The use of biomass as a cooking fuel serves the additional purpose of heating in the middle- and high-altitude regions of the HKH (Dhakal et al. 2019). In Bhutan and Nepal, our representative contexts for mountain communities, biofuels account for over 97 per cent of the total energy consumption in residences, predominantly in rural areas.

In industry, coal is the largest source of energy in Nepal, comprising nearly 60 per cent of all energy consumed by the sector in 2017. Electricity's share was 26 per cent, followed by biofuels and oil (UNSD 2020). Process heat demand in industries, including agro-processing, potteries, blacksmiths, dairies, and workshops, is generally fulfilled by fuelwood and other biomass, petroleum products, coal, and electricity. The agricultural sector in Nepal is a significant energy consumer, especially as it transitions from subsistence to high-value commercial farming.

In Bhutan, electricity is the largest source of energy used by industry, at 60 per cent in 2017, while coal accounted for 39 per cent (UNSD 2020). The dominance of electricity use in industry in Bhutan is likely to be the result of the country's substantial hydropower generation and its availability at a low cost. However, the use of coal by industry is rising with the exploitation of domestic resources – consumption has nearly tripled between 2012 and 2017. Households continue to rely heavily on traditional biofuels due to easy access in the mountains compared to modern energy sources from large infrastructure.

Regarding energy production, fossil fuel-based commercial energy sources such as coal and natural gas have the highest shares across most countries of the HKH. The exceptions are Nepal and Bhutan where the household sector is the largest energy consumer and non-commercial sources of energy such as biofuels/waste dominate energy production. In the electricity sector, however, hydropower plays an important role in the countries of the HKH.

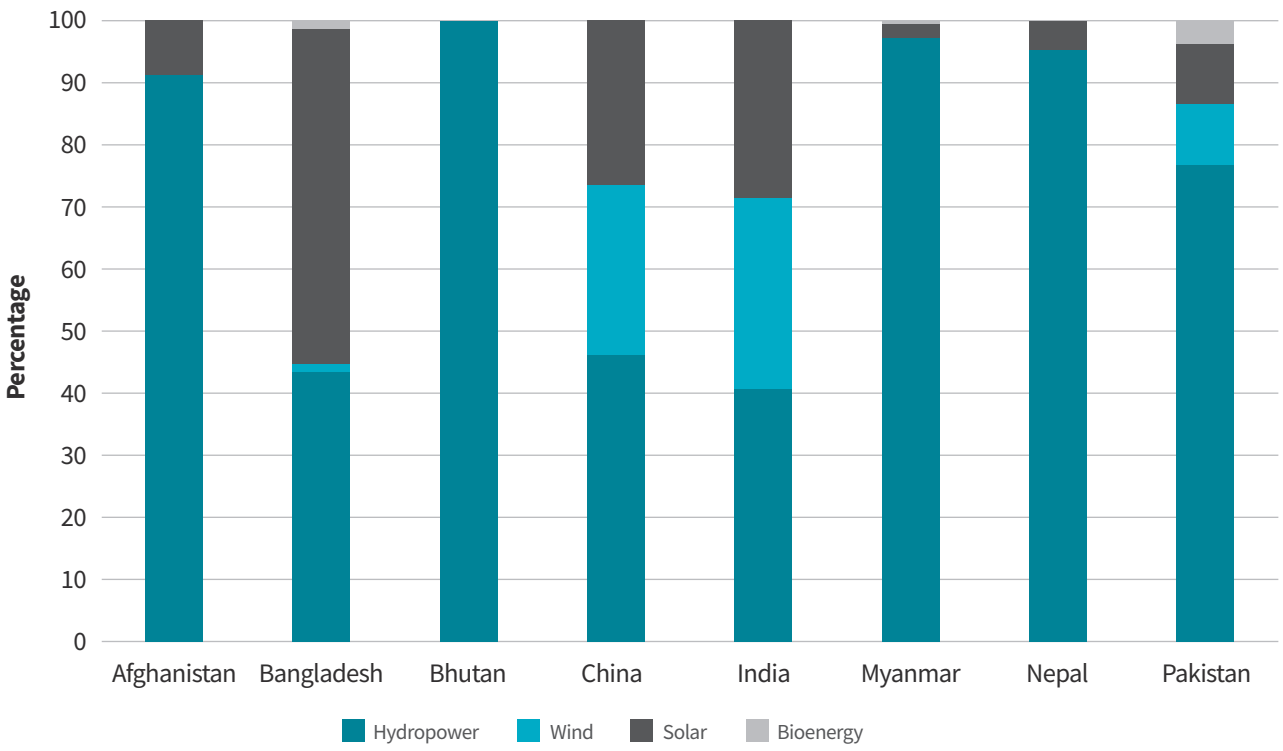
In Bhutan and Nepal, hydropower accounts for nearly all the power generation. Afghanistan's share of total power generation capacity was over 90 per cent in 2020, while the figure for Myanmar stood at 54 per cent. Bangladesh is the least reliant on hydropower among HKH countries, its share being barely 1 per cent. Even as the development of other renewables such as solar photovoltaic (PV), wind, and bioenergy has grown, hydropower accounts for the largest share of renewables' capacity deployed in the majority of the HKH countries (Figure 1).

The development of large hydropower, or broadly centralised energy infrastructure, benefits those areas presently served by the national grid and where adequate transmission and distribution infrastructure exists. Extending national grid electricity to sparsely populated, remote, and low-density settlements in the HKH is challenging and, where feasible, often faces low quality of supply. It also has high transaction costs associated with operation and maintenance, which can be steep when spread over remote areas with low consumption levels. Hence, centralised energy infrastructure, including large hydropower, gives rise to important questions of equity and the extent of benefit-sharing between urban power centres and mountain communities (Dhakal et al. 2019).

The per capita energy consumption in mountain areas is also lower than in the plains. In India, for instance, per capita electricity consumption in mountain states, particularly in the North-east, is far lower than the national average. Rural areas in the north-eastern states also suffer from less reliable electricity access, with the average daily supply as low as around 14 hours per day in states such as Arunachal Pradesh and Mizoram. This points to the possibility of a strong latent demand due to unmet energy needs, and reduced economic activities as a result of unreliable or expensive access to energy.

Distributed renewable energy solutions are found to be increasingly delivering sustainable, affordable, and reliable electricity supply to mountain communities as an alternative to grid-based solutions. A more detailed discussion of this will follow in the next subsection.

FIGURE 1 RENEWABLE ENERGY CAPACITY BY SOURCE IN HKH COUNTRIES, 2020



Source: IRENA (2021)

Note: Total RE capacity in 2020: Afghanistan – 365 MW; Bangladesh – 522 MW; Bhutan – 2.3 GW; China – 772 GW; India – 123 GW; Myanmar – 3.4 GW; Nepal – 1.2 GW; Pakistan – 1.3 GW

2.3 Extent of access to modern energy services

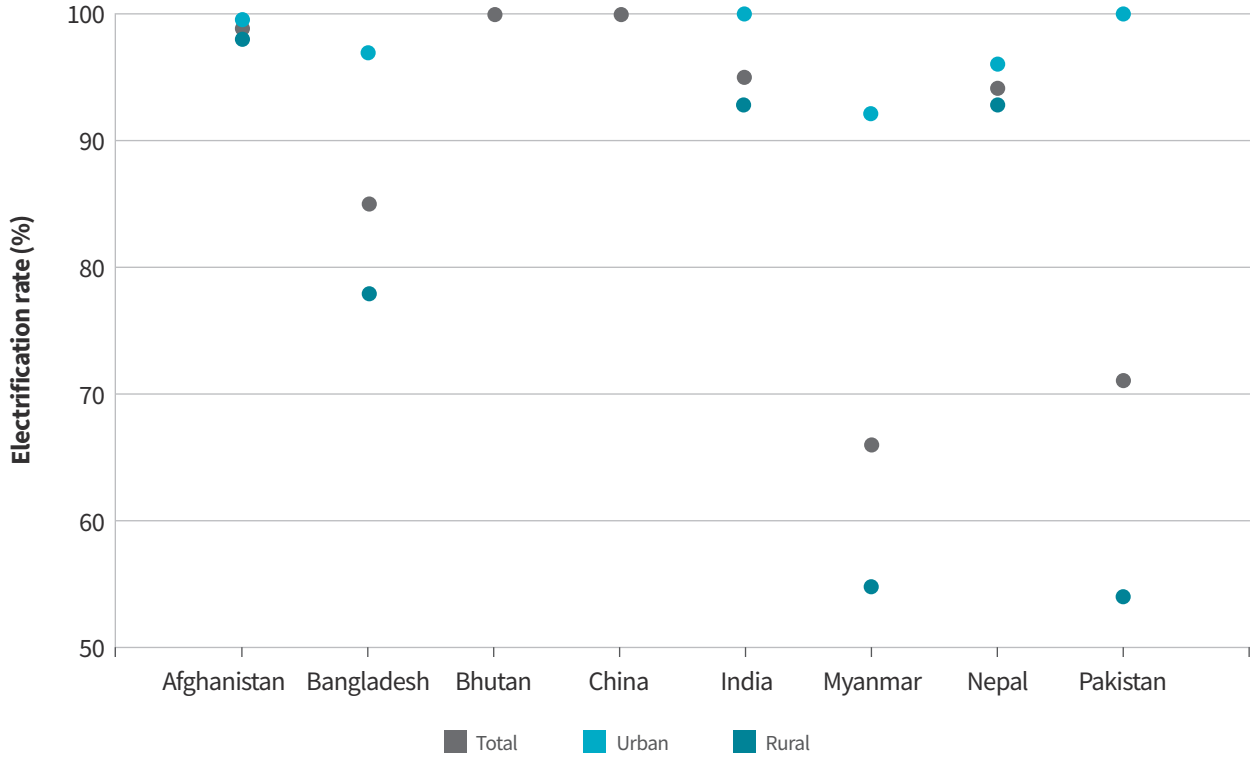
As the energy sector has expanded across countries of the HKH, significant strides have been made in improving access to modern forms of energy for their people. Two countries – Afghanistan and India – report total electrification rates of over 95 per cent, while China and Bhutan are known to have reached universal electricity access (Figure 2). India has seen remarkable progress in terms of electricity access in the past decade, with the total electrification rate rising from 80 per cent of households in 2012 to 95 per cent in 2018, bringing access to nearly 190 million more people (IEA et al. 2020). However, total electricity access rates hide important disparities between urban and rural areas.

Electricity access rates in rural areas are substantially lower than urban levels. In Bangladesh, while urban access rates stood at 97 per cent in 2018, the figure for rural areas was 78 per cent, with around 20 million people without access. Such a stark contrast can also be seen in Myanmar (92 per cent urban access compared to 55 per cent in rural areas) and Pakistan (100 per cent in urban areas compared to 54 per cent rural access). Nearly 170 million people were without electricity across countries of the HKH in 2018, 165 million of them in rural areas (IEA et al. 2020). National, urban or rural access rates also do not fully capture the qualitative aspects of energy access, specifically related to consumption levels, reliability, quality, and sufficiency of supply.

The importance of the qualitative aspects of energy access cannot be overstated, particularly in the context of enterprise development. Without reliable and quality access to energy, investments by enterprises to expand or strengthen their products or services will be hindered. In some cases, such as for cold storage, there is no livelihood possible without a reliable supply of energy.

Estimates of electricity access rates among mountain communities are limited. Over 1.47 million people in the rural areas of Nepal were without electricity access in 2018 (World Bank 2019). Bhutan has seen a remarkable decrease in the number of people in rural areas without access to electricity, from nearly 200,000 in 2010 to reported universal access in 2018. In India, some of the lowest rates of household electrification were recorded in the mountain states of Arunachal Pradesh (76 per cent), Meghalaya (77 per cent), Nagaland (80 per cent), and Assam (82 per cent) (Niti Aayog 2018). In Pakistan, rural and mountainous

FIGURE 2 TOTAL, URBAN, AND RURAL ACCESS TO ELECTRICITY IN COUNTRIES OF THE HKH IN 2018 (%)



Source: IEA et al. (2020)

regions, such as the Khyber Pakhtunkhwa province, can have electricity access rates well below 20 per cent (ADB 2018).

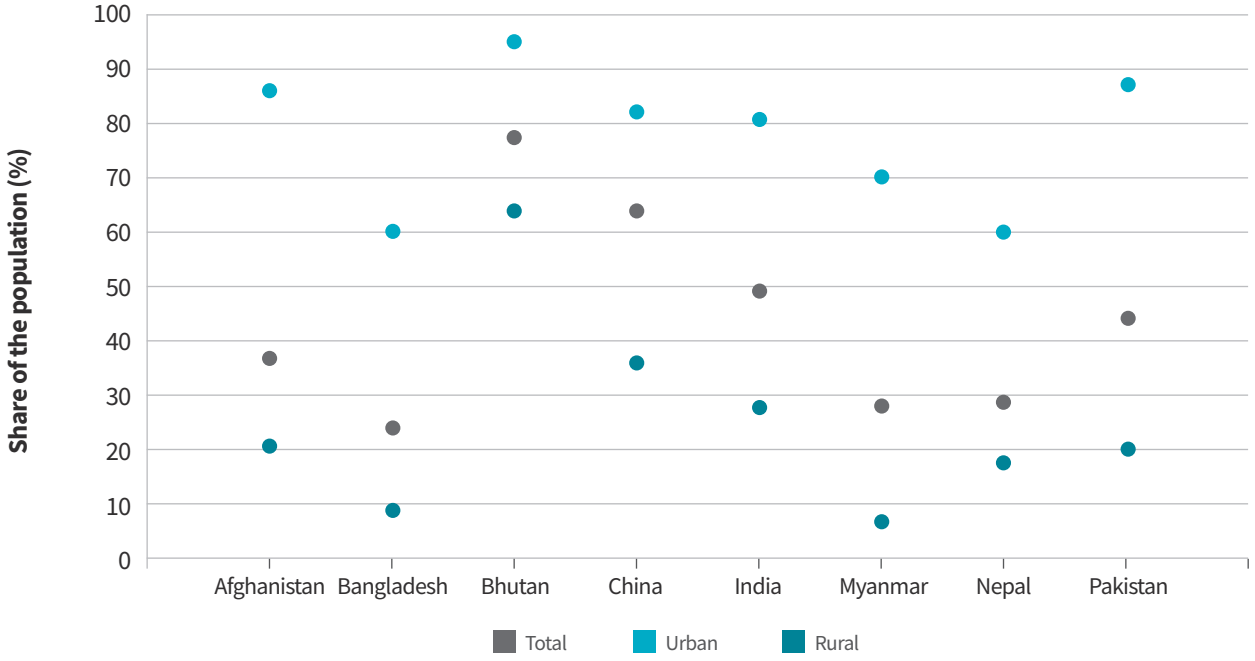
Where access to electricity does exist, its reliability, sufficiency, and affordability of supply becomes a key determinant in ensuing benefits. Importantly, an exclusive focus on household electrification results in local enterprises being unable to secure or afford a connection, and those connected facing unreliable supply and high costs. This has driven the growth of large off-grid electricity generation fuelled by fossil fuels (mainly diesel) and renewables. This is discussed in greater detail in the next subsection. In stimulating income-generating activities, affordability is also strongly influenced by access to high-efficiency productive end-use appliances that can play an important role in unlocking economic potential.

The dependence on traditional fuels for meeting non-electricity energy needs remains high in countries of the HKH, especially in rural areas. Access to clean fuels and technologies for cooking in rural areas in 2018 ranged from under 10 per cent in Bangladesh and Myanmar, to around 20 per cent in Afghanistan, Nepal, and Pakistan (Figure 3). Bhutan reports the highest share of rural population with access to clean fuels, at 64 per cent (IEA et al. 2020). Electricity is widely used for cooking in both urban and rural households in Bhutan, although a third of the rural population still uses fuelwood for cooking. Households in Samtse, Trashigang, and Samdrup Jongkhar dzongkhags have relatively high levels of dependence on fuelwood for cooking. Besides cooking, traditional fuels continue to be used in mountain areas for space heating and process heating for various income-generating activities.

The challenge of energy access in the HKH region has led to the large-scale deployment of off-grid renewable energy (RE) solutions. These are well-suited to the local conditions of mountain communities and offer reliable, environmentally sustainable, and affordable energy services in terms of electricity, heating/cooling, and transport (Dhakal et al. 2019).

In Nepal, traditional water mills (*ghattas*) have been used for maize- and wheat-processing for centuries. Recently, improved water mills that are more efficient and offer a wider range of processing capabilities, including hulling, oil expelling, saw milling, as well as electricity generation, are being deployed (UNFCCC 2019). In addition, Nepal has also experienced the rapid adoption of micro hydro systems for rural electrification. Currently, approximately 1,700 off-grid micro hydro plants — almost all of them community-owned — have been installed throughout the country with a total installed capacity of about 30 megawatts

FIGURE 3 SHARE OF THE URBAN AND RURAL POPULATIONS WITH ACCESS TO CLEAN FUELS AND TECHNOLOGIES FOR COOKING, 2018 (%)



Source: IEA et al. (2020)

Note: The data presented includes point estimates for 2018

(MW) (World Bank 2018). One of the key challenges for community-owned mini-grids has been low utilization factors and the lack of productive end-uses.

Myanmar is estimated to have over 5,600 micro hydro systems under 1 MW capacity for rural electrification, as well as over 10,000 biomass gasifiers for powering small-scale rice mills, and over 500 systems for electrification (Vaghela 2019). In Afghanistan, under the National Solidarity Programme and Remote Hydro Light initiative, more than 5,000 community-owned and managed micro hydro mini-grids were deployed between 2003 and 2015 (USAID n.d.). Under the UNDP's National Area-Based Development Programme, another 138 micro hydropower projects have been developed, bringing electricity to more than 168,000 people.

In the mountain states of India, the use of off-grid RE solutions has also gained momentum. Solar thermal systems are being widely used in Himachal Pradesh, Uttarakhand, and Ladakh, primarily for heating water for cooking, residential use, and space heating.

There is a long track record of the use of off-grid RE solutions for promoting modern energy access in the HKH. The better integration of such solutions with livelihood applications and income-generating activities can have a multiplier effect in terms of the socio-economic benefits for end-users, households and enterprises both. This requires a holistic approach in looking at the entire value chain of products and services prevalent in the mountain communities, as well as new opportunities that can be availed of due to the comparative advantages offered by specificities of local context. The next chapter will analyse further how renewable energy can be harnessed for the development of livelihoods and to support enterprises in the HKH region.

SECTION III

Renewable energy for resilient enterprise development in the Hindu Kush Himalaya

Mountain enterprises, including households, community-owned organisations, and MSMEs make up 95 per cent of the private sector in the HKH region and are crucial for employment generation. Designed around primary sector activities – such as tourism, agriculture, and water-related services (Figure 4) – and due to the low value addition at the supply end of the value chain, these enterprises, and the livelihoods they support, are vulnerable to climate change impacts and other shocks. Further, the reliance of these enterprises on traditional and inefficient sources of energy and the projected growth of the sector presents a key local and global environmental risk.

FIGURE 4 KEY VALUE CHAINS

There is a growing body of evidence that access to reliable, affordable, and sufficient energy can support productive end-uses across various economic sectors, catalyse local economies, and bring substantial socio-economic benefits (Eberhard and Dyson 2020; IRENA 2019; SeforAll 2020). We conducted a systematic review of 32 cases in which renewable energy has been deployed by enterprises to enhance livelihoods, incomes, and welfare. A systematic analysis of these cases illustrates the positive impacts renewables can have on the entrepreneurial and market orientation of enterprises; it enables them to better anticipate and plan for change, innovate and diversify production, and establish new market linkages (Box 1).

Based on primary data gathered through field research, this chapter presents insights from three value chains – bamboo, tourism, and yak dairy – on existing energy flows in the respective value chains, challenges faced, and the conditions under which renewables could contribute to the development of resilient enterprises, and bring value forward and closer to mountain communities. The selection of economic value chains for this phase of the assessment has been based on their relevance to the mountain economy in the HKH region, as well as access to case studies that would enable the gathering of primary data.

3.1 Insights from a systematic literature review

While significant progress has been made to promote relevant renewable energy solutions to enable energy access over the last decade, the lack of its productive end-use remains a challenge. Very few projects explicitly mention the productive use of RE as a targeted objective, and focus instead on rural electrification, that is, for consumption uses (for example, lighting, charging mobile phones, and the delivery of education and health services).

Even when projects and programmes focus on energy access broadly, the extent to which value chains are being impacted by the introduction of

BOX 1

DEFINING ENTERPRISE RESILIENCE

For the analysis presented in this study, a resilient enterprise is defined as one that has the ability to absorb, adapt, and/or transform (AAT) its value proposition – in other words, to create economic value alongside social and environmental value – in response to climatic and other shocks. For instance, when exposed to frequent and/or high-magnitude climatic shocks, a resilient tourism enterprise is one that is able to maintain, improve, or fundamentally change its return on investment and its contribution to job creation and greenhouse gas (GHG) emissions reduction (Agrawal et al. 2019).

We focus on how an enterprise's strategic orientation shapes its ability to absorb, adapt, and transform its value proposition in response to climate shocks. An enterprise's strategic orientation determines how it sets priorities, views customers, and defines its operations.

We focus on three domains of strategic orientation that influence the ability of enterprises to address climate resilience in their operations:

1. Entrepreneurial orientation: This refers to the creation of value driven by entrepreneurship. Factors that shape an entrepreneur's ability to create a climate-resilient value proposition include: knowledge and awareness to anticipate and manage climate shocks and opportunities; the ability to learn, change and innovate the value proposition; and leadership, proactiveness, and risk-taking behaviour.

2. Market orientation: It refers to the creation of value in response to market demands. The focus on customers and the market along with quality management enables enterprises to respond to emerging market demands for climate-resilient goods and services. In addition, climate-resilient enterprises rely on strong networks and alliances to ensure diversity, risk management, and redundancy in the value chain.

3. Management capacity: It refers to the management values, capabilities, and operating structures of an enterprise. Management values – which encompass the creation of economic value alongside social values (green job creation, inclusion of the marginalised) and environmental values (emissions reduction, sustainable enhancement of ecosystem services) – shape the resilience of an enterprise. Regarding capabilities, enterprises that invest in skilled labour and continuous training are better able to create resilient enterprises. In terms of operating structures, decentralised and autonomous decision-making structures improve an enterprise's flexibility and responsiveness to climatic shocks and opportunities.

Source: Saklani et al. (2022)

renewable energy technologies is not fully captured during project reporting.

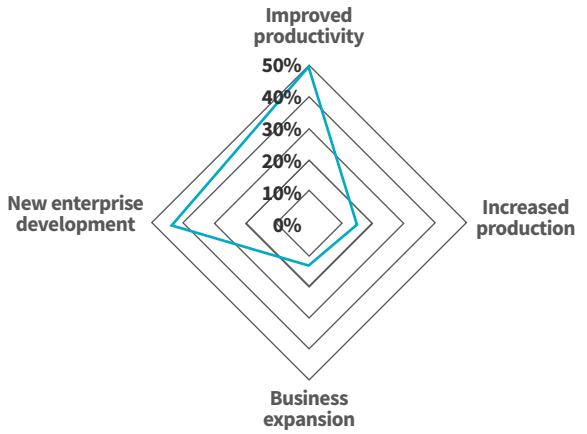
To better understand how renewables can contribute to enterprise development, a systematic review of 32 cases in which renewable energy has been deployed was conducted.[3] The objective of the systematic review was two-fold: (i) to gather evidence about whether renewables positively affect enterprise development; and (ii) to understand the contextual and mechanistic factors – such as the degree of job specialization and layers of management control – that enable such impacts to be realised. This section provides findings from the analysis.

3.1.1 Renewable energy's contribution to the development of resilient enterprises

The impacts of renewable energy interventions on enterprises, particularly in rural and remote areas, were assessed across three parameters – market orientation, entrepreneurial orientation, and management capacity – resulting in improved profitability and benefits to the local economy (see Box 1 for an elaboration of these parameters).

The systematic review finds that renewable energy solutions positively impact the market orientation of enterprises – an explicit focus on meeting consumer and end-user needs (Figure 5). In 44 per cent of the cases studied, new enterprises were established, while in 13 per cent of cases existing businesses expanded to meet diverse consumer needs. This includes cases in which individuals purchased new equipment such as oilseed pressing machines, juicers, sewing machines, and egg incubators as a result of access to electricity. The development of new enterprises included the establishment of mechanical workshops, poultry farms, fruit processing units, metal works, and communication services, mostly with the support of solar power or micro hydropower. Other examples include workshops established by masons and technicians who received training in the installation of new renewable energy technology.

FIGURE 5 CONTRIBUTION OF RENEWABLE ENERGY TO THE MARKET ORIENTATION OF ENTERPRISES



Importantly, the enterprises also reported improvements in productivity and production. Half of the cases show an increase in productivity and production due to more efficient processes and longer working hours. Meanwhile, some also reported an increase in production and lesser business expenses with access to adequate and sustainable sources of energy.

Renewable energy solutions are seen to also positively impact the **entrepreneurial orientation** of enterprises – a measure of proactiveness and competitive aggressiveness aimed at product diversification and resilience. Such impacts are often not comprehensively captured in traditional evaluation frameworks for renewable energy projects. With improved access to energy, enterprises reported having better information on markets, new opportunities, and a greater ability to meet customer needs. This can also enhance the ability to anticipate and manage shocks, including tapping opportunities in the future. Entrepreneurs are also able to increase their time spent on innovation, business development, and product diversification as result of having access to reliable and sustainable sources of energy. Innovation and diversification are important climate risk management strategies.

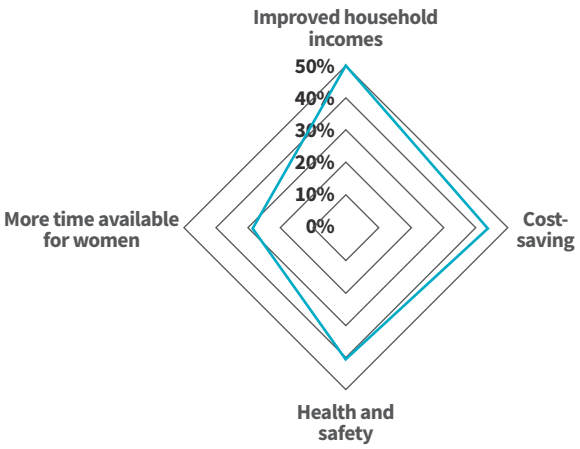
Improved entrepreneurial and market orientation leads to **positive changes in the local economy**, including improved household incomes (in 16 out of 32 cases), increased cost savings due to the switch from kerosene or diesel to RE and hence higher profitability (14 out of 32), enhanced health and safety outcomes (13 out of 32), and better living conditions for women due to reduced drudgery, freeing up time for other activities (9 out of 32) (Figure 6). Renewable energy solutions also provide environmental benefits by reducing the use of traditional fuels, hence slowing deforestation, reducing indoor air pollution, and mitigating greenhouse gas emissions.

3.1.2 Ecosystem for renewable energy and resilient enterprise development

The systematic review further analysed the factors that need to be in place to realise the benefits of renewables in resilient enterprise development. It indicated that finance, partnerships, skill development, and technology choices are key ingredients (Figure 7).

[3] Out of the 32 cases, 11 had a regional focus (HKH) and six projects were representative of mountain contexts. The other 15 were outside the HKH.

FIGURE 6 RENEWABLE ENERGY'S CONTRIBUTION TO THE LOCAL ECONOMY



ACCESS TO FINANCE

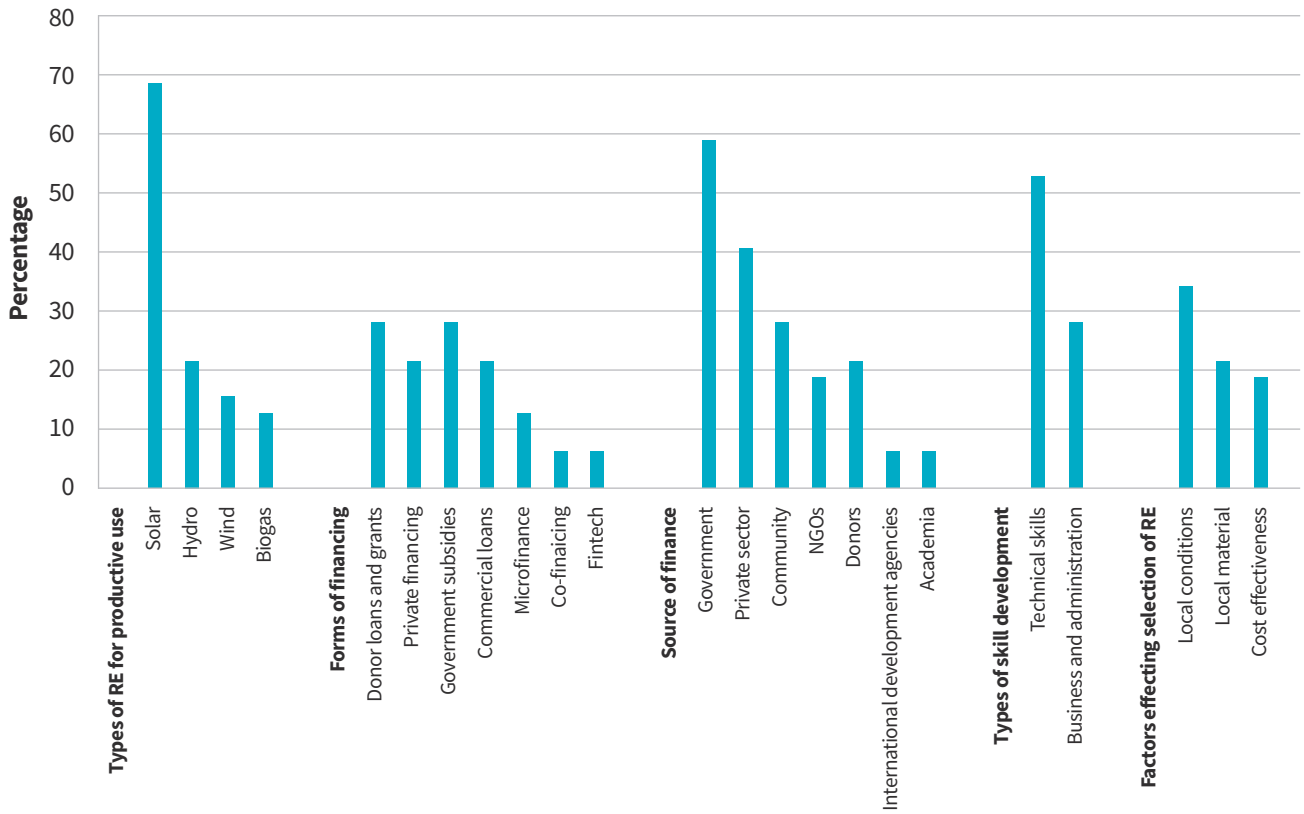
Access to finance is key to the uptake of renewable energy in the development of mountain enterprises. The financial ecosystem, including access to the banking infrastructure, intermediaries, and various products (for example, loans, deposits, and insurance), varies greatly from context to context in the mountains. Among the cases analysed, several financial instruments had been made available to support the deployment of renewables. The most common ones included concessional loans and grants from donor agencies and governments (9 of 32 cases), commercial loans, and private equity financing.

Four cases explicitly aimed at deploying renewables for the development of new enterprises. In these cases, financing for productive end-use was found to be dependent on several socio-economic factors such as ownership of agricultural assets, remittances by family members working outside the country, savings, and access to machinery and appliances.

Co-financing has also been reported in some cases, with a combination of public financing (grants and loans), private capital, and community contributions. While grants and capital subsidies enable enterprises to meet the upfront costs associated with the installation of renewable energy infrastructure, concessional loans, co-financing arrangements, and private investment (involving both equity and debt) provide crucial finances for the growth of enterprises.

In terms of financial intermediaries, microfinance institutions and fintech-based solutions such as mobile money improve access to financing for enterprises. To overcome the challenges of accessing finance, innovations in business models, such as pay-as-you-go,

FIGURE 7 FACTORS THAT INFLUENCE RENEWABLE ENERGY'S CONTRIBUTION TO ENTERPRISE DEVELOPMENT



rent-to-own, and direct purchase with cost share, are increasingly being offered and adopted.

PARTNERSHIPS

Partnerships play a key role in the uptake of renewable energy solutions in mountain enterprise development. Given the complexity and multi-stakeholder nature of economic value chains, a range of partnerships is required to support research and development to design innovative and sustainable business models, to strengthen the capacities of actors in the value chain, and to promote investment in resilient enterprises.

In nearly 60 per cent of the cases under review, it was found that governments are the key stakeholders in supporting the adoption of renewables for enterprise development. Besides introducing enabling policies, in many cases the governments offered financial incentives, set up mechanisms for private sector participation in the delivery of renewable energy solutions, introduced product certification, and forged public–private partnerships (PPPs) to scale up deployment. Several cases also demonstrated the crucial role played by local governments and village committees in enhancing local ownership and the long-term sustainability of renewable energy projects.

Partnerships between service providers, community-based organisations, and non-governmental organisations (NGOs) were also seen to play a crucial role in creating a holistic ecosystem for enterprises to gain from modern forms of energy. Such partnerships also helped improve the skills base and access to markets. By placing value on strong partnerships between stakeholders, financial institutions can strongly influence the sustainability and long-term impacts of renewable energy on enterprises.

SKILLS TRAINING

In the cases analysed, the most emphasis (17 out of 32 cases) was given to the acquisition of technical skills such as installation, maintenance, and repair of RE infrastructure. This was followed by business, administrative, accountancy, management, and marketing skills (9 out of 32). The case studies showed that training was needed not only for end-users but also for government officials, employees of financial institutions, and service organisations such as technology providers.

TECHNOLOGY CHOICES

Eleven of the 32 projects justified the use of one renewable energy option over the others, with local conditions such as availability of the resource or local material being the most common factor (7 out of 11), followed by cost effectiveness (6 out of 11). In the cases from the HKH region, biogas and hydropower technologies were the preferred options. The adoption of solar technologies for productive use by enterprises appears to be limited in mountain regions. Several factors could be contributing to this – the relative maturity of biogas and micro hydro in the region and their ability to provide higher amounts of energy needed for productive applications. It is also possible that of a number of solar projects being deployed in the region are not yet documented in the literature. In this case, field interviews would be useful in bridging this knowledge gap.

This working paper is part of an ongoing effort at documenting the deployment of renewable energy technologies in productive enterprises. For the purposes of this study, the focus is on-farm and off-farm enterprises that are, or have the potential of, making use of renewable energy for value addition. The remainder of this chapter will analyse three value chains from the HKH – bamboo in Bangladesh and Myanmar, yak milk in China and Bhutan, and tourism in Nepal and India – with the objective of highlighting the energy needs in each segment, existing energy flows, and the opportunities for renewables to strengthen constituent enterprises.

3.2 Bamboo value chains from Bangladesh and Myanmar

Bamboo – often referred to as green gold – is a fast-growing plant that can grow under a variety of climatic conditions. It offers several benefits, such as maintaining soil stability, reducing deforestation, and aiding carbon fixation, and is a source of food, biomass, and economic opportunities for rural communities. Using bamboo is an age-old practice within the HKH region for the construction of houses, furniture, mats, handicrafts, flooring, mat boards, parquet, scaffolding, and charcoal production. Different units of MSMEs have sprung up across the bamboo value chain, involving households, family-owned businesses, cooperatives, and private companies.

Bamboo offers tremendous potential to establish enterprises and create employment opportunities both for skilled and unskilled rural people. However, despite bamboo being a major livelihood activity in the rural areas of the HKH region, its potential for value creation is largely untapped. Traditional processes of bamboo production and processing, developed over generations, are largely followed, with a limited use of modern technologies. Furthermore, the lack of reliable supplies, know-how, and uniform quality has hindered

the commercial development of products and access to new markets (Karki et al. 1997). For bamboo enterprises to improve productivity, raise incomes, and diversify their products to tap into high-value markets, access to reliable and affordable energy will be a crucial input at each stage of the value chain.

To understand the energy flows within the bamboo value chains in the mid-hills of the HKH region, two bamboo enterprises – one each in Shan State in Myanmar and in the Chattogram Hill Tracts (CHT) region in Bangladesh – were analysed (Box 2). As part of the primary data-gathering effort, key informant interviews and focus group discussions were conducted with a wide range of stakeholders to understand key opportunities for renewable energy integration and prevalent challenges.[4]

In Bangladesh, the bamboo sector has played a key role in income-generating activities for the rural poor in general and women in particular. Further, logging restrictions has facilitated a transition towards bamboo-based goods, such as furniture, resulting in more incomes and jobs in rural communities across the value chain (INBAR 2015). In Myanmar, bamboo's traditional uses include the construction of homes and bridges, the manufacturing of furniture, woven products, and handicrafts, and the production of foodstuffs.

BOX 2

BAMBOO ENTERPRISES STUDIED IN MYANMAR AND BANGLADESH

Primary data-gathering in Myanmar focused on three village clusters in the Let Maung Kwe village tract in Nyaung Shwe township of Southern Shan State, where major bamboo cultivation takes place. It is a hilly township and the major livelihood activities in this area relate to agriculture. The three village clusters selected were Kyaungnar, Kyaungtaung, and Enpak. Key informant interviews were conducted to understand the bamboo value chain from different actors comprising producers, processors, and entrepreneurs.

In Bangladesh, the hilly areas of the CHT are a major source of bamboo. Chattogram has three districts – Rangamati, Bandarban, and Khagrachari. The hilly districts are isolated and remote, with communities lagging behind in terms of socio-economic indicators. The CHT is the focus of a government project on 'Production of Quality Bamboo for Livelihood Support of Backward Communities'.

3.2.1 Energy in the bamboo value chain

The bamboo value chain primarily comprises three stages – primary production, processing, and marketing (Figure 8). The production stage typically involves the tasks of planting, cutting, and stripping the bamboo, which are undertaken manually in Bangladesh and Myanmar. Processing activities differ from context to context depending on the end-product. For handicrafts, the processing involves cutting the bamboo into the required shape, treating the bamboo culms, cutting, stripping, smoothening, and polishing. For the manufacture of bamboo furniture, the processes involve cutting, stripping, smoothening, compacting, shaping, and polishing. Marketing activities involve market development, creating market linkages, packaging, transport, and retail sales.

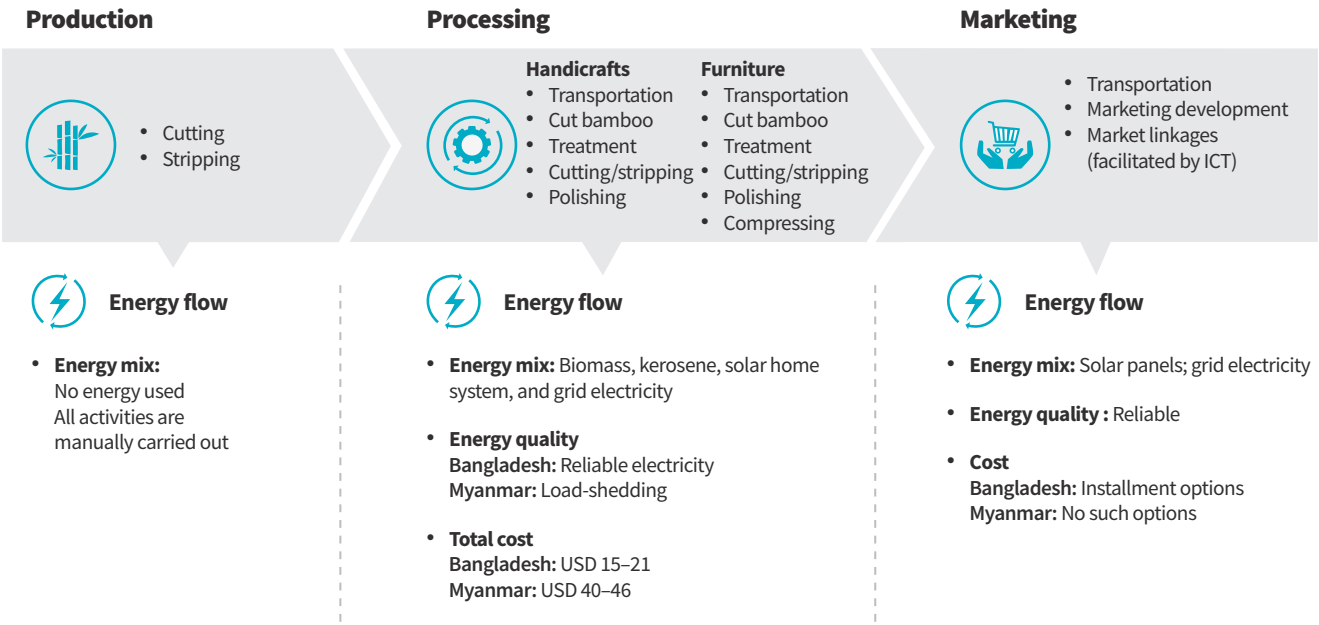
The energy flows in the bamboo enterprises in Bangladesh and Myanmar are similar in nature. During the **production stage**, farmers need to know the bamboo species appropriate for different purposes, and gain the knowledge and skills needed for cultivation and harvesting. In this stage, the majority of the processes are manual, with limited energy inputs.

The major energy gap in the bamboo value chain exists at the **processing stage**. In both Bangladesh and Myanmar, the handicrafts persons have local knowledge of producing bamboo mats and crafts, which does not require much energy inputs. However, the demand for mats and bamboo crafts is decreasing, while the demand for housing construction material and bamboo flooring is soaring in both these countries and internationally. Diversifying their product portfolio to meet changing demand requires energy inputs for powering various processing activities and to generate heat for curing, energy that is difficult to access.

Among the cases studied in Myanmar, one found that bamboo enterprises in rural areas undertake most activities manually; distributed renewable energy (DRE) is mainly used for lighting. The access to lighting enables improved productivity in the evenings. Making handicrafts is a part-time activity carried out by the women of a household during the evenings, and which is only possible due to the solar lighting. Further, biomass is a major energy source required for processing bamboo products (curing). Women and children have the task of collecting biomass from the local forest. If households want to operate an

[4] Stakeholders consulted and the criteria for participation in the study are given in Annex 1.

FIGURE 8 ENERGY FLOWS ALONG DIFFERENT STAGES OF THE BAMBOO VALUE CHAIN



enterprise dealing with bamboo products, they use diesel generators, which are noisy and emit smoke. These rural entrepreneurs have to travel to the market thrice a week to collect diesel. The market is located about eight kilometres away from the villages.

Bamboo enterprises in towns in Myanmar that have access to the electricity grid are better equipped to make products that are in demand, such as furniture and construction material. Their monthly energy costs are between USD 40–46. However, even in urban centres, these enterprises face power supply interruptions of 12 hours a day during the summers. This hampers their ability to produce during summer, which is the peak season for bamboo product development. Due to their lack of awareness about available technologies, these households do not have any other alternative to tackle the supply disruption.

In Bangladesh, rural households generally sell the bamboo poles to the market. Some households with local skills make chicken cages and mats for household use. In urban areas, where they have access to electricity from the public grid, enterprises make a variety of bamboo products, including furniture, construction material, and souvenirs. They use diverse tools that require electricity supply. They also use kerosene for shading the bamboo products to make them attractive. The survey found that the monthly costs of energy supply for a bamboo enterprise in urban centres in Bangladesh was in the range of USD 15–21.

In the **marketing** of their products, bamboo enterprises have benefited from access to telecommunication services. Distributed renewable energy solutions enable mobile phones to be charged, allowing enterprises to benefit from information-sharing and exchange across local markets for various products. Some enterprises have utilised internet platforms to establish direct market linkages through online portals for various bamboo products.

3.2.2 Potential of RE and energy efficiency for switching fuel and scaled-up access

The governments of Bangladesh and Myanmar introduced targets and plans to reach universal electricity access by 2021 and 2030 respectively. Both countries recognise the role of DRE solutions to reach the target. However, an explicit focus on linking this with productive applications in enterprises such as bamboo units is limited.

In Bangladesh, FGDs highlighted the opportunities for mini-grids to supply energy for both consumption and production in River Island in the CHT. Connecting rural enterprises with mini-grid supply reduces the tariff burden on household consumers substantially, which can otherwise be about BDT 30 per unit. The enterprises can also utilise off-peak generation, which further ensures the long-term sustainability of the mini-grids (Bhattacharyya 2015).

In Myanmar, the site studied – Shan State – has seen the most widespread deployment of solar systems as compared to any other region in Myanmar. They mainly provide electricity to charge mobile phones and for lighting, used to support income-generation

activities in the evenings, such as weaving and making bamboo mats. However, such technologies are yet to be directly employed for operations in rural enterprises, such as powering tools and running machinery for processing activities. Awareness among the rural communities of other decentralised technologies was found to be limited. Those engaged in bamboo-processing underlined that with sufficient access to energy, they could transition from making basic handicraft products to furniture and construction material, which are in high demand.

In addition to augmenting energy supply, attention needs to be paid to the efficiency of the tools used in bamboo production and processing. A number of machines are required for cutting, splitting, drying, slicing, pressing, polishing, and other bamboo-processing needs. Improving the efficiencies of productive appliances would reduce both the energy and overall costs for the enterprises. This would directly improve the economic attractiveness (that is, the payback periods) for distributed renewable energy interventions.

3.2.3 Energy and its contribution to enterprise resilience

The study also sought to gather evidence regarding the impacts of energy on enterprise resilience examined through the prisms of market and entrepreneurial orientation.

MARKET ORIENTATION

Profitability: Evidence of a growth in profits was seen with the adoption of DRE solutions. In Myanmar, profits made by the bamboo enterprises grew by 20 per cent over a 4–5-year period after gaining access to electricity. Further, the products are more durable and carry a 15-year guarantee. In Bangladesh, an enterprise selling bamboo furniture, Ashika Craft, has trebled its profits compared to what it made earlier from selling bamboo poles.

Improved productivity (efficiency): The lack of energy technology has hampered the productivity of the bamboo handicrafts persons as all the activities are carried out manually, reducing productivity.

Increased production (volume): Access to energy enables higher levels of production since greater productivity allows for a greater volume of products to be produced in the same time. Bamboo enterprises lacking access to energy are compelled to carry out production manually, which is time-consuming. As a result, their production is significantly hampered.

ENTREPRENEURIAL ORIENTATION

Product diversification and innovation: The lack of reliable energy access hampers the ability of people to diversify into, and make new products that have market demand. Although the farmers in Myanmar want to develop products from the bamboo grown in their homestead gardens, the lack of access to energy and technology is an impediment, resulting in raw bamboo being sold at low prices to enterprises further along the value chain. Similarly, bamboo handicrafts persons looking to develop modern products with high demand in the market, such as furniture and parquet, are hampered by the lack of access to technology and energy.

Improved quality: Tapping into the local and international markets for bamboo products requires a certain level of consistency and quality to be maintained by small handicrafts producers. Energy and technology need to be integrated at the processing stage to ensure this.

Ability to anticipate and plan for shocks: Bamboo enterprises are mainly reliant on the producers/suppliers of quality bamboo. However, in the absence of the reliable energy supply needed to access different communication channels, the bamboo producers are themselves left unaware of important information with respect to the bamboo plant. For instance, in the case of its flowering, producer groups are unable to anticipate and plan for shocks or unexpected events, as a result of which all the nodes of the bamboo value chain get impacted.

Business development: In both Bangladesh and Myanmar, it was found that telecommunication services, enabled by access to electricity, strongly support market linkages. The household-level bamboo enterprises were well connected to middlepersons or traders to sell bamboo poles or other products. In Myanmar, bamboo handicraftspeople displayed their products on Facebook, where they would also gather orders from clients. Communities in both Bangladesh and Myanmar reported the positive role of renewable energy in helping them connect better to the market and enhance business development.

3.2.4 Ecosystem to support the contribution of renewable energy to the development of resilient enterprises

The two bamboo value chain cases studied, in Myanmar and Bangladesh respectively, highlight the role access to reliable and affordable energy can play in enterprises' ability to increase productivity, diversify products, raise incomes and, as a result, become more

resilient. The analysis also points to key aspects of an ecosystem that supports achieving these outcomes via the adoption of renewable energy by enterprises.

SUPPORTIVE POLICIES

A number of intersecting policies impact the adoption of renewables in the bamboo value chain. Policies related to energy access, MSME development (particularly in the mountain context), agriculture, and forest management directly impact enterprises operating across the bamboo value chain. In both Myanmar and Bangladesh, the focus on improving access to electricity for lighting through solar-based solutions is seen to positively impact the ability of small enterprises to undertake income-generating activities after daylight hours. To actively support productive uses of energy, utilizing DRE solutions as inputs into certain production and processing activities ought to be incentivised through targeted policy interventions. It will yield higher positive outcomes for enterprises.

In Myanmar, the Forest Law of 1992 classifies bamboo as timber, subjecting it to regulations related to the transport of raw bamboo from one township to another. It also lays down that cutting more than 100 poles of bamboo requires permission from the Forest Department. Under such law, the trading of bamboo is not beneficial to rural communities and, therefore, the use of bamboo to produce value-added products can better enhance rural livelihoods. Tailored bamboo-based livelihood development programmes supported by DRE solutions can be important catalysts for accessing new markets and income-generation by local communities.

ACCESS TO FINANCE

Access to finance is a critical component for enterprises to adopt renewable energy solutions. In Bangladesh, a strong financing ecosystem for stand-alone solar systems has been developed over the past few decades. It builds on the extensive network of microfinance institutions, and offers tailored financial products to even the remotest communities for solar home systems (SHSs). The programme has been tremendously successful; as of January 2019, there were over 4.1 million SHSs in place, covering about 12 per cent of the country's population. It has been implemented by a non-banking financial institution, Infrastructure Development Company Limited (IDCOL), working with a network of partner organisations that deliver the technology and finance for solar home systems. Leveraging the success of the solar home system programme, dedicated initiatives that focus on solar water pumps and mini-grids have also been launched by IDCOL.

In the communities living on Rangamati River island that were covered under this study, households had received SHSs through Grameen Shakti, a partner organisation under the IDCOL programme. Households pay about 15–20 per cent of the total cost of the system upfront, with the remainder to be paid back over 36 months through regular instalments. The tailored financial support enables households to afford solar systems that enable lighting, cooling, and charging mobile phones, and hence raise the quality of life.

A key challenge, however, has been to financially support the use of such systems for productive uses. There are several reasons for this, including a lack of awareness regarding financial support, limited access to skills building programmes, and the absence of an entrepreneurial orientation, limiting the deployment of technologies for enterprise creation. Financial institutions (FIs) also require capacity-building towards an improved understanding of value chain activities, enterprise cash flows, and market opportunities to devise appropriate schemes for various rural livelihood applications.

In Myanmar, financial schemes to support the deployment of renewable energy for productive uses in enterprises are less developed than in Bangladesh. The FGDs highlighted the fact that all the solar systems, ranging from 20 W to 120 W, were acquired by households after paying an upfront price. They are primarily used for lighting and charging mobile phones. Diesel generators are used for powering productive appliances, and the diesel needs to be transported thrice a week from nearby markets. Awareness regarding DRE technologies for productive uses is limited, and there are currently no financial incentives available for bamboo enterprises to adopt RE solutions.

It is important that the financial support for DRE interventions is closely coordinated with support for the adoption of energy-efficient processing equipment. One without the other will yield limited outcomes for enterprise resilience. Enterprises should be able to access asset-based financing for productive appliances. Alternatively, they should be able to avail of packaged financial solutions that combine stand-alone RE technologies with a portfolio of productive appliances. Sector-level financing programmes should also cover energy supply as a key component, in addition to funding for other aspects of bamboo enterprise development.

SKILLS DEVELOPMENT

Equipping bamboo enterprises with the technology and access to markets is necessary but insufficient;

an explicit focus on skills development and capacity-building is also needed. Developing new bamboo products requires upskilling from creating traditional handicrafts to, for instance, making bamboo furniture and flooring tiles/parqueting requiring the use of new tools and processing techniques. In the Nyaung Shwe township in Myanmar, it was found that lack of skills in using the tools needed hindered the development of bamboo products in rural areas, particularly by women. Training events conducted by the Small-Scale Industries Department (SSID) and bamboo associations in Myanmar focus on the development of basic skills; however, advanced skills development programmes that focus on rural areas are needed to develop products that are in high demand in local and international markets. In Bangladesh, the Chattogram Hill Tracts Development Board is partnering with a private sector entity, Ashika Craft, to train locals to make bamboo handicrafts.

TECHNOLOGY CHOICES

In Myanmar, rural households in the areas studied are currently off-grid. However, as per the Myanmar National Electrification Project, the villages where the study was conducted (Pantin, Thayetpin, Kyaungnar, Kyaungtaung, and Enpak villages in the Let Maung Gwe village tract, Nyaung Shwe township) will be connected to the public electricity grid in the next 2–3 years. In the interim, as the township waits for the grid to be set up, households are purchasing solar systems from the local market to meet consumption needs. During this time, the intention is to continue making handmade bamboo products, with no technology integration. Discussions with bamboo handicrafts people here highlighted the fact that even with access to the grid, the stability of supply was not guaranteed through the year. During the summer season, household enterprises face load-shedding up to 13 hours a day, resulting in them struggling to meet clients' orders. Such grid-connected urban entrepreneurs also using alternative sources for electricity supply during summer.

From a technology perspective, it is evident that DRE solutions could still bring value to bamboo enterprises that are not connected to, or underserved by the grid. For instance, reliable grid-based access is unlikely to be achieved even in the long-term in the area studied in the hilly regions of the CHT in Bangladesh. In such a scenario, efforts are needed not just to deploy DRE solutions for consumption uses but also to support livelihood clusters (for example, based on bamboo), either as stand-alone systems or mini-grids.

PARTNERSHIPS

Cross-sector partnerships will play a crucial role in the development of DRE solutions to support bamboo enterprises. Tailored partnerships that focus on the design of technology solutions, their financing and delivery, implementation, and long-term operation and maintenance are needed. In Bangladesh, IDCOL, along with partner organisations, supports the financing and implementation of DRE solutions, including mini-grids, that can contribute to bridging the energy gap for bamboo enterprises. In Myanmar, the Department of Rural Development works closely with private companies to deploy both off-grid solar and solar mini-grids that are mostly subsidy-driven.

Further, partnerships are also needed to support market linkages for new products, which becomes feasible through improved access to energy. In Myanmar, for instance, the Small Scale Industries Department trains rural farmers to make bamboo products as well as assists the Tourism Board in creating an international market for local bamboo products.

3.3 Yak products value chains from Bhutan and China

Yaks are climate-hardy mountain animals that can adapt to varied temperature ranges. They are found predominantly in the Himalayan range and in the Qinghai–Tibetan Plateau at altitudes ranging from 2,500 to 6,000 metres above mean sea level (masl). In Bhutan, yak herders constitute about 5 per cent of the population, whereas in the Tibetan Plateau in China, 25 per cent of the population are yak herders. Yak herders still practice a nomadic lifestyle, migrating to summer pastures in the highlands in the warmer months, and to village settlements at lower altitudes during the winters. Yak herding is therefore a manifestation of the culture associated with the migratory lifestyle of highland mountain communities.

Yaks also play an important role in the livelihoods of mountain communities and the natural ecosystems there. They provide niche products such as milk, butter, cheese, meat, and wool, are used for transport, as well as being a major source of fuel (dried dung cakes). They contribute to about 80 per cent of the household incomes, and are a major dietary source in terms of protein and fat for these mountain communities. Compared to cow milk, yak milk contains higher fat, crude protein, lactose, dry matter, vitamin B, and free amino acids and have a lower cholesterol content (Alexandraki et al. 2016).

To understand the energy flows in the yak products value chains in the HKH region, case studies were carried out in three districts in Bhutan (Paro, Thimphu, and Haa) and in Hongyuan county of Sichuan province, China. The sites for study in both countries were chosen based on different ecosystem factors that shape context-specific yak products value chains with the objective of identifying energy flows and the contribution of renewable energy to the development of resilient enterprises. The following subsections briefly summarise the energy flows across the yak products value chain, the ecosystems shaping renewable energy's contributions, and the scope for the development of resilient enterprises in Bhutan and China.

3.3.1 Energy flows in the yak products value chain

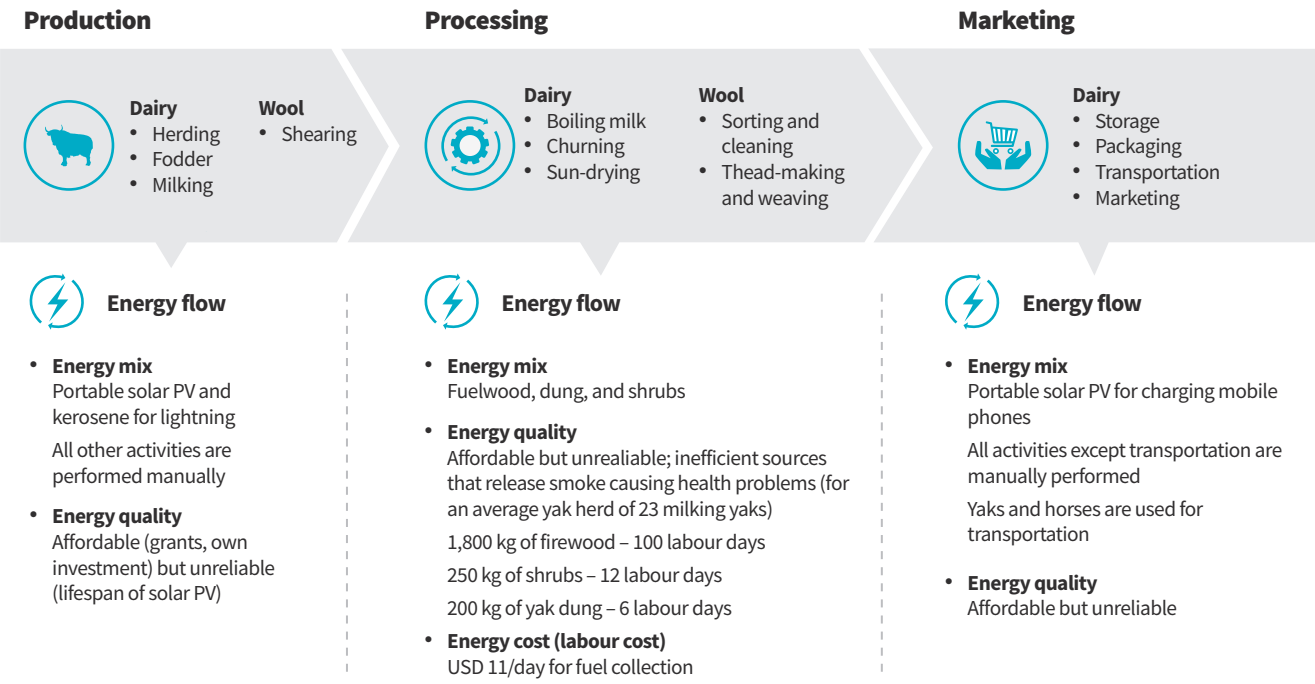
A) Yak products value chains in Bhutan: In Bhutan, nomadic pastoralists from 11 districts rear yaks in the high-altitude northern areas ranging from 2,800 to 5,000 masl (Wangda 2016). There are altogether over 41,500 yaks and nearly 9,000 dzos and dzoms (hybrids of yaks and local cattle) in the country (MoAF 2017). The alpine meadows in the remote highlands provide summer grazing grounds for the yaks, whereas the winter grazing grounds are located near their villages. The grazing grounds in spring and autumn are located along the transit routes used for the seasonal movement of yaks.

In recent years, yak herding has become less attractive to Bhutanese nomadic communities, especially the youth. This is due to several challenges such as the poor road network, limited access to energy and information and communication technologies (ICT), the lack of technical capacities and skills in processing yak products, poor yak healthcare and yak inbreeding, and shortage of household labour. In addition, climate change has been adversely impacting yak populations as rising temperatures affect yaks' health given their sensitivity to higher temperatures (Deneen 2018). Notwithstanding these challenges, yaks provide varied livelihood opportunities, given favourable policies, appropriate technological interventions, and the development of a cottage industry for yak products (Wangda 2016).

The yak products value chain primarily comprises three stages – primary production of products, their processing, and marketing (Figure 9). Over the last ten years, Bhutan produced 178,670 million tonnes (Mt) of yak milk, 7,932 Mt of butter, 16,643 Mt of cheese, 1,871 Mt of hard cheese (chugo), and 1,863 Mt of yak meat. There are no official records available for yak wool production. In this yak products value chain study, we mainly focused on dairy products and wool production to assess energy use and demand.

In the **production stage**, the major activities include yak herding, fodder collection, and milking, whereas the production of wool entails the shearing of both coarse and fine wool. Although access to energy could have improved the productivity and the quality of

FIGURE 9 ENERGY FLOWS IN THE YAK PRODUCTS VALUE CHAIN IN BHUTAN



production, all these activities are carried out manually by the herders. Presently, the herders use solar PV for lighting their living space and for charging mobile phones. The solar PV systems are provided by the Department of Livestock at no cost, but if damaged, the herders would need to either repair or replace them at their own cost. They also use kerosene, fuelwood, and yak dung for cooking, and lighting and heating up their living space.

Activities at the **processing stage** include boiling the yak's milk, churning it, and sun-drying yak products, whereas for wool the major activities are sorting, cleaning, thread-making, and weaving. The herders mainly rely on traditional and inefficient sources of energy such as fuelwood, yak dung, and shrubs for processing. A significant amount of time and money is incurred to access these energy sources. For instance, interviews revealed that managing an average-sized herd of 23 milking yaks needed an investment of up to USD 1,300 per season, to pay for the 118 days of labour required to collect fuelwood, dung, and shrubs. The herders interviewed also indicated that such traditional sources did not provide sufficient energy to process higher volumes of milk and produce quality products. They also had adverse impacts on the health of household members due to indoor air pollution, especially of women, who are primarily responsible for the milk processing.

The activities related to **marketing** the yak dairy and yak wool products include storage, packaging, transportation, and marketing. Most of these activities are performed manually by the herders themselves. They use mobile phones to access market information. Yaks and horses are used for transportation. The herders usually sell their dairy products in the local markets and sometimes to middlemen, who then transport those products to the capital, Thimphu. Woollen products such as rope, sacks, tents, and some clothes are used by the herders themselves and not sold in the market, unlike in China.

With limited infrastructure and processing facilities in the rugged terrain of Bhutan, the nomadic herders are the main actors across the yak products value chain, who produce, process, and also market their dairy products. A few middlepersons such as wholesalers and retailers sometimes sell dairy products to shops in local towns. Due to the lack of access to sufficient and reliable modern forms of energy, the processing of the high-volume yak milk produced during the summer is tedious and time-consuming. The hygiene and quality of the products tends to get compromised as well. The decentralised nature of the yak products value chain makes it suitable for distributed renewable energy solutions, as compared to a cattle-based dairy value chain, which is very different given the sedentary nature of rearing and involvement of a wider range of actors at different stages of the value chain in the latter case. Box 3 presents a comparative analysis between the two value chains to understand the key differences in energy flows and infrastructural requirements – social, physical, and economic – that influence outcomes.

BOX 3

INSIGHTS FROM CATTLE-BASED DAIRY VALUE CHAINS IN BHUTAN

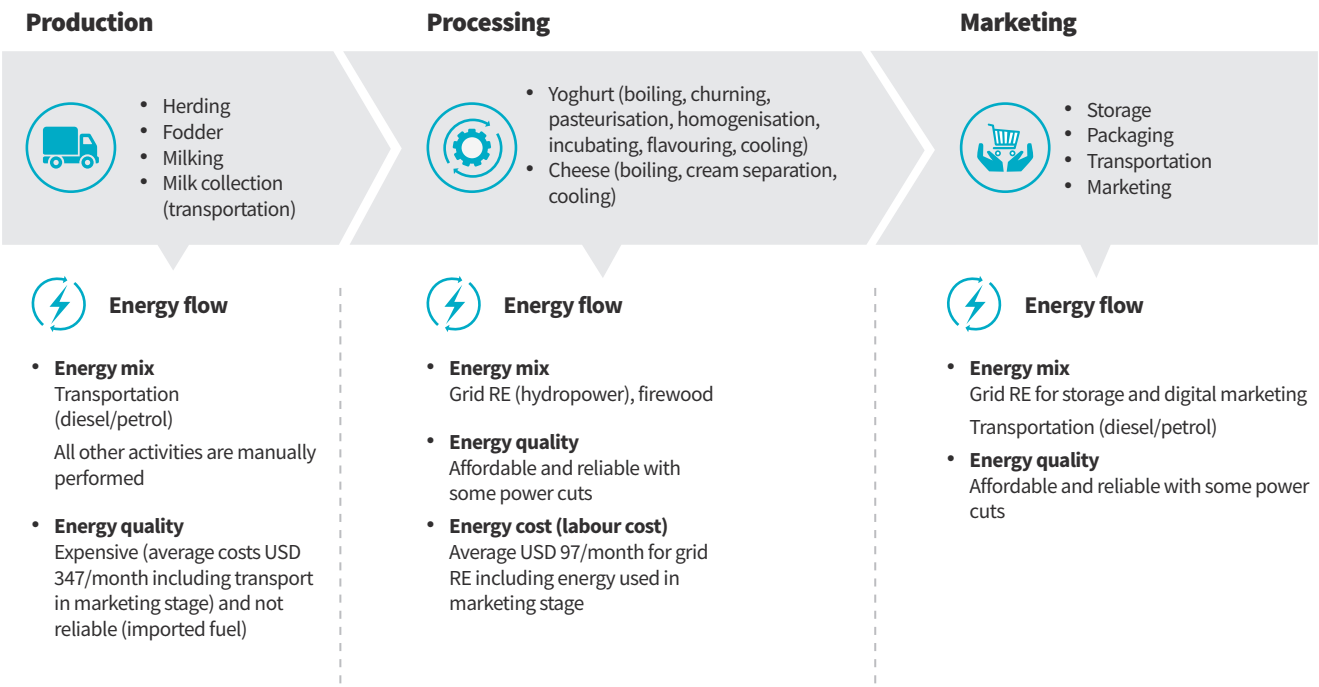
A key difference between yak- and cattle-based value chains in Bhutan is that cattle-rearing takes place close to villages, unlike mobile yak-herding that is done in the high mountains. The collection of cattle milk from more than one village makes it easier to provide sufficient volumes for milk-processing units. Furthermore, the processors have better access to infrastructure, such as grid-based electricity, road networks, communication, and opportunities to diversify milk products. These include soft cheese, butter, yoghurt, and cottage cheese (paneer).

The stages of the cattle-based dairy value chain in Bhutan – production, processing, and marketing (Figure 10) – are similar to those for the yak products value chain illustrated in Figure 9. Local entrepreneurs/enterprises usually collect milk from agriculturalists in several villages for processing. They rely on diesel and petrol for transportation, spending approximately USD 347 per month on average to collect the milk and transport the finished products to the market.

Further, the processing entities rely on grid-based electricity (primarily derived from hydropower) to process the dairy products. The electricity in rural areas is subsidised by the government – it is free for the first 100 units consumed, 2.1 US cents per unit for 100–200 units of consumption, and 4.9 US cents per unit above 200 units. Representatives of the small and medium dairy enterprises who were interviewed said they invested approximately USD 97 per month on electricity to process the dairy products, for storage (refrigeration), and digital marketing.

Most of the enterprises import packaging products from India. Several drew attention to the frequent power cuts and said they needed a more reliable supply of energy to support growth in their enterprises. Consequently, some use diesel generators, given the high installation costs of renewable energy systems such as solar PVs which are not affordable without funding support in the form of capital subsidies or concessional loans.

FIGURE 10 ENERGY FLOWS IN THE CATTLE-BASED DAIRY VALUE CHAIN IN BHUTAN



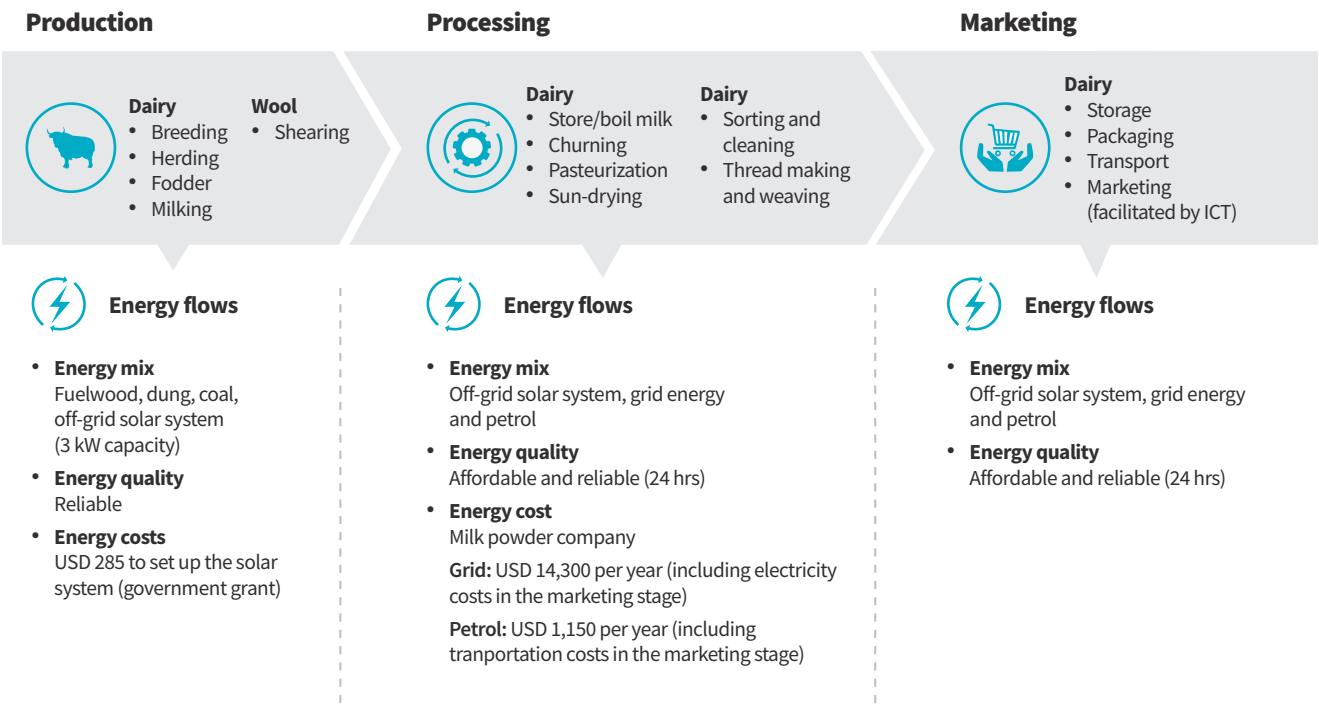
B) Yak products value chains in China: The yak is an iconic species of the Qinghai–Tibetan Plateau in China. Yaks are found in the rangelands of six provinces in western China – the Tibet Autonomous Region (TAR), Qinghai province, Sichuan province, Gansu province, Xinjiang Uygur Autonomous Region, and Yunnan province. There are altogether 13 yak breeds officially recognised in these provinces (Ping and Xeuzhi 2016).

The processed yak dairy products in China include milk powder, ultra-high temperature (UHT) milk, yoghurt, butter, and chhera (sun-dried buttermilk). Yak herders also sell live yaks to meat companies; varieties of processed yak meat are available in the markets. New products such as yak milk-based ice cream and cosmetics are currently undergoing quality certification testing processes before being made available in the markets. Yak wool products are mostly used by the herders themselves, although they do sell raw wool to middlemen. As yak fibre has 50 per cent higher heat retention capacity than other wool varieties (sheep, angora), it is in high demand among mountain populations in the Himalaya.

The functions across the yak products value chain in China are similar to those in Bhutan and comprise the production, processing, and marketing stages (Figure 11). However, unlike in Bhutan, the yak products value chain in China involves diversified actors along different stages of the value chain. The major activities in the **production stage** include breeding, herding, fodder collection, and milking; wool production includes the shearing of coarse and fine wool. Most of these activities are carried out manually, although solar-powered automatic milking machines have been recently deployed by some for milking yaks. The herders still use fuelwood, dung, and coal for heating purposes, whereas they have an off-grid solar home system (of 3-kilowatt capacity) for cooking, watching television, and powering other electrical appliances. The solar home system was provided in the form of grants by the State Grid Hongyuan County Power Supply Corporation in cooperation with the Department of Livestock, and the herders have to repair or replace it on their own in case of any damage to it.

The activities related to the **processing stage** in the dairy value chain include the collection of fresh milk from herders during the summer (June–October), boiling milk, storage, pasteurization, churning, and sun-drying chhera. In the value chain for wool, the major activities include sorting, cleaning, thread-making, and weaving. Some of these processing activities are carried out by the herders for their own household consumption, mainly butter and chhera. They use solar-powered separators for churning the milk and producing cream, and sell the products they don't consume in local markets. Processing companies such as the Hongyuan Milk Powder Company and the yak farmers' cooperative use solar-powered chilling vehicles to collect fresh milk from the yak herders and use grid-based electricity to process it. The milk powder company spends about USD 71,150 annually for transportation and USD 14,300 for electricity, including the transportation costs incurred during marketing.

FIGURE 11 ENERGY FLOWS IN THE YAK PRODUCTS VALUE CHAIN IN CHINA



For yak wool collection, enterprises such as Himal Yak Company rely on suppliers from a large trading centre based in northern China due to the practical challenges associated with directly collecting raw yak's wool from the nomadic herders across the Qinghai–Tibetan Plateau. The company then sells that raw wool to international partners and domestic collaborators, who make woollen products such as shirts, suits, scarves, shawls, and inner trousers. The major challenge these companies face is spinning the yak wool, which is relatively more difficult compared to cashmere wool. However, advanced technological solutions are available in China to resolve this.

The major activities in the **marketing stage** include storage, packaging, transporting the processed goods to markets, and using ICT platforms. Companies such as the Hongyuan Milk Powder Company and the yak farmers' cooperative have their own marketing outlets. They also supply products to supermarkets and use online marketing platforms. The Hongyuan Milk Powder Company does packaging during winter when the processing facility is closed due to the unavailability of enough yak's milk. They purchase packaging material from suppliers in Chengdu and Xian, whereas the dairy products are usually sold in South-western China and in Hong Kong. The yak farmers' cooperative has its own outlet in Hongyuan. It also supplies yak milk-based yoghurt to local hotels and the airline company, Air China. The Himal Yak Company, however, does not have its own outlets for marketing yak wool outfits. It collaborates with retail outlets in downtown Chengdu, and also uses online digital platforms for marketing. Some yak herders have formed cooperatives in China, and sell yak wool products in local markets.

3.3.2 Potential of RE and energy efficiency for switching fuel and scaled-up access

The case studies from Bhutan and China offer insights into the key energy gaps that enterprises in the yak products value chain face and the opportunities that renewable energy solutions could provide. RE solutions have been adopted in both cases, although in Bhutan, their use has been limited to only providing lighting, while in China the milking equipment, creaming machines, and chilling vans are solar-based. A key challenge during the production and processing stages has been the provision of modern energy solutions for heating and cooking, currently delivered through the use of traditional fuels such as dung and fuelwood. In sedentary, cattle-based value chains, processing is likely to take place in areas with access to electricity. However, the opportunities to switch to stand-alone renewables-based options are available to ensure greater reliability and sufficient supply of electricity to support enterprise expansion. Biogas solutions that use livestock waste to provide energy for heating and cooking applications may also be feasible during the production stage, but would face practical challenges in the case of nomadic yak-herding.

Access to modern energy sources is also critical in establishing market linkages and supporting the diversification of yak products offered by enterprises.

Telecommunication services and online marketing and retail channels have been tapped to access markets for varied products from yaks, including various types of cheese, milk powder, and wool-based clothing, among others. The transportation of raw material, especially milk, is an important part of the value chain and the available infrastructure can have a strong bearing on the volume and quality of products that can be created. Likewise, distributed refrigeration infrastructure powered with renewable energy can expand supply chains, reduce losses, and improve product quality, while also supporting economies of scale for investments in processing infrastructure.

3.3.3 Energy and its contribution to enterprise resilience

The illustrative case studies conducted in Bhutan and China revealed that the entrepreneurial and market orientation of different actors across the value chain varied. As a result, their profitability and contribution to the local economy in a changing socio-economic context and a changing climate also differed. The renewable energy contribution to the resilience of enterprise development was therefore assessed from each case study in terms of market orientation, entrepreneurial orientation, profitability, and contribution to the local economy.

MARKET ORIENTATION

In Bhutan, yak herders face challenges in maintaining the quantity and quality of products due to a continued reliance on traditional energy sources such as fuelwood and dung for processing. Cattle-based dairy products also give rise to similar challenges. Despite high domestic demand, especially from high-end hotels, the ability of enterprises in Bhutan to meet requirements is constrained by their limited capacity to maintain volumes and quality. Amankora, an entity in Bhutan's hospitality sector, for instance, largely imports cheese and also buys 'Italian' cheese produced locally in Haa after a trading link was established through the Department of Livestock, but the quality and quantity of supply remains uncertain. Improving access to affordable, reliable, and sustainable energy supply can strengthen the market orientation of enterprises in the yak products (and cattle-based dairy) value chain in Bhutan, in particular meeting energy needs during the processing stage and tailored to the local contexts (for example, mobile solutions for nomadic yak herders).

In China, several factors contribute to the enhanced market orientation which ensures both quality and quantity of products and the ability to respond to consumer preferences and market demand. The government imposes strict quality control rules, with only certified products allowed to be sold. Enterprises that operate at a larger scale compared to Bhutan require assured volumes of raw material (milk). The Hongyuan Milk Powder Company, for instance, collects 100 tonnes of fresh yak's milk daily in summer from June to October. In winter, milk production tends to be lower and therefore the company does not collect milk from the yak herders then; it utilises this time to clean and maintain the processing plant and equipment, and carries out the packaging of the milk products. They sell their products through their own retail outlets, supermarkets, and online platforms. There are several online digital platforms selling dairy and woollen yak products.

ENTREPRENEURIAL ORIENTATION

In Bhutan, yak herders and cattle farmers have a limited capacity to anticipate and cope with climate uncertainty and market shocks, or to develop and diversify the products they offer. Without access to technology and storage facilities, yak herders in particular are unable to pasteurise and process milk to produce high-end products such as Gouda cheese, presently imported by the hospitality industry in Bhutan. Even the cattle-based dairy produce is limited in quantity and linked primarily to niche local markets. Cattle-based dairy entrepreneurs are trying to diversify into flavoured yoghurt and Italian cheese and seek local market linkages, but this is a challenge. Nevertheless, there is a high demand for dairy products, especially from yaks, and thus access to reliable, affordable, and sustainable energy along with technological support and skill development could transform the yak products value chain, as seen in China.

In China, there exists a strong entrepreneurial orientation in terms of diversified yak products, innovations, market linkages, and access to, and the use of information technologies. With different actors involved in various stages of the value chain, there have been targeted interventions to address challenges associated with the production, processing, and marketing stages. This further provides opportunities for research and innovation, and to anticipate changes better. For instance, the Chinese government, through the Department of Livestock, has supported the construction of winter shelter houses for the yaks. The Hongyuan Milk Powder Company is using modern technologies to produce four types of powdered milk targeted at different age groups based on human milk oligosaccharides (HMO) micronutrient research, along with UHT-treated milk that can be stored for up to six months at room temperature. Likewise, the yak farmers' cooperative in Hongyuan is diversifying yak

products apart from yoghurt and processed meat, to produce ice-cream and cosmetics which they plan to sell after quality control approvals and certification by the government.

PROFITABILITY AND CONTRIBUTION TO THE LOCAL ECONOMY

Yaks contribute to about 80 per cent of the household income for the majority of herding families in Bhutan. There are also several cattle-based dairy enterprises that provide jobs to local youths, who earn an average income of about USD 140 per month, plus a bonus. Most of these enterprises are able to generate 25 per cent return on investment. The adoption of RE technologies (hydropower) in the cattle-based dairy value chain has led to job creation, income generation, reduced costs, improved health and safety of workers, reduced indoor pollution, and less drudgery for women.

In China, yak herders receive several grants from the government to pay for solar-based solutions such as cream separators, automated milking machines, and improved cookstoves. A solar-powered cream separator helps herders spend only a sixth of the time usually spent on churning milk, time saved that they can put to other productive uses. In addition, financial support is also offered to construct winter yak shelters, community houses, and road networks, encouraging yak herders to enhance production and benefit economically.

Yaks contribute to about 90 per cent of household income for most herding families in China. Yak-based enterprises have created jobs and generated income for local youth. For example, the Hongyuan Milk Powder Company employs about 400 local workers during summer and about a hundred in winter, and pays them more than CNY 40,000 (roughly USD 5,600) per year, including social insurance. This company's annual revenues amount to USD 14 million a year, and their return on investment is about 10 per cent. On the other hand, the yak farmers' cooperative makes 30 per cent profit annually, and yak herders from 34 villages directly benefit from marketing their products.

3.3.4 Ecosystem to support the contribution of renewable energy to the development of resilient enterprises

The two yak products value chain cases studied, from Bhutan and China, point to the potential role access to reliable and affordable energy can play in enterprises' ability to increase productivity, diversify their products, raise incomes and, as a result, become more resilient. The analysis also points to key aspects of an ecosystem that supports achieving these outcomes via the adoption of renewable energy by the enterprises.

SUPPORTIVE POLICIES

Enabling policies and regulations play an instrumental role in supporting the uptake of renewable energy solutions. In Bhutan, policies focus on electrification – there is less emphasis on encouraging productive end-uses in rural areas – especially when it comes to the use of off-grid energy solutions. Solar PV solutions are provided to the nomadic yak herders for lighting purposes only, and hence the processing of yak products is still done using traditional fuels such as fuelwood and dung, thus compromising the quality of the products and resulting in the herders spending more time on processing those products. In China, enabling policies have supported the development of a more mature and diverse yak products value chain. They have promoted the deployment of solar-based solutions with cream separators and automated milking machines, as well as developed the broader infrastructure (for example, processing and storage facilities, winter shelters for yaks, community houses for herders, road networks, marsh gas tanks, and machinery) that enables market access and strengthens the resilience of the value chain. Where yak herders are predominantly nomadic, rental or service-based models may be created, linked to centralised infrastructure, such as shelters, community houses, and machinery, that could benefit from improved access to energy.

The development of physical infrastructure is important in addition to supplying energy, developing skills, and providing finance. In Bhutan, the infrastructure gap in the yak products value chain is larger than China's and requires specific policy focus. For cattle-based dairy value chains, the government in Bhutan, through the Department of Livestock, has provided grants for equipment such as pasteurisers and refrigerators and the construction of milk-processing units. It also provides SMEs with concessional loans (at 4 per cent interest) to install processing plants and machinery.

Despite stark differences between the two cases, the importance of enabling policies to strengthen the yak products value chain is evident. Specifically, measures are needed to ensure access to renewable energy solutions tailored to the needs of nomadic yak herders as well as cattle dairy farmers. These measures could be aligned with the focus of Bhutan's Twelfth Five Year Plan (2018–2023) on improving the livelihoods of highlanders through improved yak product development, processing, and mechanization (Gross National Happiness Commission 2018).

ACCESS TO FINANCE

The provision for financial services and intermediaries to support the use of RE for yak-based enterprise development varies across Bhutan and China. The research found that yak herders in Bhutan did not have access to any financial support, whereas cattle-based enterprises utilised grants from governments and social foundations and other concessional loans to install an Italian cheese production and processing unit, set up a yoghurt processing plant, and purchase machinery. For instance, the Rural Enterprise Development Cooperation Ltd. provides concessional loans at 4 per cent interest per annum without collateral. The Bhutan Development Bank also provides credit to farmers. Yak herders and cattle farmers in Bhutan are both willing to invest in context-specific solar technologies, as well as opt for cost-sharing financial instruments such as subsidies, concessional loans, grants, and long-term repayment schemes. Such improved access to finance by the enterprises for renewable energy systems and equipment can contribute to strengthening local value chains. The choice of the financial instruments and their design (for example, a combination of grants and concessional loans) should account for the enterprise's capacity to pay and the long-sustainability of the RE systems.

In China, the yak herders have been receiving grants and subsidies from the government for machinery and equipment, the construction of shelter houses and marsh gas tanks, and to increase production and processing of dairy products. Whereas the government has schemes that offer collateral-free loans to SMEs, access to them has been limited because the criteria for access are challenging, and consequently, many enterprises in the yak products value chain use their own money to invest in the business or seek loans from friends and family.

SKILLS DEVELOPMENT

There is a lack of skill in product development in Bhutan although some attempts have been made to support product development and diversification through training sessions organised by the Department of Livestock. Yak herders and cattle-based dairy entrepreneurs both need to have skills in processing, packaging, and branding products, and maintaining adequate hygiene throughout the value chain process, including maintaining equipment. Loden Foundation, a local civil society organisation (CSO) based in Thimphu, provides interest-free start-up grants and training to young entrepreneurs about business development and business management. However, their reach is limited to major towns; yak herders living in remote highlands are not aware of, and unable to access such opportunities.

The major actors in the yak products value chain tend to vary, with the herders involved in the production phase, private entrepreneurs or companies and cooperatives involved in processing and marketing, and other actors solely engaged in marketing, distribution, and retail. There are several skill development opportunities, depending on the competence of each actor in the value chain. The Chinese government organises training sessions on business management and marketing for SMEs and supports networking and partnership development. It also promotes yak products through expos and concerts. In Hongyuan county, the Department of Livestock, the Yak Breeding Centre, the Sichuan Academy of Grassland Science, and the Sichuan Agricultural University regularly provide training sessions to yak herders on new technologies, maintenance of machines, yak breeding, disease management, yak nutrition (concentrated feed and choice of grass species), and alpine meadow–pasture management (rotational grazing). Members of the yak farmers' cooperative in Hongyuan have received training from a Shanghai-based private company to produce yak ice-cream. The Hongyuan Milk Powder Company is working closely with the University of Wisconsin, USA to research yak milk micro-nutrients. It has also received organic certification of its products from the Government of China, United States Department of Agriculture, and ECOCERT in Europe. Similarly, the Himal Yak Company organises training workshops for local herders in weaving yak wool products.

TECHNOLOGY CHOICES

The production and processing of goods in the yak products value chain mainly takes place during summer when the yak herds are grazing in high-altitude pastures. Decentralised energy solutions are thus required to enable individual and/or collective processing of dairy products. In Bhutan, herders only have access to solar PV for lighting purposes and charging mobile phones. It does not provide sufficient energy for the heating, cooling, churning, and storage of processed products. The herders indicated a need for additional energy supply to support growth, either through the grid or through a combination of sources, including stand-alone solar systems and diesel generators. In the case of China, the herders and enterprises in Hongyuan county mainly had access to solar-based home systems and grid-based electricity respectively. For large processing companies, such as the Hongyuan Milk Powder Company, stand-alone solar solutions are insufficient given its large energy

demand to operate the processing plants and its facility. Nevertheless, the potential for renewable energy development in the yak products value chain is large where access to modern energy sources is either limited (for example, the highlands of Bhutan) or is insufficient and unreliable (where the higher demand for energy by enterprises is not met through grid-based solutions).

PARTNERSHIPS

Partnerships across the yak products value chain are important to develop and grow sustainable enterprises. As outlined in the systematic review earlier, a range of partnerships across government, the private sector, community organisations, and other actors in civil society is required. To promote the yak products value chain in Bhutan via collective action, the Department of Livestock has begun forming yak herders' cooperatives in different districts. It works closely with yak herders and cattle farmers, who can tap into the financial support offered, including training in skills development. Some private enterprises have also established partnerships with CSOs such as Loden Foundation and SABAH Bhutan. In China too, yak herders have strong partnerships with the Department of Livestock and the State Grid Hongyuan County Power Supply Corporation for grants and subsidies on solar home systems, solar-powered cream separators, and infrastructure development. The Hongyuan Milk Powder Company and the yak farmers' cooperative mainly purchase yak products from the herders ensuring off-take of their products, especially fresh yak milk. The Hongyuan Milk Powder Company has sales networks that includes supermarkets, their own retail outlets, and online platforms. The yak farmers' cooperative mainly has trading contacts with schools, local hotels in Hongyuan, and Air China to supply yoghurt. Research and academic institutes such as the Yak Breeding Centre, the Sichuan Academy of Grassland Science, and the Sichuan Agricultural University also work closely with yak herders on animal health, the restoration of alpine meadows and pasturelands, the provision of improved seed and grass species, and imparting training regarding new technologies. The Himal Yak Company also partners with international brands, with Dhaulagiri Enterprises in Nepal, and domestic partners in Jiangsu and Zhejiang provinces, who produce readymade products and market them. Therefore, the role of partnerships is seen to be crucial, right from the production to the marketing stage, in order to build a resilient yak products value chain.

3.4 Tourism value chains from India and Nepal

The tourism sector is an important driver of economic growth worldwide, contributing to over 10 per cent of the global GDP and one in 10 jobs in 2019 (WTTC 2020). The sector generates millions of jobs worldwide, bestows a wide range of socio-economic benefits for destinations and host communities, and is a driver of inclusive economic growth and development (Tourism Council of Bhutan 2018). As a cross-cutting sector, tourism stimulates productive capacities across a very large and diversified value chain. Tourism enterprises are responsible for one in five jobs created across the world over the past five years. Jobs in tourism are also known to particularly support women, youth, and other, often marginalised groups in society (WTTC 2020).

Tourism is critical to national economies in the HKH region, contributing significantly to GDP, foreign exchange earnings, and employment generation. Tourism's contribution to the GDP of different countries in the region ranges from about 3 per cent in Bangladesh (in 2019) to around 7 per cent in India and Nepal, and over 9 per cent in Bhutan and China. In terms of employment, over 10 per cent of the jobs in China are tourism-related. Tourism is the second-largest employer, after the civil services, in Bhutan (Dolkar 2019).[5] Employment creation by the tourism sector is significant across all eight countries of the HKH (Table 1) (WTTC 2020).

Tourism value chains provide multiple products and services and engage diverse stakeholders, including households, associations, cooperatives, and MSMEs.

The linkages between energy supply (both renewable and non-renewable) and tourism have been increasingly studied over the past 20 years (Bohdanowicz et al. 2001; Calderon-Varagas et al. 2019; Frantal 2017; Jiricka et al. 2010; Michalena 2008; Shaheen et al. 2019). Some case studies have also focused on countries in the HKH region (Akkinapalli 2018; Anup 2017; Tiwari et al. 2013; Zhang and Liu 2019). However, most studies have focused at the national level and a knowledge gap exists regarding tourism value chains in the mountain context.

The case studies presented in this working paper seek to address this knowledge gap by assessing mountain tourism value chains from an energy perspective. The objective is to understand better the energy flows across tourism value chains, specifically regarding accommodation, identify renewable energy's contribution to the development of resilient tourism

[5] The Tourism Council of Bhutan (TCB) plans to employ 3,000 Bhutanese in the tourism sector each year.

TABLE 1	TOURISM'S IMPACT ON THE NATIONAL ECONOMIES OF THE HKH IN 2018		
Country	**Contribution to GDP (%)**	**Tourism sector growth (%)**	**Total number of people employed**
Bangladesh	3	6.8	1.8 million
Bhutan*	9	NA	30,000
China	11.3	9.3	79.8 million
India	6.8	4.9	40 million
Myanmar	4.6	4.5	1.07 million
Nepal	6.7	7.5	1.03 million
Pakistan	5.9	4.7	63.9 million

Source: WTTC (2020)

* **Note:** Bhutan's data pertains to 2016

enterprises, and pinpoint key aspects of ecosystems shaping such a contribution.

This section presents findings from Mustang (Nepal) and Ladakh (India). They represent high-altitude tourism destinations. The case studies focus on communities lying along well-known trekking routes – Kagbeni and Lo Manthang in Mustang, Nepal and Leh, Skiu village, Kaya village, Tsogsty village, and Sumda Chhom village in Ladakh, India. Ladakh and Mustang are both high-mountain deserts with various traditional and geographical similarities. Both are located between elevations of 2,000–8,000 masl and are recognised as prominent mountain tourist destinations with spiritual and religious significance (Goering 1990) (Box 4).

A typical global tourism value chain begins at the point of departure for the tourist, starting with transport, until they reach the country of destination. The value chain would then include additional segments: national distribution, transport, accommodation, and excursion. Given the centrality of lodges in the tourism value chain, the focus of renewable energy opportunities will remain on accommodation at this stage of the case study and in this working paper, but with the intention of capturing other segments in the future. For the purpose of this case study and working paper, two main categories of accommodation in the HKH region – hotels and homestays – were approached for focus group discussions and key informant interviews. Stakeholders in the tourism sector, including government officials and members of various tourism associations active in the two mountain destinations, were also interviewed.

BOX 4

TOURISM IN LADAKH AND MUSTANG, AND ITS CHALLENGES

Ladakh is situated in the far north of India where subsistence agriculture has traditionally been the mainstay of the economy (Akhter 2013). However, with the growth of tourism in the region since the 1970s, there has been an increasing number of Ladakhis involved in the sector. There have also been substantial investments in the sector over the past two decades. From around 40 guesthouses in the early 2000s, there are now over 500 private accommodation facilities, mainly hotels in Leh and homestays across various villages in Ladakh. The homestays bring secondary incomes for the families, while also stimulating the local economy with the growing demand for various goods and services. In 2016, nearly 200,000 tourists from India and over 38,000 foreign tourists travelled to Ladakh.

Tourism in Ladakh is mainly restricted to summer due to the extreme winters, when temperatures can plummet to less than minus 30 degrees Celsius. The lack of road connectivity during the cold season also restricts winter tourism. However, this situation is likely to change as connectivity improves and the larger hotels in Leh offer heating facilities. Winter tourism, with a focus on the famous Chadar trek – trekking on the frozen Zanskar River, and possible sightings of the snow leopard – looks set to grow rapidly in Ladakh (Mansingka 2017).

Mustang is a remote district in northern Nepal. Summer tourism has been a prominent source of income for a majority of the households here since the early 1990s. Much of the tourist influx in Mustang happens in Kagbeni, Lo Manthang, and Muktinath. Lo Manthang, also known as Upper Mustang, opened to tourists in 1992, when it received 483 tourists. This number has grown rapidly since, reaching 3,344 tourists in 2013 (Limbu 2013). In the year before the earthquake that shook Nepal in 2015, Mustang as a whole received over 31,200 tourists. Though the earthquake impacted the number of arrivals, tourism has recovered. Winter tourism is not prominent in Mustang due to the lack of proper heating facilities across homestays in Lo Manthang, and even in larger hotels in Kagbeni. The residents of Lo Manthang mainly travel to Pokhara and Kathmandu during the winter months to avoid the harsh weather conditions at home.

3.4.1 Energy in the tourism value chain, with a focus on accommodation

Value chains in tourism enterprises are different from typical product-based value chains that have production, processing, and distribution functions. The main segments under the tourism value chain do not represent continuous processes either. Accommodation, value-added activities, and promotion of the destination are the three segments of the mountain tourism value chain. The energy flows across tourism enterprises in Ladakh and Mustang, based on interviews, are presented in Figure 12. This working paper focuses on the accommodation segment. Within this segment, the energy flows differ for the two major kinds of accommodation, hotels and homestays. A majority of the hotels are located in the city of Leh in Ladakh and Kagbeni in Mustang, while homestays are located across several rural villages in Ladakh and Lo Manthang in Mustang.

HOTELS IN LEH

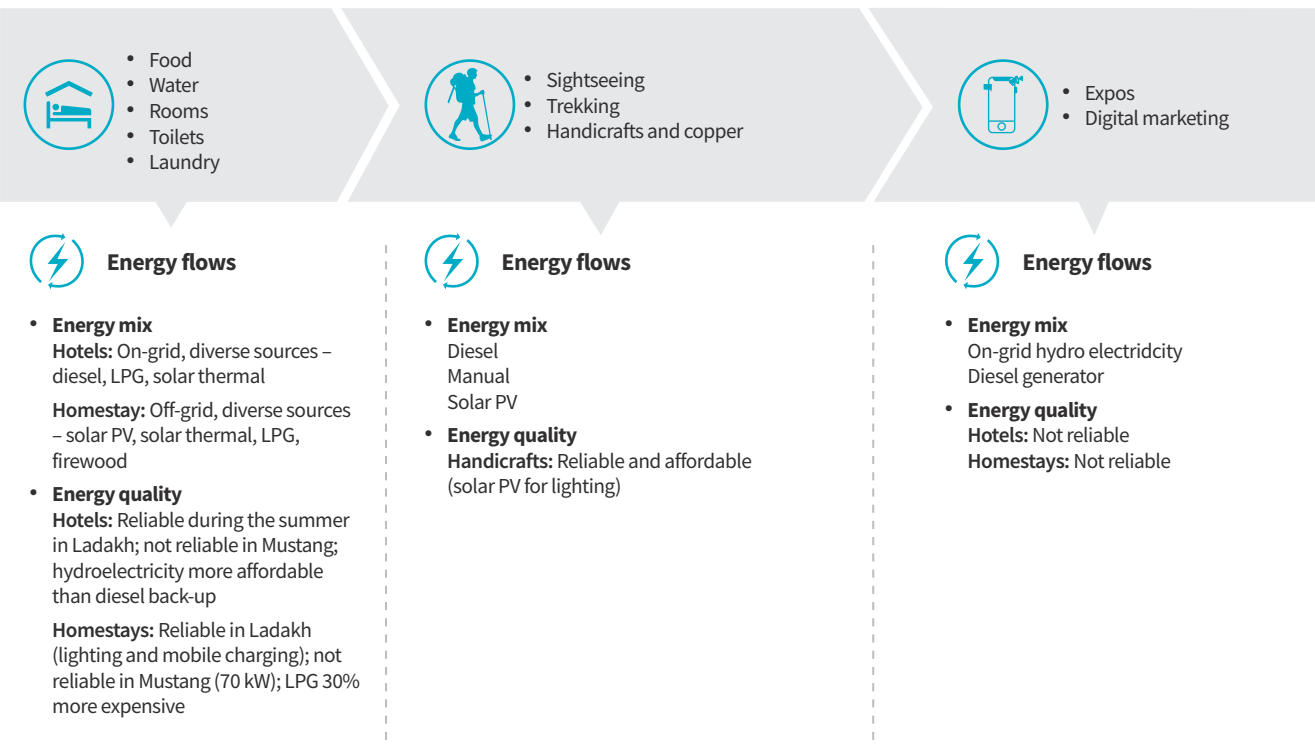
Hotels in Leh receive electricity from the grid. The hotel industry is reported to be the largest consumer of on-grid electricity in Ladakh. Electricity in Leh is sourced from the 45 MW Nimoo Bazgo power project – a run-of-the-river power plant located in Alchi village about 75 km from Leh, and which has been operational since 2013. Diesel was the major source of electricity in Leh before the Nimoo Bazgo plant began operating. It produces reliable electricity during the summer, although during the winters, generation is limited as the water in the Indus River freezes. Hotels in Leh that have heating facilities are open throughout the year but are forced to use diesel due to the lack of reliable on-grid electricity during the winter season.

Liquefied petroleum gas (LPG) is used for cooking by a majority of the hotels in Leh. Solar thermal water heaters are extremely popular, being both reliable and affordable. Very few hotels use electricity for cooking and heating water.

HOTELS IN KAGBENI

Hotels in Kagbeni are also powered with on-grid electricity. Depending on the size of the hotel, the monthly expenditure on electricity is around USD 44 on average. However, frequent power cuts result in unreliable supply and the larger hotels have invested in diesel generators as back-up. Around 500 litres of diesel are consumed a month on average by these hotels. Smaller hotels use subsidised SHSs for the same purpose. Their installation costs around USD 120, but they are sufficient to provide power to only approximately five lights and are unable to support energy-intensive appliances.

FIGURE 12 ENERGY FLOWS ACROSS TOURISM ENTERPRISES IN LADAKH, INDIA AND MUSTANG, NEPAL



LPG is used for cooking by almost all the hotels in Kagbeni. They use one LPG cylinder a day on average during the peak tourist season. The respondents highlighted the issue of affordability, as one cylinder costs up to USD 22. Very few, smaller hotels still use fuelwood for cooking, consuming around 50–60 kilograms (kg) of fuelwood a day. Since Mustang district only has around 3 per cent forest cover, fuelwood is expensive, and can cost these hotels around USD 440 a month.

A majority of the hotels have installed solar thermal water heating systems. The bigger hotels use larger systems of 30 tubes, whereas smaller hotels use systems of 16 tubes. Solar water heaters are considered affordable by the hoteliers as 15 per cent of the upfront investment is provided by the Annapurna Conservation Area Project (ACAP). Hoteliers have paid approximately USD 440 on average for the installation of solar water heaters.

HOMESTAYS IN LADAKH

Homestays in Tsogsty village in Ladakh are not grid-connected, but are completely electrified through the 250-watt (W) solar home systems provided by Global Himalayan Expedition (GHE). According to those interviewed, the SHSs produce reliable electricity for powering up to 11 lights. They are also affordable; each homestay pays a monthly installment of USD 1.40 for the SHS. Homestays in Sumgda Chhum village also use SHSs for lighting and charging mobile phones. The monthly installments go into a fund created by GHE, which is utilised for the maintenance of the solar panels and batteries.

Homestays in Kaya village are powered through a combination of solar power and diesel. The Ladakh Renewable Energy Development Agency (LREDA) has installed a 25-kilowatt (kW) solar farm, which provides free electricity to the homestays. The electricity supplied is used mainly for lighting, charging mobile phones, and television. Government-run diesel generators are also used during certain times of the day when the solar electricity is insufficient. Homestay owners pay around USD 2.80 per month for the diesel generator.

Skiu village is electrified through a combination of government-supported diesel generators and SHS solutions provided by GHE. Homestays in the village use diesel every morning from 06:00 to 10:00. However, the diesel generators get damaged frequently, and this has resulted in the electricity supply becoming unreliable. SHSs are used at other times of the day and during the night. The SHSs produce electricity reliably, but it is only used for lighting and charging mobile phones. The homestay owners are forced to use diesel generators for other activities that require a higher power capacity.

LPG is used for cooking in all the villages studied. Field respondents considered LPG to be affordable and a reliable source of energy. Solar thermal water heaters are used by all homestays in Skiu and Tsogsty villages. The water heaters have been installed by LREDA. Solar water heaters are found to be of good quality, reliable, and affordable. Homestays pay a highly subsidised rate of USD 57 for the installation of the water heaters.

HOMESTAYS IN LO MANTHANG

Electricity in Lo Manthang is mainly sourced from a 70-kW solar farm.[6] Most of the households here operate homestays and pay around USD 0.11 per unit of electricity consumed, which goes towards the maintenance of the solar farm. However, this 70-kW solar farm is not sufficient to meet the electricity requirements of the approximately 200 households here. This results in a lack of sufficient electricity supply, particularly during peak hours. This has forced many homestays to install SHSs as back-up. Typically, 30-W SHSs can be found across homestays in Lo Manthang. Their installation costs approximately USD 263, considered affordable by most homestay owners. However, even with the additional SHSs, there is not sufficient power for services other than providing lighting and charging mobile phones. The larger homestays, therefore, also use petrol-based generators, which are expensive and can cost around USD 1,650. Due to the lack of petrol pumps in Lo Manthang, fuel is sourced largely from neighbouring China and from Pokhara, making the running of these generators even more expensive. Homestays spend approximately USD 309 in the summer season on petrol.

LPG is used by most homestays for cooking. The freight charges to Lo Manthang are much higher than most places in Nepal because of its remoteness. Hence, one cylinder of LPG, which costs about USD 16 in cities across Nepal, costs nearly USD 22 in Lo Manthang. There are also reliability issues with the LPG as the gas stored inside the cylinders often freezes due to cold conditions even during summer.

Most homestays in Lo Manthang have installed solar thermal water heaters. The 24-tube solar heater system was found to be the most popular amongst homestays. They spend around USD 570 to purchase the water heaters, an amount not considered expensive by the

[6] It has been reported that China is to build a 100 kW solar power station in Upper Mustang.

respondents. However, issues such as damage to the solar thermal systems caused by excessive snowfall have been regularly reported.

3.4.2 Potential of RE and energy efficiency for switching fuel and scaled-up access

The tourism sector in Ladakh and Mustang has experienced rapid growth over a short period of time. The total number of enterprises, catering to a rising number of tourists, has expanded rapidly. As a result, the local economy and households in these places have also benefited. Renewable energy solutions have played an important role in supporting tourism enterprises in Ladakh and Mustang. However, many of the stakeholders in both places see substantial potential for the further growth of renewables to support tourism in the mountain context.

Insufficient and non-continuous electricity generated from a solar plant and SHSs in Lo Manthang has limited the extent of basic services, such as lighting and charging mobile phones, provided to tourists. Hotels in Kagbeni face similar issues. The solar farm in Kaya village and SHSs used in other homestays in Ladakh are much more reliable. However, the limited electricity supplied constrains the capacity of homestays in operating high-powered appliances such as televisions, washing machines, coffee machines, irons, fans, and many others. To ensure a consistent inflow of tourists, the services offered must be expanded. Improved road connectivity to these destinations also creates the opportunity of attracting a more diverse set of tourists. This entails expanding the current RE systems deployed to meet the growing demand, or introducing new solutions that may be more feasible as consumption grows (for example, transitioning from SHSs to larger mini-grids).

The lack of renewable energy options for cooking is yet another challenge facing tourism enterprises, particularly in Lo Manthang. While mature and affordable options exist for lighting and heating water, RE cooking technologies have not yet reached any of the mountain destinations considered in this case study. LPG is mostly used for cooking, but is not affordable in Lo Manthang due to high freight charges. The high prices of LPG are found to be one of the reasons why food is much costlier in Mustang compared to other tourist destinations in Nepal. In these circumstances, tourism enterprises in Mustang are willing to adopt RE technologies for cooking, if appropriate solutions are made available. Where sufficient organic waste – food waste, agricultural residue, livestock waste – is available, biogas solutions may be feasible. With the rapidly reducing costs of RE and the wider prevalence of energy-efficient induction stoves, electric cooking options may also be explored. It would enable a higher utilization of renewable energy power projects, substantial savings in terms of fuel costs, and less environmental damage, as it would reduce the fuelwood being used.

Winter tourism is not prominent in both the destinations due to the lack of heating infrastructure. Most tourism enterprises in both places currently generate their income only during the summer season. A few large hotels which have installed diesel-operated heating systems operate during the winter in Leh. A willingness to adopt suitable RE technologies to support heating facilities and enable the growth of winter tourism is observed in both Mustang and Ladakh.

Linking the wider use of renewable energy with the development of tourism is also closely tied to the need for minimizing the environmental impacts of this sector on the fragile ecosystem of the mountain areas. Bhutan, for instance, adheres strongly to its policy of 'high value, low impact' tourism. Several eco-trekking initiatives are also being developed in Nepal (Box 5). Field respondents drew attention to environmental concerns such as groundwater pollution, groundwater scarcity, and solid waste generation prevailing as a result of unregulated tourism.

Traditionally, people in Ladakh have used dry toilets, which do not contaminate groundwater. To cater to the needs of tourists, flush toilets have been installed by most hotels, but without installing sewage treatment plants (STPs) despite a government mandate to do so. The waste produced is directly pumped into the ground. There are also no regulations on the number of hotels in Leh, which carries the risks of over-construction and groundwater scarcity. The generation of solid and plastic waste is another issue that hinders environmental sustainability. Almost 60 tonnes of unmanaged garbage are generated per day during the summer season and dumped across several dump yards in Leh (Dolma 2018). In Kagbeni, all forms of garbage are generally burnt in the open every week, contributing to air pollution. In Lo Manthang, disposing of empty glass bottles has been a significant challenge for the homestay operators as recycling companies are unable to reach them and nor are they able to send the bottles for recycling due to the high transportation costs. Given the impacts of these challenges on the attractiveness of the tourist destinations, there is a strong willingness to support the adoption of appropriate technology solutions to tackle these issues.

BOX 5

ANNAPURNA DHAULAGIRI COMMUNITY ECO-TOURISM DEVELOPMENT AND PROMOTION ORGANISATION

The 50-kW Dhostekhore Khola Micro Hydropower Project, initiated by the Annapurna Dhaulagiri Community Eco-tourism Development and Promotion Organisation, has been developed to promote eco-tourism in the Annapurna region of Nepal. The project provides electricity to three community-owned lodges, in Khopra, Bayeli, and Dhankharka, which lie along trekking routes. The micro hydro project provides sufficient power for cooking food using a cooker, an oven, and electric stoves, to heat the rooms, provide hot water, recharge mobile phones and cameras, run Wi-Fi routers, provide lighting, and operate washing machines. The micro hydro project also powers the wireless relay station for telecommunication services.

The project is community-owned, with the profits from its operations going to community schools, clinics, and develop infrastructure as the direct beneficiaries. Its indirect beneficiaries are the local farmers and those involved in tourism (local guides, porters, cooks, those who conduct local cultural programmes) who have benefited from the growing footfall. The people of the three villages have formed a users' committee to manage the project. An operator has been hired and trained for the power project's operation and maintenance. Due to seasonal fluctuations in water supply, power is not produced for about five months a year.

The model has a high potential to be replicated, is aligned with the 'Zero Carbon Emission Lodges' concept appropriate for the fragile Himalayan region, and contributes to Nepal's responsible tourism programme.

Source: Pun (2019)

3.4.3 Energy and its contribution to enterprise resilience

The potential for RE solutions to deliver a wide range of services has not been fully tapped yet in Ladakh and Mustang. The evidence points to the need for such solutions and the impact they can have on different aspects of the resilience of mountain tourism enterprises.

MARKET ORIENTATION

The productivity of certain tourism enterprises studied has grown because of the adoption of renewable energy. In Ladakh, homestay operators who are also involved in copper-making have been able to produce more goods now due to longer working hours resulting from the installation of solar PV and storage solutions. These copper handicrafts are then sold to tourists and in the local market. Also, with electricity powering appliances such as washing machines, it enables operators to cater to a larger number of tourists and offer better services.

Access to the internet through mobile phones has also led to an expansion of business to new markets by various tourism enterprises. In the past, Ladakh and Mustang were recognised as only trekking destinations. Now, local tourism enterprises have also promoted their villages as family vacation destinations, and suitable for video recording and photoshoots for various purposes. The expansion of telecommunication services has also supported marketing activities in attracting a larger number of tourists.

The deployment of solar PV for lighting and solar thermal for heating water has enabled new enterprise development in Sumda Chun and Tsogsty villages in Ladakh. Households here did not operate homestays before the introduction of these technologies. New homestays here are promoted as solar homestays to make tourists aware that even in these remote villages, basic facilities are available and sustainably provided.

ENTREPRENEURIAL ORIENTATION

Information technology such as mobile phones has reached most tourism enterprises. Presently, RE technologies that are being used in the remotest areas studied are not able to provide sufficient power to operate large appliances, but charging mobile phones has become possible. Tourism enterprises are able to access climatic information as a result. It has made them better equipped to anticipate and plan for changes resulting from sudden weather turbulence in the Himalayan region. For instance, if a certain day is predicted to be not suitable for trekking, they are able

to plan alternative activities for the day in advance and keep the tourists occupied.

Business development through digital promotion has happened in both destinations. Tourism enterprises have been able to reach more tourists through social media platforms. Homestay operators located even in remote villages are found to have promoted their homestays on the internet. Online platforms have also been used as a means to maintain connections with previous customers. A personal bond is often created between homestay operators and visiting tourists while sharing the same house and food for a certain period of time. Online messaging applications in mobile phones have helped both parties nurture this bond further. A greater number of examples of this was found in Mustang, where the English language is spoken. As a result, more tourists are coming in through word of mouth being spread by these personal networks.

Product diversification has also become possible after the installation of RE solutions, especially across villages of Ladakh. Earlier, the lack of access to proper lighting restricted villagers from carrying out any sort of activity in the evenings. With the arrival of solar lighting, villagers are able to produce handicrafts in the evenings after serving dinner to the tourists. These handicrafts are sold to the tourists living in homestays and also in the local market.

Moreover, tourism is mostly restricted to the summer currently but there is scope for expanding winter tourism. Suitable heating technologies coupled with adequate RE infrastructure and services can hence help tourism enterprises introduce winter tourism as a new product for tourists.

PROFITABILITY AND CONTRIBUTION TO THE LOCAL ECONOMY

Renewable energy technologies have helped increase household incomes for many. Business expansion to new markets and digital promotion have brought in more tourists and hence more income for homestays. Households in these villages that earlier were dependent entirely on small-scale farming for their income are now able to earn secondary incomes by providing homestay services.

These tourism enterprises are also able to benefit from energy cost-saving. Hotels in Ladakh have reported an overall decrease of 15 per cent in annual energy costs after the Alchi hydropower plant began to operate. The electricity generated through the Alchi plant has reduced diesel consumption during the summer season. However, RE produced through the Alchi hydropower plant is currently not available during the winter. Renewable energy technologies are capable of providing services that require high power supply, such as refrigeration and air conditioning. Currently, expensive diesel-based energy is used for these services, especially during winter for heating. Replacing it with RE can further reduce costs for hotels in Leh. Kerosene was used by village households in the past for lighting purposes, which was expensive. Homestays both in Ladakh and Mustang are spending less money on lighting by installing solar photovoltaic lights. Importantly, the indoor air pollution resulting from burning kerosene has also reduced.

As hotels and homestays attract a larger number of tourists, it has a positive ripple effect throughout the local economy. Demand for produce from local farms grow, and for local guides, handicrafts, tea, and other consumables, goods, and services. In Kagbeni, seasonal agriculture is now carried out commercially to meet the demand created by tourism. Products such as dried apples, dried apricots, Mustang peanuts, walnuts, essence sticks, dried milk, shaligram (ammonite fossils), Sichuan pepper, and yak wool are mostly sold to tourists during the tourism months of September and October. In Leh, the manufacturing of handicrafts made especially from copper has expanded, as has the sale of Ladakhi pashmina and apricots.

3.4.4 Ecosystem to support the contribution of renewable energy to the development of resilient enterprises

The cases studied in India and Nepal point to the potential that access to reliable and affordable energy has in the ability of tourism enterprises to increase their productivity, diversify their products, raise incomes, adapt to changing conditions, and, as a result of all this, become more resilient. The analysis also points to key aspects of an ecosystem that supports achieving these outcomes via the adoption of renewable energy by enterprises.

SUPPORTIVE POLICIES

Policy direction for greater renewable energy uptake by enterprises in Ladakh is provided through the central government's Green India Mission and the LREDA. However, the implementation of government policy is considered a major challenge by enterprises here. Community eco-tourism solutions, which allow local communities to be active stakeholders in developing the tourism sector in an environmentally sustainable manner while also creating income-generation opportunities, are gaining a foothold in Ladakh (Jain 2019). In the case of Mustang, policy direction to promote the use of renewable energy in the tourism sector has been absent.

Given the strong role that RE solutions could play in the sustainable development of tourism in the mountain regions, dedicated policies are needed that incentivise the adoption of appropriate technologies. Policy frameworks should recognise the unique mountain contexts and facilitate partnerships between the local communities, active CSOs in the region, and technology providers to identify needs and devise appropriate RE solutions. Cross-sector policy-making is equally essential to identify synergies among energy needs across multiple livelihood activities and consumption activities and services in the region, such as schools and health clinics.

ACCESS TO FINANCE

Homestays in Ladakh and Lo Manthang have been using grants and subsidies to finance solar photovoltaic and solar thermal technologies. The Ladakh administration and the government of Gandaki province are the primary financial intermediaries. In the case of homestays in Tsogsty and Sumda Chun, social enterprises such as Global Himalayan Expedition have also played the role of financial intermediary. GHE has used household equity as an instrument to raise funds towards the regular maintenance of solar technologies. The energy requirements of hotels in Kagbeni and Leh are being met mostly through self-financing, and via commercial loans in certain cases, with banks as the intermediaries.

The challenges regarding access to finance for RE solutions will vary from context to context, depending on the enterprises' ability to pay and the level of financial inclusion. Tailored financing schemes should be made available to enterprises to adopt RE solutions for both electricity and heating. The financing should be structured to ensure the long-term sustainability and operations of the system. Where community-based systems, such as micro hydro mini-grids, may be more feasible, the financing will need to be directed at community-based organisations or energy-generating entities that will be responsible for the project implementation, operation, and maintenance over its lifetime.

INFRASTRUCTURE

There is a lack of energy infrastructure such as sub-stations in the villages of Ladakh and Lo Manthang. This has restricted the capacity of hydropower to reach these remote locations. Micro hydro resources, where available, have the potential to provide a wide range of electricity services for tourism enterprises and other consumers in the community.

TECHNOLOGY CHOICES

The deployment of off-grid solar PV solutions and solar thermal technologies has been responsive to the geographical contexts of both Ladakh and Lo Manthang. At a small scale, off-grid technologies, however, often prove insufficient to provide the complete spectrum of electricity services required in the tourism sector. While such solutions may be appropriate in certain regions where tourism is in its early stages, a dynamic approach is needed that would allow for the expansion of energy access in mountain areas. Depending on local resources and needs, this may involve a single large solar PV plant and storage, or a micro hydro project, or a combination of mini-grids and stand-alone solar solutions, including solar heating options. There is no one-size-fits-all solution. However, it is important to build into energy policies and programmes the tools for adapting to a changing energy demand profile of tourism enterprises. An emphasis on energy efficiency will also be crucial as the sector expands, focusing on appliances and processes within homestays and other accommodations themselves, as well as of community infrastructure such as public toilets, streetlights, and retail outlets.

PARTNERSHIPS

In Lo Manthang, a unique cross-country collaboration between the governments of Nepal and China has supported the installation of a solar farm. Partnership between government bodies and homestay operators has become instrumental in deploying solar thermal and solar PV technologies in remote areas. The LREDA is involved in supporting solar installations in villages of Ladakh and the ACAP in Lo Manthang and Kagbeni. Social enterprises such as GHE are responsible for similar installations in Tsogsty and Sumda Chun villages. Partnerships with governments have however not focused on the maintenance of disseminated technologies. Tourism enterprises have reported various unresolved maintenance issues with technologies provided through government support.

SECTION IV

Key action areas: Driving the energy transformation with speed and at scale

The economy of the HKH region includes a rich variety of value chains for various mountain goods and services. From agricultural products to handicrafts and tourism services, the value chains mainly involve several different units of local enterprises – households, communities, and MSMEs – and are a major source of employment in the mountains.

In the face of a high incidence of poverty, growing climatic risks, and significant social and economic disruption caused by the COVID–19 pandemic, urgent measures are needed to advance inclusive growth and development in the mountains by strengthening the competitiveness and resilience of value chains and local enterprises.

In order to meet this objective, access to modern, reliable, affordable, and sustainable energy is an important enabler. The lack of access to energy limits the production and processing of high-quality mountain products and in large volumes, as well as delivery of services. This inhibits value addition and livelihood diversification at the supply end of key economic value chains. The energy needs assessment presented in this report and conducted by IRENA and ICIMOD for the bamboo, yak milk, and tourism value chains in the HKH region reinforces these findings. It concludes that local enterprises across the value chains grapple with a lack of access to affordable, reliable, and sufficient modern forms of energy, resulting in their use of traditional fuels at the expense of the environment, missed opportunities for value-creation, and drudgery that disproportionately affects women.

Increasingly cost-competitive and adaptable renewable energy solutions offer tremendous opportunities to meet energy needs across disbursed economic value chains in mountain contexts. Such solutions also enable mountain economies to develop while preserving their fragile environments, limiting emissions, and increasing resilience. The assessment finds that while renewable energy technologies exist and are being increasingly deployed, these are often not tailored for productive end-uses across value chains. With an enabling ecosystem in place, renewable energy can indeed enhance livelihoods, offer opportunities for value addition, improve the resilience of enterprises, and support several development objectives related to gender, food security, health, and employment.

To strengthen renewable energy's contribution to value chain and enterprise development in the HKH region, the Regional Action Plan proposed in this working paper puts forward seven key action areas, presented below. These are based on the findings of the needs assessment presented in this working paper as well as extensive regional stakeholder consultations (see Annex 1 for the detailed list of those consulted). Replicating the scale and speed of the global energy transition – championed in large part by several countries from the HKH region – in the mountain context will ensure inclusiveness, a key pillar of the 2030 Agenda for Sustainable Development. Speed is of the essence as mountain communities face the brunt of climate change impacts on fragile ecosystems and the livelihoods they support.

4.1 Adopt an ecosystems approach to shape sustainable energy's contribution to enterprise development

Local communities and enterprises should be empowered to utilise renewable energy solutions to improve the competitiveness and resilience of value chains through the development of a local ecosystem. Such an ecosystem rests on the pillars of a tailored policy environment, access to finance, end-use oriented technology solutions, capacity development, and multi-stakeholder partnerships (Figure 13). Programmes and initiatives deploying renewable energy solutions in the mountain context are strongly encouraged to adopt an ecosystems approach to support local enterprise development, improve resilience, and bring socio-economic benefits for all.

The following key actions are proposed:

- Provide practical guidance on how holistic ecosystems for renewable energy can be used to support value chains and enterprise development. Impart the lessons about best practices that have been developed through previous experiences in the region.
- Improve the understanding of the contextual and mechanistic factors – such as the degree of job specialization and layers of management control – that can enhance the impacts of renewable energy and energy-efficient productive use applications on the competitiveness of value chains and enterprises in the regional mountain context.

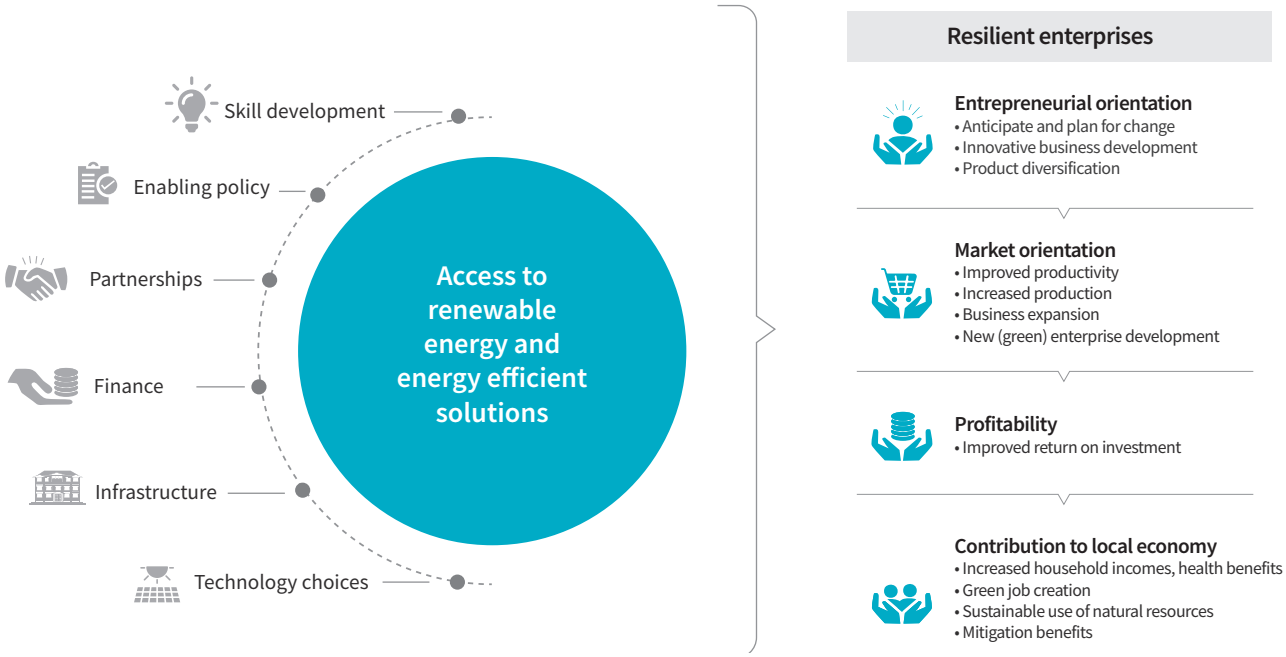
4.2 Integrate sustainable energy measures in policies and planning for mountain development

Policy and planning efforts towards strengthening value chains and enterprises need to be tailored to the unique mountain contexts. Incentives for productive end-use of renewable energy solutions need to be strengthened with local enterprises as the key agents of change. Given the cross-sector nature of mountain value chains, different sector development plans, such as for agriculture, or tourism, would benefit from integrating sustainable energy as a key pillar. Accordingly, there is a need to involve energy and non-energy ministries and public bodies.

The following key actions are proposed:

- Increase awareness about the productive end-use applications, economics, and benefits of renewable energy technologies among enterprises within the different mountain value chains and of various ecosystem actors.
- Support sector-specific energy needs assessments for various economic value chains at a country as well as regional level to identify synergies for market creation and product/service diversification. Integrate energy supply into cross-sector policy objectives and institutional mandates for effective implementation.
- Introduce policies that are tailored to the specificities of mountain contexts and that create a conducive environment for local enterprises

FIGURE 13 AN ECOSYSTEMS APPROACH TO RE SOLUTIONS



to adopt and deploy renewable energy solutions. Through policy design, incentivise local resource use, ownership models, and gender-sensitive delivery models that strengthen sustainability, inclusive access, and the benefits of sustainable energy investments.

- Facilitate policy implementation and update it through monitoring, impact assessments, and multi-stakeholder consultations, including with the private sector and local communities.

4.3 Catalyse accessible finance for end-users and enterprises

Access to affordable and tailored finance is a critical part of the ecosystem for deploying renewable energy to enhance the competitiveness and resilience of value chains and enterprises. The experience from the countries analysed in the report underlines the need to mobilise public and private capital from multiple sources of finance, tailor financial products for end-users and enterprises, layer multiple instruments, and deploy responsive financial intermediaries, such as cooperatives and microfinance institutions, which can play a crucial role in improving access to energy in remote mountain contexts. The financial products should cover energy technology as well as efficient, productive end-use appliances.

The following key actions are proposed:

- Design and operationalise dedicated financial schemes to support investment in the productive use of renewable energy. Tailored to local contexts and financial needs, suitable channels need to be established to make accessible affordable capital to end-users and enterprises working across mountain value chains. Targeted subsidies may be needed in the initial period, especially to support long-term market development. Digital technologies could facilitate financial inclusion, especially in areas with limited infrastructure.
- Develop the capacity of local financial institutions, including commercial banks, cooperatives, microfinance institutions, and sector-specific development banks, to design tailored financial products for local enterprises as well as to evaluate proposals. Development financial institutions (DFIs) and national development banks (NDBs), along with other ecosystem actors, have an important role to play through partnerships and on-lending instruments with local FIs.
- Strengthen the capacity of value chain actors and enterprises to evaluate investment opportunities in renewable energy, prepare bankable project proposals, and access available financial products.

4.4 Support technological innovation and adaptation processes

Technological innovation and adaptation processes are crucial for linking renewable energy solutions and energy-efficient productive appliances with the needs of local end-users and value chains. In the mountain context, value chains for the same goods and services are likely to be uniquely configured to the local conditions requiring tailored technological solutions to meet diverse energy needs. Targeted measures are needed to facilitate participatory technological innovation and adaptation processes, as well as end-of-life replacement of technologies.

The following key actions are proposed:

- Increase awareness about the energy use, gaps, and opportunities at each stage of the different economic value chains to effectively guide the technological innovation and adaptation processes.
- Support the development of a conducive ecosystem for local and regional technology suppliers, to advance experimentation and innovation, including through partnerships with technical institutions, access to early-stage, low-risk finance, and platforms for experience- and knowledge-sharing.
- Facilitate South–South knowledge-sharing between regional stakeholders focused on renewable energy applications in the HKH region and complementary technologies such as appliances and metering devices.

4.5 Build capacities across value chains of mountain products and services

To accelerate the adoption of renewable energy and its impacts on value chains and enterprise development in the region, adequate capacity needs to be developed of actors across the ecosystem for the various value chains. Such capacity development has to be an ongoing activity, focused on skills regeneration and upgradation, and with an emphasis on the technical and non-technical aspects of the energy use and livelihood activities of end-users. For instance, developing new bamboo products via improved access to energy requires upskilling from traditional handicrafts to bamboo furniture and flooring tiles/parqueting with the use of new tools and processing techniques. The scoping exercise conducted by IRENA and ICIMOD identified important capacity gaps that ought to be the focus of capacity-building initiatives and programmes.

The following key actions are proposed:

- Establish the infrastructure and mechanisms to deliver training in technical skills such as installation, maintenance and repair, and knowledge about system components to ensure the long-term sustainability of RE solutions in remote mountain contexts. Partnerships with technical research institutions would be useful.
- Provide MSMEs – the backbone of the HKH economy – access to capacity development programmes that cover writing funding proposals, business administration, and accounting and marketing skills to facilitate access to finance and develop forward market linkages for mountain products and services.
- Expand the capacity-building programme to include government officials, development practitioners, technology providers, and financial institutions to improve awareness about the uniqueness of the mountain context, the challenges, and opportunities available.
- Leverage country experiences where value chains for specific mountain goods and services are relatively mature compared to other countries across the region. Facilitate peer-to-peer exchange of know-how, technologies, and lessons to develop the ecosystem for strengthening local enterprises and value chains.

4.6 Improve the data and information base regarding energy flows in mountain value chains

Data regarding the energy needed for adding value to mountain products and services, and the energy consumption of MSMEs specific to the HKH region is extremely limited. For value chain development of mountain products and services, an understanding of the existing energy flows is critical for effective policy-making and planning, and to assess alternative energy sources. Building on the needs assessment conducted by IRENA and ICIMOD for the bamboo, tourism, and yak dairy value chains, the following key actions are proposed to address the data and information gaps:

- Strengthen the capacity of regional organisations, and national and local governments to gather and report data on energy flows – from supply to consumption – across end-users within the mountain economy.
- Improve and regularly update the data and information available on energy needs and use across the various value chains of mountain goods and services in countries of the region.
- Invest in evidence-generation and training to enhance investor confidence in the viability of renewable energy-based productive end-use investments. Further, improve the knowledge about existing financial and support programmes available for end-users and enterprises.

4.7 Leverage regional partnerships to deliver transformation

The HKH region hosts a rich diversity of value chains of different scales, capacities, and depths, cutting across multiple sectors and stakeholder groups. Key stakeholders identified through the needs assessment include governments, the private sector, including technology providers, financial institutions, non-governmental entities such as industry associations, and local communities. Each plays a specific role in developing the ecosystem to enhance the contribution of renewable energy to enterprise development.

Multi-stakeholder partnerships are needed between the government, the private sector, financial institutions, and mountain entrepreneurs to develop, integrate, and scale up investment in the productive use of energy. Regional and cross-country partnerships will play a fundamental role in advancing coherent action towards the development and adoption of renewable energy and to realise its full potential for socio-economic benefits and enterprise development. A harmonised, regional approach offers several benefits by unlocking new opportunities and markets for mountain enterprises to access.

The following key actions are proposed:

- Increase the visibility and outreach of renewable energy opportunities in the HKH region through joint events between relevant countries of the HKH and regional organisations at high-level platforms.
- Build cross-sector partnerships at the regional and national levels to assess and facilitate the adoption of renewable energy in product and service value chains that are key to the livelihoods of mountain communities.
- Attract finance at a regional level for the development of critical infrastructure at scale, including RE-based solutions for value chain development (for example, cold storage infrastructure for agricultural and dairy products).
- Leverage platforms, such as REEECH, and chart out action-oriented programmes and services backed by commitment from the regional member countries and partners (Box 6).

BOX 6

ROLE OF REEECH IN ADVANCING RENEWABLE ENERGY FOR ENTERPRISE DEVELOPMENT IN THE HKH

The goal of the recently-launched Renewable Energy and Energy Efficiency Capability for the Hindu Kush Himalaya (REEECH) is to contribute to improved access to appropriate, modern, affordable, and reliable energy services to meet the energy needs of mountain populations in the HKH region, and enhance the safeguarding of essential mountain ecosystem services. As identified in the feasibility and baseline study (ICIMOD et al. 2019), a key focus must also be to enhance access to sustainable energy for both consumption (lighting, cooking, and heating) and productive uses of energy, focusing foremost on economic value chains central to the mountain economy.

Leveraging its regional convening power and close collaboration with regional member states and focal agencies, REEECH is well positioned to act as a platform for stakeholders to deliver the concrete actions proposed in this chapter to advance renewables for enterprise development in the region. The recommended actions are well aligned with REEECH's four thematic areas – knowledge management and awareness; inputs into policy development and implementation; promotion of investment, entrepreneurship, and innovation; and capacity development.

Annex

The participants for the focus group discussions and key informant interviews were selected based on the criteria given below:

- Respondents directly engaged in value chain functions, including input suppliers, producers, processors, and traders;
- Representatives of financial institutions and agencies providing business development services, and development organisations (NGOs, local governments, donor-funded projects) engaged in promoting value chains as part of their livelihoods/resilience-building programmes; and
- Representatives from government departments that have a role in creating enabling environments for the productive and efficient use of renewable energy.

The list of stakeholders engaged for the case study analysis are summarised in Table A1 below.

TABLE A1 STAKEHOLDERS ENGAGED WITH FOR THE CASE STUDIES ACROSS SIX COUNTRIES

BANGLADESH	BHUTAN	CHINA
Chattogram Hill Tracts Development Board, Rangamati	**Paro district**	Sichuan Agricultural University, Ya'an
Bamboo Forest Research Institute, Chattogram	District livestock office and veterinary office, Paro	Sichuan Academy of Grassland Science
Chittagong University, Chattogram	Yak herders from Nurbi Thongphu and Yakcha villages, Paro	Yak Breeding and Research Centre, Chengdu
Bamboo producers, Kaptai Lake, Rangamati	Laykha Dairy Delights and Luni Geowg, Paro	Mubang Agriculture Technology Company, Chengdu
Modern Bamboo Furniture, Rangamati	Shaba Milk Cooperative, Paro	Science Technology Livestock Department Office, Hongyuan
Ashika Craft, Rangamati	Amankora Hotel and Resort, Paro	State Grid Hongyuan County Power Supply Corporation
Local solar shops, Rangamati	**Thimphu district**	Yak herders in Masa and Dagewa villages, Hongyuan
Bright Green Energy Foundation, Rangamati	Department of Livestock, Thimphu	Hongyuan Milk Powder Company
International Centre for Climate Change and Development, Dhaka	Department of Renewable Energy, Thimphu	Yak farmers' cooperative, Hongyuan
Infrastructure Development Company Limited (IDCOL), Dhaka	National Post Harvest Center, Department of Agriculture, Thimphu	Himal Yak Company, Chengdu
Rahimafrooz Bangladesh Limited, Dhaka	Yak herders from Chamgam (Dakarla Gewog), Mentsefu, Takshithan (Naro Gewog), Dhondo, and Getala villages, Thimphu	
	Loden Foundation, Thimphu	
	SABAH Bhutan, Thimphu	

INDIA

Ladakh

Global Himalayan Expedition (GHE), Leh

All Ladakh Tour Operators Association (ALTOA)

Nimoo Bazgo Hydroelectric Plant, NHPC Limited, Ladakh

Department of Wildlife Protection, Office of the Regional Wildlife Warden, Leh

Ladakh Renewable Energy Development Agency (LREDA)

The Grand Dragon, Ladakh

Local homestay operators in Sumda, Chun, Skiu, Kaya, and Tsogsty villages

Haa district

District livestock office, Haa

Haa Value Cooperative, Haa

Sanam Tshongkhang milk processing unit, Haa

Yangthong milk processing unit, Haa

Yak herders from the yak herders' cooperative, Haa

MYANMAR

Department of Rural Development, Shan State

Ministry of Electricity and Energy, Shan State

Bamboo trainer, Inle Lake, Shan State

Myanmar Rattan and Bamboo Association, Yangon

Bamboo producers, Nyaung Shwe Township, Shan State

Aung Umbrella, Pyitawtha Quarter, Pindaya

Bamboo handicrafts seller, Nyaung Shwe Township, Shan State

Online Bamboo Handicrafts, Shan State

Myanmar Institute for Integrated Development, Yangon

NEPAL

Mustang

Trekking Agencies' Association of Nepal (TAAN)

Annapurna Conservation Area Project (ACAP)

Gharapjhong Gaunpalika, Jomsom

Barhagaun Muktichhetra Gaunpalika, Kagbeni

Yac Donalds, Kagbeni

Local hotel operators, Kagbeni

Local shop owners, Kagbeni

Local homestay operators, Lo Manthang

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About ICIMOD

The International Centre for Integrated Mountain Development (ICIMOD), is a regional knowledge development and learning centre serving the eight regional member countries of the Hindu Kush Himalaya – Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan – and based in Kathmandu, Nepal. Globalisation and climate change have an increasing influence on the stability of fragile mountain ecosystems and the livelihoods of mountain people. ICIMOD aims to assist mountain people to understand these changes, adapt to them, and make the most of new opportunities, while addressing upstream-downstream issues. We support regional transboundary programmes through partnership with regional partner institutions, facilitate the exchange of experience, and serve as a regional knowledge hub. We strengthen networking among regional and global centres of excellence. Overall, we are working to develop an economically and environmentally sound mountain ecosystem to improve the living standards of mountain populations and to sustain vital ecosystem services for the billions of people living downstream – now, and for the future.

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