*Research Paper*

**Senator Group 6**

# The Impacts of Dam Construction on Cambodia's Environmental and Socio-Economic Development

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## Executive Summary

Approximately 65% of the Cambodian population still lacks access to reliable electricity. They are more likely to be poor and have poorer health status resulting from this situation. In addition, electricity is commonly cited as a major barrier for business and industrial development. To sustain economic growth, reduce poverty and increase the welfare of the people, and reduce air pollution from oil, coal and traditional energy, Cambodia requires more efficient and clean energy generated from hydropower plants. However, the construction of hydropower plants can result in, serious social and environmental consequences in the long run. Although hydroelectricity can be viewed by some as a sub-optimal solution, it is arguably the best option.

This research is based on a variety of sources and techniques such as strategic planning tools and analyses from economic, political, sociological, and environmental perspectives to analyse the economic benefits and to compare these to the social and environmental costs of dam construction.

The demand for electricity has increasedsignificantly and has a very strong association with economic growth in the last decades. To date, electricity is mostly generated from imported energy which is expensive and polluting. Hydroelectricity accounts for 3.3% of total electricity produced across the country and it continues to increase which results in the decline in the volume of imported energy and CO2 emissions. This has a positive implication on poverty reduction, equality and health. However, in the long run, the construction of dams along the Mekong River and its tributary will reduce the amount of fish which is the main diet of Cambodian people and lead to relocation of people.

Hydropower projects emit very little greenhouse gas, do not use up any resources, and could reduce the seasonal cycle of the river by increasing flows during dry season and decreasing flows during the wet season. However, they decrease stream power leading to altered groundwater levels and preventing the river from transporting sediments, cause waterlogging and inundation that lead to a lack of oxygen for vegetation in the riparian zone (i.e., land along the river bank) and as a result, could cause increased bank erosion. Additionally, operating the dam in this way may cause polluting substances to come downstream in pulses, which is more harmful than the natural situation whereby pollutants come down gradually in a (more) diluted form.

## 1. Introduction

Cambodia's demand for energy in the last decade was greater than the amount of power generated and this discrepancy continues to increase due to the rise of household electricity consumption, expansion of the industrial sector, increasing urbanisation, and a population growth(of around 1.5% per year[1]). In order to keep up with the increasing demand, plans are made to exploit the Mekong River's energy to generate electricity. Under the development plan 2008-2020, hydropower would develop to the point where it would contribute more than 50% of Cambodia's total power suppl.[2] Generating large amounts of hydropower would be beneficial for the economy because, in addition to decreased electricity prices, well managed hydropower dams could control the flow of water to avoid floods or water shortage.[3] Moreover, construction of additional[4] hydropower dams would increase available electricity while keeping greenhouse gas emissions low.[5] And, because hydropower is a renewable energy source, no resources are being used up.

Although hydropower does not exhaust any resource directly, the dams (and their reservoirs) may alter the natural characteristics of the Mekong River, and could thus have a negative effect on resources on the Mekong River and its tributaries. For example, the altered water levels will affect natural succession of the flora and fauna, leading to possible deforestation and loss of biodiversity. In addition, the construction of hydropower dams would lead to a significant reduction of migratory fish in the river, expelling (and possibly even eradicating) certain species from the Mekong, such as the *Mekonginaerythrospila.*[6] Thus, the dams are predicted to disrupt the lives and livelihoods of many fishermen and farmers; either because they would have to relocate or because changes in the environment would reduce their normal yields of fish or agricultural products.[7] While the impact of hydropower dams could reap economic rewards for certain industries (like manufacturing), the benefits and costs would be unequally distributed through society as farmers, fishermen, and the poorer segments of society would experience the negative impacts disproportionally.[8]

In other words, hydropower dams represent a solution for Cambodia's electricity need but bring with them a complex composition of possible concomitant benefits and repercussions.

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[1] National Institute of Statistics, *General Population Census of Cambodia 2008*, Cambodia: Phnom Penh, 2008.
[2] Heng Pheakdey, "Cambodia's energy challenges: Is hydropower the solution?" (presentation summary, Regional Public Forum: Mekong and 3s Hydropower Dams, Phnom Penh, June 3-4, 2013)
[3] International Hydropower Association et al., *Hydropower and the World's Energy Future* (November, 2000)
[4] Cambodia currently has six operational hydropower projects: Kamchay, Kirirom I, Kirirom III, Stung Atay I, Stung Atay II, O Chum II. There are two more under construction and another sixty-three are either being studied or planned on the moment. See: http://www.opendevelopmentcambodia.net/company-profiles/hydropower-dams/
[5] International Hydropower Association et al., *Hydropower*
[6] Ian G. Baird, *Best Practices in Compensation and Resettlement for Large Dams: The Case of the Planned Lower Sesan 2 Hydropower Project in Northeastern Cambodia* (Phnom Penh: Rivers Coalition in Cambodia, 2009)
[7] International Centre for Environmental Management (ICEM), *Strategic Environmental Assessment of Hydropower on the Mekong Mainstream: Final Report* (Hanoi, Vietnam: Mekong River Commission, 2010)
[8] Ibid. and Claudia Kuenzer et al., "Understanding the impact of hydropower developments in the context of upstream–downstream relations in the Mekong river basin," *Sustainability science 8,* no. 4 (2013): 565-584.

To ascertain all the outcomes of hydropower dam construction, this research is based on a variety of sources and techniques such as strategic planning tools and analyses from economic, political, sociological, and environmental perspectives. The study is aimed at answering some specific questions in response to a request from “Senator Group 6.” The main objective of this study is to analyse the economic benefits and to compare these to the social and environmental costs of dam construction.

The research paper is structured as follows: Section 2 discusses the social, economic, and environmental impacts as a consequence of the construction of dams. Section 3 proposes some scenarios for possible policy options. Section 4 concludes the study and provides policy options.

## 2. Geomorphology of Cambodia

Cambodia is located between latitudes 10° and 108° East, with a total land area of 181,035 $km^2$ and shares its 2,438 km border with Thailand in the west and north, Laos PDR in the north and Vietnam in the east and southeast and the coastal zone encompasses estuaries, bays and some 64 islands of various dimensions[9] all with high ecological importance. The landscape is predominantly low-lying with territories occupying the middle part of the lower Mekong river basin and surrounded by relatively dense forested mountain ranges to the west, east and north side of its territory. The dominant features of Cambodia landscape are the large almost centrally located Tonle Sap (Great Lake) and rivers which generally run through the country from the north to the south; these rivers include the San River, Sen River, Bassac River and the Mekong river basin.

The traditional subsistence farming method is being replaced by modern commercial farming methods[10] as a result of population growth and increased food demand. In tandem with this development is a shift in landscape management type; from the traditional *laissez faire* method towards a full control approach whereby man made infrastructures are introduced to control the natural system. The lower Mekong river basin is a semi-natural environment where people and nature are living together with a very complex natural system. The region has a unique landscape with many mineral resources, including gemstones, iron ore, manganese, phosphates, oil and natural gas as well as biological resources such as timber and the aquatic environment that are present in the Mekong River Basin. This environment contributes to the livelihoods of the people in the region. In order to manage the water channels effectively, an in depth understanding of the lithosphere (composed of the earth’s crust and the upper most part of the Mantle) and the Mekong River Basin system must be achieved in order to improve the control over the channel flow and the development of channel morphology of bedrock-constrained rivers which have variable sedimentary fill, also known as an *astomosed* mixed bedrock-alluvial system.[11]

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[9] Ministry of Environment, *Cambodia Environment Outlook* (Cambodia: Ministry of Environment, 2009)
[10] IWMI and World Fish, *Rethinking Agriculture in the Greater Mekong Subregion: How to sustainably meet food needs, enhance ecosystem services and cope with climate change*, (Printel Private Limited, 2010), 1.
[11] Luibov V. Meshkova and Paul A. Carling, “The geomorphological characteristics of the Mekong River in northern Cambodia: a Mixed bedrock-alluvial multi-channel network,” *Geomorphology* 147 (2012): 2-17.

## 3. The Socio-Economic and Environmental Impacts of Dam Construction

Stated benefits of dam building are an increase in local employment and skills development, rural electrification and the expansion of physical infrastructure, including roads and schools.[12] On the other hand, concerns are raised about the impact of dams on people, rivers and ecosystems. There is also additional unease that the economic benefits may have possibly been overstated in the past. The building of (all) the hydropower dams is a trade-off between biodiversity, food security, and loss of fisher communities and the potential for economic growth. The impacts of the dam construction are divided into two categories: socio-economic impacts and environmental impacts.

### 3.1. Socio-Economic Impacts of Dam Construction

#### 3.1.1. The Value of Electricity in Economic Development and Welfare

Energy not only benefits economic growth, but can also contribute to improving education and reducing poverty. The structure of energy demand is however dependent on the stage of economic development and income per capita of a country. In the early stages, energy sources are predominantly biological (wood, dung, and sunshine) followed by processed biofuels. Electricity comes later during the advanced stage.[13] Cambodia's energy demand falls into all the stages of development. In rural areas, the poorest groups are still dependent on biological sources and some others who are financially better-off use biofuels. Wealthier people living in cities and industry demand greater access to electricity.[14]

In the last two decades the demand for electricity has been greater than the supply. Electricity has been generated mostly with imported oil,[15] implying that the price of electricity is contingent on the volatile (global) oil market.[16] Currently, approximately 65% of the population still lacks access to reliable electricity.[17] The limited supply keeps the electricity price in Cambodia higher than the ASEAN average[18] which means that Cambodia has the lowest energy consumption in the ASEAN region, with an annual 370 Kgoe[19] per capita.[20] The Figures 1 and 2 provide further information on the energy shortage. Figure 1 shows that

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[12] UNESCO, ''Basic Education'', accessed on September 1, 2014, URL: http://www.unescobkk.org/education/resources/resources/education-system-profiles/cambodia/basic-education/

[13] Douglas F. Barnes and Michael A. Toman, "Energy, Equity, and Economic Development," in *Economic Development and Environmental Sustainability: New Policy Options 2006*, ed. Ramon Lopez and Michael A. Toman (Oxford: Oxford University Press, 2006), 245–272.

[14] Asian Development Bank, *Key Indicators for Asia and the Pacific 2013, 44th ed.* (Philippines: Asian Development Bank, 2013)

[15] Ibid.

[16] Heng Pheakdey, "Cambodia's Energy Security Is at Risk," *The Cambodia Daily*, November 7, 2012 and Kongchheng Poch and Savong Tuy, "Cambodia's Electricity Sector in the Context of Regional Electricity Market Integration," in *Energy Market Integration in East Asia: Theories, Electricity Sector and Subsidies, ERIA Research Project Report 2011-17*, ed. Yanrui Wu, Xunpeng Shi, and Fukunari Kimura (Jakarta: ERIA, 2012).

[17] Asian Development Bank, *Key Indicators for Asia and the Pacific*

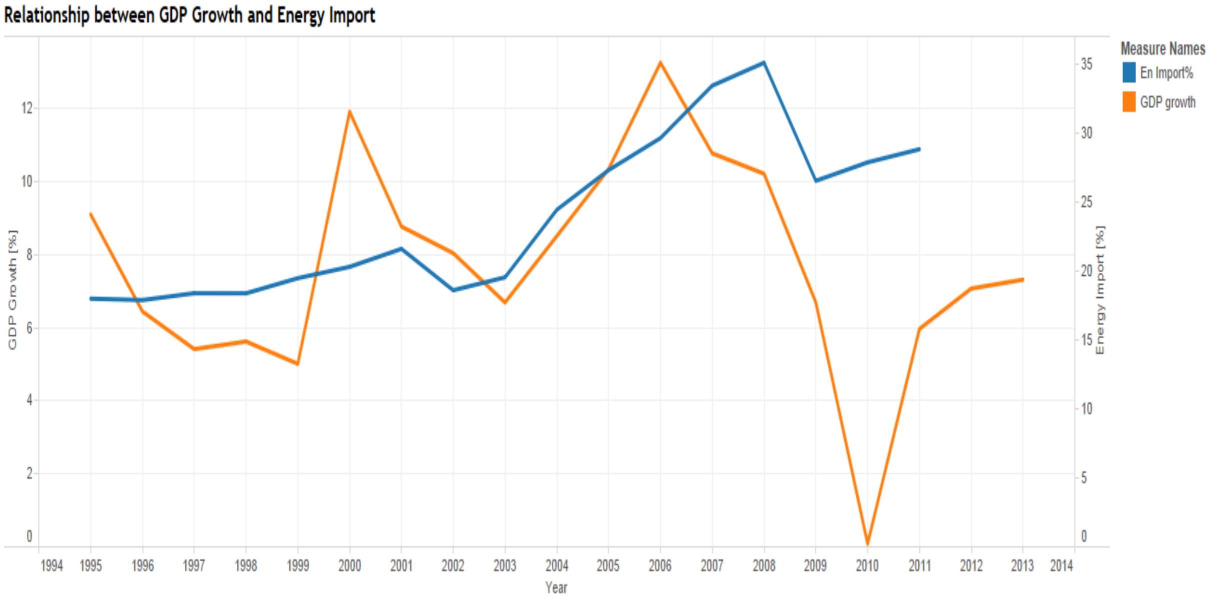
[18] Electricity Authority Of Cambodia, *Report on Power Sector of the Kingdom of Cambodia: 2013* (Cambodia: Electricity Authority of Cambodia, 2013) and Kongchheng Poch and Savong Tuy, "Cambodia's Electricity Sector"

[19] Kilogram of oil equivalent; 370 kgoe equals 4,303 kWh or 15.5 GJ (rounded)

[20] Heng Pheakdey, "Cambodia's energy challenges: Is hydropower the solution?"

GDP grew at an average rate of 9% from 1995 to 2008 and 7% from 2012 to the first quarter of 2014. And, at the same time, imported energy grew at a faster pace."[21]

**Figure .** GDP Growth and Imported Energy




**Source:** The authors computed from World Bank Data.

According to Figure 1, imported energy increased dramatically from 1998 to 2008 and reduced sharply between 2009 and 2010, but bounced back a slower rate from 2010. The sharp reduction in 2009 and 2010 may be linked to the impact of the global economic crisis which reduced electricity consumption at industrial and household levels. A simple calculation by the authors on the relationship between GDP growth and imported energy shows that imported energy is positively correlated with GDP growth, being able to explain for a 27% of their relation. Electricity consumption accounts for 79% of the explained variance; and $CO_2$ emissions as a result of liquid fuel consumption for 80% (see Table 1).The high correlation between imported energy, mainly oil, and electricity consumption indicates that imported energy is used to produce electricity, which results in increased $CO_2$ emissions from liquid fuel consumption (see Figure 5). High $CO_2$ emissions may have a detrimental effect on the environment and human health, possibly causing increased demand for medical treatment.[22] Because cost of living includes energy consumption and healthcare expenditure, a rise in the cost of electricity and high $CO_2$ emissions will significantly reduce the consuming power of the consumers. Lower energy prices and sufficient energy provision are essential to achieve sustainable development. Compared to other energy prices, in theory, hydropower is a low-cost form of energy once projects are completed. When taking the cost of construction, production, and decommission into account, power in the US hydropower cost $0.03 per kWh

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[21]Also see Kongchheng Poch and SavongTuy, "Cambodia's Electricity Sector"

[22] As for medical treatment, there are no official data to verify the claim, but experiences from other countries suggest a positive relationship between CO2 emissions and health problems.

for hydro power, compared to $0.06 for nuclear, $0.08 for wind power, $0.06 for natural gas, $0.10 for coal, and $0.21 for petroleum. [23]

UNDP's baseline study on "Residential Energy Demand in Rural Cambodia" reported that when the development of electricity provided by the government is biased toward urban areas, the lowest social class or the poorest spend around half of their disposable income on other energy sources such as candles, batteries , kerosene, and especially firewood both purchased and collected. Compared with the higher income population, the same study revealed that when the poor can access electricity provided by the government their share of energy consumption over disposable income is reduced significantly. [24] Hydropower plants can arguably be a solution to economic growth and the reduction of poverty and inequality, although it comes with costs.

**Table .** Relationship between GDP Growth, Electricity Consumption, Emission, and Imported Energy

| | GDP Growth | Electricity Consumption | Emission from Liquid Fuel Consumption | Imported Energy |
|---|---|---|---|---|
| **GDP Growth** | 1.000 | | | |
| **Electricity Consumption** | -0.184 | 1.000 | | |
| **Emission from Liquid Fuel Consumption** | -0.110 | **0.951** | 1.000 | |
| **Imported Energy** | **0.271** | **0.798** | **0.813** | 1.000 |

**Source:** The authors computed from World Bank Data.

**Note:** The word "Correlation" refers to the relationship between each variable or to the association with each other. The greater the number suggests the higher correlation.

Hydropower plants are more flexible than other forms of power generation as they are not dependent on meteorological conditions and have 'black start' capability (i.e. can start almost instantaneously without the addition of outside power). [25] Apart from being more flexible, hydropower plants also have a longer plant life and lower maintenance costs than other power plants, which mean that hydropower is a very economical method of power generation. [26]

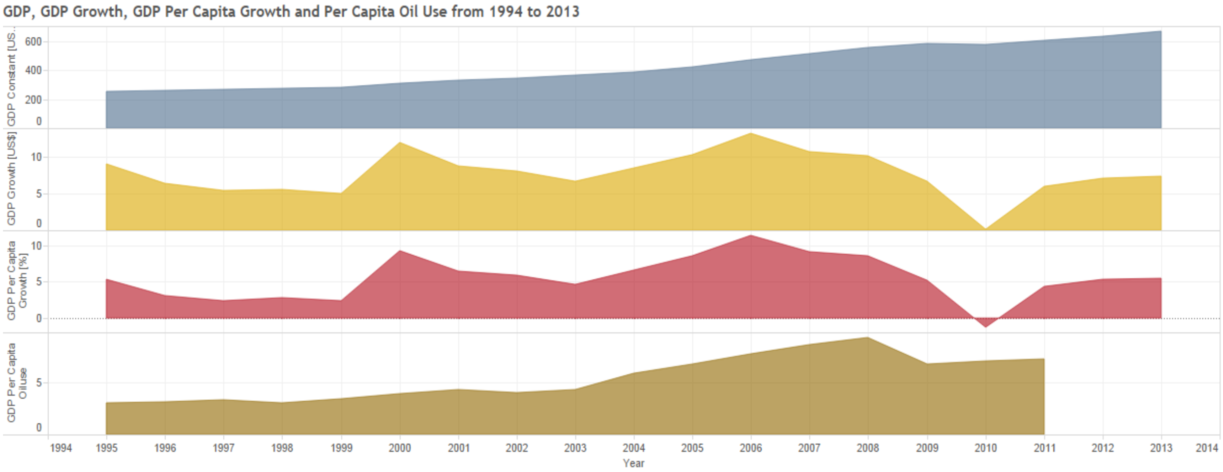
[23] David Manukjan, "Energy Sources and the Production of Electricity in the United States," *Honors College Theses*, Paper 111 (2012)

[24] UNDP, *Residential energy demand in rural Cambodia: An empirical study for Kampong Speu and Svay Rieng* (Cambodia: UNDP, 2008)

[25] Helen Locher, *Environmental Issues and Management for Hydropower Peaking Operations*, (UN Symposium on Hydropower and Sustainable Development, Beijing, China: 27/29 October, 2004)

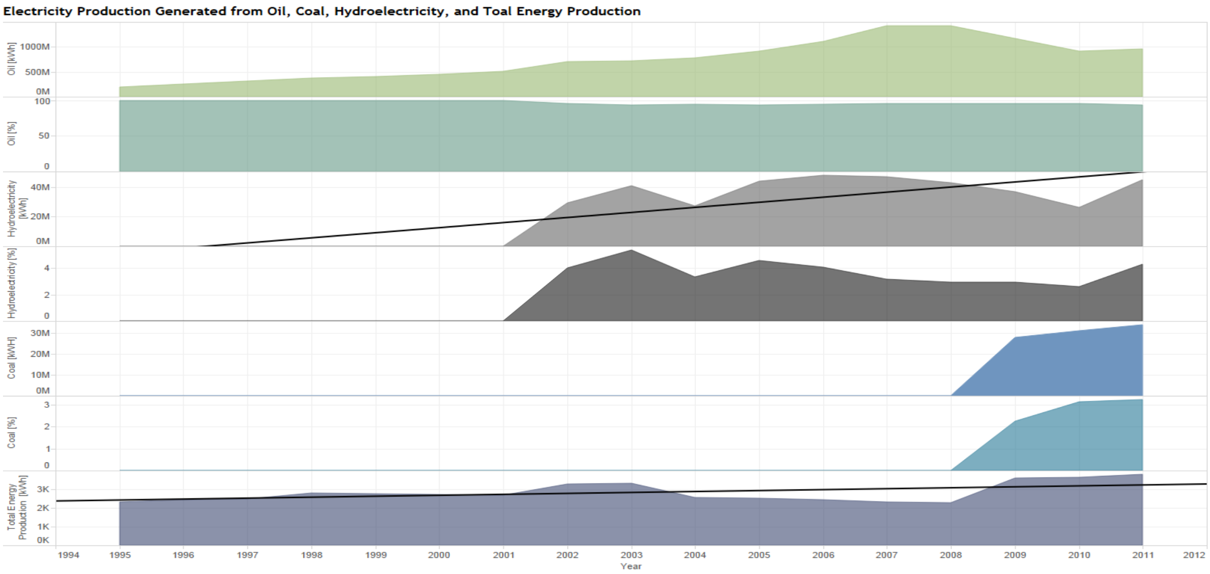
[26] International Hydropower Association et al., *Hydropower*

**Figure .** Comparison between GDP Per Capita Growth and GDP Per Capita Oil Use




**Source:** World Bank Data
**Note:** 1) GDP is measured at a constant price 1=2011.
2) GDP Per Capita oil use: GDP per unit of energy use is the PPP GDP per kilogram of oil equivalent of energy use. PPP GDP is gross domestic product converted to 2011 constant international dollars using purchasing power parity rates. An international dollar has the same purchasing power over GDP as a U.S. dollar has in the United States.

**Figure .** Comparison of Electricity Production by Sources



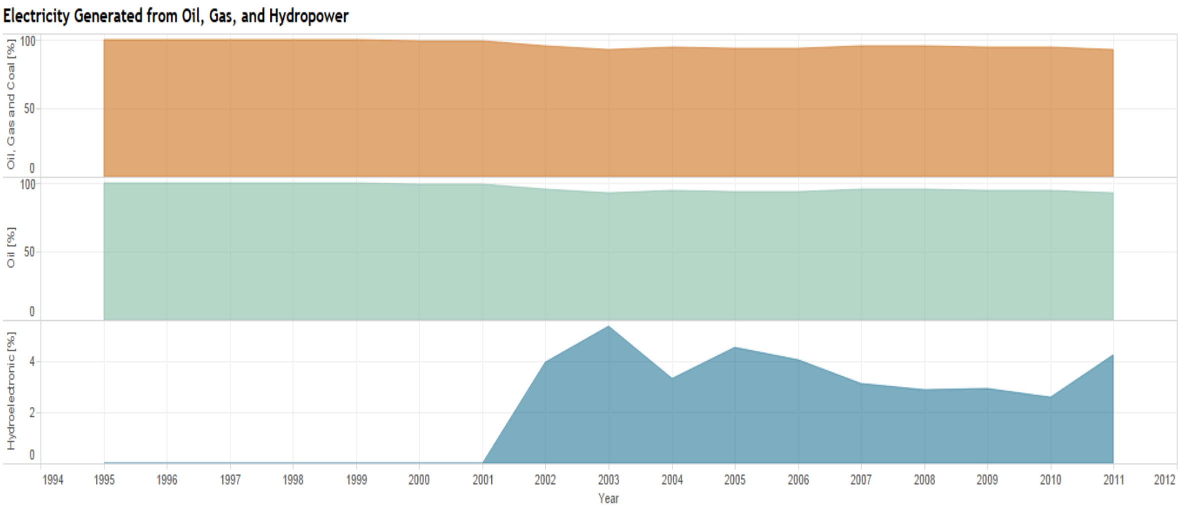

**Source:** The authors calculated from World Bank Data.
**Note**: 1) The linear line is the regression line (y=a+bx+e; where e=Random Standar Error). The line suggests that given year, energy production has increase steadily.
2) In this figure, the amount of anergy and electricity production from oil, hydropowerplant, coal, and fossil in kWh in each upper panel.

The Cambodian state would initially only accrue an estimated 26-31% of gross revenues from new hydropower projects, as the rest will go to the initial investors. Cambodia would receive full financial benefits[27] after the concession agreement ends (normally around 25 years after the beginning of operations) and ownership of the project is transferred to the State.[28] However, even before the end of the concession agreements, hydropower projects would benefit the Cambodian economy as the lower electricity costs and more reliable access would reduce production costs while increasing production of manufacturing industry and might attract more foreign investment.[29] Additionally, cheaper and more reliable access would lower the cost of living and increase human security and welfare. The positive relationship between

[27] International Centre for Environmental Management (ICEM), *Strategic*
[28] Ibid.
[29] Joosung J . Lee, "An Outlook for Cambodia's Garment Industry in the Post-Safeguard Policy Era," *Asian Survey 5*, no. 3 (2011): 559-580.

the increase of hydroelectricity supply, GDP per capita of oil use and the relationship between $CO_2$ emission from liquid fuel consumption shown in Figures 2 and 5 indicates that hydroelectricity can contribute to the welfare of people who have had access to electricity. Figure 5 shows that when the supply of the hydroelectricity started to rise in 2010, $CO_2$ emissions from liquid fuel use consumption became constant. At the same time, GDP per capita oil use increased at a slower rate (Figure 2) resulting in people paying less for electricity and the environment benefiting from lower CO2 emissions.[30] This phenomenon at least suggests that hydroelectricity has a positive impact on the welfare of the people.

**Figure** . Share of Electricity by Source

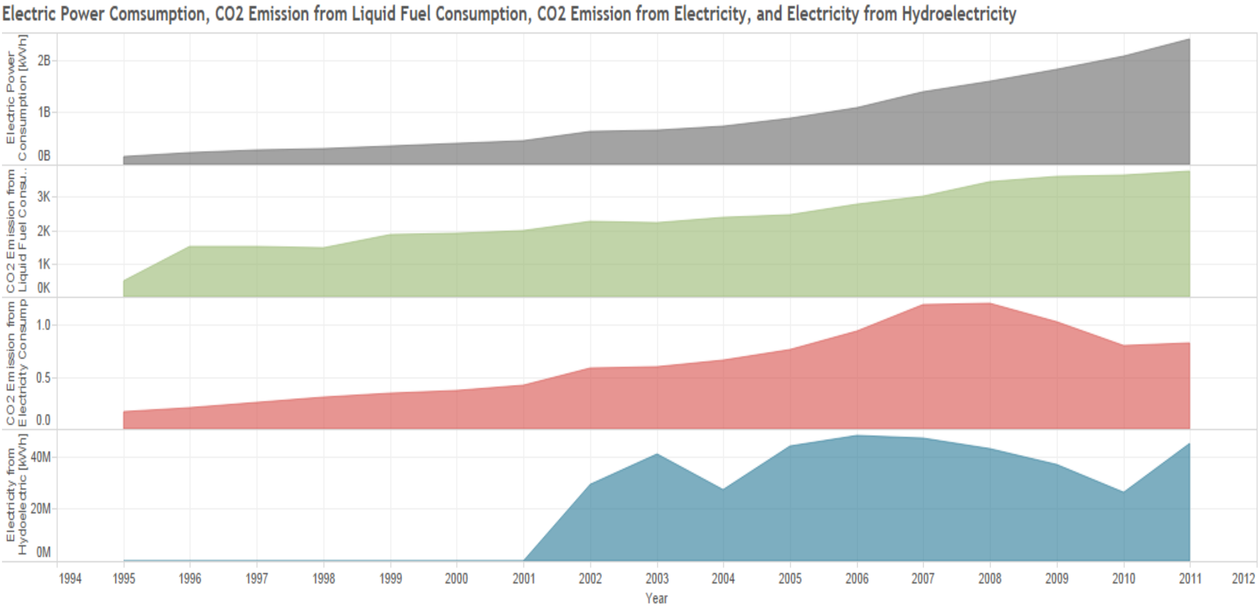



Source: World Bank Data

In order to be able to compare the benefits and costs from dam construction, “Cost Benefit Analysis” is used to convert environmental costs into a monetary value. At a 10% discount rate, with 6 dams on the Mekong River main stem, the costs of lost fish alone would be USD4 billion per year; the annual costs with the same discount rate would become USD13.3 billion if 11 dams are constructed.[31] When costs to agriculture are included and compared to the expected profits from the hydropower projects directly and the same 10% discount rate is used, the construction of  dams would lead to an estimated USD6.9 billion loss for Cambodia annually. While the Mekong region as a whole would benefit, it seems that (in this analysis) Cambodia would financially suffer as it has to bear a disproportionate amount of the environmental impact.[32] It is also worth noting that at the different discount rates, i.e. 1% and 5%, the estimated results are different, but this study takes only uses the 10% discount rate for discussion.

[30] UNDP, *Residential Energy Demand*
[31] Ida Kubiszewski, Robert Costanza, Peter Paquet, and Shpresa Halimi, "Hydropower development in the lower Mekong basin: alternative approaches to deal with uncertainty," *Regional Environmental Change 13*, no. 1 (2013): 3-15.
[32] Ibid.

**Figure .** Comparison of Electricity Consumption, CO2 Emission and the Supply of Hydroelectricity




**Source:** World Bank Data

Note: 1) Electric power consumption measures the production of power plants and combined heat and power plants less transmission, distribution, and transformation losses and own use by heat and power plants.

2) Carbon dioxide emissions from liquid fuel consumption refer mainly to emissions from use of petroleum-derived fuels as an energy source.

3) CO2 emissions from electricity and heat production is the sum of three IEA categories of CO2 emissions: (1) Main Activity Producer Electricity and Heat which contains the sum of emissions from main activity producer electricity generation, combined heat and power generation and heat plants. Main activity producers (formerly known as public utilities) are defined as those undertakings whose primary activity is to supply the public. They may be publicly or privately owned. This corresponds to IPCC Source/Sink Category 1 A 1 a. For the CO2 emissions from fuel combustion (summary) file, emissions from own on-site use of fuel in power plants (EPOWERPLT) are also included. (2) Unallocated Autoproducers which contains the emissions from the generation of electricity and/or heat by autoproducers. Autoproducers are defined as undertakings that generate electricity and/or heat, wholly or partly for their own use as an activity which supports their primary activity. They may be privately or publicly owned. In the 1996 IPCC Guidelines, these emissions would normally be distributed between industry, transport and "other" sectors. (3) Other Energy Industries contains emissions from fuel combusted in petroleum refineries, for the manufacture of solid fuels, coal mining, oil and gas extraction and other energy-producing industries. This corresponds to the IPCC Source/Sink Categories 1 A 1 b and 1 A 1 c. According to the 1996 IPCC Guidelines, emissions from coke inputs to blast furnaces can either be counted here or in the Industrial Processes source/sink category. Within detailed sectoral calculations, certain non-energy processes can be distinguished. In the reduction of iron in a blast furnace through the combustion of coke, the primary purpose of the coke oxidation is to produce pig iron and the emissions can be considered as an industrial process. Care must be taken not to double count these emissions in both Energy and Industrial Processes. In the IEA estimations, these emissions have been included in this category.

### 3.1.2. Dam Construction and Social Welfare

For generations fish has been an important staple in the Cambodian diet. Fish products represent 18% of Cambodian nutritional intake[33] and provide 75% of Cambodians' animal protein intake[34] as well as 28% of the fat and 27% of the iron in the Cambodian diet.[35] The loss of such a source of nutrition would be especially detrimental to pregnant women and children.[36] Also, a reduction of fish will have a serious impact on the livelihood of around 1.6 million fishermen and the welfare of many millions more.[37] The construction of dams is estimated to reduce the fish available for food consumption by between 20% and 50%, with

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[33] Inland Fisheries Research and Development Institute (IFReDI), *Food and nutrition security vulnerability to mainstream hydropower dam development in Cambodia: Synthesis report of the FiA/Danida/WWF/Oxfam project* (Phnom Penh: Inland Fisheries Research and Development Institute, Fisheries Administration, 2013)

[34] Mahfuzuddin Ahmed et al., *Socioeconomic assessment of freshwater capture fisheries in Cambodia: report on a household survey* (Phnom Penh: Mekong River Commission, 1998)

[35] Seeing as how fat and iron are scarce in the Cambodian diet, fish and fish products are dietary resource of paramount importance, see: Inland Fisheries Research and Development Institute (IFReDI), *Food and nutrition security*

[36] Kent G. Hortle, *Consumption and the yield of fish and other aquatic animals from the Lower Mekong Basin: MRC Technical Paper No.16* (Vientiane, Lao P.D.R.: Mekong River Commission, 2007) and Mahfuzuddin Ahmed et al., *Socioeconomic assessment*

[37] International Centre for Environmental Management (ICEM), *Strategic*

the Sesan II alone being responsible for a 9.2% reduction of consumable fish.[38] Although the reservoirs created by dams could provide a space for fish farms and aquaculture production which has been proffered as a solution, it cannot respond to an increased demand for fish products because aquaculture has already expanded by more than 300% over the last decade and still accounts for only a fraction of fish products in Cambodia.[39]

The change in aquatic life will also have serious implications on human pathology.[40] For example, some Laotians living near dams have been infected by the parasite "Opisthorchisviverri" after they consumed fish from fish farms.[41] In other countries such as Sudan, Egypt, Ethiopia, and China, the parasite *schistosomiasis* (*bilharzias*) had struck many people living near hydropower projects.[42] Malaria is a cause of death for many people each year. The reduction of forest as a result of dam construction has a positive correlation with the numbers of malaria carrying mosquitoes.[43] Dam construction in Cambodia is expected to have such adverse effects.

Looking at it in terms of distribution, the International Centre for Environmental Management (ICEM) predicts that the mainstream hydropower projects on the Mekong River will exacerbate inequalities in rural Cambodia where the dams are constructed, because the benefits of these projects would be accrued mainly by developers and financers, while the burden of the costs would be carried by the poor, rural, and vulnerable segments of the population.[44] Furthermore, the poor and vulnerable are unlikely to have a sustainable secondary livelihood source when the primary livelihood source falls away.[45] Arsenic poisoning of water wells is a serious problem in rural Cambodia and it is unlikely that those displaced have the means to prevent newly dug wells from being contaminated.[46] The "cumulative impact"[47] of these above problems as a result of dam construction increases the difficulty of finding a solution for these vulnerable people.[48]

### 3.1.3. Dam Construction and Relocation

Relocation refers to the process in which a group of people living in an area where a dam is to be constructed are forced to relocate to a new place. As a consequence, these people could

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[38] Ibid. and Guy Ziv et al., "Trading-off fish biodiversity, food security, and hydropower in the Mekong River Basin," *PNAS* 109, no. 15 (2012): 5609-5614 and Inland Fisheries Research and Development Institute (IFReDI), *Food and nutrition security*.
[39] Inland Fisheries Research and Development Institute (IFReDI), *Food and nutrition security*
[40] Kent G. Hortle, *Consumption and the yield of* and Mahfuzuddin Ahmed et al., *Socioeconomic assessment*
[41] Alan D. Ziegler et al., "Dams and disease triggers on the lower Mekong River." *PLoS neglected tropical diseases* 7, no. 6 (2013): 2166-2200.
[42] Ibid.
[43] Wayne McCallum, *Before the dam: A study of environmental impacts and community rights associated with the construction and operation of the approved Kirirom III hydropower scheme, Sre Ambel District, Southwest Cambodia* (American Friends Service Committee and Rivers Coalition in Cambodia, 2008).
[44] International Centre for Environmental Management (ICEM), *Strategic* and Claudia Kuenzer et al., "Understanding the impact of hydropower developments"
[45] Paula Nuorteva, Marko Keskinen, and Olli Varis, "Water, livelihoods and climate change adaptation in the Tonle Sap Lake area, Cambodia: learning from the past to understand the future," *Journal of Water and Climate Change* 1, no. 1 (2010): 87-101.
[46] Ian G. Baird, *Best Practices in Compensation and Resettlement for Large Dams*
[47] Ibid.
[48] Ibid.

lose their livelihoods, local cultural heritage, and cultural image. A rough estimate suggests that construction of the Sesan II would directly affect the livelihood (fisheries) of 38,675 people in 86 villages and would prevent another estimated 78,000 people living upstream from catching migratory fish, in addition to the 22,277 people whose lives would be disrupted by the loss of domestic water supply.[49] Besides cultural values, loss of social welfare (a sum of individual income within a society or the need of people who are being relocated) as a result of dam construction and relocation is expected to be even greater if environmental and social-cultural factors are taken into account, but it is hard to quantify those factors.

Relocation as a result of dam construction may also affect the socio-cultural foundation of indigenous groups and the cultural image of an area. Indigenous groups may consider their current habitat to hold special cultural or religious value.[50] Cultural image, however, can also matter for Cambodian people who are not from an indigenous minority. For example, the rare fish "Mekonginaerythrospila" or "Trey Pa Sa Ei" has been venerated by Cambodian people for many generations and is considered a cultural image of Stung Treng province, but risks extinction if dams block its migratory path.[51]

According to the ADB, any group of people who are subject to relocation should be compensated.[52] Taking into account the opportunity costs that the people give up because of their relocation, the compensation must be equal or greater than what they would have gotten from continued living in their community of origin. Location and quality of the new relocation site(s) are critical factors in relocation planning because they ultimately determine access to land, social support networks, employment, business, credit, and market opportunities. Each site has its own constraints and opportunities. Selecting sites that match closely the previous site in terms of environmental, social, cultural, and economic characteristics will make it more likely that relocation and income restoration will be successful (ADB 1998: 56).[53]

The land on which people are relocated, however, tends be in remote areas, less fertile, with fewer diversified livelihood strategy options, and unclear property rights.[54]The ambiguity of the property rights regime could have serious implications regarding the level of trust between the authority and the people who are relocated. Indicative of this, ADHOC reported it handled 48% more land conflicts in 2013 than it did in 2012. While they speculate that this may be in part due to increased mistrust and willingness (of villagers) to fight land concession; ADHOC also believes that geological mapping and construction of hydropower dams contribute to an increased number of land disputes.[55]

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[49] Ibid.
[50] Phak Seangly, "Ethnic group petitions UN to halt Areng dam," *The Cambodia Daily*, April 4, 2014
[51] There is a statue of it in Stung Treng town, which is mentioned in many tourist guides. The loss of this fish would not only hurt economically, but would also hurt the culture of the province. See: Ian G. Baird, *Best Practices in Compensation and Resettlement for Large Dams*
[52] ADB *Key Indicators for Asia and the Pacific 2013,* 2013.
[53] ibid.
[54] Ibid.
[55] ADHOC, *Land Situation in Cambodia in 2013* (Cambodia: Adhoc, 2014).

### 3.2. Environmental Impacts of Dam Construction

For centuries, the water of the Lower Mekong River has been diverted for irrigation and to provide fresh water for household use. Reservoirs were created to store water, while canals were constructed for navigation and farming. Today, there is greater constraint placed on the land as development continues increasing at a rapid pace in both rural and urban environments. At the same time, given that the annual cost of damage resulting from floods has reached $18 million,[56] the need for better disaster prevention planning is becoming more crucial than ever before. Therefore, dams which, to a certain extent can control flooding are viewed as fundamental components in the development and management of multipurpose water resources.

In Cambodia, hydroelectricity accounts for 3.3% of the total energy produced,[57] which is accessible to only 26% of the population.[58] Thus, the construction of dams is viewed primarily as a strategy to produce electricity in order to meet the increasing demand. However, the construction of dams also creates economic, environmental and social benefits such as recreational areas for tourism. Dams, if managed efficiently, can provide multiple functions such as debris or sediment control, navigation, flood control, irrigation and increased water supply in the dry season. Despite all the associated benefits of dams, significant adverse environmental effects could arise in the longer run, which in turn, may cause irreversible damage to the environment. The following sections will review the environmental issues, using the watershed approach (see Section 3.2.1 below), combined with external impacts such as climate change. The analyses sheds light on the functioning of the natural system in the Lower Mekong River Basin.

#### 3.2.1. Understanding the Watershed Approach

A watershed is a topographical unit defined by the flow of water. A watershed focus is an analytical method with a strong focus on practices to control quantity, quality, and timing of water flows, which are seen as essential aspects of the analysis. Coupled with this is the fact that land-use patterns and changes thereof have a direct effect on the flow and quality of water. Dam construction impacts the watershed by changing land-use patterns, forest cover, species distribution, and the flow and quality of water. One major concern identified is the impact of dam construction on groundwater in the aquifers. Thus, the watershed approach will analyse two categories of natural resource issues: water resources issues and land resources issues.

The Prey Veng and Svay Rieng aquifer present excellent examples of the way in which the natural water system functions. The Mekong River lies along the west side of Prey Veng and a large part of the province is a floodplain that is subject to annual inundation. The

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[56] Mekong River Commission, *Working paper 2011-2015: The Impact & Management of Floods & Droughts in the Lower Mekong Basin & the Implication of Possible Climate Change* (Mekong River Commission, 2012).
[57] Kingdom of Cambodia, *Cambodia Climate Change Strategic Plan 2014-2023*, (Phnom Penh: National Climate Change Committee, 2013)
[58] Hydroworld, "Cambodia seeks collaboration despite criticism of Lower Se San 2 hydro project," *Hydroworld*, December 18, 2013. http://www.hydroworld.com/articles/2013/12/cambodia-seeks-collaboration-despite-criticism-of-lower-se-san-2-hydro-project.html

groundwater in the aquifer is easily accessible through the presence of wells. According to research carried out by the International Development Enterprises of Cambodia, the groundwater in the aquifer under the area adjacent to the Mekong River generally flows in an east to west direction with the rise and fall of the Mekong flood cycle and has more than two sources of groundwater recharge.[59]

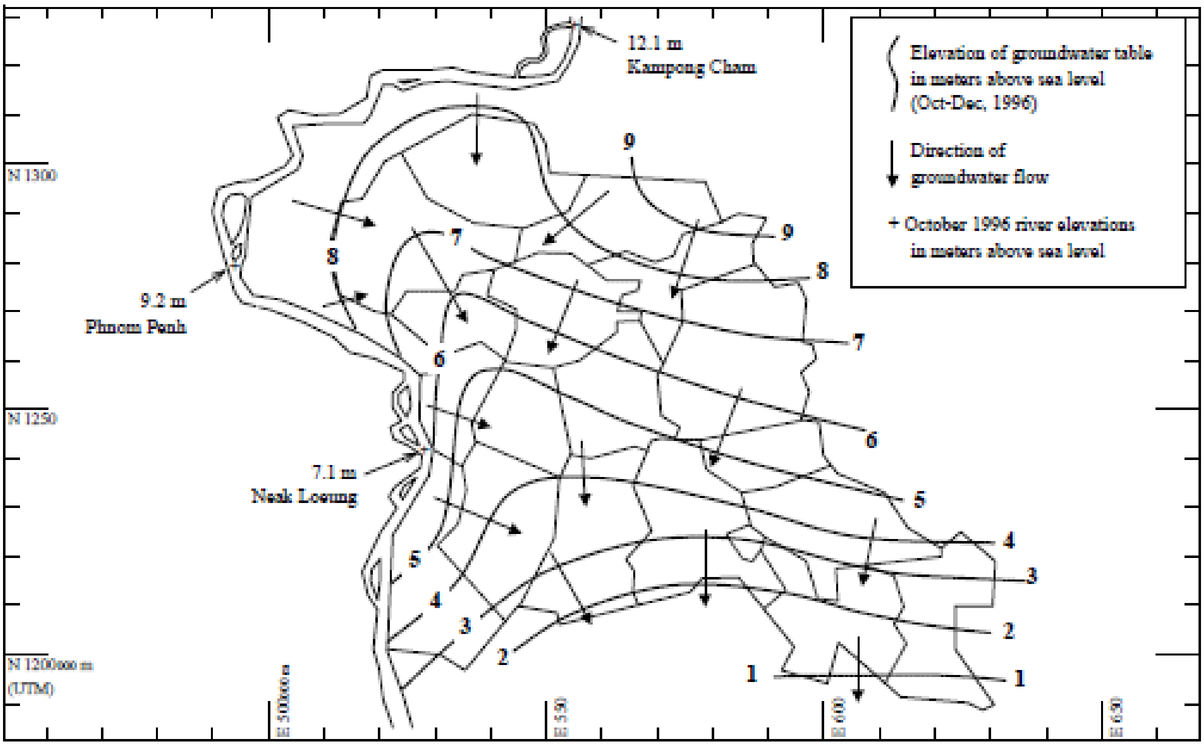


**Figure .** Elevation of Groundwater in the Wet Season
**Source:** International Development Enterprises Cambodia[60]

As the river flow increases, the aquifer gets recharged with groundwater. When the river level drops, groundwater drains out of the aquifer, which in effect contributes to the Mekong base flow. As demonstrated in Figure 6, during the wet season, the water in the Mekong River increases in height and volume, and then seeps into the aquifer system and follows the general direction of the groundwater flow. Contrary to this, as demonstrated in Figure 7, during the dry season the groundwater seeps into the Mekong River channel as a result of greater saturation level in the aquifer and lower water quantity in the river channel.

[59] International Development Enterprises Cambodia, *Strategic Study of Groundwater Resources in Prey Veng and Svay Rieng (Phase I)*: *Final Report*, Seila Task Force Secretariat Rural Poverty Reduction Project, (Phnom Penh: International Development Enterprises Cambodia, 2005), 11-16.
[60] Ibid.

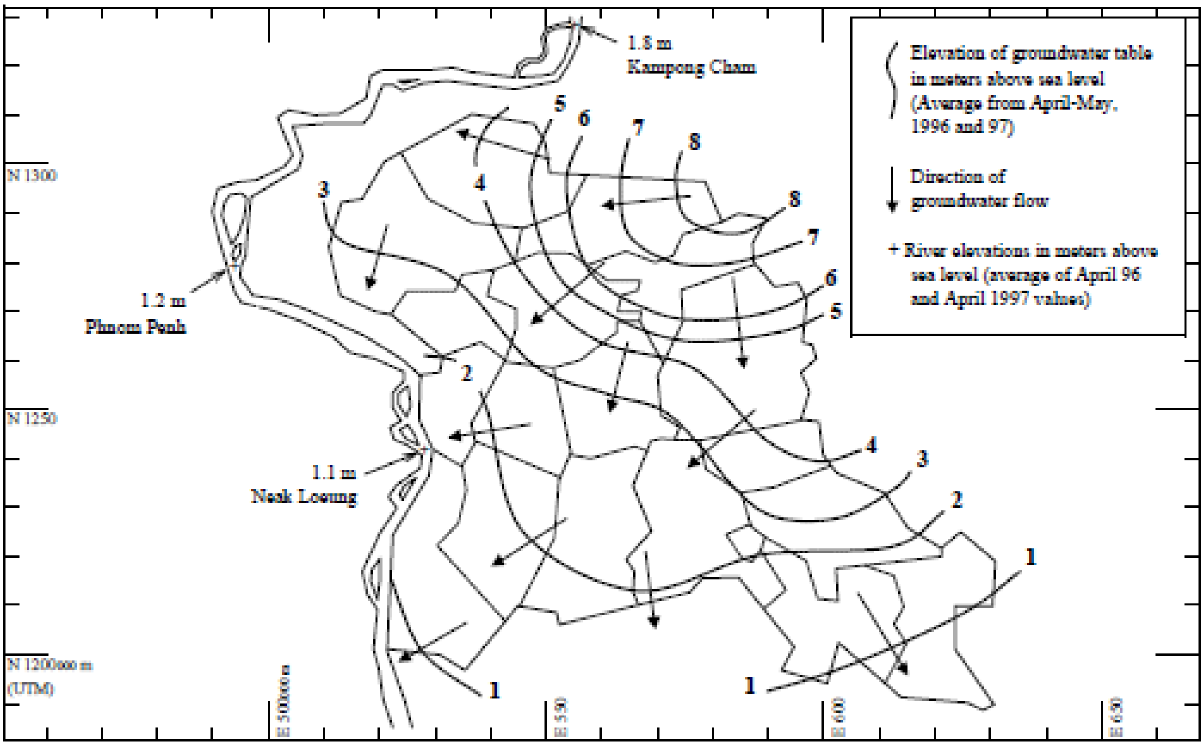


**Figure .** Evaluation of Groundwater in the Dry Season
**Source:** International Development Enterprises Cambodia[61]

### 3.2.2. Impact of Dam Construction on the Environment

Dam construction is one of the oldest methods to manage water flow and to produce electricity without polluting water or air. Even though hydropower projects emit very little greenhouse gas[62] and do not use up any resources,[63] the facilities can have significant environmental impacts by simply altering the environment. It is also important to note that other renewable resources, including geothermal power, wave power, tidal power, wind power, and solar power[64] could be developed to help guarantee a reliable long term solution to meet the current energy shortage.

Hydropower dams could reduce the seasonal cycle of the river by increasing flows during dry season and decreasing flows during the wet season. The exact impact of this depends on the operational schedule and location of the dam, but the operational schedule can be used to keep the flow (and availability) of water in the downstream regions consistent and regular.[65]

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[61] Ibid.
[62] Hydropower dam greenhouse gas emissions are 30 to 60 times lower than greenhouse gas emissions of fossil fuel generation.
[63] International Hydropower Association et al., *Hydropower*
[64] US Department of the Interior, *Reclamation: Managing water in the West, Hydroelectric Power*. url: http://www.usbr.gov/power/edu/pamphlet.pdf
[65] International Centre for Environmental Management (ICEM), *Strategic* and T. Piman, T. A. Cochrane, M. E. Arias, A. Green, and N. D. Dat, "Assessment of Flow Changes from Hydropower Development and Operations in Sekong, Sesan, and Srepok Rivers of the Mekong Basin," *Journal of Water Resources Planning and Management 139*, no. 6 (2013): 723-732.

It is worth noting, that dam related floods are usually caused by the inefficient control of operational activities or technical failure of dams and dykes.[66] It is therefore important to note that a sudden release of large amounts of water could cause unexpected rises in downstream water levels causing water to overtop the banks and create floods. In the event of a dam breakage—when a dam embankment fails due to structural failure or the undermining of its foundations—the outcome of such an event could cause a rapid increase in water levels and water flow velocity, which could be extremely hazardous for human lives and settlements downstream. In event of a dyke breach, although less hazardous, it could still cause floods at a smaller scale. Based on data from the last 20 years, it seems that major floods in Cambodia occur about once every 1.6 years and cost 87 lives per event, or on average 44 lives per year. In addition, floods have cost an average of USD15.6 million per year over the same period.[67]

### 3.2.3. Impacts of Dam Construction on Climate Change

Dams in the mainstream will reduce the Mekong River's natural 'stream power,' which is the rate at which energy is lost by the river. Decreased stream power will lead to altered groundwater levels and will prevent the river from transporting sediments. An estimated 80% of the fertilising sediments will get stuck in the water reservoir, resulting in loss of fertility for about 18,000 $km^2$ of Cambodian floodplain (of which 309,000 hectares is farm land) if all planned dams are build.[68] As Cambodia is a downstream Mekong country and its floodplains are heavily dependent on sediments from the river, the environmental impact and loss in fisheries and agriculture will impact Cambodia to a larger extent than the other Mekong countries.[69] Computer simulations show that, if all 78 tributaries and 11 main-stream dams[70] in the Lower Mekong Basin are constructed, fish biomass could drop by 51.3%. The worst contributor to this would be the Lower Sesan II dam, as it is estimated that it would be solely responsible for a 9.3% drop in fish biomass basin-wide.[71]

In addition, the processes of waterlogging and inundation lead to a lack of oxygen for vegetation in the riparian zone (i.e., land along the river bank). The loss of riparian vegetation could cause increased bank erosion. This process of increased bank erosion is expected to first take place in Vientiane (in Lao P.D.R.) before working its way down to Kratie province in 15 to 30 years.[72] It is possible to prevent the de-oxygenation of the riparian zone by draining the zone for a couple of hours each day. However, such an operation would cause seedlings to be

[66] Mekong River Commission, *The Impact & Management of Floods & Drought*
[67] Ibid.
[68] International Centre for Environmental Management (ICEM), *Strategic*
[69] Richard P. Cronin and Timothy Hamlin, *Mekong tipping point: Hydropower Dams, human security and regional stability* (Washington D.C.: Stimson, 2010).
[70] Right now 11 dams are going to construct on the mainstream (some dams are under construction) and 78 other dams are also planned to build on the Mekong tributaries. Some are completed, few others are under construction, and some others are still in the plan.

It is important to note that simulation method is used to simulate the impacts of dam construction given different scenarios (or the different numbers of dams). In this context, economists and environmentalists employ the simulation method to evaluate the environmental impacts as a result of these dams. There are a number of scenarios. For example, Scenario A: If two or three dams were to construct; Scenario B: if 10 dams were to construct; and Scenario C: if all dams were to construct.
[71] Guy Ziv et al., "Trading-off fish biodiversity"
[72] International Centre for Environmental Management (ICEM) *Strategic*

flushed away, so that the trees and woody shrubs in the riparian zone would likely be replaced by grass-like and semi-aquatic plants.[73] Additionally, operating the dam in this way may cause polluting substances to come downstream in pulses, which is more harmful than the natural situation whereby pollutants come down gradually in a (more) diluted form[74].

### 3.3. Legislative Framework

As set out in the Cambodian Constitution:

‘‘*The state shall protect the environment and the balance of abundant natural resources and establish a precise plan of management of land, water, air, wind, geology, ecological system, mines, energy, petrol and gas, rocks and sand, gems, forests and forestry products, wildlife, fish and aquatic resources.*’’[75]

Two international law documents ratified by Cambodia are important within this context: First, in 1995 Cambodia signed the “Agreement on the Cooperation for the Sustainable Development of the Mekong River Basin.” This agreement was to establish cooperation between Laos, Vietnam, Thailand, and Cambodia in order to conserve and protect the environment and the resources of the Mekong River Basin including fisheries and hydro-power. In order to facilitate this cooperation the Mekong River Commission was established, as per chapter IV of the agreement.[76] In addition, Cambodia has ratified the “Convention on Wetlands of International Importance, especially as Waterfowl Habitat” (informally known as the “Ramsar convention”), which requires signatory countries to establish protected “Ramses sites.”[77] There are a number of important laws that were in place to protect the environment prior to that, such as the 1993 Royal Decree on the Creation and Designation of Protected Areas, which created 23 Protected Areas (PAs)[78] which falls under the jurisdiction of the Ministry of Environment, based upon the legal framework provided by the Law on Environmental Protection and Natural Resource Management (1996). Today, there are 34 protected sites in Cambodia which include the following: 3 multiple use areas; 8 National Parks; 8 Protected Landscape; 1 Ramsar Site; 14 Wildlife Sanctuaries.[79] This law includes provisions for community participation in natural resource management.[80] However, it has been argued that apart from these laws effective implementation may require “effective

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[73] Helen Locher, *Environmental Issues and Management*

[74] Ibid.

[75] Cambodian Constitution as cited in Mekong Law Center, *The Kingdom of Cambodia: Constitutional Provisions*. url: http://www.mekonglawcenter.org/download/0/cambodia.htm

[76] Mekong River Commission, *Agreement on the Cooperation for the Sustainable Development of the Mekong River Basin* (Chiang Rai: April 5, 1995). http://www.mrcmekong.org/assets/Publications/policies/agreement-Apr95.pdf

[77] Convention on Wetlands of International Importance, especially as Waterfowl Habitat, Ramsar, 1971, for which Cambodia prepared by a Kram dated October 22, 1996 named Law on the Adoption of the Convention on Wetlands of International Importance especially as Waterfowl Habitat concluded at Rammer, Iran on February 2, 1971.

[78] San, Socheat Leakhena, "Indicating Success: Evaluation of Community Protected Areas in Cambodia," in *Hanging in the Balance: Equity in Community Based Natural Resource Management in Asia*, ed. Sango Mahanty et al. (Bangkok: RECOFTC, 2006), 14

[79] Open Development, *Natural Protected Areas*, (2014) url: http://www.opendevelopmentcambodia.net/natural_resource/protected-areas/ accessed on October 6 2014.

[80] Norodom Sihanouk, *Royal Decree on the Creation and Designation of Protected Areas*, 1993.

functioning of state agencies, alongside the private sector and civil society to help translate policy goals into practice."[81]

It is worth noting that the objective of the Law on Environmental Protection and Natural Resources Management is ''*to protect and upgrade the environment quality and public health by means of prevention, reduction and control of pollution[;] to assess the environmental impacts of all proposed projects prior to the issuance of [a] decision by the Royal Government of Cambodia to ensure the rational and sustainable preservation, development, management and the use of the natural resources of the Kingdom of Cambodia."* This is supported by Chapter II of the law that states that the national and regional environmental plans should support the objectives of the law, and Chapter III which highlights that all existing activities, projects as well as planned projects must undergo an Environmental Impact Assessment as stated in Chapter III, Article 6 and Article 7.[82] Some common themes of all these environmental laws include their focus on planning, development and management, and public participation in natural resource management.

In addition, Cambodia has developed a National Biodiversity Strategy and Action Plan (NBSAP), with support from a Global Environment Facility (GEF) Enabling Activity through the UNDP. The strategy provides a framework for action at all levels,[83] which will enhance Cambodia's ability to ensure productivity, diversity, and integrity of its natural systems and, as a result, its ability as a nation to reduce poverty and improve the quality of life of all Cambodians. A number of important sites were identified that require greater protection. One of the many sites is the Kulen Promtep Wildlife Sanctuary.

Cambodia's first land law was enacted in 2001, the new forestry law in 2002, and sub-decrees on community forestry and wildlife protection in 2003. This provided, for the first time in Cambodian history, sufficient legislation to cope with issues of land tenure, community user rights and resource utilisation (including wildlife). However, more effort is needed to ensure that all stakeholders are aware of these new laws through sound mechanisms that could be developed to help increase understanding of the implications and possibilities arising from these laws.

## 4. Conclusion

There are a number of social, economic and environmental benefits associated with the construction of dams in Cambodia based upon the premise that building dams could be the solution to generating economic growth, alleviating poverty and inequality in the country. In comparison to other types of power plants, hydropower presents a more economical method

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[81] Blake D. Ratner, *Natural Resource Governance and Food Security in Cambodia: Policy Discussion Note* (Washington DC: International Food Policy Research Institute, 2011), 3.

[82] Ministry of Land Management Urban Planning and Construction, *Preah Reach Kram/NS-RKM-1296/36*, trans.by ADB TA 3577 and LMAP TA GTZ (Enacted on November 18, 1996) http://www.cambodia-redd.org/wp-content/uploads/2013/05/LAW-1296-36-96-Environmental-Protection-Natural-Resources-Mgt-E.pdf

[83] Kingdom of Cambodia, *National Biodiversity Strategy and Action Plan: To Use, Protect And Manage Biodiversity For Sustainable Development In Cambodia*, FAO/UNDP/GEF Project CMB/98/G33 (Cambodia: Ministry of Environment, 2002)

of generating electricity because of the ‘‘black start’’ capability and also for the fact that it is not dependent on weather conditions. [84] Some findings suggest that Cambodia could accumulate 26-31% of gross revenues from hydropower projects and that consumers would benefit. This is based upon the combination of two factors—Cambodians would pay less for electricity and the state would receive full financial benefits from hydropower which creates a win-win situation for both the state and consumers.[85]

Despite the numerous benefits associated with hydropower, it is worth pointing out that the Cost Benefit Analysis noted that at 10% discount rate, with six dams in the Mekong River’s main stream, the cost of the loss of fish alone would total up to 4 billion US dollars per annum. With the same discount rate and 11 dams constructed, the annual cost could accumulate up to 13.3 billion US dollars. In addition, the loss of biodiversity, food security, and fisher communities are also associated impacts as a result of the hydropower construction in Cambodia.

Given the fact that current understanding of the geomorphology of the Mekong’s basin and watershed area is still limited and considering the complexity of the ecosystem that co-exists, key findings suggests that more analysis is required when altering the water system for the benefit of power generation which can cause serious environmental impacts. Another aspect also worth considering is the fact that, in the longer run, the construction of dams could create adverse effects on the aquifers existing adjacent to the Mekong River and its tributaries. The analysis using a watershed approach combined with the findings of the research carried out by the International Development Enterprises of Cambodia demonstrated when river flow increases, the aquifer gets recharged with groundwater and when the river level drops, groundwater drains out of the aquifer, which in effect contributes to the Mekong base flow. Therefore, stopping the natural flow of the river using dams would not only flood large areas of land, but also affect groundwater levels that play a crucial role in maintaining the livelihoods of the population.

Given both the positive and negative issues surrounding the development of hydropower it would seem appropriate that careful consideration be given to all of these aspects when considering and planning for the development of hydropower.

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[84] Helen Locher, *Environmental Issues and Management*
[85] International Centre for Environmental Management (ICEM), *Strategic*

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