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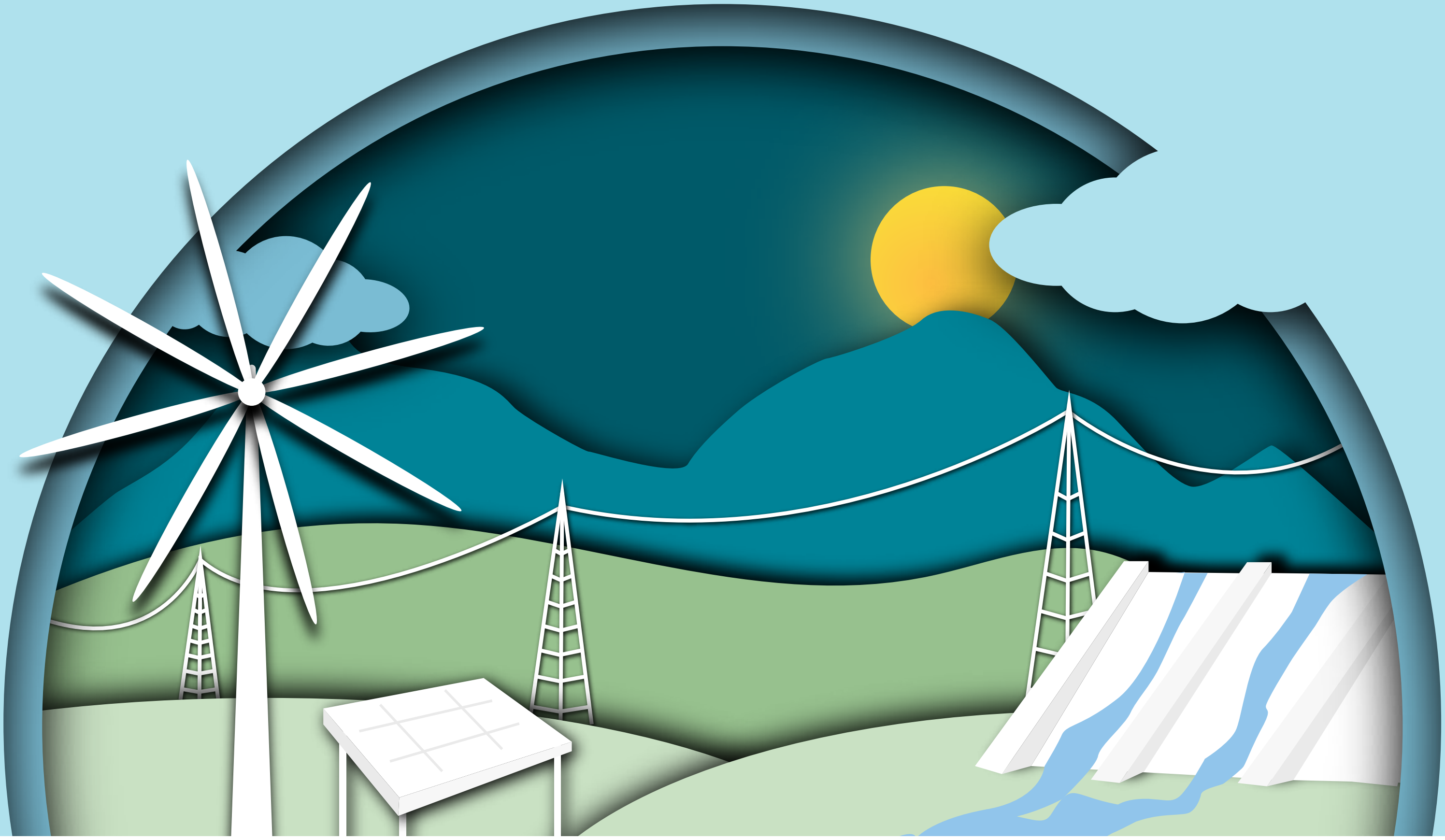

Together we have more power:

Status, challenges, and the potential for regional renewable energy cooperation in the Hindu Kush Himalaya

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ICIMOD's Regional Action Area facilitates the co-generation of credible knowledge on critical issues concerning the people and ecosystems of the Hindu Kush Himalaya (HKH) region, through comprehensive assessments, thematic studies, focused analyses, and regional outlooks, to inform policy, planning and decision-making processes in HKH countries to address priority issues and challenges effectively.

This report on 'Together we have more power: Status, challenges, and the potential for regional renewable energy cooperation in the Hindu Kush Himalaya ' covers the status and challenges of energy in the HKH, and the benefits of regional cooperation on renewable energy at a time when the region is affected by unprecedented and rapid climatic, environmental, and socio-economic changes. The report deepens understanding of the need and potential for regional cooperation for transitioning to renewable and clean energy sources for sustainable development in the region.

On behalf of the Director General of ICIMOD, we extend our sincere gratitude to the vast network of our knowledge partners, experts and organisations for their valuable intellectual contributions. Our special thanks are due to the authors, reviewers, and editors who made this report possible.

Together we have more power:

Status, challenges, and the potential for regional renewable energy cooperation in the Hindu Kush Himalaya

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Foreword

The Hindu Kush Himalaya (HKH) region is home to some of the world's most diverse landscapes, cultures, and ecosystems. Spanning eight countries and serving as a vital source of water, energy, and livelihoods for more than two billion people, the HKH is an essential driver of economic and social development. However, the region faces increasing challenges from the triple planetary crisis of climate change, biodiversity loss, and pollution. In addition, the people in the HKH region also face higher socio-economic vulnerabilities in the form of poverty – including energy poverty – food insecurity, and gender and social inequalities. Addressing these challenges requires collective action – particularly in the energy sector, where regional cooperation can unlock immense opportunities for sustainable growth.

In most HKH countries, government sources lack disaggregated data on mountain and hilly areas (the HKH region) in their databases, resulting in a significant gap in reliable and representative information on economic deprivations, vulnerabilities and mountain/hill economies. Assessment of national-level data of HKH countries reveals that, despite notable progress in economic growth and development in countries, some 260 million people still experience extreme monetary poverty, 591 million face multi-dimensional poverty, and over 47 million lack access to electricity. As energy demand surges, the HKH countries are aiming to transition to low-emission development pathways by expanding their renewable energy portfolios. This transition requires accelerated and concrete efforts at national and regional levels in the face of worsening macro challenges such as climate change and air pollution. However, most existing arrangements for cooperation are bilateral in nature; such arrangements need to evolve into regional collaboration to optimise energy benefits and achieve the sustainable development goals (SDGs). The HKH countries have a lot of potential for regional cooperation, particularly through resilient hydropower development (which by its nature is often transboundary), disaster risk reduction (the use of multipurpose reservoirs for reducing the risk of floods and droughts), renewable energy trade, and sharing knowledge and technologies for wind, solar and other renewables for a diverse energy mix and stable energy supply.

This report highlights the status, challenges, and opportunities for renewable energy development in the region. It examines existing energy sources, the share of renewable sources in the overall energy mix, analyses the climatic and non-climatic risks to the energy sector, and explores the potential for regional cooperation around renewable energy in the HKH. In doing so, it underscores the crucial role of regional collaboration in strengthening overall energy security, expanding access to clean energy, and fostering economic resilience amidst growing climatic and non-climatic risks and other uncertainties. Through a comprehensive analysis, the report provides valuable insights into how regional cooperation could help realise the region's energy potential to drive transformative change.

ICIMOD remains committed to advancing sustainable energy solutions in the HKH through facilitating regional cooperation and collaboration on research, knowledge sharing, and partnerships. By working together, countries in the region can create a more resilient and sustainable energy future – one that not only meets the needs of today but also safeguards the well-being of future generations.

We extend our gratitude to all the experts from the HKH countries who have collaborated to produce this significant report. We are confident that the findings and recommendations presented here will serve as a valuable resource for policymakers, researchers, and practitioners working towards a greener, more sustainable HKH.

Pema Gyamstsho
Director General

Izabella Koziell
Deputy Director General

Abbreviations and acronyms

BBIN	Bangladesh, Bhutan, India and Nepal
BIMSTEC	Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation
COVID-19	Coronavirus disease 2019
CPI	Consumer Price Index
DEs	dam equivalents
DISCOM	distribution company (India)
FY	fiscal year
GCMs	general circulation models
GDP	gross domestic product
GHG	greenhouse gas
GII	Gender Inequality Index
GLOF	glacial lake outburst flood
GW	gigawatt
HDI	Human Development Index
HKH	Hindu Kush Himalaya
IRENA	International Renewable Energy Agency
LPG	liquefied petroleum gas
MDP	multidimensional poverty
MW	megawatt
NDC	Nationally Determined Contributions
NEST	NExus Solutions Tool
RE	renewable energy
RoR	run-of-river
SAARC	South Asian Association for Regional Cooperation
SDG	Sustainable Development Goal
SEC	SAARC Energy Centre
TES	total energy supply
TPES	total primary energy supply

Executive summary

Despite notable progress in economic growth and development in the eight Hindu Kush Himalayan (HKH) countries, 260 million people still experience extreme monetary poverty, and 591 million are facing multidimensional poverty. More than 47 million people in these countries do not have access to electricity. With rising populations and economies, energy demand is surging. At the same time, countries are aiming to transition to low-emission development pathways. This means that HKH countries need to expand their renewable energy portfolios to meet the growing demand of the population and economies whilst achieving low emissions. Currently, in China and India, the contribution of the energy sector to total national greenhouse gas (GHG) emissions is 88% and 72% respectively. The expansion of the share of clean renewable energy (generated from hydro, solar and wind sources) in total energy supplies will help significantly reduce GHG emissions, particularly in these two countries and in general in all HKH countries. The transition from fossil fuels to clean renewable energy requires concrete efforts at national and regional levels in the face of worsening macro challenges such as climate change and air pollution. However, most of the existing arrangements for cooperation in the region are bilateral; such arrangements need to evolve into regional collaborations to optimise energy benefits and achieve the sustainable development goals (SDGs).

This report examines existing energy sources, the share of renewable sources in the overall energy mix, analyses the climatic and non-climatic risks to the energy sector, and explores the potential for regional cooperation for renewable energy in the HKH. The report is mainly based on a review of available data, peer-reviewed publications, reliable reports, and policy documents.

KEY FINDINGS

- Current economic [i.e., gross domestic product (GDP) growth rate, account deficits, unemployment rate, and inflation] and socioeconomic indicators (i.e., food insecurity, poverty and gender inequality) of HKH countries reveal significant potential for the productive and efficient use of renewable energy to boost economic growth and reduce socioeconomic inequalities and disparities.

- Among the HKH countries, Bhutan, Myanmar, Nepal, and Pakistan heavily depend on biofuels and waste (including agricultural residues, and industrial and municipal waste from a range of sources) with, respective shares of 25.1%, 51.2%, 66.7%, and 26.8% in total primary energy supply (TPES). In China and India, primary coal and peat are the major contributors to TPES. However, In Bangladesh, natural gas is the major energy source in TPES.

- In the HKH countries, the share of clean renewable energy (CRE) sources (hydro, wind, and solar) in TPES is only 6.1%. Bhutan has the highest share (37.8%) of CRE sources in TPES. China and Nepal have respective CRE shares of 7.1% and 6.8% in TPES. All other HKH countries have very small shares (0.3–3.7%) of CRE in TPES.

- The HKH countries generate only 28% of their electricity from RE sources. Bhutan and Nepal generate 100% of their electricity from renewable sources. Five HKH countries – Bangladesh, China, India, Myanmar and Pakistan – generate electricity mainly using fossil fuels with respective shares of 99%, 70%, 80%, 51%, and 76% in total electricity generated in these countries.

- The HKH countries have viable potential for around 882 GW through hydropower, and currently, only 49% of this has been tapped. As of 2023, Afghanistan, Bhutan and Nepal had developed only 2%, 10%, and 6% of their hydropower potential, respectively. Myanmar and Pakistan utilised 8% and 18% of their total hydropower potential. Of the total viable hydropower potential in the HKH countries, around 635 GW is estimated for the HKH area (hills and mountains) of these countries (see Table 9A for a list of states and areas). The potential for solar and wind power production in the HKH areas of these countries is nearly 3,000 GW. The HKH part of China has the highest potential for power production from solar (1772 GW) and wind (741 GW) sources. The HKH part of India also has the potential for 224 GW through solar power. The HKH parts of Afghanistan, Pakistan, and Nepal have respectively the potential of 80 GW, 56 GW and 24 GW to produce solar power.

- In Bhutan and China, 100% of the population has access to electricity. Access is lowest in Myanmar (72%). In other countries, approximately 90–99% of the population has access to electricity.

- In the HKH countries, the household sector is the main consumer of energy, except in China and India, where industry is the major consumer of energy – indicating the priorities of these two countries for value-added products and economic growth. Overall, in all HKH countries, there is a huge scope to enhance the productive consumption of energy in industries and agriculture. All HKH countries, except Bhutan, are net importers of energy with major imports of non-renewables.

- In the HKH, climate change is significantly impacting the energy sector, particularly hydropower production, through increased water variability, extreme weather events, and infrastructure damage. Hydropower generation faces challenges from changing hydrologic regimes, with variations in streamflow and seasonal shifts affecting output. Glacial lake outburst floods (GLOFs) and other extreme hydrological events pose major risks to existing and planned hydropower projects.

- The HKH countries also face severe non-climatic risks that threaten their energy sector, including economic, social, technical, environmental, and political challenges. High capital costs, low returns on investment, and limited financial resources hinder energy infrastructure development. Social risks such as lack of access to energy, social dislocation, and ecological degradation impact local communities, while technical challenges stem from insufficient technology and dependence on fossil fuels. Geopolitical conflicts and environmental threats like earthquakes and floods further complicate the situation.

- Despite several challenges to the energy sector in the HKH, there is high potential for multiple benefits through regional cooperation, particularly in developing integrated approaches for water, energy and agriculture, disaster risk reduction (energy relevant), energy trade, technology sharing, and collective efforts to meet global commitments [i.e. SDGs, and nationally determined contributions (NDCs) etc.].

POLICY MESSAGES

- The HKH countries need to increase the share of RE in their national energy mix to reduce GHG emissions, improve energy security, reduce their dependence on fossil fuel imports and mitigate the vulnerability of their economies to global market shocks. Currently, HKH countries, including Bangladesh, India, and Pakistan are heavily dependent on fossil fuel imports. Any changes or shocks in global energy markets are likely to impact energy prices and the national economies of these countries.
- There is an urgent need for regional cooperation to expand the CRE portfolio in total energy supplies in the HKH countries. Most of the existing arrangements for cooperation in the region are bilateral and need to evolve into regional collaborations involving more than two countries, to optimise energy benefits for countries.
- The energy sector is very complex and cross cutting and needs a holistic/multidimensional approach for regional cooperation to cope with the challenges and increase the mutual benefits for countries. For effective regional cooperation in the HKH energy sector, a holistic approach is needed beyond just hydropower trade. This includes developing resilient hydropower projects, sharing knowledge and technology for all renewables, promoting regional energy trade, and integrating disaster risk reduction and green growth strategies. Cooperation should address economic, social, technical, and environmental challenges, ensuring sustainable development, reduced emissions, and enhanced energy security, while meeting global commitments and supporting local communities.

1

Introduction

The Hindu Kush Himalaya (HKH) region extends 3,500 km across eight countries – Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan. The HKH countries have a combined population of 3.36 billion, constituting 42% of the global population, which grew annually by 0.9% between 2011 and 2021 (World Bank, 2021a). Some of the countries in the region i.e., Bangladesh, China, and India, are among the fastest-growing economies, and other countries also have the potential to grow in the future. Three countries – Bangladesh, Bhutan and Nepal – are in the process of graduating to low and middle-income country status (UNCTAD, 2021). The region is very rich in natural resources such as water, biodiversity, fertile land, and diverse seasons, which can play an important role in economic growth and development. Despite fast economic growth in recent decades in the HKH countries, almost 260 million people are still living in extreme monetary poverty[1] (Islam et al., 2021), and 591 million are facing multidimensional poverty[2] (OPHI-UNDP, 2021). Poverty varies across age groups and social segments such as gender, caste, ethnicity, and education status. It is also important to note that about 300 million people in the HKH countries are undernourished (FAO, et al., 2017). The energy access in the HKH countries has improved significantly over the years. Around 47.11 million people in the HKH countries have no access to electricity. Despite improved access to electricity, 829 million people in HKH countries still use traditional biomass for cooking (World Bank, 2023a; IEA et al., 2024). Traditional biomass in the region includes wood, crop residues and livestock dung, depending on local availability.

With a growing population and rising economy, HKH countries face several fundamental challenges, including meeting the growing demand for energy (Rasul et al., 2019). Notably, most countries in the

[1]Poor at $1.90 a day (2011 PPP)

[2]Three dimensions of health, education and standard of living were considered. These dimensions spanned ten indicators (nutrition, child mortality, years of schooling, school attendance, cooking fuel, sanitation, drinking water, electricity, housing, and assets).

HKH are transitioning to low-emission development pathways and are committed to the global 1.5°C target and to achieving net zero emissions by a certain target date, ranging from 2045 to 2070, including 2045 for Nepal, 2050 for Bhutan, 2050 for Pakistan, 2060 for China, and 2070 for India. To achieve these targets, all nations have either developed or are in the process of developing country-specific National Adaptation Plans (NAPs) (Goodrich et al., 2022). Besides, almost all countries in the region have submitted their NDCs and revised NDCs, highlighting the emphasis on the transition to a sustainable energy trajectory. With the net-zero emission targets, the HKH countries are likely to shift gradually from non-renewable to renewable energy sources in the future in all sectors.

Energy is fundamental for economic growth and has the potential to help alleviate all forms of poverty. Without regional cooperation, it will be difficult for countries to meet the growing demand for energy, particularly renewable energy, for increasing population and economic growth. Hydropower is a significant source of potential renewable energy in many HKH countries. All HKH countries are hydrologically linked because most of the rivers with hydropower potential are transboundary i.e., Indus, Kabul, Ganges, Brahmaputra, Mekong, and Meghna rivers. These rivers offer significant potential for the development of water resources for hydropower, irrigation, navigation, transportation, fisheries, tourism, and ecosystems. Their management has regional implications, and many of these rivers serve as shared resources. Downstream countries depend heavily on water flowing from upstream countries for agriculture, hydropower production and other uses, while the upstream countries depend on downstream countries for connectivity, trade, and transit (Rahaman, 2009; De Fraiture et al., 2010; World Bank, 2014; Rasul et al., 2019). Despite the high potential for regional benefits of cooperation on energy, hydropower in the HKH faces regulations that are related not just to energy, but also to water and environment. All these sectors have a significant influence on governments' decisions within each country about regional cooperation. In addition to hydropower, other sources of renewable energy, such as solar, wind and biofuels, also need to be prioritised at the regional level for cooperation on technology development and sharing.

In most countries in the HKH, demand for energy is increasing fast to meet the needs of the growing population, industrial development, and to foster economic growth. At the same time, these countries are highly vulnerable to climate change-induced risks and hazards such as floods, droughts, and heatwaves. Their carbon dioxide emissions continue to increase. In fact, this region is identified as the most vulnerable region to climate hazards and climate shocks (World Bank, 2023b). Some countries such as Bangladesh, India, and Pakistan are facing the energy trilemma – the triple challenges of energy security, energy equity, and environmental sustainability (WEC, 2022). These countries have become more dependent on the volatile global energy market in recent years. For example, India is the third largest global importer of crude oil and products, with over 87.7% (281,032 MT) of its consumption met by imported products (PPAC, 2024; Prasad, 2024). Bangladesh and Pakistan also depend mainly on imported sources of fuel. Any changes or shocks in global energy markets are likely to impact energy prices and the national economies of these countries. In recent years, the vast population in Bangladesh and Pakistan has faced power outages that at times have lasted around 10 hours a day. In the face of energy shortages, the cost of electricity generation in these countries has also spiked dramatically (Amjad, 2022).

In the HKH, the energy trilemma, increasing demand for energy, and uneven spatial distribution of natural resources have created a pressing need for regional cooperation in the energy sector, particularly in hydropower (Gippner, 2010; WEC, 2022). Achieving the SDGs, particularly SDG-7 on 'clean and affordable energy', requires strong intergovernmental cooperation to enhance economic opportunities at the regional level (Hussain et al., 2019).

Realising the significance of energy in boosting economic growth and improving people's quality of life, several bilateral agreements on energy have been implemented by the HKH countries. However, to ensure optimal use of the available water resources for hydropower, capitalising on the potential for other renewable energy sources, and maximising the benefits of energy trade, it is now imperative to shift action from bilateral to regional collaboration.

In the context of this report, 'regional' here signifies multiple countries working together on specific issues, shared river basins and trade priorities. Indeed, no matter how much technical potential power generation exists, it will not optimally benefit the countries unless regional cooperation and an effective mechanism are developed and implemented (Yazdanie et al., 2010). It requires a wide range of actions, including establishing cross-border infrastructure and promoting regional fora to exchange both the experience and technology that is widely available within countries (ADB, 2013). For example, to boost hydropower trade, cross-border infrastructure is very important. Countries with abundant hydropower resources can use cross-border infrastructure such as high-voltage transmission lines to use their reservoirs as 'batteries' to balance variable power generation in neighbouring countries (WEC, 2015). Tapping the potential benefits of energy as a regional good also requires harmonising country-level regulations, policies, and legal institutions with each other to smoothen the process of creating a common platform and establishing regional mechanisms (Hussain et al., 2019).

In the HKH, there are a few examples of regional mechanisms for cooperation on energy. In 2000, a formal process of energy cooperation was established by the South Asian Association for Regional Cooperation (SAARC). This process included six HKH countries, which are part of the South Asian region. Under this process, the South Asia Regional Initiative for Energy Integration is one of the initiatives designed to move South Asian countries towards increased regional energy security (IRADe, 2013). The programme aims to address policy, legal and regulatory issues related to energy in the region. It has been supporting regional efforts and bilateral energy development programmes through large-scale infrastructure investment, technical assistance, feasibility studies and advisory services (Rahman et al., 2011). Despite these efforts, there is still a need for concrete regional efforts to effectively implement and sustain these programmes. The imperative to implement regional efforts to address the energy issues in the region becomes magnified, taking into account recent changes to the focus on renewable energy and climate change in all HKH countries.

Cognisant of the urgent need for regional cooperation on energy in the HKH, this report evaluates the current state of energy resources, national policies, and regional mechanisms on energy, climate and non-climatic risks to energy sources. Additionally, the report explores the potential benefits of regional cooperation on energy in the HKH and suggests a mechanism for moving towards regional cooperation.

THANA GLACIER, BHUTAN

2

Method and approach

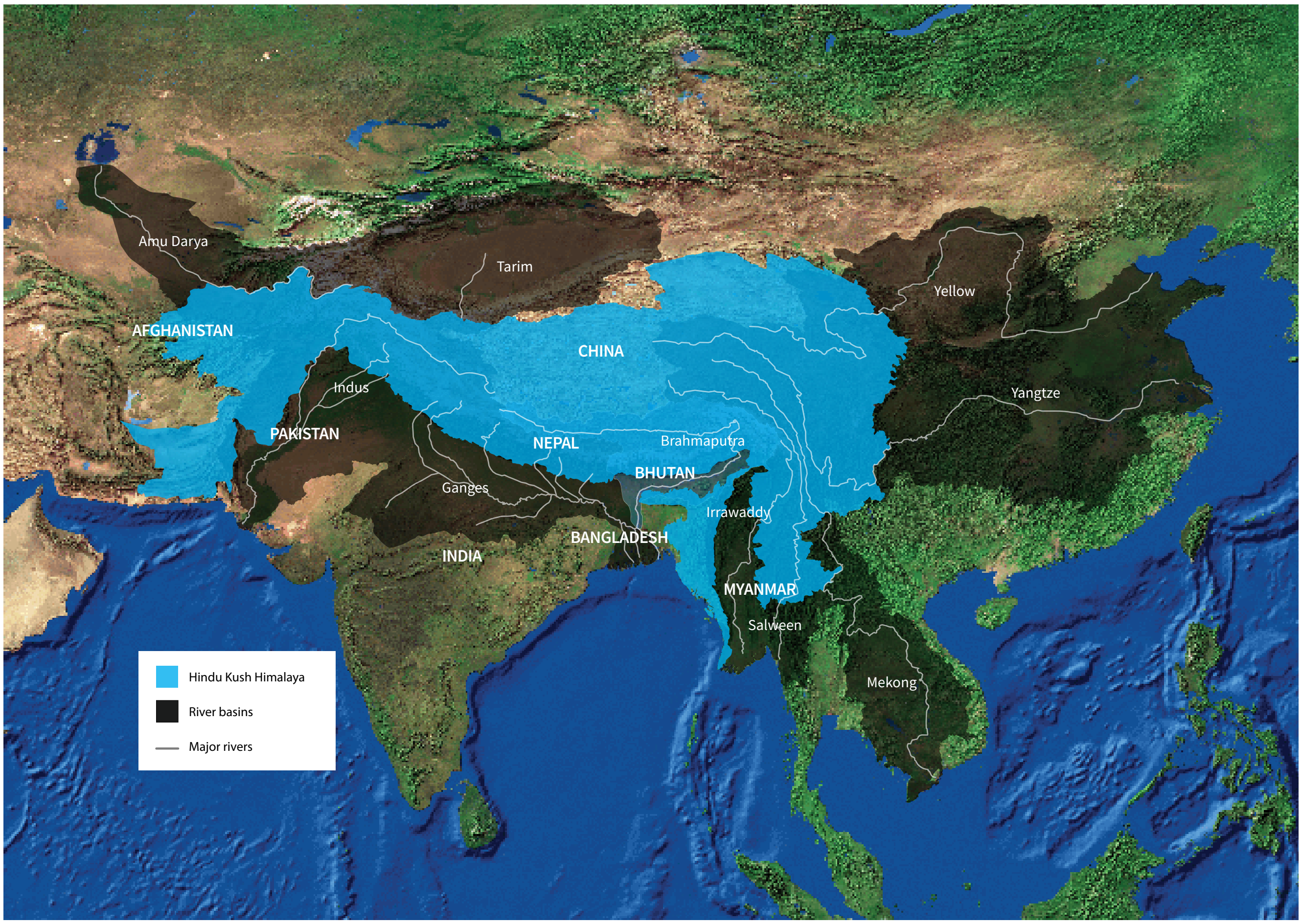
The geographical focus of this report is the HKH region (Figure 1). This region extends 3,500 km across eight countries – Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan – covering a hilly and mountainous area of 3,441,719 km^2 and accommodating 270 million people (2024 projection based on statistics by Wester et al., 2019, see Table 1A). The HKH has a huge potential for hydropower generation. This is manifested by high mountains, many glaciers and large rivers. The region is a source of ten large river basins – the Amu Darya, Indus, Ganges, Brahmaputra (Yarlung Zangbo), Irrawaddy, Salween (Nu), Mekong (Lancang), Yangtse (Jinsha), Yellow River (Huanghe) and Tarim (Dayan) (Shrestha et al., 2015). These rivers provide water, ecosystem services and the basis for the livelihoods of 2.1 billion people living in both upstream and downstream areas – one-fourth of the world's population (see Table 2A, projected for 2024 based on statistics in Wester et al., 2019). More importantly, power generated from the water of these rivers benefits the national economies of HKH countries and serves the total population of 3.36 billion (World Bank, 2021a) living in these countries.

This report primarily focuses on the HKH region (hilly and mountainous areas). However, the analysis uses data from both national and HKH-specific areas of the countries for two key reasons. Firstly, reliable and comprehensive energy-related data specific to the mountain and hill areas of the HKH countries were inadequate (except for Bhutan and Nepal). Secondly, critical decisions and actions regarding energy production, distribution, and trade are predominantly undertaken by national governments. Consequently, the analysis chiefly relies on national-level data. Wherever feasible, HKH-specific data were also utilised to bring in the mountain perspective.

This report has been prepared based on the review of available data, peer-reviewed publications, governments' official reports, and policy documents (national policies, programmes, plans, and regional frameworks). The report evaluates the current state of knowledge on the energy sector in the HKH countries with an aim to suggest policy-oriented recommendations and inform relevant decision-makers to promote regional cooperation to address the challenges in the sector and benefit from the potential and opportunities. Moreover, the report has attempted to translate scientific knowledge into easily understandable content that is important, legitimate, and credible to wider audiences (based on learning from Wester et al., 2019). This report mainly focuses on issues of regional importance with examples and case studies from countries and river basins. It is also important to mention here that the report has not adequately covered China, due to the lack of access to official reports and policy documents in the English language. For this study, in addition to published literature, reports and policy documents, various key informants from four HKH countries – China, India, Nepal and Pakistan – were also interviewed for a better understanding of the national policies on energy and their flexibility for any regional cooperation. The study also benefitted from several policy roundtables and workshops organised by ICIMOD during the period 2019–2024.

It is also important to provide clarification regarding the estimation of statistics for the broader category of 'Biofuels and Waste' within the total primary energy supply, as presented in this report (Table 1). In accordance with the methodological guidelines outlined by the International Energy Agency (IEA, 2024a), the 'Biofuels and Waste' category encompasses both renewable and non-renewable segments. The renewable segment includes liquid biofuels (such as biodiesel, bioethanol, and other liquid biofuels), traditional renewable energy sources like solid biofuels (e.g., plant matter, fuelwood), wood pellets, charcoal, bagasse, animal waste, sludge gas, and the renewable fraction of municipal and industrial waste. Additionally, the 'waste' component within this category incorporates certain non-renewable materials, such as industrial and municipal waste (e.g., old tyres and plastics), which are utilised as energy sources.

FIGURE 1: THE HINDU KUSH HIMALAYA (HKH) REGION



3

An overview of the economy and social wellbeing in HKH countries

Energy is cross cutting, considered the most important input to all economic sectors and is key to improve the socioeconomic wellbeing of populations. For example, the productive and efficient use of energy for production in primary sectors (i.e. agriculture), water supplies (including irrigation, industrial use, household use, etc.), value addition in economies (secondary sectors), and provision of adequate services (i.e., transportation, storage, tourism etc.) is key to economic growth (Rasul et al., 2019) and addresses socioeconomic issues and disparities such as food insecurity, poverty, social and gender inequalities, water insecurity, and inadequate human development and wellbeing (Amjath-Babu, 2019; Goodrich et al., 2022; Hussain et al., 2019).

Currently, the HKH countries are at different stages in terms of economic growth and socioeconomic indicators. GDP per capita growth in Afghanistan and Myanmar was negative in 2021 due to the surge of COVID-19 and political instability, which led to significant economic contractions in both countries. China and India had the highest GDP growth per capita in the region in 2021, with about 8 percent growth in both countries (Table 3A). COVID-19 in 2020 impacted the growth rate in most of the HKH countries, with some even experiencing negative growth in that period. The unemployment rate in the HKH countries remained around 2–6%, except for Afghanistan, where a double-digit unemployment rate has been observed due to recent political instability and uncertainty in the job market. Most HKH countries had recorded inflation in the range of 3–6%, with only Bhutan and Pakistan registering an inflation rate higher than 7%. However, China maintained its inflation rate at less than 1% (Table 3A).

As far as socioeconomic indicators are concerned, most countries in the HKH are categorised in the ‘medium’ human development level, with a score in the range of 0.55–0.7. However, China comes under the ‘high’ human development level with a score in the range of 0.7–0.79. The incidence of multidimensional poverty and gender inequality is very high in HKH countries, except China (Table

ENERGY-EFFICIENT STOVES, YUNNAN, CHINA.

4A). Afghanistan has the highest proportion of a multidimensionally poor population, with more than half of the population falling in this group. About 37% of the population is multidimensionally poor in Bhutan, Myanmar, and Pakistan. Roughly a quarter of the population in Bangladesh and India can be classified as poor according to this measure. Notably, the gender inequality index is above 0.45 in all HKH countries except China. Similarly, the prevalence of moderate or severe food insecurity in the HKH region is around 30 percent of the population in most of the countries, except for Afghanistan, where 70% of the population is moderately or severely food insecure (Table 4A).

Overall, with respect to their economic growth, HKH countries either need to maintain this growth (China and India) or improve (other HKH countries) and reduce the unemployment rate and inflation through improving production in primary sectors, expediting the transition from primary to value-added products and services, and improving the provision of allied services (i.e. trade, transportation). The productive and efficient use of renewable energy can not only facilitate economic growth and improvement in socioeconomic indicators but can also help the transition of economies toward green and low-emission systems. During this transition, there is also a need to reduce social inequalities and disparities through creating income opportunities for women, youth and marginalised mountain communities.

4

Current energy resources and potential for renewable energy in the HKH

4.1 PRIMARY ENERGY SUPPLY

Data on total primary energy supply (TPES) from HKH countries (Table 1) show that there is variation in terms of dependency on different energy sources – coal, natural gas, nuclear, hydro, wind and solar, biofuels and waste, and oil – across countries.

Afghanistan heavily relies on oil (60.9%) and coal (24%), underscoring its dependency on fossil fuels and the related energy security risks. Bangladesh's energy mix is dominated by natural gas (52.7%) and oil (26%), reflecting its reliance on natural gas reserves. Bhutan stands out with a focus on renewable energy, primarily depending on hydro (37.4%) and biofuels and waste (25.1%) (in this context, 'waste' includes agricultural residues, and industrial and municipal waste from a range of sources). In contrast, China's energy supply is heavily coal-based (61%), with significant contributions from oil (17.9%) and natural gas (7.8%), indicating a strong reliance on fossil fuels. India's energy profile mirrors China's, with coal (45.9%) and oil (24%) being major sources, supplemented by biofuels and waste (20.7%). The large share of non-renewable energy sources in TPES in China and India significantly impacts GHG emissions globally. In China and India, the contribution of the energy sector to total national GHG emissions is respectively 88% and 72% (Table 5A). Expanding the share of renewable energy in TPES, particularly in these two countries and in general in all HKH countries, is crucial for reducing GHG emissions.

Myanmar's primary energy sources are biofuels and waste (51.2%) and oil (27.6%), highlighting a mix of traditional biofuels (i.e. wood fuel) and fossil fuels. Nepal is distinct with a predominant use of biofuels and waste (66.7%), showcasing its heavy reliance on biomass energy (Table 1). Lastly, Pakistan's energy mix is varied, with substantial contributions from natural gas (24.2%), biofuels and waste (26.8%), and oil (25.5%). This scenario illustrates that each country's energy profile highlights different strategic priorities and challenges in transitioning to renewable energy sources.

TABLE 1: ENERGY SOURCES IN TOTAL PRIMARY ENERGY SUPPLY (TPES)

Energy source	Total energy supply by source (Terajoules)							
	Afghanistan	Bangladesh	Bhutan	China	India	Myanmar	Nepal	Pakistan
Coal	38,527 (24.0%)	114,576 (5.5%)	6,519 (19.6%)	97,026,297 (61.0%)	19,499,798 (45.9%)	14,332 (1.6%)	40,804 (6.3%)	686,008 (14.3%)
Natural gas	2,610 (1.6%)	1,095,792 (52.7%)	-	12,449,865 (7.8%)	2,161,701 (5.1%)	142,783 (15.9%)	-	1,160,327 (24.2%)
Oil	97,749 (60.9%)	541,319 (26.0%)	5,844 (17.5%)	28,481,573 (17.9%)	10,191,822 (24.0%)	248,721 (27.6%)	130,433 (20.2%)	1,224,434 (25.5%)
Nuclear	-	-	-	4,557,548 (2.9%)	500,301 (1.2%)	-	-	293,605 (6.1%)
Biofuels and waste	18,559 (11.6%)	321,679 (15.5%)	8,372 (25.1%)	5,352,800 (3.4%)	8,802,022 (20.7%)	460,857 (51.2%)	430,035 (66.7%)	1,286,111 (26.8%)
Hydro	2,656 (1.7%)	2,839 (0.1%)	12,473 (37.4%)	4,726,214 (3.0%)	625,208 (1.5%)	32,660 (3.6%)	38,115 (5.9%)	124,685 (2.6%)
Other renewables (solar, wind, geothermal, etc.)	338 (0.2%)	3,135 (0.2%)	101 (0.3%)	6,531,547 (4.1%)	734,183 (1.7%)	572 (0.1%)	5,741 (0.9%)	26,074 (0.5%)

Note: Year of data is 2022
Source: Afghanistan: UNSD, 2023; International Renewable Energy Agency (IRENA), 2024a, Bhutan: DoE, 2022; Other countries: IEA, 2024b

Biofuels and waste have major contributions from traditional renewable energy sources derived from plants and animals (also called biomass). However, it is difficult to consider biomass (e.g., wood fuel, biogas) and other biofuels (e.g., biodiesel) as clean energy sources. Around 61% of the rural population in the HKH countries (as of 2021), a majority of whom live in the mountain areas, are largely dependent on biomass (Dhakal et al., 2019; Our World in Data, 2024a). Interestingly, the share of clean sources (hydro, solar and wind) of renewable energy in TPES in the HKH countries is very small, ranging from 0.3% to 7.1% across HKH countries, except Bhutan (Table 1 & Table 6A). In Bhutan, the share of clean renewable energy in TPES is 37.8%. In China and Nepal, the share of clean renewable energy is 7.1% and 6.8% respectively. In the other five countries (Afghanistan, Bangladesh, India, Myanmar and Pakistan), the share of clean renewable energy in TPES is well below 5%. Overall, the share of clean renewable energy is only 6.1% (Table 6A).

Increasing the proportion of clean renewable energy in the total energy supply is crucial for promoting sustainable development and reducing GHGs in the HKH region.

4.2 ENERGY BALANCE AND SECTORAL CONSUMPTION

It is important to examine the energy balances to understand the national production and energy trade dependency of countries. It is also important to examine the consumption of energy by different sectors within countries to identify which sectors could benefit the most from regional cooperation and energy trade. Overall, HKH countries, except Bhutan, are net importers of energy with major imports of non-renewables. Afghanistan is a net importer of energy, primarily importing oil products and electricity. However, the country exports primary coal and peat (IEA, 2019; UNSD, 2019). Bangladesh relies heavily on imports for a substantial amount of its energy needs, which include coal, crude oil, oil products, natural gas, and electricity. Imports account for around 30% of the country's total energy supply. Bhutan is a notable net exporter of energy, with electricity being its primary exported commodity. The country's vast hydropower potential allows it to export electricity to the neighbouring countries. China, being the largest country in the region, has a significant dependence on energy imports, including non-renewable sources such as oil products, coal, crude oil and natural gas. Nevertheless, it functions as a country that exports more electricity than it imports, utilising its extensive infrastructure and capacity for electrical generation. Similarly, India imports a significant amount of non-renewable energy sources and is a net exporter of electricity, due to its substantial infrastructure and renewable energy initiatives. Myanmar is a net exporter of energy with major exports of natural gas. Nepal imports a substantial amount of energy, primarily non-renewables such as coal, oil products, and electricity. Imports of energy are crucial for the country to meet its domestic energy demand. Pakistan is a net importer of energy, with non-renewables making up most imports. To achieve its internal energy requirements, the country heavily relies on imports (IEA, 2019; UNSD, 2019).

In HKH countries, a sector-wise breakdown of the final energy consumption shows that the household sector is the main consumer of energy, except in China and India (Table 7A). In both China and India, industry is the major consumer of energy, indicating the priorities of these countries for economic growth and development. In addition to household and industry, the transport sector also consumes a significant proportion of energy in countries. Minor proportions of energy are also consumed by commercial and public activities, agriculture and forestry, and other consumers. Expanding energy access in industry and agriculture is particularly crucial for enhancing productivity and economic development (Table 7A). Overall, in all HKH countries, energy consumption continues to rely heavily on non-renewable energy sources. The abundant use of fossil fuels has posed a greater danger to environmental concerns, including high-energy-related emissions (EEA, 2017; Van et al., 2017; Brown et al., 2012). However, there is a huge scope to increase the share of renewable energy in both supply and consumption, which could enhance energy security while reducing environmental impacts (Table 7A).

4.3 CURRENT SHARE OF RENEWABLE ENERGY SOURCES IN ELECTRICITY PRODUCTION

There are notable differences in the proportion of renewable and non-renewable energy resources in electricity generation in the HKH countries. Table 2 shows electricity production by source in the HKH countries. Electricity generation in Bangladesh, China, India, Myanmar, and Pakistan is predominantly dependent on non-renewable energy sources. In Bangladesh, fossil fuels account for 98% of the total electricity generated, with a substantial reliance on gas (69,190 GWh) and oil (25,810 GWh). In China, most of the power, accounting for 67%, is generated from fossil fuels, primarily coal, which contributes to a total of 5,397,800 GWh. In India, fossil fuels, mostly coal (1,380,100 GWh) and gas (47,040 GWh), contribute to 77% of the country's electrical generation. In Myanmar, fossil fuels account for 56% of the total energy generation. The primary sources of this electricity are gas, which contributes 8,030 GWh, and coal, which contributes 2,170 GWh. In Pakistan, most electricity production (68%) is derived from non-renewable sources, with gas accounting for 56,450 GWh and oil contributing 18,800 GWh.

Conversely, Afghanistan, Bhutan, and Nepal mostly generate their electricity from renewable sources, with hydropower being the leading source. Afghanistan relies on renewable sources, mostly hydropower, for 84% of its electricity generation, amounting to 620 GWh. Nevertheless, Afghanistan relies heavily on importing most of its electricity from neighbouring countries to fulfil its local energy needs (Ahmadzai & McKinna, 2018). Bhutan exclusively depends on hydropower as its sole source of electricity generation, producing a total of 9,000 GWh, which accounts for 100% of its energy supply and is derived entirely from renewable sources. Nepal exclusively generates all its electricity, amounting to 9,670 GWh, from renewable sources, with hydropower being the primary source.

China and India, despite their substantial dependence on non-renewable sources, have made remarkable progress in renewable energy. China derives 30% of its electricity from renewable sources, with hydro (1,303,130 GWh), solar (427,720 GWh), and wind (762,700 GWh) making significant contributions. India's energy generation from renewable sources accounts for 20% of its total output, with significant contributions from hydro (174,920 GWh), solar (95,160 GWh), and wind (70,050 GWh). Myanmar and Pakistan demonstrate moderate levels of renewable energy source utilisation for electricity production, accounting for 49% and 24% respectively. Myanmar heavily depends on hydropower, generating 9,700 GWh of electricity. In contrast, Pakistan has a more varied renewable energy portfolio, which includes hydropower (34,580 GWh) and bioenergy (1,910 GWh). Overall, the HKH countries produce 28% of electricity from renewable sources (solar, wind, hydro and bioenergy).

TABLE 2: ELECTRICITY PRODUCTION BY SOURCE

Countries	Electricity production by source (GWh)								
	Coal	Oil	Gas	Nuclear	Solar	Wind	Hydro	Bio-energy	Share (%) of renew-ables
Afghanistan	30	100	-	-	80	-	620	-	84%
Bangladesh	5,660	25,810	69,190	-	530	10	790	-	1%
Bhutan	-	-	-	-	-	-	9,000	-	100%
China	5,397,800	72,370	290,580	417,800	427,720	762,700	1,303,130	176,630	30%
India	1,380,100	3,780	47,040	46,190	95,160	70,050	174,920	40,740	20%
Myanmar	2,170	120	8,030	-	100	-	9,700	270	49%
Nepal	-	-	-	-	140	10	9,670	-	100%
Pakistan	30,020	18,800	56,450	22,280	1,300	3,190	34,580	1,910	24%
Overall	6,815,780	120,980	471,290	486,270	525,030	835,960	1,542,410	219,550	28%

Note: Year of data is 2022
Source: Our World in Data, 2024b

4.4 POTENTIAL FOR RENEWABLE ENERGY SOURCES FOR ELECTRICITY PRODUCTION

The HKH countries have huge potential for the use of renewable sources to produce electricity. Overall, these countries have a viable potential of 882 GW for hydropower production; of which only 49% is harnessed. Similarly, these countries have enormous potential to produce electricity from wind and solar sources (Table 8A). Within these countries, the HKH areas also have a huge potential for the production of electricity from renewable sources, which could help in reducing dependency on fossil fuel-based electricity (Vaidya, 2012). The region alone has the potential for over 635 GW of hydropower production, though a very small percentage of this is utilised (See Table 3). Maximising the use of hydropower potential in the HKH areas can support countries to reach net-zero carbon emissions (ADB, 2017a; REN21, 2019; World Bank, 2021b). It can also be an opportunity to expand the share of renewable energy in the energy mix, boost greener economic activities, and open the doors for trade and broader regional cooperation. The HKH region also has huge potential for the use of solar and wind sources to produce electricity. The region has the potential for nearly 2,200 GW and 750 GW of electricity generation, respectively, from solar and wind sources (Table 3). The HKH areas of China have the highest potential for electricity production from solar (1,772 GW) and wind (741 GW) sources. The HKH areas of India have the potential for 224 GW from solar energy. The HKH parts of Afghanistan have a solar energy potential of 80 GW and around 6 GW of wind energy potential. Pakistan and Nepal have, respectively, a solar energy potential of 56 GW and 24 GW. Myanmar and Bhutan also have significant potential for solar energy of 12.7 GW and 12 GW, respectively (Table 3).

TABLE 3: RENEWABLE ENERGY POTENTIAL IN THE HKH PARTS OF COUNTRIES

Country	Hydro (GW)	Solar (GW)	Wind (GW)	Biomass (GW)
Afghanistan	22.84	80.2	5.8	nd
Bangladesh	0.14	nd	nd	nd
Bhutan	23.76	12.0	0.8	2.6
China	358.94	1,772.4	741.1	nd
India	122.77	224.0	0.7	0.5
Myanmar	11.27	12.7	nd	nd
Nepal	43	23.6	0.45	nd
Pakistan	52.32	56.0	nd	nd
Overall	635.04	2180.9*	748.85**	-

nd = no data available; 1gigawatt (GW) = 1000 megawatt (MW)
Data is only for the HKH parts of the countries. Data from the Chittagong Hill Tracts of Bangladesh was not available.
*Excluding Bangladesh
**Excluding Bangladesh, Myanmar, and Pakistan
Note: Biomass, refers to biofuels and all types of renewable wastes (i.e. from plant and livestock matter) used for energy production
Source: Rana et al. 2022

Country-level data shows that Afghanistan, Nepal, and Bhutan had developed only 2%, 6% and 10% of their country's total hydropower potential respectively (Table 8A). Myanmar and Pakistan utilised 8% and 18% of their country's total hydropower potential. There are supply-side constraints that have prohibited the development in these countries (Zhengming et al., 2002; ADB, 2017b; Soe et al, 2017; Gunatilake et al., 2020; Liu et al, 2022; DGPC, 2022; DOED, 2024; MNRE, 2024; Solar Mag, 2024). Likewise, the harnessed potential of solar, wind and bioenergy is also very low (Table 4). China and India are ahead of other countries in solar and wind energy technologies. Despite this fact, China has harnessed only 23% of solar and 18% of wind energy potential. India has tapped around 10% of solar and 6% of wind energy potential (see Table 4 and Table 8A). Other HKH countries are well behind in the utilisation of the potential of these renewable sources.

The detailed renewable energy potential by states and provinces of the HKH countries is shown in Table 9A.

TABLE 4: TOTAL INSTALLED CAPACITY FOR RENEWABLE ENERGY OF THE HKH COUNTRIES

Country	Installed capacity for renewable energy (MW)				
	Solar	Wind	Hydro	Bioenergy	Total
Afghanistan	35	-	458	-	493
Bangladesh	754	-	231	41.04	1,026
Bhutan	-	-	2,336	-	2,336
China	610,554	450,647	363,425	29,074	1,453,701
India	73,892	43,984	47,502	10,556	175,934
Myanmar	105	-	3,334	70	3,509
Nepal	112	-	2,687	-	2,799
Pakistan	1,274	1,840	10,617	425	14,156

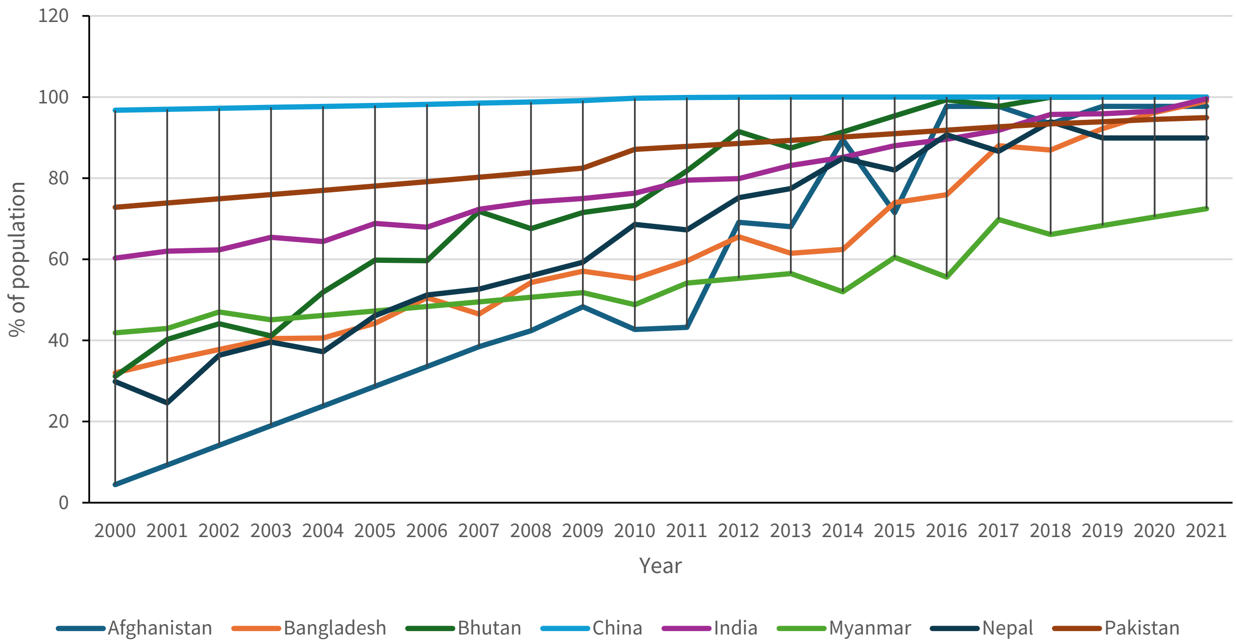
Note: Year of data is 2023
Source: IRENA, 2024a; IRENA, 2024b

4.5 POPULATION WITH ACCESS TO ELECTRICITY

The HKH region has made tremendous progress in improving access to electricity for its people (Figure 2). According to the SDG 7 Tracker (2024), Bhutan and China have nearly reached 100% electrification. Bangladesh and India are similarly close, with 99.4% and 99.2% of their people having access to electricity, respectively. Afghanistan has made significant progress, with 85.3% electrification. Nepal has also made great progress, with 91.3% of the population now having access to electricity. Pakistan has achieved a 95% electricity rate, indicating consistent progress in recent years. Myanmar, on the other hand, remains the farthest behind, with only 73.7% of its population having access to electricity, despite improvements in previous years. The data demonstrates the disparities in access to electricity within the HKH countries, emphasising the necessity for ongoing efforts to attain universal electrification.

The region's overall population is around 3.36 billion, and ensuring full access to electricity for all remains a vital goal for long-term sustainable development.

FIGURE 2: POPULATION WITH ACCESS TO ELECTRICITY IN HKH COUNTRIES



Source: Our World in Data, 2024c

BAND-E AMIR NATIONAL PARK, BAMYAN, AFGHANISTAN

5

National policies and regional mechanisms on energy

5.1 NATIONAL POLICIES

Various research sources have identified the possibility of energy cooperation in the South Asian region with benefits exceeding costs, and have suggested a regional approach for energy management (e.g., Wijayatunga et al., 2015; Pandey et al., 2020). However, for regional cooperation to develop between nations, the national policies of countries are important as they ignite a possible cooperation approach that manifests on a regional scale. Therefore, national policies are considered a key element, out of many, for devising a successful regional policy (Simanavičienė & Kilijonienė, 2005; Kolosovska et al., 2020). All eight HKH countries have a deep repository of national-level policies related to energy generation, utilisation, distribution and use. National-level policies are also present for various sub-sectors of energy and at various governance levels. However, the number of policies addressing or directed towards regional cooperation is rather low.

Foreign investment in hydropower development is quite evident in the national policies of the countries. It is worth noting that the extraordinary hydropower potential of almost all HKH countries has led policymakers to develop strategies that attract foreign investment for hydropower development. The countries with high energy demand and low energy generation capacity and vice-versa, have incorporated provisions to import and export energy from/to neighbouring countries and to collaborate on infrastructure development, such as cross-border transmission lines, grid interconnections, and regulatory frameworks, to enable efficient energy trade. In some policies, such approaches are reiterated as fostering international cooperation with regional neighbouring countries for the settlement of logistical and administrative issues related to energy trading and settling confusions and disputes that may arise. Unsurprisingly, countries seem to prioritise national interests while considering the export and import of energy. The countries have formulated policies that develop and support clean energy generation, especially through hydropower development and have also highlighted the necessity to reduce dependency on imported fuel, mainly fossil fuels.

Energy export, especially hydropower, has been a major source of foreign revenue generated in countries like Bhutan (DoE, 2022), and this is reflected in the energy policies of the countries. Further, to attract foreign investors to energy sector development, countries have policies that are favourable for foreign investors through tax exemption, land acquisition/lease, foreign employment, borrowing facilities, etc. (policies in Bangladesh, Bhutan, Myanmar and Nepal). The policies also reflect the forward-looking strategy, especially through organising network events and fostering international partnerships for collective learning, development and the transfer of knowledge and technology. The inclusion of regional energy markets and regional economic development is envisaged through hydropower development and extending the power system at bilateral and regional levels. Overall, issues of the bilateral energy trade and aims for foreign investment appear to have more emphasis on the policies rather than on the regional approach.

In addition to their national policies, the HKH countries have made specific global commitments after the Paris Agreement in the form of nationally determined contributions (NDCs). The main aim of the NDCs is to reduce greenhouse gas emissions and adapt to the impacts of climate change in each nation. In accordance with the NDCs, countries have set up conditional and unconditional targets to reduce GHG emissions through the use of clean and renewable energy. In alignment with the NDC commitments, the majority of HKH countries have outlined specific targets and plans to transition key sectors, such as transport, household (cooking), agriculture, small and medium-sized enterprises, industries and services to low-emission solutions, through an increased share of renewable energy in production and supply chains. The energy requirements for these sectors are planned to be fulfilled from electricity and energy generation from hydro, solar, wind, and biomass resources. Regional integration and international cooperation are also identified in the NDCs, mainly through energy generation and trading from countries whose generation capacity exceeds consumption (UNFCCC, n.d.).

In the HKH countries, national policies that include subsidies for different categories of energy consumers have received specific attention from governments, policymakers, and energy sector stakeholders. Governments of most countries in the HKH have subsidised electricity (often targeting low-income households, agricultural consumers, or specific industries), as well as for gas [natural gas and liquefied petroleum gas (LPG)], petroleum products and coal. This makes them comparatively cheaper; therefore, people prefer using these energy sources instead of the currently expensive alternatives, which are clean renewable energy sources. For instance, annually, China gives USD 18 billion in subsidies for petroleum products and USD 12.4 billion for gas. Likewise, India is giving annual subsidies of USD 21.0 billion for oil and USD 0.9 billion for gas. Pakistan is giving USD 1.7 billion for gas, and Bangladesh is giving USD 0.9 billion for gas (IEA, 2019; Global Subsidies Initiative-IISD and BIDS, 2020). The provision of subsidies appears to feed this overconsumption of non-renewable energy fuels, which in turn leads to implications for regional air pollution. Likewise, the use of traditional renewable energy sources such as wood fuel and biogas by a majority of the rural population in the HKH countries contributes to air pollution.

There are also some positive examples of gradual transitioning to clean renewable energy, particularly in areas that are remote and mountainous, where it is extremely difficult to set up grid lines for electricity. A number of governments are making attempts to increase the use of clean renewable energy in their decentralised form, often called Decentralised Renewable Energy (DRE). For instance, in the absence of grid electricity, low-cost solar lighting systems are being used in rural areas that are distant from urban centres or infrastructure (Haque et al., 2022). In India, the government has introduced several initiatives, including subsidies to the rural poor to move away from their dependence on firewood (Thomas et al., 2022).

5.2 REGIONAL AND BILATERAL MECHANISMS FOR COOPERATION ON ENERGY

Countries in the HKH have a growing demand for energy, attributed mainly to rapid industrial and agricultural development (Nepal et al., 2020). Through regional cooperation, countries can meet their energy requirements and benefit from trading energy surplus with other countries (Agrawal, 2022). For instance, in South Asian transboundary river basins, regional cooperation on cross-border energy trade can yield benefits 30 times more than the cost (Wijayatunga & Fernando, 2013; Wijayatunga et al., 2015). However, multilateral cooperation between the nations of the region is lacking as they have resorted to bilateral mechanisms chiefly involving India (Table 7; Saklani et al., 2020). Higher transaction costs, power asymmetry, and operational challenges have driven countries to prefer bilateral agreements to multilateral agreements (Pandey et al., 2020). Additional bilateral mechanisms exist in the form of energy trading between nations, such as between India and Bhutan. These countries comply with their energy needs pragmatically by engaging in electricity trade and hydropower projects (MFA, 2024). Significant bilateral procedures are power trading agreements that are overseen by organisations such as Druk Green Power Corporation (DGPC) and PTC India Limited. For example, PTC India Limited signed a long-term Power Purchase Agreement (PPA) with the Tangsibji Hydro Energy Limited (THyE), through the DGPC, to enable the sale of hydropower from Bhutan to Indian states. With the intention to grow, Bhutan now supplies India with over 1,400 MW of hydropower from facilities including Chhukha, Tala, and Kurichhu hydropower plants, which are located in the western and central parts of Bhutan (PTC India, 2024; DGPC, 2024a). However, during the winter months, Bhutan also imports electricity from India to compensate for the seasonal drops in hydropower generation (Wangdi, 2023). Furthermore, trading power from Bhutan into the Indian short- and medium-term energy markets is a focus of the Dagachhu Hydropower Corporation, a joint venture with DGPC, Tata Power Trading Company, and other stakeholders (DGPC, 2024b). These bilateral projects are critical for both countries, assuring mutual benefits and energy security.

TABLE 5: EXISTING TREATIES ON SHARING ENERGY IN THE HKH REGION

Name of the agreement/treaty	Signatories	Date Signed	Energy-related topics
Chhukha Hydroelectric Project	India, Bhutan	27 May 1905	Development for hydropower
Agreement on the Kosi Project	India, Nepal	25 April 1954	Hydropower/Hydroelectricity
Gandak Irrigation and Power Project	India, Nepal	04 December 1959	Hydropower/ Hydroelectricity
Indus Waters Treaty 1960	India, Pakistan	19 September 1960	Water quantity, including energy generation
Amended agreement concerning the Kosi Project	India, Nepal	19 December 1966	Hydropower/Hydroelectricity
Integrated development of the Mahakali River	India, Nepal	12 February 1996	Flood control/relief, Hydropower/ Hydroelectricity, Water quantity
India-Nepal Power Agreement	India, Nepal	21 October 2014	Enable cooperation (exchange and trading) in the power sector

Source: World Bank, 2018; Pandey et al., 2020

Although countries are resorting to bilateral agreements, there are several regional initiatives aiming to cooperate in the energy sector. The SAARC Energy Centre (SEC) was created through the Dhaka Declaration in 2005, to realise the vision of SAARC leaders to establish an energy ring in South Asia. Article 20 of the declaration states, "The Heads of State or Government welcomed the Joint Statement of the First SAARC Energy Ministers meeting in October 2005 in Islamabad. They agreed to the recommendation to establish the SAARC Energy Centre in Islamabad; to promote the development of energy resources, including hydropower; and energy trade in the region; to develop renewable and alternative energy resources; and to promote energy efficiency and conservation in the region. They underlined the need to constitute a South Asian Energy Dialogue process, involving officials, experts, academics, environmentalists and NGOs, to recommend measures to tap the potential of cooperation in the energy sector to provide inputs to the Working Group on Energy" (SAARC Secretariat, 2005, p.3). Following the declaration, the SAARC leaders also signed a Framework Agreement for Energy Cooperation in 2014, endorsed by Bangladesh, Bhutan, India, and Nepal, on issues specifically relating to cross-border energy trade (Islam & Karim, 2019). However, contentious issues and the complex geopolitics of the region lead to countries prioritising bilateral agreements over multi-lateral cooperation (Islam & Karim, 2019; Nag, 2021).

Other regional mechanisms include the Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC), which is a regional organisation comprising seven countries as members (Bangladesh, Bhutan, India, Myanmar, Nepal, Sri Lanka and Thailand). At the First BIMSTEC Energy Ministers' Conference, the participants agreed to set up an energy centre to share experience in reforms, restructuring, regulation and best practices. Besides research and groundwork on the status of energy, the objective of the centre is to coordinate, facilitate and strengthen cooperation in the energy sector to promote experience sharing, and capacity building (BIMSTEC, n.d.). This region recorded one of the most robust economic growths, higher than the global average, and is projected to grow further in the coming years (Panda & Karthik, 2020). To fulfil the growing energy demands of the BIMSTEC states, countries have harvested various initiatives for energy cooperation in the region. An earlier discussion focused on developing a regional natural gas grid; however, this initiative lost momentum due to mismatches in expectations of demand and supply. However, discussions have revived towards developing a regional electricity grid – with an MoU signed to advance energy trade (Powell, 2017).

6

Climate change and related risks to the energy sector

Climate change is impacting the energy sector in various ways in the HKH. Water variability is directly impacting the stability of the production of hydropower. Extreme events such as floods, avalanches and landslides are causing damage to the infrastructure for hydropower and the transmission lines of electricity (ADB, 2019). Climate change is affecting water availability and poses a challenge to the sustainable production of hydropower. Particularly, increased variability in streamflow and shift of seasonal flows can have strong impacts on hydropower production (IEA, 2022). The impact of climate change on hydrologic regimes in downstream hydropower plants varies across river basins. The hydropower generation in run-of-river hydropower plants is largely impacted by low flow during seasons like late spring and early summer. Analysis of the sensitivity of climate-induced changes from the Trishuli River basin in Nepal shows that power production in storage-type power plants of about 20 MW would increase by 15% where climate change impacts seem negligible, while higher-capacity power plants were found to be more sensitive to climate-induced changes in river flows (Mishra et al., 2020).

An increase in run-off has been projected by Lutz et al. (2014) due to increasing precipitation in the Ganges and Brahmaputra basins and accelerated melt in the Indus basin at least until 2050. Similarly, the projections by Bajracharya et al. (2018) for the Kaligandaki basin (Nepal) suggest an increase in precipitation, snowmelt, water yield and discharge, which points to increased water availability enhancing the hydropower potential. In contrast, Shrestha et al. (2016a) have projected a decrease in energy production by 0.69–13.4% using General Circulation Models (GCMs) for the Upper Tamakoshi Hydroelectric Project. The Shrestha et al. (2020) report results are along the same lines for the Kulekhani Hydroelectric project. Therefore, the impacts of climate change need to be analysed on a case-by-case basis as there are variations from one basin to another. Along the same lines, changes in seasonal flow and greater hydrological extremes need to be considered as they can crucially counteract the benefits of the increase in run-off (Mukherji et al., 2015).

Hydrological extreme events in the form of floods and glacial lake outburst floods (GLOFs) are a big risk to hydropower and its infrastructure. GLOFs have been a major concern in the HKH because of the rising temperature and increasing incidence of glacier melt. The HKH region has been experiencing a decrease in snow cover since the early 21st century, and glaciers have retreated since the 1970s. This decrease is projected to continue, largely accelerated by higher GHG emissions, which can lead to the melting of almost two-thirds of the Himalayan glaciers by 2100 (Wester et al., 2019).

Close to two-thirds of the current and planned hydropower projects in the Himalaya are vulnerable to potential glacier floods (Schwanghart et al., 2016). In February 2021, the Dhauliganga hydropower plant in India collapsed due to massive flooding that was most likely triggered by a glacial burst. During the same time period, a similar event in the Rishiganga River in India damaged the 520 MW Tapovan Vishnugad Hydropower project and the 13.2 MW Rishiganga Hydropower project, which was under construction. In July 2019, the GLOF event damaged and closed down the Golen Gol power station of 108 MW in Pakistan. The glacial lake outburst was responsible for significant damage to the 45 MW Upper Bhote Koshi Hydropower plant of Nepal in July 2016 (IEA, 2022). Nepal is no stranger to these outbursts as there have been 26 recorded GLOFs since 1977 (Bajracharya et al., 2020). There have been many instances of hydropower plants being harmed by GLOF events over the years and the hydropower plants continue to be vulnerable to these events in the future.

BOX 1: CLIMATE CHANGE-INDUCED RISKS TO HYDROPOWER INFRASTRUCTURE IN NEPAL

In Nepal, climate change-caused variability in precipitation is impacting river flows (OECD, 2003) and leading to power generation variation, especially in run-of-river (RoR) projects. In addition, Nepalese perennial rivers depend on snow and glacier melt from high-altitude areas, which are likely to be changed in both quantity (streamflow, evaporation, soil moisture) and quality under climate change. This causes financial implications to project developers, along with potential power purchase agreement (PPA) penalties. In the Budhigandaki River, the probability of losing and gaining power generation during the dry season for an RoR-type project could be 30–40%, respectively. Further, the probability of producing less power than the design estimation is for 11 consecutive years and 27 consecutive years for dry and wet seasons, respectively. This causes huge uncertainty for hydropower developers in investment plans and subsequent returns (Marahatta et al., 2021).

Studies have indicated that future water availability might increase at the annual level, but there would be too much and too little water for different seasons. The hydrological extremes are likely to increase in Nepal's river basins. The 50-year return flood level is likely to increase in the range of 50–100% in the future under different climate scenario conditions (Wijngaard et al., 2017). This also indicates that the present definition of the flood return period for hydropower infrastructure might change under climate change and can cause a higher magnitude of impact.

Climate change also induces disasters and creates a high sediment load in the river (Sangroula, 2009). In addition to the current sedimentation issues, the extreme conditions pose further challenges to the headworks and erosion of the turbines, causing generation loss and high maintenance and downtime (Pradhan, 2004). In recent years (2020–21), 19 hydro plants with a combined capacity of 355 MW were reported to be damaged by floods and landslides. Twelve plants suffered intake damage, followed by transmission lines in 9 plants and 4 powerhouses (DOED, 2022). Due to such frequent extreme events, the insurance companies have increased the premium by threefold, and many claims are under negotiation. Similarly, flood damages halted over 80

MW power evacuation from Attariya-Dadeldhura transmission and recently, the post-monsoon rain inundated the Duhabi substation, leading to power failure in many districts of Province 1 and a shutdown of interconnected stations, leading to a halt in power evacuation. In 2017, the Terai flood led to USD 2.1 million in damage to electrical distribution lines (ADB, 2019). Extreme rainfall can cause a huge impact on the reservoir type of hydropower plants. In 1993, the Kulekhani area witnessed heavy rainfall of about 540 mm in 24 hours. The landslides and debris flow brought a sediment volume of 5.1 million m^3 to the Kulekhani reservoir (Dhital, 2003). Such events pose a threat to current and future investments in the sector.

Nepal has recorded 26 GLOF events in the past with significant damage and loss of lives reported (Bajracharya et al., 2020). Nepal has 21 potentially dangerous glacial lakes, and there are another 26 such lakes in the Tibet Autonomous Region of China which can potentially have impacts in Nepal. In July 2016, a GLOF originated in China and caused massive destruction of infrastructure, including the 36 MW upper Bhote Koshi hydropower project in Nepal.

MARSHYANGDI HYDROPOWER PROJECT, NEPAL

7

Non-climatic risks to the energy sector

Many non-climatic risks pose severe threats to the growth and stability of energy sectors in the HKH countries. These risks are economic, social, technical, environmental, and political and have the potential to have a serious influence on the region's energy security, economic growth, and social wellbeing. Managing these risks is critical for encouraging regional collaboration on energy in the HKH region, which is necessary for the region's sustainable development (Hussain et al., 2019).

The economic risk posed by high capital costs and low returns on investment is one of the most significant non-climatic risks to the energy sector in HKH countries. The region's energy infrastructure requires significant investment to meet growing energy demands, and the returns on these investments are frequently low. This makes it difficult to attract private investment, which is critical for the sector's development. There are limited financial institutions and bodies to support renewable energy projects, and most of the existing institutions desire to fund small projects rather than large ones. It appears that there exists credit market failure in disbursing funds for risky renewable energy projects by financial and non-financial institutions. The lack of government subsidies, grants, and innovative financial and business models further hampers private investment participation in renewable energy development (Seetharaman, 2018; Elavarasan et al., 2020). Overall, inadequate financial resources and incentives present a major obstacle to efforts aimed at developing the necessary energy infrastructure and improving regional energy security (Hussain et al., 2019; Insights, n.d.). Many countries in the region have limited financial resources, making it difficult to fund energy projects on their own. Innovative financing mechanisms and instruments, and policies that foster a favourable investment climate for the private sector are required to address these economic risks.

In the HKH, the energy sector experiences technical difficulties and carries substantial social risks. The region's social and economic growth is stunted, in large part because so many people lack access to energy. Yet, energy production has the potential to have far-reaching consequences for local communities, including dislocation, ecological degradation, and health risks. A lack of public awareness and information about renewable energy often results in social resistance, but the success of renewable energy projects depends on local community support. To address this, policies and regulations must ensure that the benefits of energy production are distributed equitably among all stakeholders, including local communities. In addition, it is crucial to guarantee that underprivileged groups in the region have access to energy, as this can greatly contribute to poverty reduction and social empowerment (Hussain et al., 2019; Insights, n.d.).

The energy sector in the HKH countries faces multiple technical and infrastructure challenges, largely due to a lack of technology and experience. This slows the growth of clean renewable energy, keeping these countries dependent on fossil fuels such as coal and oil for their energy needs. Despite technological innovation and adaptability over the years, deployment of renewable energy continues to face challenges related to land availability and acquisition for renewable energy infrastructure, evacuation infrastructure, lack of research and development, lack of knowledge on operations and maintenance of innovative technologies, technical complexities such as storage, and equipment standards and certifications. Most countries in the region struggle to fund the substantial research and development (R&D) needed to develop new renewable energy projects. To deal with these challenges, the region needs investment in R&D and the transfer of technology and skills from developed countries (Kumar & Majid, 2020; Kumar & Pal, 2020; Dhananjayan et al., 2023).

Geopolitical conflicts and opposing interests frequently impede collaboration on energy issues, creating considerable political risks for the energy sector in HKH countries. Several nations in the region have opposing interests, which might result in conflicts over energy resources and infrastructure. Political uncertainties in some places lead to delays in the implementation of renewable energy projects and programmes. Lack of political will and trust deficit are some of the major challenges the energy sector faces in the region (Ferdousi & Mostaque, 2020).

In the HKH, environmental, ecological, physical, and geological threats to the energy sector include natural calamities such as earthquakes and floods, as well as the environmental impact of energy production. The generation of fossil-heavy energy can have substantial environmental effects, such as air and water pollution and the emission of greenhouse gases that contribute to climate change. To address these environmental risks, it is necessary to adopt rules and regulations that ensure sustainable energy production with minimal environmental impact. Therefore, it is essential to engage in disaster risk mitigation strategies that limit the effects of natural catastrophes on electricity infrastructure.

In addition, the region's energy industry is fragmented, with numerous small-scale initiatives lacking coordination and integration (Chadha, 2020). Many nations in the region lack the institutional frameworks and capacity to properly implement policies and regulations. To address these institutional and sectoral issues, a regional approach to energy that encourages cooperation and coordination amongst countries in the region must be developed. It is essential to invest in institutional capacity building and the creation of legal frameworks that promote private investment in the sector.

The lack of regulatory uniformity, multiple bureaucratic and administrative hurdles, and inadequate incentives for policy and regulation create additional barriers to renewable energy expansion. The expansion of renewable energy requires a robust political and regulatory framework – a lack of adequate policy and regulatory measures, along with weak interdepartmental coordination, hinders the effective implementation of renewable energy programmes and subsidies. Even though there is a long-term target for renewable energy among the HKH countries, most of these targets are ad hoc, and it would be unrealistic to achieve them in many places. A lack of coordination leads to duplication of efforts and disputes between local and national-level institutions (ESMAP, 2010; Polzin et al., 2015; Rathore, 2018; Seetharaman, 2018).

Another challenge in the energy sector is that distribution companies (known as DISCOMs in India) are reluctant to procure power from renewable sources due to their technical and financial constraints. DISCOMs play a crucial role in integrating renewable energy into national grids. Addressing this challenge requires targeted policy interventions that incentivise DISCOMs to support renewable energy procurement.

8

Benefits of regional cooperation on energy

The energy sector in the HKH is not isolated; it is closely linked to agriculture, water, and climate change. To maximise its impact, the energy sector requires an integrated, cross-sectoral approach within individual countries, but also regional cooperation between countries to ensure its optimal contribution to both national and regional economies. This section aims to highlight the major benefits of regional cooperation among the HKH countries in the energy sector and related fields.

8.1 BENEFITS OF AN INTEGRATED APPROACH FOR WATER, ENERGY, AND AGRICULTURE

An integrated approach for water, energy, agriculture and disaster risk reduction, combined with regional cooperation, can yield significant benefits for all HKH countries. Most of the HKH countries are hydrologically linked as there are many transboundary tributaries that originate from China, Bhutan and Nepal and supply water to Bangladesh, India and Pakistan (Rasul, 2014; Rasul, 2015). This interconnectedness means that the Himalayan rivers offer a huge potential for the development of hydropower and irrigation for agriculture, leading to a multitude of benefits that can meet regional energy, water, and food security needs in the process. The growing demand for water for energy, food and other uses requires integrated solutions which can be beneficial, with proper management, for both upstream and downstream populations (Rasul et al., 2019). In addition to hydropower generation, the construction of reservoirs would bring more agricultural land under irrigation (Misra et al., 2007; Rahaman, 2009) and augment river flow during the dry season, mitigating water stress (Rahaman, 2009; Wu et al., 2013; World Bank, 2014).

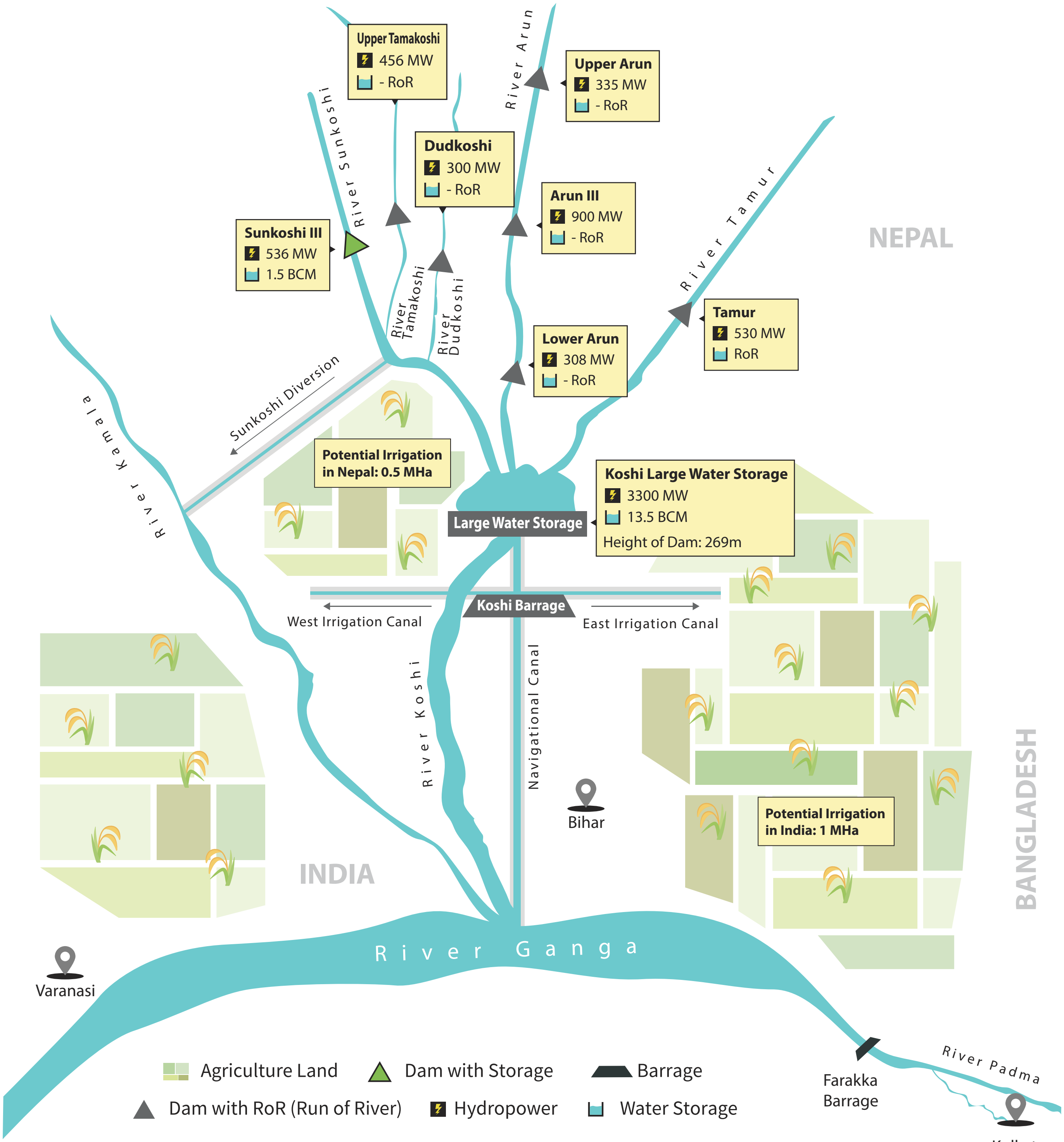
A clear example of an integrated approach can be taken from the proposed hydropower projects in the Koshi River Basin (Figure 3). The Koshi River is a transboundary perennial river fed by monsoon precipitation and glacier melt, which originates from the Tibetan plateau of China and flows through the mountains and plains of Nepal, making its way to meet the Ganges in India and eventually ending up in the Bay of Bengal. This river has an economically viable hydropower potential of 10,000 MW. However, less than 200 MW of its total potential is utilised (Rasul et al., 2019). A series of hydropower projects has been proposed in the upstream of the Koshi River (Figure 3) with the outflow stored in a large reservoir near Barahachhetra, Sunsari, in Nepal. If Nepal taps the viable potential for hydropower generation in the Koshi River, it will result in economic benefits in both upstream and downstream areas. For example, any surplus production in Nepal would then be exported to Bangladesh and India. This would promote and ensure inter-regional trade in hydroelectricity. The proposed reservoir at Chatara can supply year-round irrigation water in the downstream areas that would include the Indian state of Bihar. It is estimated that this could tentatively irrigate 546,000 ha in Nepal in the districts of Mahottari, Dhanusha, Siraha, Saptari, Sunsari, Morang, and Jhapa, and about 1,053,000 hectares of land in Bihar (Rasul et al., 2019). Amjath-Babu et al. (2019) estimates present significant potential economic benefits from electricity generation, increased agricultural production and flood damage control because of these proposed projects in the Koshi basin. It has been estimated that the total economic benefits of these hydro projects would be around USD 2.3 billion per year, with the greatest contribution coming from hydropower (61%) and an increase in crop production amounting to 36% (Amjath-Babu et al., 2019).

Another example of the benefits of such an integrated approach comes from the Ganges River Basin. The Ganges is one of the main river basins in the HKH region, originating in the Himalayas and making its way down to the Indo-Gangetic Plains of Bangladesh, India, Nepal, and Pakistan. Wu et al. (2013) estimated that the economic benefits of building 23 dam projects include the economic value of hydropower production, irrigation water for cultivation of agricultural crops, reduced flood losses, and incremental low flows to Bangladesh. The economic optimisation model includes 29 existing reservoirs and 23 potential dams (at the time of the study), with most of the new dams located in Nepal. The economic benefits of hydropower from these 23 sites were estimated to be in the range of USD 3 to 8 billion per year. These benefits are dependent on 25% of the power produced being sold to India. Similarly, the estimated benefits of irrigation and low flow augmentation in downstream areas range from USD 0.3 to 5.5 billion, depending on the assumed parameters in the model.

A similar illustration of the potential benefits can also be observed in the Indus River Basin. This basin contains the largest glacier area in Asia and about 250 million people, of whom 61% live in Pakistan, 35% in India, 4% in Afghanistan and less than 1% in China (Vinca et al., 2021). Vinca et al. (2021) have used a NExus solution tool (NEST) that links hydrological modelling with engineering economic capacity planning to study nexus benefits by testing many scenarios. The model investigates a framework where electricity and food production are increased in the upper parts of the basin through a cooperative approach between the basin countries on energy, agriculture and water management, demonstrating a win-win strategy for all. From a country-wise perspective, the authors estimate that Pakistan and Afghanistan see an overall economic benefit of about USD 7.75 billion and USD 0.43 billion, respectively. India could save on investment in canals for water distribution. Overall, the authors conclude that an increase in cooperation around water allocation, energy, and food trade will be cost optimal and environmentally beneficial.

Despite the multiple benefits of water reservoirs and hydropower projects, it is crucial to analyse their impacts on the environment, ecosystems, and societies. In some respects, the main aim of these projects is to achieve national and regional economic goals, and they do not pay adequate attention to the adverse impacts on the environment and affected local populations, mostly mountain communities (Shrestha et al., 2016b).

FIGURE 3: PRESENTATION OF POTENTIAL BENEFITS OF AN INTEGRATED APPROACH IN THE KOSHI BASIN



Source: Rasul et al., (2019)

8.2 POTENTIAL FOR DISASTER RISK REDUCTION THROUGH COOPERATION ON WATER AND ENERGY

An integrated approach to water and energy with regional cooperation can benefit the HKH countries as it reduces the risks of disasters such as floods and droughts. The water-regulating mechanism in the hydropower projects and reservoirs can help improve water availability during the dry season in downstream irrigation systems (Wu et al., 2013). As such, it reduces the risks of losses from water stresses in areas with high vulnerability to dry spells and droughts. In the HKH countries, almost 40% of the cultivated area is vulnerable to droughts, and the livelihoods of more than 290 million people (in both mountains and downstream) are affected by frequent droughts (Rasul et al., 2019). Regional cooperation and an integrated approach to energy and water can play a vital role in reducing the impacts of droughts on agriculture and the livelihoods of the people who depend on it.

Water reservoirs constructed for hydropower and irrigation can be used for flood moderation using flow forecasting (Das et al., 2007; Mei et al., 2015; Poff & Olden, 2017; Yang et al., 2017). For example, in India, hydropower and water projects along the Damodar River in West Bengal moderated flood events by 64% over the last 50 years (Biswas, 2015). In China, the Three Gorges Dam reduced the average flood height by 1.7 metres, mitigating flood risks in downstream areas (Yang et al., 2017). Controlling floods with multipurpose water reservoirs has become more important in the HKH due to increasing flood-induced losses and damages. The recent floods (2022) in Pakistan caused loss and damage of around USD 30 billion and affected around 33 million people, with around 8 million people displaced (MoPD&SI, 2022). The 2010 flood in Pakistan caused an economic loss of USD 10 billion. More than half of the loss was in the agriculture sector due to damage to crops and the killing of livestock (ADB, 2013).

Regional cooperation is not only limited to the collective management of transboundary rivers for energy, irrigation, and disaster risk reduction. Countries can also share knowledge, technologies, and experiences with other countries to manage their water resources and related infrastructure effectively. Pakistan can learn from China and other countries to construct multipurpose water reservoirs to moderate flood risks. The proposed project of Kalabagh Dam could play an important role in flood moderation by capturing and regulating flood water from the Chitral, Kabul, Haro, Swat, and Soan Rivers, in addition to its role in hydropower generation and irrigation. This dam reservoir could store up to 6.1 MAF of water, generate 3600 MW of hydropower, and manage about 2.2 million cusecs of floodwater (Luna & Jabbar, 2011; Butt et al., 2015).

The contrary opinion on the role of water reservoirs highlights that large water reservoirs cannot be effective in moderating mega-flood events. Neither can they address water wastage, pollution, mismanagement, and corruption issues, nor does their storage last long. Therefore, there is a need to adopt ‘dams equivalents’ (DEs). As stated by Abbas (2018), “A DE comprises suites of contemporary technological, structural, and institutional interventions within a hydrologic regime, which mimic the purposes for which large dams are built but avoid replicating their downsides”. DE solutions may comprise updating the irrigation systems to reduce water wastage, on-farm water-efficient and climate-resilient practices, water pollution control measures, urban water storage and management plans, and adoption of other renewable energy sources, i.e., solar and wind. Using the waterways and rivers for inland transportation can also reduce energy costs arising from road and air transportation (Abbas, 2018). DEs also have the potential for regional cooperation and the sharing of technology and experiences.

8.3 ENERGY TRADE AND GREEN GROWTH

The HKH region has an enormous potential for renewable energy. The HKH region has a vast renewable energy potential, with over 635 GW of potential from hydro and 3 TW from non-hydro sources like solar and wind (see Table 3). If we consider the total viable potential for hydropower production in HKH countries, it is around 842 GW (Table 8A). There is also huge potential for solar and wind sources. However, the current share of clean renewable energy in HKH countries (Table 6A), particularly in mountain areas (Table 9A), is still very low, and the people and economies still heavily depend on fossil and traditional fuels.

The reliance on fossil fuels has resulted in economic downturns in countries like Bangladesh, which have experienced power crises due to the increasing global fuel prices. This has caused the shutdown of several power plants, affected industries, and led to a slowdown in the economy. The power crisis caused by rising global fuel prices is expected to decrease the economic growth rate from 7.1% to 6.6%, which is a significant impact (Al Jazeera, 2022). Additionally, the rising cost of fuel imports has led to inflationary pressures on the government subsidy for electricity. The subsidy increased by 158% from the fiscal year (FY) 2019–20 to FY 2020–21, with the electricity subsidy for FY 2020–21 amounting to USD 1.1 billion (BPDB, 2021). This upward trend is unsustainable in the long term, given the volatility of global fuel prices.

To mitigate the economic impacts of price fluctuations in global fuel markets, countries in the HKH region should prioritise diversifying their energy sources and reducing their dependence on fossil fuels. One effective strategy is to invest in domestic and regional trading of renewable energy sources, such as solar, wind, and hydropower. These sources have more stable prices and are sustainable in the long run, making them a reliable energy source for the region. By investing in renewable energy sources, countries can reduce their reliance on costly fuel imports, which can weigh heavily on their economies. Additionally, promoting regional trading of renewable energy can foster cooperation among countries, resulting in more stable energy prices and a more resilient energy infrastructure. Furthermore, such investments will contribute to global efforts to combat climate change.

There is a fair degree of bilateral renewable energy trade happening within the HKH among India and Bhutan, Nepal, Bangladesh and Myanmar (MoP, 2021a). In the fiscal year 2022–23, Bhutan exported 6742.5 GWh to India, while Nepal and Bangladesh acted as net importers of 1,854.52 GWh and 12,309 GWh, respectively (BPDB, 2023; CEA, 2023; NEA, 2023). With the upcoming construction of hydro plants in the next few years, it is projected that Nepal will become a net exporter. Furthermore, there is interest and ongoing dialogue for cross-border trade between Nepal, Bangladesh, and Bhutan, which would involve transit through India (SASEC, 2022).

Cross-border trade has the potential to tremendously aid in the rapid economic development of India and Bangladesh, which are among the fastest-growing economies among the HKH countries (World Bank, 2022) and are some of the largest energy consumers. India ranks as the 3rd largest energy consumer globally, and its electricity demand is projected to rise by 7% annually. Similarly, Bangladesh is projected to see a rise of 10% annually (BPDB, 2021). These two countries are likely to be major electricity markets for Bhutan and Nepal. The proposed bilateral and trilateral trade will not only benefit their economies but also help to stabilise the electricity grid in the region, especially during dry seasons when hydropower generation in countries like Bhutan falls below 20% (DGPC, 2023). The potential for renewable energy trading in the region is significant, as it could operate as one unified geographical market with a degree of flexibility. Studies highlight load complementarity across countries in the region, creating a strong foundation for energy trading (Timilsina et al., 2015). India's location and existing transmission infrastructure, as well as its plans for expansion, make it well-positioned to play a key role in promoting cross-border trade and connectivity in South Asia and beyond. India's existing cross-border links with Bangladesh, Bhutan, Myanmar, and Nepal, as well as its plans to expand electricity corridors to other Asian countries via Myanmar, can facilitate the flow of electricity across national borders and promote regional integration. This can help reduce energy costs, increase energy security, and improve access to electricity in the region.

In addition, promoting cross-border connectivity and trade can have broader economic and geopolitical implications, deepen regional cooperation and promote stability in the region.

8.4 EXCHANGE OF KNOWLEDGE AND TECHNOLOGY

Knowledge sharing and technology exchange can support countries in the HKH to strengthen their capacity to improve existing processes, technologies and infrastructure. There is a huge scope for sharing knowledge on renewables, particularly on solar and wind energy technologies. Knowledge exchange can help countries with the cost-effective development of renewables (Kirchherr & Urban, 2018; Downing et al., 2021; Grigorescu et al., 2022). China and India are ahead of other countries in the region with regard to the use of technologies for the production of solar, wind, and other forms of renewable energy. China aims to increase its wind and solar power generation capacity to 1,200 GW by 2030. The country has also planned to develop 450 GW of solar and wind power generation capacity in the Gobi and other desert regions. Overall, the country aims for renewable energy to account for more than 50% of its electricity generation capacity by 2025 (Reuters, 2023). India has also planned to build capacity by 2026 to manufacture solar modules worth 100 GW annually to be a net exporter of solar power. Overall, the country targets to install 500 GW of electricity capacity from non-fossil sources by 2030. The central government in India also aims to spend INR 34,422 crore (USD 4.21 billion) to support farmers in installing solar power plants worth 10,000 MW. Under this scheme, the government targets the installation of 2.0 million solar-powered agriculture pumps (off-grid) and converting 1.5 million pumps from grid-connected to off-grid solar-powered pumps (Koshy, 2023). China and India can share their knowledge, experience, and technologies with other countries in the region to improve their capacity for renewable energy production. This has the potential to lead to an expansion of the share of renewable energy in national energy portfolios and to positively contribute to reducing national emissions from all energy-consuming sectors. The Energy Centre of the South Asian Association for Regional Cooperation (SAARC) can play a vital role in the exchange of knowledge and technologies across countries in the region. This centre intends to foster regional energy cooperation and the exchange and transfer of information and technology among its member nations (SAARC Energy, 2022). Even collaboration among universities and institutions working in the energy sector could prove beneficial in the acceleration of renewable energy in the region. Training and capacity-building activities could be another mechanism to build capacity in emerging areas and technologies in the renewable energy space.

8.5 CONTRIBUTIONS TO NATIONAL COMMITMENTS ON GLOBAL PROCESSES

Regional cooperation on energy can help countries to achieve their national goals and meet their targets for global commitments such as Nationally Determined Contributions (NDCs) and Sustainable Development Goals (SDGs). In line with the Paris Agreement (Article 4, Paragraph 2), NDCs by the HKH countries aim to reduce national emissions and adapt to the impacts of climate change. Currently, emissions from the energy sector in the HKH countries are very high. For instance, in China and India, the contribution of the energy sector to the total national GHG emissions is 88% and 72%, respectively (Table 1A). However, the HKH countries are aiming to transition to low-emission development that incorporates both mitigation and adaptation solutions across sectors – including energy, water and agriculture. Most countries in the region are committed to the global 1.5°C target and to achieving net-zero emissions by 2050 (Goodrich et al., 2022). The countries are also aiming to reduce vulnerability to climate change impacts by building adaptive capacity and improving resilience. In this regard, the HKH countries either have developed or are in the process of developing country-specific National Adaptation Plans (NAPs).

As mentioned earlier in this report, there is immense potential to expand the share of renewable energy in the overall energy portfolio in the HKH countries. While the region is rich in primary resources, harnessing them effectively requires the right technology and financial support to convert them into usable energy. Regional cooperation to expand the production and use of renewable energy through the integrated use of water resources, energy trade, and technology sharing can play a vital role in reducing national as well as regional emissions (positive contribution to NDCs). Moreover, the use of multipurpose reservoirs to reduce the impacts of climate change-induced hazards such as floods and droughts will contribute to the adaptive capacity and resilience of the countries (positive contributions to NAPs). As a result of regional cooperation, the increased use of renewable energy for economic activities, particularly in vulnerable and remote mountain areas, will also contribute to improving the adaptive capacity and resilience of communities.

Regional cooperation on energy is crucial for achieving several SDGs (Dhakal et al., 2019). In the HKH region, improved access to renewable energy can reduce indoor air pollution (SDG 3) and can have positive effects on the health of women (SDG 5) and children. In the HKH, women, particularly in remote mountain areas, are more vulnerable to energy poverty than men. The global gender gap index of 2021 shows that among the HKH countries, only Bangladesh is in the top 70 countries (out of 156) in terms of gender parity (WEF, 2021a; see Table 10A). Improved household access to clean or modern energy sources can reduce the burden placed on women of carrying fuelwood from distant areas (Dhakal et al., 2019). Harnessing the potential of renewable energy resources will reduce emissions and will partially replace fossil fuels, thus supporting climate change mitigation (SDG 13). Greater access to renewable energy could provide opportunities for better agriculture production (SDG 2) and entrepreneurship, stimulate economic development, and improve livelihoods (SDG 1) (Perera et al., 2015). Understanding how SDGs cut across different sectors may help in the design and appraisal of common strategies and cross-sectoral policies for integrated development programmes (also see sub-section 8.1) in the region (Mainali et al., 2018).

SOLAR POWERED WATER PUMPING SYSTEM, TALAGANG, PAKISTAN.

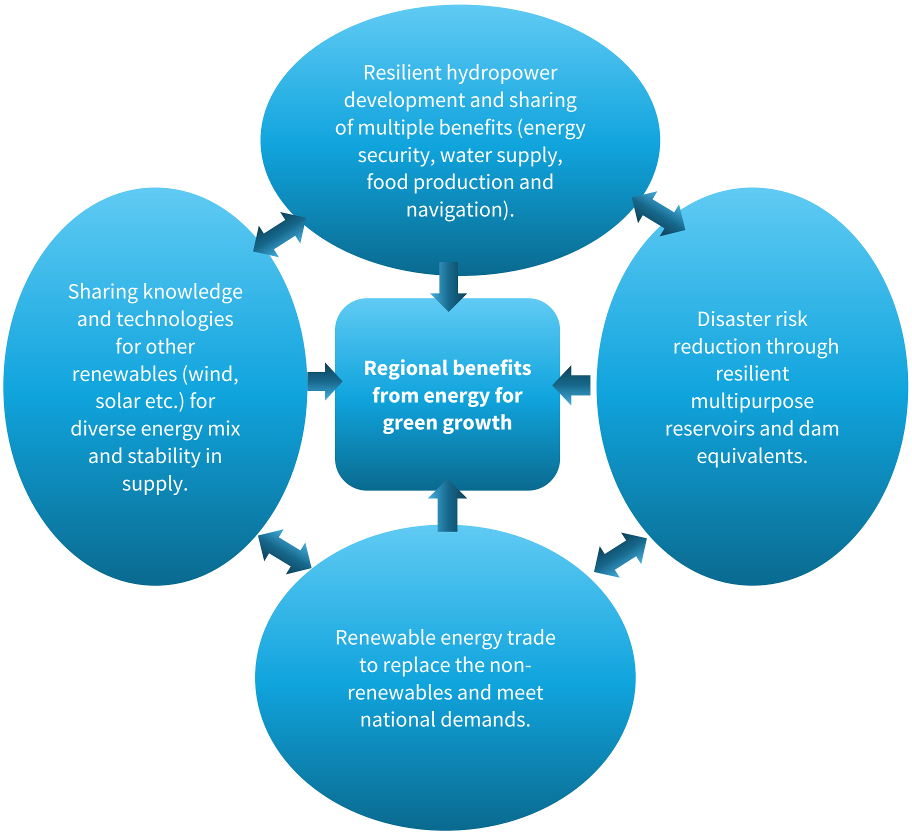
9

Moving towards regional cooperation

In the HKH, regional cooperation for energy is mainly being seen in the context of energy trade with a particular focus on hydropower. Merely focusing on energy trade (particularly hydropower) alone cannot serve as a lever for regional growth and development. Energy is a complex and cross-cutting sector and needs a holistic and multidimensional approach for regional cooperation to cope with challenges and increase mutual benefits for countries. Regional cooperation measures need to consider all types of potential benefits in the form of renewable energy trade, disaster risk reduction, agriculture productivity (with boosted water supplies), agricultural trade, industrial development, water navigation (use of rivers for transportation), transfer of technologies and knowledge for all types of renewable energy, green growth and job creations, and contributions to national and global commitments. Regional cooperation measures also need to consider the mitigation of common climatic and non-climatic risks posed by larger reservoirs to settlements and ecosystems, particularly in hilly and mountain areas, through the exchange of knowledge and technologies for the construction of resilient infrastructure with minimal impacts on ecosystems.

In the HKH, the framework for regional cooperation needs to consider the following four dimensions (also see Figure 4):

FIGURE 4: DIMENSIONS FOR REGIONAL COOPERATION ON RENEWABLE ENERGY IN THE HKH



1. Resilient hydropower development for multiple benefits

Resilient hydropower development through regional cooperation can greatly benefit HKH countries, which are hydrologically interconnected through numerous transboundary rivers. This approach can enhance hydropower generation and irrigation for agriculture with multiple benefits for agricultural productivity and related trade, better access to water and energy in countries, and opportunities for water navigation. Examples include the proposed hydropower projects in the Koshi River Basin, which aim to generate 3300 MW of hydropower and irrigate significant agricultural land in Nepal and India, with estimated economic benefits of USD 2.3 billion per year. In the Indus River Basin, cooperative strategies for water and energy management could result in substantial economic gains for Pakistan, Afghanistan, and India. However, these projects must ensure resilient infrastructure and balance economic goals with environmental and social impacts, particularly on local mountain communities.

2. Exchange of knowledge and technology for other renewables

Knowledge sharing and technology transfer can enhance the capacity of the HKH countries to improve their renewable energy processes, technologies, and infrastructure, particularly in solar and wind energy. China and India, leaders in renewable energy, plan substantial increases in wind and solar power generation by 2030, with China targeting 1,200 GW (Reuters, 2023) and India 500 GW (Parikh & Dhananjayan, 2024) of capacity for power generation from non-fossil sources. Both countries aim to expand their renewable energy production, with significant investments in solar power. Sharing their expertise and technology with other HKH countries can help expand the share of renewable energy in national energy portfolios and reduce emissions. Regional inter-governmental centres such as the SAARC Energy Centre and ICIMOD can facilitate this regional cooperation by promoting the exchange of knowledge and technology. Regular capacity-building and training activities shall be conducted, which could facilitate the transfer of knowledge across the countries in the region.

3. Renewable energy trade

The HKH region has a vast renewable energy potential, with over 635 GW of potential from hydro and 3 TW from non-hydro sources like solar and wind (see Table 3). Despite this, the region remains heavily reliant on fossil fuels, causing economic challenges, such as power crises and inflation due to rising global fuel prices. To mitigate these impacts, HKH countries should diversify their energy sources by investing in renewable energy and promoting regional energy trade. This shift would reduce dependence on costly fuel imports and stabilise energy prices, fostering economic resilience. Currently, significant bilateral renewable energy trade exists among HKH countries, with Bhutan exporting to India, Nepal, and Bangladesh as net importers. Future cross-border trade, particularly involving India, could further stabilise regional electricity grids and support rapid economic growth in major energy markets like India and Bangladesh. Enhanced cross-border connectivity and trade would not only lower energy costs and increase energy security but also promote regional cooperation and stability.

Lessons from other regional power pools (Table 11A) highlight six critical elements for successful energy trading: cross-border trade provisions, third-party transmission access, domestic power sector reforms, trade protocols, regional coordination centres, and transmission interconnections (Vaidya et al., 2021a). While the HKH countries, particularly BBIN countries (Bangladesh, Bhutan, India and Nepal), have provisions for cross-border trade and regulatory commissions, third-party access and regional coordination are lacking. Moreover, financing cross-border infrastructure remains a challenge, with international financial institutions playing a crucial role. Harmonising regulations and establishing a regional coordination centre are essential steps. Regional cooperation should adopt a holistic approach, integrating energy trade with disaster risk reduction, agriculture productivity, technology exchange, and green growth, while addressing climate and non-climate risks to ensure sustainable development.

4. Renewable energy as a lever for reduction in risks, emissions and disparities

Regional cooperation in water and energy management can significantly mitigate disaster risks such as floods and droughts. Hydropower projects and reservoirs can regulate water flow, enhance dry-season water availability and reduce drought impacts, which is crucial for regions like the HKH where 40% of cultivated land is drought prone (Rasul et al., 2019). These integrated approaches can also moderate floods, as evidenced by projects in India and China that have significantly reduced flood risks. Sharing data, knowledge and technologies across borders can further improve disaster management. Countries upstream and downstream can benefit from constructing multipurpose reservoirs which would generate power in upstream areas and aid the downstream areas with floodwater regulation and irrigation.

Wherever large reservoirs are not feasible and carry high risks to the environment and communities, regional cooperation for 'dam equivalents' (DEs) can also lead to multiple benefits. DEs involve contemporary technological, structural, and institutional interventions that mimic the purposes of large dams without their downsides. These solutions include the use of solar and wind sources for renewable energy and using solutions/ technologies for water saving and quality, such as the upgrading of irrigation systems, on-farm water-efficient practices, pollution control, and urban water management. Additionally, using waterways for inland transportation can reduce energy costs. Overall, the DE approach offers significant potential for regional cooperation in sharing technology and experiences.

Additionally, regional cooperation among HKH countries on energy is essential for the reduction of emissions, achieving national goals and meeting global commitments like Nationally Determined Contributions (NDCs) and Sustainable Development Goals (SDGs). The HKH countries aim to transition to low-emission development and achieve net-zero emissions by 2050. Regional efforts can enhance renewable energy use, reduce emissions, and improve climate resilience through multipurpose reservoirs and dam equivalents (i.e. adoption of wind and solar power technologies). Cooperation also supports SDGs by contributing to improving health, reducing gender and social disparities, reducing food insecurity and poverty, and boosting economic development, particularly in vulnerable areas such as mountains. Currently, the penetration of clean renewable energy is very low in mountain areas. There is an urgent need to improve mountain people's access to clean renewable energy to replace dirty sources of renewable energy (i.e. biomass) and transform primary production (i.e. agriculture sector) to value-added goods and services. Integrated policies across sectors within countries can further help to achieve sustainable development and national and mountain-specific goals.

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Annexe

TABLE 1A: POPULATION OF THE HKH PARTS OF COUNTRIES

	Population of HKH parts of the countries (million)	
Countries	**2017**	**2024 (projected)**
Afghanistan	22.85	26.41
Bangladesh	1.78	2.03
Bhutan (entire country)	0.78	0.78*
China	33.29	36.18
India	86.27	98.54
Myanmar	11.7	13.01
Nepal (entire country)	28.75	31.62
Pakistan	51.47	61.96
Total	236.89	270.53

Populations for 2024 are projected based on population statistics presented by Wester et al., (2019). For projections, the linear growth method was used with the assumption that in- and out-migration rates and fertility and mortality rates remained stable during 2017–2024.

*2024 population statistics for Bhutan are collected from NSB, 2024.

TABLE 2A: POPULATION OF THE TEN MAJOR RIVER BASINS ORIGINATING IN THE HKH

	Population (millions)	
River basins	**2015**	**2024 (projected)**
Amu Darya	30.18	36.41
Brahmaputra	68.07	74.73
Ganges	580.09	661.16
Indus	268.42	317.97
Irrawaddy	42.87	48.17
Mekong	77.31	82.48
Salween	17.88	17.34
Traim	11.37	12.79
Yangtze	604.94	612.24
Yellow River	198.02	207.66
Total	1899.15	2070.95

Populations for 2024 are projected based on population statistics presented by Wester et al., (2019).

For projections, the linear growth method was used with the assumption that in- and out-migration rates and fertility and mortality rates remained stable during 2015–2024.

TABLE 3A: ECONOMIC INDICATORS OF THE HKH COUNTRIES

Country	GDP per capita growth (annual, %)	Inflation (CPI, annual, %)	Unemployment (% of total labour force)
Afghanistan	-22.0	5.2	13.3
Bangladesh	5.7	5.6	5.2
Bhutan	3.4	7.4	4.3
China	8.0	0.9	4.8
India	7.8	5.5	6.0
Myanmar	-18.0	3.6	2.2
Nepal	1.8	3.6	5.0
Pakistan	4.5	8.9	4.3

Note: GDP – Gross Domestic Product; CPI – Consumer Price Index. All figures are for the year 2021 unless stated in parenthesis.
Source: ADB, 2022; World Bank, 2023c

TABLE 4A: SOCIOECONOMIC SITUATION IN HKH COUNTRIES: SELECTIVE INDICATORS

Country	Prevalence of undernourishment in the total population (%)	Prevalence of moderate or severe food insecurity in the population (%)	HDI	GII	Population living in MDP (%)	Population using at least basic drinking water services (%)	Population using at least basic sanitation services (%)	Renewable internal freshwater resources per capita (m^3)
Afghanistan	29.8 (2019–21)	70 (2020)	0.511	0.655	55.9 (2015–16)	75.1	43.4 (2020)	1299
Bangladesh	11.4 (2019–21)	31.7 (2020)	0.632	0.537	24.6 (2019)	97.7	54.2 (2021)	657
Bhutan	n.a.	n.a.	0.654	0.421	37.3 (2010)	97.3	76.5 (2021)	104619
China	<2.5 (2019–21)	n.a.	0.761	0.168	3.9 (2014)	94.3	92.4 (2021)	2029
India	16.3 (2019–21)	31.6 (2017-19)	0.645	0.488	16.4 (2019–21)	90.5	71.3 (2021)	1080
Myanmar	3.1 (2019–21)	25.5 (2020)	0.583	0.478	38.3 (2015–16)	83.7	73.6 (2021)	18789
Nepal	5.5 (2019–21)	37.8 (2020)	0.602	0.452	17.5 (2019)	90.1	76.6 (2021)	7173
Pakistan	16.9 (2019–21)	32.6 (2020)	0.557	0.538	38.3 (2017–18)	90.1	68.4 (2021)	265

Note: HDI – Human Development Index; GII – Gender Inequality Index; MDP – Multidimensional Poverty; n.a. = not available. HDI includes dimensions of standard of living, education and life expectancy.

HDI & GII figures are for the year 2019. The figures for population (%) with basic drinking water services and renewable internal freshwater resources per capita are for the year 2021.

Source: WEF, 2021a; Alkire et al., 2022; FAO, 2022; FAO et al. 2022; UNDP, 2022a; UNDP, 2022b

TABLE 5A: TOTAL GREENHOUSE GAS EMISSIONS AND EMISSIONS FROM THE AGRICULTURE AND ENERGY SECTORS

Country	Total GHG emissions ($MtCO_2e$)	GHG emissions from agriculture sector		GHG emissions from energy sector	
		$MtCO_2e$	Percent of total emissions	$MtCO_2e$	Percent of total emissions
Afghanistan	28.79	15.54	15.98	8.27	28.73
Bangladesh	237.70	87.19	36.68	102.75	43.23
Bhutan*	0.36	0.50	138.89	0.70	194.44
China	12055.41	662.55	5.50	10618.71	88.08
India	3363.59	719.82	21.40	2422.24	72.01
Myanmar	242.95	86.89	35.76	39.56	16.28
Nepal	48.37	26.00	53.75	13.70	28.32
Pakistan	439.49	194.41	44.24	200.60	45.64
Total	16416.66	1792.9	10.92	13406.53	81.66

$MtCO_2e$ = Metric tons of carbon dioxide equivalent; Year of data is 2019

*Bhutan's total emissions are less than the emissions from the agriculture and energy sectors because of the country's high capacity of forests to absorb carbon dioxide annually.

Source: Climate Watch, 2019

TABLE 6A: SHARE (%) OF GROUPS OF ENERGY SOURCES IN TPES

Groups of energy sources	Afghanistan	Bangladesh	Bhutan	China	India	Myanmar	Nepal	Pakistan
Clean renewable energy (hydro, other renewables)	1.9	0.3	37.8	7.1	3.2	3.7	6.8	3.1
Biofuels and waste (largely renewables)	11.6	15.5	25.1	3.4	20.7	51.2	66.7	26.8
Non-renewables	86.6	84.2	37.1	89.6	76.1	45.1	26.5	70.1

Note: Year of data is 2022 (nuclear energy is considered under non-renewables)

Source: Afghanistan: UNSD, 2023; IRENA, 2024a; Bhutan: DoE, 2022; Other countries: IEA, 2024b

TABLE 7A: SECTOR-WISE FINAL CONSUMPTION

Sectors	Percentage							
	Afghanistan	Bangladesh	Bhutan	China	India	Myanmar	Nepal	Pakistan
Household	31.5	43.7	71.53	16.80	25.4	54.7	75.4	48.1
Industry	26.7	33.1	15.08	48.90	38.5	18.8	7.7	24.9
Transport	34.7	12.2	10.76	15.50	16.7	10.6	11.1	18.4
Commercial and public	2.6	2.5	0.45	4.20	3.6	3.8	2.5	3.1
Agriculture and forestry	0.4	3.7	0.01	2.00	4.9	6.8	1.9	1
Other consumers	1.2	-	1.04	-	-	-	-	-
Non-energy use	2.9	4.4	1.12	8.50	8.2	2.4	1.2	4.4
Non-specified		0.4	-	4.10	2.8	2.7	0.2	0.2

Note: Data year is 2019

Source: IEA, 2019; UNSD, 2019

TABLE 8A: POTENTIAL FOR RENEWABLE ENERGY IN HKH COUNTRIES

Country	Viable potential for hydropower (MW)	% of hydropower potential harnessed*	Solar (GW)	Wind (GW)
Afghanistan	23.00	2	222.85	66.73
Bangladesh	1.89	12	nd	nd
Bhutan	23.76	10	12	0.8
China	542.00	67	2,674	2,495
India	148.70	32	748.98	695.5
Myanmar	39.72	8	35	153
Nepal	4292	6	23.6	nd
Pakistan	59.80	18	nd	nd
Overall	882	49	-	-

Note: Harnessed potential for wind and solar is not calculated because of the non-availability of compatible data on potential and installed capacity.

*Data on installed capacity is used from Table 4 to calculate the percentage of harnessed potential.

Sources: Sun et al., 2019 ; IHA, 2020 ; Vaidya et al., 2021b; Lei, 2022

TABLE 9A: RENEWABLE ENERGY RESOURCE POTENTIAL AND THE CLEAN COOKING TRANSITION OF THE HKH REGION BY STATES/PROVINCES

HKH areas in countries	Clean cooking transition		Potential for regional contribution			
	Biomass-based	Electric	Hydro	Solar	Wind	Biomass
	Households (in millions)	Households (in millions)	GW	GW	GW	GW
HKH States/Provinces	-	-	635	2,180	749	3.1 (limited data)
HKH Afghanistan	n.a.	n.a.	22.838	80.194	5.798	n.a.
Badakhshan	n.a	n.a	20.137	3.736	0.331	n.a
Badghis	n.a	n.a	n.a	5.328	0.191	n.a
Baghlan	n.a	n.a	n.a	1.536	0.208	n.a
Balkh	n.a	n.a	0.76	2.9	0.786	n.a
Bamian	n.a	n.a	n.a	1.863	0.024	n.a
Daikondi	n.a	n.a	n.a	1.911	n.a	n.a
Faryab	n.a	n.a	n.a	4.679	0.252	n.a
Ghazni	n.a	n.a	n.a	5.802	0.048	n.a
Ghowr	n.a	n.a	n.a	10.539	0.084	n.a
Jowzjan	n.a	n.a	n.a	2.23	0.043	n.a
Kabul	n.a	n.a	1.941	0.432	0.041	n.a
Kapisa	n.a	n.a	n.a	0.183	0.081	n.a
Khost	n.a	n.a	n.a	0.364	n.a	n.a
Konar	n.a	n.a	n.a	0.447	0.081	n.a
Kunduz	n.a	n.a	n.a	1.279	0.007	n.a
Laghman	n.a	n.a	n.a	0.842	0.255	n.a
Lowgar	n.a	n.a	n.a	0.451	n.a	n.a
Maidan Wardak	n.a	n.a	n.a	1.043	0.018	n.a
Nangarhar	n.a	n.a	n.a	1.687	0.146	n.a
Nuristan	n.a	n.a	n.a	0.888	n.a	n.a
Paktia	n.a	n.a	n.a	5.042	0.099	n.a
Paktika	n.a	n.a	n.a	0.374	0.018	n.a
Panjshir	n.a	n.a	n.a	0.51	n.a	n.a
Parwan	n.a	n.a	n.a	0.548	0.127	n.a
Samangan	n.a	n.a	n.a	2.912	0.266	n.a
Sar-i-Pol	n.a	n.a	n.a	4.131	0.182	n.a
Takhar	n.a	n.a	n.a	2.543	1.199	n.a
Uruzgan	n.a	n.a	n.a	6.53	0.495	n.a
Zabol	n.a	n.a	n.a	9.464	0.816	n.a
HKH Bangladesh	0.3724	n.a.	0.14	n.a.	n.a.	n.a.

Chittagong Hill Tracts	0.3724		0.14	n.a	n.a	n.a
HKH Bhutan	0.14	n.a.	23.76	12	0.8	2.6
HKH China	40.5	16.01	358.94	1772.4	741.09	nd
Gansu	7.09	0.79	9	290.3	264.46	n.a
Qinghai	0.65	1.25	2.34	30.6	n.a	n.a
Sichuan	15.74	7.47	120	11.6	1.2	n.a
Tibet	0.8		110	1.5	n.a	n.a
Xinjiang Uyghur	7.58	0.02	15.6	1367.4	475.43	n.a
Yunnan	8.64	6.48	102	71	n.a	n.a
HKH India	10.463	4.044	122.77	223.99	0.729	0.492
Arunachal Pradesh	0.18226	0.0766	52.13	8.65	0.274	0.008
Assam	5.063	1.218	0.85	13.76	0.246	0.22
Himachal Pradesh	0.8684	0.573	22	33.84	0.151	0.144
Jammu & Kashmir	1.324	0.658	15.25	111.05	0.003	0.043
Manipur	0.351	0.1513	1.86	10.63	n.a	0.015
Meghalaya	0.443	0.073	2.53	5.86	0.001	0.013
Mizoram	0.1001	0.1165	2.3	9.09	n.a	0.003
Nagaland	0.31524	0.0809	1.63	7.29	n.a	0.01
Sikkim	0.0683	0.0534	4.51	4.94	n.a	0.002
Tripura	0.687	0.1499	0.05	2.08	n.a	0.005
Uttarakhand	1.061	0.893	19.66	16.8	0.054	0.029
HKH Myanmar	1.32	n.a.	11.267	12.68	n.a.	n.a.
Chin	0.09	n.a	1.31	1.44	n.a	n.a
Shan	0.49	n.a	7.7	6.22	n.a	n.a
Rakhine	0.48	n.a	0.25	1.47	n.a	n.a
Kachin	0.26	n.a	2.01	3.55	n.a	n.a
HKH Nepal	n.a.	4.8	43	23.6	0.448	n.a.
HKH Pakistan	4.54	0.14	52.31	56	n.a.	n.a.
Azad Jammu & Kashmir	nd	nd	6.45	2	n.a	n.a
Balochistan	1.25	0.063	0.0005	43	n.a	n.a
Federally Administered Tribal Areas (FATA)	0.53	0.013	n.a	n.a	n.a	n.a
Gilgit-Baltistan	n.a	n.a	21.125	2	n.a	n.a
Khyber Pakhtunkhwa	2.76	0.065	24.74	9	n.a	n.a

Source: The data is a compilation of various research articles, country census data, annual reports, including ADB, 2017b; Sibtain et al., 2021; Raza et al., 2022; Zhang et al., 2016; Liu et al., 2018; Xiao et al., 2015; MoP 2021b; Sun et al., 2019; Bhandari and Subedi, 2023; WECS, 2021; Zhengming et al., 2002; Soe et al, 2017; Liu et al, 2022; DGPC, 2022; DOED, 2024; MNRE 2024; Solar Marg 2024

Note: n.a. = data not available

TABLE 10A: THE GLOBAL GENDER GAP INDEX 2021 RANKINGS

Rank* in 2021	Country	Score (0-1) in 2021	Rank change in 2021 compared to 2020	Change in score of 2021 compared to 2020
65	Bangladesh	0.719	-15	-0.006
106	Nepal	0.683	-5	+0.003
107	China	0.682	-1	+0.006
109	Myanmar	0.681	5	+0.016
116	Sri Lanka	0.670	14	-0,009
128	Maldives	0.642	-5	-0.004
130	Bhutan	0.639	1	+0.004
140	India	0.625	-28	-0.042
153	Pakistan	0.556	-2	-0.007
156	Afghanistan	0.444	n/a	n/a

Note: *Global Gender Gap Index 2021 ranks out of the 156 reviewed countries and its progress, represented on a 0-to-1 scale, towards closing the gender gap and achieving full gender parity (benchmark score of 1)

Source: WEF, 2021b

TABLE 11A: MAIN FEATURES OF THE FOUR REGIONAL POWER POOLS

Broader indicators	Greater Mekong Sub-Region (GMS) Energy Programme	Southern African Power Pool (SAPP)	Central American Electricity Interconnection System (SIEPAC)	Nordic Power Pool
Countries involved	Cambodia, Laos PDR, Myanmar, Thailand, Vietnam, and two provinces of the People's Republic of China (PRC)	Angola, Botswana, DR Congo, Lesotho, Malawi, Mozambique, Namibia South Africa, Swaziland, Tanzania, Zambia, and Zimbabwe	Costa Rica, Honduras, El Salvador, Guatemala, Nicaragua, and Panama	Denmark, Finland, Norway, and Sweden
Year of formal establishment	1992	1995	1996, came into effect in 1999	1963, as Nordel, followed by creation of NORD Pool Spot in 1996
Is it fully functional?	Not yet fully operational and most power trade based on bilateral agreements	Fully operational; has reached the second stage of market integration	Fully operational; has reached the second stage of market integration	Considered the world's most advanced electricity market

Broader indicators	Greater Mekong Sub-Region (GMS) Energy Programme	Southern African Power Pool (SAPP)	Central American Electricity Interconnection System (SIEPAC)	Nordic Power Pool
Degree of power sector reforms by countries	Mixed, but overall, most countries have not undertaken desired level of power sector reforms	All except two countries have electricity regulators; the regulators are all members of the Regional Electricity Regulators Association (RERA) established by South Africa	All six countries have moved towards a single-buyer utility model from the old state-owned vertically integrated model. However, the degree of private sector participation varies	Conforms to European Union (EU) norms on power sector reforms like supply competition, unbundling, and third-party non-discriminated access to all transmission and distribution systems
Type of regional institution	Has a secretariat, but no independent legal entity	A permanent SAPP Coordination Centre was established in 2000, but has yet to become a supranational institution	Mercado Eléctrico Regional (MER) has supranational power	As the Nordic power system moved from the first to the second phase of regional cooperation, market forces took over the running of the system
Degree of autonomy of regional institution	Very low, most decisions through MoUs and bilateral agreements	Low, the ultimate decisions remain with the national governments, not with SAPP	High, MER can operate independently, parallel to the national power systems	The Nord Pool Spot Regulatory Council is a platform for information exchange on wholesale energy market monitoring as per EU norms
Degree and nature of regional trade	None, all electricity trade so far on a bilateral basis	Medium, electricity trade takes place through long-term bilateral arrangements and a short-term competitive market (5–10% of the total)	High, electricity trade occurs via two channels: medium- and long-term bilateral contracts (about 80% of total) and spot market trading	Very high, the Nord Pool Spot is a fully competitive market that is open to all parties that have signed agreements with Nord Pool
Degree of physical interconnectedness	Started in 2002, eight high-voltage power interconnections above 220 kV and several low- to medium-voltage interconnectors	High, and with a long history of physical interconnectedness starting in 1955	Started in 1976, now a 1,793 km international transmission line passing through each of the six member states	Very high, the Nordic transmission grid connects all Nordic states by combining the national grids into one synchronous power system

Broader indicators	Greater Mekong Sub-Region (GMS) Energy Programme	Southern African Power Pool (SAPP)	Central American Electricity Interconnection System (SIEPAC)	Nordic Power Pool
Role of facilitation by outside agencies	High degree of involvement of ADB and external consultants	Largely a regional effort, but with support from the Governments of Norway and Sweden, among others	The Spanish Government and international financial institutions – the Inter-American Development Bank (IADB) and the Central American Bank for Economic Integration (CABEI) – played an important role in establishing the pool	Largely a regional effort, with Norway leading; later developments have been largely driven by EU regulations
Degree of effectiveness in terms of regional integration and electricity trade	Low	High, good market integration within a decade of operation	High, good market integration within a decade of operation	Very high, considered the gold standard
Lessons for the HKH energy cooperation	Market integration is not possible without an independent secretariat with legal powers	Presence of interconnected transmission grids and surplus generation capacity can accelerate the regional power integration process in the early stages	Existence of basic power sector reforms, including domestic regulatory bodies, and creation of supranational regional institutions are needed	Presence of strong political will and commitment and creation of an independent market surveillance unit is key to success

Source: Vaidya et al., 2021a

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