Developing Nepal's Hydroelectric Resources: Policy Alternatives

Madeline Bergner

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List of Acronyms

ADB	Asian Development Bank
AEPC	Alternative Energy Promotion Centre
AEPB	Alternative Energy Promotion Board (to supersede AEPC)
CPN-M	Communist Party of Nepal-Maoist
DoED	Department of Electricity Development
EIRR	Economic Internal Rate of Return
FDI	Foreign Direct Investment
FIRR	Financial Internal Rate of Return
GDP	Gross Domestic Product
GWh	Gigawatt Hours
GoN	Government of Nepal
HDI	Human Development Index
HPL	Himal Power Limited
IAP	Indoor Air Pollution
IFC	International Finance Corporation
IPP	Independent Power Producer
IPPAN	Independent Power Producers' Association, Nepal
KW	Kilowatts
KWh	Kilowatt Hours
MH	Micro-hydro
MHPs	Micro-hydro Projects
MHVE	Micro-hydro Village Electrification
MoEn	Ministry of Energy
MoEnv	Ministry of Environment
MoF	Ministry of Finance
MW	Megawatts
NEA	Nepal Electricity Authority
PDF	Power Development Fund
PDP	Power Development Project
PPA	Power Purchase Agreement

REDP	Rural Energy Development Program
RERL	Renewable Energy for Rural Livelihood
ROR	Run-of-river
UNDP	United Nations Development Programme
WHO	World Health Organization

Executive Summary

Nepal's current electricity supply is insufficient, unreliable, and expensive. Despite having 83,000 megawatts (MW) of theoretical hydroelectric potential, about 42,000 MW of which is technically and economically viable, current annual hydropower output barely exceeds 700 MW.[1] These supply problems impose a number of costs on society, including economic inequity, health and environmental impacts, and economic losses due to unreliable connectivity and productivity losses.

Approximately 50 percent of the population has access to electricity, and only 5 percent of the rural populace has access to electricity from the national grid. Even residents in Nepal's capital city of Kathmandu experience outages several times a day for up to 16 hours during the dry season. These electricity shortages have led to a heavy reliance on biomass burning for energy in rural Nepal, which has negative health and environmental impacts, particularly for women and children.

In 2011, peak power demand in Nepal reached 950 MW, and is projected to continue increasing by around 7.5 percent annually until 2020. This analysis considers several alternatives to address the 300 MW imbalance between supply and demand for electricity given feasibility and cost constraints. The alternatives for increasing hydroelectric capacity include:

1. Letting present trends continue;
2. Developing micro-hydropower projects (<100 kW);
3. Expand capacity using mid-range dams (1-100 MW); and
4. Pursuing large-scale hydroelectric projects (>100 MW)

Ultimately, this report recommends pursuing micro-hydroelectric development while taking political steps to effectively build up small, medium, and large-scale projects in the long term. Expanding micro-hydro initiatives such as the Rural Energy Development Program (REDP) will address Nepal's overall economic development as well as rural-urban disparities in connectivity, health, and economic outcomes. Further, micro-hydro projects are comparatively feasible given Nepal's political climate. Large-scale projects are subject to greater government oversight, and must include a grid expansion or transmission element. Micro-hydro power is a smaller scale, community-based alternative with proven success in fostering rural development in Nepal.

Despite the short-term recommendation of building up capacity through micro-hydro development, concrete steps must be taken to facilitate large-scale projects in the long run. The current political and regulatory environment in Nepal is not conducive to small and medium project development, let alone large-scale dams that would fully take advantage of Nepal's vast hydroelectric potential.

[1] Technically and economically viable potential refers to viability for development given presently available infrastructure, such as roads and the electricity grid.

PART I: Problem Analysis

Insufficient Electricity Supply in Nepal

Nepal's current electricity supply is unreliable, expensive, and insufficient. These supply problems can be attributed to a number of factors, including: "high transmission and distribution losses, piecemeal expansion of the national grid, high cost of power purchase agreements, inefficiencies at the Nepal Electricity Authority, and underutilization of existing capacity."[i] In particular, this report addresses the inadequate development of Nepal's potential hydroelectric capacity. The insufficient electricity supply imposes a number of costs on society, including equity costs, health and environmental impacts, and economic losses due to unreliable connectivity and productivity losses.

Despite having one of the world's largest hydropower resources in the world, Nepal lacks reliable and sufficient access to electricity.[ii] Overall, of the theoretical hydropower potential of 80,000 MW, about 42,000 MW are technically and economically viable for exploitation.[2][iii] However, the Nepal Electricity Authority (NEA) reports current annual hydropower output of 659 MW. This amount is insufficient to meet domestic energy demand, let alone serve as a potential source of export revenue to bolster Nepal's struggling economy. Despite having among the highest commercially feasible hydropower potential, Nepal has harnessed about 1 percent, far below the level of every other South Asian country (Table 1). Evidently, Nepal has developed only a fraction of its realizable hydropower potential.

Table 1: Hydropower potential and percent exploited in South Asian countries

Country	Hydropower Capacity (MW)			% Harnessed of commercially feasible capacity
	Gross	Commercially Feasible	Installed	
India	148,700	84,044	39,060	46.48
Pakistan	100,000	59,000	6,555	11.11
Nepal	**80,000**	**43,000**	**659**	**1.53**
Bhutan	30,000	24,000	1,488	6.20
Sri Lanka	-	2,550.7	1,401	54.93
Bangladesh	-	755	230	30.46
Total	**365,006**	**213,350**	**49,394**	**23.15**

Source: CEB (Ceylon Electricity Board) Statistical Digest 2011; CEA (Central Electricity Authority) of India Annual Report 2010-11; Pakistan Water and Power Development Authority, Hydro Potential in Pakistan, November 2011; NEA Year in Review, Fiscal Year 2010/2011; Annual Report 2011, Bangladesh Power Development Board; Power Sector of Bhutan, Bhutan Power Corporation Limited; The World Bank, Project Information Document: Kali Gandaki A Hydropower Rehabilitation Project, 2012.

[2] Estimates of feasible hydropower potential vary. This report uses the numbers corroborated by both the World Bank and Asian Development Bank (ADB). The agreed upon figures are 80,000 MW of theoretical potential and about 42,000 MW of technically and economically viable potential.

As Nepal continues to develop and experience population growth, it will require an even greater supply of electricity. Even now, residents in Nepal's capital city of Kathmandu experience power outages several times a day for up to 16 hours during the dry season due to "load shedding," or planned power cuts.[iv] In 2011, Nepal's peak power demand reached 950 MW, far beyond the total installed capacity of 705 MW.[v] During fiscal year 2010-2011 Nepal's energy demand rose about 10 percent, and is projected to continue increasing by around 7.5 percent annually until 2020.[vi]

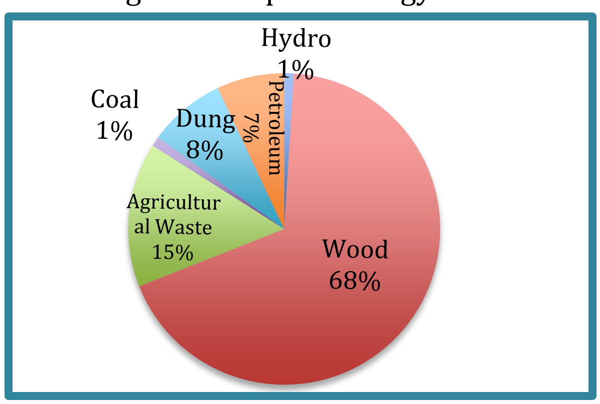
Nepal's electricity tariff is among the highest in South Asia. Table 2, below, displays electricity tariff rates by country for the domestic, industrial, agricultural, and commercial sectors. Tariff rates, or the price of power generation, differ by country based on "the type and market price of the sources/fuels used, government subsidies, government and industry regulation, and even weather patterns."[vii] Nepal's domestic consumer tariff in particular is the highest in the region. This impacts poor Nepalese who, upon gaining access to electricity, are unable to enjoy the full scope of development benefits that resulting from electrification.

Table 2: Consumer Tariff Rates in South Asia (US cents per KWh)

	Nepal	**India**	**Pakistan**	**Bangladesh**	**Sri Lanka**
Domestic consumer tariff	0-20 KWh: 5.6 21-250: 10.3 >250: 13.9	0-200 KWh: 5.5 201-400: 8.8 >400: 10.4	0-50 KWh: 2.2 0-100: 5.1 101-300: 7.6 301-700: 12.4 >700: 15.4	0-100 KWh: 3.3 101-400: 4.2 >400: 7.0	0-30 KWh: 2.7 31-60: 4.3 61-90: 6.8 91-120: 19.1 121-180: 21.8 >180: 32.8
Industrial	9.3	11.3	10.3	5.4	9.1
Agricultural	5.0	3.5	6.2	2.6	13.6
Commercial	10.8	-	15.1	7.1	13.6

Source: Websites of Ministry of Power, India; Nepal Electricity Authority, Nepal; Bangladesh Power Development Board; Ceylon Electricity Board; Sri Lanka and Pakistan Economic Survey, 2010-11.

Figure 1: Nepal's Energy Profile



Energy Profile Nepal's population has surpassed 30 million and the country is already facing a severe energy shortage, particularly in rural areas. A little over half (56 percent) of households in Nepal have access to electricity, including those with off-grid solutions.[viii] According to the Center for Rural Technology, approximately 90 percent of Nepal's electricity comes from hydropower, yet Nepal only consumes 1 percent of electricity. The vast majority of Nepal's total energy supply comes from traditional, non-electric sources of energy such as wood, agricultural waste, and dung (Figure 1). Commercial energy sources such as petroleum and coal provide another eight percent. The remaining one percent is supplied by hydroelectricity (Source: SARI, 2012). Therefore, despite the country's vast hydroelectric potential and the large share of electricity met by hydropower, the overall energy portfolio hydropower represents a negligible portion of the overall energy profile of Nepal.

Developing Nepal's hydroelectric potential can not only satisfy domestic energy demand and create opportunities for domestic growth and development, but also provide additional revenue by exporting electricity to rapidly developing countries like India.

Nepal's energy forecast to 2028 indicates the national electricity shortage will only become more severe in the future (Table 3). In 2028, Nepal will face an energy output of 17,404 GWh and the system peak load is forecasted to reach about 3,679 MW under a medium growth scenario.[ix]

Table 3: Nepal's Energy Forecast to 2028

Fiscal Year	Energy (GWh)	System Peak Load (MW)
2010-11	4,430.70	967.10
2011-12	4,851.30	1,056.90
2012-13	5,349.60	1,163.20
2013-14	5,859.90	1,271.70
2014-15	6,403.80	1,387.20
2015-16	6,984.10	1,510.00
2016-17	7,603.70	1,640.80
2017-18	8,218.80	1,770.20
2018-19	8,870.20	1,906.90
2019-20	9,562.90	2,052.00
2020-21	10,300.10	2,206.00
2021-22	11,053.60	2,363.00
2022-23	11,929.10	2,545.40
2023-24	12,870.20	2,741.10
2024-25	13,882.40	2,951.10
2025-26	14,971.20	3,176.70
2026-27	16,142.70	3,418.90
2027-28	**17,403.60**	**3,679.10**

Source: NEA Annual Report, 2011.

Despite these obstacles, the Government of Nepal, independent power producers (IPPs), and foreign investors have successfully completed a range of micro, small, and medium-sized hydroelectric projects. This report will analyze completed projects based on a number of criteria to determine the best strategy for increasing capacity in the short-term.

Costs and Concerns Arising from Insufficient Electricity Supply

Equity
Almost 85 percent of the population of Nepal lives in rural areas that lack access to Nepal's national grid. Between rural and urban populations "[d]isparity in access is stark, with almost 90 percent of the urban population connected, but less than 30 percent of the rural".[x] Further, of the 30 percent in rural areas with access to electricity, only 5 percent have access to electricity from the grid.[xi]

Environment and Health Impacts
As a result of poor connectivity, rural Nepalese rely on firewood and other traditional fuels for cooking and heating. Relying on biomass as a primary source of energy has impacted Nepal's forests and led to increased carbon dioxide emissions. Deforestation has become a growing problem in rural Nepal, and "only 29 percent of the country remains forested, compared to 37 percent in 1990."[xii]

In addition to the environmental impacts associated with a dependence on biomass for fuel, there are adverse health outcomes that disproportionately affect rural Nepalese. In rural Nepal, fuel wood supplies about 86 percent of the total energy requirement, and is supplemented by animal dung, agricultural residues, and petroleum products.[xiii] According to a UN World Health Organization (WHO) report, an estimated 7,500 people in Nepal die annually as a result of indoor air pollution (IAP) from solid fuel use.[xiv] These air quality issues in turn have a disproportionately negative impact on women and children in rural Nepal, who are subject to greater exposure.

Economic Impacts
In a 2012 overview of Nepal's present investment climate, Afram and Del Pero found "over 99 percent of the firms suffered power outages and on average firms suffered 57.3 outages per month each lasting 4.9 hours". These outages are costly to the private sector, resulting in losses of 22.1 percent of annual sales.

Further, Nepal lacks fossil fuel reserves of its own, but fossil fuel imports from India make up 7 percent of total annual energy supplies. In 2005-2006, the total cost of importing petroleum products was USD$35 million.[xv] There has been a steady increase in the quantity of petroleum purchased annually, and this increasing dependency "coupled with rising fuel price[s] in the international market is severely impacting the already fragile economy of the country."[xvi] Although around 50 percent of petroleum imports are used for transportation, and would therefore not be offset by developing hydropower resources, the other 50 percent that goes to residential, commercial and public services would be offset by substituting hydropower for petroleum.[xvii] Therefore, the long-term implications of continued fossil fuel dependence serve as further rationale to increase hydroelectric capacity.

Implications for development

Almost seven years after the end of a 10-year internal conflict, Nepal remains one of the poorest countries worldwide, ranking 157th out of the 187 countries on the Human Development Index. Harnessing hydroelectric potential along the Himalayas will not only provide Nepal with a more reliable source of electricity, it would also address the costs currently borne by the population. Rural electrification could mitigate national inequities by bringing health and economic well-being to millions of Nepalese.

In addition to domestic benefits of hydroelectric development, surplus energy harnessed from hydroelectric projects can be sold to generate export revenue. According to the U.S. Energy Information Administration (EIA), between 2008 and 2035, China and India's share of world energy consumption will jump from 21 percent to 31 percent.[xviii] Both countries have expressed interest in developing hydropower projects in Nepal to address this projected growth in demand.

Development of hydroelectric potential in Nepal is not a question of if, but rather when, and by whom. The potential for poorly planned or executed hydroelectric projects runs a significant risk and necessitates a strategy for development that will cause minimal environmental damage in Nepal. This analysis will attempt to identify the development strategy that addresses the supply and demand disparity for electricity in the short term while incurring minimal economic, political, and environmental costs.

PART II: Regional Overview and Background

This section provides a brief economic, political and regulatory overview of the present conditions in Nepal. Additionally, it includes a description of Nepal's current hydroelectric profile.

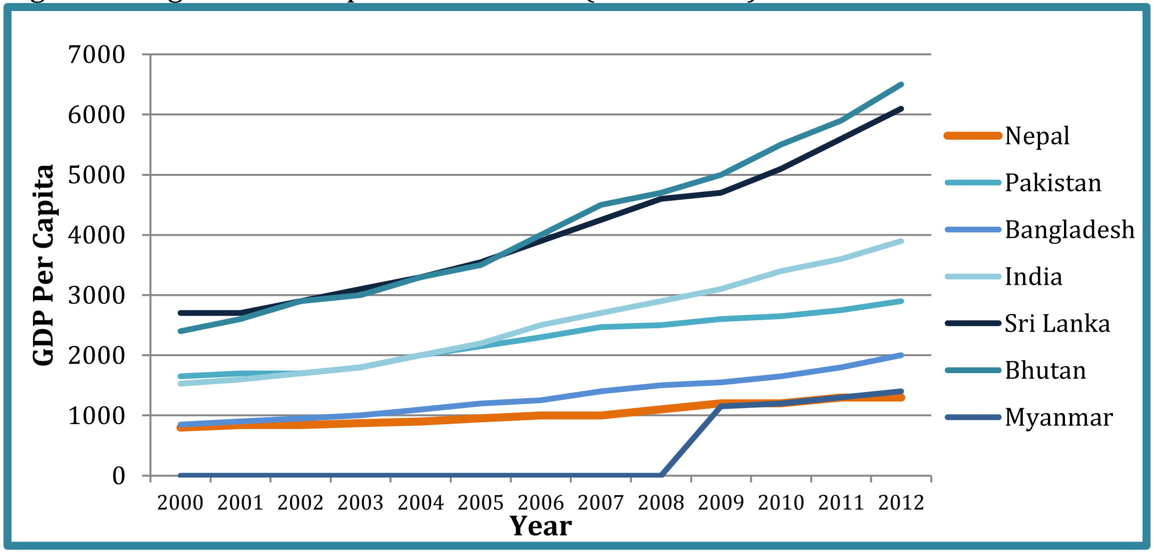
Figure 2: Map of Nepal

Source: CIA World Factbook, 2013

Economic Overview

Nepal is one of the poorest and least developed countries in the world. About one-quarter of Nepal's population lives below the poverty line, obtained by aggregating food and non-food expenditures.[xix] In 2011, average per capita income was only $427, with 55 percent of the population living on $1.25 or less per day.[xx] In 2012, per capita gross domestic product (GDP) in Nepal was only $1,300. Compared with other South Asian economies, Nepal's performance is notably weak. In 2012 Nepal's per capita GDP remained the lowest in the region (Figure 3). Even Burma, a country whose own internal conflict ended in 2011, has surpassed Nepal in per capita GDP.

Figure 3*:* Regional Per Capita GDP Growth (2000-2012)



Source: Calculated from CIA World Factbook, 2013; World Bank World Development Indicators, 2013

According to the United Nations Development Programme (UNDP), in 2012 Nepal's Human Development Index (HDI) was 0.463 compared to an average of 0.558 for South Asia overall. Based on the HDI, which encompasses health, education and living standards, Nepal is ranked 157 out of 187 countries worldwide.

Agriculture currently employs around 74 percent of Nepal's workforce and accounts for 36 percent of GDP.[xxi] Potential hydropower projects should take this into account, as hydroelectric development can alter river flows in a way that may negatively impact farmers or villages downstream.

Political and Regulatory Environment

One current barrier to hydropower development projects in Nepal is political instability. In February 1996, the Communist Party of Nepal-Maoist (CPN-M) led an uprising against the constitutional monarchy. The Maoists sought to install a one-party communist government, but the insurgency gave way to ten years of political struggle. In April 2006, the king of Nepal transferred power to a coalition called the Seven Party Alliance. The Seven Party Alliance and the Maoists established a peace agreement in November of the same year, ending the ten-year insurgency and establishing a new coalition government. Under this agreement, a Constituent Assembly was to be formed through elections in 2007, although these elections did not actually take place until April 2008.[xxii] The peace agreement marked a significant step in Nepal's political transformation, and ended the decade-long struggle against the monarchy. However, Nepal's Maoist insurgency left over 12,000 people dead and 100,000 people displaced, and political issues continue to plague the country.[xxiii]

Despite tremendous political progress since the Comprehensive Peace accord between the Nepalese government and the Maoist insurgency was signed in 2006, Nepal's government remains in a volatile state. According to the World Bank, as of May 2013 Nepal has had 20 governments since the country became a democratic republic in 1990. Furthermore, in just three years from 2008 to 2011, Nepal had four separate coalition governments.[xxiv] Nepal is currently following the 2007 Interim Constitution despite ongoing constitutional reform efforts.

In May 2012, Nepal's Constituent Assembly ended its four-year term without even drafting a new constitution. Between May 2012 and March 2013, Nepal's government remained without a parliament. However, in mid-March 2013, the appointment of Nepal's chief justice as head of an interim government was announced. This appointment "increases the chances of an early election in June to choose an assembly to complete the drafting of Nepal's first constitution after the abolition of the 239-year-old monarchy in 2008."[xxv] While this step marks great progress from a yearlong stalemate, lingering uncertainty remains surrounding Nepal's election prospects and the drafting of a new constitution.

According to World Bank Governance Indicators, Nepal ranks below the 50th percentile in every category, including: voice and accountability, political stability and the absence of violence; government effectiveness; regulatory quality; rule of law; and control of corruption. Nepal ranks particularly low in political stability, falling in the 6th percentile on a 0-100 scale.

Political instability makes Nepal less attractive to foreign investors, "has stalled domestic reform efforts, and dissuaded foreign investors from pursuing energy projects in Nepal".[xxvi] Countries such as China and India are interested in developing energy projects to take advantage of Nepal's natural resources, but often not willing to risk lost investments due to political turmoil. Overall, political instability serves as a barrier to lasting and transformative growth and development in Nepal.

There is no "one window" agency managing hydropower development, which has dissuaded potential investors from pursuing projects in Nepal. According to the U.S. Department of State's 2012 Investment Climate Statement on Nepal, despite recent Government of Nepal (GoN) initiatives to open the hydropower generation sector to private development, a wide variance between laws and implementation persists. In fact, although the Government announced a new policy in August 2011 to attempt to increase the number of licenses awarded for projects above 10 MW, the process remains cumbersome and "[u]nreasonable delay in the evaluation of hydropower survey licenses…discourage long-term investment in this sector".[xxvii] Although Nepalese law requires licensing decisions to be made within 30 days of application, the government rarely makes this deadline. Nepal ranks 107th out of 183 countries according to the World Bank's ease of doing business standards. These conditions have all stalled private investment in Nepal and prevented any measurable progress in developing the country's vast hydroelectric potential.

Although the GoN awards hundreds of licenses annually for hydropower project development, few projects move forward. The Department of Electricity Development (DoED), overseeing the issuing of licenses for hydropower projects, has issued around 13,289 MW of survey licenses to date, with only a small fraction of these moving forward to construction.[xxviii] Additionally, the GoN recently increased the minimum survey license fee by 100 percent, from around US$575 to US$1,150.[xxix] Further, since March 2013, the DoED has cancelled survey licenses for some 40 projects with a combined capacity of more than 1,400 MW.[xxx] These recent indicators provide even less incentive for foreign investors to pursue projects in Nepal.

To meet growing national power demands, the Government of Nepal has set a a development goal of harnessing 10,000 MW of hydroelectric potential by 2020.[xxxi] The targeted development plan was revised to reach 2,035 MW of hydropower capacity for both domestic use and export by 2017, and 4,000 MW by 2027.[xxxii] However, the GoN's previous target figure was to increase generation capacity to 824 MW with 70 MW of exports by 2007, and as of 2013 the generation capacity still had not met these goals.[xxxiii] Although the government recognizes the enormous potential for hydropower development and sets lofty targets to increase capacity, these targets have proven unattainable given political and social constraints.

Hydropower Overview

Based on size and production capacity, there are several major types of hydropower projects.[3] Micro-hydro projects are those with an overall capacity of less than 100 kW; small-scale hydroelectric dams harness between 1 and 10 MW; medium-scale projects are those between 10 and 100 MW installed capacity; and large-scale hydropower projects are those with 100 MW capacity or greater.

In addition to different-sized projects, the schemes implemented in Nepal fall under two broad categories: storage projects, or run-of-river (ROR) dams. A storage project stores water for release during the wet season, or times of low electricity demand, and releases it for quick generation during peak hours or the dry season.[xxxiv] Contrastingly, ROR projects cannot regulate river flow, and rather generate electricity proportional to the river's flow. Therefore, the ROR structure does not alter the natural environment as much as a storage project, but also provides a less reliable supply of power. Nepal's hilly landscape is well suited to ROR projects, as natural drops in elevation provide great hydropower potential without constructing a reservoir. In terms of cost, storage projects are typically more costly than ROR projects of a similar size due in part to a need to construct a large reservoir dam for storage.[xxxv]

Climate Change Impacts

Hydroelectric projects designs are based on river flow; therefore changes in runoff can have significant impacts on the viability of certain projects. Based on a GoN Water and Energy Commission Secretariat report, although hydropower plants are designed based on

[3] Classification for hydropower projects varies by source. This report uses the Government of Nepal's standards as its source for classifying different hydroelectric projects.

65 percent dependable river flow, under severe conditions of climate change, average runoff may be reduced by as much as 14 percent.[xxxvi] Further, climate scientists predict increasingly intense monsoon seasons, decreased rain and snow in the winter, and continued glacial retreat, all of which diminish the reliability of water resources in Nepal.[xxxvii]

Another concern associated with climate change is the dependability of river flow during the dry season. In this case, the variability of river flow increases, making hydropower planning more complex and difficult. Chaulagain notes initial increased glacier melt due to warmer temperatures will give way to reduced glacial reserves, decreasing hydropower potential over the long run.[xxxviii] This study learned, based on present rates of retreat for Himalayan glaciers, "there will be a 6 percent decrease in hydropower potential at the end of this century even without any further warming".[xxxix] Another factor associated with climate change are glacial lake outburst floods (GLOF). Atmospheric warming and glacial retreat in the Himalayas has created new meltwater lakes, several of which have burst naturally occurring dams in Nepal, resulting in extremely destructive flood surges.[xl] Although GLOFs are not a recent phenomenon, the frequency and rate at which lakes grow large enough to flood has changed and will likely continue to accelerate with climate change.

Operation and maintenance problems arising from sediment wear on hydro machinery has already become a problem in Nepal. Flooding due to altered weather patterns can impact sediment load, which increases the costs of operation and maintenance and decreases turbine efficiency.[xli]

To address climate change concerns, in 2009 the GoN instituted a subsidy policy for renewable rural energy. This subsidy covers micro-hydro, biogas, solar energy, water mills, wind energy, and improved cooking stoves to promote renewable energy technologies in poor and rural households.[xlii]

PART III: Evaluative Criteria

This section evaluates options for harnessing hydroelectric potential in Nepal along the following criteria:

- Cost-effectiveness;
- Feasibility;
- Equity; and
- Environmental & health impacts

Cost-Effectiveness

In this section, cost considerations include a calculation of cost-effectiveness and a discussion of other costs and benefits associated with a given alternative.

This section evaluates the cost-effectiveness of a given alternative based on the cost (US$) per kilowatt (kW) added to Nepal's installed electricity capacity. This analysis relies on data from past hydropower projects in Nepal completed by the World Bank, Asian Development Bank (ADB), United Nations Development Programme (UNDP), Government of Nepal (GoN), Nepal Electricity Authority (NEA), and private investors such as Nepal's Independent Power Producers (IPPs).

According to the NEA, in 2011 Nepal's peak power demand reached almost 970 MW, compared to a total installed capacity of only 659 MW. Therefore, cost-effectiveness is measured as the cost to add 300 MW to Nepal's total installed capacity. This addition would balance the supply and demand of Nepal's present energy situation. The most desirable option will be that which requires the lowest cost to achieve the desired increase of 300 MW in Nepal's installed capacity. The average cost for each option is measured by taking a weighted average cost of the available project data for previously constructed dams in Nepal. A list of the projects with cost per kW data can be found in Appendix 3, along with weighted cost calculations.

To determine the total cost to increase capacity by 300 MW, this analysis uses the following calculation: Weighted average cost * 300,000=Average cost to achieve desired capacity under a given alternative.[4]

Another cost measure includes the estimated economic internal rate of return (EIRR) based on World Bank and ADB project appraisals. The EIRR is the interest rate at which the costs and benefits of a project are equal, discounted over the lifespan of a project. According to the World Bank EIRR definition, in developing countries projects with an EIRR above 12 percent are typically the most viable.[xliii] Therefore, those projects with EIRRs above 12 percent are considered more favorable in this analysis.

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[4] 300 MW=1,000 kW; 300*1,000=300,000. Therefore, 300,000 is the amount to multiply by to increase capacity by 300 MW.

A discussion of further costs and benefits of each alternative will include: operation and maintenance costs and potential export revenue generated.

Feasibility

This section considers political, social, and financial factors in determining the overall feasibility of each option.

Political Feasibility

Political feasibility refers to the likelihood of a policy option being adopted given the political landscape in Nepal. A tumultuous political environment in Nepal presents an obstacle to developing hydroelectric projects. Therefore, project types successfully completed in the past will be considered more politically feasible than those with no past precedent. Projects with less government oversight or fewer steps to license procurement are considered more politically feasible.

Social Acceptability

One obstacle to hydropower project implementation in the past has been community objection and dam-related protest. The rationale behind developing micro-hydro schemes with active community involvement is to facilitate project completion while increasing capacity and other development benefits. Proposals for large-scale hydropower projects have often evoked public protest in Nepal, particularly in communities where projects will be located. Therefore, community perceptions of different hydroelectric options are important to consider when evaluating the feasibility of different policies. Proposals involving India-Nepal collaboration for dam building have been met with particularly strong protest.

Financial Implementation

Despite tight domestic capital markets, there are multiple funding sources available for hydropower development in Nepal. However, different sized projects will attract different funders, with development banks, government expenditures and foreign aid as the most likely funding sources for micro-hydro and foreign direct investment a more likely option for large-scale dams. As such, the accessibility of funding sources for each option are considered as another measure of feasibility. External aid is critical for developing Nepal's hydroelectric potential, as domestic commercial banks have a combined lending capacity of around US$115-140 million, the cost to install only up to 150 MW of capacity.[xliv] Some of the major donor agencies that have operated in Nepal include: the Norwegian Agency for Development Cooperation (NORAD); the United States Agency of International Development (USAID); the United Nations Development Programme (UNDP); the World Bank; the Asian Development Bank (ADB); and German Aid Agency (GTZ).

Equity

Disparate grid access and off-grid electrification between rural and urban populations is another problem associated with insufficient electricity in Nepal. Depending on project size and location, certain hydropower projects will favor different populations. For example, large-scale hydroelectric projects aimed at export revenue and grid-based electricity supply will not benefit rural populations unless they incorporate a grid extension into the project area as well. On the other hand, micro-hydro projects do not produce enough electricity to contribute any sizeable amount for export or national use, and therefore have a disproportionately favorable impact on rural populations.

Due to the different benefits associated with different types of hydropower projects, this assessment will consider horizontal and vertical equity. Horizontal equity refers to equal treatment for an entire population, whereas vertical equity considers whether an alternative will benefit the most vulnerable members of society. In the context of this study, where Nepal's rural population is disproportionately affected by limited electricity supply, it will be important to consider both types of equity.

Environmental & Health Impacts

As discussed in the problem analysis, Nepal's reliance on biomass and other traditional fuels has led to negative environmental and health outcomes. In particular, deforestation, carbon emissions, and indoor air pollution are key environmental and health problems resulting from Nepal's current energy supply structure.

Policy options exerting less negative impacts on the environment are rated as more favorable. Those with positive health impacts are assessed as beneficial for health outcomes.

PART IV: Policy Alternatives

This section presents four options for development strategies in Nepal's hydropower sector: letting present trends continue; focusing on micro-hydro projects to stimulate rural growth and development; developing small-and-medium-scale hydroelectric projects; and exclusively pursuing large-scale dam building. This section briefly introduces the four alternatives, which will be evaluated in depth in Part V.

Alternative I: Let present trends continue

One policy alternative is allowing present trends to continue. There are currently no well-established practices or principles for hydropower development in Nepal. Although the GoN has set ambitious development goals for harnessing Nepal's vast hydroelectric potential, the variance between laws and implementation dissuades investors and causes costly delays for current projects.

Funding for hydroelectric projects comes from a variety of sources, including the GoN, the Asian Development Bank (ADB), the World Bank, and limited foreign direct investment (FDI) from other countries such as Norway, India, and Japan. The GoN, ADB and World Bank have provided funding for many of Nepal's projects, and will likely continue to fund development until the political and regulatory climate changes to facilitate FDI.

Appendix 1 lists the existing power projects in Nepal. Appendix 2 lists those that are under construction, planned, or proposed.

Alternative II: Develop micro-hydro projects (MHPs) to power rural growth and domestic economic development

According to the Nepal Electricity Authority (NEA), a hydroelectric plant is classified as "micro" if it has an installed capacity between 10 and 100 kW. Nepal is geographically well suited for run-of-the-river (ROR) hydroelectric development, which "uses the natural flow and elevation drop of the river to generate power".[xlv] Conventional storage projects include dam construction, which creates a lake behind it. This model is beneficial because the storage component ensures there will be water available for generations even during times of drought. Despite this, ROR projects exert little impact on the environment and the local population. Further, due to Nepal's great natural hydroelectric potential and natural drops in elevation, the terrain is well suited for ROR projects.

Micro hydro projects generate small amounts of energy, but are ideal for local communities lavking access to a national electricity grid. Instead of connecting to the national grid, MHPs typically supply power through local mini grids. As Nepal currently lacks a comprehensive or functional national energy grid, a number of communities have already developed micro hydro projects to gain access to electricity for lighting, refrigeration, cooking, and communications technologies.[xlvi] Existing MHPs provide electricity to Nepal's far-reaching rural communities that might otherwise take years to gain connectivity to the national grid. The average lifetime for a micro-hydropower project is around “15 years before major refurbishments are needed”.[xlvii]

Since the 1970s, an estimated 2,500 MHPs have been completed in 40 districts in rural Nepal, generating a total of around 17,000 kW of electricity.[xlviii] Development banks such as the World Bank and ADB have endorsed micro projects for their transformative effects on rural communities. These community benefits include home lighting, electricity for small enterprises, higher local incomes, increased educational opportunities, and fewer adverse health impacts from kerosene lanterns.[xlix] The benefits and costs of developing these systems are detailed in the evaluation section of this report.

Recently, mini-grid technology has begun to appear as a potential solution to efficiency concerns about micro-hydropower projects. Mini-grids connect two or more micro-hydro units, and can improve the quality and reliability of isolated MH units. Further, this technology will give communities the option of selling surplus electricity to the national grid, if and when the grid is extended to those rural areas.[l] The first micro-hydro mini-grid was completed in Baglung, western Nepal in 2011 by the Alternative Energy Promotion Centre (AEPC). This grid connects six MHPs over 8 kilometers and now serves 1,180 households. Mini-grid connectivity has ensured that locals enjoy 24-hour access to electricity and has reduced the monthly cost of electricity from US$1 to US$0.80.

Alternative III: Pursue mid-range (1-100 MW) hydropower development

In Nepal, small-scale projects are between 1 and 10 MW, and medium-scale hydropower projects are those between 1 and 100 MW installed capacity. Small and medium projects will be evaluated as one alternative due to their relatively similar features.

A number of mid-scale projects already exist in Nepal, the majority of which require grid connectivity. Although there is past precedent for these projects, the regulatory process can be lengthy due to site feasibility studies and other hurdles.

Typical funders for mid-range hydropower projects include: GoN; development banks such as the World Bank and ADB; and independent power producers (IPPs). Appendix 1 contains a list of the major medium-and-small-scale hydropower projects in Nepal.

Alternative IV: Focus development efforts on large-scale hydroelectric projects (>100 MW)

For the purpose of this study, dams classified as “large-scale” in Nepal are those with a capacity of 100 MW or more. There is only one complete large-scale project in Nepal to date, the Kali Gandaki A. Construction on the 144 MW Kali Gandaki A began in 1997 and was completed in 2002. Since 2002, it has operated as a run-of-the-river (ROR) plant producing around 592 gigawatt-hours (GWh) per year (ADB, 2012).

Although most complete hydroelectric projects in Nepal are ROR, several of the proposed or planned large-scale dams involve a storage component. The GoN has indicated that

Nepal should add capacity from a large storage project to increase the reliability of the electricity supply, as ROR projects produce energy subject to variable river flows.

All large-scale projects require a significant investment in infrastructure, including transmission lines, grid expansion, and road construction. These high costs make large-scale projects impossible to complete in Nepal without funding aid. Despite highup-front costs and a longer period on returns due to lengthy construction time, foreign funders such as China, India, and Japan have expressed interest in developing projects in Nepal. Additional funding is available from international development banks such as the World Bank and ADB.

PART V: Evaluation

Evaluation of Alternative I: Let present trends continue

Cost-Effectiveness
As mentioned in the discussion of criteria, cost-effectiveness is measured as the cost to increase Nepal's total installed capacity by 300 MW. Presently, Nepal has a number of hydropower projects under construction (Table 4).

Table 4: Hydroelectric projects under construction in Nepal

Name	Capacity (MW)	Type	Projected Commissioning date
Projects under NEA			
Chamelia	30	ROR	August 2013
Trishuli-3A	60	ROR	May 2014
Kulekhani-III	14	STO	September 2014
Rahughat	30	ROR	2016
Under NEA Subsidiary Companies			
Upper Tamakoshi	456	ROR	2 units March 2015, 4 units March 2016
Sanjen	14.3	ROR	December 2015
Upper Sanjen	42	ROR	July 2015
Rasuwagadhi	102	ROR	2016
Bhotekoshi	111	ROR	December 2016
Trishuli-3B	37	ROR	--
Bheri-Babai Diversion	48	ROR	2018
Budhi Ganga	20	ROR	--
Approximately 300,000 kW of projects with different capacities are under construction by IPPs			

Note: ROR refers to run-of-river dams, STO to a storage project.
Source: International Water Power & Dam Construction, 2013.

Under this scenario, Nepal will add around 850 MW based on hydroelectric projects currently under construction. The earliest commissioning date for any of these projects, barring delays, is August 2013. However, Nepal's fractured internal politics threatens the national energy outlook and prevents any measurable success in increasing hydroelectric capacity. For example, the Chamelia, scheduled for commissioning in August 2013, was initially scheduled for completion in 2011. In April 2013, the project chief admitted completion was unlikely even by late 2013.[li] Nepal's unstable political and regulatory climate will likely prevent these projects from being completed in time to address Nepal's present energy shortage, let alone meet growing demand projections.

According to the World Bank, resettlement costs in Bank projects exceed initial estimates by an average of 54 percent.[lii] In the case of the 70 MW Middle Marsyangdi Hydro Electric

Project (MMHEP), a separate office under the Environmental Division of the NEA was established to address resettlement concerns. Although dam construction in Nepal does not necessarily involve resettlement, these costs are often underestimated in the planning stage. This impacts the project cost-effectiveness, particularly for those dams that are constructed in more densely populated areas.

Nepal's current electricity situation does not harness enough capacity to satisfy domestic demand and prevents hydropower from being used as a source of export revenue. Nepal's present strategy for hydroelectric development is not optimal for any measure of cost-effectiveness.

Feasibility

Overall, increasing Nepal's hydroelectric capacity through the status quo faces severe feasibility challenges. The aforementioned projections for increasing capacity by 850 MW by late 2013 do not account for delays that may occur as a result of construction problems or local unrest. As noted in the political overview, although the GoN has set targets in the past for increasing hydro capacity, they have consistently failed to meet these targets. According to Dr. Sandip Shah, president of the Independent Power Producers Association (IPPAN), the GoN's goal of increasing capacity by 10,000 MW by 2020 is unfeasible.[liii] Therefore, Nepal's total installed capacity is unlikely to change dramatically for the next several years.

Political Feasibility

Letting present trends continue is politically feasible, because it requires no change. However, this method fails to address the problem of insufficient electricity supply. Further, the political and regulatory climate both serve as obstacles to hydroelectric development in the present scenario.

Hydropower development in Nepal is unlikely to occur without government reform. Government spending on hydropower development has remained low and the proportion of hydropower development expenditure to GDP, in the last two decades, has not surpassed 1.1 percent.[liv]

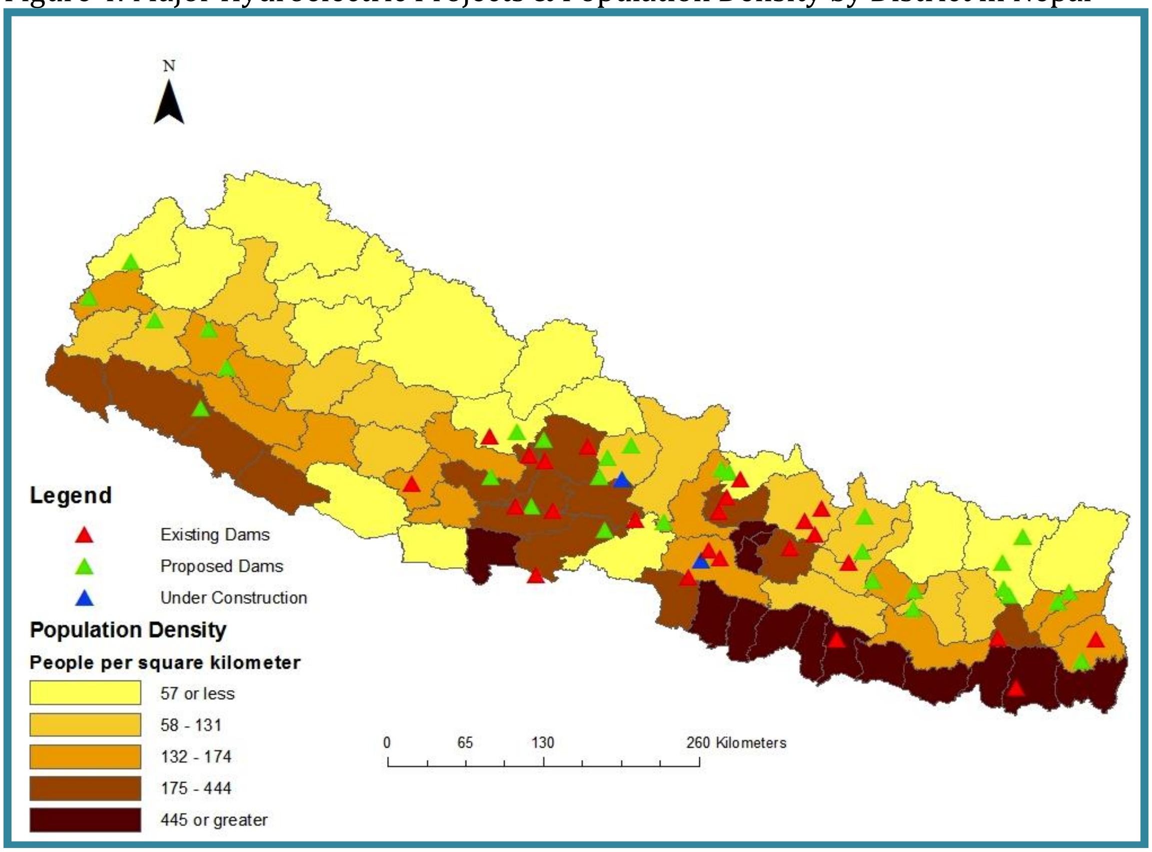
Community Attitudes

Local attitudes toward hydropower development in Nepal vary depending on the size and impacts associated with different projects. Nepal's radical Maoist faction is staunchly against large-scale projects designed to export electricity to India or China. However, low-impact projects such as micro-hydropower units are typically well received by the communities in which they are built.

In addition to the Maoist party's opposition to foreign funded hydropower projects, there have been several protests regarding planned hydroelectric development. Most recently, a controversial government decision to upgrade the Upper Trishuli 3A project using Chinese contractors sparked protests from several employee unions as well as former Nepali leaders. On June 12, 2013, just two weeks after the proposal was submitted, the Nepal Electricity Authority revoked the upgrade due to strong opposition.[lv] Several groups, including the National Youth Volunteers, the youth wing of the Maoist faction, have also opposed foreign development from India, calling it "'Indian intervention' in Nepali hydro resources". [lvi]

Figure 4 displays Nepal's population density by district as well as existing, under construction, and proposed major dam sites. This map provides a visual indication of districts where large-scale projects may meet opposition due to greater population density. There are no proposed dams in the districts with the greatest population density, but a number of proposed and planned sites are located in areas with moderate population density.

Figure 4: Major Hydroelectric Projects & Population Density by District in Nepal



Data provided by: World Bank, 2013; Statoids, 2013.
Source: Author Depiction using GIS software.

Financial Feasibility

The current regulatory environment for developing hydropower projects in Nepal is both time consuming and confusing. As described in the political and regulatory overview, the complexity and uncertainty of Nepal's current regulatory environment dissuades investors from pursuing hydropower projects. Despite GoN initiatives to facilitate investment both generally and in the hydropower sector specifically, there is no standardized process for issuing permits and implementing projects.

Equity

At present, only 56 percent of households in Nepal have access to on- or off-grid electricity. ,There is a large connection disparity between urban and rural areas. Around 90 percent of urban households are connected to an electrical grid, compared to less than 30 percent of rural households.[lvii] Considering that the rural population accounts for around 84 percent of Nepal's total population, this lack of connectivity has huge implications for national development. Further, social and economic development in electrified households vastly outpaces that of non-electrified households.[lviii] The Government is unlikely to extend the national grid to rural Nepalese households in the immediate future due to financial and technical constraints. It is very likely that this inequity between urban and rural connectivity will persist under the current scenario in Nepal, with vertical equity remaining an obstacle to national development.

Environmental & Health Impacts

In the status quo scenario, rural Nepalese still rely on biomass and traditional fuels to supply their electricity and heat. Thus, if present energy trends are not addressed, Nepal's deforestation problem will continue. Further, the problem of indoor air pollution would also persist. Although the development of the abovementioned 850 MW would ease negative environmental and health factors associated with burning biomass for electricity, it is unclear how much of this potential hydropower would benefit rural versus urban Nepalese.

Evaluation Summary of Alternative I: Let present trends continue

Benefits
- Politically feasible in that it requires no change

Challenges
- Unclear how long it will take Nepal to balance electricity supply and demand
- Low government spending on hydropower development
- Local opposition to currently proposed large-scale dams
- Very few licenses moving to implementation; licensing process is lengthy and confusing
- Rated poorly for ease of doing business, thus discouraging potential investors
- Only 56 percent of the population has any access to electricity
- Rural-urban connection disparity is vast, with 90 percent of urban Nepalese connected compared to less than 30 percent of rural Nepalese
- Unclear environmental standards for project development
- Reliance on burning biomass and other traditional fuels, perpetuating deforestation and indoor air pollution particularly in rural Nepal

Overall, this option does not significantly alter present development patterns, and therefore does not solve the problem of insufficient electricity supply in Nepal. Letting present trends continue is not an optimal choice for short- or long-term economic and development goals.

Evaluation of Alternative II: Micro-hydro development

Cost-Effectiveness

The outcomes of interest for this criterion are the number of kilowatts produced and the cost to produce them. Building up total installed capacity by pursuing micro hydropower projects would be a very cost-effective alternative because the average cost per kilowatt generated is low compared to larger hydropower plants.

Since the 1970s, an estimated 2,500 micro hydro projects (MHPs) have been completed in 40 districts in rural Nepal, generating a total of around 17,000 kW of electricity.[lix] Cost and capacity data are not available for all projects, and such a comprehensive cost analysis is beyond the scope of this report. Therefore, average cost data from the Rural Electrification Development Programme (REDP) serves as an approximation for average cost to build future MHPs in Nepal.

The REDP is a joint venture between the United Nations Development Programme (UNDP) and the Government of Nepal (GoN). The REDP alone has installed 317 micro-hydro plants in Nepal. The cost range for installing these units is between $1,279 and $1,779 per kW of output.[lx] Therefore, the total cost to increase Nepal's overall installed capacity by 300 MW to reach the quantity demanded in 2012 (950 MW) would be between $384 and $534 million.[5]

Initial investment costs for micro-hydro plants are generally competitive compared to installing small and medium scale hydropower, which costs around US$2,000 per kW or more.[lxi] Further, national grid expansion to Nepal's hilly and widespread rural communities is technically and financially unfeasible. As mentioned in the alternative description, developing mini-grid technology may increase the reliability of individual MH units, and minimize the cost of electricity for locals. This technology is still being tested in a few pilot communities, but initial cost and efficiency returns indicate that it may be a viable option for large-scale implementation in rural Nepal.

In 2003, the World Bank and the GoN implemented the Power Development Project (PDP), which included three components: a Power Development Fund (PDF), a Micro-hydro Village Electrification (MHVE) Program, and transmission improvements for the national grid. Under the PDF, a range of small and medium-scale projects were completed. In the project analysis, the World Bank determined the economic internal rate of return (EIRR)

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[5] See Appendix 3 for calculations.

for the micro-hydro initiative as well as the small and medium projects. The EIRRs for the MHVE reached approximately 10 percent. These systems exhibit a relatively poor EIRR due to the "numerical scale of the program (125 to 150 systems), and the community-based approach".[lxii] The report notes there are a number of economic benefits not quantified that would alter this analysis, including benefits from increased energy consumption due to lower prices, community education benefits, the ability to generate income during the evening, reduced incidence of indoor air pollution, and reduced carbon emissions from transitioning away from diesel and kerosene usage.[lxiii] The economic internal rate of return was higher for larger MH units in the project, those around 35 kW, compared to smaller schemes of around 15 kW. The larger MHP exhibited returns of around 12.2 percent, compared to an 8.3 percent EIRR for the small project.

Discussion of further costs and benefits

In addition to the average cost per kW of electricity produced, this evaluation considered a number of other costs and benefits associated with installing MHPs in rural Nepal. It takes about 21 months to complete a micro-hydro plant in Nepal, "including a feasibility study, review, government approval, construction and installation".[lxiv] Given the percentage of the population that still lacks access to electricity, or reliable electricity, this time frame is advantageous compared to larger-scale projects that can take years or even decades to finish.

Some of the REDP development benefits include increases in annual household incomes from access to electricity by an average of US$121, a difference of 8 percent. Additionally, districts saw around 40 new businesses created along with the installation of a micro-hydropower unit.

Hydropower installation also benefits agricultural productivity in rural Nepal. Micro-hydro units can be used for agricultural processing, which leads to time savings of 30 to 110 hours depending on the processing activity. Table 5 depicts the different time requirements for processing with and without hydropower.

Table 5*:* Average time requirements of agricultural processing

Activity	Traditional (hours)	Hydropowered (hours)
Milling	32.3	1.2
Hulling	32.5	1.1
Expelling	117.5	4.5

Note: Milling refers to the agricultural process of grinding grain in a hand mill. Hulling uses a traditional Nepalese rice beater called a dhiki to remove the outer husks of grains of rice. Expelling refers to the process of oil expelling from mustard seed, using a tool called a khol.

Source: Sovacool, 2011.

Time savings and improvements in productivity resulting from electrification greatly benefit under-developed rural communities in Nepal. Another agricultural benefit from electrification is refrigeration, which enables farmers in rural Nepal to keep milk and other products in cold storage. One farmer noted that he now owned two cows and was able to sell 4 to 5 liters of milk a day, whereas before he only owned one and "could barely sell a liter of milk a day".[lxv]

There are several costly technical challenges to implementing micro-hydropower projects. The turbines used for MHPs "have natural limits to their efficiency, operating at only 60 to 70 percent the efficiency of other designs".[lxvi] Additionally, although most micro-hydro units produce electricity 24 hours a day, Nepalese communities, on average, use electricity for less than six hours a day.[lxvii] Despite these inefficiencies, the average cost of installing a MH unit is competitive with other size hydroelectric plants.

Feasibility

Political Feasibility

The precedent for development of MHPs has been set through programs such as the REDP mentioned above. In 2011, after completing the third phase of the REDP, the GoN, UNDP, and The World Bank launched the Renewable Energy for Rural Livelihood (RERL) program. RERL aims to further increase rural access to electricity by scaling up the REDP to an additional 28,500 households, totaling around 3.15 MW of hydropower. In the first three months of its implementation, RERL expanded electrification from MHPs to an additional 984 households.[lxviii]

Although political precedent exists for pursuing micro-hydro electrification in rural Nepal, there are several political challenges associated with this option. Sovacool et. al. (2011) conducted research interviews with key stakeholders in Nepal, including government officials, members of civil society, businesses, and local communities. A majority of respondents highlighted institutional capacity and aid dependency as the two greatest political barriers to implementation of MHPs in rural Nepal. Regarding institutional capacity, one respondent noted, "the AEPC is understaffed and donor dependent, progress is not as fast as it could be". Primary concerns with aid dependence included, "donor dysfunction," where "sponsors give money too quickly, but with no sense of responsibility, funding microhydro plants that work for a few years and are then quickly forgotten about".

Community Attitudes

This option ranks very high in terms of community attitudes. In the previously mentioned PDP, unlike the small and medium projects, MHPs "were not prone to be targeted by insurgents during the protracted Maoist civil war, in part due to the extensive involvement of grassroots village communities in these projects".[lxix] The community interest in maintaining micro-hydro units further strengthens this option. Indeed, the World Bank "expected 5-10 percent of all microhydro units under the MHVE to 'fail,' due in part to the lack of maintenance but also the uncertain political environment," but instead "99 percent of all plants are still working technically," with failure rates between one and five percent.[lxx] Since the primary benefits of installing micro-hydropower systems are accrued by the community residents themselves, this option is seen as most favorable for and acceptable to rural communities.

Some social challenges associated with micro-hydropower systems include community disagreement over whether or not to pursue a MH project, equity concerns for access, and the role for electricity in agricultural processing.[lxxi] Specifically, as noted above, the time required for various agro-processing activities is drastically reduced using hydropower. Some community members argue that the electricity should be reserved for agro-processing exclusively, postponing rural electrification for households.

Financial Feasibility

In 2009, the Government of Nepal passed a wave of new subsidies for renewable rural energy technologies. Micro-hydropower falls under this new program, and the subsidy depends on the number of households that will be served by a given project. Table 6 displays the subsidy program for micro hydropower.

Table 6: Micro Hydro Subsidy Program (2009)

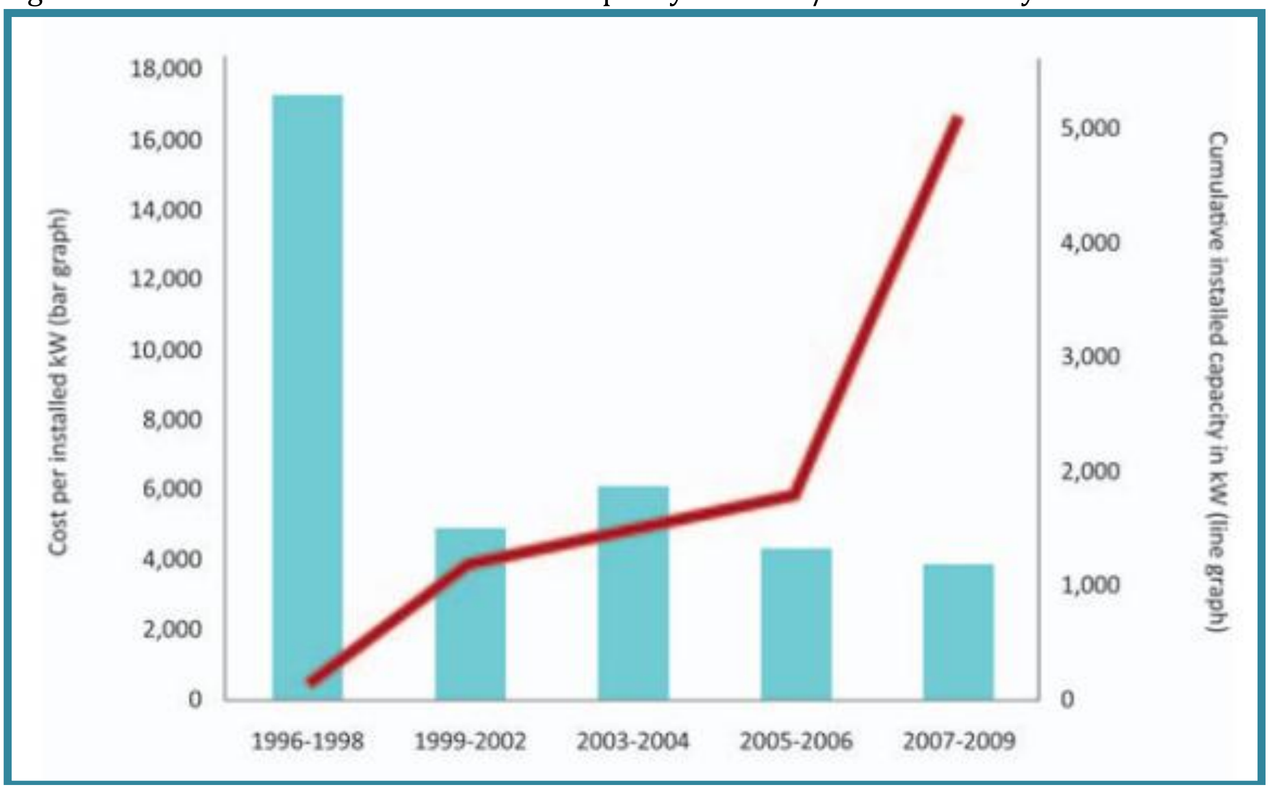
Micro hydropower Project	Subsidy amount per household ($)*	Subsidy ceiling ($/kW generated)*
New micro project (up to 5 kW)	137.50	1,117
New micro project (5 kW-500 kW)	172	1,432
Rehabilitation of micro project (more than 5 kW)	50 percent of the installation cost	716
Project to be installed for institutional and community use	1,117 (for plants up to 5 kW capacity)	344
Project with a business plan for productive use of energy	115 per kW	Not exceeding 2,864 per project

Source: CPEIR, 2011.
*Dollar amounts converted from Nepal Rupees (1 NR=0.01 USD)

Despite government subsidies for communities constructing micro hydro projects, they cover less than 40 percent of the total project cost, and the remainder is borne by developers.[lxxii] However, most Nepalese live on less than $1 a day, and average annual income is less than $200.[lxxiii] If an average micro-hydropower project costs between $1,279 and $1,779 per kW of output, and does not exceed 100 kW, we can assume a high-end cost between $127,900 and $177,900. Assuming the community pays twenty percent of total project cost, this requires between $25,580 and $35,580 per project constructed. The Micro-hydro Village Electrification (MHVE) project carried out by the World Bank and the Government of Nepal, among others, "distributed more than 250 [micro-hydro] units to 50,000 households.[lxxiv] Based on this information, one household would be responsible for providing between $128 and $178 to support the initiative. As mentioned above, this amount exceeds the total annual income for most families. Similarly, the heavily subsidized REDP cost beneficiaries around US$85 per person, still representing a significant investment for a poor Nepali family.[lxxv]

However, between 1996 and 2006 the MHVE and REDP initiatives noted significant improvements in technology leading to lower costs for installment. In ten years, "hardware costs declined 33 percent, and capacity development costs declined 84 percent," demonstrating that as these technologies become more proven and widespread, the cost of installment will serve as less of a barrier to implementation. Figure 5 depicts the change in installation cost and cumulative capacity of MHVE and REDP units over a thirteen-year period.

Figure 5: Installation cost and cumulative capacity of MHVE/REDP micro-hydro units



Source: Sovacool, 2011.

Although the installation costs of MHPs have fallen in the past 20 years, finding a viable source of funding is still an obstacle. The most likely option is to pursuing such as the GoN, ADB and World Bank, and the UNDP.

Equity

This analysis of MHPs found significant benefits for vertical equity, or distributing benefits to the most vulnerable members of society. In the case of Nepal, vulnerable members of society include the general rural population, more specifically women and children. Increased access to electricity in rural households increases consumption expenditures by 6 percent and non-farm income by 11 percent. Additionally, there are positive social outcomes associated with rural electrification, including girls' completed schooling years, lower incidence of respiratory problems for women and children, and overall women's fertility and empowerment indicators.[lxxvi]

However, in terms of horizontal equity, this option does not contribute to any short-term benefits for urban Nepalese, some 6 percent of whom still lack access to electricity. Micro-hydropower projects are located in far-reaching rural communities, and rarely include a grid connectivity aspect, although a growing number will likely be part of a mini-grid in the future as that technology becomes more prevalent. The overall contribution to development still ranks favorably, as the majority of Nepalese live in rural areas that would eventually be served by these projects. Raising rural incomes and fostering business creation in rural Nepal for 86 percent of the population will have long-term positive implications for the overall development.

Environmental & Health Impacts

Evidence from communities that have implemented MHPs indicates these projects have positive environmental and health impacts. In particular, the environmental benefits include a decrease in kerosene use and reduced firewood consumption. As a result, there has been a corresponding increase in "greenery" in communities, and prevention of some 517 tons of carbon dioxide emissions per year.[lxxvii]

As noted above, there was a marked decrease in incidence of respiratory problems for women and children in micro-hydro households versus women and children in households without connectivity.

Evaluation Summary of Alternative II: Micro-hydropower

Benefits
- $1,279 to $1,779 per kW of installed capacity
- Increase local incomes by an average of 8 percent
- Around 40 new businesses created per district following MHP installation
- Avoids costly extension of the national grid
- Addresses disparity between rural and urban electrification
- Precedent established through REDP, RERL, MHVE programs
- Government commitment to rural electrification
- No incidence of protest or sabotage from insurgents
- Government subsidy program and bank funders
- Decreased incidence of respiratory problems for women and children
- Lower reliance on fossil fuels and biomass
    - Households with MH access emit about 3.6 kilograms of carbon dioxide less than their counterparts
    - Greater energy independence
    - Reduce deforestation

Challenges
- Low interest from foreign funders (i.e. China and India)
- Technical challenges related to design and project sites, maintenance and manufacturing
- Economic efficiency losses from low plant load factors (meaning that electricity is not constant)
- Institutional challenges and aid dependency
- Community disagreement about electricity equity and usage
- Unclear environmental standards for project development

Evaluation of Alternative III: Mid-range projects between 1 and 100 MW

Cost-Effectiveness

Cost-effectiveness for this alternative was calculated by averaging the available cost per kW data for small-and-medium-scale hydroelectric projects in Nepal. Appendix 3 displays a list of projects and their average cost per kW. These costs have been indexed to 2013 prices.

To determine a range for the cost of small and medium scale projects, this analysis found average cost per kW data for 13 medium-scale projects and 17 small-scale projects in Nepal. These data (see Appendix 3) were obtained from the World Bank, ADB, and NEA reports. Then a weighted average cost per kW was determined for both the small and medium-scale projects, with the cost per kW of larger projects counting proportionally toward the average cost. These two weighted average costs make up the range for this option.

For the 13 medium-scale projects, ranging from 12 to 70 MW, the weighted average cost per kW installed was determined to be US$3,635. The 17 small-scale projects, with installed capacity between 0.1 and 10 MW, had a weighted average cost per kW of US$2,450. Therefore, the range for this option is quite wide, with weighted average costs between $2,450 and $3,635.

From this weighted average cost calculation, a range of the cost to increase Nepal's installed capacity by 300 MW was calculated using the same formula as the MH option. The cost range to increase capacity by 300 MW for the mid-range option was found to be between $735 million and $1.1 billion.[6] For small and medium projects, the wide range of average costs is indicative of the broad scope of this option, encompassing plants with capacity between 1 and 100 MW.

The World Bank calculated EIRRs for small hydropower projects constructed during the Power Development Project (PDP). This included four plants between 2.2 and 5 MW installed capacity. Each of these projects had EIRRs of around 30 percent.[lxxviii] The EIRR for two medium-scale projects in the PDP were estimated at 12 and 13.4 percent.[7] The Bank analysis recommended minimizing construction costs and improving plant efficiency to make these projects more viable. Overall, EIRRs for small (<10 MW) plants are more attractive than medium (10-100 MW), consistent with the findings for weighted average costs of small versus medium-size plants.

Discussion of further costs and benefits

In a comparison of hydropower options for developing countries, Williams and Porter found that small hydropower projects may not be cost-effective, as transmission and environmental mitigation costs are too high for many rural consumers and local communities to cover.[lxxix] Rural incomes are insufficient to cover the cost of micro-hydro projects, let alone small-scale projects. Typically, these projects are only viable when pursued by development agencies or foreign investors. However, this leads to the political infeasibility problem that has obstructed Nepal's hydropower development progress thus far. Equipment maintenance costs vary depending on the project, but the tariff levied on rural households may increase as a result of higher-than-projected costs.[lxxx] Therefore, in many cases ongoing assistance would be necessary to ensure rural households have the funding necessary to properly maintain equipment.

Himal Power Limited (HPL) began constructing the 60 MW Khimti hydropower project in 1993 and completed it in May 2000 at a total cost of US$140 million. Funders included the ADB, IFC and World Bank, and the Norwegian government. Despite numerous issues during construction, including "geological, logistical, and other local problems," the overall results were positive.[lxxxi] Khimti was Nepal's first completely private sector attempt at hydroelectric development. In addition to constructing the hydroelectric project, funders

[6] See Appendix 3 for calculations.
[7] See Appendix 4 for EIRR and FIRR data.

supplied money to build a project clinic and school. The clinic offers services that government funded health posts "are unable to offer," and treats "between 50 and 70 patients" every day.[lxxxii] Several of Nepal's medium-scale projects have included school or health facilities to provide local communities with an incentive to comply with development.

Job creation is often cited as a local benefit to communities where dams are constructed. However, in the case of the Khimti project, most laborers were brought in from abroad, with only a few low-level staff hired locally. The same analysis found that about 0.1 percent of the total revenue was distributed as income in Nepal, amounting to around US$115,000 (Shrestha, 2008).[lxxxiii] Government funding could address local employment concerns, but government expenditures on hydropower development remain low, never having exceeded 1.1 percent of GDP.

Feasibility

Political Feasibility

In terms of political feasibility, this option ranks fair, with greater past precedent than large-scale hydropower, but incorporates a comparatively longer regulatory process compared to that of micro-hydro projects. The Khimti I, Nepal's first medium-scale fully private sector project, established much of the existing framework of agreements. The government now provides: partial guarantees; fiscal incentives such as tax holidays; a greater degree of acceptance of foreign ownership; and fixed royalty payments.[lxxxiv] Additionally, in the 2002 Water Resources Strategy, the GoN emphasized developing small and medium projects to address domestic needs, with a longer-term goal of developing large projects for export.

Despite establishing a regulatory framework to facilitate private investment in the energy sector, the licensing process to pursue hydropower projects in Nepal remains confusing and is fraught with delays. In the case of the Nepal PDP, the World Bank restructured the project in 2008 to allocate more funds toward pragmatic and small-scale development. The report cited "delays in project implementation" due to the political environment as the primary reason for restructuring.[lxxxv]

Community Attitudes

Community response to mid-size hydroelectric projects in Nepal has been mixed. The acceptability of these projects is often dependent upon whether the host community receives any benefits. In the Khimti I case, the project school and clinic have improved the standards of living for households in several districts.

Contrary to micro-hydro projects, small- and-medium scale projects often alter communities and force relocation. This option is rated moderately in terms of community attitudes, as general attitudes are less favorable than for MHPs, but more favorable than large-scale dam construction. Violent protests and community activism are common in Nepal in response to large project proposals.

Financial Feasibility

There are many funding sources available for small and medium projects in Nepal. Khimit I was the first fully private sector project, operating under a regulatory framework established in 1992. Under this framework, private developers have a concessions period of up to 50 years, after which they transfer partial or whole ownership to the NEA.[lxxxvi] Developers must follow the agreed upon Power Purchase Agreement (PPA) rate, which is 5.52 U.S. cents per unit in the wet season and 9.65 U.S. cents per unit in the dry season, for projects up to 25 MW.[lxxxvii] However, for projects larger than 25 MW, rates are negotiated with the GoN. Provided that Nepal's government gains stability in the coming years, private financing will likely increase and small- and-medium projects will become more viable without relying on public funding.

Independent power producers (IPPs) and international developers provide funding for many small- and medium-sized hydropower projects. The Clean Energy Development Bank in Nepal has established a US$ 3 million development fund to conduct feasibility studies for small- and medium-sized projects, as these projects often suffer from an early-stage financing gap.[lxxxviii] Recently, the GoN has allowed 100 percent foreign direct investment in hydropower, which will likely induce greater interest in investment, but developers still must work with the NEA to distribute electricity. In the long-term, the GoN has expressed interest in privatizing and unbundling the NEA to facilitate IPP-developed projects and allocate more responsibility to communities.

Equity

The primary equity concern regarding this option is small and medium-scale projects are grid-connected in Nepal. Larger projects provide electricity to customers in relatively developed areas of Nepal, and do not increase connectivity for the 85 percent of the population living in rural communities. Further, negative health and environmental factors associated with dam development often disproportionately impact the immediate surrounding community. Therefore, this option has relatively poor outcomes in terms of vertical equity. If small- and-medium-scale projects include a transmission expansion that targets rural communities, they will better satisfy development needs and equity concerns in Nepal. Environmental assessments should account for the likely impacts of project development and provide compensation to address any inequities created.

Horizontal equity impacts are generally positive, with the majority of small- and medium-scale projects aimed at increasing the domestic energy supply.

Environmental & Health Impacts

Williams & Porter (2006) note when comparing the environmental impacts of different size dams, most experts agree that the larger the project, the greater the negative impact on wildlife, communities, and ecology. The vast majority of the negative impacts of hydropower projects are those inflicted upon the environment. In the construction and development process, acquiring building materials and carrying out construction are associated with greenhouse gas emissions. Additionally, dam construction alters river flow and obstructs fish migration. Therefore, during the planning and proposal process, mitigation measures such as fish ladders and pumps to control sediment displacement must be considered.

Small- and-medium projects typically use less intrusive construction measures than large-scale dams, such as low diversion weirs.[lxxxix] A thorough environmental assessment of the 60 MW Middle Marsyangdi identified several major issues with this type of dam construction, including: change in hydrology as a result of tunneling and excavation; drainage changes; soil erosion; sedimentation; land instability; loss of fish diversity; loss of terrestrial vegetation; and increased noise pollution during construction and operation.[xc]

The Middle Marsyangdi also resulted in negative impacts on the health and sanitation of the community from the increased exposure to an outside workforce. Additional health outcomes included the degradation of air quality, water quality, and solid waste.[xci] Despite these negative health and environmental outcomes, there are positive health impacts inherent in replacing traditional fuels with hydroelectricity. Indoor air pollution in Nepal far exceeds optimal levels, resulting in around 7,500 premature deaths annually.[xcii] Greater access to hydroelectricity provided by constructing small-and-medium-scale dams would combat the negative health and environmental outcomes associated with burning fuels for energy.

Evaluation Summary of Alternative III: Mid-range (small and medium) dams

Benefits

- Moderate cost per kW to install small schemes ($2,450/kW)
- Community benefits (clinics, schools) developed along with some projects
- Public and private funding sources available

Challenges

- High costs per kW for medium-scale projects ($3,635/kW)
- Political climate restricts financing from foreign investors and developers
- Few local jobs created if foreign-developed
- Distribution of electricity to on-grid users or for export sale
- Environmental and health impacts harm local communities
- Unclear environmental standards for project development

Evaluation of Alternative IV: Pursue large-scale hydroelectric projects

Cost-Effectiveness

Nepal has only completed one large-scale hydroelectric project to date. Construction on the 144 MW Kali Gandaki A began in 1997 and was completed in 2002. Since 2002, it has operated as a ROR plant producing around 592 GWh per year.[xciii] According to data collected by the Nepal Electricity Authority, the cost per kW of installed capacity for the Kali Gandaki A is USD$3,613.[8] As calculated in the other sections, the cost to increase Nepal's total installed capacity by 300 MW under this scenario would be around $1.1 billion.

The EIRR, as calculated in the ADB project review document of the Kali Gandaki, was estimated at 18.2 percent, compared with the projected EIRR of 15 percent.

Nepal's only large-scale dam ranks poorly with higher costs than both mid-range projects and micro-hydropower units. However, the 456 MW Upper Tamakoshi, a ROR plant that is under construction in Nepal, has a projected cost per kW of only US$1,000.[xciv] The Upper Tamakoshi has a low projected cost due to the great natural damming potential of the construction site. However, delays in construction, increasing machinery costs, and other unknown factors may cause the final cost to be higher than projected.[xcv] Large-scale projects require extremely high initial investments with a long return period, and therefore it is not the most optimal choice for addressing Nepal's energy crisis in the short-term. Furthermore, as discussed in the following section, much of the motivation behind developing large-scale projects is to generate electricity for export rather than domestic consumption. Increasing large-scale potential is not motivated by domestic connectivity concerns, and therefore does not address the problem at hand, namely, Nepal's insufficient electricity supply.

Discussion of further costs and benefits

One project with great potential is the jointly proposed 6,720 MW Pancheswor mega-dam,between India and Nepal. However, in the 16 years since India and Nepal agreed to pursue this joint venture, there has been no substantial progress in developing this project.[xcvi] Progress has stalled in this negotiation due to lingering mistrust between Nepal and India, as well as Nepal's political instability. On paper, the two countries have a history of cooperation in the energy sector, with five signed treaties fostering cooperation and management of common resources. However, many in Nepal view these treaties as unequal, with India receiving a disproportionate share of benefits in these arrangements.[xcvii]

Equality concerns linger, as some critics of large-scale dams contend that Nepal will receive poor returns from foreign-developed projects. In the case of the proposed 750 MW West

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[8] Cost adjusted to 2013 price levels.

Seti, the project would generate around 3,636 GWh of energy annually. The ADB project analysis indicates that by exporting this energy to India, the direct economic benefits to the GoN will amount to US$33 million annually, totaling $991 million over the 30-year license period (ADB, 2007).[xcviii] Critics of the project note the majority of export earnings will be spent on dam operation and maintenance, taxes and royalties to the government, and loan repayment. Provided India and Nepal are able to mitigate bilateral mistrust, the potential for cross-border energy exchange is great, and India is the likely funder of and destination for the majority of Nepal's eventual electricity exports.

As noted in the analysis of the mid-range alternative, foreign laborers often fill jobs created by foreign directed projects. Therefore, as many of Nepal's large-scale dams would rely on foreign direct investment, any benefits to local salaries or employment prospects are unclear.

One clear benefit of developing large hydropower projects is the potential for export revenue to bolster Nepal's struggling economy. In the case of Bhutan, the government-directed development of the hydropower sector has turned hydropower into one of the main drivers of economic growth. With an overall potential of around 30,000 MW, Bhutan has developed only 1488 MW (around 5 percent), and in 2009 this made up almost 19 percent of GDP.[xcix] Overall, hydropower made up around 39 percent of Bhutan's exports in 2009, with a goal of 80 percent by 2021. Nepal has similarly high potential to turn into a driver of domestic economic growth, and should look to Bhutan as an example of successful hydroelectric development.

Feasibility

Political Feasibility

The biggest proponent of large-scale dams is the GoN. Large dams would take advantage of Nepal's rich water resources and capitalize on the nation's "liquid gold". Although the government is eager to build large-scale schemes, it faces opposition from Nepal's "active civil society keener on small-scale hydropower".[c] The GoN views large dams as a source of export revenue that could bolster Nepal's struggling economy and promote national growth and development.

Despite government interest in developing large-scale hydroelectric projects, political instability and local resistance have served as major obstacles to dam construction. The Snowy Mountain Engineering Group (SMEC), an Australian company, completed a feasibility study for the Kali Gandaki A in July 1979, but the project did not begin until 1997 and was completed in 2002.

In 1995, the World Bank withdrew funding from a 404 MW hydroelectric project (Arun III) scheduled for development in northeastern Nepal as a result of outspoken community criticism.[ci] The Arun III would have produced electricity mainly for urban areas with national grid connectivity. In addition to community outcry, the World Bank Inspection

Panel found that the Nepalese government and the World Bank did not create a sufficient land compensation and resettlement plan for the rural Nepalese who would be affected by the structure.

Prior to the Maoist insurgency, the Government of Nepal awarded the SMEC development rights for the 750 MW West Seti project. However, the project has been at a standstill due to opposition from the Maoist faction to "awarding economic deals to foreign companies and citizens' anger over the export of electricity at the expense of domestic needs".[cii] Political instability and an unclear regulatory process have thus far prevented large-scale development from making measurable progress. This will likely continue to be the case, thus making large-scale projects infeasible in the short-term.

Community Attitudes

Community attitudes are another barrier to the development of large-scale hydroelectric projects in Nepal. During construction of the Kali Gandaki, militant behavior of some local Nepalese caused project delays.[ciii] Additional issues with locals included community strikes; ultimatums from communities; and occasional violent conflict between project developers and locals. Further, construction on the project transmission line was delayed when a local refused to sell his land the line was projected to pass through.[civ] Overall, the project impacted 12 villages in Nepal and affected the assets of 1,468 families. Out of these families, 263 were "seriously project-affected" and 1,205 were "project-affected".[cv] In the case of the West Seti, construction would have displaced more than 15,000 people from their homes.

Positive impacts of the Kali Gandaki for local communities include increased access to: "electricity, roads, water transport, local markets, schools, and water supply".[cvi] Despite these positive impacts for general development of rural communities, mitigation efforts have "not been very effective" in either adding to development opportunities or addressing negative environmental impacts.[cvii]

Financial Feasibility

Funding for large-scale projects is available from neighbors like India and China who are interested in gaining access to Nepal's vast hydroelectric potential to supply future energy needs. However, the Nepalese are resistant to the acquisition of projects by foreign investors, who have indicated their willingness to develop in Nepal for years.[cviii]

Similarly, regarding small- and-medium-scale alternatives, although there are numerous donors interested in developing hydroelectric projects in Nepal, the political climate dissuades investment.

Equity

Developing large-scale hydroelectric projects is rated poorly for equity concerns, as the electricity produced would primarily benefit urban Nepalese or be sold for export. These equity concerns could be addressed in part if this option includes an expansion of Nepal's electric grid to reach more rural communities. However, as mentioned before, national grid expansion at this time is neither technically nor financially viable. Much of Nepal's rural populace is located in extremely hilly and far-flung areas, and it will be years if not decades before the national grid is extended to these communities.

Although rural Nepalese would not be the primary beneficiaries of large-scale projects, most of the negative impacts associated with dams would be borne by rural communities. In addition to resettlement and population displacement concerns, to repay loans the World Bank required an increase in the electricity tariff for the whole country. Although they did not benefit from connectivity as a result of the Kali Gandaki construction, rural Nepalese faced an increase in their electricity tariff.

Developers often cite job creation as a local benefit to large-scale dam construction. However, countries such as China often bring in workers fromabroad. Further, hydroelectric facilities require minimal human and energy inputs once completed. Even in the case of the Kali Gandaki, where employment opportunities were created for about 106 project-affected families and 100 additional local Nepalese, a follow-up assessment found that the training-acquired skills did not last in the communities.[cix]

Environmental & Health Impacts

Some of the environmental impacts of large-scale dams include: inundation, impacts on biodiversity and wild habitats. Additionally, critics have raised concerns regarding dam safety along the seismically active Himalayas. The project assessment for the Kali Gandaki noted that environmental and social protection based on existing regulations continue "to be at a lower scale than should be the case for a country with extensive hydro potential in world heritage setting".[cx] Specifically, the project reportedly has increased the risk of flooding and inundation at several religious and heritage sites.

The Nepalese economy relies heavily on agriculture, and any large-scale projects should be designed to account for changes in river flow that may negatively impact farmers downstream.

According to the project completion report, one beneficial impact of the Kali Gandaki A was the "displacement of inefficient and polluting diesel generators burning expensive imported fuels for industrial and commercial consumers, and switching from kerosene to electric lighting for rural consumers".[cxi] There are indeed benefits to pursuing large-scale projects to further decrease Nepal's reliance on fossil fuels. However, given the uncertainty surrounding the quantity of hydroelectricity that would be consumed domestically versus sold for export, the overall environmental benefits are unclear.

Evaluation Summary of Alternative IV: Large-scale hydropower

Benefits

- Wide availability of funding from India, China, and development banks
- Relatively high EIRR (18.2 percent)
- Lower projected cost of future projects such as Tamakoshi may increase economic viability
- Potential export revenue could have tremendous impact on Nepal's domestic economy
- Opportunity for collaboration with India
- Positive local impacts, including electricity supply, water transport, and general development benefits
- Displacement of non-renewable energy and decreased reliance on fossil fuels

Challenges

- Only one successfully completed large-scale project
- Cost per kW of installed capacity is relatively high at $3,613
- Extremely high initial investments and long return period makes large-scale unfitting to solve current energy crisis
- Concerns about domestic benefits from foreign-developed projects
  - Domestic anger and equity concerns about export of electricity being prioritized over domestic development
- History of failed or difficult large-scale projects (Arun III, West Seti).
- Rural resettlement and negative environmental impacts from inundation
- Unclear environmental standards for project development

PART VI: Summary

Table 7. Cost-effectiveness summary table

Cost criteria	**Policy Alternatives**			
	Status Quo	Micro (<100 kW)	Mid-scale (1-100 MW)	Large-scale (>100 MW)
Average cost (US$/kW)	--	$1,279-1,779	$2,450-3,635	$3,613
Total cost to increase by 300 MW	--	$384-$534 million	$735 million-1.1 billion	$1.1 billion
EIRR	--	8.3-12.2%	30.4-33.4% (S) 12-13.4% (M)	18.2%

Decision Matrix

The following decision matrix summarizes the evaluation of each of the four policy alternatives based on all four of the primary criteria. Each has been assigned a score between 1 and 5 depending on how well it satisfies each criterion. In this matrix, 1 represents the lowest score and 5 represents the highest score. This facilitates comparison of each alternative based on the desired outcomes.

Criteria	Outcomes	Policy Alternatives			
		Status quo	**Micro (<100 kW)**	**Mid-scale (1-100 MW)**	**Large (>100 MW)**
Cost considerations	Average cost (US$/kW)	--	5	4	3
	Operate within national infrastructure	4	3	3	2
	Revenue generated	0	0	2	4
	EIRR	--	2	4	3
Feasibility	Political	5	4	3	2
	Community attitudes	3	5	3	2
	Financial	2	3	4	4
Equity	Vertical	2	4	3	2
	Horizontal	2	3	3	3
	Population resettlement and displacement	3	5	3	2
Environmental & health impacts	Beneficial environmental impact	3	4	3	2
	Positive health impact	3	4	4	4
Totals		27	**42**	39	33

PART VII: Recommendation and Implementation

Recommendation

This report recommends pursuing micro-hydroelectric development in Nepal to see more immediate results in increased electrification for rural Nepalese. Although micro projects fail to fully capture Nepal's vast hydroelectric potential, the economic, social and environmental benefits of pursuing these projects are undeniable. Mini-grid technology should be further developed to increase reliability and cost viability of hydroelectricity in rural Nepal. In addition to addressing Nepal's problem of insufficient electricity, the potential impact of micro-hydropower units on agro-processing should be considered. Constructing micro projects now may help pave the way for small, medium, and large-scale projects in the future. Pending greater political stability and financial sector transparency, the growth of Nepal's hydropower sector will expand even further down the road.

Potential Concerns

Increasing micro-hydroelectric development in Nepal presents a politically, socially, environmentally, and cost-efficient strategy for increasing Nepal's installed hydroelectric capacity. However, it is important to note that domestic political instability and poor regulatory climate remains a barrier to the overall national development. The following steps must eventually be realized to facilitate hydroelectric development in Nepal:

1) Pass a permanent constitution

   Potential investors and other international partners see Nepal's lack of a permanent constitution as a sign of lingering instability and as a deterrent to pursuing hydroelectric projects in Nepal. The appointment of Nepal's chief justice as head of the interim government marks an important step in moving toward a new constitution, but until the drafting process is complete this will remain a great barrier to development in Nepal.

2) Create a community mapping and resettlement plan

   Dam construction disproportionately affects vulnerable populations such as rural or indigenous groups. The Government of Nepal (GoN) should establish baseline criteria to promote effective resettlement for communities whose homes or livelihoods are impacted by hydropower development.

3) Build up domestic and cross-border grid abilities

   Although constructing a comprehensive national grid is unfeasible both technically and financially at this time, the GoN should recognize the necessity of building up mini-grids in inaccessible localities, while expanding the national grid to areas wherever feasible. This will help to provide more a reliable and cost-effective source of electricity to Nepalese across the country. Recognizing the great export potential to India, as well as the possible benefits of importing electricity during the dry season or times of drought, the GoN should pursue cross-border grid development to facilitate this transaction.

4) Facilitate foreign investment

    One company, Global Renewable Infrastructure Development (GRID), is attempting to break the barrier for foreign investors by working with local partners in Nepal. According to CEO Nenad Kostic, his company's affiliation with a local partner has enabled them to penetrate the market in Nepal, and they are now in final negotiations to develop three mid-range projects.[cxii] Significant progress has been made on this front with the implementation of measures such as enabling investors to recover profits from development projects and more favorable PPA tariffs.

5) Establish standardized environmental impact assessments

    Similar to creating a community mapping and resettlement plan, establishing reliable and consistent environmental protocols for hydropower project development would help ensure a thorough review of potential ecological damage that proposed development could inflict.

Implementation

The first step of implementing an expansion of Nepal's current micro-hydropower capacity is to increase funding for MHPs. Many of the projects designed to target micro-hydro expansion, such as the REDP, PDP, and REP, were only funded through 2012.[cxiii] There are a wide array of potential funders to consider, including major development banks, the GoN, and foreign investors such as DANIDA and NORAD. Based on World Bank experience from the Nepal PDP, larger micro schemes should be pursued, as projects with capacity above 25 kW receive greater rates of return.

The GoN currently spends around $35 million annually on petroleum imports from India. To reduce dependence on foreign energy supplies and build up renewable capacity, the government could allocate some of this money toward scaling up micro-hydro initiatives.

After funding is secured, the GoN along with development banks and foreign investors, should identify and select new communities for development. This can be done using selection criteria similar to those used by the World Bank in the Power Development Fund micro-hydro initiative. These criteria include: availability of micro hydro potential; potential for poverty reduction; extent of grid coverage or grid viability; demonstrated commitment to financial support; not located in the Kathmandu Valley; and target areas that have not received similar development opportunities.[cxiv]

Finally, development plans should incorporate community engagement and training, as projects with high community participation have experienced more success. These steps will help to scale up micro-hydropower development in Nepal and address the country's energy crisis in the short term.

Appendices

Appendix 1. Existing power projects in Nepal*

Name	Capacity (kW)	Micro (MHP), Small (S), Medium (M) or Large (L)	Owned by	Type
Major Hydropower Projects				
Kali Gandaki "A"	144,000	L	NEA	PROR
Marsyangdi	69,000	M	NEA	PROR
Khimti	60,000	M	HPL	ROR
Kulekhani I	60,000	M	NEA	STO
Bhotekoshi	36,000	M	BKPC	ROR
Kulekhani II	32,000	M	NEA	STO
Trisuli	24,000	M	NEA	ROR
Chilime	20,000	M	CHC	PROR
Gandak	15,000	M	NEA	ROR
Modi Khola	14,800	M	NEA	ROR
Devighat	14,100	M	NEA	ROR
Jhimruk	12,000	M	BPC	ROR
Sunkosi	10,050	M	SHPC	ROR
Indrawati	7,500	S	NHPC	ROR
Puwakhola	6,200	S	NEA	ROR
Andhikhola	5,000	S	BPC	ROR
Small Hydropower Stations				
Chatara	3,200	S	NEA	ROR
Piluwa	3,000	S	AVHDC	ROR
Panauti	2,400	S	NEA	ROR
Tatopani/Myagdi (I) & (II)	2,000	S	NEA	ROR

Chaku Khola	1,500	S	Alliance Power	ROR
Seti (Pokhara)	1,500	S	NEA	ROR
Fewa (Pokhara)	1,000	S	NEA	ROR
Tinau (Butwal)	1,024	S	NEA	ROR
Sundarijal	640	S	NEA	ROR
Pharping	500	S	NEA	ROR
Jomsom	240	S	NEA	ROR
Baglung	200	S	NEA	ROR
Small Hydropower Stations (Isolated/no national grid connectivity)				
Dhankuta	240	S	NEA	ROR
Jhupra	345	S	NEA	ROR
Doti	200	S	NEA	ROR
Phidim	240	S	NEA	ROR
Gorkhe	64	MHP	NEA	ROR
Jumia	200	S	NEA	ROR
Dhading	32	MHP	NEA	ROR
Syangja	80	MHP	NEA	ROR
Helambu	50	MHP	NEA	ROR
Darchula	300	S	NEA	ROR
Chame	45	MHP	NEA	ROR
TapleJung	125	S	NEA	ROR
Manang	80	MHP	NEA	ROR
Chaurjhari	150	S	NEA	ROR
Syarpudaha	200	S	NEA	ROR
Khandbari	250	S	NEA	ROR
Terhathum	100	S	NEA	ROR
Bhojpur	250	S	NEA	ROR
Ramechhap	150	S	NEA	ROR
Bajura	200	S	NEA	ROR
Bajhang	200	S	NEA	ROR
Arughat Gorkha	150	S	NEA	ROR
Ikhaldhunga	125	S	NEA	ROR

Rupalgad	100	S	NEA	ROR
Surnaiyagad	200	S	NEA	ROR
Achham	400	S	NEA	ROR
Dolpa	200	S	NEA	ROR
Kalikot	500	S	NEA	ROR
Heldung	500	S	NEA	ROR

Derived from USAID South Asia Regional Initiative for Energy (SARI) data, 2012.
Note: PROR=Peaking run-of-river; ROR= run-of-river; STO=storage
*This only includes a few major micro-hydro projects, as there are around 2,500 units in Nepal.

Appendix 2. Under construction, planned, or proposed projects in Nepal

Name	Capacity (kW)	Micro (MHP), Small (S), Medium (M) or Large (L)
Under Construction		
Upper Tamakoshi	309,000	L
Middle Marsyangdi	70,000	M
Chamelia	30,000	M
Kulekhani No. 3	14,000	M
Gamgadhi	400	S
		Total: 423,400 kW
Planned and Proposed		
Upper Trishuli-3 ‘A’	60,000	M
Upper Trishuli-3 ‘B’	37,000	M
Budhi Gandaki	600,000	L
Rahughat	30,000	M
Upper Seti (Storage)	128,000	L
Seti Trishuli (Storage)	128,000	L
Upper Modi ‘A’	42,000	M
		Total: 1,025,000 kW

Derived from USAID South Asia Regional Initiative for Energy (SARI) data, 2012.

Appendix 3. Average cost calculations

1. Large-scale projects

Project name	Installed Capacity (MW)	Year Commissioned	Cost per kW (adjusted to 2013 price levels, US$)
Kaligandaki 'A'	144	2002	3613.46

Source: Nepal Electricity Authority

2. Mid-range projects

Medium-scale

Project	Installed Capacity (MW)	Cost per kW (adjusted to 2013 price levels, US$)	Weight	Weighted cost
Marsyangdi	69	6012.72	0.151017728	908.0273145
Middle Marsyangdi	70	5529.64	0.153206391	847.1761873
Kulekhani 1	60	4560.22	0.131319764	598.8470125
Kulekhani 2	32	1052.44	0.070037207	73.70995842
Trisuli	24	828.15	0.052527905	43.5009849
Gandak	15	464.76	0.032829941	15.25804334
Modi Khola	14.8	2734.63	0.032392208	88.58070475
Devighat	14.1	1582.98	0.030860144	48.85099146
Khimti Khola	60	3147.62	0.131319764	413.3447144
Bhotekoshi	36	2855.4	0.078791858	224.9822718
Chilme	20	2039.11	0.043773255	89.25848107
Jhimruk	12	2579.35	0.026263953	67.74392646
Kabeli-A	30	3292.39	0.065659882	216.1779383

Total weighted average cost for medium scale projects: 3635.46

Small-scale

Project	Installed Capacity (MW)	Cost per kW (adjusted to 2013 price levels, US$)	Weight	Weighted cost
Indrawati 3	7.5	3442	0.090689238	312.1523579
Andhi Khola	5.1	655.62	0.061668682	40.43122128
Khudi	3.5	2665.61	0.042321644	112.8129988

Piluwa Khola	3	1830.99	0.036275695	66.42043531
Sunkosi Small	2.5	2012.15	0.030229746	60.82678356
Thoppalkhola	1.7	2988.03	0.020556227	61.42262394
Chakukhola	1.5	3452.79	0.018137848	62.62617896
Phemekhola	1	1838.54	0.012091898	22.23143894
Sisnekhola	0.8	1471.91	0.009673519	14.23854897
Sangekhola	0.1	1692.97	0.00120919	2.047122128
Mailun Khola	5	2386.38	0.060459492	144.2793229
Belkhu Khola	2.2	1793.15	0.026602177	47.70169287
Rahughat	27	3322.05	0.326481258	1084.587062
Sunkosi	10	778.55	0.120918984	94.14147521
Puwakhola	6.2	3416.12	0.07496977	256.1057316
Chatara	3.2	964.02	0.038694075	37.30186215
Panauti	2.4	1063.23	0.029020556	30.855526

Sources: BPI; World Bank; ADB

Total weighted average cost for small-scale projects: 2450

Micro-hydropower projects

Average cost data for MHPs were derived from the UNDP Rural Electrification Development Programme (REDP), which estimates a unit cost of $1,279-$1,779 per kW generated.

The REDP alone has installed 317 micro-hydropower systems in Nepal. It is estimated that since the 1970s, an estimated 2,500 micro hydro projects have been completed in 40 districts in rural Nepal, generating a total of around 17,000 kW of electricity. Cost and capacity data are not available for all of these projects, and such a comprehensive cost analysis is beyond the scope of this report. Therefore, average cost data from the REDP serves as an approximation for average cost to build future MHPs in Nepal.

Appendix 4. EIRR data

EIRR data for small, medium, and micro-hydro projects were gathered from the World Bank Power Development Project (PDP) appraisal document. EIRR data for the Kali Gandaki A was retrieved from the ADB performance evaluation report.

Small hydro projects	
MW	EIRR
5	30.5
2.2	32.4
2.6	30.4
3.9	33.4

Medium projects	
MW	EIRR
27	13.4
30	12

Micro schemes	
MW	EIRR
0.015	8.3
0.025	10.9
0.035	12.2

Large-scale	
MW	EIRR
144	18.2

Endnotes

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