

# **Energy, Economics, and Politics: An Analysis of Decisions to Pursue Large Hydropower Projects in Bhutan and Nepal**

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## Executive Summary

Large hydropower projects are on the rise. Once subject to universal condemnation by environmentalists and largely abandoned by international donors, these projects have been reborn as a critical component of “sustainable development” in the age of climate change. This resurgence of interest in large hydropower projects raises questions for policymakers about whether these projects provide a net benefit to their constituents. While rigorous economic analyses could provide guidance to the policymakers grappling with these questions, the complexity of this endeavor and the politics that almost always enmesh large infrastructure projects mean that decisions to pursue these projects are likely influenced by a different calculus—one that may vary across countries based on their unique history and political dynamics.

Nepal and Bhutan, two developing countries that hold tremendous hydropower potential, provide an illustration of how these decisions are being carried out and what is driving them. The two mountainous, landlocked countries both neighbor India, whose insatiable need for energy is capable of driving development even after domestic demand for electricity is met. While neither Bhutan nor Nepal has fully developed its hydropower potential, Bhutan has forged well ahead of Nepal in terms of completed and planned projects. Thus, this paper aims to answer the question: *What drives decisions to pursue large hydropower projects in Bhutan and Nepal?* To answer this question, this paper first examines the political discourse surrounding hydropower projects in each country and how the projects fit within their development narrative. It then turns to a cost-benefit analysis of two large projects that were recently pushed forward, Punatsangchhu I (or “Puna I”) in Bhutan and Arun III in Nepal.

This paper concludes that the overwhelming economic benefit of the hydropower generated by these projects has driven and will continue to drive development in both Bhutan and Nepal, with the potential to bring substantial net benefits to the region. As a result, people who are concerned about the social and environmental costs of projects may be more successful in arguing for stronger safeguards for projects rather than a complete halt in their development. The economic value of clean energy for an area that has not been fully electrified is simply too large for policymakers to ignore.

However, the results also suggest that political and international dynamics play a substantial role in development choices and may help explain why Bhutan has made more progress in hydropower development than Nepal. Bhutan’s relative stability and strong centralized government, combined with a less robust tradition of grassroots activism and close ties to India, have created a stable environment for the planning and foreign investment that projects require. Nepal’s divisive politics, rooted in a long civil war, along with sometimes tense relations with India, have made it difficult for the country to focus on hydropower—and attract the necessary foreign capital.

A second consideration that could contribute to the difference in hydropower development between Nepal and Bhutan is differences in the shadow price of capital. If Nepal has a higher shadow price of capital than Bhutan, it would diminish the net benefits of projects,

which would need to compete for limited government expenditures with a wide range of other development projects. This reality makes Nepal almost entirely reliant on the Indian private sector as a source of the initial capital investment, which may suggest a path forward for Nepal. By allowing the project developer to own the project for a set period of time before transferring it to the government, policymakers have found a way to address the high shadow price of capital for government expenditures and transfer the risks of cost overruns to the developer. This structure could work in Bhutan as well, reducing government debt related to projects and freeing up government revenue for other development projects designed to address the country's growing unemployment problem.

## **I. Introduction**

Large hydropower projects are on the rise. The 6,000 MW Grand Renaissance Dam in Ethiopia will begin generating electricity this year. China's 22,500 MW Three Gorges Dam stands as the largest power station in the world. If built, the proposed Grand Inga project in the Democratic Republic of Congo will have a staggering 40,000 MW capacity. Once subject to universal condemnation by environmentalists and largely abandoned by international donors, these projects have been reborn as a critical component of "sustainable development" in the age of climate change (World Bank, 2009; World Bank, 2013).

A resurgence of interest in large hydropower projects in developing countries raises a number of questions. Should the government invest directly in projects or turn to private investment? What is the role of foreign investment and multilateral lending institutions? Is it better to pursue large projects or a series of mid-size projects? How does national hydropower policy weigh potential harms to local (and often rural) stakeholders with national (and usually urban) benefits—or even benefits enjoyed by citizens of other countries?

Rigorous economic analyses could provide guidance to the policymakers grappling with these complex questions. With sufficient, unbiased data, the benefits of large projects could be weighed against their costs. The distribution of costs and benefits across localities and countries could be delineated, and concerns could be addressed. However, the complexity of this endeavor and the politics that almost always enmesh large infrastructure projects mean that decisions to pursue these projects are likely influenced by a different calculus—one that may vary across countries based on their unique history and political dynamics.

Nepal and Bhutan, two developing countries that hold tremendous hydropower potential, provide an illustration of how these decisions are being carried out and what is driving them. The two mountainous, landlocked countries both neighbor India, whose insatiable need for energy is capable of driving development even after domestic demand for electricity is met. While neither Bhutan nor Nepal has fully developed its hydropower potential, Bhutan has forged well ahead of Nepal in terms of completed and planned projects.

Bhutan has installed 1,600 MW, or about 7 percent of its approximately 24,000 MW potential and an amount that well exceeds peak domestic demand. Thus, a majority of this developed capacity is exported to India, and more projects are in the pipeline specifically dedicated to this purpose. Nepal, on the other hand, has only constructed plants capable of generating 700 MW, less than 2 percent of its 42,000 MW potential, in spite of having a larger population and thus higher demand. Its current installations do not currently meet domestic demand, and Nepal faces frequent energy shortages that hinder overall growth.

With Bhutan's hydropower development touted as a regional success story—and a pathway to economic development—Nepal has recently become more intent on tapping into its

own resources and formulating a hydropower development model that fits its needs. However, because hydropower plants require large amounts of upfront capital and technical expertise, both countries need foreign investment to tap into their vast reserves. In reality, this dependence on foreign investment translates to dependence on India specifically. India's self-interest in seeing these projects completed makes it withstand the delays and cost overruns that scare away other investors. Furthermore, funding from international donors requires India's agreement since the safeguards of those institutions require cooperation and consent from downstream countries (Rex et al., 2014). Thus, each country's relationship with India enters the political calculus of whether to pursue projects.

Both Bhutan and Nepal are at a crossroads when it comes to hydropower policy. Nepal is on the cusp of pushing the industry forward and using it as a pillar of its economic growth in the next decade. Bhutan has a more developed industry but one that is still reliant on outside support and is increasingly under scrutiny for its environmental and social ramifications. Furthermore, both countries are increasingly turning to larger projects to meet their ambitious targets for installed capacity. These larger projects undoubtedly come with higher costs—financial, social, and environmental—that may not always be outweighed by the project's benefits.

This paper aims to answer the question: *What drives decisions to pursue large hydropower projects in Bhutan and Nepal?* To answer this question, this paper first examines the political discourse surrounding hydropower projects in each country and how the projects fit within the development narrative of each country. It then turns to a cost-benefit analysis of two large projects that were recently pushed forward, Punatsangchhu I (or "Puna I") in Bhutan and Arun III in Nepal. In juxtaposing political considerations with economic analyses, this paper is able to draw conclusions as to the relative influence of politics and economics on policy decisions related to large hydropower projects.

This paper proceeds as follows: Section II provides a review of the literature on the costs and benefits of hydropower projects and decisions to pursue these projects. Section III provides background on the political systems of Bhutan and Nepal, as it is important to understand these systems in order to analyze whether and how politics is a motivating factor in decisions to pursue hydropower projects. Section IV traces the narrative around hydropower projects in each country and in the wider river basin and analyzes the political discourse related to the projects. Section V presents the framework for and the results of the cost-benefit analyses of Puna I and Arun III. Section VI draws conclusions based on considering the political discourse and the cost-benefit analyses together and discusses the policy implications of those conclusions.

## **II. Literature Review**

### ***A. Costs and Benefits of Hydropower Projects***

Much of the literature on the costs and benefits of hydropower projects focuses on the environmental and social costs of these projects (Siciliano et al., 2015; WCD, 2000). For the

environment, the main concerns are around river and ecosystem fragmentation, soil quality, water quality, species and biodiversity, and geological changes. Social costs center around displacement and resettlement, changes to livelihoods that rely on the river, impacts on culture and social relations, health and water access. Social impacts are often exacerbated when a project affects indigenous or rural communities for the benefit of urban elites. A number of NGOs, most notably International Rivers, are also focused on highlighting the social and environmental issues that stem from large hydropower projects.

Other literature focuses on the benefits of such projects, notably increased electrification and corresponding economic growth. Lipscomb et al. (2013) find that the electrification of Brazil from 1960-2000, largely through hydropower, led to increases in the UN Human Development Index for a county and average housing values. Bhatia et al. (2008) show that projects can have substantial indirect benefits and suggest analytical tools that can be used to measure such benefits. Even the World Commission on Dams' (WCD) seminal report, *Dams and Development*, widely seen as a response during the low point for international opinion of hydropower, acknowledges that large dams are part of the economic development of a region and often create indirect economic benefits that are difficult to reduce to a dollar amount (2010). However, calculating the economic benefits of hydropower projects involves a significant amount of uncertainty, particularly given the long lifespans of projects and the difficulty in predicting the impacts of climate change on river flow (Jeuland and Whittington, 2013).

Another body of literature focuses on deficiencies in cost-benefit calculations of hydropower projects—specifically, that these calculations often understate or are unable to accurately calculate costs. One study in particular, conducted by Ansar et al. (2014) garnered significant press attention for its claim that the budgets of large hydropower projects “are systematically biased below actual costs” due to the exclusion of “inflation, substantial debt servicing, environmental, and social costs.” The WCD report (2000) also provided evidence that the costs of large dam projects are often understated and fail to adequately value social and environmental costs. Bakker (1999) argues that, in the context of the Mekong basin, evaluations of potential impacts are at best “highly speculative” given the complexity of downstream and ecosystem impacts and a lack of local personnel capable of evaluating such impacts.

Both Zhang et al. (2015) and Zheng et al. (2016) argue that the externalities of hydropower are often not fully taken into account. Through an analysis of projects in Tibet, Zhang et al. contend that externalities due to civil works, reservoir impoundment, and cumulative impacts are regularly not accounted for. They also focus on the greenhouse gas (GHG) emissions associated with these externalities and claim that the climate change benefits of hydropower are often over estimated. Some policymakers have called for ensuring that the economic costs of responding to the social and environmental risks are adequately accounted for in cost-benefit analyses—implying that doing so may make some projects no longer economically feasible (Brown, 2014).

In their meta-analysis of the economic value of hydropower externalities, Mattmann et al. (2016) find that people place a high value on the negative effects of projects, but at the same time place a low value on mitigation measures. They conclude that projects should therefore be sited in an area where they will have the least negative impact to begin with, since policymakers may have difficulty justifying expensive mitigation measures. They furthermore conclude that the value of the positive externality of reduced GHG emissions is generally only large enough to outweigh the value of negative externalities in countries that already have a high share of hydropower production. Specifically, the percentage change in the portion of the country's energy produced by hydropower must be at least 60 percentage points in order for this threshold to be met. They attribute this result to greater awareness in those countries about hydropower's role in reducing emissions.

Finally, much of the literature on the costs and benefits of hydropower focuses on the distributions of those costs and benefits across society (Bhatia et al., 2005). Focusing on the Mekong region, Bakker (1999) expresses concern about the tendency of hydropower projects to transfer revenue away from local communities toward the state. Thus, she argues, one should always consider the distribution of costs and benefits associated with these projects. Duflo and Pande (2007) show that while rural poverty decreases in areas downstream from a dam, it increases in the area surrounding the dam and conclude that, as a result, "neither markets nor state institutions have alleviated the adverse distributional impacts of dam construction."

Klipmt et al. (2002) argue that local communities should reap benefits from a hydropower project. They highlight a key issue for these projects is "the fair distribution of project costs and benefits among local communities, society at large, project proponents and governments" and are particularly concerned with the potential for local communities to bear most of the costs (e.g. relocation) while others receive the benefits (e.g. urban end users of the electricity produced). They recommend a participatory planning process as a way to ensure the "equitable sharing of benefits," as it allows locals to define what constitutes a benefit, which can range from support for local schools to improved roads, in addition or in lieu of monetary compensation.

### ***B. Decisions to Pursue Hydropower Projects***

The literature on decisions to pursue hydropower projects is in agreement on one point—such decisions are complex and multi-faceted. As Crain and Oakley (1995) glean from their analysis of decisions to invest in public infrastructure by U.S. state governments, "public capital decisions are not made in a political vacuum." The World Commission on Dams (2000) highlights that the decision to build a dam can serve as "a focal point for the interests and aspirations of politicians, centralized government agencies, international aid donors and the dam-building industry," often at the cost of a fair consideration of alternatives. They also point to the significant momentum that gathers behind a project at a certain stage of its development, which can overwhelm other factors. Finally, Jeuland (2010) highlights that large dam projects are



planned through a “very political and social enterprise,” and the economic value of a project will be interpreted differently by different policymakers and constituents.

At a government level, policymakers may turn to large hydropower projects to generate foreign exchange when national economic growth lags behind its potential. A country with large hydropower potential and a small population can find itself “in a situation of ‘statistical poverty amidst environmental plenty’” where it simply ‘can’t afford’ to refuse investment” in a project (Bakker, 1999; 224). Developing countries, such as Nepal and Bhutan, that possess hydropower resources, see development of these resources as a golden ticket to economic growth, energy security and even modernization. Thus, policymakers tend to become focused on attracting the private investment needed to usher along the development of these projects. The location of the projects in poorer and less developed regions can actually become part of the narrative justifying these projects—a way to even out regional inequalities rather than perpetuate them (Huber and Joshi, 2015).

Bakker (1999) focuses on how a forced reliance on foreign investors, often large international firms, distorts decision-making related to hydropower. She argues that this setup favors large-scale projects—and perhaps different projects than would be selected by policymakers alone. Furthermore, government and multilateral support for these projects often allows investors to pursue projects without a full assessment of the risks and potential for negative returns. Bakker also points out that the redistribution of resources from a local community to a city or even a foreign country that often accompanies a hydropower project explains why these projects become so politicized.

This paper adds to the literature in two ways. First, in conducting cost-benefit analyses of two large hydropower projects, it supports arguments about the difficulty in accounting for social and environmental costs, as well as indirect economic benefits. Second, it builds on the literature finding that hydropower decisions are often political by providing a specific case study that sheds light on which political factors matter and how these factors interact with economic analyses.

### **III. Background on the Political Systems in Bhutan and Nepal**

#### ***A. Bhutan***

Bhutan’s foray into democracy is a recent development, with its transition from an absolute monarchy to a constitutional monarchy occurring within the last decade (D’Ambrogio, 2014). In 2008, the Bhutanese people voted in their first parliamentary elections, and a new constitution was drafted that same year. Candidates hailed from two political parties, Druk Phuensum Tshogpa (DPT) and the Peoples’ Democratic Party (PDP), and the DPT captured a firm majority. Since parliament members are elected for five-year terms, the country’s second democratic elections were carried out in 2013 (Kharat, 2016). Two additional parties sprung up for the 2013 election, and the PDP took the majority this time (V. Kumar, 2016). General

assembly members are elected by 47 different constituencies spread across the 20 districts (Sebastian, 2015).

Bhutan is ethnically diverse, and its people fall roughly into four ethnic groups, which speak a multitude of languages: (1) people of Tibetan origin (the Ngalops), (2) the Indo-Mongoloid people (the Sharchops), (3) small indigenous groups (e.g. the Lephass and Doyas), and (4) Nepali Bhutanese (the Lhotshampas). The Ngalops constitute the “social and political elite” (Rajput, 2015; Sebastian, 2015). The government, and the monarchy in particular, have sought to unite the country as “one Bhutan” in spite of these differences. At his coronation in November 2008, the Fifth King proclaimed, “We must always be one nation with one shared goal” (Rajput, 2015; 53).

Bhutan’s modern history has been one dominated by the centralized control of the king. However, the Fourth King, Jigme Singye Wangchuck, who reigned from 1972 to 2006, embarked on a concerted effort to decentralize power in favor of local communities. Bhutan’s development policies are set forth in five-year plan documents, and the Fifth Five Year Plan (1981-1986), heralding decentralization as its main theme, planted the seeds for democracy to emerge at the village and district level. Eventually, this developed into the formation of District Development Committees (DDCs), and below DDCs at the village level, Block Development Committees (BDCs). The country currently has 20 districts, broken into 205 “Gewogs” (a block of villages). The purpose of these administrative bodies is to increase local participation in policy decisions. Elections were first held for DDCs and BDCs in 2011, although engagement was less than hoped. Of the 1102 candidates elected, 535 candidates ran unopposed. An additional 370 positions remained vacant (V. Kumar, 2016; Premkumar, 2016).

Scholars of Bhutanese politics observe that the country’s citizens generally do not have a strong tradition of challenging government decisions (D’Ambrogio, 2014). Rajput (2015; 56) states:

[F]or Bhutanese the king is like a father and they have firm faith that a father will always remain a father and will never neglect his children. They have full faith in royal decisions. They see royal decisions as wisdom unfolded.

He harkens this trust back to the fact that the king introduced democracy to Bhutan for the good of the people and not because they demanded it. In fact, the king warned the people *not* to “adopt the attitude that whatever is required to be done for your welfare will be done entirely by the government” (Rajput, 2015; 50).

Bhutan has surely benefited from its bloodless transition to democracy, but one consequence of democracy coming from above rather than being demanded from below is a lack of political participation from the people. Since 2008, there have been only small increases in public participation in politics. Political participation at the grassroots level still leaves much to

be desired, particularly in terms of engagement from rural people (Kharat, 2016; V. Kumar, 2016).

Some scholars trace a lack of political engagement to the authoritarian tendencies of the government. Vikash Kumar (2016) cites reports that public demonstrations are not allowed and that the media is fined for criticizing the government. In his analysis of the “nascent” media in Bhutan, Sandeep Kumar (2016) discusses a 2013 survey of journalists that found 50 percent believed there was no freedom of the press. 77 percent reported that access to information is difficult, exacerbated by the fact that the press is still largely reliant on government for funding.

In terms of its relationship with India, Bhutan enjoys long-standing diplomatic ties with its large neighbor. Until 2007, Bhutan was bound by a “Treaty of Friendship” to consult India regarding foreign relations. Today, India continues to be Bhutan’s dominant trading partner and source of development aid (Benedictus, 2014). The Fourth King focused in particular on building and maintaining a good relationship with India. India, in turn, gave Bhutan economic aid, invitations to international meetings and avoided any pressure on the kingdom to transition to democracy (Rajput, 2015). As a sign of the important links between the two countries, Indian Prime Minister Narendra Modi made Bhutan the destination of his first trip abroad after being elected (Dharmadhikary, 2016).

## ***B. Nepal***

Nepal, too, has a modern history dominated by kings and centralized control; however, with little of the peace and stability found in Bhutan. In 1768, King Prithivi Narayan Shah unified the country under one ruler, gave it the name Nepal, and established Kathmandu as the capital. From 1769 to 1846, the Shah dynasty he founded ruled the country with absolute power and a “highly centralized” administration. 1846 brought a violent transition to the Rana period, during which the country was ruled by a prime minister with absolute power for 104 years. During this time, however, the state began the process of decentralizing control (Asia Foundation, 2012).

In 1951, Rana rule came to an end, and Nepal began to experiment with democracy. Concepts like political parties and separation of powers were introduced, although the king retained substantial power. The government began to focus on the nation’s development and delivering services to its citizens for the first time. However, in 1960, King Mahendra abandoned democracy and implemented the Panchayat system. This system divided the country into 14 administrative regions and 75 districts, each charged with carrying out development projects while being directly accountable to the central government (Asia Foundation, 2012).

The authoritarian Panchayat system was overthrown in 1990 by a “people’s movement.” Leaders drafted a new constitution, and elections followed in 1991. Local government structures were largely left in place, although they became formally known as village development committees (VDCs) and district development committees (DDCs) (Asia Foundation, 2012).

The 1990s saw frequent changes in the political party controlling the government, as well as the outbreak of civil war. In 1996, the Communist Part of Nepal, known as the Maoists, instigated a “people’s war” against the constitutional monarchy in place, calling for Nepal to instead become a communist republic. They engaged in a “low-intensity insurgency” for the rest of the decade, primarily in rural areas (Sharma, 2008). In spite of the turmoil, the Local Self-Governance Act was promulgated and local elections were held in 1992 and 1998 (Asia Foundation, 2012).

However, the Maoists escalated their efforts beginning in 2001, and full-scale guerilla war engulfed the country until 2005 (Sharma, 2008). As a result, in 2002, the government indefinitely suspended local elections. Later that year, King Gyanendra Shah suspended the elected government and assumed executive authority. By November 2005, in the face of protests and united opposition from the parliament he disbanded, the king stepped aside in favor of reinstating parliament (Asia Foundation, 2012).

The new government, led by Prime Minister Koirala, reached a peace agreement with the Maoists in November 2006, ending a long conflict that had killed 13,000 people (Sharma, 2008). At this point, Nepal could finally turn to the much-needed task of structuring its state and institutions. The inclusion of the Maoists in the 2008 elections resulted in the party becoming the largest one in the country. Over the next four years, four different governments were formed, all of which failed to agree on a long-overdue constitution for the country (Asia Foundation, 2012).

VDCs and DDCs have still not seen elections since 1998. Governments since then have taken to the habit of appointing officials to these bodies. As a result, they have largely become an arm of the central government rather than a means through which citizens can engage with democracy. VDCs are charged with a number of functions, falling under the following categories: agriculture, rural drinking water, construction and transport, education and sports, irrigation, soil erosion and river control, physical development, health, forest and environment, language and culture, and tourism and cottage industry. DDCs have 48 enumerated functions, including power, works and transport, land reforms and land management, forest and environment, and soil erosion control and river training. When planning projects, VDCs and DDCs are supposed to involve all relevant stakeholders, but in reality, they rarely consult marginalized groups. Ultimately, these bodies are accountable to the central government and not local people, who complain about a lack of transparency and corruption (Asia Foundation, 2012).

Thus, in spite of the potential offered by these local institutions, authority in Nepal is still overwhelmingly centralized. This tendency can be traced back to centuries of monarchy rule prior to 2008, which has been perpetuated by Nepal’s political parties. Furthermore, institutions have been constructed in a hierarchal manner to exert control over the country, rather than serve the people (Asia Foundation, 2012).

More recent years have not yielded much stability. From 2008 to 2016, nine different governments were formed. The finalization of the new constitution last year has not provided the stability hoped for, and the political parties continue to challenge each other for power. One journalist observed:

The sole purpose of the political class has been centered on survival... The average tenure of each government has been so short-lived that no one has focused on building up the state's capacity.

The constant changes in government are often blamed for stunting economic growth and development. The instability makes foreign investors hesitant to invest, and the government reports an emigration of 1500 Nepali youth every day in search of employment abroad. The government was barely able to unite in response to the devastating earthquake of 2015, and in many cases, it took over year to disburse reconstruction funds (Bhattarai, 2016; Tharoor, 2015).

The difficulties faced by Nepal's political system are a reflection of the fact that Nepal is "a multi-ethnic and multi-lingual, culturally complex nation" (Tharoor, 2015; Bhattarai and Conway, 2010). The Nepali people belong to a multitude of castes and ethnic groups; in total, the country has 62 different ethnic groups. Its people live across three ecological regions—the mountains, hills and tarai. Population density varies across these regions, with 33, 167, and 330 people per square kilometer, respectively.

India and Nepal have ties that date back centuries. The two countries share an "open border" that Nayak (2014) describes as "a symbol of their deep trust and friendship." However, their relationship is complex and has at times been soured by periods of suspicion. Nepal and India signed a Treaty of Peace and Friendship in 1950, which sought to recognize their open border and cement social and economic ties. This Treaty became sensitive in Nepal, with many political parties calling for its end, and the regime that signed the treaty lost power six months later. The Maoists were one party that capitalized on anti-India sentiments in the country and called for renegotiation of the Treaty on terms fairer to Nepal. However, no political party has succeeded in gaining political consensus over what specifically to change and it has not been renegotiated.

Nayak (2014) argues that it is "fashionable to be anti-India," particularly in the capital. As its main neighbor and trading partner, India looms large over Nepal, and nationalism and patriotism are often expressed in anti-India sentiments. He describes a common pattern of political parties not in power accusing the government of being the puppets of India and then changing their tune once in power. For example, the Maoists became the largest party in the 2008 elections and are credited with spreading anti-India sentiment to rural areas through propaganda. They accused India of meddling in the country's internal affairs and stoking instability. In 2011, however, Maoist Prime Minister Baburam Bhattari was elected and subsequently sought to improve relations with India.

#### **IV. The Politics of Hydropower in Bhutan, Nepal and the Larger River Basin**

This section examines the political discourse surrounding large hydropower projects in Bhutan, Nepal, and the wider river basins within which they sit. Specifically, this section contextualizes the discussion of hydropower decisions in Bhutan and Nepal by providing background on how the industry has developed over time in each country and the industry's role within the development narrative of each country.

##### ***A. Bhutan***

Bhutan's policymakers view aggressive hydropower development as fully in line with its development philosophy and pursuit of "gross national happiness" (GNH), which the government officially monitors rather than GDP (Walker, 2015; ADB, 2013a). The Minister of Hydropower and Economic Affairs has declared hydropower to be in perfect balance between "material and spiritual needs," by allowing neighboring India to replace fossil fuels with clean energy, contributing 25 percent of Bhutan's GDP, and generating significant government revenue (roughly 50 percent of total revenue) (Walker, 2015; ADB, 2014).

Official government documents further highlight the exalted nature of the hydropower industry in Bhutan. The Eleventh Five Year Plan, the key policy document that sets the development framework for the country, describes hydropower as the "lynchpin" of Bhutan's economy (GNHC, 2013). The Tenth Five Year Plan is effusive with praise for the industry, stating:

Hydro-power energy production is Bhutan's outstanding and singular comparative advantage and its sustainable exploitation has had an immeasurable impact in boosting the country's economic situation (GNHC, 2009; 80).

In short, the government recognizes hydropower as the "catalyst of the Bhutanese economy" (Bhutia, 2016). As a small, landlocked state that faces geographical constraints to the development of farming and agriculture, Bhutan has little else to turn to. As a result, predictions hold that by 2020, hydropower will contribute half of the country's GDP and three-fourths of government revenues.

The explosion of hydropower development in Bhutan can be largely attributed to Indian support—in the form of loans, technical expertise, and labor ("Water in them hills," 2014; Dharmadhikary, 2015). As of 2014, Bhutan had 1,500 MW of installed capacity—five times its 300 MW peak demand. Thus, it exports roughly 75 percent of this energy to India, leading hydropower to become "the backbone of the country's economy" (Ogino & Acharya, 2014; Dharmadhikary, 2015). This relationship is predicated on an agreement Bhutan signed with India in 2006, and amended in 2009, that commits India to supporting the development of 10,000 MW of hydroelectric power in Bhutan by 2020 and importing all surplus power (ADB, 2014). As

discussed further below, meeting this lofty goal will require increased development of large projects, including several in the 1000 MW to 2500 MW range.

Policymakers in both Bhutan and India view their hydropower arrangement as a “win-win situation” (Dharmadhikary, 2015). Bhutan, for its part, has ensured that its people reap benefits from the development of the industry even if most of the electricity is exported to India. The website of the Indian Embassy in Bhutan (n.d.) claims that hydropower cooperation is “the centerpiece of India-Bhutan bilateral relations” and lists the large number of projects on which the two nations have collaborated.

The Bhutanese government has, at times, included discussions about rural electrification in its hydropower discourse, which is primarily focused on exports. Royalties obtained from exports are used to subsidize domestic rates (Premkumar, 2016). While the Tenth Five Year Plan had set a goal of universal electrification by 2013, the Eleventh Plan (published in 2013) cites a rate of only 92.82 percent. This amounts to 6,372 households still without electricity. The Eleventh Plan notes a 15 to 20 percent increase in tariffs effective in 2013 but cites a new policy of providing rural homes free electricity for the first 100 kWh, with the stated aim of cutting down on firewood use.

The pace and scale of Bhutan’s hydropower development, however, has led to concerns about both the social and environmental impacts on the country’s people and resources. To this end, the government commissioned a World Bank study on how to best manage these impacts. This report (World Bank Group, 2016) cites strong institutional capacity “to mitigate negative impacts and to distribute and communicate benefits” as key to the continued successful development of hydropower in Bhutan. It also found that the main concern is for aquatic biodiversity, as more and more projects come online and their cumulative effects reverberate through the ecosystem (World Bank Group, 2016).

In spite of the all-around success of individual projects, large-scale development of hydropower in Bhutan comes with environmental and social challenges. ADB (2010) has expressed concerns about the ability of the National Environment Commission to monitor and enforce mitigation of projects’ negative environmental impacts. There is also a lack of (and no requirement for) studies on the cumulative impacts of these projects, which is critical given the massive growth policymakers are seeking in the coming years (ADB, 2010; Walker, 2015; Dharmadhikary, 2015).

Walker (2015), Dharmadhikary (2015) and Premkumar (2016) also point to growing environmental concerns. Fish ladders have been of questionable efficacy, and of late, people are beginning to realize that projects can have repercussions far downstream—even in India. The Puna projects, in particular, have been criticized for destroying the habitats of an endangered species of heron. Walker and Dharmadhikary both point out that the Indian contractors on these projects do not have good track records on environmental sensitivity. In addition to these environmental challenges, it is also increasingly likely that people will need to be relocated given

the scale of the hydropower development planned. For example, reports suggest that an indigenous community will need to move to make way for the 540 MW Amochhu Reservoir Hydro Electric Project (Arora & Dema, 2016).

Premkumar (2016) reports that India and Bhutan will sign an agreement to implement a project based on technical and financial analyses, and only after the agreement is signed will an analysis of the social and environmental costs be conducted. These studies, therefore, become pro forma items to complete rather than meaningful documents that influence a decision to proceed or not. Furthermore, Environmental Impact Assessments, although required to be completed, are not made public.

Similarly, information on the social costs of projects is not made readily available. In many cases, local people did not consent to the sale of their land for projects but were only informed the project was happening and were told that it would benefit them. Bhutan does not have a formal system in place that allows local residents to address issues they may have with the project. They can complain to their local BDC, who then convey concerns to the project company. Residents report small concessions being made but rarely see permanent, fundamental changes to project design or implementation. However, little information is available on the pervasiveness of such complaints. More fundamentally, the projects have not contributed to local economies in ways hoped. While local schools, health clinics, and roads have been built, projects do not increase local employment and have had only a minimal positive impact on local businesses (Premkumar, 2016).

Bhutan does have policies in place meant to offset social and environmental costs. Project developers must plant two acres of forest for every acre that they clear. A minimum of 1 percent of the project cost must be set aside for compensating people who need to be resettled. Any households losing land must be provided with 10,000 units of free electricity per year for each acre that they lose. However, administrative officials have suggested that sometimes these policies are not strictly followed, and are adjusted to suit specific projects if needed. Furthermore, in the case of mandatory funds, there is not always proper oversight in how they are spent.

The Tenth Five Year Plan, however, essentially dismisses concerns about environmental impacts and is silent on social impacts. To the contrary, it identifies compliance with Bhutan's "extremely strong environmental conservation policies" as causing delays in projects. Although it maintains that "addressing genuine environmental concerns are necessary," there is a stated challenge in doing this and ensuring development of projects is done "efficiently and in a cost effective manner" (GNHC, 2009). As discussed above, Bhutan generally lacks a robust civil society that is willing to challenge government policies and decisions when such concerns arise (Walker, 2015). Moreover, projects are reportedly shrouded in secrecy, particularly regarding environmental assessments (Arora & Dema, 2016; Premkumar, 2016).



Nonetheless, Bhutanese policymakers themselves have also recently become concerned with signs that the hydropower boom may not be all good news for the Bhutanese economy (Dharmadhikary, 2015). Its most recent five-year development plan, the Eleventh Five Year Plan, recognizes that economic growth is coming largely from government investment in the hydropower sector. However, it acknowledges that this has led to “macroeconomic challenges,” namely the failure to create the non-agricultural jobs the country needs (GNHC, 2013).

The Plan identifies several challenges for the sector: (1) attracting financing to cover high upfront costs, (2) balancing “the needs of domestic consumption and export earnings” (3) infrastructure development, system reinforcement and human resource capacity. Included in this last category are concerns about glacial lake outburst flooding. It goes on to identify result areas for the sector as “enhancing” energy security, building local capacity to build and operate hydropower and increasing contribution to GDP and employment and follows with strategies for meeting these goals. Absent from this list is anything related to ameliorating social or environmental impacts (GNHC, 2013).

Questions about the financial and economic benefits of projects are likely most concerning to Bhutanese policymakers, as projects are no longer a guaranteed source of profits. The net profit per unit of electricity being sold to India has decreased since 2007, and projects like Puna I are facing significant cost overruns. As India has shifted from financing a larger portion of the projects through a loan rather than a grant, Bhutan’s debt has increased substantially (Premkumar, 2016).

In spite of these concerns, Bhutanese policymakers continue full speed ahead with hydropower development, as detailed in both the Tenth and Eleventh Plan (GNHC, 2009; GNHC, 2013). The Eleventh Plan maintains the goal of reaching 10,000 MW by 2020 with Puna I, Puna II and Mangdecchu leading the way. Of seven pipeline projects listed, six of them exceed 500 MW and two (Sankosh and Kuri-Chamkharchhu-1) exceed 2500 MW. The Tenth Plan specifically commits to the “accelerated development of additional mega hydro-power plants,” which it describes as essential to raising the prominence of the sector in the national economy. However, International Rivers, an NGO that fights dams and large hydropower projects, claims that both Sankosh and Kuri-Chamkharchhu have stalled due to India’s unwillingness to commit funding.

The Puna I project, is the largest project undertaken thus far in Bhutan. It will be a 1200 MW run-of-the-river project that also involves construction of a diversion dam and will be located in the western district of Wangdue Phodrang. The Project Authority formed to implement the project is a joint venture between the governments of India and Bhutan. The Government of India is supporting the project through a 40 percent grant and 60 percent loan, and the loan comes with a 10 percent interest rate and 12 year term (Premkumar, 2016).

Building the project required 542 acres of land, 425 of which came from government forests and 117 acres from private landowners. 23 families will lose their homes and have to be

relocated. The project's location makes it susceptible to both landslides and floods, as well as the risk of a Glacial Lake Outburst Flood. Geological and technical challenges have delayed completion to 2019 (from 2015), after the Project Authority decided to move the location of the project upstream. These delays have been accompanied by substantial cost overruns, as discussed in Section V. Experts have also complained that the environmental standards of the project are "pretty low" (Premkumar, 2016).

Over the course of its 35 year life, the project will supply electricity both domestically and for export to India. It has also been granted a Clean Development Mechanism Certified Emission Reduction credit from the UNFCCC (Premkumar, 2016).

### ***B. Nepal***

The story of hydropower development in Nepal is largely one of unrealized potential. Numerous sources discuss Nepal's hydropower resources as a ticket to success. Poudel (2010; 169) describes hydropower as the "one major hope" for Nepal's snail-paced development process. Britain's Department for International Development has estimated that four large-scale hydropower projects could earn Nepal \$17 billion in the next 30 years ("Water in them hills," 2014). Rana & Karmacharya (2014) estimate that Nepal could double its GDP if it began exporting hydropower to India.

Nepal has an incredible 42,000 MW of hydropower that is economically and technically capable of being developed (Obaidullah, 2010). Yet as of 2014, the country only produced 787 MW, which did not even cover domestic demand that year of 1200 MW (Dhungel et al., 2016). As a result, Nepal faces rampant electricity shortages—power cuts up to 14 hours per day—and relatively low electrification rates, particularly in rural areas. Policymakers recognize that this energy shortage stunts development and that solving this problem will "open up new economic opportunities" (Adhikari, 2016). Yet, currently, Nepal produces less than half of the hydropower Bhutan does in spite of having twice the resources, and a much higher population and local demand for energy (ADB, 2013a; Wijayatunga & Nepal, 2016; Bhushal, 2016).

A 2008 study of the National Electric Authority (NEA) found that the country did not produce 41 percent of demanded electricity, leading to frequent load shedding. The opportunity cost of this shedding has been calculated to be \$1.28/kWh (average of \$0.41/kWh). An IPPAN report (2009) estimates the monetary loss of load shedding at 2.17 billion rupees per year, which it correlates with an indirect loss of 21.7 billion rupees per year. Given this reality, the government is faced with the difficult decision of whether to focus on its own electrification or exporting power to India. Rural electrification may not bring the same gains as exports—and in fact, may not even be profitable. Thus, any focus on rural electrification by the NEA or the government will likely be motivated by social concerns rather than financial ones (Poudel, 2010).

The development of hydropower has the potential to unleash economic growth for impoverished Nepal—and not only through exporting power to India. Establishing reliable and

sufficient power could also make Nepal more attractive to industry, as energy is a critical input to economically-productive activity. A cement industry, for example, could form to exploit Nepal's extensive limestone resources. Nepali policymakers and industry are aware of both aspects of this potential, yet hydropower development in the country still lags well behind its potential ("Water in them hills," 2014; Wijayatunga & Nepal, 2016).

The government has increasingly claimed that energy development is a national policy priority, yet, as Dr. Govind Nepal, the Chief Economic Advisor to the Ministry of Finance, points out, they have not achieved results (Wijayatunga & Nepal, 2016). He suggests that the energy crisis caused by India's "unofficial" blockade of the Nepali border in 2015 has forced the government to double-down on its efforts.

*The Economist* cites "local politics, a ten-year civil war, suspicion of India and a lack of regulation that puts off creditors" as the key obstacles long standing in the way of hydropower development in Nepal ("Water in them hills," 2014). Nepal and Jamasb (2012) similarly blame civil war and frequent leadership change as hindering the ability of the country to implement planned reforms and engage in long-term policy planning. Several sources also turn attention to structural policy reforms that will be needed to spur hydropower development, particularly for export outside of Nepal, which include the establishment of an independent regulator, integrated planning, and ensuring open access to the transmission network (Wijayatunga & Nepal, 2016). Other sources have focused on the limited capacity of Nepal's energy institutions as the key barrier to hydropower development (Sharma & Awal, 2013).

Policies around hydropower development have in many ways been a victim of Nepal's political instability. Projects become the subject of debate between the parties, which have been known to take one position on a project while in government and the opposite position when out of government. Officials will take painstaking effort to develop a plan and policy, only to see the subsequent government start from scratch. This inconsistency deters foreign investors, which are further turned off by the multitude of government agencies, departments, commissions and planning boards with some type of authority over hydropower (Dhungel et al., 2016).

Nepal also faces obstacles not present in Bhutan. For instance, the devastating earthquakes that hit Nepal in April 2015 have led to setbacks to hydropower development, as investors are wary of potential damages to infrastructure, particularly dams (Bhushal, 2016). Nepal's overall investment climate also hinders the industry's development, which requires foreign capital and expertise. Multiple investors have withdrawn from projects over frustration with Nepal's bureaucracy and political situation. For example, a Norwegian firm recently pulled out of a \$1.5 billion project that would have generated 650 MW of power for export ("Norway firm quits \$1.5bn Nepal hydropower project," 2016).

Tense relations with India, soured by suspicion and mistrust and worsened by the recent blockade, are at least in part to blame for the stunted development of Nepal's hydropower industry. India essentially has a monopoly on exports so it has leverage to negotiate favorable

terms (Poudel, 2010). Kumar (2016) explains that Indian aid to Nepal comes primarily in the form of lines of credit (LOC). These LOCs unsurprisingly come with strings attached, including requirements that all projects contract with Indian companies. These LOCs do include a development aid component that renders a certain percentage of the LOC into a grant that does not need to be repaid. The 32 MW Rahughat project illustrates the complications that come with Indian participation on Nepali projects (P. Kumar, 2016). An Indian LOC was extended to cover the \$67 million cost; thus the engineering, procurement, and construction (EPC) contract was awarded to IVRCL, an Indian infrastructure company. Although local subcontracting is usually allowed under the LOCs, in this case almost all the construction workers were brought in from India.

Policymakers from Nepal's Ministry of Energy, Ministry of Finance and the Nepal Electricity Authority all reported a negative experience with the Rahughat project specifically, primarily due to the LOC restrictions and frustration with the Indian EPC contractor. They attribute the extensive delays of the project to the restrictions that come with the LOC. Interestingly, local residents have a more positive view of the project. The project did create some construction jobs and the presence of foreign workers stimulated the local economy (P. Kumar, 2016). However, the Rahughat project serves as an example of why hydropower projects in Nepal have gone awry or fallen short of expectations.

Furthermore, it is this dissatisfaction with India that has led Nepal to turn to its other neighbor for the foreign investment needed to boost the hydropower industry—China (Bhushal 2016). In 2011, the Nepali government signed a memorandum of understanding with a Chinese company to build the West Seti dam. Policymakers, however, express doubts that the Chinese company will fully commit to the project, which has suffered from many delays. The mountainous border between the two countries means China has little strategic interest in Nepal's hydropower development, so it is unlikely that it will supplant India as a partner in the industry's development. As Sharma & Awal (2013) argue, Nepal has no other choice but to work with India if it wants to develop an export-driven strategy.

Although decisions to pursue projects are made by the central government, in consultation with international donors or investors, local policymakers in Nepal also play a role in hydropower policy. VDCs and DDCs are given authority over natural resources at the local level and can demand royalties from projects. Local communities are sometimes given ownership interests in projects. However, without a clear delineation of the rights and responsibilities of local government, questions of whether control rests with a local or national body can create issues during project development (Dhungel et al., 2016).

Finally, Nepal has also not ensured the equitable distribution of revenue generated by hydropower projects. Poor rural areas have not been able to share in these revenues and have thus received no economic benefits from the industry (Balasubramanya et al. 2014). This failure can be politically fatal for the continued development of hydropower projects, as the rural communities that often bear the brunt of the costs must see some benefit in the project in order to

support it. Rivers have historically contributed to the Nepali economy through agriculture, tourism, fisheries, power production and transportation. Poudel (2010) posits that a project's impact on these uses should be evaluated and questions should be asked about who will win and who will lose. But rarely has this been the case; more attention has been paid to criteria like the specific benefit to the ruling elite.

Contrary to calls in Bhutan for less direct government investment in projects, many observers of the industry in Nepal see private investment as key to making progress on hydropower development. Poudel (2010) is critical of NEA as an institution and suggests privatization as the answer to meet the load shedding issue. Devkota (2010) also criticizes state control of the industry and suggests that private sector involvement needs to be increased. She also favors small community-based hydro development rather than large projects.

There are some signs that the Nepali government is getting serious about hydropower. By 2020-2021, 118 projects supplying 3859 MW are expected to be commissioned. The 2014 Indo-Nepal Power Trade Agreement guarantees “non-discriminatory access” and is expected to increase foreign investment in the hydropower sector (Dhungel et al., 2016). Bhushal (2016) reports that in February 2016, the Nepali government released a plan to develop 10,000 MW of hydropower in the next ten years. Most of this power will be exported to India. Some projects, however, are also being designed to ensure that Nepal receives at least some benefits, and the 2011 Hydro Power Policy commits to the dual purpose of rural electrification and developing hydro power for export. The Upper Karnali project, being developed by an Indian firm, will set aside 12 percent of production for free for Nepal. Nepal will also obtain a 27 percent stake in the project and full ownership after 25 years of operation (“Water in them hills,” 2014).

Policymakers in particular are focused on pushing through big projects, with the Investment Board of Nepal highlighting the following projects on its website: Arun III (900 MW), Tamakoshi III (650 MW), Upper Marsyangdi (600 MW), Upper Karnali (900 MW), and West Seti (750 MW). In 2011, Energy Secretary Bala Nanda Poudel stated, with respect to the West Seti project, “The government is committed to construct the project at any cost” (“West Seti Hydro Electricity Project,” 2011).

The Arun III project has a long history that in many ways tracks the mood on hydropower at an international level and internally within Nepal. It was proposed as a 402 MW project to both meet Nepal's domestic demand and to begin export to India. The country sought World Bank funding for what would be its biggest project. It was conceived as a run-of-river project but would also involve construction of a dam. Its rural location necessitated construction of a road and a transmission line that would bring the power to Kathmandu. However, the World Bank withdrew support in August 1995.

Complaints against the project in the early 1990s related to the high cost of the project, the risk to Nepal of relying on one project to generate such a substantial proportion of electricity, and the social and environmental costs for people living in the Arun Valley. However, the World

Bank withdrew support based on concerns over Nepal's capacity to execute the project, the diversion of funds away from social projects and the country's inability to get final commitments on financing (Chettry, n.d.; Udall, 1995).

According to the Investment Board's website, the project is currently planned as "a 900 MW, export-oriented Peaking Run-of-River (PRoR) project with 3.65 hours minimum peaking capacity." It will be located in Sankhuwasabha district, in the mountain region, where population density is lowest.

In 2015, the Sankhuwasabha Journalists Association organized a meeting in Kathmandu titled, "Arun III Project: Concerns and Challenges" for the people of the six VDCs impacted by the project. There, people who will be displaced or otherwise affected by the project voiced concerns over not having seen a plan for how the project will address social and environmental issues. One project site resident accused the government of only focusing on the project's benefits and "bypassing people in the affected areas." Although the Environmental Impact Assessment includes mitigation measures, those at the meeting felt these measures did not address the concerns specifically raised by locals. They were also critical of errors in the report related to census data that understated how many households would be displaced. As a result, they submitted a "26-point demand" to the Ministry of Environment, Science, and Technology in an effort to have their concerns addressed. Some of the demands include roads connecting the six villages, reconstruction of earthquake-damaged schools, new health facilities, and technical trainings for locals. A representative of Satluj Jal Vidyut Nigam Limited (SJVNL), the project developer, attended the meeting and stated that the company has prepared the EIA with extensive input from people affected by the project ('EIA report fails to address concerns of locals', 2015)

At the time of the meeting, one complaint of locals was that they had not seen the Project Development Agreement signed between the government and SJVNL, which obligates the developer to specify benefits for local communities. However, the PDA is currently available on the Investment Board's website and provides for both free electricity to households in the affected VDCs and ownership interests in the company that owns the project ('EIA report fails to address concerns of locals', 2015).

### ***C. Larger River Basin***

In addition to considering the politics of the bilateral relationships of Bhutan and Nepal with India, the dynamics of the larger river basins also have a bearing on the regional discourse around hydropower development. Nepal lies within the Ganges River Basin (GRB), and Bhutan is situated within the Brahmaputra River Basin (BRB). Recent research has shown that hydropower development in both of these basins could bring substantial benefits to the energy-starved region—although not all stakeholders are fully aligned behind this development.

The GRB includes parts of India and Bangladesh, in addition to the entirety of Nepal, and stands as the most populated river basin the world. The 665 million people who call this region

home rely on the basin's rivers for freshwater, energy, food, and navigation. Most developments in the GRB thus far have not considered basin-wide implications, due to a lack of information and coordination challenges. Unsurprisingly, the different players in the region have differing ideas about how the basin should be developed, creating complex international political dynamics.

A World Bank team produced the Ganges Strategic Basin Assessment in 2013 in an attempt to develop the information needed to increase coordination among stakeholders and maximize benefits for all. They found substantial support for regional benefits from hydropower development—a total net economic value of \$5 billion per year, with the vast majority of these benefits attributable to the hydropower itself, rather than other downstream benefits, such as irrigation and flood control. The team concludes that the minimal importance of these ancillary downstream benefits should make coordination over these projects somewhat easier (Sadoff et al., 2013).

BRB straddles four countries—China, India, Bangladesh, and all of Bhutan. Like the GRB, the 130 million inhabitants of the BRB rely on the rivers for multiple uses, including water, energy, and food. No multilateral treaty or institution governs the use of BRB resources, and it is susceptible to conflicts of interest over differing uses (Yang et al., 2016). At the same time, BRB is also a source of development potential for the region, particularly given its huge hydropower potential. Rahaman and Varis (2009) cite a cross-basin desire for hydropower development as “the key driving force behind the prospect of potential cooperation.”

Although the Indian government supports hydropower development in both Nepal and Bhutan, stakeholders within the country have begun to express concern over the rapid pace of hydropower development upstream. For example, experts in Assam state have called for downstream impact assessments for any Bhutan dam or hydropower project, particularly given India's role in supporting these projects (‘Assam jittery over Bhutan hydel plans,’ 2015). Specifically with respect to the BRB, there is growing opposition to upstream hydropower among states and civil society groups, stemming from concerns that benefits will not be shared equally within India (Rahaman and Varis, 2009).

## **V. Cost-Benefit Analyses of Two Large Hydropower Projects**

### ***A. Analytical Framework for Cost-Benefit Analysis***

This paper now transitions to creating an analytical framework for the cost-benefit analysis of a hydropower project in each of Nepal and Bhutan. The two run-of-river projects—900 MW Arun III in Nepal and 1095 MW Puna I in Bhutan—were selected for analysis due to the relative similarities in their sizes, financial commitments, and associations with India. Indian contractors will construct both projects, both projects are reliant on Indian investment, and both projects will ultimately export a majority of their power to India. Furthermore, both projects have attracted controversy amongst locals, potential donors, and international NGOs. For instance, as discussed above, the development of Arun III was on hiatus for nearly twenty years due to

concerns about cost and social and environmental impacts, while Puna I encountered five years of delays and cost overruns amidst ongoing questions about its own social and environment impacts.

The Government of Bhutan approved Puna I in 2006, and the Government of Nepal approved Arun III in 2015. Thus, the purpose of assessing these projects now is to see whether they would have passed an ex-ante cost-benefit analysis, which should have been conducted along with the financial analysis at the time of each project's approval. Each cost-benefit analysis compares a scenario in which the hydropower plants are successfully commissioned to provide clean energy with a scenario in which the status quo is maintained and energy needs are met via fossil fuels. The results of each cost-benefit analysis are evaluated in terms of net present value (NPV). The calculated NPV will indicate whether the present value of the future benefits gained from a project is greater than the present value of the accumulated costs of that project. A positive NPV, however, does not necessarily mean that the project represents the best use of public or private expenditure for society (Whittington et al., 2004).

In outlining the analytical framework for the cost-benefit analyses of the projects, this section covers the following: (1) the typology of costs and benefits, (2) selection of the appropriate discount rate, (3) an explanation of the data and modeling approach, and (4) the formulas used to calculate the net benefits.

### 1. Typology of Costs and Benefits

Before the NPVs of these projects can be evaluated, it first must be decided whose costs and benefits will be included, what categories of costs and benefits will be included, and how these costs and benefits will be quantified. Given the transnational flow of Himalayan rivers, as well as the cross-border effects of climate change, a large hydropower project in Bhutan or Nepal will have economic implications that go beyond their national borders. Therefore, the analysis for each project uses a partial-equilibrium model, as done by Jeuland and Whittington (2013) and incorporates the regional costs and benefits of each project. This regional perspective allows for a more accurate accounting of the economic costs and benefits of each project than just looking at them from the perspective of Nepal or Bhutan, since India incurs some of the costs and benefits of both projects.

The decision about what costs and benefits to include in the analysis is influenced by the typology provided by Jeuland and Whittington (2013) in their assessment of the costs and benefits of large water storage facilities in the Blue Nile gorge. Their typology is adapted to incorporate only the costs and benefits that are most relevant to run-of-river projects, as opposed to multi-purpose projects that can provide benefits in addition to generating power, such as irrigation and flood control. Those costs and benefits that are omitted from the typology, either because they could not be quantified or monetized or because they only had a negligible impact, are discussed qualitatively. Table 1 sets forth the costs and benefits included in the analyses, and lists those that were omitted.



**Table 1: Costs and Benefits of Large Run-of-River Hydropower Projects**

<b>Costs</b>	<b>Benefits</b>
Capital Investment (Plant and Transmission)	Hydropower Generation
Operations and Maintenance (O&M)	Carbon Offsets
Opportunity Cost of Project Land	
Resettlement of Displaced Households	
Catastrophic Risk	
<b>Omissions</b>	
Downstream Costs and Benefits (e.g. Flood Control)	
Environmental Impacts (including Loss of Endangered Species Habitat)	
Implications for Recreation, Navigation, and Fisheries	
Spillover Benefits of Electrification	
GHG Emissions Associated with Construction	

Existing financial analyses provide a source for some of the economic costs and benefits that are included in each cost-benefit analysis. SJVN Limited (2016), the developer of Arun III, produced a financial analysis for the Nepali project in a report submitted to the Government of India for project approval. The project company for Puna I, Punatsangchhu-I Hydroelectric Project Authority, included a financial analysis in the Project Design Document it submitted to the United Nations Framework Convention on Clean Climate (UNFCCC) to designate the plant as a Clean Development Mechanism project (PHPA, 2013). Financial costs and benefits that appear in these reports are adjusted to better reflect their true opportunity costs; these adjustments are discussed more thoroughly in the following section. Assumptions for other costs, benefits, and parameters not discussed in these reports are made using resources from the World Bank and Asian Development Bank (ADB), as well as the literature on similar hydropower projects in other developing countries.

#### **a. Summary of Cost Categories**

Borrowing from the typology of Jeuland and Whittington (2013), the costs included in the analyses are as follows: (i) the capital investment in the projects, (ii) the operations and maintenance (O&M) costs for the projects, (iii) the opportunity cost of project land, (iv) the cost of resettling displaced households, and (v) the cost of catastrophic risk.

##### *i. Capital Investment*

According to the global cost analysis of the International Renewable Energy Agency (IRENA) (2012), hydropower projects are capital intensive, with most of the investment generally earmarked for civil works and electrical and mechanical (E&M) equipment. IRENA includes both development costs and the costs of any infrastructure needed to access the site in its civil works category. This category also includes construction of any dam and reservoir, tunnels and canals, powerhouse and any other engineering, procurement and construction (EPC), as well as the cost of connecting the project to the grid.

Costs related to civil works can vary widely from one site to another due to variations in project location, size, and localized differences in hydrology, geology and topography. Projects

located in remote sites often incur higher costs due to the need for more connecting infrastructure and transmission lines. The cost of E&M equipment, which includes turbines, generators, valves, controllers, and hydraulic steel structures, varies less from site to site because this equipment is purchased on the international market at similar prices (IFC, 2015).

Hydropower projects frequently experience cost overruns and delays (IFC, 2015). The WCD's study of 99 large hydropower projects (2000) found that only half were completed on time. Delays ranged from one to two years for 30 percent of projects, three to six years for 15 percent of projects and over ten years for the remaining 5 percent. The same WCD report analyzed 88 projects for cost overruns and found that 75 percent of projects were completed over budget. The average cost overrun was 56 percent but went as high as 180 percent—although cost overruns were more frequent and higher in magnitude for multi-purpose projects.

Despite this high upfront capital investment, hydropower projects are attractive because of their long operating lifespans relative to other energy sources. According to the IFC (2015), both economic and financial analyses of hydropower projects typically assume a 30 to 40 year lifespan. However, IRENA (2012) notes that projects can last anywhere from 30 to 80 years, if the E&M equipment is regularly upgraded.

Arun III: According to its developer, Arun III requires capital investment of \$702 million and is scheduled to take five years to complete (SJVN Limited, 2016). However, the model considers a range of five to ten years for completion, given the propensity of large hydropower projects to experience delays. For simplicity, capital costs are distributed evenly across the construction schedule, and these costs have been adjusted to remove taxes, tariffs, interest, and contingencies to better reflect the true economic capital costs of the project. Total capital investment was allowed a range of 100 to 150 percent for sensitivity analysis to account for the potential for cost overruns. SJVN Limited (2016) assumes a lifespan of 50 years for the project's civil works and 35 years for E&M equipment. For purposes of this analysis, a lifespan of 40 years (range of 30 to 50 years) is assumed for Arun III.

Besides the capital investment required to construct Arun III, the project also requires investment in transmission infrastructure to carry the electricity from Nepal to India. The proposed Dhalkebar-Muazaffarpur 400kV DC transmission line has a 1000 MW capacity and requires an estimated investment of \$186 million, according to ADB (Wijayatunga et al., 2015). The inputs that went into this cost estimate are not outlined, and therefore, a 100 to 120 percent range is used for sensitivity analysis.

Puna I: The agreement reached between the Governments of Bhutan and India to construct Puna I required an initial capital investment of \$673 million and was scheduled to take seven years to construct (PHPA, 2013). Knowing in hindsight that Puna I has already experienced four years of delays and cost overruns, the model considers a range of seven to fourteen years. Capital costs are again distributed evenly across the construction schedule for simplicity. Like the model above, total capital investment is allowed a range of 100 to 150 percent for sensitivity analysis. Again, a lifespan of 40 years is assumed for Puna I (range of 30 to 50 years).

Puna I also requires a significant investment in transmission infrastructure to carry electricity from Bhutan to load centers in India. In its report to UNFCCC (2013), the project company includes \$148 million earmarked for the Lhamoizingkha-Alipurduar 400 kV DC transmission line, which has a 2100 MW capacity—double the capacity required for Puna I. This potential foresight in transmission needs is due to Bhutan’s desire to eventually build another dam on the Punatsangchhu River. However, total transmission costs are included in this analysis because the full investment will be made before the second dam even breaks ground. Like the model above, a 100 to 120 percent range is used for sensitivity analysis.

Shadow Price of Capital: Another consideration for both projects is whether to use a shadow price to calculate a more accurate opportunity cost of the capital investment (Whittington et al., 2004). Given the development needs of the region, there is a high opportunity cost associated with the capital invested in hydropower projects because governments and private investors are foregoing a wide range of other development projects to pursue hydropower. However, the literature does not directly provide an appropriate shadow price of capital for Nepal or Bhutan. Acknowledging that estimating a shadow price of capital is highly subjective, the model applies a multiplier for the shadow price of capital of 2 (range of 1 to 2) to the capital investment and transmission costs for each analysis, based on the estimate of Whittington et al. (2004).

*ii. Operations and Maintenance (O&M)*

O&M costs accrue annually over the lifetime of commissioned hydropower plants and are essential to ensure the most efficient production of electricity. Both the civil works components of the project and the E&M equipment involve O&M costs. Expenditures include the general upkeep costs of maintaining the plant, such as fencing, access roads, and administrative buildings, ongoing preventative maintenance, and the cost of stocking spare parts for planned rehabilitation or unforeseen replacement of E&M equipment (IFC, 2015). Salaries of permanent employees needed to manage and maintain the plant are also included in O&M costs. Annual O&M costs are usually estimated as a percentage of total capital investment and range from 1 to 4 percent of total capital investment costs, while the value of spare parts in stock for E&M replacements is about 2.5 to 3 percent of the E&M component of the capital investment (IFC, 2015; IRENA, 2012).

Arun III: Annual O&M costs for Arun III are estimated to be 2.5 percent of total capital investment, with an additional 15 percent of annual O&M costs allocated for maintenance spares (SJVN Limited, 2016). This works out to be about 3 percent (range of 2 to 4 percent) of total capital investment. In addition, O&M costs are assumed to escalate by 4 percent annually (range of 2 to 6 percent) to account for the reality that as the plant ages, it will cost more to operate and maintain.

Puna I: Annual O&M costs for Puna I are estimated to be 1.5 percent of total capital investment, with an additional 1 percent of total capital investment allocated for maintenance spares (PHPA, 2013). Therefore, 2.5 percent (range of 2 to 4 percent) will be used as the base case O&M cost for this analysis. O&M costs are again assumed to escalate by 4 percent annually (range of 2 to 6 percent).

### *iii. The Opportunity Cost of Project Land*

Large hydropower projects require the acquisition of varying sized tracts of land to construct the reservoir, transmission lines, quarries, and access roads. Especially in rural areas, this leads to changes in land use and a potential loss of agricultural or forestry production. The opportunity cost of land is based on this lost production. The land requirement for run-of-river projects is low relative to similarly sized multi-purpose projects that involve large dams or reservoirs.

Arun III: Arun III requires 180.32 hectares of land, according to SJVN Limited (2016). The developer estimated the value of this land and divided it into five categories based on its current use—sloping agriculture, paddy fields, cardamom fields, small farmland, or residential land. The estimated land cost for the Arun III site is \$6.25 million. This estimate makes for a good initial proxy for the opportunity cost of the land required for Arun III and represents the opportunity cost of land in the base case scenario. For the purposes of this analysis, it is assumed that the opportunity cost of land will range from \$6.25 million to \$12.5 million.

Puna I: Puna I requires 542.48 hectares of land, according to a report from the World Bank Group (2016). 117.9 hectares has been acquired from private landholders, while the remainder is assumed to come from government reserve forest. Despite being roughly three times the land requirement of the Nepal project, the estimated land cost for the Puna I site is \$3.25 million. Since much of the land acquired for this project came from government-owned forests, it is assumed that the land cost estimate probably does not reflect the true economic value of forestry products in Bhutan. For the purposes of this analysis, it is assumed that the opportunity cost of land is \$3.25 million in the base case scenario. The opportunity cost of land will now range from \$3.25 to the same upper bound of \$12.5 million used in the other model.

### *iv. The Resettlement of Displaced Households*

Along with lost agriculture and forestry production, large hydropower projects can cause the displacement of people, ranging from a few households to entire communities. This displacement is often the most severe social impact of hydropower projects (IFC, 2015). Furthermore, the rural nature of both Arun III and Puna I means the forced relocation of people who are likely already marginalized.

Arun III: Arun III requires the resettlement of 391 (range of 300 to 500) displaced households (Pangeni, 2016). The cost to resettle each displaced household is assumed to be 10 (range of 5 to 15) times the average GDP per capita in Nepal in 2015 (\$743.33). This equation is adopted from Jeuland and Whittington (2013) and is based on Cernea's (1999) research into the economics of involuntary resettlement.

Puna I: Puna I requires the resettlement of 90 (range of 70 to 110) displaced households and speaks to Bhutan's sparse population relative to Nepal ('Displaced families disappointed,' 2009). The cost to resettle each displaced household is again assumed to be 10 (range of 5 to 15) times the average GDP per capita in Bhutan in 2006 (\$1,348.73).

v. *Catastrophic Risk*

Nepal and Bhutan are prone to natural disasters due to their location in the Himalayas. Some of the disasters that can affect an ongoing hydropower project or commissioned plant include earthquakes, landslides, flash floods, glacial lake outburst floods (GLOF), and drought (Delinic and Pandey, 2012). To quantify catastrophic risk, this analysis uses the methodology of Jeuland and Whittington (2013). The risk is included as an expected cost and is calculated by multiplying the probability of a catastrophic failure in any given year by the sum of the cost of rebuilding the project and the benefits that would be lost while the project is being rebuilt.

Arun III: No clear estimate of the probability of catastrophic risk in Nepal exists in the literature—unsurprisingly, given how difficult this risk is to predict. Whittington (2004) approximates an economic cost from the risk of earthquakes in any given year with a probability of 0.1 percent, or one in every 1000 dam-years. This seems to be a low estimation given Nepal’s more recent history. A probability of 0.2 percent (range of 0.1 to 0.3 percent) is used instead.

Puna I: Like Nepal, no clear estimate of the probability of catastrophic risk in Bhutan exists in the literature either. While it does sit in a seismic zone, Bhutan’s history lacks evidence of major earthquakes compared to Nepal. However, the project is sited in an area of high risk for GLOF, with 25 lakes considered dangerous located in close proximity (PHPA, 2013). Therefore, the risk of catastrophic failure in any given year is given as a probability of 0.1 percent. A range of 0.05 to 0.15 percent is used for sensitivity analysis in this model.

**b. Summary of Benefit Categories**

Again basing off the typology of Jeuland and Whittington (2013), the benefits included in the analysis are (i) hydropower generation and (ii) carbon offsets.

*i. Hydropower Generation*

The generation of power is unsurprisingly the principal economic benefit of Arun III and Puna I. The calculation of the projects’ benefits, therefore, flows primarily from the economic value of this generated power (Jeuland and Whittington, 2013). This value is calculated by deriving the amount of power generated by each project and the per unit value of the power.

Much of the generated power from these two projects will be exported to power-hungry India. Specifically, it will end up in the eastern grid of India, where demand currently exceeds supply (SJVN Limited, 2016). Therefore, this analysis assumes that all the output of these projects will be utilized to meet unmet electricity demand. It is also likely that the new power plants that would be constructed to meet demand if the hydropower projects were not built would be based on fossil fuels (PHPA, 2013). The analysis thus also assumes that the projects will replace an equivalent amount of carbon-based fuels that otherwise would have been used to meet this demand.

Electricity prices are set below their true market value in Nepal, Bhutan, and India despite the imbalance between supply and demand. For this analysis, a shadow price of electricity is used to estimate the market-clearing prices of electricity in the region. The shadow price of electricity was developed for each individual country in South Asia using econometric techniques by Carlin and Schaffer (2012) from 2009 World Bank enterprise survey data. These surveys specifically looked at World Bank “Doing Business” indicators, so are based on business owners’ willingness to pay for electricity. Since both Nepal and India have more urban-based economies than Bhutan, it is assumed that these shadow prices are on the higher side for Nepal and India and on the lower side for Bhutan. Therefore, they are used as the upper bound of the range for sensitivity analysis for Nepal and India and the lower bound of the range for Bhutan.

Finally, the capacity factor must be determined for each project in order to calculate the amount of power it generates. Based on an analysis of CDM hydropower projects, IRENA (2012) calculated an average capacity factor of 50 percent. This amount is just slightly below the estimates projected by the respective project developers, which is likely based on a slightly optimistic scenario.

Arun III: For simplicity, 900 MW Arun III is assumed to have a capacity factor of 50 percent (range of 40 to 60 percent) and will generate about 3650 GWh for export in the base case scenario after transmission losses of 7.5 percent (range of 5 to 10 percent). Of this 3650 GWh, 78 percent will go to India and the other 22 percent will remain in Nepal (SJVN Limited, 2016).

The three-year average electricity price in Nepal is \$0.1157/kWh (Arlet, 2017) and is based on tariffs set by the Nepal Electricity Authority. The multiplier used to calculate the shadow price of electricity is 2.74 for Nepal and will represent the upper bound multiplier. The lower bound multiplier is 1, while the base case multiplier falls in the middle at 1.87.

The three-year average electricity price in India, set by a regulatory body, is \$0.187/kWh (Arlet, 2017). The multiplier for the shadow price of electricity is 1.75 for India and will also represent the upper bound multiplier for the sensitivity analysis. The lower bound multiplier is 1 and a 1.375 multiplier is used for the base case scenario.

Puna I: 1095 MW Puna I is assumed to have a capacity factor of 50 percent (range of 40 to 60 percent) and will generate about 4450 GWh after transmission losses of 7.5 percent (range of 5 to 10 percent) for export in the base case scenario. In this instance, 84 percent of the 4450 GWh will go to India and the other 16 percent will remain in Bhutan (PHPA, 2013).

Electricity prices in Bhutan are low relative to Nepal and India. The three-year average electricity price in Bhutan is \$0.051/kWh and is based on tariffs set by the Bhutan Electricity Authority (Arlet, 2017). The multiplier used to calculate the shadow price of electricity is 0.84 for Bhutan and will represent the lower bound multiplier. The multiplier could be less than 1 in Bhutan for several reasons. The shadow price is based on willingness to pay for electricity and highly subsidized pricing, combined with relatively high rural electrification, translates to a low willingness to pay for most people. Bhutan’s strong transmission and distribution networks also mean the country does not suffer from frequent outages. People in Nepal and India are willing to pay more for reliability; this same impetus is not present in Bhutan. Finally, the fact that

hydropower already produces enough electricity to meet the economy's current needs make it less of a prerequisite to growth as it is in Nepal and India. In this analysis, the upper bound multiplier is 1 and a .94 multiplier is used for the base case scenario.

## *ii. Carbon Offsets*

In these analyses, carbon offsets appear as a function of the size of the plant, the expected reduction in GHG emissions, and the social cost of carbon.

The expected reduction in GHG emissions is an estimate of the power generated by a commissioned hydropower plant that will displace an equivalent amount of electricity that otherwise would have been provided by a fossil fuel-based plant. It is calculated by multiplying the plant's net power generation by its emission factor, which is estimated at 0.78213 kgCO<sub>2</sub>e/kWh for hydropower projects in Asia (U.K. DECC and DEFRA, 2012). This estimate is used for both analyses (range of 0.78213 to 1.4226 kgCO<sub>2</sub>e/kWh).

The social cost of carbon is defined by ADB (2013b) as “the calculated price of carbon emissions that will balance the incremental costs of reducing carbon emissions with the incremental benefits of reducing climate damages.” According to the International Panel on Climate Change, \$36.30 per ton of CO<sub>2</sub> or its equivalent should be used for social cost of carbon, and this value should be increased by 2 percent annually to account for growing potential marginal damage due to climate change over time (ADB, 2017). Based on this guidance, \$36.30 (range of \$18.15 to \$54.45) is used as the base case social cost of carbon for both analyses, which can increase in value over time by 2 percent (range of 1.5 to 2.5 percent).

## **c. Omitted Cost and Benefit Categories**

There are several potential costs and benefits omitted from these analyses—either because their magnitude is insignificant for run-of-river hydropower projects or because quantifying and monetizing their values would require research and modeling tools that are outside the scope of this paper. However, their inclusion would make for a more complete cost-benefit analysis. The cost and benefit categories omitted from the analysis include the following: (i) downstream impacts, including flood control benefits, (ii) costs of damage to the environment, including loss of endangered species' habitat, (iii) implications for recreation, navigation, and fisheries, (iv) the spillover benefits of increased electrification, and (v) GHG emissions due to construction.

### *i. Downstream Costs and Benefits*

Hydropower projects can be constructed solely to produce electricity or for multiple purposes. Multi-purpose projects often involve a large dam or reservoir while run-of-river projects like Arun III and Puna I are primarily used for power generation. These projects have fewer environmental and social impacts relative to multi-purpose projects because they require less land. As a result, run-of-river projects have lower costs, but also accrue fewer benefits relative to multi-purpose projects, particularly as it relates to downstream impacts. For instance, multi-purpose projects can be used to control floods by storing flood waters in a reservoir and then releasing the water over time. The reservoirs can also be used to supply water for

agriculture and drinking. However, because these benefits are less relevant to run-of-river projects, they were not included in this analysis and are generally not cited by developers in project documents for Arun III and Puna I.

*ii. The Cost of Environmental Damage*

Large hydropower projects can have a variety of environmental impacts, although run-of-river projects are generally less damaging to the surrounding ecosystem than multi-purpose projects. Clearing land to make way for the project and interrupting the normal flow of the river change the habitat of terrestrial and aquatic species, usually to the detriment of the species (IFC, 2015). Concerns about wildlife impacts are especially acute when the project touches the habitat of an endangered species.

As discussed above, the run-of-river nature of Arun III and Puna I means that less land is required relative to what would be needed if they were multi-purpose projects. However, these projects will still have impacts on the unique flora and fauna of the Himalayan region. For instance, Puna I may push the endangered white-bellied heron into a smaller, shared habitat with its predators and potentially alter the migratory patterns of the golden mahseer (Premkumar, 2016; World Bank Group, 2016). Negative impacts to the golden mahseer are particularly concerning, as Bhutan remains one of the last refuges of the fish, which has symbolic associations with the country's Buddhist population (Gyelmo, 2016). More research about project impact, coupled with surveys meant to devise an existence value of these endangered species, is needed before this category is added to the analysis—although, admittedly, these costs are likely not significant enough to alter the outcome of the cost-benefit analysis.

*iii. Potential Costs and Benefits to Recreation and Fisheries Industries*

Proponents of large, multi-purpose hydropower often promote the recreation, navigation, and fisheries benefits of these projects (IFC, 2015). These benefits, however, are usually tied to the creation of a large dam or reservoir and are thus less relevant for run-of-river projects. No data exists that could be used to estimate how large of an effect, good or bad, run-of-river projects have on recreation, navigation, and fisheries in Nepal and Bhutan. However, the ability to use the relevant river for recreating, navigating, or fishing will likely be curtailed in some way by the interruption to the natural river's flow. Whitewater rafting, for instance, is a major recreation experience for tourists in both countries and may be impacted. The implications of the projects on recreation, navigation, and fisheries is not included in the analysis due to lack of data, but is worthy of further investigation.

*iv. Spillover Benefits of Increased Rural Electrification*

A key benefit of the projects—reflected in the analyses—is the generated power. This power increases electrification rates in Bhutan, Nepal, India, which in turn creates economic opportunity and increased development of the region. In fact, access to electricity is often viewed as a condition to economic growth, by creating education, health, environment, and time use benefits (Anderson et al., 2012). The projects can also create local jobs and lead to the construction of infrastructure that increases access to schools and hospitals (IFC, 2015). These



benefits were not included in the analyses due to the difficulty of quantifying these spillover benefits and isolating the hydropower project as the precise source of the benefits.

v. *Cost of GHG Emissions due to Project Construction*

Critics of hydropower often argue that it creates GHG emissions and should, therefore, not be considered a “renewable” form of energy. In reality, the GHG emissions associated with run-of-river projects like Arun III and Puna I are minimal. GHG emissions during the construction of hydropower plants are primarily associated with the clearing of forests, which are natural carbon sinks (IFC, 2015). Bhutan’s policy requiring developers to plant two acres for every acre of forest that is cut down, combined with the minimal land required for either project, means these costs were too minimal to merit inclusion.

2. Estimating the Discount Rate

A discount rate must be selected before the cost-benefit analysis can be conducted. The discount rate allows for the comparison of future benefits and costs with benefits and costs from earlier time periods. The challenge is deciding on an appropriate discount rate that best captures either the opportunity cost of capital or the social rate of time preference (Whittington et al., 2004). ADB (2013b) recommends applying a discount rate between 8 and 15 percent for projects in developing countries. This figure reflects the estimated opportunity cost of capital in these countries, which is high given the multitude of other development needs. However, this higher rate might understate the future benefits of the hydropower projects and make these investments unattractive relative to other development opportunities. Since a shadow price of capital is being used to estimate the opportunity cost of capital for both projects, it might be more appropriate to use the social rate of time preference as the discount rate (Whittington et al., 2004). This analysis will use 4 percent as the base case discount rate, with a sensitivity analysis range of 2 to 6 percent, as used by Jeuland and Whittington (2013).

3. Data and Modeling Approach

As discussed throughout the sections above, the analysis for each project assumes values for the included parameters related to costs and benefits. Table 2 sets forth a comprehensive list of these parameter assumptions.

**Table 2: Parameter Assumptions for Costs and Benefits (uncertainty ranges in brackets)**

Description	Symbol	Puna I (Bhutan) Parameter Value		Arun III (Nepal) Parameter Value	
<i>General Parameters</i>					
Base Year		2006		2015	
Installed Capacity (MW)	$MW$	1095		900	
Economic Lifespan of the Plant (Yrs)	$t$	40	[30-50]	40	[30-50]
Discount Rate (%)	$r$	4	[2-6]	4	[2-6]
<i>Cost Parameters</i>					
Capital Cost of Plant Investment (millions of USD)	$c^{plant}$	673	[673-1,009]	702	[702-1,053]
Capital Cost of Transmission Infrastructure (millions of USD)	$c^{transmission}$	148	[148-222]	186	[186-279]
Shadow Price of Capital (multiplier)	$c^{shadow}$	2	[1-2]	2	[1-2]
Plant Construction Time (Yrs)	$t^c$	7	[7-14]	5	[5-10]
O&M Expenditures (% of Capital Costs)	$c^{o\&m}$	2.5	[2-4]	3	[2-4]
Change in Value of O&M per Year (%)	$\Delta c^{o\&m}$	4	[2-6]	4	[2-6]
Opportunity Cost of Land (millions of USD)	$c^{land}$	3.25	[3.25-12.5]	6.25	[6.25-12.5]
Number of Displaced Households	$n$	90	[70-110]	391	[300-500]
Economic Loss per Displaced Household (USD)	$c^{resettlement\ hh}$	13,487	[6,743-20,230]	7,433	[3,716-11,149]
Risk of Catastrophic Failure (%)	$\mu$	0.1	[0.05-0.15]	0.2	[0.1-0.3]
<i>Benefit Parameters</i>					
Hydropower Generation to India (GWh)	$h^{India}$	3726	[See Equation]	2844	[See Equation]
Value of Power to India (USD/kWh)	$v^{India}$	0.19	[0.15-0.22]	0.19	[0.15-0.22]
Shadow Price of Electricity for India (multiplier)	$s^{India}$	1.38	[1-1.75]	1.38	[1-1.75]
Hydropower Generation to Host Country (GWh)	$h^{host}$	709	[See Equation]	802	[See Equation]
Value of Power to Host Country (USD/kWh)	$v^{host}$	0.05	[0.04-0.06]	0.12	[0.09-0.14]
Shadow Price of Electricity for Host Country (multiplier)	$s^{host}$	0.92	[0.84-1]	1.87	[1-2.74]
Price of Carbon Offsets (USD/ton CO <sub>2</sub> )	$v^{offsets}$	36.30	[18.15-54.45]	36.30	[18.15-54.45]
Carbon Emissions Factor (kg/CO <sub>2</sub> E/kWh)	$\varepsilon$	0.78	[0.78-1.42]	0.78	[0.78-1.42]
Change in Value of Offsets per Year (%)	$\Delta v^{offsets}$	2	[1.5-2.5]	2	[1.5-2.5]
<i>Electricity Parameters</i>					
Capacity Factor (%)	$p^{CF}$	50	[40-60]	50	[40-60]
Hours per Year	$p^{hrs/yr}$	8760		8760	
MWh to GWh Converter	$\eta$	0.001		0.001	
Transmission Losses (%)	$p^{losses}$	7.5	[5-10]	7.5	[5-10]
Proportion of Energy to India (%)	$p^{India}$	0.84		0.78	
Proportion of Energy to Host Country (%)	$p^{host}$	0.16		0.22	

Making inherently subjective assumptions about base case costs, benefits, and project parameters from mixed data sources adds a layer of uncertainty to the evaluations of these projects. For this reason, Monte Carlo simulations are used to illustrate how sensitive the NPV calculations are to a range of input values, as done by Whittington et al. (2004). The results can thus help determine the extent to which Arun III or Puna I would still have a positive NPV or negative NPV in spite of uncertain assumptions. The results of the Monte Carlo simulations, which run 10,000 trials, can also provide insight into which assumptions or parameters have the most influence over the NPV of each hydropower project.

#### 4. Calculation of the Net Benefits

The equations used to calculate the net benefits of Arun III and Puna I are set forth in Table 3. These equations are based on those developed by Jeuland and Whittington (2013), adjusted where necessary to accommodate the run-of-river nature of the projects.

**Table 3: Equations for Cost-Benefit Analyses of Arun III and Punatsangchhu I**

Description	Equation
<i>Discounting Factor in year t</i>	$\delta = 1/(1-r)^{t-1}$ for $t = 1, \dots, t$
<i>Energy Calculations</i>	
Total Hydropower Generated (GWh)	$H^{total} = MW \cdot p^{CF} \cdot p^{hrs/yr} \cdot \eta$
Total Transmission Losses (GWh)	$H^{transmission\ losses} = H^{Total} \cdot p^{losses}$
Net Energy for Export	$H^{exports} = H^{total} - H^{transmission\ losses}$
Net Gain in Hydropower in Host Country (GWh)	$H^{host} = H^{exports} \cdot p^{host}$
Net Gain in Hydropower in India (GWh)	$H^{India} = H^{exports} \cdot p^{India}$
<i>Benefits</i>	
Total Value of Hydropower (millions of USD in year t)	$V^{hydro}_t = (h^{India} \cdot \nu^{India} \cdot s^{India}) + (h^{host} \cdot \nu^{host} \cdot s^{host})$ , after commissioning
Value of Carbon Offsets (millions of USD in year t)	$V^{carbon}_t = H^{exports} \cdot \nu^{offsets} \cdot \varepsilon \cdot (1 + \Delta \nu^{offsets})^{t-1} / 10^3$ , after commissioning
<i>Total Benefits</i>	$B = \sum_t [\delta_t \cdot (V^{hydro}_t + V^{carbon}_t)]$
<i>Costs</i>	
Capital Cost (millions of USD in year t)	$C^{capital} = (c^{plant} + c^{transmission} + c^{shadow}) / t^c$
Opportunity Cost of Land (millions of USD)	$C^{land} = c^{land}$ , if $t^c = 1$
Resettlement and Economic Rehabilitation (millions of USD)	$C^{resettlement} = C^{resettlement\ hh} \cdot n$ , if $t^c = 1$
Operations and Maintenance Cost (millions of USD in year t)	$C^{O\&M} = c^{o\&m} \cdot (c^{plant} + c^{transmission} + c^{shadow}) \cdot (1 + \Delta c^{o\&m})^{t-1}$ , after commissioning
Cost of Catastrophic Risk (millions of USD in year t)	$C^{failure}_t = \mu \cdot (Cost\ of\ Reconstruction + Lost\ Benefits\ during\ Reconstruction)$ , after commissioning
<i>Total Costs</i>	$C = \sum_t [\delta_t \cdot (C^{capital} + C^{land} + C^{resettlement} + C^{O\&M} + C^{failure}_t)]$

## B. Results

### 1. Base Case Scenario

Table 4 shows the results of the base case scenario cost-benefit analyses for Puna I and Arun III. Panel A displays the values associated with each cost category, while Panel B displays

the values associated with each benefit category. Panel C reflects the net benefits from a regional perspective in the base case scenario using millions of U.S. dollars as the unit of analysis.

Both projects have a positive NPV at a 4% discount rate. Despite differences in several of their parameters values, these two projects coincidentally produce quite similar net benefits to the region. The two projects also have a very similar economic internal rate of return (EIRR), which represents the discount rate at which the NPV of net benefits would be equal to zero (Boardman et al., 2010).

The benefits are largely due to the value of the hydropower produced. The value of the carbon offsets is significant, especially compared to a model that uses a higher discount rate. This result is unsurprising given that climate economists argue for a low discount rate to accurately account for the future harms of climate change.

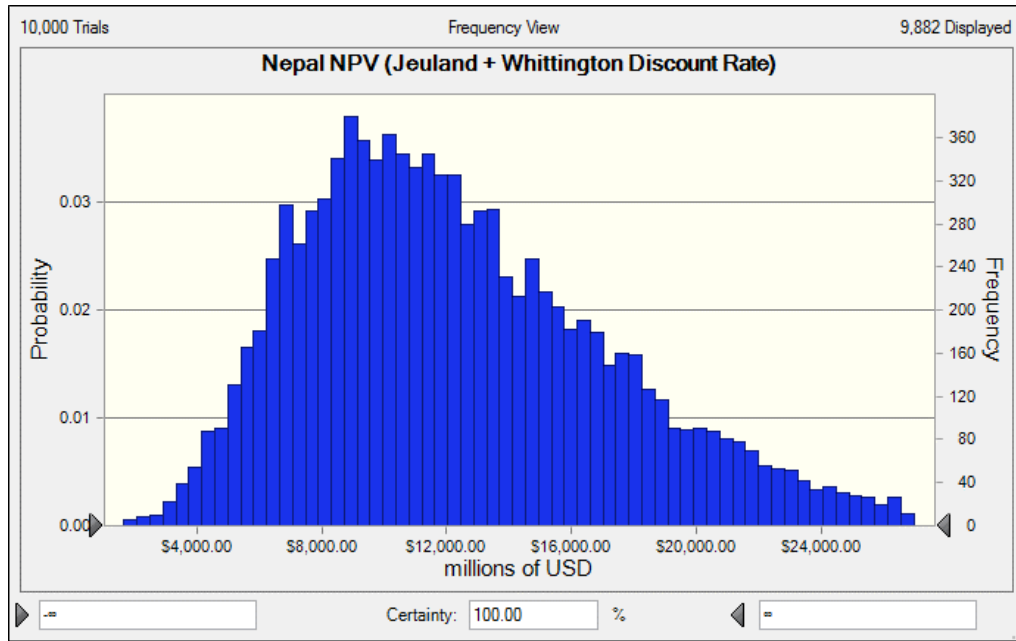
**Table 4: Results of Cost-Benefit Analyses of Puna I and Arun III (Base Case Scenario)**

	<b>Punatsangchhu I – Bhutan</b>	<b>Arun III - Nepal</b>
<i>Discount Rate</i>	4%	4%
<i>Panel A: Costs (millions of USD)</i>		
Capital Investment	\$1,353.76	\$1,521.58
O&M Costs	\$1,153.65	\$1,620.72
Opportunity Cost of Land	\$3.13	\$6.01
Resettlement and Economic Rehabilitation	\$1.17	\$2.79
Cost of Catastrophic Risk	\$120.73	\$194.05
<i>Panel B: Benefits (millions of USD)</i>		
Total Value of Hydropower	\$14,339.44	\$14,154.37
Value of Carbon Offsets	\$2,485.33	\$2,173.53
<i>Panel C: Net Benefits</i>		
<b>Total Costs</b>	\$2,632.43	\$3,345.15
<b>Total Benefits</b>	\$16,824.78	\$16,327.90
<b>Net Benefits</b>	<b>\$14,192.34</b>	<b>\$12,982.74</b>
<b>EIRR</b>	<b>27.69%</b>	<b>29.34%</b>

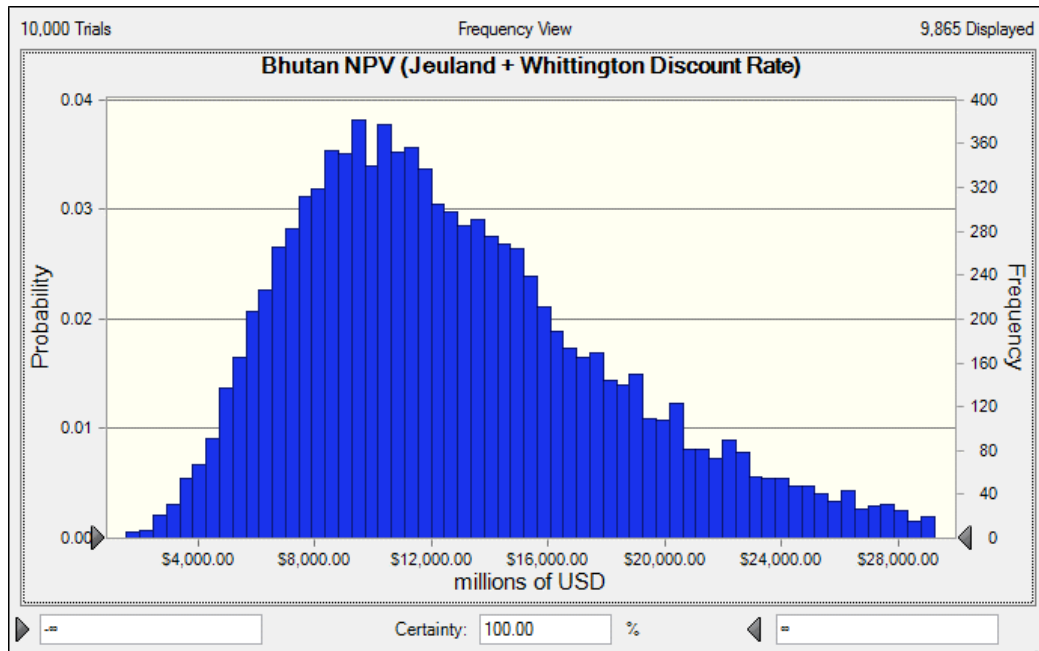
## 2. Variations in Net Benefits

The results of the Monte Carlo simulations shed light on how the projects' NPVs are affected by the various parameters and assumptions. This exercise is particularly important given the reliance on capital costs set forth by project developers in approval documents, which may be slightly underestimated. Figures 1 and 2 show that the results for both projects are largely positive within the given range of discount rates. The mean NPV for Arun III was \$12.47 billion, while the mean NPV for Puna I was \$12.99 billion.

**Figure 1: Variation in Net Benefits of Arun III (4% Discount Rate)**



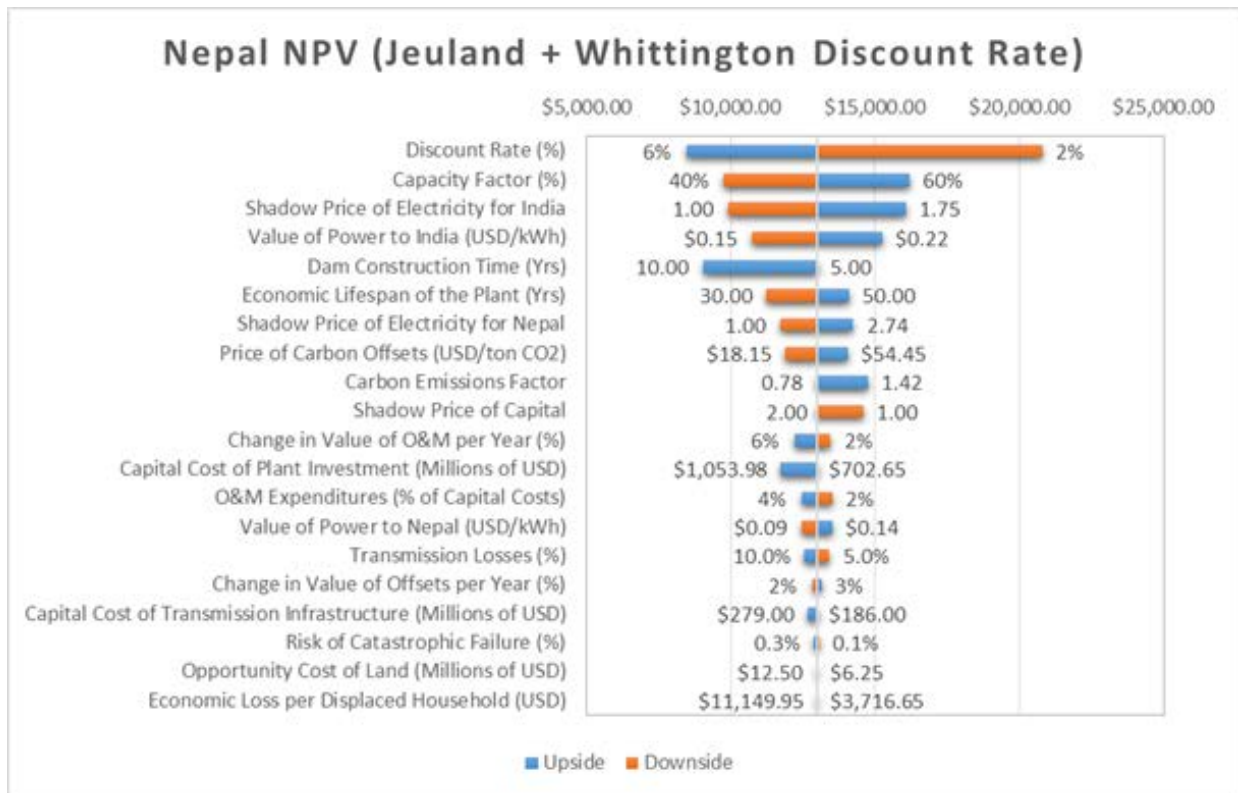
**Figure 2: Variation in Net Benefits of Puna 1 (4% Discount Rate)**



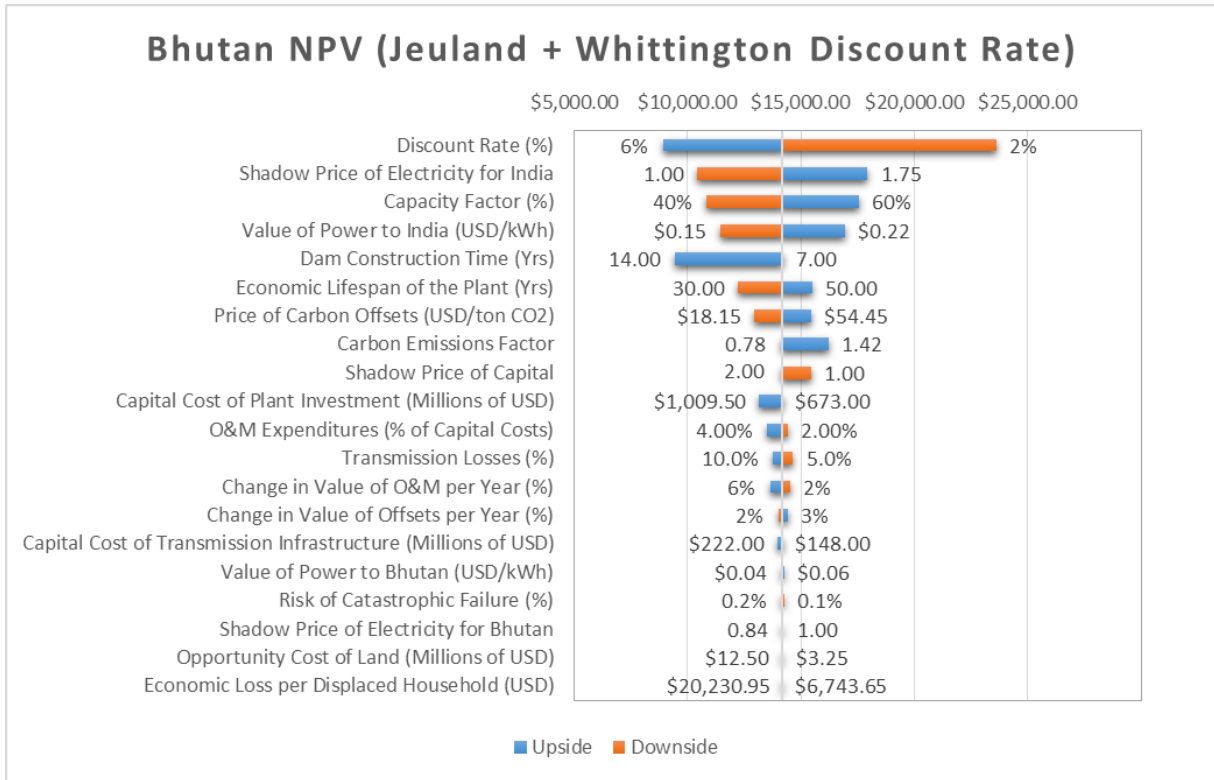
### 3. Influential Parameters on Net Benefits

Figures 3 and 4 show the factors that have the most impact on NPV for each project. For Arun III (Figure 3), both discount rate and capacity factor are among the most important factors, while the shadow price of electricity in India and dam construction time also have influence. The NPV of Puna I (Figure 4) is most sensitive to discount rate and the shadow price of electricity in India, while capacity factor and dam construction time also influence the NPV of this project. So, these same four factors have the largest impact on NPV across projects, with the discount rate clearly having the most power to sway the results of both projects.

**Figure 3: Net Benefits of Arun III (4% Discount Rate)**



**Figure 4: Net Benefits of Puna I (4% Discount Rate)**



## VI. Discussion and Policy Implications

The results of the cost-benefit analyses show that these projects fit squarely within the current framing of hydropower on the international stage. In spite of social and environmental costs, hydropower projects produce energy desperately needed in developing regions like South Asia—without increasing emissions. Run-of-river projects, in particular, impose fewer costs and are thus particularly attractive options from an economic perspective.

In short, at the heart of Bhutan’s and Nepal’s pursuit of hydropower is its ability to address energy poverty amidst growing concerns about climate change internationally. This reality means that Bhutan and Nepal are likely to continue the pursuit of these projects for the foreseeable future. As a result, people who are concerned about the social and environmental costs of projects may be more successful in arguing for stronger safeguards for projects rather than a complete halt in their development. The literature highlights the need in both countries for stronger capabilities with respect to enforcement of social and environmental protections. If hydropower is likely to continue in this region, it is a worthwhile endeavor to strengthen the institutions tasked with this enforcement.

Although there is a risk of reading too much into a comparison between only one project in each of Bhutan and Nepal, it is nonetheless interesting to consider whether there might be a fundamental economic difference between projects in the two countries. As expected, Nepal’s higher population density translated into a higher opportunity cost of land and higher

resettlement costs. Nepal's recent history of earthquakes also means it requires a higher value to account for catastrophic risk. However, these increased costs for Nepal are still dwarfed by the overall benefits—the economic value of clean energy for an area that has not been fully electrified.

Thus, the juxtaposition of the two analyses suggests that the political realities and discourse around hydropower in these two countries—and their relationships with India—have been a critical driver for pursuing projects. A number of political factors are conducive to hydropower development in Bhutan and likely contribute to why it has surged past development in Nepal. It has a stronger centralized government that is generally more orientated toward considering the well-being of the nation as a whole, which favors development where local costs are outweighed by national benefits. After years of stability, the literature suggests that there is considerable trust in the decisions of the government and a less robust tradition of challenging government decisions. Finally, the industry in Bhutan has enjoyed a favored position among policymakers, who articulate it as the key to national success in a variety of policy documents.

Nepal, on the other hand, has faced political realities that likely stunted hydropower development. Divisive politics in Nepal, rooted in a long civil war, mean that a project may become a pawn in the power struggle between political parties and forever be subject to uncertainty. A project's inevitable ties to India also make it an easy target for derision, given the political sensitivity of overreliance on their large neighbor.

A second consideration that could contribute to the difference in hydropower development between Nepal and Bhutan is differences in the shadow price of capital. Although the analyses of the two projects assumed the same shadow price of capital, estimating this figure is highly subjective and was difficult to do in the absence of country-specific literature on this point. However, if Nepal has a higher shadow price of capital than Bhutan, it would diminish the net benefits of projects. A lower shadow price of capital in Bhutan could be attributable to its status as a more developed country and less competition for government and private sector expenditures. The Nepali government, on the other hand, may have a wider range of development needs to fulfill, particularly as the country rebuilds after years of civil war and two major earthquakes.

This reality makes Nepal almost entirely reliant on the Indian private sector as a source of the initial capital investment. Hence, the country's perceived instability and at times sour relationship with India may be particularly significant to the stunting of industry growth. It also means that in some ways, Nepal must compete with Bhutan over this source of capital—a difficult proposition given the relative strength of Bhutan's institutional capacity in hydropower development.

However, this conclusion also suggests a path forward for Nepal—one that it may have already caught onto with Arun III and one that differentiates it from Bhutan. The initial capital investment for Arun III is put forth by the Indian developer. That developer will own the project for a set time period, directly receive payments for power produced during that period, and then transfer the project to the Nepali government. In addition to addressing the high shadow price of



capital for government expenditures, this structure also transfers the risks of cost overruns to the developer.

In a similar vein, Bhutan may consider transitioning to a project structure that relies less on government investment and more on the private sector. The Bhutanese government's practice of directly funding projects with loans and grants from India means that it is increasingly taking on large amounts of debt, as well as the risk of increased costs. Transitioning to a model similar to the one deployed for Arun III could free up government revenue for other development projects designed to address the country's growing unemployment problem.

In conclusion, hydropower development will likely continue in both Bhutan and Nepal, as these projects have the potential to bring substantial net benefits for the region. Thus, there will be a need for strong institutions capable of enforcing robust social and environmental safeguards in both countries. As Nepal addresses the political factors that may have previously slowed hydropower growth, it can continue to attract private investment in the industry, rather than directly invest in development itself. Such a structure may also work in Bhutan, as a way of addressing current financial barriers to further development.

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