Bangladesh's Energy Policy: Economic, Environmental, and Climate Change Impacts

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Bangladesh’s Energy Policy: Economic, Environmental, and Climate Change Impacts

A Dissertation Presented

By

ROHINI KAMAL

Submitted to the Graduate School of the University of Massachusetts Amherst in partial fulfillment of the requirements for the degree of Doctor of Philosophy

September 2019

Department of Economics
Bangladesh’s Energy Policy: Economic, Environmental, and Climate Change Impacts

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This dissertation is every bit the result of the dedication of my supervisors as it is my own work. I would also like to thank all of my mentors over the years. I would not have made it here without my mentors’ kindness and faith in me. Thank you all for making so much time and being there for me. I would like to thank Mahsoun, my family, and my friends for supporting me through my all the tricky times, especially through my health issues. Very little of what we achieve is just us, but is rather due to the input from all our support systems; indeed my wish to do a doctorate was very much influenced by my father’s own unfulfilled dreams during his graduate studies, and so it can be argued that the origins of this work was founded long, long before my life began! I want to thank everyone in Bangladesh who helped me get all the data that went into this work: the Planning Commission; Dr. Selim Raihan of South Asian Network on Economic Modeling (SANEM); Khaled Mahmud, Chair of the Power Development Board; and Professor Wahidduddin Mahmud for making key phone calls! Lastly, I want to remember my grandfather, who would have been immensely proud. My Nana and Ma are my two biggest inspirations in life. Ma this one is for you, you made me who I am.
ABSTRACT

BANGLADESH’S ENERGY POLICY: ECONOMIC, ENVIRONMENTAL, AND CLIMATE CHANGE IMPACTS

SEPTEMBER 2019

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The research examines Bangladesh’s energy policies with respect to development, climate change, and environmental risks by comparing three plans for 2050: business-as-usual (BAU), a government renewable plan, and an alternate green plan, along five aspects: investment costs, employment, greenhouse gas (GHG) emissions, environmental costs, and social costs. The model used is an Input Output Model, which calculates factor inputs (land, water, labor, emissions: GHG and co-pollutants) for energy-related sectors considered in the three plans. To apply the model to specific plants for a more accurate estimate of localized environmental and social costs, and to analyze distributional impacts, a supplemental field-study was conducted for fossil fuel and renewable energy plants at two different locations in Bangladesh.
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CHAPTER 1
INTRODUCTION

1.1 Summary

The research examines Bangladesh’s energy policies with respect to development, climate change, and environmental risks. Specifically it compares three energy plans for 2050: business-as-usual (BAU) based on current energy investment trends, a renewable plan put forth by the government of Bangladesh, and an alternate green plan. The first two plans are obtained from government reports and the third plan is built to limit per capita GHG emissions to 1.8 metric tonnes carbon dioxide equivalent (CO$_2$e) by 2050 by investing a small percentage, 0.81 percent, of Gross Domestic Product (GDP) in renewables and efficiency measures. The energy mix is based on cost estimates on renewable energy production and efficiency measures. The plans thus differ according to the different energy sources, the mix and the percentages used of each source to meet energy demand, and efficiency investments.

The model used is an Input Output Model, which calculates factor inputs (land, water, labor, emissions: GHG and co-pollutants) that go into a unit investment in different sources (coal, oil, gas, solar, hydropower, wind) and in energy saving through efficiency measures (transit rail, grid, building upgrades), thus allowing a comparison between investing in the three plans. Though the framework estimates
overall impacts at a national level, it does not show site-specific environmental and social impacts, nor which groups benefit or lose out from the different policies. To this end an in-depth case study examines localized impacts on the community and environment, including a review of policies that moderate these impacts.

The dissertation begins with **Chapter 1 Introduction** that provides the summary and motivation for this work, including a climatic overview for Bangladesh. The key aim of this research is to evaluate different paths for Bangladesh’s energy future by comparing three options for the country’s trajectory for the year 2050. The first step is to thus project energy demand for 2050 and to identify the key energy-related sectors in **Chapter 2**. **Chapter 3** builds the three energy plans considered in this research from the nine energy-related sectors identified previously. **Chapter 4** presents the Input Output methodology used in the research to compare the plans along the five key aspects of power generation that pertain to socio-economic and environmental concerns. **Chapter 5** presents and discusses the results of the Input Output analysis. Chapters 2-5 together thus present the national level impacts of different energy paths in Bangladesh using Input Output (IO) analysis. In the next two chapters, Chapters 6-7, the research turns its focus on project-level and impacts. Land-impacts are estimated for two energy sources in **Chapter 6** using the IO analysis. **Chapter 7** considers distributional impacts and policies moderating these impacts.

The first theme of **Chapter 2, Energy Overview** is to project energy demand for 2050
Energy projections are based on the current energy mix and its future trajectory in terms of level of development, overall economic activities, energy use, rate of urbanization, rate of access to electricity, and population growth. The chapter explains how these factors can be expected to change over the coming decades, based on which energy demand for 2050 is determined in Section 2.1. Next, the chapter considers ways in which to meet this projected demand. I do this in Section 2.2 by reviewing the state of affairs and prospects for energy production and efficiency measures in the country, and by looking at the cost per unit energy associated with each measure. The chapter identifies nine key energy-related sectors that include power generation and efficiency measures. These nine sectors then allow us to consider national energy plans for the economy for 2050.

**Chapter 3: The Plans** begins with a brief introduction of the three energy plans considered in this research, built from the nine energy-related sectors identified in the previous chapter. The first two plans can be described as i) the current path given what has been happening till date and ii) the most likely alternative given government renewable policy objectives. The first two plans are obtained from government reports. However, when we estimate GHG emission, we find that these two plans fall woefully short of what is globally required to limit warming to 2 degree Celsius. Thus a third plan an alternative is presented, built around a lower emission target for 2050.
The main objective of this chapter is to present an alternate green plan based on the same nine energy-related sectors presented in Chapter 2 but with the aim to limit GHG emissions, even as the economy continues on its high growth rate path. I do this by choosing an emission target for Bangladesh, based on warming probabilities and an equity approach given Bangladesh’s level of development and cumulative emission levels. In addition, the cost of such a proposal is presented in Section 3.3. The chapter considers the climate change impact, as estimated in Section 3.4 through GHG emissions, of the three energy alternatives for Bangladesh. The GHG emissions for the plans are estimated from estimates of emission per unit energy for the three fossil fuel sources, which combine in different ratios to constitute the three plans.

The chapter finds that for a 50 percent chance of limiting warming to the target amount, per capita emission in Bangladesh for 2050 must be 1.8mt CO$_2$e. This is possible through a certain amount of expansion in clean renewable sectors and efficient investments. Using cost of power generation for clean renewables and efficiency measures, the chapter concludes that this can be achieved through investing 0.81 percent of the country’s GDP in these sectors every year till 2050.

**Chapter 4 Input Output Model** presents the method used in this research to compare different energy paths for 2050. In the previous chapter, three options for Bangladesh’s energy future were presented based on current trends, the most-likely alternative based on government renewable targets, and an alternate green plan
that has much lower GHG emissions in light of climate change concerns. In Chapter 4, I finally compare the plans along the five key aspects of power generation that pertain to socio-economic and environmental concerns. The chapter begins by describing how the comparison is done, in other words the method used.

The research uses an Input output or IO model which estimates how much of these factor inputs (capturing the five key aspects of power generation) are associated with each plan, not just in the direct production of energy but in all upstream economic activities. The details of the model are presented in Section 4.1. The Input Output (IO) framework is used to calculate factor inputs (land, water, labor, emissions: GHG and co-pollutants) associated with $1 invested in the nine energy-related sectors (coal, oil, gas, solar, hydropower, wind, and three efficiency measures). I can then calculate the factor inputs that go into the three plans. Section 4.3 of the chapter provides more information on these inputs, in other words the variables considered. The next chapter presents the total estimates of the five factors for the three national energy plans.

**Chapter 5 Factor Input Estimates** begins by looking at which of the twenty-five industries in the IO table are included in the energy-related sectors, and by what fraction, in terms of per dollar invested in the sector. Next it considers at the extent to which each energy-related sector is included in the three plans considered. Once I have the factor inputs for the nine energy-related sectors I use the weights of the sector for each plan to estimate the factor inputs for the three plans. The results
show that the alternate green plan requires the least land and water (direct and indirect) for US$1 investment in each plan. Given that Bangladesh is land-constrained, and given the dependency on land for agricultural needs in Bangladesh, the results show that overall the alternate green plan is socio-economically and environmentally suited for the country.

Though the estimates show that the alternate green plan requires the most energy for upstream activities per dollar invested, for the purpose of this research energy input is only calculated to estimate the total, direct and upstream, emissions under the three plans. The alternate green plan is designed to produce the least direct GHG emissions from power generation of the three plans considered. Upstream emissions to produce the energy under three plans are calculated from the direct and indirect energy inputs for the three plans. We find that the alternate green plan, produces the least upstream GHG emissions and that the government plan produces the most. For emission of copollutants, the results show that the government plan produces the most copollutants, which is not surprising since it is the most coal intensive of the three plans.

In Chapter 6 IO Application for Project Level Impact the IO model is used to estimate the impacts on land from power generation. We know that for 2050 the greatest expansion in power generation comes from coal under the government plan and solar under the alternate green plan. We also know the land impacted varies widely for the two sources. The land-impact input includes degraded or partially used land
estimated from secondary research on the specific power plant using studies on its environmental impacts. Because of the site and project specific impact on land, two individual plants, one coal and one solar, were chosen to demonstrate the land-impact variable.

Section 6.1 looks at the land-use results from Chapter 5 and develops a way to apply it to gauge land impacted by individual plants. Section 6.2 describes the model used to capture the land-impacted variable for individual plants. The first power plant analyzed here is coal-powered and I use the land-use multiplier matrix from our previous estimates for the coal sector. In Section 6.3 I apply the Input Output (IO) results for the land impact variable to the Barapukuria coal plant. Next I use the land-use multiplier matrix from our previous estimates for the solar sector to estimate land impacted by the proposed Kaptai solar plant.

This chapter thus supplements the previously estimated land-use estimates for coal and solar with new estimates for land impacted by a solar plant and a coal plant. I next estimate the land-intensity for land use and land impacted but for unit energy produced instead of dollar invested under the two sources. Coal power generation is less land-intensive per unit energy output than solar. For a land-constrained country like Bangladesh this is understandably a concern that could explain the coal intensive path laid by the government. However the results from Chapter 7 shows that once we take into account the upstream and indirect impacts of the two sources, coal becomes almost as land intensive as solar. This coupled with the
emission-intensity and water-use impacts considered in this research, suggest that a more solar-intensive energy path is suited for Bangladesh considering key aspects of power generation.

Chapter 7 Field Work Barapukuria Coal Plant takes an in-depth look at the on-ground impacts of power projects in Bangladesh, with the aim to gauge the ways in which vulnerable communities will be potentially impacted by the government plan, which is the most-likely energy future of Bangladesh given current policies. The aim of this research is to not only demonstrate how the framework can be applied to the land impacted variable that incorporates environmental and social impacts, but to also examine the distributional effects of power plants. Though the IO model gives overall impacts, it does not show which groups benefit or lose out from the different policies. Chapter 7 examines this through a case study on Bangladesh’s one existing coal plant in Barapukuria, focusing on five key aspects of power generation: financing, employment, other socioeconomic aspects, environment and climate change. The chapter also examines the different policies moderating these impacts.

The chapter starts with a background of the power plant. Section 7.2 identifies the key players along the different types of impacts considered. The findings from the case study are presented in Section 7.3. For this case study, five sets of relevant policies were reviewed in Section 7.4 that have the potential to moderate the above impacts. This includes those of the host country Bangladesh and the financier China Export Import Bank. More generally, given the role of China as Bangladesh’s main
energy partner, China’s policies on overseas investments are also relevant. Future coal plants in Bangladesh will include private finance, which are governed not only by the country’s policies but can also be governed by the Equatorial Principles for signatories. Thus the Principles was referred to as a benchmark for private investment and reviewed. The policies of the Asian Development Bank or ADB were reviewed and served as a benchmark for international standards for policy banks. These five sets of policies were examined, with respect to their relevance to and their implementation in Barapukuria.

And finally Chapter 8, the concluding chapter, examines if the country’s current path and future plans are at all suitable based on the findings from previous chapters. This research provides an alternate plan for 2050 and a framework with which to examine the key impacts of a country’s energy policy. The last chapter analyzes the impacts of the alternate plan, summarizes the findings from the new framework and provides ways in which the framework can be used to create policies that more adequately address socio-economic and environmental concerns of Bangladesh. The chapter ends with policy recommendations based on the review of safeguard policies in the previous chapter.

1.2 Motivation
My work is motivated by the three risks mentioned above, namely, development, climate change and environmental risks; focusing on energy allows us to address all three. These challenges are perhaps visible nowhere more than in Asia. Asia is now witnessing the confluence of various global phenomena that will shape our planet for centuries to come. It is a region with the fastest growth in population and immense developmental needs including in energy and infrastructure, while facing environmental and climate change risks. It is also experiencing the fastest growth in markets and of financing capacity, so that we are seeing a shift away from Western-led financing towards Asia.

In many ways Bangladesh is at the epicenter of these discussions. Bangladesh has among the most concerning levels of poverty on the planet, is among the most vulnerable to climate change, and has a disturbing mix of fossil fuel power plants on the horizon. What is more, it attracts a significant amount of attention from both Western-and Asian-backed developmental financial institutions. Focusing on this region allows a microcosmic glimpse into the wider challenges of climate change, environment and development globally. Communities that are most vulnerable in terms of development are often also vulnerable to climate change and environmental degradation. And though policies addressing each risk are often presented as being mutually exclusive to the other, in reality these are interrelated; resilience to climate change is conditioned by the level of socioeconomic welfare and in turn economic development is hindered by increased exposure to environmental risks.
In order to ensure access to electricity to all its population, and for its economy to grow, Bangladesh is on a path to expand energy production. By far, the largest source of global greenhouse gas (GHG) emissions is burning fossil fuel to produce energy. Going forward it is essential Bangladesh takes into account GHG emissions associated with energy production. Despite growing energy demands, the need for a low-carbon growth path is more urgent than ever— with arctic ice melting faster than expected and many scientists predicting that the world is dangerously close to exceeding our carbon budget consistent with the less than 2 degrees Celsius target.

At the same time, in 2016 we saw an unprecedented consensus on global commitment to curbing GHG emissions, with the Paris Agreement entering into force. But to ensure that this promise is carried out in time, we need to dramatically reduce GHG emissions through a variety of measures.

Limiting GHG emissions, and thus mitigating climatic risk, is one aspect of climate change response— adaptation is the other. Vulnerability to climatic events is moderated according to the resilience of communities and ecosystems facing those risks. These have to do with complex combinations of factors, including: exposure to physical risk of the actual events, such as proximity to the coast; economic resilience of affected communities to withstanding climate events such as storm, flooding and drought— this minimizes how long and how deep the impacts are felt; macro-level characteristics such as the existence of risk-reducing features, be it structural— such as embankments, or natural— such as flood plains or mangroves. Part of the
vulnerability or resilience of the communities is tied to aspects that also have mitigation components. Examples include mangroves— which act as a carbon sink but also as a protection against storm surges, and infrastructure investments such as efficient electricity transmission systems that contribute to the economic development of the community in addition to reducing carbon emission.

Energy production, therefore, has costs and benefits other than GHG emissions. These include livelihood considerations— including job creation and land use issues such as access to arable land or water bodies for fishing; environmental impacts, including pollution, degradation, and impacts on ecosystems; and social impacts such as displacement and health hazards from power plants. This research presents a framework to capture and evaluate key aspects of the different options that exist for developing countries to meet their energy needs. As new financing options from developing countries emerge for energy projects, it is important for countries with multiple vulnerabilities to assess the needs of their at-risk population. Moreover, as development institutions move towards a more decentralized country-systems for their environmental and social safeguards, there is further need to create a push for clean energy from within vulnerable countries in the Global South appealing to governments and financing institutions from the Global South. I hope this research serves as a way to ensure that the interests of communities impacted by environmental degradation and climate change in developing countries are protected even as regulations around social and environmental safeguards weaken in the international arena.
1.3 Country Background

Bangladesh is a low-lying deltaic region with 67 percent of its critical infrastructure under 5 meters above sea level and 46 percent of its population within 10 meters of the average sea level coast. The region is prone to tropical cyclones and naturally occurring river, rainwater and tidal flooding. Low intensity flooding inundates approximately 20 percent of the country on a yearly basis and makes important contributions to the country’s ecosystems and agricultural livelihoods (Boyce, 1990). However, less frequent, high intensity cyclonic and flooding events constitute the majority of natural disasters (Vicarelli et al., 2016). The risk of floods, and loss of life and property associated with floods, is one of the highest in Bangladesh due to the significant proportion of its population living in low-lying coastal zones and flood plains (IPCC WGII, 2014).

The Intergovernmental Panel on Climate Change (IPCC) projects that climate change is expected to exacerbate floods linked to extreme rainfall events, rising sea level and tropical storms in the region. (IPCC WGII, 2014) Even if the frequency or severity of such storms remained the same, their impacts would nevertheless be magnified in low-lying and coastal zone communities where sea level (IPCC WGII, 2014) is expected to rise and population and economic activity are growing (IPCC WGII, 2014; Mimura, 2013; Lichter et al., 2011). Overall, in the coming decades, the exposure of population and assets to coastal risks is projected to increase. The most
vulnerable areas are predominantly agrarian, where the primary sources of rural livelihoods are agriculture, fisheries, forestry and forestry products, and livestock (Nandy, 2013). The rural poverty is thus at risk of deteriorating due to the projection of negative impacts from climate change on rice production, as well as the general increase in food prices and cost of living (IPCC WGII, 2014; Wassmann et al., 2009; Rahman et al., 2009).

In addition to the challenges posed by increased risks from climatic events, underlying socioeconomic conditions exacerbates Bangladesh’s vulnerability. The country is currently classified as a “Least Development Country” (LDC) under the United Nations Department of Economic and Social Affairs (DESA) categorization. Part of the strategy to move the country to a “Developing Country” classification is by aggressively growing the economy through expanding its manufacturing industries; and for this, the country will need to dramatically increase power generation. For a country that is still developing its energy infrastructure, a sustainable energy infrastructure development would be an opportunity for Bangladesh to get it right the first time, instead of risking stranded assets and other losses in the future.
CHAPTER 2
ENERGY OVERVIEW

The research evaluates different paths for Bangladesh’s energy future by comparing three options for the country’s energy trajectory for the year 2050 in light of environmental, socioeconomic, and climate change concerns. The first step is to thus project energy demand for 2050. Energy projections are based on the current energy mix and its future trajectory in terms of level of development, overall economic activities, energy use, rate of urbanization, rate of access to electricity, and population growth. The chapter explains how these factors can be expected to change over the coming decades, based on which, the energy demand for 2050 is determined.

Next, the chapter considers ways in which to meet this projected demand. I do this by reviewing the state of affairs and prospects for energy production and efficiency measures in the country, and look at the cost per unit energy associated with each measure. These were identified by reviewing literature that explores what is currently happening in the country, where its trajectory lies based on pipeline projects and investments trends, and what is possible going forward. The chapter identifies nine key energy-related sectors that include power generation and efficiency measures. With the nine specific sectors, we can next look at the overall pathways or plans for the economy for 2050.
2.1 Energy Demand Projection

The Bangladesh Power Development Board (BPDB) publishes energy demand projections till the year 2030. Their methodology is outlined in the latest Power System Master Plan (PSMP, 2016) and uses data on i) national trends in power usages by household use, industrial use, and commercial use; ii) economic growth rate projections for Bangladesh using World Bank projections and the latest, 2015, Poverty Reduction Strategy Paper (PRSP) which provide further breakdown of iii) government growth projections for the agricultural, mining, industrial, and service sectors, including growth projections for the high energy consuming industries; and iv) growth of electrification rate in the country, which includes past data and projections for planned power outages.

The current trend in energy-use intensity growth is assumed to hold for the projection period (2050). The reasons for this assumption are discussed below.

The current energy development of the country, estimated using Energy Development Index (EDI) indicates that energy use intensity can be expected to continue rising for Bangladesh. The EDI, developed in the World Energy Outlook 2011, report is a multi-dimensional indicator that tracks energy development country-by-country. At the household level, it focuses on two key dimensions: access to electricity and access to clean cooking facilities. When looking at community level access, it considers modern energy use for public services (e.g. schools, water and sanitation, etc.) and energy for productive use, that is energy use
for economic activity. The EDI is constructed by creating a separate index for each indicator, using the actual maximum and minimum values for the countries covered. Performance is expressed as a value between 0 and 1. Bangladesh scores 0.23 out of 1 (OECD/IEA, 2011).

Bangladesh’s low EDI score arises from low household level access to electricity, low energy use in the public sector and for production use. The rapidly increasing access to electricity, which has the effect of increasing Bangladesh’s energy intensity, can be expected to continue till 2050. Based on the decomposition of factors contributing to energy demand, Ravindranath and Sathaye (2002) find that relative to the other contributing factors such as population and GDP, the impact of energy intensity was found to be the strongest.

2.1.1 Household access

World Bank and government data indicate that the access rate to electricity amounted to about 60 percent in 2015. Thus for universal coverage by 2030, in accordance with government plan, there needs to be a 40 percent growth in coverage in 15 years starting from 2015. This translates to 2.7 percent for 15 years to reach full coverage by 2030. The current rate of increase in access to electricity is 2.2 percent per year. Access here does not indicate that the power supply is constant, as we see from the PSMP data on power outages. Thus it is clear that the increasing access rate will positively affect Bangladesh’s energy intensity until full coverage is reached, and this will not occur, given current trend in coverage
expansion, before 2034. In addition, coverage here means basic access to electricity for every household; the government report does not include projections for changes in use-intensity for households, which remain very low. The per capita annual consumption of 392 kilowatts per hour is among the lowest levels in the world. We may thus expect that the household intensity of energy use will continue to rise for our period of interest, even after universal coverage is achieved.

2.1.2 Economic Structure

The World Energy Outlook (WEO 2007) finds that primary energy intensity fall in developed countries due to rapid structural economic change away from heavy manufacturing and towards less energy-intensive service activities and lighter industry. However, given that Bangladesh is planning to develop heavy manufacturing away from agriculture, we can expect energy intensity to rise in Bangladesh’s case. Indeed, the PSMP report predicts an increase in industrial and commercial energy-use intensity for their period of interest (2010-2030). In addition, investment trends reported in the PRSP indicate that the manufacturing sector will continue to grow till 2050.

Urbanization is another factor relevant for energy use intensity in the case of Bangladesh. Gunter and Rahman (2012), in their study of Bangladesh’s energy projections for 2050, and York, Rosa and Dietz (2003) suggest that indicators of urbanization along with industrialization are important determinants for energy use. Thus, Gunter and Rahman use population density, reflecting agglomeration and
urbanization, as a contributing factor and conclude that urbanization can be expected to have an added positive impact on energy-intensity rate over our period of interest.

Connected to the above factors is GDP growth. The PSMP report present data on GDP based on 2010 constant United States dollar (USD), using data from the Bangladesh Bureau of Statistics and the World Bank. Bangladesh is experiencing a growth of 7 percent second year in a row, and this rate is expected to hold for the next year as well. However, in estimating energy demand, Gunter and Rahman (2012) differentiate between Bangladesh’s real GDP growth rate in USD and the real GDP growth rate in purchasing power parity (PPP) terms. The difference between expressing GDP growth rates in USD and PPP terms is important especially for this purpose, as living standards are more accurate for calculating the impact of GDP growth on energy use than using USD-based GDP growth rates (Gunter and Rahman, 2012). Therefore for the purpose of this work, taking into account the expected trends mentioned above over our period of interest, we assume a real GDP growth rate in United States dollar (USD) terms at 7 percent, and the real GDP growth rate in purchasing power parity (PPP) terms at 5.1 percent, following the work of Hawksworth and Cookson (2008) and a population projection of 202.21 million for the year 2050, we use the PSMP methodology to project energy demand for 2050 at 1.53E+12 kWh (kilo Watt hour) by extending their projection for 2030 to 2050.
2.2 State of Affairs and Prospects

2.2.1 Energy production: Fossil Fuel and Renewables


The clean energy sources considered for the alternate green plan are limited to solar, wind, and small hydropower. I assume these sources have zero emission in energy production. Here I do not include emissions from activities further up or down in the supply chain such as net emission from construction of the plant or from building roads and new transmission lines for accessing the energy source. Large hydropower, defined by International Renewable Energy Agency (IRENA) as having greater than 100 megawatts capacity, high-emission bioenergy, and nuclear power are excluded from the definition of clean energy in this work. Bioenergy involves high carbon emissions, as is common with most bioenergy production practices unless specific steps, such as low-emission refining methods, are taken to ensure otherwise. Large hydropower involves high risk of methane, a potent GHG, emission in tropical regions. Furthermore, there are likely to be serious
environmental issues connected with additional large-scale dam construction in terms of disrupting existing communities and ecosystems. Energy from nuclear power is excluded in the study due to the uncertainty with regard to waste and the GHG emissions involved with the waste processing, storage, and disposal (Pollin et al., 2015).

Bangladesh has a well-developed infrastructure based around gas and is moving towards establishing infrastructure for coal-based power generation over the next decades. The national coal policy since 2010 waived corporate tax for contractors or licensees to encourage coal mine exploration, development and marketing, as well as a rebate of import duty, tax and value added tax (VAT) on the import of machinery for use in coal mining to encourage investment in coal. However, clean energy, particularly solar power including rooftop solar, is already proving to be a viable alternative for Bangladesh. As of July 2017 roughly 4.5 million rooftop solar units for residential use have been installed, generating over 2E+08 Watt of electricity (SREDA 2017). According to a 2018 study the annual generation potential of renewables in Bangladesh (for solar photovoltaic or PV, concentrated solar power or CSP with and without 6-hour storage, and wind) is approximately 3.69E+14 Wh, while the annual generation capacity for renewables in the country was estimated to be 1.23E+10 Wh in 2016 (Shiraishi et al., 2019).

2.2.2 Efficiency Gains
There is scope for efficiency improvements, particularly in production and transmission sectors, as identified in the PSMP report. Bangladesh’s transmission losses amount to around 14 percent, while collection efficiency is high at around 90 percent. Production losses however vary widely across sources and plants. During power outages, back-up energy generators are used, which are powered by inefficient and carbon intensive diesel and fuel oil. An internal World Bank report by Gulati and Rao, quoted in the Global Monitoring Report 2009, states that an estimated 45 percent of generated power is lost in Bangladesh due to technical and commercial inefficiencies (Gunter and Rahman, 2012).

The 2015 book, Global Green Growth: Clean Energy Industrial Investments and Expanding Job Opportunities, further provides a useful way to gauge variations in per capita CO₂ emissions level by country by decomposing the emissions per capita ratio into three component parts. This exercise will help indicate where Bangladesh stands relative to the world and the countries studied in the book. It will further help identify which of the three components could contribute to gains in efficiency, and thus warrant policy and investment focus.

The decomposition of the per capita CO₂ emissions level yields three ratios, each of which provides a simple measure of one major aspect of the global climate change challenge (Pollin et al., 2015). CO₂ emissions per capita can be expressed as follows:

\[
\text{Emissions/population} = \left( \frac{\text{GDP/population}}{} \right) \times (\text{mWh/GDP}) \times (\text{emissions/mWh}).
\]

These three ratios provide measures of the following in each country setting:
1. Level of development: Measured by GDP/capita;

2. Energy intensity: Measured by mWh /GDP;

3. Emissions intensity: Measured by emissions/ mWh.

The unit for energy used is Watt hour (Wh), with mWh denoting mega or $10^6$ Wh.

The book presents a table, reproduced below, to show a comparison between the results of the decomposition for the world, the U.S, China, as well as Brazil, Germany, Indonesia, South Africa, and the Republic of Korea (ROK). For the U.S. and China, for instance this breakdown helps identify that emissions per capita are three times higher in the U.S., at 18.2 metric tonnes (mt) versus 6 for China and that the three factors generating this overall result are:

1. Level of development: Average GDP per capita in the U.S, at $50,000, is 8 times higher than that for China;

2. Energy intensity: The U.S. is twice as efficient as China, with its mWh /GDP ratio at 1.82 versus 3.55 for China;

3. Emissions intensity: The mix of energy sources in the U.S. is 40 percent cleaner than that in China, with emissions at 196.20 mmt/mWh versus 270.58 for China.

Table 1: Determinants of per capita CO₂ emissions level by country, 2010: Level of development, energy intensity, and energy mix

<table>
<thead>
<tr>
<th>Country</th>
<th>CO₂ emissions/population in mt</th>
<th>GDP/population in US$</th>
<th>Energy intensity ratio: mWh /trillion dollars GDP</th>
<th>Emissions intensity ratio: CO₂ emissions/mWh in million mt (mmt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td>4.6</td>
<td>10300</td>
<td>2.08</td>
<td>224.86</td>
</tr>
<tr>
<td>China</td>
<td>6.0</td>
<td>6200</td>
<td>3.55</td>
<td>270.58</td>
</tr>
<tr>
<td>U.S.</td>
<td>18.2</td>
<td>50000</td>
<td>1.82</td>
<td>196.20</td>
</tr>
<tr>
<td>Brazil</td>
<td>2.3</td>
<td>11600</td>
<td>1.49</td>
<td>136.14</td>
</tr>
</tbody>
</table>
In the case of Bangladesh the decomposition shows that largest factor contributing to the low per capita emissions is the low per capita GDP despite a moderate energy and emissions intensity. The emissions intensity is lower than that of most countries in Table 1 mainly because the main energy source has been natural gas for the past decade. However the government plan indicates that the share of coal is set to increase greatly. The energy intensity level is in part a reflection of Bangladesh still being in the process of transitioning to a more energy-intensive manufacturing economic structure from the economic current structure dominated by rural agricultural activities requiring relatively less energy. As the PSMP shows, the government is also adopting policies to aggressively grow the economy to a mid-income level country by 2024 through growth in heavy-manufacturing industry.

With our population growth rate falling drastically over the last two decades and the projection that the average number of children per household will continue at its current figure of 2.1, a rise in per capita GDP, an increase in energy and emission intensity would greatly increase the per capita emission level without an improvement in the efficiency level.

The 2015 Energy Efficiency and Conservation (EEC) Master Plan from the Government of Bangladesh identifies several sectors in which investments will be
made for efficiency gains. This study focuses on three key sectors: residential and commercial building, in particular air-conditioning and appliances; mass transportation in the growing urban areas, specifically transit rail; and grid upgrades for transmission loss reductions and power factor improvement (EEC Master Plan, SREDA). The investment in these three sectors is built from the potential for conservation under each sector. Currently the main investment is in grid upgrades and expansion, which is projected to continue over our period of interest with the expansion in power generation. Transit rail in one area of the capital city, Dhaka, has commenced and can be expected to expand to other areas in the city. The EEC Master Plan also details investment plans in buildings. Based on government investment plans and the potential of efficiency gains in the country, this study assumes that the investment in grid is almost twice as much as the investment in rail, which in turn is double that of building upgrades in the coming decades.

This chapter finds that given the country’s investment trajectories based on existing academic research and government reports, over the coming decades Bangladesh is likely to continue in its path of growing rate of access to electricity, of urbanization, and of industrialization. Therefore the rate of energy-use intensity can be assumed to hold till 2050. Based on this the energy projection for 2050 is estimated to be 1.53E+12kWh.
A review of the state of affairs and prospects for energy production and efficiency measures in the country revealed nine key energy-related sectors: power generation through three fossil fuel sources (coal, oil, gas), through three clean renewable sources (solar, wind, small hydropower), and through three efficiency measures (transit rail, grid, and building upgrades). The nine sectors identified then allow us to analyze national energy plans for the economy for 2050.
CHAPTER 3
THE PLANS

This chapter begins with the three energy plans considered in this research, built from different combinations of the nine energy-related sectors identified. The first two plans can be described as i) the current path given what has been happening till date and ii) the most likely alternative given government renewable policy objectives. However, when we estimate GHG emission, we find that these two plans fall woefully short of what is globally required to limit warming to 2 degree Celsius. Moreover, the first plan BAU is not feasible till 2050 given gas supply shortages in the country. Thus a third plan an alternative is presented, built around a specific emission target for 2050.

The main objective of this chapter is to present an alternate green plan based on the same nine energy-related sectors presented above but with the aim to limit GHG emissions, even as the economy continues on its high growth rate. I do this by choosing a target for Bangladesh, based on warming probabilities and an equity approach given Bangladesh’s level of development and cumulative emission levels. In addition the cost of such a proposal is presented in this chapter.

3.1 Overview of the Three Plans

Plan 1: Business As Usual Energy needs for 2050 are met through the following energy mix built from current trends: Natural gas 62 percent, Oil 29 percent, Coal 2

27
percent, Hydropower 1 percent, Solar 1 percent and Imports 5 percent. The projections of natural availability in Bangladesh indicate that Plan 1 is not a feasible alternative for 2050. Though this research includes estimates for Plan 1, in reality this energy mix is not an option beyond 2030.

**Plan 2: Government Renewable Plan** The government renewable plan is based on the 2015 government report “Bangladesh Green Energy Plan— Investment Plan for Bangladesh”. Under the government plan energy needs will be met through the following energy mix: Coal 50 percent, Natural gas 25 percent, Renewable 10 percent, Oil 10 percent, and 10 percent Imports.

**Plan 3: Green plan** For a 50 percent chance of limiting warming to 2 degree Celsius, as showed by Van Vuuren et al. (2008), the global CO₂ emissions for 2050 must be 10E+9 mt. In accordance with the Paris Agreement, the Nationally Determined Contributions (NDCs) of the OECD¹ (Organisation for Economic Co-operation and Development) countries will provide almost three-quarters of the emissions reductions in 2050, and thereby is allowed one-quarter of the emissions, while the rest of the world will be allowed three-quarters of the emissions. Using the population projections for OECD countries and rest of the world from World Bank and OECD data, we can thus calculate the per capita 2050 emissions target for non-OECD countries, which includes Bangladesh. This value comes to 1.81 mt and as

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¹ 35 States including: Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israël, Italy, Japan, Korea, Latvia, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom, and United States.
shown in the next section, per capita emissions estimates for Plans 1 and 2
overshoot this target emission.

3.2 The Alternate Plan Assumptions

The main aim of Plan 3, the alternate green plan, is to thus limit per capita carbon
dioxide (CO₂) emission to 1.81 mt by the year 2050. This follows the approach in
Pollin et al.'s 2015 book Global Green Growth, which set the per capita CO₂ emission
limit to 2.4 metric tonnes (mt) by the year 2030. To achieve this reduction, the
budget in Global Green Growth was 1 percent of GDP for production and 0.5 percent
for efficiency investments. To formulate the plan for 2050 I, therefore, first need to
estimate how much is needed in clean renewables and efficiency investments to
bring per capita CO₂ emissions close the target amount. The following calculation
shows that a budget of 0.81 percent is needed to reach the 2050 per capita emission
target.

3.2.1 Growth Assumptions

We assume one and half year start up phase for the energy production to
commence, so we assume a period from 2020-2050 or 30 years. The budget for the
clean investment is some percentage, say X, of GDP over 30 years. The midpoint of
that period is the year 2035, so we take the GDP projection of Bangladesh for 2035
and multiply by 30 to get an approximation of the budget over the time period.

Using the 2016 Power Sector Master Plan (PSMP) projection for Bangladesh for 2035, the GDP is $399.4 billion (PSMP, 2016). The following section shows how we determine that percentage given our per capita emission target for 2050.

3.2.2 Cost assumptions

1. Production Costs: The cost of energy production is calculated from the total levelized cost of electricity (LCOE), which includes: i) capital costs; ii) fixed operations and maintenance costs—these include standard costs that do not vary with output levels, including land, equipment and project development costs, and maintenance of buildings and machines; iii) variable operations and maintenance—these include fuel costs for operating renewable energy projects; iv) transmission costs—these include the operations of the electrical grid system; and finally v) capacity utilization rate.

The projected utilization rate for equipment varies with market demand and resource availability (Pollin et. al., 2015). The approach used in the analysis presented here is based on a discounted cash flow analysis. The cost calculations assume an average LCOE for all renewables. Here LCOE of the different energy sources is determined from the PSMP, which provides cost estimates and projections for different sources over the period 2010-2030. The cost of renewable energy production used in this research is $125 per Q-BTU or $0.43 USD per kWh,
from Chapter 8 of Global Green Growth. If anything these is an overestimate and the cost of clean renewables is likely to be even lower over our 30-year period of interest than the value used here.

2. Efficiency costs: The cost calculations of efficiency investments are based on the PSMP and the 2010 McKinsey study, “Impact of the Financial Crisis on Carbon Economics: Version 2.1 of the Global Greenhouse Gas Abatement Cost Curve”. The study includes efficiency investments from Africa, Middle East, South East Asia, China, and Eastern Europe. The study estimates that, using existing technologies, developing countries could slow the growth of energy demand through 2020, at a rate of 1.4 to 3.4 percent per year, so by more than half in total for the entire period, without having to reduce GDP growth. The study estimates the cost of saving 1 QBTU or 2.93 E+11 kWh (kilowatt-hour) of energy to be $11 billion (McKinsey, 2010). The per kWh cost comes to $0.04. Since our period of interest extend to 2050, this value is also likely to be an overestimate.

The book also cites efficiency cost estimates from a United Nations Industrial Development Organization (UNIDO) study that is based on a survey of 357 industrial firms in developing countries; estimate from a World Bank study based on a study of 455 projects in both industrial and developing economies; and a U.S. National Academy of Sciences NAS study based on buildings and industrial sectors in the United States. The McKinsey estimate not only focuses non-OECD countries, but the projects surveyed are mostly in developing countries. The projects include
transportation sector, building, and grid upgrades as is most relevant to this work. As a comparison, the World Bank estimates the average costs of energy savings to be $1.9 billion per Q-BTU, compared to the more expensive McKinsey estimate at $11 billion per Q-BTU.

3.3 Cost of Alternate Plan

We can now formulate the alternate green plan for the period 2020-2050 using our two cost estimates, namely: clean renewable energy production cost of $C_P per kWh and efficiency gains cost of $C_E per kWh. The study will assume a particular GDP growth rate as discussed in the previous section and will use the midrange value of GDP for the time period to calculate the yearly spending on investments for the alternate green plan. Assuming the plan takes and year and a half to implement the period over which the investment occurs is 30 years. The amounts estimated above are $B_P and $B_E per year for the budgets for energy production and efficiency investments respectively. Thus the total spending budget comes to $30* $B_P and $30* $B_E for energy production and efficiency investments. Dividing this by the associated costs ($C_P and $C_E) per unit energy we are able to calculate the energy produced and saved through efficiency gains. For 2050, as shown, this must account for 63 percent of the energy used.
We based our estimates for the costs of achieving these gains in both efficiency and renewables at $0.04 USD per kWh for efficiency investments and $0.43 USD per kWh for expanding clean renewable capacity from Chapter 8 of Global Green Growth. We assume that the budget allocated for clean renewable production is twice that of the amount for efficiency investments. Thus the percentage of GDP for efficiency is E, that of production is 2E. The X mentioned above will be 3E which is calculated below by working backwards from our 2050 emission target, and using our energy demand estimate for 2050 and average GDP for the 30 years considered. The percentage GDP allocated for clean energy investments comes to 0.81 percent of GDP every year for our period of interest with 0.54 percent allocated to clean renewable production and 0.27 percent allocated to efficiency investments.

Calculations for the percentage of GDP allocated for clean energy investments using the cost estimates from Global Green Growth are shown below:

\[ D_{2050} = 1.53E+12 \text{ kWh} \]

\[ GDP_{2035} = \$369.4bn \text{ (2006US$)} \]

\[ C_P \$4.27E-10 \text{ bn per kWh} \]

\[ C_E = \$3.75E-11 \text{ bn per kWh} \]

\[ 0.63 \times \text{energy demand 2050} = 30 \times \left( \frac{P \times GDP_{2035}}{C_P} + \frac{E \times GDP_{2035}}{C_E} \right) \]

\[ 0.63 \times D_{2050} = 30 \times GDP_{2035} \times \left( \frac{P}{C_P} + \frac{E}{C_E} \right) \]
\[0.63 \, D_{2050} = 30 \times GDP_{2035} \, (2E/C_P + E/C_E)\]

\[0.63 \, D_{2050} = E \times 30 \times GDP_{2035} \, (2/C_P + 1/C_E)\]

\[E = 0.63 \, D_{2050} / [30 \times GDP_{2035} \times (2/C_P + 1/C_E)]\]

\[E=0.0027 \text{ and } P=2E=0.0054\]

Table 2 gives the budgetary breakdown of our alternative framework, in which Bangladesh’s growth process incorporates clean energy investments—i.e. investments in renewable energy and energy efficiency—at a rate of 0.81 percent of GDP annually over a full 30-year period. We assume that this 0.81 percent of GDP is allocated such that the funding for clean renewable production is twice that for energy efficiency investments.

<table>
<thead>
<tr>
<th>Table 2: Clean energy 30-year (2020-2050) investment trajectory</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mid-range GDP for investment spending estimates (GDP for year 2035)</strong></td>
</tr>
<tr>
<td><strong>Average annual clean renewable investments (=0.54% of midrange GDP)</strong></td>
</tr>
<tr>
<td><strong>Average annual clean renewable investments (=0.27% of midrange GDP)</strong></td>
</tr>
</tbody>
</table>

As Table 2 shows, to estimate an average level of clean-energy investment spending over this 30-year period, we use the midrange GDP value for the year 2035. That
figure is $369.4 billion. This then means that the average level of annual spending on clean energy would be 0.54 percent of $369.4 billion per year for renewables, which is $2.05 billion, and 0.27 percent for energy efficiency, which is $1.02 billion per year.

The 2050 energy demand is projected to be 1.53E+12 kWh. Using the energy mix under each plan, I can calculate the amounts of fossil fuel, renewables, and energy saved. I use the following values for average costs associated with fossil fuel, renewable, and energy saved: $0.43 per kWh for renewables (solar, wind, hydro); $0.15 per kWh for fossil fuel (oil, natural gas, coal); and $0.04 per kWh for energy saved through efficiency measures. This provides a rough estimate of the costs of each plan for the 2050 demand. Plan 1 is $2.29E+11, Plan 2 is $2.52E+11, and Plan 3 comes to $5.19E+11. Thus Plan 3, the alternate green plan costs the most at $519 billion, Plan 1, the BAU scenario is $229 billion, and Plan 2, the government renewable plan is the least costly at $252 billion. It is important to keep in mind the BAU option is not realistic for 2050 given shortages of natural gas, thus in reality the two options are between government renewable plan and the alternate green plan.

### 3.4 Emissions Estimate

I can now calculate per capita emissions for 2050 for the first two plans as well using the respective energy mix obtained from government reports. For 2050
projections I use projections for energy demand and population discussed previously. Total primary energy consumption of Bangladesh excluding transportation and biomass (2050 projection) is projected to be 1.53E+12 kWh. The population projection is 202.21 million. Since we know the energy mix for Plans 1 and 2, the emission under the two plans can be estimated using emission information from the Carbon Dioxide Information Analysis Center (CDIAC) data. CO₂ emissions per kWh of fossil fuel source are assumed to be: Coal 979.6E-6; Natural Gas 553.38E-6; and Oil 798.32E-6 mt. For Plan 3, I keep the Gas and Oil near to their government renewable plan targets, under Plan 2. Working backwards we see that to keep within Plan 63 per capita emission 2050 target, renewables and efficiency measures must account for 63 percent of the demand. The energy mix and emission results from the three plans are summarized in Table 3.

Table 3: 2050 emission calculations for the three plans

<table>
<thead>
<tr>
<th>Plan 1 (2% renewable 5% imported)</th>
<th>10¹⁰ kWh</th>
<th>10⁷ metric tonnes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>0.02</td>
<td>3.05</td>
</tr>
<tr>
<td>Gas</td>
<td>0.62</td>
<td>3.05</td>
</tr>
<tr>
<td>Oil</td>
<td>0.29</td>
<td>94.70</td>
</tr>
<tr>
<td>total emission</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Plan 1 per capita emission (mt)** 4.49

<table>
<thead>
<tr>
<th>Plan 2 (10% renewable, 10% imported)</th>
<th>10¹⁰ kWh</th>
<th>10⁷ metric tonnes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>0.50</td>
<td>76.37</td>
</tr>
<tr>
<td>Gas</td>
<td>0.25</td>
<td>38.19</td>
</tr>
<tr>
<td>Oil</td>
<td>0.05</td>
<td>7.64</td>
</tr>
<tr>
<td>total emission</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Plan 2 per capita emission (mt)** 5.05

<table>
<thead>
<tr>
<th>Plan 3 (63% renewable)</th>
<th>10¹⁰ kWh</th>
<th>10⁷ metric tonnes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>0.05</td>
<td>7.64</td>
</tr>
<tr>
<td>Gas</td>
<td>0.27</td>
<td>41.24</td>
</tr>
<tr>
<td>Oil</td>
<td>0.05</td>
<td>7.64</td>
</tr>
</tbody>
</table>
3.5 Approach for Setting Emission Target

The approach I took depended to set the 2050 per capita emission target on certain choices I made due to time and budget limitations on the level of detail I could incorporate. First I had to decide which timeline and global emission target to choose. I picked 2050 as the time period for Bangladesh to achieve the target, and the target was based on a 50 percent chance of limiting warming to 2 degrees. Alternately I could have chosen a different timeline (e.g. 2020 to 2035 given the urgency), a higher probability, and/or lower warming level e.g. 1.5 degrees.

I combined some aspects of the 'capability' approach with the 'equality' approach as summarized by Working Group III of IPCC's AR5 report on the five categories of burden sharing (Edenhofer et al., 2014). Once I had the global emission target for 2050 (for a 50 percent chance of limiting warming to 2 degrees), I prescribed that OECD countries should be responsible for $2/3^{rd}$ of the reduction, in other words OECD countries should be 'allowed' only $1/3^{rd}$ of the emission budget. So developing countries like Bangladesh are allowed $2/3^{rd}$ of that emission. But then amongst developing countries I did not differentiate based on level of development, thus adopting somewhat of an equality approach. So all countries (including obviously
China and India) other than the 35 OECD countries are allowed the same per capita emission.

Once I had that target (1.8 metric ton per capita) I then looked at Bangladesh’s development path, main contributor to GHG emissions going forward, and land availability constraints to prescribe a path. For Bangladesh’s case, it is mainly power generation that is projected to be the key culprit given where the country is developmentally. China and more recently India are already over their 'hump' of energy-use intensity. For Bangladesh, the most viable alternative for renewables are solar and small hydro, and to a smaller extent wind energy. For some other developing country, such as Indonesia, for the same emission target, the path prescribed would be different. One of the key prescriptions for Indonesia would be land use change, especially for palm since that is one of their main emissions contributors, and alternate energy could even include a small percentage geothermal. The choice of path for emission reduction using a particular energy-mix and efficiency investments was therefore country-dependent and constrained by natural constraints and current path-dependency of government policy.

*The chapter considers the climate change impact, as estimated through GHG emissions, of three energy alternatives for Bangladesh. The GHG emission for the plans are estimated from emission estimates per unit energy for the three fossil fuel sources—these combine in different ratios to constitute the three plans. The first two*
plans are obtained from government reports and are found to fall short of what is 
globally required to limit warming to 2 degree Celsius.

The chapter finds that for a 50 percent chance of limiting warming to the target 
amount, per capita emission in Bangladesh for 2050 must be 1.8mt CO$_2$e. This is 
possible through a certain amount of expansion in clean renewable sectors and 
efficient investments. Using cost of power generation for clean renewables and 
efficiency measures the chapter concludes that this can be achieved through investing 
0.81 percent of the country’s GDP in these sectors every year till 2050. Thus an 
alternate green plan is built around the per capita emission target for 2050.

To achieve this plan investments in clean renewables and efficiency measures will need 
to be over our period of interest. To estimate an average level of clean-energy 
investment spending over this 30-year period, we used the midrange GDP value for the 
year 2035, which is $369.4billion. This then means that the average level of annual 
spending on clean energy would be 0.54 percent of $369.4billion per year for 
renewables, which is $2.05 billion, and 0.27 percent for energy efficiency, which is 
$1.02 billion per year.
CHAPTER 4
INPUT OUTPUT MODEL

In the previous chapter, three options for Bangladesh’s energy future were presented, one based on current trends, one based on the most-likely alternative based on government renewable targets, and thirdly an alternate green plan built around lower GHG emissions in light of climate change concerns.

Now that we have our three plans we can finally compare them along the five key aspects of power generation that pertain to socio-economic and environmental concerns. These aspects are captured through the variables, or the factor inputs, of land-use, employment, water-use, GHG emissions, and copollutants. Specifically I want to evaluate how much of these factor inputs are associated with each plan, not just in the direct production of energy but in all upstream economic activities. As the aim of the research is to compare across plans, I need to normalize in dollar in order to estimate the impact of the same investment across the three plans. To do this I use an Input Output (IO) model. The details of the model are presented in this section.

4.1 Background

The aim of the research is to assess Bangladesh’s energy policy with respect to developmental, environmental, and climate change challenges facing the country.
The previous section considers the cost and the availability of the different energy sources for Bangladesh. Currently these are the main considerations in formulating energy policies. In addition, individual power plants are approved after project-level evaluation of environmental and social impacts through conducting an Environmental Impact Study (EIS) for each power plant. These studies are limited in scope and at best include direct on-site environmental and social impacts. However in addition to direct impacts, power plants also have indirect impacts through upstream economic and associated activities. For instance a power plant will not only impact land and water and create jobs during its construction and operational phase but will also generate other off-site economic activities— which themselves create jobs and have environmental impacts. These could arise from the industry producing the machinery used in the power plant and the land impacted from the production of these machines. The process of industrial interdependence proceeds infinitely in an upstream direction through the whole life cycle of all products and Input Output (IO) analysis is a technique that enables the calculation of these indirect effects (Lenzen et al., 2003).

Previous work using IO to look at economic and environmental impacts include the work of Isard et al. (1972) studying a proposed marina in Massachusetts and Goldrick and James (1994) who used national IO with combustion emission model and regional water quality and air pollutant dispersion models to look the impacts on employment, emission, and water pollution of coal power plant in Hunter Valley Australia. More recently the works of Lenzen and Murray (2001) and Lenzen et al.
(2003) developed a method to incorporate land use and disturbance, emissions, water use, and employment into a single IO framework for projects. This research follows the methodology of Lenzen and Murray and applies it to assess national energy policy, which is a combination of multiple projects.

### 4.2 Methodology

The result of generalized input output analyses is a $f \times n$ matrix of factor multipliers, that is embodiments of $f$ production factors per unit of final consumption of commodities produced by $n$ industry sectors, denoted here by matrix $F$.

A multiplier matrix $M$ can be calculated from the $f \times n$ matrix $F$ containing sectoral production factor usage, and from a $n \times n$ direct requirements matrix $A$ according to:

$$M = F(I - A)^{-1}$$

where $I$ is the $n \times n$ unity matrix.

Steps:

- Input Output Matrix $A$= (Input/Output)
- Leontif Inverse $(I - A)^{-1}$ = (Output/Input)
- Calculate the Factor–Output Ratio for each individual levels of industry
- Sort the Factor – Output Ratio according to the Input-Output table
- Factor/Input = (Factor/Output)*(Output/Input)

or $M = F(I - A)^{-1}$
The diagonal elements in the $M$ matrix give the direct factor required and the off-diagonals are the indirect factors generated. For instance if $f=1$, that is, we were looking at one factor input, say labor or employment, then the diagonal elements would give direct employment figures and the off-diagonals would be the indirect employment generated.

A simple example clarifying each step has been included below to demonstrate how this works:

1. Input Output Table

*Definition:* The IO table gives the amount of input from all industries in an economy needed to produce 1 unit of output in each industry.

Example:

In a two-industry economy with manufacturing and agriculture the IO table is a $2 \times 2$ matrix, let’s call it matrix $A$.

Let the elements of matrix $A = \begin{pmatrix} x & y \\ m & n \end{pmatrix}$

where $x,y,m,n$ are scalar numbers between 0 and 1.

Let the first industry be manufacturing and the second agriculture.
So to produce 1 unit ($1 in our example) of output in manufacturing industry we need:

- $x$ units (i.e. $x$) of input from manufacturing and
- $m$ units (i.e. $m$) of input from agriculture

Similarly to produce 1 unit ($1 in our example) of output in agriculture industry we need:

- $y$ units (i.e. $y$) of input from manufacturing and
- $n$ units (i.e. $n$) of input from agriculture

2. Output Input Table

*Definition of Output Input:* The OI table gives the amount of Output in all industries in an economy generated from 1 unit of Input in each industry.

We now get an Output Input matrix from the IO matrix through the following steps:

If $I$ is the 2X2 Identity Matrix

\[
\begin{pmatrix}
1 & 0 \\
0 & 1
\end{pmatrix}
\]

then its Leontiff Inverse $(I-A)^{-1}$ gives us the OI Matrix.

Note: the elements in $I-A$ are

\[
\begin{pmatrix}
1-x & -y \\
-m & 1-n
\end{pmatrix}
\]

also between 0 and 1.

Let the elements of its inverse i.e. $(I-A)^{-1} =

\begin{pmatrix}
X & Y \\
M & N
\end{pmatrix}

The diagonal elements $X$ and $N$ are therefore $>1$
And the off-diagonal elements $Y$ and $M$ are between 0 and 1.

So with 1 unit ($1$ in our example) Input in manufacturing industry we get:

- $X$ units (i.e. $X$) of Output in manufacturing (own industry) and
- $M$ units (i.e. $M$) of Output in agriculture

and with 1 unit ($1$ in our example) of Input in agriculture industry we get:

- $Y$ units (i.e. $Y$) of Output in manufacturing and
- $N$ units (i.e. $N$) of Output in agriculture (own industry)

2. Employment Output Table

*Definition*: The Employment Output Table gives employment (in $\$1$ in our example) generated in each industry for unit ($\$1$) Output in that industry. We assume Employment is the only Factor in this example.

For our two-industry economy let $EO = F = \frac{a}{b}$

So ($\$1$) 1 unit Output in manufacturing entails ($\$a$) employment in manufacturing.
And ($\$1$) 1 unit Output in agriculture entails ($\$b$) employment in agriculture.

3. Employment Input (EI) Table

*Definition* Employment Input Table gives the total amount (in $\$1$) Factor or Employment generated in all industries with unit ($\$1$) input in each industry

$F = \frac{a}{b}$
$$M = F(I-A)^{-1}$$

$$M = \begin{bmatrix} a & b \times X & Y \\ M & N \end{bmatrix}$$

$$M = aX + bM \quad aY + bN$$

If we want to separate direct and indirect employment:

Then $$F = \begin{bmatrix} a & 0 \\ 0 & b \end{bmatrix}$$

So $$M = \begin{bmatrix} a & 0 \times X & Y \\ 0 & b & M & N \end{bmatrix}$$

$$M = \begin{bmatrix} aX & aY \\ bM & bN \end{bmatrix}$$

Direct employment are the diagonal elements, indirect the off-diagonals.

Total employment is sum of rows in each industry’s column.

For $1$ input in manufacturing, total employment generated is $aX + bM$

For $1$ input in manufacturing, direct employment generated (in Manu.) is $aX$

recall $a$ is Employment in manufacturing per $1$ (unit) Output in manufacturing.

and $X$ is Output in manufacturing for $1$ input in manufacturing.

For $1$ input in manufacturing, indirect employment generated (in Agri.) is $bM$

recall $b$ is Employment in Agri. per $1$ (unit) Output in agriculture

and $M$ is Output in agriculture for $1$ input in manufacturing.
For $1$ input in agriculture, total employment generated is $aY + bN$
For $1$ input in agriculture, direct employment generated (in Agri.) is $bN$
recall $b$ is Employment in agriculture per $1$ (unit) Output in agriculture.
and $N$ is Output in agriculture for $1$ input in agriculture.

For $1$ input in agriculture, indirect employment generated (in Manu.) is $aY$
recall $a$ is Employment in manufacturing per $1$ (unit) Output in manufacturing.
and $Y$ is Output in manufacturing for $1$ input in agriculture.

The total, direct and indirect employment figures for each individual energy sector
Can thus be calculated using industry weights for energy source, that is, how much
of each industry is used for a given energy source for that factor.

4.3 Variables

Employment is understood as full-time-equivalent employment, measured as full-
time employment plus 50 percent of part-time employment of employees, including
employers, own account workers and contributing family workers for the case
study. The data was obtained from the Bangladesh Bureau of Statistics. The unit
used is jobs-per-year. This measurement addresses the time aspect implicated in
employment measurements. The jobs-per-year measure looks at the total jobs
created over the total number of years that jobs have been created to distinguish
between an economic activity that creates 10 jobs a year versus one that creates 10 jobs for 10 years. This follows the approach of the 2015 book, Global Green Growth.

**Greenhouse gas** emissions are expressed in CO₂ equivalents in accordance to guidelines set out by the IPCC, which are calculated as a weighted sum of nominal emissions of various gas species using gas-specified global warming potentials with CO₂ normalized to 1. The emission level for all the industries in the Input Output table is estimated using the energy input by source for each industry or for average energy input using average emission intensity values. **Co-pollutants** include emissions of gases NOₓ and SO₂ from the Eora dataset. **Water use** comprises both main water and surface water extracted from rivers or lakes for plant’s operation. It reflects net water use, and as such excludes in-stream users such as hydroelectric power plants or water polluted. The industry-level water use was obtained from the Bangladesh Bureau of Statistics and Eora dataset. Industry-level land use was from the Eora dataset. **Direct land-use** data for the direct use is from project documents of the power plants obtained from the Power Development Board under the Ministry of Power, Energy, and Minerals Resources of Bangladesh.

*The main part of this study is a static calculation of the total effects in terms of land use, water use, GHG emissions, co-pollutants: NOₓ and SO₂, and employment for the three plans. The research uses an Input output or IO model to estimate these factor amounts. IO is a linear macroeconomic approach to describe industrial structure. Applied to economic and environmental indicators such as employment, land*
disturbance, water and energy use, it yields total indicator intensities, that is the amount of a factor indicator required to produce and deliver a value unit of a particular commodity, energy for the purpose of this research. Total indicator intensities include direct and indirect contributions. The next chapter goes through the details of how this model is applied to calculate the total effects for the three energy plans.
This chapter describes the steps for estimating the how much of these factor inputs are associated with each plan. It starts with an Input Output table of 25 industries for Bangladesh. Next I estimate the direct and upstream factor input (water, land, etc.) associated per dollar invested in each of the 25 industries.

Of the 25 industries listed in the IO table I identify those that make up the energy related investment categories or sectors (six power generation by source and three efficiency measures). I estimate what fraction of a dollar invested in each of nine categories (coal, solar, grid upgrades etc.) go into the industries involved. This allows me to estimate how much direct and upstream factor input (employment, land etc.) is associated per dollar invested in the nine energy related sectors. Since the three plans are made up of different combinations of these nine sectors, I can estimate how much of land, employment, emissions, and water goes into each plan. Though Plan 1, the BAU scenario is not an option for 2050, some of the factor estimates for Plan 1 are included in the chapter.

5.1 Data inputs
5.1.1 Input Output Table

The Input Output Table for Bangladesh was obtained from the Eora global supply chain database consisting of a multi-region input-output table (MRIO) model built from the UN’s System of National Accounts and COMTRADE databases, Eurostat, Japan External Trade Organization (IDE/JETRO), and national agencies. The 25 industries included in the IO tables for Bangladesh is listed below in Table 4.

Table 4: Input Output industries

<table>
<thead>
<tr>
<th>Number</th>
<th>Industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Agriculture</td>
</tr>
<tr>
<td>2</td>
<td>Fishing</td>
</tr>
<tr>
<td>3</td>
<td>Mining and Quarrying</td>
</tr>
<tr>
<td>4</td>
<td>Food &amp; Beverages</td>
</tr>
<tr>
<td>5</td>
<td>Textiles and Wearing Apparel</td>
</tr>
<tr>
<td>6</td>
<td>Wood and Paper</td>
</tr>
<tr>
<td>7</td>
<td>Petroleum, Chemical and Non-Metallic Mineral Products</td>
</tr>
<tr>
<td>8</td>
<td>Metal Products</td>
</tr>
<tr>
<td>9</td>
<td>Electrical and Machinery</td>
</tr>
<tr>
<td>10</td>
<td>Transport Equipment</td>
</tr>
<tr>
<td>11</td>
<td>Other Manufacturing</td>
</tr>
<tr>
<td>12</td>
<td>Recycling</td>
</tr>
<tr>
<td>13</td>
<td>Electricity, Gas and Water</td>
</tr>
<tr>
<td>14</td>
<td>Construction</td>
</tr>
<tr>
<td>15</td>
<td>Maintenance and Repair</td>
</tr>
<tr>
<td>16</td>
<td>Wholesale Trade</td>
</tr>
<tr>
<td>17</td>
<td>Retail Trade</td>
</tr>
<tr>
<td>18</td>
<td>Hotels and Restaurants</td>
</tr>
<tr>
<td>19</td>
<td>Transport</td>
</tr>
<tr>
<td>20</td>
<td>Post and Telecommunications</td>
</tr>
<tr>
<td>21</td>
<td>Financial Intermediation and Business Activities</td>
</tr>
<tr>
<td>22</td>
<td>Public Administration</td>
</tr>
<tr>
<td>23</td>
<td>Education, Health and Other Services</td>
</tr>
<tr>
<td>24</td>
<td>Private Households</td>
</tr>
</tbody>
</table>
5.1.2 Industry weights

The weights given for the industries (agriculture, fishing, mining and quarrying, and so on) for each investment source (three renewable, three fossil fuel, three efficiency measures) are shown in the Table 5 below. Weights given for the industries under energy related sectors (solar, wind, building upgrades, etc.), listed on the left, should add up to 1. The table is based on Pollin’s 2015 book, Global Green Growth. The weights were built using a combination of referencing the Development Project Proposal (DPP) of the power plants I visited and the Indonesia chapter of Greening the Global Economy and matching those to the industries of the IO table used. The three efficiency investment categories were based on the book and previous discussion on the prospects for efficiency gains from transit rail, grid updates, and building upgrades in Bangladesh.

Table 5: Industry weights for the nine energy-related sectors

<table>
<thead>
<tr>
<th>Sector</th>
<th>I-O Industry</th>
<th>Weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar</td>
<td>Construction</td>
<td>0.30</td>
</tr>
<tr>
<td></td>
<td>Electrical and Machinery</td>
<td>0.53</td>
</tr>
<tr>
<td></td>
<td>Public Administration</td>
<td>0.18</td>
</tr>
<tr>
<td>Wind</td>
<td>Other Manufacturing</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td>Metal Products</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td>Electrical and Machinery</td>
<td>0.43</td>
</tr>
<tr>
<td></td>
<td>Construction</td>
<td>0.26</td>
</tr>
<tr>
<td></td>
<td>Education, Health, and Other services</td>
<td>0.07</td>
</tr>
</tbody>
</table>
### Hydro

<table>
<thead>
<tr>
<th>Petroleum, Chemical and Non-Metallic Mineral Products</th>
<th>0.18</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical and Machinery</td>
<td>0.21</td>
</tr>
<tr>
<td>Construction</td>
<td>0.18</td>
</tr>
<tr>
<td>Education, Health and Other Services</td>
<td>0.43</td>
</tr>
</tbody>
</table>

### Efficiency investments

<table>
<thead>
<tr>
<th>Building Upgrades</th>
<th>Construction</th>
<th>0.70</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity, Gas and Water</td>
<td>0.20</td>
<td></td>
</tr>
<tr>
<td>Other Manufacturing</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td>Transit Rail</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transportation</td>
<td>0.55</td>
<td></td>
</tr>
<tr>
<td>Construction</td>
<td>0.45</td>
<td></td>
</tr>
<tr>
<td>Grid Upgrades</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construction</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>Transport Equipment</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>Electrical and Machinery</td>
<td>0.38</td>
<td></td>
</tr>
<tr>
<td>Electricity, Gas and Water</td>
<td>0.13</td>
<td></td>
</tr>
</tbody>
</table>

### Fossil Fuel Energy Production

<table>
<thead>
<tr>
<th>Coal</th>
<th>Mining and Quarrying</th>
<th>0.50</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Petroleum, Chemical and Non-Metallic Mineral Products</td>
<td>0.50</td>
</tr>
<tr>
<td>Oil/Gas</td>
<td>Mining and Quarrying</td>
<td>0.50</td>
</tr>
<tr>
<td></td>
<td>Petroleum, Chemical and Non-Metallic Mineral Products</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td>Transport</td>
<td>0.30</td>
</tr>
</tbody>
</table>

For this work the matrix $F$ has five factors (labor, land, water, greenhouse gas emissions, co-pollutants) thus $f = 5$. If we return to the example with only one factor, labor, we see that the total employment generated under each plan is then calculated using the energy and efficiency mix for each plan. Similarly this is repeated for the other factors (land, water, GHG, co-pollutants). For emissions I first used energy as a factor input, which I will then convert to emissions, thus vector $F$ has four factors for the purpose of initial calculations.

### 5.1.3 Plan Weights
Total factor input under the three plans is then calculated for $1 invested in each plan. For the alternate green plan (third plan), an investment of $1 would mean that one-third goes into efficiency investments and two-thirds to renewable energy production. Of this two-third, a certain ratio is considered for each source, depending on projections of cost and availability. Of the amount allocated for efficiency investments, for instance, half is for grid upgrades, and the rest divided equally between efficiency gains in industry and for building upgrades. Table 6 shows the energy source and efficiency investment weights for each plan. For each plan, the weights for each the ‘investment type’ (Renewables, Efficiency Measures, Fossil Fuel) add up to 1. The weights for the efficiency investments were built on the basis of government plans as detailed in the EEC Master Plan by SREDA and referred to in the previous section on efficiency.

Table 6: Investment mix by energy source and efficiency measures for each plan.

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Plan 1</th>
<th>Plan 2</th>
<th>Plan 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas</td>
<td>0.62</td>
<td>0.25</td>
<td>0.18</td>
</tr>
<tr>
<td>Coal</td>
<td>0.02</td>
<td>0.5</td>
<td>0.03</td>
</tr>
<tr>
<td>Oil</td>
<td>0.29</td>
<td>0.1</td>
<td>0.03</td>
</tr>
<tr>
<td>Hydro</td>
<td>0.01</td>
<td>0.02</td>
<td>0.07</td>
</tr>
<tr>
<td>Solar</td>
<td>0.01</td>
<td>0.08</td>
<td>0.32</td>
</tr>
<tr>
<td>Wind</td>
<td>0</td>
<td>0</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Efficiency investments
<table>
<thead>
<tr>
<th></th>
<th>Plan 1</th>
<th>Plan 2</th>
<th>Plan 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rail</td>
<td>0</td>
<td>0.025</td>
<td>0.1</td>
</tr>
<tr>
<td>Grid</td>
<td>0.05</td>
<td>0.025</td>
<td>0.2</td>
</tr>
<tr>
<td>Building Upgrades</td>
<td>0</td>
<td>0</td>
<td>0.04</td>
</tr>
</tbody>
</table>

The weights of each investment under the three plans are used to compare the total employment generated by investing $1 in the three plans to address concerns that
employment opportunities under clean energy investments are low. Similarly the impacts of each plan on the other variables (land, water, and energy) are also estimated.

5.2 Factor Results

5.2.1 Employment

In this section, I present results of estimates on employment created through spending on energy related sectors, comprising of renewable energy and energy efficiency. The specific renewable energy and energy efficiency sectors modeled within the national Input Output model are hydropower, wind, and solar among the renewable sectors; and building upgrades, transit rail, and grid upgrades under energy efficiency.

I report a set of estimates of overall job generated through investments in the different energy related sectors. This includes both direct and indirect employment. I first present the full set of results in terms of jobs-per-year created per $1 spent. To facilitate comparisons on job creation levels across sectors, weighted averages of employment creation figures for renewables, energy efficiency and fossil fuels are presented. Finally in order to estimate overall effects on annual employment levels through clean energy investment project at the level of 0.81 percent of GDP under the alternate green plan, the weighted averages of the energy related sectors under
the alternate plan is estimated and a comparison between the overall results under the government plan and alternate green plan is presented.

Table 7 presents employment generated from direct energy related sectors and from their respective upstream economic activities. The results are presented for each of the nine energy related sectors. The estimates show that overall employment creation in Bangladesh through spending in renewable energy and energy efficiency investments will be much higher than the employment generated through the fossil fuel sectors. This is true across all renewable energy and energy efficiency sectors.

Table 7: Employment estimates (jobs-per-year) per $1 invested for each sector

<table>
<thead>
<tr>
<th>Energy-related sectors</th>
<th>Total</th>
<th>Direct</th>
<th>Indirect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas</td>
<td>24.83</td>
<td>13.18</td>
<td>11.64</td>
</tr>
<tr>
<td>Coal</td>
<td>37.69</td>
<td>32.93</td>
<td>4.77</td>
</tr>
<tr>
<td>Oil</td>
<td>24.83</td>
<td>13.18</td>
<td>11.64</td>
</tr>
<tr>
<td><strong>Fossil fuel</strong></td>
<td>87.35</td>
<td>59.30</td>
<td>28.05</td>
</tr>
<tr>
<td>Hydro</td>
<td>51.48</td>
<td>12.18</td>
<td>39.30</td>
</tr>
<tr>
<td>Solar</td>
<td>15.32</td>
<td>0.48</td>
<td>14.85</td>
</tr>
<tr>
<td>Wind</td>
<td>41.00</td>
<td>21.47</td>
<td>19.53</td>
</tr>
<tr>
<td><strong>Renewable</strong></td>
<td>107.81</td>
<td>34.12</td>
<td>73.68</td>
</tr>
<tr>
<td>Rail</td>
<td>30.12</td>
<td>0.02</td>
<td>30.10</td>
</tr>
<tr>
<td>Grid</td>
<td>14.56</td>
<td>0.90</td>
<td>13.66</td>
</tr>
<tr>
<td>Building upgrades</td>
<td>41.09</td>
<td>17.14</td>
<td>23.95</td>
</tr>
<tr>
<td><strong>Efficiency measures</strong></td>
<td>85.77</td>
<td>18.06</td>
<td>67.71</td>
</tr>
</tbody>
</table>

The results show that hydropower generates the most employment with 51.48 jobs-per-year per $1 in spending. In the other renewable energy areas, wind and solar, total (direct and indirect) job creation ranges between 15.32 and 41 jobs-per-year per $1. Under the energy efficiency categories, building upgrades generates
substantially more yearly jobs per $1 in spending, at 41.09 jobs. These are mostly jobs linked to the construction industry. With transit rail and grid upgrades, the estimates are 30.12 and 14.56 annual jobs per $1. The estimates for coal, oil and natural gas, range between $24.83 and 37.69 yearly jobs per $1 invested.

Using the results derived from employment estimates for the nine energy related sectors per $1 in spending from Table 7, I use the weights from Table 5 to estimate the direct and indirect jobs under the two plans for each investment category: fossil fuel (coal, gas, oil); renewable (hydro, solar, wind); and efficiency measures (transit rail, grid updates, building retrofits). I can next estimate the total employment created under the government plan and alternate plan. The BAU plan, Plan 1, is not presented, as the plan is unfeasible over our time period, given shortages in natural gas availability in the country.

The employment generated per dollar in (i) renewables is the weighted average of solar, wind, and hydropower, therefore the sum of the estimates shown in green in Table 8. The employment per dollar in (ii) efficiency is the sum of the weighted estimates for rail, grid, and building upgrades shown in maroon in Table 8. The last row shows the estimated employment multipliers for the overall Bangladesh economy under the government plan and the alternate green plan. The figure under the alternate plan is 23.98 jobs per $1.

<table>
<thead>
<tr>
<th>Plan weights</th>
<th>Total jobs</th>
</tr>
</thead>
</table>

Table 8: Overall weighted employment generation (yearly jobs) in 2050 Plans 1, 2
<table>
<thead>
<tr>
<th></th>
<th>Govt. Plan</th>
<th>Alternate Plan</th>
<th>Govt. Plan</th>
<th>Alternate Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas</td>
<td>0.25</td>
<td>0.18</td>
<td>6.21</td>
<td>4.47</td>
</tr>
<tr>
<td>Coal</td>
<td>0.50</td>
<td>0.03</td>
<td>18.85</td>
<td>1.13</td>
</tr>
<tr>
<td>Oil</td>
<td>0.10</td>
<td>0.03</td>
<td>2.48</td>
<td>0.74</td>
</tr>
<tr>
<td>Hydro</td>
<td>0.02</td>
<td>0.07</td>
<td>1.03</td>
<td>3.60</td>
</tr>
<tr>
<td>Solar</td>
<td>0.08</td>
<td>0.32</td>
<td>1.23</td>
<td>4.90</td>
</tr>
<tr>
<td>Wind</td>
<td>0.00</td>
<td>0.03</td>
<td>0.00</td>
<td>1.23</td>
</tr>
<tr>
<td>Rail</td>
<td>0.03</td>
<td>0.07</td>
<td>0.75</td>
<td>2.11</td>
</tr>
<tr>
<td>Grid</td>
<td>0.03</td>
<td>0.20</td>
<td>0.36</td>
<td>2.91</td>
</tr>
<tr>
<td>Building</td>
<td>0.00</td>
<td>0.07</td>
<td>0.00</td>
<td>2.88</td>
</tr>
</tbody>
</table>

**Weighted average employment per $1**

<table>
<thead>
<tr>
<th></th>
<th>Govt. Plan</th>
<th>Alternate Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30.91</td>
<td>23.98</td>
</tr>
</tbody>
</table>

The spending amounts for renewables and efficiency investments under the alternate plan are presented in Table 9, assuming a 0.81 percent of yearly GDP invested for clean renewables and efficiency investments over 30 years. The average annual spending allocated for renewables is $2.05 billion and for efficiency investments is $1.02 billion. The total spending over our period of interest comes to $61.5 billion and $30.7 billion respectively. From these spending amounts we can calculate the total yearly employment created this period. As shown in Table 9 this value comes to 407 billion with 325 billion created in renewables and 81.4 billion created in efficiency measures.

**Table 9: Spending and employment estimates under the alternate green plan**

<table>
<thead>
<tr>
<th></th>
<th>Renewable</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual spending level ($)</td>
<td>2.05E+09</td>
<td>1.02E+09</td>
</tr>
<tr>
<td>Total spending 30 y ($)</td>
<td>6.15E+10</td>
<td>3.07E+10</td>
</tr>
<tr>
<td>Total yearly jobs per $</td>
<td>9.74</td>
<td>7.90</td>
</tr>
<tr>
<td>Av. annual jobs given spending</td>
<td>2E+10</td>
<td>8.06E+09</td>
</tr>
<tr>
<td>Total jobs 30 y</td>
<td>5.99E+11</td>
<td>2.43E+11</td>
</tr>
</tbody>
</table>

These results show that the overall employment created under the government plan is higher than under the alternate green plan. This is because the number of jobs
created per dollar under solar, the main investment category under Plan 3, is less than the jobs created per dollar under coal, the main investment category in Plan 2. We find that under the proposed alternate plan, the total spending over the next thirty years comes to $61.5 billion for clean renewables and $30.7 billion for efficiency investments which result in the creation of 842 billion jobs in the overall economy, with $599 billion created in renewables and 243 billion created in efficiency measures. It is important to note here that Bangladesh suffers from widespread unemployment, underemployment, informal employment, and poor working conditions despite its robust growth (ILO, 2016). Policies around power generation and efficiency investments can be structured to address these issues and provide training to support job expansion in the requisite areas.

5.2.2 Land, Water, Energy

1. Land

Table 10 presents the land-use estimated from direct energy-related economic activities and from indirect, or upstream, activities. The results are shown for the nine energy-related sectors. The estimates show that relative to the clean energy investments in power generation and efficiency measures, more aggregate land is used in the production of energy through all three fossil fuel sources for the same
amount of investment, with the oil production being the most land-intensive at 1.24E-01 ha/$.

Table 10: Land estimates (ha) for $1 invested under each investment measure

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Direct</th>
<th>Indirect</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fossil Fuel</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gas</td>
<td>4.54E-04</td>
<td>4.37E-04</td>
<td>1.63E-05</td>
</tr>
<tr>
<td>Coal</td>
<td>2.95E-04</td>
<td>2.62E-04</td>
<td>3.31E-05</td>
</tr>
<tr>
<td>Oil</td>
<td>3.34E-01</td>
<td>2.09E-01</td>
<td>1.24E-01</td>
</tr>
<tr>
<td><strong>Renewable</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydro</td>
<td>1.84E-05</td>
<td>9.93E-09</td>
<td>1.84E-05</td>
</tr>
<tr>
<td>Solar</td>
<td>1.02E-05</td>
<td>1.03E-08</td>
<td>1.01E-05</td>
</tr>
<tr>
<td>Wind</td>
<td>1.29E-05</td>
<td>1.68E-08</td>
<td>1.28E-05</td>
</tr>
<tr>
<td><strong>Efficiency</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rail</td>
<td>1.63E-05</td>
<td>2.20E-10</td>
<td>1.63E-05</td>
</tr>
<tr>
<td>Grid</td>
<td>1.63E-05</td>
<td>6.97E-06</td>
<td>9.33E-06</td>
</tr>
<tr>
<td>Building</td>
<td>2.75E-05</td>
<td>1.10E-05</td>
<td>1.66E-05</td>
</tr>
</tbody>
</table>

Table 11 presents estimates of the effects on total land-intensity under the three plans, which are built from different combinations of the nine energy-related sectors. Using the weights shown in green on the left half of Table 11, we first calculate the amount of land under each energy-related sector used for the three plans. The last row thus shows the land multiplier for $1 invested in the three plans.

Table 11: Land estimates (ha) for $1 invested under each plan

<table>
<thead>
<tr>
<th></th>
<th>Plan weights</th>
<th>Total Land (ha) per sector</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plan 1</td>
<td>Plan 2</td>
</tr>
<tr>
<td><strong>Plan weights</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gas</td>
<td>0.62</td>
<td>0.25</td>
</tr>
<tr>
<td>Coal</td>
<td>0.02</td>
<td>0.5</td>
</tr>
<tr>
<td>Oil</td>
<td>0.29</td>
<td>0.1</td>
</tr>
<tr>
<td>Hydro</td>
<td>0.01</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>Solar</td>
<td>Wind</td>
</tr>
<tr>
<td>---------------</td>
<td>-------</td>
<td>------</td>
</tr>
<tr>
<td></td>
<td>0.01</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The aggregate of land-use estimates for direct energy-related sectors and all upstream economic activities reveal that Plan 1 or the BAU plan is the most land-intensive at 4.20E-04 ha/$ and Plan 3, the alternate green plan, the least land-intensive at 1.15E-04 ha/$. The coal-intensive government plan requires around 62 percent more land compared to the alternate green plan for the same investment. This is pertinent for a land-constrained country like Bangladesh.

Section 3.3 provided a rough estimate of total costs associated with each plan. Plan 1 was estimated to cost $229 billion, Plan 2 $252 billion, and Plan 3 $519 billion. Using the total land intensity per dollar invested, presented in Table 11, I can estimate the total land used under the three plans. Plan 1 would require the most land at 9.63E+07 hectares, Plan 2 would require 7.79E+07 hectares, and Plan 3 the least at 5.97E+07 hectares.

2. Water
A similar treatment is applied to estimate direct and upstream water input for the nine energy-related sectors. The total water input for the sectors are shown in blue on the left hand column in Table 12 below. Using the weights corresponding to each sector for the three plan, the total water input for the sectors under each plan is shown in the right three columns. The last row of Table 12 gives the water multiplier of $1 invested in the three plans.

Table 12: Water input (m$^3$) for $1$ invested under each sector and plan

<table>
<thead>
<tr>
<th>Sector</th>
<th>Total water</th>
<th>Plan weights</th>
<th>Total water (m$^3$) per sector</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Plan 1</td>
<td>Plan 2</td>
</tr>
<tr>
<td>Gas</td>
<td>3.34E-01</td>
<td>0.02</td>
<td>0.25</td>
</tr>
<tr>
<td>Coal</td>
<td>3.07E-01</td>
<td>0.62</td>
<td>0.02</td>
</tr>
<tr>
<td>Oil</td>
<td>3.34E-01</td>
<td>0.29</td>
<td>0.1</td>
</tr>
<tr>
<td>Hydro</td>
<td>2.37E+00</td>
<td>0.01</td>
<td>0.02</td>
</tr>
<tr>
<td>Solar</td>
<td>2.31E-01</td>
<td>0.01</td>
<td>0.08</td>
</tr>
<tr>
<td>Wind</td>
<td>3.34E+00</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Rail</td>
<td>2.95E-01</td>
<td>0</td>
<td>0.025</td>
</tr>
<tr>
<td>Grid</td>
<td>3.17E+00</td>
<td>0.05</td>
<td>0.025</td>
</tr>
<tr>
<td>Building</td>
<td>3.17E+00</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total water (m$^3$) for the three plans/$</strong></td>
<td><strong>3.28E-01</strong></td>
<td><strong>3.08E-01</strong></td>
<td><strong>2.82E-01</strong></td>
</tr>
</tbody>
</table>

The results from Table 12 show that the alternate green plan is the least water intensive per dollar invested at 1.30 m$^3$, the BAU plan is the most intensive at 3.28E-01 m$^3$ and the government renewable plan ranks second at 3.08E-01 m$^3$. The water intensity estimates for the nine energy-related sectors show that the government plan is most intensive because of the water intensity of fossil fuel at 0.97 m$^3$ per dollar invested versus renewables at 0.80 m$^3$ per dollar. Given the dependency on water for agricultural and aquacultural needs in Bangladesh, this could be a policy
concern. One potential response is policies specifically targeting upstream economic activities that are water intensive in order to reduce water stress on competing activities. It is also important to note here that estimates for Plan 3 is an over estimate because it extrapolates from the coefficients based on the current plant, which is a large hydro facility, where as the hydropower plant under Plan 3 exclude large scale hydropower plants.

3. Energy

A similar treatment is applied to estimate direct and upstream energy input for the nine energy related sectors. The total energy input for the sectors are shown in blue on the left hand column in Table 13 below. Using the weights, shown in green, of each sector under the three plans, total energy input for the sectors under each plan is shown in the right three columns. The last row of Table 13 gives the energy input multiplier of $1 invested in the three plans.

Table 13: Energy input (TWh) for $1 invested under each sector and plan

<table>
<thead>
<tr>
<th>Sector</th>
<th>Total energy TWh/$</th>
<th>Plan weights</th>
<th>Energy (TWh/$) by sector for each plan</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Plan 1</td>
<td>Plan 2</td>
</tr>
<tr>
<td>Gas</td>
<td>1.71E-05</td>
<td>0.62</td>
<td>0.25</td>
</tr>
<tr>
<td>Coal</td>
<td>1.61E-05</td>
<td>0.02</td>
<td>0.5</td>
</tr>
<tr>
<td>Oil</td>
<td>1.71E-05</td>
<td>0.29</td>
<td>0.1</td>
</tr>
<tr>
<td>Hydro</td>
<td>1.15E-05</td>
<td>0.01</td>
<td>0.02</td>
</tr>
<tr>
<td>Solar</td>
<td>1.06E-05</td>
<td>0.01</td>
<td>0.08</td>
</tr>
<tr>
<td>Wind</td>
<td>1.15E-05</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
The results from Table 13 shows that Plan 3, the alternate green plan is the most energy intensive per dollar invested at 1.94E-05 TWh. Energy production under the current mix under Plan 1 or BAU requires less energy at 1.78E-05 TWh, while the government renewable plan requires the least energy input at 1.65 E-05 TWh. However, energy input is only calculated to estimate the total, direct and upstream, GHG emissions and copollutants under the three plans.

5.3 Emissions Calculations

5.3.1 Greenhouse Gas

1. Power Generation: The greenhouse gas (GHG) and copollutant emissions from power generation are calculated from the energy demand projections for the three plans. The GHG emissions from burning fossil fuels for the three plans were previously calculated in Chapter 3. Using estimates of NO\textsubscript{x} and SO\textsubscript{2} emitted per kWh of coal we can also calculate the associated copollutants. The energy mix and total emissions under the three plans are reproduced in Table 14 below.

Table 14: Energy mix and total 2050 emission calculations for each plan

<table>
<thead>
<tr>
<th></th>
<th>Energy mix</th>
<th>Total TWh/$/for the three plans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rail</td>
<td>2.25E-05</td>
<td>0.025 0.07 0.00E+00 5.63E-07 1.58E-06</td>
</tr>
<tr>
<td>Grid</td>
<td>3.41E-05</td>
<td>0.05 0.025 0.2 1.70E-06 8.52E-07 6.82E-06</td>
</tr>
<tr>
<td>Building</td>
<td>3.41E-05</td>
<td>0 0 0.07 0.00E+00 0.00E+00 2.39E-06</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1.78E-05 1.65E-05 1.94E-05</td>
</tr>
<tr>
<td></td>
<td>mix</td>
<td>Power ($10^{10}$ kWh)</td>
</tr>
<tr>
<td>--------</td>
<td>---------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>Coal</td>
<td>0.02</td>
<td>3.05</td>
</tr>
<tr>
<td>Gas</td>
<td>0.62</td>
<td>3.05</td>
</tr>
<tr>
<td>Oil</td>
<td>0.29</td>
<td>94.70</td>
</tr>
<tr>
<td>total GHG emission</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plan 2 (10% renewable, 10% imported)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coal</td>
<td>0.50</td>
<td>76.37</td>
</tr>
<tr>
<td>Gas</td>
<td>0.25</td>
<td>38.19</td>
</tr>
<tr>
<td>Oil</td>
<td>0.05</td>
<td>7.64</td>
</tr>
<tr>
<td>total GHG emission</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plan 3 (60% renewable)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coal</td>
<td>0.05</td>
<td>7.64</td>
</tr>
<tr>
<td>Gas</td>
<td>0.27</td>
<td>41.24</td>
</tr>
<tr>
<td>Oil</td>
<td>0.05</td>
<td>7.64</td>
</tr>
<tr>
<td>total GHG emission</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. **Upstream emissions**: Upstream emissions associated with the energy related sectors under three plans are calculated from the direct and indirect energy inputs for the three plans. The total energy inputs per dollar invested have been presented in Table 13. Using the total energy input estimates along with the energy mix for the three plans I can estimate greenhouse gas emissions.

For Plan 1 the total energy input is $1.78E-5$ TWh. The energy mix from Table 14 is 2 percent Coal, 62 percent Gas, and 29 percent Oil. Therefore of this $1.78E-5$ TWh, 2 percent or $3.56E-07$ TWh is coal power generation corresponding to GHG emission amount of $3.49E-1$ mt since I know the carbon dioxide equivalent emission per kWh (in metric tons) of fossil fuel source, which are: Coal $9.8E-4$ mt; Natural Gas $5.5E-4$ mt; and Oil $7.9E-4$ mt. Table 14 shows the emission associated with producing energy for the year 2050 under the three plans. The results show that Plan 3, the
alternate green plan, produces the least upstream GHG emissions at 1.05 mt, and the government plan or Plan 2 produces the most at 1.10E+01 mt.

Table 15: Upstream GHG emission from the three plans

<table>
<thead>
<tr>
<th>Plan</th>
<th>Total Input Energy TWh</th>
<th>1.78E-05</th>
<th>1.65E-05</th>
<th>1.94E-05</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total emission (mt)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>from energy input under Plan 1</td>
<td></td>
<td>1.06E+01</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total emission (mt)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>from energy input under Plan 2</td>
<td></td>
<td>1.10E+01</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total emission (mt)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>from energy input under Plan 3</td>
<td></td>
<td>1.05E+00</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Plan</th>
<th>Total Input Energy TWh</th>
<th>1.78E-05</th>
<th>1.65E-05</th>
<th>1.94E-05</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coal</td>
<td>0.02</td>
<td>3.56E-07</td>
<td>9.80E-04</td>
<td>3.49E-01</td>
</tr>
<tr>
<td>Gas</td>
<td>0.62</td>
<td>1.10E-05</td>
<td>5.53E-04</td>
<td>6.11E+00</td>
</tr>
<tr>
<td>Oil</td>
<td>0.29</td>
<td>5.16E-06</td>
<td>7.98E-04</td>
<td>4.12E+00</td>
</tr>
<tr>
<td></td>
<td>Total emission (mt)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>from energy input under Plan 1</td>
<td></td>
<td>1.06E+01</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coal</td>
<td>0.50</td>
<td>8.25E-06</td>
<td>9.80E-04</td>
<td>8.08E+00</td>
</tr>
<tr>
<td>Gas</td>
<td>0.25</td>
<td>4.13E-06</td>
<td>5.53E-04</td>
<td>2.28E+00</td>
</tr>
<tr>
<td>Oil</td>
<td>0.05</td>
<td>8.25E-07</td>
<td>7.98E-04</td>
<td>6.59E-01</td>
</tr>
<tr>
<td></td>
<td>Total emission (mt)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>from energy input under Plan 2</td>
<td></td>
<td>1.10E+01</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coal</td>
<td>0.05</td>
<td>9.70E-07</td>
<td>9.80E-04</td>
<td>3.49E-01</td>
</tr>
<tr>
<td>Gas</td>
<td>0.27</td>
<td>5.24E-06</td>
<td>5.53E-04</td>
<td>3.49E-01</td>
</tr>
<tr>
<td>Oil</td>
<td>0.05</td>
<td>9.70E-07</td>
<td>7.98E-04</td>
<td>3.49E-01</td>
</tr>
<tr>
<td></td>
<td>Total emission (mt)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>from energy input under Plan 3</td>
<td></td>
<td>1.05E+00</td>
<td></td>
</tr>
</tbody>
</table>

5.3.2 Copollutants

1. **Direct copollutants:** I can use the quantity of energy produced by coal under the three plans and the estimates of SO$_2$ per kWh and NO$_x$ per kWh of coal to estimate the copollutants emissions under the three plans. The particulars of each power plant, such as size, efficiency, capacity, and abatement techniques greatly impact the per unit copollutant emissions and these values should be treated as rough estimates. The SO$_2$ per kWh is estimated to be 7.45-8.76 g/kWh and NO$_x$ emissions in the range of 1.81-2.37 g/kWh for coal plants in India of 250 MW in a 2012 study (Mittal et al., 2012). I use the mid-point values of 8.11 g of SO$_2$ per kWh and 2.09g NO$_x$ per kWh of power generated. I also assume these values hold for our time.
period of 2020-2050. Table 15 shows that the government plan, Plan 2 produces the most copollutants, which is not surprising since it is the most coal intensive of the three plans.

Table 16: Direct copollutant estimates for the three plans

<table>
<thead>
<tr>
<th>Plans</th>
<th>Coal ($10^{10}$ kWh)</th>
<th>CO2 emissions (mt)</th>
<th>$10^{10}$ g SO$_2$</th>
<th>$10^{10}$ g NO$_x$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.05</td>
<td>90.76</td>
<td>24.72</td>
<td>6.38</td>
</tr>
<tr>
<td>2</td>
<td>76.37</td>
<td>102.05</td>
<td>618.98</td>
<td>159.61</td>
</tr>
<tr>
<td>3</td>
<td>7.64</td>
<td>36.4</td>
<td>61.92</td>
<td>15.97</td>
</tr>
</tbody>
</table>

2. Upstream copollutants: Next I calculate the upstream copollutants for the three plans using emission intensities of 8.11 g of SO$_2$ per kWh and 2.09g NO$_x$ per kWh of power generated. I use the upstream direct and indirect energy input from coal power generation under the three plans to estimate the associated copollutant emissions as shown in Table 16 below. Here we see that Plan 1 or BAU has the least emission and Plan 2, government plan, the most. As stated in the beginning of the chapter, Plan 1 is not an option for our time horizon given the gas depletion projected beyond 2030.

Table 17: Upstream copollutant emissions under the three plans

<table>
<thead>
<tr>
<th>Upstream</th>
<th>Coal (kWh)</th>
<th>SO$_2$ (g)</th>
<th>NO$_x$ (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plan 1</td>
<td>356</td>
<td>2885.38</td>
<td>744.04</td>
</tr>
<tr>
<td>Plan 2</td>
<td>8250</td>
<td>66866.25</td>
<td>17242.5</td>
</tr>
<tr>
<td>Plan 3</td>
<td>970</td>
<td>7861.85</td>
<td>2027.3</td>
</tr>
</tbody>
</table>
This chapter examines how the three plans compare in terms of employment, water, land, GHG emissions and copollutants. The chapter estimates how much of these factors are associated for the same investment, $1, in each plan. The chapter finds that the overall employment created under the alternate green plan is twenty three percent lower than under the government plan. An aggregate of land used for direct energy-related sectors and all upstream economic activities reveal that the government renewable plan is the most land intensive at 4.20E-04 ha/$ and Plan 3, the alternate green plan, the least land-intensive at 1.15E-4 ha/$. This is pertinent for a land-constrained country like Bangladesh.

We see that the alternate green plan is also the least water intensive per dollar invested at 0.28m³, and the government renewable plan is in second place at 0.31m³. Looking at the water intensity for the nine energy-related sectors, we see that this is because of the water intensity of fossil fuel sources particularly from direct economic activities.

Plan 3 or the alternate green plan is designed to produce the least GHG emissions of the three plans considered. Upstream emissions to produce the energy under three plans are calculated from the direct and indirect energy inputs for the three plans. We find that Plan 3, the alternate green plan, produces the least upstream GHG emissions at 1.05 mt, and the government plan or Plan 2 produces the most at 1.10E+01 mt. For direct emission of copollutants the results show that the government plan, Plan 2 produces the most copollutants, which is not surprising since it is the most coal
intensive of the three plans. I use the upstream direct and indirect coal power
generation under the three plans to estimate the associated upstream copollutants
emissions. Plan 2, government plan, has the most emissions, at 6.69E+04 g SO\textsubscript{2} and
1.72E+04 g NO\textsubscript{x}. 
CHAPTER 6
INPUT OUTPUT APPLICATION FOR PROJECT LEVEL IMPACTS

In this chapter I apply the IO framework to estimate the impacts on land of different energy paths. We know that for 2050 the greatest expansion in power generation comes from coal under the government plan and solar under the alternate plan. We also know the land impacted varies widely for the two sources. The land-impact input includes degraded or partially used land from secondary research on the specific power plant using studies on its environmental impacts. Because of the site and project specific impact on land, two individual plants were chosen to demonstrate the land-impact variable.

The first power plant analyzed here is coal-powered and I use the land-use multiplier matrix from previous estimates for the coal sector. In this chapter I apply the Input Output (IO) results for the land variable to the Barapukuria coal plant. Next I use the land-use multiplier matrix from our previous estimates for the solar sector to estimate land impacted by the Kaptai solar plant.

This chapter thus supplement the previously estimated direct land-use estimates for coal and solar with new estimates for land impacted by a solar plant and a coal plant. I next estimate the land-intensity for land use and land impacted but for unit energy produced instead of dollar invested under the two sources.
6.1 Methodology

This section lays out the methodology used to build the land-used variable from the IO framework described in the previous section to the land-impacted variable to determine the impact of individual power plants. It then applies this new framework on a coal plant and a solar plant following Lenzen and Murray's 2001 paper, “A Modified Ecological Footprint Method and Its Application to Australia”.

6.1.1 Methodology: Land-use Variable

I present the model used for the land-impacted variable by first reviewing the model for land-use variable. Indirect land-use refers to all the land used by upstream activities for power generation. Thus the total indicator intensity for land include direct and indirect contributions, for instance:

- Direct or zeroth-order land used by the commodity (unit of energy produced): the land on which the plant is built.
- First-order indirect contribution: land used for producing supporting goods and services for the plant and workers—where they stay, food produced, or roads or energy used for producing the equipment used for construction of the plant.
• Second-order indirect contribution: land used or water used for producing energy needed for the equipment used for constructing the plant and so on.

Recall: The result of generalized input–output analyses is a $f \times n$ matrix of factor multipliers, that is embodiments of $f$ production factors per unit of final consumption of commodities produced by $n$ industry sectors, denoted here by matrix $F$.

A multiplier matrix $M$ can be calculated from the $f \times n$ matrix $F$ containing sectoral production factor usage, and from a $n \times n$ direct requirements matrix $A$ according to:

$$M = F (I - A)^{-1}$$

where $I$ is the $n \times n$ unity matrix.

Steps:

- Input Output Matrix $A = (\text{Input/Output})$
- Leontif Inverse $(I - A)^{-1} = (\text{Output/Input})$
- Calculate the Factor–Output Ratio for each individual levels of industry
- Sort the Factor – Output Ratio according to the Input-Output table
- Factor/Input = (Factor/Output) * (Output/Input)
  
  or $M = F (I - A)^{-1}$

The diagonal elements in the $M$ matrix give the direct factor required and the off-diagonals are the indirect factors generated. For instance if $f=1$, that is, we were
looking at one factor input, say land, then the diagonal elements would give direct land used and the off-diagonals would be the indirect land used.

A simple example clarifying each step has been included below to demonstrate how this work for land-use. This was previously done for employment.

Steps:
1. Input Output Table

*Definition:* The IO table gives the amount of input from all industries in an economy needed to produce 1 unit of output in each industry.

Example:
In a two-industry economy with manufacturing and agriculture the IO table is a 2×2 matrix, let’s call it matrix A.

Let the elements of matrix \( A = \begin{pmatrix} x & y \\ m & n \end{pmatrix} \)

where \( x,y,m,n \) are scalar numbers between 0 and 1.

Let the first industry be manufacturing and the second agriculture.

So to produce 1 unit (\$1 in our example) of output in manufacturing industry we need:

\( x \) units (i.e. \$x) of input from manufacturing and
$m$ units (i.e. $\$m$) of input from agriculture

Similarly to produce 1 unit ($\$1$ in our example) of output in agriculture industry we need:

$y$ units (i.e. $\$y$) of input from manufacturing and

$n$ units (i.e. $\$n$) of input from agriculture

2. Output Input Table

*Definition of Output Input:* The OI table gives the amount of Output in all industries in an economy generated from 1 unit of Input in each industry.

We now get an Output Input matrix from the IO matrix through the following steps:

If $I$ is the 2X2 Identity Matrix

\[
\begin{pmatrix}
1 & 0 \\
0 & 1 \\
\end{pmatrix}
\]

then its Leontiff Inverse $(I-A)^{-1}$ gives us the OI Matrix.

Note: the elements in $I-A$ are

\[
\begin{pmatrix}
1-x & -y \\
-m & 1-n \\
\end{pmatrix}
\]

also between 0 and 1.

Let the elements of its inverse i.e. $(I-A)^{-1} = \begin{pmatrix} X & Y \\ M & N \end{pmatrix}$

The diagonal elements $X$ and $N$ are therefore $>1$

And the off-diagonal elements $Y$ and $M$ are between 0 and 1.

So with 1 unit ($\$1$ in our example) Input in manufacturing industry we get:
$X$ units (i.e. $\$X$) of Output in manufacturing (own industry) and

$M$ units (i.e. $\$M$) of Output in agriculture

and with 1 unit ($\$1$ in our example) of Input in agriculture industry we get:

$Y$ units (i.e. $\$Y$) of Output in manufacturing and

$N$ units (i.e. $\$N$) of Output in agriculture (own industry)

3. Land Output Table

*Definition:* The Land Output Table gives land (in hectares in our example) used in each industry for unit ($\$1$) Output in that industry.

For our two-industry economy let $EO = F = \frac{a}{b}$

So ($\$1$) unit Output in manufacturing entails $a$ (ha) land in manufacturing.

And ($\$1$) unit Output in agriculture entails $b$ (ha) land in agriculture.

4. Land Input (EI) Table

*Definition* Land Input Table gives the total amount (in ha) Factor or Land used in all industries with unit ($\$1$) input in each industry

\[
F = \frac{a}{b}
\]

\[
M = F(I-A)^{-1}
\]

\[
M = aX + bM\quad aY + bN
\]
If we want to separate direct and indirect land-use:

Then \( F = \begin{pmatrix} a & 0 \\ 0 & b \end{pmatrix} \)

So \( M = \begin{pmatrix} a & 0 & X & Y \\ 0 & b & M & N \end{pmatrix} \)

\( M = \begin{pmatrix} aX & aY \\ bM & bN \end{pmatrix} \)

Direct land used are the diagonal elements, indirect the off-diagonals.

Total land used is sum of rows in each industry's column.

For $1$ input in manufacturing, total land used is \( aX + bM \) hectare

For $1$ input in manufacturing, direct land used (in manufacturing) is \( aX \) ha

recall \( a \) is land used in manufacturing per $1$ (unit) Output in manufacturing.

and \( X \) is Output in manufacturing for $1$ input in manufacturing.

For $1$ input in manufacturing, indirect land used (in Agri.) is \( bM \) ha

recall \( b \) is land used in agriculture per $1$ (unit) Output in agriculture

and \( M \) is Output in agriculture for $1$ input in manufacturing.

For $1$ input in agriculture, total land used is \( aY + bN \) ha

For $1$ input in agriculture, direct land used (in Agri.) is \( bN \) ha
recall \( b \) is land used in agriculture per $1 \) (unit) Output in agriculture. And \( N \) is Output in agriculture for $1 input in agriculture.

For $1 input in agriculture, indirect land used (in Manu.) is \( aY \) ha
recall \( a \) is land used in manufacturing per $1 \) (unit) Output in manufacturing. And \( Y \) is Output in manufacturing for $1 input in agriculture.

The total, direct and indirect land used figures for each individual energy sector can thus be calculated using industry weights for energy source, that is, how much of each industry listed in the IO table is used for a given energy source for that factor. For this application the energy source is coal and factor is land used.

### 6.1.2 Methodology: Land-impacted Variable

The \( f \times 1 \) land impact \( E \) of a plant is determined by multiplying the proposal cost (represented by a \( n \times 1 \) commodity inputs vector \( \Upsilon \)) with the multiplier matrix \( M \), and adding a \( f \times 1 \) vector \( E_d \) of direct (on-site) impacts:

1. \( M \times \Upsilon \) represents indirect requirements, that is land-use indicator quantities embodied in all inputs into the plant’s operation. The vectors \( \Upsilon \) and \( E_d \) is extracted from project information on the power plant.

Recall \( M = aX + bM \quad aY + bN \)
\(M\) gives the direct and indirect factor (land here) used for unit (\$1) Input in each industry

\(aX+bM\) is the direct and indirect land used for \$1 Input in the first industry, manufacturing, in our two-industry example.

And \(aY+bN\) is the direct and indirect land used for \$1 Input in the second industry, agriculture.

\[\mathbf{Y} = \mathbf{Y}_M \mathbf{Y}_A\]

\(\mathbf{Y}\) in our example will have only two elements, the

\(\mathbf{Y}_M\) the amount (in \$) of manufacturing used in the project

\(\mathbf{Y}_A\) the amount (in \$) of agriculture used in the project

Therefore \(\mathbf{M}^*\mathbf{Y}\) gives amount of land used in project

\(\mathbf{M}^*\mathbf{Y} = (aX+bM) \mathbf{Y}_M + (aY+bN) \mathbf{Y}_A\)

i.e. the sum of \((aX+bM) \mathbf{Y}_M\) the direct and indirect land used for \$ \(\mathbf{Y}_M\) Input in the manufacturing industry and \((aY+bN) \mathbf{Y}_A\) the direct and indirect land used for \$ \(\mathbf{Y}_A\) Input in the agriculture industry.

Note here ‘direct’ refers to own industry use. It does not refer to the actual land on which the power plant is built and impacted. Let the actual land used or impacted be \(E_d\).
2. $E_d$ has two components: the land on which the power plant is built and the land ‘disturbed’ by the power plant. This information is obtained from the project document and environmental impact studies and added to the above estimate to give total land used by project.

$$E_d = \sum D_i = \sum A_i \times C_i$$

**Land-impacted** $E_d$ is estimated through the following equation $E_d = \sum D_i = \sum A_i \times C_i$ expressed as a weighted sum of land use areas $A_i$ with weights $C_i$. The weights reflect the degree of alteration of land from its natural state, or the land condition. This is dependent on the type of land impacted by each plant. The total impact is then added for each plan.

The framework involves categorization of impacted land as: agricultural, grazing, mangrove, floodplain, and water bodies or proximity to water-bodies. These constitute the main land types in Bangladesh. Following this categorization, existing or potential costs for each land-type will be calculated for the power plants. These will include income lost from loss of access to agricultural land or water-body for fishing, cost of damage avoided per unit area of mangrove or floodplain.

Next I use the environmental impact assessment and ecosystem evaluation literature to assign a value between 0 and 1. Depending on the location and extent of damage, these sites will have different extents of ‘use’ per unit area. Total use gets 1,
damaged gets 0.8, degraded gets 0.6, disturbed gets 0.4, and partially disturbed gets 0.2. The following section includes a table to show the damage type and corresponding damage ‘value’ and a discussion on the criteria used to assign these values. The risk reducibility for mangroves, for instance, is specific to the type, density, and width of mangroves, as well as to geomorphological and specific storm event characteristics of the area. Because of the specific nature of the impacts, alongside the broad categorization and damage calculations for each energy source, a more focused case study helps demonstrate how the method can be applied to specific power plants.

6.2 Results: Coal Plant

The previous section modeled the environmental impact \( E = M \times Y + E_d \)

1. \( M \times Y \)

We begin with the Multiplier Matrix \( M \) for the land variable. Matrix \( M \) was obtained by multiplying the Land per Output Matrix with the Leontif Inverse of the 25 industry-Input Output Matrix \((I-A)^{-1}\) obtained from the Eora database. Thus \( M \) is a matrix of 1\times 25 dimension since we are looking at only one factor, land, for this section.
The commodity inputs vector $\mathbf{Y}$ is the amount (in US dollars) of each of the 25 industries that went into the project. This information is obtained from the Development Project Proposal (DPP) of the Barapukuria Coal Plant.

This involved looking at the line items of each project cost from the DPP and matching it to the 25 industries listed in the Input Output Table.

### Table 18: 25-Sector commodity inputs for Barapukuria coal plant

<table>
<thead>
<tr>
<th></th>
<th>US$ (million)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Agriculture</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Fishing</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Mining and Quarrying</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Food &amp; Beverages</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Textiles and Wearing Apparel</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Wood and Paper</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Petroleum, Chemical and Non-Metallic Mineral Products</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>64.29</td>
<td>Metal Products</td>
</tr>
<tr>
<td>9</td>
<td>481.50</td>
<td>Electrical and Machinery</td>
</tr>
<tr>
<td>10</td>
<td>Transport Equipment</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Other Manufacturing</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Recycling</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>0.12</td>
<td>Electricity, Gas and Water</td>
</tr>
<tr>
<td>14</td>
<td>40.41</td>
<td>Construction</td>
</tr>
<tr>
<td>15</td>
<td>0.18</td>
<td>Maintenance and Repair</td>
</tr>
<tr>
<td>16</td>
<td>Wholesale Trade</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Retail Trade</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Hotels and Restaurants</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>5.25</td>
<td>Transport</td>
</tr>
<tr>
<td>20</td>
<td>Post and Telecommunications</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Financial Intermediation and Business Activities</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Public Administration</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Education, Health and Other Services</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>Private Households</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Others</td>
<td></td>
</tr>
</tbody>
</table>
This table above is thus the \((1 \times 25)\) inputs vector \(\mathbf{Y}\) which gives the amount (in $ million) of each of the 25 industries that went into this project.

We already have \((25 \times 1)\) multiplier vector \(\mathbf{M}\) which gives land in hectares (direct and indirect) for $1 input in each of the 25 industries.

\(\mathbf{M} \times \mathbf{Y}\) gives total land (direct and indirect) in hectares that went into the project.

This is calculated to be 5182.60 hectares as shown. For scale comparison Bangladesh’s total land area 14.76 million ha.

2. \(E_d\)

Using the environmental impact assessment and environmental reports on the project I now estimate the land impacted directly \(E_d\) using the methodology described above. The first step involves categorizing the land impacted into arable, flood plain, water body, or forestland, with corresponding amounts of land in hectares. The next step is to assign extent-of-use values, between 0 and 1, to the land areas, with 1 being totally used.

The coal plant was built on, thus has completely used 100 hectares. In addition it has impacted agricultural land and water body. From the information presented in detail in the case study on the Barapukuria coal plant in the next chapter, the following impacts can be evaluated.
i. **Impact on water body**: A 2015 study found that hourly 9 cubic meter of industrial wastewater from the plant is discharged directly into the Tilai River without treatment. The river is around 5km in length but is connected to other tributaries and seeps into the underground water. In addition, the power plant contains two ash ponds. The study found that the ash pond contains harmful heavy metals, which could seep into underground water sources over time (Hossain et al., 2015). Therefore, ground water could get polluted and could become unsuitable for domestic use. The findings support the experience of local community members interviewed, who said that the Tilai river has been polluted since the coalmine and power plant started operations.

The area in hectare that the river impacts was estimated from the number of villages that the river traverses, which is four. The average area of each village is 450.41 ha. This is an underestimate given the interconnectedness of water bodies and the impact on ground water that can result from the polluted Tilai river. The total area impacted is 1801.64 ha. The time aspect involved for the manifestation of these indirect impacts means that the quantification of these costs and assign a value would require not only area estimates of the extent of impact but also projected timelines and costs (for instance in terms of reduced aquaculture output) discounted to the present. The stream-flow from the uphill areas and the rain in the area plays a role in providing fresh water to offset some of the impacts on the household water-use, fisheries, and ecosystem impacted by the pollution. We thus
ignore this indirect aspect entirely for this research. The weight of this cost is assigned to be 0.4.

ii. **Impact on agricultural land:** The case study shows that 15 villages have been impacted by water shortage as a result of the activities of the coal plant. Conversations with the community members, local rights groups, and environmental reports revealed that the water shortage impacts the agricultural productivity of the land for those unable to buy water to compensate the loss. However an exact estimate of the loss could not be obtained. The impact of water shortage compound over time and thus raises similar challenges of incorporating future impacts. The case study revealed that the cost of the water that some families buy to offset the water shortage is low at $0.11 monthly per person. The total agricultural land impacted is 6756.15 hectares. Thus the negative impact on agricultural land is assigned a cost of 0.2.

<table>
<thead>
<tr>
<th>Table 19: Land disturbance table</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Land</strong></td>
</tr>
<tr>
<td>Used totally (Built on)</td>
</tr>
<tr>
<td>Damaged</td>
</tr>
<tr>
<td>Arable and grazing land</td>
</tr>
<tr>
<td>Flood Plain</td>
</tr>
<tr>
<td>Nearest to Water body</td>
</tr>
<tr>
<td>Mangrove/Forest</td>
</tr>
<tr>
<td>Degraded</td>
</tr>
<tr>
<td>Arable and grazing land</td>
</tr>
<tr>
<td>Flood Plain</td>
</tr>
<tr>
<td>Disturbed</td>
</tr>
<tr>
<td>Arable and grazing land</td>
</tr>
<tr>
<td>Flood Plain</td>
</tr>
<tr>
<td>Nearest to Water body</td>
</tr>
<tr>
<td>Mangrove/Forest</td>
</tr>
<tr>
<td>Partially disturbed</td>
</tr>
<tr>
<td>Arable and grazing land</td>
</tr>
<tr>
<td>Flood Plain</td>
</tr>
<tr>
<td>Nearest to Water body</td>
</tr>
</tbody>
</table>
The total land impacted directly $E_d = 2171.89$ ha

$E = (M \times Y) + E_d = 5182.60$ ha $+ 2171.89$ ha $= 7354.49$ ha

6.3 Results: Solar Plant

The above methodology can now be used to calculate land-impacted estimates for a 5 MW solar power plant in Kaptai, Chittagong occupying a land area of 2.02 hectares. The project was undertaken by the Power Development Board (PDB), the power generation and distribution entity of the Bangladesh government. The total cost of $15.21$ million was financed through a loan from the Asian Development Bank (ADB). All information presented below was from the Development Project Proposal (DPP) obtained at the field site of in Kaptai, Chittagong, Bangladesh. The line items of the cost summary from the project documents was compared to the 25 industries listed in the IO table. The commodity inputs vector $Y$ or the amount (in US dollars) of each of the 25 industries that went into the solar project is presented below.

<table>
<thead>
<tr>
<th>Table 20: Commodity inputs vector $Y$ for Kaptai solar plant</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Table 20: Commodity inputs vector $Y$ for Kaptai solar plant" /></td>
</tr>
</tbody>
</table>
The multiplier vector $M$ estimates land in hectares (direct and indirect) for $1$ input in the 25 industries. $M \times \Upsilon$ thus gives direct and indirect land in hectares that went into the project. It is calculated to be 88.94 hectares as shown in the attached excel sheet. The direct land use is 2.02 ha and indirect impact of power generation is zero. Thus the total impact $(M \times \Upsilon) + E_d$ is 100.96 ha.

### 6.5 Multiple Land-Use for Solar Power

The land-impact estimated for solar however is an overstatement if generalized, because for the Kaptai solar plant considered in this study, the area on which the panels are installed are not used for any other purpose. In reality the land on which panels are installed could have multiple purposes, from doubling as building-tops...
for solar roof-top projects to serving as arable land for growing tomatoes which require more shade than is available in Bangladesh, making the area covered by solar panels ideal for such multiple uses. The land thus directly ‘used’ by the solar panel, valued at 1, could then be weighted as ‘displaced’ at 0.6. This would change the total impact as shown below.

\[ E = (M \times Y) + E_d \]
\[ E_d = \Sigma D = \Sigma D_i = \Sigma i A_i \times C_i \]
\[ E = (M \times Y) + \Sigma i A_i \times C_i \]
\[ E_d = \Sigma i A_i \times C_i = 2.02 \times 0.6 = 1.21 \text{ ha} \]

1. **Direct land-impacted for power generation:** The main energy source under the government plan is coal power, producing 50 percent of the country’s energy needs. Under the alternate plan presented in this work, the solar power forms the largest source in the energy mix. In this section I compare the direct land impacted between coal power generation and solar power. I then project the direct land impacted through the two sources under the government plan, referred to as Plan 2 here and the proposed alternate plan, Plan 3.

The two power plants considered here are the Kaptai solar power and the Barapukruia coal plant. The solar plant of 5 MW capacity is built on 2.02 hectares of land, while the coal plant has a capacity of 525 MW and is built on 100 hectares of land. The land impacted \( E_d \) from the power plant was estimated using land-
impacted weights. As shown in Table 18 the impacted area for the coal plant is estimated to be 2071.89 ha. Table 20 compares the land impacted by the two power plants using this methodology. It shows that once we take into account the land-degradation from coal power generation and the dual-use of land on which solar power can be generated the land-intensity values changes such that solar becomes less land intense than coal.

Table 21: Land impact power generation under solar and coal from case studies

<table>
<thead>
<tr>
<th></th>
<th>Direct impact</th>
<th>Land intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar: Kaptai Plant size, land-use</td>
<td>5 MW, 2.02 ha</td>
<td>0.4 ha/MW</td>
</tr>
<tr>
<td>Coal: Barapukuria Plant size, land use</td>
<td>525 MW, 100 ha</td>
<td>0.19 ha/MW</td>
</tr>
<tr>
<td>Land impact (ha) solar</td>
<td>0</td>
<td>0.4 ha/MW</td>
</tr>
<tr>
<td>Land impact (ha) coal</td>
<td>2071.89 ha</td>
<td>3.95 ha/MW</td>
</tr>
<tr>
<td>Impact solar (direct-dual use +impact)</td>
<td>2.02*0.6=1.21 ha</td>
<td>0.24 ha/MW</td>
</tr>
<tr>
<td>Impact coal (direct +impact)</td>
<td>2171.89 ha</td>
<td>4.14 ha/MW</td>
</tr>
</tbody>
</table>

We can use the land-intensity estimates from Table 20 to estimate the land-intensity for 2050 under the two sources for Plan 2 and Plan 3. The projected energy need for 2050 is used to estimate the energy output for the two sources, coal and solar, under the two plans. Table 21 shows that using this new methodology direct land impact is greater under the government plan than the alternate plan. This is especially pertinent for Bangladesh given its land-constraints and its dependency on agriculture and aquaculture, which though is projected to reduce in the coming decades, is still likely to continue to be a major source of income for lower-income households in 2050.

Table 22: Total Land Impact 2050, Government Plan and Alternate Plan

<table>
<thead>
<tr>
<th>Total Energy Output MWh</th>
<th>1.53E+09</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plan 2</td>
<td>Mix</td>
</tr>
</tbody>
</table>

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2. **Upstream Impacts**: I now estimate the land-impact from upstream activities related to power generation through solar and coal. I first consider the direct land impact according to the current land-use in Kaptai solar power plant. As presented above, the 5MW solar power plant involved direct land-use of 2.02 ha. The potential dual use of land for solar power generation is not considered here. The coal power plant produced 525 MW through direct land-use of 100 ha. As a rough estimate we can say that solar power needs 0.40 hectares per MW whereas coal uses 0.19 ha/MW, thus solar requires over twice as much land for the same amount of power generated relative to coal. However when we take into account total land impacted by the power plant we find that to produce 5MW by solar, total land disturbance is estimated to be 100.96 ha, or 20.19 ha/MW and for coal, generating 525 MW of power impacts 7354.49 ha, or 14.01 ha/MW. The difference between the land area required to generate power using solar versus coal becomes smaller, with solar requiring only 1.44 times the land used for coal.

If we consider the dual-land use for solar power the difference in land-intensity between solar and coal reduces further. The direct land-impact considering dual-land use for the Kaptai solar plant was estimated to be $E_d = \Sigma A_i \times C_i = 2.02 \times 0.6 = 1.21$
ha. Upstream impacts from solar power generation was estimated to be $(M \times \Upsilon)$ = 88.94 ha. Thus total impacts is $E = 88.94 \text{ ha} + 1.21 \text{ ha} = 90.15 \text{ ha}$. This reduces the land estimate to produce 5MW to 90.15 ha, or 18.03 ha/MW a mere 1.29 times the land intensity under coal power generation.

*This chapter shows that though coal power generation is less land-intensive per unit energy output than solar, when we take into account the upstream and indirect impacts of the two sources, we see that coal becomes almost as land intensive as solar.*

*This coupled with the emission-intensity, employment generation, and water-use impacts considered in this research, suggest that solar is more suited for Bangladesh taking into account the key aspects or concerns of power generation.*
The aim of this research is to not only demonstrate how the framework can be applied for the land disturbance variable that incorporates aspects of environmental and social impacts, but to also examine the distributional effects of power plants. Though the IO model gives overall impacts, it does not show which groups benefit or lose out from the different policies. This chapter examines this through a case study on the one existing coal plant in Barapukuria, focusing on five key aspects of power generation: financing, employment, other socioeconomic aspects, environment and climate change.

The chapter first identifies the key players along the different types of impacts considered and it also examines the different policies moderating these impacts. These details are not extractable from currently available information on the power plants, and are difficult to establish through remote communication, therefore an on-site study was required. I decided to do the study on a coal plant as coal power constitutes the largest expansion under the government policy.

To this end in this chapter I examine localized impacts by taking a closer look at the following questions:
• employment: what is amount of local and national jobs created by these plants and do they benefit those whose livelihoods have been negatively impacted by the plant?
• land: what are the mechanisms through which the land was acquired by the power companies and did it lead to changes in access of local communities to land resources?
• environmental impacts: have there been impacts on land, water, and air?
• social impacts: have there been displacement and compensation of local communities?
• financing: how does the mode of financing or financing entity mediate these impacts?
• policies: what are the different policies that moderate the above impacts and how were they applied in the case of Barapukuria?

This chapter is arranged in the following manner: it begins with a background of the power plant, then provides an overview of the key players involved. Next it describes the methodology and gives a more detailed look into the five variables or key aspects. The next section summarizes the findings under each variable and identifies those who benefitted and those who lost out with respect to each key aspect. The chapter ends with an overview of relevant policies mediating these impacts.

7.1 Background
The fieldwork examines how economic, environmental and climate change impacts are interconnected, and provides the opportunity to apply our theoretical model, incorporating analytical work alongside its application, to gain insights into how our global energy system is evolving. This brings into focus how challenges faced on ground do not occur in separate spaces that academic fields often occupy; thus to truly understand how the impacts play out it is essential to take an on-site look.

As indicated in the government plan, Bangladesh is hoping to almost triple its power generation by 2030 (Power System Master Plan, 2016). Since 2016 the GDP growth rate has accelerated to over 7% driven by a double-digit growth in manufacturing and construction sectors (Bangladesh Development Update, 2018). The government is committed to continue on this path and is anticipating a change in the country’s categorization from a “Least Development Country” (LDC) to a “Developing Country” by 2024 under the United Nations Department of Economic and Social Affairs (DESA) categorization (forthcoming Committee for Development Policy CDP Review, March 2018 Press Release).

In the latest Poverty Reduction Strategy Paper (PRSP) and Power System Master Plan (2016) the government outlines its plan to increase access to electricity and to grow the economy by expanding its heavy manufacturing sector, which is energy-intensive (PRSP, 2015). Currently most of the power is from domestic gas, but in the early 2000s the government announced that the country is at risk of running out of gas reserves by 2025, so the new policy is to switch to coal as the main energy
source since there are coal reserves (Scaling Up Renewable Energy, 2015). To meet its growing energy needs, Bangladesh’s energy policy is to increase coal’s share in the total energy mix from 2 percent to 50 percent.

The government is planning to finance this frenzy of new power plants construction partly through the usual channels of foreign loans. Because of budget limitations, immaturity of financial markets, and relative higher cost of capital domestically, the availability of long term financing is limited within the country. Thus, Bangladesh finances most of its infrastructure investments through multilateral and bilateral loans. Though infrastructure funding has traditionally been dominated by Western banks, following the recent financial crisis many developing countries are increasingly attracting financing from newly emerging Asian sources, particularly China.

China has become one of Bangladesh’s main development partners in recent years. Chinese companies and individuals are now offering assistance in developing the information and communication technology industry, power sector, river management, and industrial zones in Bangladesh (Basu, 2017). Recently Bangladesh and China signed a Memorandum of Understanding on strengthening investment and production capacity cooperation, with Bangladesh set to receive $24.45 billion in bilateral assistance for 34 projects and programs (Byron and Rahman, 2016). And since last year China has become Bangladesh’s biggest energy partner (Siddique, 2016).
Most notably, Bangladesh is looking to China’s Export Import Bank to finance two of its largest coal plants, namely the Moheshkhali and Patuakhali coal plants, both at 1320MW capacity. Currently Bangladesh has only one coal plant and coal mine in Barapukuria, both of which were financed through a credit line with China’s Import Export Bank. The construction was undertaken by a Chinese company, Harbin Electric International Company Limited (henceforth referred to as Harbin Electric), which is also in charge of operating the mine and plant jointly with the Bangladesh government for the next five years. As Bangladesh plans to dramatically increase the share of coal in its power sector, a case study on its sole coal plant could be used to gauge potential impacts of the government’s coal intensive national policy in the coming decades, in particular its distributional aspects. It also sheds a light on how key players, such as the investor and borrowing government, can regulate the impacts of these projects.

7.1.1 Key Questions Raised

The specific questions listed below were chosen for this case study because they shed light into the distributional impacts under the broad categories of labor, land, environment, social impacts that were examined in terms of national impacts for the three energy plans. The following questions were examined for each plant.

1. Employment:
• Number and type of employment: (full-time, part-time)
• Wage and benefits
• Outsourcing to foreign companies/national/ local content
• Potential multiplier effect from worker spending

2. Factor/Production Inputs:
• National/regional content- machines and other inputs
• Multiplier effect- e.g. from boost to industry producing machines

3. Net Revenue:
• Price (of different sources)- fluctuation/production capacity in n years:
  plant’s lifetime or over period of interest (2020-2050)
• Cost of production- government subsidy/price guarantee by government
• Tax and royalties- how much re-invested in local economy
• Government/individual shares- government purchase of product

To examine the distributional impacts from the employment generated by the plant, I first look at the number of jobs created nationally and if there are foreign companies/employees involved. I further investigate if the employees are from the local communities. In other words I try and determine who are the people employed by the plant. Next I look at the type of job created by the plant, if they are full time or part time and if they include pension packages, injury/death compensation packages. To examine potential indirect jobs created by the plant I look at the national content of the inputs of the plant such as examining how much of the machines used to build and operate the plant are nationally made.
To determine the costs and benefits from the plant operations it is useful to examine if there is any royalty paid to the government, if there are duties, and so on. I ask if the government or Bangladeshi investors own shares in the company; does the government provide special tax allowances to the company; and if the energy is sold at a price guaranteed by the government and/or if there are subsidies involved. This becomes important for long-term cost estimates over our period of interest. In addition, price projections for different energy sources help us determine the revenue and profits of the company over time and how much of that could indirectly benefit people through government revenue and national and local public spending.

To determine the distributional aspect from the plants’ environmental and social impacts, the following information was collected:

- Displacement and resettlement/compensation plan.
- Changes in access to land-use/resources: livelihood option for those with reduced access— are they getting work at the plant?
- Land acquisition process: who owned land and sold it? What is the land price?
- Water bodies: any changes to community’s access to fishing, pollution, interruption to stream-flow/drainage?

If the direct land use involved people being displaced in order to build the plant, then along with estimates of the number displaced where possible I examine if the
company, financial institutions or the state had a compensation and relocation plan. In addition I try to determine the following: did those relocated find alternate livelihood options? Did it lead to changes in access to services such as schools and hospitals? Do the people who have lost access to resources for example grazing-land, water-bodies for fishing have adequate alternatives? Is their access to water reduced? This is relevant for coal plants that use a lot of water. Central to distributional impacts of direct land-use in Bangladesh is the question of how the land was acquired, were there any land disputes, any evidence of force used by the company to acquire the land and was the plant built on indigenous land (relevant for the Dinajpur and Chittagong plants)? Indigenous and other marginalized communities have tenuous land-ownership documentation and thus are vulnerable to forceful eviction.

To assess environmental risks I examine the following questions: did the construction create pollution from waste dumped on the roadside or in nearby water-bodies? Is the operation of the plant itself causing pollution? In order to assess risks to the plants as well as the communities I look at the risk of land subsidence, storms, and flooding.

7.2 Research

7.2.1 Overview of the Plant
Barapukuria power plant is located in the northwestern part of Bangladesh, in Dinajpur district as shown in Figure 1. The power plant and adjoining mine are both financed by China’s Export Import bank (90 percent) through a credit line and the government of Bangladesh (10 percent). The power plant started operation in 2006, and the expansion completed in 2016. The mine started operation in 2010 and produces around 1 million tones of coal yearly, of which over 80 percent is used for the power plant; the rest is sold to brick kilns and used for other domestic industries. Figure 3 is a Google map view of the area and shows that the plant and mine are next to each other. What is more difficult to discern from the image is that the area is completely enclosed with very high walls, around 20 feet, and is heavily guarded. The Bangladesh army and border guard are both deployed there. To visit the area one needs high level of clearance which is almost impossible to obtain unless through top government officials.

Figure 1: Barapukuria, Dinajpur District.
This situation arose after public backlash in 2006 against a proposed mine expansion, which was ultimately stalled. The protests were covered globally by leading news agencies such as Al Jazeera because of the brutality of government response. At least three persons were killed and 70 others injured as police and Border Guard Bangladesh (BGB) opened fire on people protesting in the neighboring Phulbari (Four Killed, 2006). The protests were specifically around the mine’s expansion, but were fuelled by existing grievances around lack of compensation and relocation, lack of job opportunities, and groundwater depletion.

In this backdrop it becomes crucial to talk to communities living in the vicinity of the power plant and hear their concerns regarding increased coal power generation. It must be mentioned here that due to the proximity of the plant and the mine and their starting date of operation, some of their impacts were difficult to separate in
my conversations with impacted communities, particularly with regards to land acquisition and relocation.

Figure 2: Google map view of the Barapukuria coal plant and mine

Given these concerns over just one plant it is imperative to assess impacts of coal power generation under the new policy with respect to the five key aspects identified—financing, employment, other socioeconomic aspects, environment and
climate change. If we are looking at over 25 fold increase in the next decades, what should the government, the financiers, and relevant stakeholders expect in terms of impacts, and not just what but who will be impacted most and in what ways? To help tease out these aspects, the key players involved are shown in Figure 3 below.

Figure 3: Key players, Barapukuria coal plant

1. Financing: The Bangladesh government (referred to as GoB in Figure 3) borrowed 90% of the construction cost from China Export Import Banks, henceforth referred to as China ExIm, through a credit line. Power Development Board (PDB)— the
power generation and distribution entity under the Ministry of Power, Energy, and Mineral Resources (MoPEMR)—is the owner and operator of the plant. Information on financing was acquired from the ministry and the plant.

2. Employment: The coal power plant employ three categories of workers: direct employees of PDB, the employees of Harbin, and the third-party contracted workers for construction purposes, referred to as ‘civil work’ in official documents.

3. Socioeconomic Impacts: Impacted local communities include deed-holding landowners, peasants, and marginalized communities whose livelihoods and source of income were changed as a result of the power plant. Local non-governmental organizations (NGO), local politicians, and journalists play a key role in recording and moderating socioeconomic impacts.

4. Environmental Impacts: The coal plant’s impact on land, water, and air are also experienced by the local community groups identified above. Ministry of Environment, NGOs, environmental, academic, and research institutes record some of the impacts.

5. Climate change impact: The Ministry of Environment estimates net greenhouse gas emission and oversee steps to minimize net emissions from the plant.

**7.2.2 Methodology**
Following the 2011 case study on the Marlin Mine by Zarsky and Stanley, and the 2013 study Chinese Mining in Latin America by Irwin and Gallagher, the methodology for this work was to first identify key impacts of coal power plant, then identifying the groups who are most impacted or involved in each aspect. The methodology for gathering the necessary information was to first contact key players involved with the power plant along the 5 key aspects. They are listed in Table 22 below.

Table 23: Methodology: Groups contacted and type of information gathered

<table>
<thead>
<tr>
<th>Groups Providing Information</th>
<th>Type of Information</th>
</tr>
</thead>
</table>
| Ministry of Power, Energy, and Mineral Resources | Financing-related information:  
  - Financial statements  
  - Terms of loan agreement  
  - Development Project Proposal |
| Power Development Board (PDB) | Employment-related information:  
  - Wages  
  - Terms of employment |
| Employees PDB | Environment-related information:  
  - EIA  
  - Studies on environmental impacts  
  - Experiences of environmental changes |
| Ministry of Environment | Environment-related information:  
  - EIA  
  - Studies on environmental impacts  
  - Experiences of environmental changes |
| Research Institutes | Environment-related information:  
  - EIA  
  - Studies on environmental impacts  
  - Experiences of environmental changes |
| Communities | Socioeconomic Information:  
  - SIA, Resettlement information  
  - Reports on economic impacts  
  - Experiences related to:  
    - compensation, access to land,  
    - changes in job situation,  
    - availability of power |
| Journalists |  |
| NGOs |  |

To get documents on finance, operations, and access to workers I spoke to PDB and the MoPEMR. To get information and data on environmental and climate change impacts I went to the Ministry of Environment for the Environmental Impact
Assessment (EIA) for the power plant. I also contacted universities, research institutes, journalists, and environmental groups for relevant studies. Environmental groups and journalists put me in touch with impacted local communities and gave me contact information of individuals who were able and willing to talk. To get information on social impact such as resettlement, health issues, and changes in access to resources, I spoke to local NGOs and local rights groups who work on these issues. I was unable to obtain a Social Impact Assessment (SIA) for the power plant, but some of the information pertaining to social impacts was included in the Development Project Proposal (DPP). I also spoke to journalists for information on social impacts and protests. After individuals were identified from journalists, CSOs, and the PDB, a series of unofficial meetings were organized with some of the impacted communities and employees.

These groups were selected not only because of their connection to the plant and the plant's impacts but also because they are trusted authorities on the aspects studied (journalists, research groups, human rights organizations, and environmental groups). They represent the range of positions on the key impacts and include stakeholders who stand to gain the most and lose the most from the power plant. Because the spectrum of positions on these 5 aspects were already identified from reviewing studies, reports, and news articles, I spoke to people on opposite ends in order to learn about the specifics on the issues and the specifics of their experiences.
To examine the distributional impacts of employment generated by the plant, I looked at the number of jobs created nationally and if there are foreign companies or employees involved, and if the employees are from the local communities. In other words I tried to determine who are the people employed by the plant. Next I examined the type of job created by the plant, if they are full time or part time and terms of employment. To examine potential indirect jobs created by the plant I looked at the national content of the inputs of the plant such as examining how much of the machines used to build and operate the plant are nationally made.

I also considered the potential of indirect employment and benefits created through revenue to the government and domestic companies, and subsequent investment in the economy through public spending and job creation. It was thus useful to examine if there is any royalty paid to the government, if there are duties, and so on. I examined if the government or Bangladeshi investors own shares in the company; does the government provide special tax allowances to the company; and if the energy is sold at a price guaranteed by the government and if there are subsidies involved. In addition, I examined if price projections for different energy sources are included in the project proposal, as they help determine the revenue and profits of the company over time and how much of that could indirectly benefit people through government revenue and through local and national public spending.

To determine the distributional aspect from the plants’ environmental and social impacts I examined if the company, financial institutions or the state had a
compensation and relocation plan. Did those relocated find alternate livelihood options? Did it lead to changes in access to services such as schools and hospitals? Do the people who have lost access to resources for example grazing land, water-bodies for fishing or irrigation have adequate alternatives? Have there been any changes in the underground water level, drainage system, or stream-flow of a nearby river?

Central to distributional impacts of direct land-use in Bangladesh is the question of how the land was acquired; were there any land disputes, any evidence of force used by the company to acquire the land or any other discrepancies in the land acquisition process and was the plant built on indigenous land? Indigenous and other marginalized communities have tenuous land-ownership documentation and are therefore vulnerable to forced eviction. To assess environmental risks I examined the following questions: did the construction create pollution from waste dumped on the roadside or in nearby water-bodies? Is the operation of the plant itself causing pollution? In order to assess risks to the plants as well as the communities I looked at the risk of land subsidence, storms, and flooding. Details on the type of information collected and sources are included in the Appendix.

7.3 Key Findings
Table 23 lists the key players impacted and the overview for each variable. The main issues are summarized for the five variables, highlighting different impacted groups. The details are given in the rest of this section.

Table 24: Key players and findings for each variable

<table>
<thead>
<tr>
<th>Variables</th>
<th>Key Players</th>
<th>Overview</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Financing</td>
<td>Cost: construction $656m; operation and maintenance $4.76 m/year</td>
<td>Financing: 13.11%</td>
</tr>
<tr>
<td></td>
<td>i. Bangladesh Government: PBD</td>
<td>borrower, owner, and operator</td>
</tr>
<tr>
<td></td>
<td>ii. China Exlm</td>
<td>financier</td>
</tr>
<tr>
<td></td>
<td>iii. Harbin Electric</td>
<td>builder and co-operator for 5 years</td>
</tr>
<tr>
<td></td>
<td>iv. China Chamber of Commerce</td>
<td>exporter of parts</td>
</tr>
<tr>
<td>2. Employment</td>
<td>1346 people for construction (over 6 years), 586 for operation.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>i. PDB employees</td>
<td>Government contract and wages</td>
</tr>
<tr>
<td></td>
<td>ii. Harbin employees</td>
<td>34.2% of employee: mainly engineers</td>
</tr>
<tr>
<td></td>
<td>iii. Outsourced workers</td>
<td>construction, land development</td>
</tr>
<tr>
<td>3. Socioeconomic Impact</td>
<td>Land 300 acres (acquisition cost $12.96 million or 2.06% of total cost)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Title-holding land owner</td>
<td>% compensated or relocated unknown</td>
</tr>
<tr>
<td></td>
<td>Non-title holding land owners</td>
<td>not compensated</td>
</tr>
<tr>
<td></td>
<td>Farmers</td>
<td>change in access to land</td>
</tr>
<tr>
<td></td>
<td>Indigenous communities</td>
<td>Santal community mainly</td>
</tr>
<tr>
<td></td>
<td>Health impacts</td>
<td>workers, community</td>
</tr>
<tr>
<td>4. Environmental Impact</td>
<td>Water: Plant requires 2400 metric tons water per day</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Surrounding community</td>
<td>water depletion in 15 villages</td>
</tr>
<tr>
<td></td>
<td>Community using pond</td>
<td>coal ash deposit</td>
</tr>
<tr>
<td></td>
<td>Air: Co-pollutants (SO, NO) emission were found by the PDB to be within</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>limits set by the Ministry of Environment</td>
</tr>
<tr>
<td></td>
<td>Community</td>
<td>through chimney smoke</td>
</tr>
<tr>
<td>5. Climate Change</td>
<td>525MW power plant; GHG (subcritical): 4281669 tons CO₂ per year</td>
<td></td>
</tr>
</tbody>
</table>

The findings summarized above are expanded on below.

**7.3.1 Financing**

The Bangladesh government borrowed 90 percent of the $656 million that was needed for construction over 6 years from China Export Import Banks, or China
ExIm, as part of a credit line, with a repayment period of 13 years and 13.11 percent financing cost, of which interest rate constituted 3.99 percent, management fee 1.50 percent, commitment fee 1 percent, and insurance fee 6.62 percent. The plant was built by Harbin Electric, who are operating the plant for the first five years PDB. Yearly cost of operation and maintenance is $4.76 million at 80 percent capacity. All parts and machineries, constituting 60 percent of the construction cost, were imported from China Chamber of Commerce for Import and Export of Machinery and Electronic Products (Barapukuria Coal Powered Thermal Power Station DPP, 2013).

Main issues highlighting different impacted groups are summarized below:

1. Government of Bangladesh (GoB) finds a willing financier in China ExIm bank:
Since the discovery of coal in the early 1980s, the mine and subsequent plant had been on the agenda of the Bangladesh government. In addition to a preference for gas, the lack of availability of financing, necessary equipment, and technical know-how pushed back the government plans for years. The rise of China's and other Asian countries’ financing capacities coincided with Bangladesh’s increased demand for energy, a demand that intensified as the country braces itself to run out of gas reserves, its main power source. Though China is reducing its domestic production of coal-sourced power, globally it is a top financier for coal power generation and top exporter of coal production parts. These factors led to the GoB’s decision to pursue coal, and to look to China not just as its main financier, but as the builder of
the plant and provider of necessary production inputs. GoB benefits from this financing ‘package’ that includes machinery and skilled workers from China.

Development banks have recently shifted away from power generation from fossil fuel towards renewable energy, transmissions, efficiency investments, conducting feasibility studies, drawing up national energy plans with the ministries, and conducting environmental and social impact assessment for various energy sector projects, including the aforementioned coal mine expansion. For the Bangladesh government it has been difficult to find a co-financier for the Barapukuria coalmine and power plant, except through private sector and Asian Export Import banks. Similar to the financing through a credit line for Barapukuria, the financing for other large-scale proposed coal plants will be through credit lines from the governments of China, India, and Malaysia, as shown in Table 24 (Giant Coal, 2014). The differences between the operational principles of the different financing groups: private, state, and multilateral development bank (MDB) with respect to social and environmental impacts are discussed later. In a sense bilateral lending is performing a function that MDBs traditionally used to in Bangladesh. MDBs now function in alternate (e.g. renewable power generation) and complementary (e.g. feasibility study of fossil fuel projects) space alongside the new financing sources. Thus there is demand from the borrowing government for the type of projects Chinese policy banks are financing, as well as a preference for the financing terms offered.

Table 25: List of proposed coal projects in Bangladesh

<table>
<thead>
<tr>
<th>Location</th>
<th>Financing Partner</th>
<th>Size (MW)</th>
</tr>
</thead>
</table>

110
2. Potential vested interest groups within lending and borrowing governments:

Minutes from a meeting between the PDB and Ministry of Finance officials was obtained that hinted at rent-capturing motivations from specific entities under both government institutions. The hand-written minutes from the internal meeting records allegations that some Bangladeshi officials were bribed by specific Chinese companies, including Harbin Electric, that ended up winning tenders for power projects.

3. Cost and Revenue, both direct and indirect, for the Bangladesh government:

The Barapukuria plant and mine are state owned. PDB purchases coal from the mine at a fixed rate, which is updated every few years and fluctuates around the market price. The cost of production is currently around 6 taka or $0.074 per kWh. The selling price is on a scale depending on the intensity and type of customer (residential, commercial, light-use, heavy industry etc.) that follows a step-wise scale. The price ranges between 3.5-12.36 taka per kWh. After the loan repayment period of 13 years, the revenue generated go to PDB, which is responsible for

<table>
<thead>
<tr>
<th>Location</th>
<th>Company/Group</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Khulna</td>
<td>Orion Group (private)</td>
<td></td>
</tr>
<tr>
<td>Maowa</td>
<td>Orion Group</td>
<td></td>
</tr>
<tr>
<td>Char Balakia</td>
<td>Orion Group</td>
<td></td>
</tr>
<tr>
<td>Chittagong Gohira</td>
<td>Orion Group</td>
<td></td>
</tr>
<tr>
<td>Chittagong Bashkhali</td>
<td>S. Alam Group</td>
<td></td>
</tr>
<tr>
<td>Chittagong Bashkhali</td>
<td>Military Tools Factory (state owned)</td>
<td></td>
</tr>
<tr>
<td>Chittagong</td>
<td>Bangladesh Steel Re-rolling Mill (state owned)</td>
<td></td>
</tr>
<tr>
<td>Munshiganj</td>
<td>Electricity Generation Company, Bangladesh</td>
<td></td>
</tr>
<tr>
<td>Rampal</td>
<td>Bangladesh, India Export Import Bank</td>
<td></td>
</tr>
<tr>
<td>Mobeshkhali</td>
<td>Malaysia, China Export Import Bank</td>
<td></td>
</tr>
<tr>
<td>Patuakhli</td>
<td>China Export Import Bank</td>
<td></td>
</tr>
</tbody>
</table>

providing power to the country and is completely state-owned. PDB’s financial reports are available on their website and reveal no profits, which is expected given the price controls and regular adjustments. The current tax rebate policy in place for coal power generation, described below, will impact the cost to the government, beyond just the PDB.

4. **Coal companies (involved in extraction, generation, manufacturer of factor-inputs):**

The national coal policy since 2010 waived corporate tax for contractors or licensees to encourage coal mine exploration, development and marketing, as well as a rebate of import duty, tax and value added tax (VAT) on the import of machinery for use in coal mining to encourage investment in coal. These benefit domestic and foreign entities involved in coal mining and power generation. The cost to the government of this policy and revenue to the different (private, public, domestic, and foreign) entities involved in extraction, generation, and manufacturer of parts have not been included in the project documents.

**7.3.2 Employment**

During the 6-year construction phase, a total of 146 people were employed, of which 34.2 percent (50 employees) were Chinese. The 96 Bangladeshis are government employees and their contract is in accordance with the government employment policy. In addition, 1200 people were outsourced for ‘civil works’ that involve construction and development of land. ‘Operation’ of the power plant requires 586
government employees under the PDB who are Bangladeshi; of this number about 70 are categorized as ‘1st class’ employees, 104 as ‘2nd class’, and 406 employees are categorized as ‘below 2nd class’ employees.

Main issues highlighting impacted groups are summarized below:

1. *Government employees*: Government jobs are extremely coveted because of the favorable pay scale and terms of employment. The employees interviewed were very satisfied with the work, and among the local communities a prevalent wish was for more people to have access to these jobs. However a common complaint from labor rights activists was that these government jobs are given to people from other parts of the country or to those with connections to government and the ability to buy influence.

2. *Lack of work for local population*: The PDB officials interviewed said around half of employees in the power plant are from the local area of Barapukuria. This is following a recent policy that 50% of the power plant employees have to be local. From group conversations with the PDB employees it seemed that lower paying jobs (below ‘2nd class’) went to those who are local, but most of the higher pay-grade employees and officials did not. The lower paying jobs include cleaners and messengers.
The latest census shows that more than 43 percent of persons aged 7 years and older in the area are not able to read and write; nearly 46 percent had attained some form of primary education; and few had a secondary or higher secondary qualification (Bangladesh Bureau of Statistics, 2011). Given the average qualification of the area, there is local demand for work that is termed ‘2nd class or lower’ in the government categorization. ‘2nd class’ employees need to have completed 10th grade or secondary school, ‘below 2nd class’ employees do not need to complete 10th grade. It is mainly in this category that local communities may find work at the plant, which is why land development and construction work is a key source of employment.

3. *System of outsourcing civil works*: One major source of employment for local communities is ‘civil works’ or construction and development of land. The construction of the power plant happened in phases, and involved roads and highways being built or upgraded to support the heavier traffic and cargo loads. However all government ‘civil work’ for the plant and mine were outsourced through a tendering process. The PDB officials interviewed said they have no control over who is hired. In fact, for the power plant the responsibility of hiring the construction company was undertaken by Harbin Electric. I was unable to get any documents from Harbin Electric or talk to their employees regarding the outsourcing process.

4. *Community mobilization*: Local community members said they were sometimes hired if the tender for construction went to a company that hired locally, but at
other times, people from other regions were brought in for construction work. Given that this is outsourced, the government is not able to note down local community members for repeated engagement. The demand of the community is that the construction work should be given to those whose livelihoods were impacted as a result of the loss of agricultural land on which power plant and coal mine were built. This has lead to repeated protests and strikes since the construction first started. Local activists interviewed stated that these protests led to the 50 percent requirement of local community members for PDB jobs. This points to a lack of channel of communication between PDB and community members. The activists interviewed stated that these protests, despite being inconvenient and disruptive to their daily lives, have been the only way to get authorities to listen to their concerns and in some instances enact change.

5. **Indirect jobs**: Indirect jobs— such as from manufacturing coal plant machineries or cement factory— that are generated from construction of new power plants are also potential sources employment. However machineries and other inputs are all imported. This constituted a major part (60 percent) of the construction cost. The only local inputs are construction material such cement, brick, steel for buildings, constituting 6.56 percent of total costs. The lack of skilled engineers and employees in Bangladesh was the reason stated for hiring a considerable share (34 percent) of Chinese employees. This means a potential loss of indirect income generated through multiplier effects in Bangladesh’s economy.
7.3.3 Socioeconomic Impacts

1. **Access to land:** Land is the main income source for the majority of Bangladesh’s population. Moreover, access to land is a key determinant of socioeconomic wellbeing as Bangladesh is land-constrained. For large projects, land acquisition is often a source of complication and delay for the government. In the case of Barapukuria power plant, the direct land used was 300 acres, which the government first acquired from titled landowners before starting the project.

Main issues highlighting impacted groups are highlighted below:

i) **Titled-holders:** Interviews with local journalists and community members indicate that landowners received compensation as per government policy. Compensation amount is decided according to classification as homestead land, agricultural land, or for business (e.g. stores) and market price determined by quality of soil, nearness to highways, river etc. as per government policy. Local community members have stated the price they received was fair and some thought it to be above the market price. The compensation indicated in the DPP was $30864.2 per acre. There were no reports of undue pressure or force involved in the land acquisition process. This is in contrast to previous incidences reported of forceful eviction, pressure used to acquire the land, and other discrepancies around compensation in the land acquisition process of other large projects in Bangladesh.
ii) *Relocated families:* A number of families were relocated to a government plot of 30 acres, which was purchased by the government mainly due to the large amount of land acquired, and large number of people relocated, not just for the power plant but also for the coal mine, and more recently due to land subsidence resulting from mine activities. The 30 acres constitute only a tenth of the land on which the power plant was build, not counting the mine or subsided land area. The government plot was not sufficient for all the relocated families, and so not everyone could get access to the government plot. In the group discussion with the community members they stated some of those relocated are having difficulties settling in and finding work. This is not surprising given how important social ties are for accessing livelihood options and resources in Bangladesh.

iii) *Scope of Social Impact Assessment (SIA) and Management Plan:* The SIA for Barapukuria did not include non-title holders, sharecroppers, nor the indigenous communities whose access to the land was reduced in some ways due to the plant. The census indicates that approximately 9 percent of the surveyed households are from ethnic minority groups, with the Santal being the largest of these ethnic minority groups. Agriculture labor (mainly rice production) is an important source of livelihood and income for most farm, non-farm, and landless households in the area, but it is a particularly important source of income for ethnic minority households. Interviews with local activists revealed that many of the wage laborers in the fields who have been adversely affected by the plant and mine are from the minority Santal community. There is no special policy or practice at the mine or
plant to employ impacted minority groups. The access to land deeds and the process of legalization of land ownership is extremely complex in Bangladesh. 80% of all court cases in the country are related to land and ownership disputes (Barkat and Roy, 2004). Marginalized communities, such as indigenous groups in the area, are often most disadvantaged in accessing titles. Those who were not titled landowners did not receive compensation from the government.

iv) Indirect impacts: Stores in the locality were not directly impacted since they are not on subsided land or on the area included in the project site, but have nonetheless suffered due to fewer customers from the loss of the communities who had to relocate due to the plant and mine. The majority of the workers in the mine and plant do not shop at these stores according the owners interviewed. The plant and mine area have their own shops inside the restricted compound. The PDB officials stated that this is due to security reasons and language barrier faced by Chinese workers. The compound is completely closed off and is heavily guarded by armed forces, thus the store is not accessible to the community.

v) Abutters: The outcome of changes in property values located near the project site have been mixed. There has been no formal study but conversations revealed that the value of property near new roads and highways around the plant and mine has increased. In contrast there has been fall in value of areas that have experienced land subsidence or expect to experience land subsidence in the future.
2. **Access to electricity and improved connectivity**: As recently as 2016 the area suffered from daily power outages. The local movement demanded that the government to prioritize the electricity produced for local use in the Dinajpur district. Since then there has been fewer power outages according to the community members interviewed, some of whom had been involved in initial protest. Moreover, as a result of the coal power plant, connectivity has improved because of the new roads and increased train service.

**7.3.4 Environmental Impacts**

The environmental impacts from the power plant are described below.

1. **Water:**

   i) **Depletion of underground water**: The power plant requires 2400 metric tons per day of ground water. This has led to a severe crisis of ground water depletion. Local activists reported that people in 15 villages have suffered as a result. The average population in a village in that region is 1461 to give an idea of the number of people potentially impacted (Bangladesh Bureau of Statistics, 2011). The situation got so bad that after months of protests, last year the government built 8 overhead water tanks, that are filled from trucks bringing in water from outside the area and are partly financed from revenue from the power plant, according to the PDB officials interviewed. The cost of accessing the water is around 9 taka ($0.11) per month per person. Though this was not felt to be expensive, the community members
interviewed proposed an alternative; it would make more sense for the power plant to purchase water from the overhead tanks, since the underground water is needed for irrigation, in addition to household use, and in the future with continued coal plant operation there may be further depletion. The communities, such as the Santals and poorer households, are most dependent on agriculture, and therefore on proper irrigation and access to water. They are thus disproportionately disadvantaged from water level depletion.

ii.) Water pollution: The environmental impact assessment (EIA) conducted by the environment ministry states that the wastewater produced by the plant is treated before being released in the Tilai river. Additionally it states that chemical and bacterial test of the water released is done every month. However a 2015 study found that hourly 9 cubic meter of industrial wastewater from the plant is discharged directly into the Tilai River without treatment. The river is around 5km in length but is connected to other tributaries and seeps into the underground water. In addition, the power plant contains two ash ponds. The study found that the ash pond contains harmful heavy metals such as boron (B), arsenic (As) and mercury (Hg), which could seep into underground water sources over time (Hossain et al., 2015). Therefore, ground water could get polluted and could become unsuitable for domestic use. The findings support the experience of local community members interviewed, who said that the Tilai river has been polluted since the coalmine and power plant started operations. There were no complaints however of waste disposal in the river during the construction phase of the plant.
iii) Health concerns: A leading daily reported two cases of skin issues allegedly arising from use of the water from Tilai river, where the power plant emits wastewater, but the local doctor disagreed with the claim stating that it is not related to water use (Barapukuria Plant, 2016). The PDB authorities interviewed felt that these complaints were an attempt to get PDB to pay for treatment costs for skin issues that are unrelated to the plant’s activities. This suggests that there is a mutual lack of trust between the authorities and the community around evaluating impacts of the power plant, making third party assessments such as from universities and research institutes even more important.

2. Air:

i) Government measurements: Coal-based power plants emit carbon dioxide (CO₂), sulphur oxide (SO₂), nitrogen oxide (NOₓ), and suspended particulate matter (PM) through the chimneys (Pokale 2012). Though the SO₂ and NOₓ levels were found to be within allowed range, particulate matter less than 10 microns in equivalent aerodynamic diameter (PM10) levels in areas around the coal mine were found to be near the upper bounds of Bangladesh Environmental Standards (BES) levels from the government conducted EIA.

ii) Independent Measurements: The social activists interviewed stated that they are suspicious of measurements done by government officials. An independent study undertaken by Rajshahi University on air quality due to the coal mine’s and plant’s
activities had slight variations in results from EIA results, particularly for the mine. The study did not include independent measurements of air quality inside the mine, but reported miners’ complaints on air quality and related health issues, which raises further questions about the official measurements. Thus the lead researcher in the team recommended that the government allow third party air quality monitoring (Masud et al., 2013).

iii) Protests from communities: Local people organized mass protest when the third and last chimney for the power plant was being constructed in 2017. The activists interviewed said the protests resulted in the new chimney height being taller than others. This disperses the emissions over a larger area, such that the pollutants are less concentrated and the air quality of nearby areas is better. This is another instance of a lack of effective channel of communication between impacted communities and the PDB.

7.3.5 Climate Change

PDB reported that 40,000 trees of various species have been planted to offset some of the GHG emission from the power plant. But this would at most sequester 900 tons a year, whereas total emission from the plant is estimated to be around 4281669 tons a year, given the size of the power plant and technology— using emission factors from MIT’s 2007 Future of Coal study following the method used in Gallagher’s 2016 policy brief (Future of Coal, 2007; Gallagher, 2016).
7.4 Policies Governing Social and Environmental Impacts

The above findings point to several recurring issues over the life cycle of the project—beginning with the initial screening process that include specific requirements in terms of impact assessments; parameters around implementation that include steps to reduce negative impacts such as scope of compensation and resettlement or minimum chimney height and fly-ash deposit procedures; monitoring and evaluation process allowing third party assessments; a channel of communication with the affected communities that ensures a functional grievance mechanism system to reduce risks to the project from frequent protests that had resulted in such heavy-handed security measures in Barapukuria.

These issues summarized above are related to the policies governing social and environmental impacts of the investment and how well those policies are implemented. In the case of Barapukuria coal plant the relevant policies governing the project include the host country Bangladesh’s policies and the financier China ExIm’s policies. More generally, given the role of China as Bangladesh’s main energy partner, China’s policies on overseas investments are also relevant. The list of coal projects in Table 3 shows the growing importance of private finance, which are governed not only by the country’s policies but can also be governed by the Equatorial Principles for signatories committed to reducing environmental and
social risks. Thus the Principles can serve as a benchmark for environmental and social safeguard standards. The continued relevance of multilateral development banks (MDBs) in the power sector, such as through financing feasibility studies, and their historical role in financing power generation in Bangladesh make their safeguard policies a natural candidate to serve as a benchmark for international standards. This section provides a comparison of the relevant policies across these different entities, along with how they were implemented in Barapukuria.

7.4.1 Overview of the Policies

The different policies considered here are those that touch on the key aspects discussed in previous sections with respect to Barapukuria coal plant. Specifically these include policies pertaining screening, scoping out the scale and parameters of impacts considered, specific requirements in terms of social and environmental impact assessments or management plan, health and safety requirements, resettlement plans, monitoring policies including provisions for or requirement of independent reviews, information disclosure and public consultation including frequency of consultation and setting up a channel of communication with affected parties. Information on every one of these policies could not be gathered for each of the five entities, namely: policies of GoB, China ExIm, China overseas investment, Asian Development Bank (ADB), and Equatorial Principles, but based on a review of what was available on their websites, including other project documents, a
summary of the key aspects are presented here, noting where they explicitly differ from each other and how they compare to the experience of Barapukuria coal plant.

1. Government of Bangladesh: Bangladesh is signatory of a number of environmental agreements such as United Nations Secretariat of the Convention on Biological Diversity (CBD); United Nations Convention to Combat Desertification (UNCCD); and United Nations Framework Convention on Climate Change (UNFCCC). The GoB has also adopted or amended existing legal provisions which include the Bangladesh Environmental Policy, Regulations, and Guidelines and the 1992 National Environmental Policy. In 1995 the Department of Environment updated the screening criteria to categorize projects and in 2009 “Right to Information Act” was enacted (Environmental Impact Assessment: Bibiyana I and II Gas Power Project, 2011).

The Department of Environment has set out screening criteria to categorize the projects into Green, Orange A, Orange B and Red (in order of increasing severity of impacts), which determines the level of EIA required. The screening is based on project type only, irrespective of its scale and location. Though Bangladesh has prescribed eight locations as Environmentally Critical Areas, they are not factored in screening. A full-scale Environmental Impact Assessment (EIA) is required for Orange B and Red Categories of projects. The EIA report has to incorporate ‘Occupational and Community Health and Safety’ aspects, ‘Exclusions and Sensitivities’ and ‘Identification and Assessment of Alternatives’ (to site, routes,
process, raw materials) as part of mitigation measures (Environmental Impact Assessment: Bibiyana I and II Gas Power Project, 2011).

The Department of Environment (DoE) issues and updates emission and ambient standards, which are in general comparable to international standards. DoE recommends that a technical summary be prepared that includes Environmental Management Plan (EMP) as an outcome of the EIA. The EMP requires risk analyses when there is storage and handling of hazardous and toxic substances; ‘Compensatory Afforestation’ when more than 5 hectares of land is deforested; plans for ‘Resettlement and Rehabilitation’ when more than 1000 people are displaced. The EMP includes an implementation schedule and monitoring requirements. The workplace or occupational standards are covered under the Factories Act.

EIA Guidelines for Industrial Projects recommend a Post-Project Monitoring Programme. The DoE is responsible for monitoring and making compliance reports available to the public. The guidelines recommend that a technical summary be prepared for the purpose of communication to public. There are no formal provisions to conduct independent assessment of EIA report or independent audit of approved projects. Though not required, third party monitoring is recommended through approved laboratories. Under DoE guidelines, public consultation and participation, fixed time frames for prior disclosure of EIA to the public, and grievance mechanism are not mandatory. (Environmental Impact
Assessment: Bibiyana I and II Gas Power Project, 2011)

2. Asian Development Bank (ADB): ADB’s operational policies include three safeguard policies: the 1995 Involuntary Resettlement Policy; the 1998 Policy on Indigenous Peoples; and the 2002 Environment Policy. The project’s category is determined by the category of its most environmentally sensitive component, including direct, indirect, cumulative, and induced impacts in the project’s area of influence. Each proposed project is scrutinized as to its type, location, scale, the sensitivity and the magnitude of its potential environmental impacts (Environmental Impact Assessment: Bibiyana I and II Gas Power Project, 2011).

ADB’s Environmental Assessment (EA) is required to include occupational and community health and safety provisions, as well as exclusions and sensitivities. It precludes project activities that involve or are likely to result, directly or indirectly, in the degradation of critical habitats. The EA examines feasible alternatives to the project location, design, technology and components, environmental and social impacts. With regards to environmental standards the EA applies ‘pollution prevention and control technologies and practices’ consistent with international good practice, as reflected in internationally recognized standards such as the World Bank Group’s Environmental, Health and Safety (EHS) Guidelines (Environmental Impact Assessment: Bibiyana I and II Gas Power Project, 2011).

ADB requires the preparation of an environmental management plan (EMP) that
includes proposed mitigation measures so as to cause no significant harm to third parties; environmental monitoring and reporting requirements; implementation schedule; cost estimates and performance indicators; and applies the polluter pays principle. EMP mentions safe and healthy working conditions, and prevention of accidents, injury, and disease for workers. It also requires preventive, and emergency response measures to avoid or minimize risks to the health and safety of local communities (Environmental Impact Assessment: Bibiyana I and II Gas Power Project, 2011).

For complex and sensitive projects, independent advisory panels during preparation and implementation of projects are used. Monitoring the effectiveness of EMP implementation is scheduled in the planning stage. Periodic progress reports covering monitoring results, development and implementation of corrective actions are publicly available. Consultation with affected people include all stakeholders, with particular attention to project-affected people and concerned NGOs and is conducted early in the project preparation (Environmental Impact Assessment: Bibiyana I and II Gas Power Project, 2011).

3. China ExIm: Guidelines for Environmental and Social Impact Assessments of the China Export and Import Bank’s Loan Projects were developed in 2007 in accordance with China’s Environmental Impact Assessment (EIA) Law, Environmental Protection Law, Environmental Management for Construction Project Ordinance, and with reference to regulations and procedures for
environmental and social assessments of other international financial organizations (Matisoff and Chan, 2008).

China Exim's 2007 guidelines explicitly require overseas projects to comply with host country laws unless host countries have inadequate environmental protection regimes, then Chinese or international standards are to be used. The guidelines also mentions social impacts, including land rights and resettlement, which other Chinese policy banks (except China Development Bank) have not explicitly included in their guidelines (Gallagher and Qi, 2018).

With respect to overseas projects, social and environmental impact assessments that meet the host country laws are required. China Exim bank states that it actively participates in environmental impact monitoring throughout the entire project cycle and reserves the right to cancel financing if environmental impacts are not adequately addressed (Matisoff and Chan, 2008).

4. China's overseas investment: A 2018 report published by Gallagher and Qi outlines policies governing China’s foreign direct investments. These include the 2017 Regulations on Outbound Investment and Business Activities of Private Enterprises pertaining to the following entities: National Development and Reform Commission (NDRC), Ministry of Commerce (MOFCOM), People’s Bank of China (PBOC), Ministry of Foreign Affairs (MFA), and All-China Federation of Industry and Commerce (ACFIC); the 2013 Guidelines for Environmental Protection in Foreign Investment
and Cooperation for MOFCOM, Ministry of Ecology and Environment, formerly the Ministry of Environmental Protection (MEP); and the 2013 MOFCOM/MEP Provisions on Regulating Competitive Behaviors in the Fields of Foreign Investment Cooperation.

The 2017 Regulations on Outbound Investment and Business Activities of Private Enterprises recommends that private firms undertake environmental impact assessments for their overseas construction and business operation; apply for environment related permits from the host country, or refer to standards of international or multilateral organization; develop contingency plans for environmental emergencies; reduce the emission of pollutants; and actively engage in ecological restoration (Gallagher and Qi, 2018).

5. *Equatorial Principles*: Principle 1 requires screening and categorizing of proposed projects according to the magnitude and severity of anticipated impacts. Principle 2 requires project financiers to undertake social and environmental assessment addressing key environmental and social issues. Principle 3 requires the environmental assessment report to address baseline environmental and social conditions, follow host country laws and regulations; applicable international treaties and agreements; sustainable development and use of renewable natural resources; protection of human health, cultural properties, biodiversity, endangered species, and sensitive ecosystem. It also refers to international standards, treaties and declarations, and good practices. In instances where the laws and regulations of
host countries are not comparable to international standards and good practices, it encourages the recipient governments to make necessary adjustments. The environmental assessment is required to address endangered species, occupational health and safety, impacts on indigenous peoples and communities. Principle 3 also requires consideration of feasible alternatives to the project. Alternatives or mitigation measures to avoid or minimize adverse impact are required to be incorporated in the project plan. Based on the Environmental Assessment, Principle 4 requires the financier to make agreements with their clients on how to mitigate, monitor and manage risks through a Social Environment Management Plan. Principle 5 requires the borrower to consult stakeholders and provide them with information on risks of the project. Principle 7 and Principle 9 mandates independent monitoring and reporting for sensitive projects over the period of the project’s life (Environmental Impact Assessment: Bibiyana I and II Gas Power Project, 2011).

7.4.2 Application to Barapukuria

For this case study the most relevant set of policies are those of the host country. The summary of the policies above indicates that even when financiers have their own set of policies, the policies of the host countries play the key role in moderating the impacts of the project. It is important to note here that the policies of the host country will become even more important in the future as MDBs, including ADB, move to country or client systems, albeit with the condition of equivalency.
However, the experience of Barapukuria shows that even when the financier has a condition of equivalency, in this case China ExIm, it may not be implemented for each project.

1. Screening:
The Barapukuria coal plant falls in the ‘Red’ category under GoB screening. The GoB policy does not take into consideration scale and location when screening projects. Though the DoE has Environmentally Critical Areas listed they are not factored into screening criteria. Moreover Environment Impact Assessment is only required for Categories Orange B and Red. This is different from the policies guiding ADB, Chinese Overseas Investment, and the Equatorial Principles.

2. Public Consultation and Grievance Mechanism:
The GoB guidelines does not require public consultation and participation, fixed time-frames for prior disclosure of EIA to the public, or grievance mechanism facility, differing from ADB’s policies. The importance of an easily accessible grievance mechanism is especially important for projects like Barapukuria as indicated by the frequency of protests.

For the Barapukuria power plant community members and activists confirmed that there was prior public consultation, though potential risks such as water pollution or depletion were not mentioned. PDB official states the government has a clear policy for filing complaint with the PDB should issues arise. However the
community has organized numerous protests that have been widely reported and thus documented since the beginning of the plant operation because they felt their complaints were ignored by the authorities. One of the activists interviewed has been arrested three times and in one instance had been severely beaten. As noted earlier, some of the protests has been around the mine and plans for its expansion.

For the coalmine, provisions have been made for grievance mechanism and any complaints made are available online. For the power plant, there is an online portal on the PDB website but not for individual projects. The process is outlined in its policies, and is practiced according PDB officials. However, activists have found that no action is taken even after following the proper procedure, which includes filling out the forms and complaining to authorities about breaches. This leaves the activists and some community members no alternative to staging protests, which have led to positive results in some instances, such as increased power availability in the locality; change in policy with respect to local employment; and increased chimney height in the power plant.

3. Environmental Management Plan (EMP):
An Environmental Management Plan (EMP) is required as an outcome of EIA and should include aspects such as risk analyses when there is storage and handling of hazardous and toxic substances. In the case of Barapukuria an EMP was completed and explicitly mentioned mitigating risks from the ash pond. But in reality, when community members raised complaints about the untreated ash pond nothing was
done about it. The ADB policy follows a ‘polluter pays’ principle, which is not mentioned in the other policies examined here. For Barapukuria this would be relevant for the issues surrounding water depletion and pollution, which has resulted in surrounding communities needing to buy water.

4. Resettlement Policy:

Resettlement and Rehabilitation Plan under GoB policies is required when more than 1000 people are displaced. For GoB the scope of impacted individuals is not specified. So the plan included only those who are titleholders of the land on which the power plant was built. The government also compensated those whose land subsided due to coal extraction. Though GoB compensated and resettled titleholders, they did not provide livelihood alternatives to all affected households, some of whom faced difficulties finding suitable alternatives. Bangladesh is land constrained and migrants to new locations often face difficulties and resistance from older inhabitants. ADB and Equatorial Principles specifically mentions indigenous communities and livelihood impacts, with the ADB policies being the most detailed in terms of the scope of indirect impacts considered.

5. Monitoring:

Community members and universities have recommended institutionalizing third party independent monitoring of air and water quality in Barapukuria. The Environmental Management Plan under GoB policy requires a monitoring plan and scheduling but independent audits or third party monitoring though recommended
is not required. With respect to overseas projects China Exim bank’s policy states that it will actively participate in environmental impact monitoring throughout the entire project cycle and reserves the right to cancel financing if environmental impacts are not adequately addressed. It was not possible to access China ExIm’s reports for Barapukuria for this study.

The key findings of this case study were along five key aspects of power generation: financing, employment, other socioeconomic aspects, environment and climate change. The case study reveals that despite the benefits from more energy created by the project, there is a lack of local job-creation in the area. The compensation from government for relocation was only given to titled landowners. The compensation was thought to be fair but did not include those who do not have land-deeds or those indirectly impacted. There are no estimates on the number of families who have been displaced or lost their livelihoods.

Communities dependent on agricultural work are most impacted by the depletion of underground water due to the plant. Underground water is used for drinking, for daily use and for irrigation. Though the Environmental Impact Assessment or EIA mentioned water pollution and includes a management plan for treating wastewater before it gets released in the river, the villagers said that the water is still polluted. There is risk of contamination of ground water and connected water-bodies if the plant’s ash pond continues to be left untreated. Since freshwater fish is the main source
of protein for lower income households and a source of income, polluted rivers have
different health impacts as well as livelihood impacts.

In terms of emission, the plant is of subcritical technology and therefore highly carbon-intensive. In addition there are co-pollutants that have health impacts, which are regularly monitored by the Ministry of Environment. The levels reported were within range permitted by the Ministry. Local activists expressed a lack of trust in all government measurements. While independent studies found co-pollutant levels to be consistent with government reports, there were discrepancies in the results for water pollution and for air inside the mine.

For Bangladesh, five sets of relevant policies were reviewed in this chapter, those that have the potential to moderate the above impacts. This includes those of the host country so Bangladesh and the financier China Export Import Bank. More generally, given the role of China as Bangladesh’s main energy partner, China’s policies on overseas investments are also relevant. Future coal plants in Bangladesh will include private finance, which are governed not only by the country’s policies but can also be governed by the Equatorial Principles for signatories. Thus the Principles was referred to as a benchmark for private investment. The other set of policies examined are those of the Asian Development Bank or ADB as a benchmark for international standards for policy banks. These five sets of policies were examined, with respect to their relevance to and their implementation in Barapukuria.
For this project the host country was in charge of making decisions regarding safeguards and implementing them. China Export Import Bank was mainly hands-off throughout the process. The case of Barapukuria was not different from other government projects in the country, and for some factors such as for land acquisition this case fared better than many large-scale government projects, including the proposed Rampal coal plant.
Bangladesh, like many developing countries, struggles to balance its energy needs with its developmental and climate change concerns. The lives and livelihoods of a vast majority of its population are dependent on agriculture. In addition to considerations of job creation, most large-scale infrastructure projects in the country, including power plants, need to consider access to land and water. This exercise is a way to quantify the key considerations associated with power generation for Bangladesh, which are: **financing, employment, other socioeconomic aspects, environment and climate change mitigation.** These considerations all contribute in different ways to the challenges around development and the environment.

This research shows that the path forward following a business-as-usual or BAU approach and the path prescribed by the government renewable plan both fall short of what is required, in light of climate change concerns with respect to mitigation. Instead, this report offers an alternate path built around an emission target for the year 2050 that is more in keeping with the recommended global emission allowance. In this work I first considered the implications in terms of financing and energy output of the **alternate green plan.**
I then compare the alternate plan to the BAU and government plan along the key aspects using an Input Output framework that reveals not just direct but upstream impacts of the three plans with respect to the variables considered. Despite the limitations of the framework, summarized below, we see that for the purpose of this research and for the purpose of formulating policy this approach serves as a useful way to weigh different options that exist for countries to address their energy and environmental needs.

The framework is further applied to analyze the land impacted not just directly used in the production of energy through different sources. This is key for land-constrained and water-dependent countries like Bangladesh, especially given that it is considering a coal-intensive future over the alternative of a solar-intensive path. This framework demonstrates that though solar requires more direct land per unit energy output, the land impacted is negligible compared to coal. Furthermore, the direct land used can be used for multiple purposes reducing the overall land-intensity of solar power.

Lastly the research looked at the distributional aspects of the key variables and studies the policies that mediate each of these aspects as it plays out currently and as it is expected to play out in the context of Bangladesh. We consider whether the government plan and the current safeguard policies reviewed here, which include national, international, and private, are equipped to deal with the challenge of
reducing risks to impacted populations. The research concludes with a review of the main findings in light of our long-range period of interest.

8.1 Alternate Green Plan

Bangladesh aims to grow rapidly over the next 30 years - in the range of 7 percent per year - following the examples in recent decades of China, India and other fast-growing Asian economies. However, estimates show that the country’s carbon dioxide or CO₂ emissions will increase by more than 30 percent by 2050 relative to current levels if the economy’s GDP growth is fueled primarily by coal, oil, and natural gas as per the government’s energy policy. By contrast, this research demonstrated that, under reasonable assumptions, a significant share of Bangladesh’s energy needs for fueling a rapid growth trajectory can be met through investments in energy efficiency and clean renewable energy, as long as Bangladesh channels about 0.81 percent of GDP annually into these clean energy areas.

This research estimates future impacts of Bangladesh’s rapid growth path under the government plan outlined in the Power Systems Master Plan for the year 2050. Bangladesh’s overall energy consumption is projected to rise to 1.53E+12 kWh (kilo Watt hour) by 2050, a 2971 percent increase relative to the actual 2014 level. Bangladesh’s main energy source is also projected to change over this time period, with most of the expansion in overall supply coming from coal under the
government plan. The proportion of overall energy supplied by coal rises from 2 to 50 percent.

The impact of this large increase in energy consumption with a rising proportion supplied through burning coal, the most heavily emitting CO₂ energy source, is that overall emissions will rise from 73.19 mmt in 2014 to 102.05 mmt in 2050 under the BAU scenario, a 39.4 percent increase. Assuming Bangladesh’s population in 2050 is around 202 million, this then also means that per capita CO₂e emissions rise from 0.44 to 5.05 mt. For a mere 50 percent chance of keeping global warming to 2 degrees and with OECD countries responsible for 2/3rd of emission reduction, developing countries like Bangladesh will still need to limit per capita emission to 1.8 metric ton in 2050. Under the government plan, Bangladesh overshoots this by more than twice the amount.

An alternate green plan was presented in this research with a per capita emission target of 1.81 mt for 2050 and achieved by devoting a portion of GDP over 30 years to clean investments, assuming a cost of $0.43 per kWh for clean renewables and $0.04 per kWh for efficiency investments.

8.2 IO Framework: Findings and Limitations
The Input Output framework provides a useful way using accessible data sources to estimate and compare different impacts of power generation. The IO analysis shows that the government plan, Plan 2, falls woefully short of the 2050 per capita emission reduction target of 1.8 mt. It is also associated with the most emission of harmful copollutants: sulphur dioxide and nitrogen oxides. The alternate plan is formulated to keep GHG emission within the 2050 target and is found to require the least lan and water. However it generates less employment than the government renewable plan. The BAU scenario or Plan 1, on the other hand, is not only is not feasible over our period of interest given gas shortages but in a scenario where gas supply were to be discovered or imported the plan would fall short of the GHG emission reduction target. It is also the most land-intensive of the three plans considered.

The IO Framework, however may have uncertainties arising from: its assumption of fixed coefficients representing linear production function, source data sampling and reporting error, lags between reference years of the IO database and the development proposal, the aggregation of IO data over different producers and the aggregation of IO data over different products supplied by the same industry. In this work the model worked with a very limited number of industries. The IO table included only 25 industries, which means that different activities were grouped together, masking some of the impacts. For instance, the IO table gave lower percentage imports for power plants’ machinery and inputs than was revealed from the case study. This is because the IO table grouped together different industries in
the real economy, such as cement and steel, into one category of construction. Given than cement is fully produced domestically, whereas steel is imported, the percentage import of construction as a whole did not show the different impacts of expansion of demand for these inputs.

With respect to Bangladesh’s industrial sector, the IO exercise assumes the same factor productivity (output per factor) remains over the period of interest. This is obviously unlikely to hold true. One option going forward is to look at the projections in factor productivity over the time period given the direction the industrial sector is expected to go in. For instance labor productivity can be assumed to increase by the certain amount over the time period, and this can be factored in by changing the output/factor, say for every 10 years. Therefore the modeling will be done with three factor/output values reflecting the increased productivity. More details can be incorporated by looking at how the labor productivity in different sectors or even industries can be expected to change over time. More dynamism can be built in by incorporating frequently, or a continuously changing output/factor value over our period of interest.

Additionally the model only looked at a limited number of factors ignoring environmental and ecological effects, such as the benefits of biodiversity from larger variety of flora and fauna or cultural values derived from the key rivers and forests in the country. However, focusing on a few key variables and the static assumptions mean the interactions within the model can be examined in great detail in order to
understand how the variables are interacting. As can be seen in the work of Lenzen et al. (2003) this method not only helped quantify the direct and indirect impacts of key factors using easily available data sources but it also allowed the authors to identify which activities were the most factor-intensive. In their example of airport construction they saw that the most land used was used not only in direct construction of the airport but also in providing building-material such as land utilized in planting groves of conifer to produce timber for construction. For a densely populated country like Bangladesh such identification helps make policy makers identify the exact impacts of various policies and where to apply alternatives if appropriate. Further work could include expanding the Leontief inverse \((I-A)^{-1}\) into \(I+A+A^2+A^3+\ldots\) to reveal which activities are the most factor-intensive as we go up orders for upstream activities. This exercise could thus help target policies to ameliorate concerns such as land-use, employment, or water-intensity of the proposed alternate green plan. For instance identifying upstream water-intensive activities that go into generating power could lead to strategies to reduce water-stress such as siting decisions or mandating the use of recycled water. Going forward these can be taken into consideration when designing policies.

8.3 Distributional Impacts from Barapukuria Case Study

The Barapukuria case study highlighted the distributional impacts of coal power generation and current policies. In addition to the estimates of factor inputs for
power generation that show overall impacts for the country, the research revealed that it is important to note that different groups within a country or locality are affected differently from the power projects. Distinguishing these groups help understand public support for or resistance to a project and can help direct policy to reduce disproportionate negative impacts on specific groups.

1. *Policies around resettlement/compensation:* The financier in the case of Barapukuria had limited role to play due to adherence to host country policy despite China ExIm’s and China’s foreign investment policies which mention adherence to international standards. The Bangladesh government is in charge of decision-making and execution of acquiring land and coordinating relocation. The pushback against expanding the power plant was largely around further displacement. Thus, despite government reports of successful relocation, the experience of those displaced was negative enough to spark repeated protests.

2. *Changes in Employment:* The Barapukuria power plant and coalmine did not consider differences in the number and type of employment generated for all activities related to the project, since wage and benefits differ for employees of the power plant and workers who are from companies that are outsourced. The lack of job security for outsourced workers have caused mass protests in the power plant.

3. *Changes in access to land-use and natural resources:* The government report did not look into livelihood options for those with reduced access to land and water
resources. There was no government report on the presence of indigenous population in the area, or follow-up on indigenous households that were relocated. Detailed social impact assessment should include impacts on marginalized communities such as indigenous communities, shareholders, non-title holder whose livelihoods depend on access to agricultural land and water availability. Going forward they can be given work at the plant or other projects in the area such as road expansion, and construction of embankment. The government did not provide details on the households who have been relocated. News reports mention families who have not received compensation as well as families who have been relocated as per government policy but are suffering given their lack of social network in the new area, which greatly influence livelihood options. The adequacy of the alternative settlement should also include measures such as changes in proximity to schools, hospitals etc. The land allotted by the government for relocation was a tenth of the land from which people were relocated for the plant, not counting the mine or subsided land.

Water bodies play a large role in providing nutrition to local population, since fish is a large part of the diet, and water is important for irrigation. Coal plants severely reduce access to water, increase pollution, and interrupts stream-flow or drainage. These aspects should be incorporated when estimating socioeconomic impacts of a power plant. Water depletion was not addressed adequately in the Environmental Impact Assessment (EIA). Going forward assessment could include a ‘polluter pays’ principle, institutionalize third-party assessments especially for projects.
categorized as high risk and mandate fixed frames for prior disclosure to the public. Though there was prior public consultation in Barapukuria’s case, this is not a requirement for social impact assessment.

4. Environmental Impacts: The government regularly monitors air and water quality but the results have differed from those conducted by the environmental department in a nearby university. Universities in conjunction with non-governmental environmental institutions should formalize independent monitoring requirement for all power plants. Water pollution from wastewater from the power plant and from the ash pond are addressed in EIA but was not implemented properly. Though the policy of the financier China Export Import (ExIm) Bank states they conduct impact assessments these were not available. Social and environmental impact assessments of both Bangladesh government and China ExIm should be made available online. Going forward the host country's EIA should to be amended to include third party monitoring, public consultation and participation, fixed time frames for prior disclosure of EIA to the public, and grievance mechanism.

8.4 Sustainability: Long term Considerations

In order to plan an appropriate energy future for a country with multiple vulnerabilities a framework is needed that can combine the multitudinal aspects of power generation. Such an energy path will inevitably be one that has a longer time horizon as its key consideration. As discussed in the beginning of this work,
Bangladesh is a country that is still developing its energy infrastructure. Thus a sustainable energy infrastructure development would be an opportunity for Bangladesh to get it right the first time, instead of risking stranded assets and other losses in the future. As such the final and perhaps most important question addressed in this paper is this: Is the government plan, which is the most likely future facing the country, at all compatible with a longer time horizon? I find that even if theoretically we could better safeguard and perfectly implement the risk reduction measures, the plan has a few glaring issues.

1. Considering longer timeline for Net Revenue:

The Bangladesh government does not consider price (of different energy sources) projection for the lifetime of power plant. The repayment period of the Barapukuria coal plant loan is ten years. At the end of ten years the cost of power generation from renewables will be comparable to the cost of coal. Since the period of operation of the power plant is much longer than the repayment period, a longer time period of at least 30 years should be considered in the financial analysis of the government. Bangladesh’s price projections (levelized cost of electricity or LCOE) of different energy sources show that Solar PV will be cost competitive to coal by 2030 and will continue to fall in unit price making it more competitive relative to coal power generation, even with the less expensive subcritical technology deployed in Barapukuria (Shiraishi et al., 2019). All relevant policies such as tax rebates for coal, government subsidies and price guarantee also need to be factored in for the lifetime period of the power plant.
2. Water depletion, water and air pollution:

The output from the Barapukuria coal plant currently constitutes 2 percent of the country’s power generation. A 25 fold-increase will be needed to achieve the 50 percent coal target under the government plan for 2041. This would mean a massive jump in not only air and water pollution, but also of water depletion. The case study showed that water depletion and pollution would have a disproportionate impact on the most vulnerable populations in the area. A 25-fold increase in impact would lead to water-strain on potentially 375 villages in the country. That is a potential impact on 275,000 individuals, assuming a conservative average village size of a thousand. The plan did not account for the inevitable high cost of replacing this water for the impacted communities’ daily use and irrigation, as lower-income households are more dependent on agricultural work. Water depletion and pollution would also impact the water level and thus the fish populations in surrounding water-bodies. The livelihoods and protein-source of the poorest communities in Bangladesh are heavily dependent on the availability of fresh water fish in common water bodies.

A 2016 report IRENA “True Cost of Fossil Fuels: Saving on the Externalities of Air Pollution and Climate Change” finds that a reduction in the share of fossil fuel by half would lead to a 33 percent fall in particulate matter (PM2.5) emissions that result in serious adverse effects on human health. In addition this would also reduce health complications arising from emissions of copollutants (air pollutants
excluding GHG from burning fossil fuels) such as mono-nitrogen oxides (NO₃), sulphur dioxide (SO₂), ammonia (NH₃) and VOCs or volatile organic compounds (IRENA, 2016).

The exact cost calculations from water pollution, depletion, and from air pollution is beyond the scope of this study. These estimates involve the specific features of the power plants locations and estimates of at-risk populations with a timeline that goes beyond the lifespan of the power plants (Boyce, 2016). Bangladesh is one of the most densely populated countries with a population density of 1,115.62 people per square kilometer; the density can be assumed to increase over the next few decades. As such it is reasonable to expect the cost of pollution on the health of affected communities to be significant. The localized costs of untreated wastewater seeping into underground water and nearby water bodies and from untreated ash ponds are also beyond the scope of this research.

To give a ballpark figure of the cost of air pollution, we can refer to a number of studies that have placed monetary valuations on the air quality cobenefits obtained from reduced combustion of fossil fuels in regional and global contexts. Nemet et al. (2010) estimated an average cobenefit (benefits other than those from reducing GHG emission) of $49 per ton of CO₂ from 37 studies of air quality cobenefits from around the world. The U.S. National Academy of Sciences (2009) has calculated that premature deaths attributable to copollutant emissions from fossil fuel combustion impose a cost of $120 billion/year in the United States. A study by the Netherlands
Environmental Assessment Agency find the cobenefits from a policy involving reduced GHG emissions would offset the policy's costs even without considering long term costs of climate change (Berk et al. 2006).

3. Greenhouse Gas Emissions:

The Intended Nationally Determined Contributions or INDC of Bangladesh with respect to mitigation consists of the following elements. Firstly, an unconditional contribution to reduce GHG emissions by 5 percent from the 2015 Business as Usual (BAU) levels by 2030 in the power, transport and industry sectors. Secondly, a conditional 15 percent reduction in GHG emissions from BAU levels by 2030 in the power, transport, and industry sectors, subject to “appropriate international support in the form of finance, investment, technology development and transfer, and capacity building” (INDC, 2015). The current BAU emissions level considered above is low due to Bangladesh’s current low energy-use intensity as well as the low emission-intensity from the high proportion of gas in the energy mix. However, the Power Systems Master Plan (PSMP) shows that both are set to increase in the coming decade. As this research shows the government plan falls well below what is required to avert the worst impacts of anthropogenic climate change.

4. Global Relevance

As a developing country, Bangladesh meets a substantial portion of its energy investments through multilateral development finance. These financing sources can play a major role on the financial considerations when making choices between
different energy sources and different energy paths for the country. As such highlighting the different aspects of energy production help identify the impacts of emerging southern-led development finance in countries vulnerable to climate change. This is important in light of the shift of main financiers away from the established ‘Bretton Woods Institutions’ to emerging and developing countries; in forming environmental and social safeguard policies of these banks going forward; and in tracking on-ground outcomes in terms of environmental and distributional impacts of their projects. Even with major MDBs limiting fossil fuel financing, some developing countries find financing options to expand coal, despite falling costs of renewables globally. Therefore along with policies limiting fossil fuel financing being adopted by major policy banks and governments worldwide, it was useful to identify not only factors that will make renewables more attractive for pro-coal countries but also the existing practical impediments to switching to a low carbon economy.

As we plan towards the next few decades countries in Asia, like Bangladesh, are poised to be at the center of various global phenomena that will shape our planet for centuries to come. A research on the different energy paths that exist for a country like Bangladesh can hopefully serve as a way to address the wider challenges of climate change, environment and development. The framework used in this work allows us to weight different options along these different concerns surrounding our energy future. The approach allows us to compare different paths in light of the global carbon budget. It allows us to measure the environmental and socioeconomic
costs, including calculating jobs created, under each policy. The framework considers the financing component by comparing different costs of energy related sectors. The impacts estimated from this research clearly shows that the cost of financing includes not just borrowing costs related to different lending rates, but environmental and social costs borne by impacted communities.

The fieldwork component of the research reinforced the realization that challenges faced on ground do not occur in separate spaces that academic fields traditionally occupy; though training in specialized fields help deepen understanding, our response must incorporate the different aspects involved in a syncretic way. Similarly, the solutions to these challenges must include theoretical frameworks that are informed by and influence the on-ground realities and practices. Through this research I hoped to not only connects these two aspects but combine them through incorporating analytical work alongside its application.

The regional shift in global energy financing means we have a historical opportunity to shape the direction of development and climate responses. Analyzing and planning for future projects provides us with the opportunity to build on past experience and address the concerns stated above. Analyzing the impacts of energy policy through this framework could help develop policies designed for the benefit of the environment and affected populations worldwide and can hopefully help serve as way to transform our global energy system.
APPENDIX

QUESTIONNAIRE

The questions were developed in part around relevant stakeholders who are involved in the process of examining the questions above. The stakeholders can be grouped in the following categories:

i) Government sectors:
Questions relevant to this group are regarding:
1) the land acquisition process 2) financing aspect- amount of state financing and co-financing 3) project selection process 4) royalty amount, tax/duties/subsidies, price guarantees/government purchase 4) environmental assessment studies 5) social impacts assessment and what grievance mechanism are available to employees, local communities from the state and 6) their cost and price projections for various energy sources. 7) What are the demographic features of the communities: general idea of the household level of income, occupation, age, and ethnicity? 8) More broadly: what support is the government for power generation—support in terms of government regulations and agreements under favorable terms, access to finances, availability of financial instruments?

ii) The entities in charge of the power plant.
For Barapukuria this was the Bangladesh Power Development Board (PDB):
The questions relevant to this group are: 1) how many employees do they have? 2) are the employees local? 3) what is the national content in terms of inputs such as machine 4) have there been any environmental and social impacts 5) are there mechanisms in place for communities/employees to seek redress should the need arise? 6) what are the tax, duties, subsidies, price projections, and insurance agreements? 7) More broadly: what support are they receiving from the government and other entities such as multilateral and commercial institutions—support in terms of government regulations and agreements under favorable terms, access to finances, availability of financial instruments to produce energy?

iii) Civil Society Organizations (CSOs)/journalists/activists/researchers/academics working on power plants:

What are the impacts or potential economic, social and environmental impacts of the three plants? Are there relocated people and have they been compensated properly? Do those relocated have alternate adequate livelihood options? Have their access to resources been curtailed? Have there been land acquisition issues? If there have been pollution, flooding, lack of water etc. what steps have been taken by the various parties involved? How much local/national jobs have been created? Are there local/national benefits from plant or from ancillary investments around plant (e.g. road, better electricity access etc.)? What are the demographic features of the communities: general idea of the household level of income, occupation, age, and ethnicity?
iv) The local communities and employees:

The same questions asked to group 3 above was asked to the community members.

Individuals were identified from journalists, CSOs, and companies operating the plant. A series of unofficial meetings were organised. The meetings were to find out from the communities impacted and employees what their views are on the following: benefits resulting from the plants, or issues regarding jobs, access to livelihood and resources, and environmental impacts as a result of the power plants.

These groups (the company, employee, local communities) were selected not only because of their connection to the plant and the plant’s impacts but also because they are trusted authorities on the aspects studied (journalists, research groups, human rights organizations environmental groups). They represent the range of positions on the key impacts and contain stakeholders who stand to gain the most and lose the most from the power plant.
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