Economic Evaluation of Hydropower Projects in the Lower Mekong Basin

Apisom Intralawan, David Wood and Richard Frankel

School of Management
Natural Resources and Environmental Management Research and Training Center (NREM)
Mae Fah Luang University, Chiang Rai, Thailand

Photo Credit: Savann Oeurm/Oxfam

supported by

OXFAM

Economic Evaluation of Hydropower Projects in the Lower Mekong Basin

Apisom Intralawan, David Wood and Richard Frankel

School of Management

Natural Resources and Environmental Management Research and Training Center (NREM)
Mae Fah Luang University, Chiang Rai, Thailand

March 2017

Table of Contents

Acknowledgements

This paper is an update of a previous study entitled 'Working Paper on Economic, Environmental and Social Impacts of Hydropower Development in the Lower Mekong Basin' published in 2015. This was a revised, condensed version of the report 'Planning Approaches for Water Resources Development in the Lower Mekong Basin' (Costanza et.al. 2011). The current paper (NREM Update) used some data from Mekong River Commission (MRC) reports including 'Assessment of Basin-wide Development Scenarios – Basin Development Plan Programme, Phase 2' (BDP2) published in 2011. We thank our Peer Review group for their valuable comments and suggestions. We also thank Oxfam for their sponsorship of this paper.

Disclaimer

Any views expressed in this paper are those of the authors and do not necessarily represent the views of MRC, Mae Fah Luang University or Oxfam.

Corresponding author email: *intraa@mfu.ac.th*

1. SUMMARY

This study shows that the net economic impact of planned hydropower projects on the Mekong River and its tributaries is negative based on conservative, updated data for project economics, fisheries and social & environmental mitigation costs. This is contrary to the MRC Basin Development Plan (BDP2) which reported a large economic benefit from hydropower generation which far outweighed negative impacts. However, these projects would block fish migration routes, change flood areas, decrease sediment/nutrient loading, and significantly reduce the Mekong River fish catch. They would also affect the livelihoods, well-being and food security of millions of rural people. The updated Net Present Values (NPV) for the 11 dams scenario in BDP2 are shown below:

	BDP2 **NPV(10) - $ million**	**NREM Update** **NPV(10) - $ million**
Hydropower	32,800	6,600
Capture fisheries	-1,900	-13,000
Social Mitigation Costs	0	-1,600
Sediment & Nutrients Loss	0	-2,300
Others (details in text)	2,500	3,000
Total Economic Impact	33,400	-7,300

The hydropower NPV in this **NREM Update** is much lower than BDP2 due to the low capital investment data, high electricity price and flawed electricity trading model used in BDP2. The forecast capture fisheries loss NPV in the **NREM Update** is much larger than the hydropower benefit using the same discount rate (10%) for all benefits and costs including natural resources. The **NREM Update** included costs for social impacts and reduced sediment and nutrients loading caused by the dams; these costs were not taken into account in BDP2.

Another major finding relates to the cost/benefit distribution between the Lower Mekong Basin (LMB) countries. BDP2 concluded that all LMB countries would benefit from hydropower development and that Lao PDR would be the main beneficiary, assuming that all hydropower profits would accrue to the host country. The **NREM Update** assumed 30% benefit for the host country and 70% for the country funding the project and/or importing the electricity during the 25-30 year concession period. This results in Thailand being the main beneficiary; the economic impact on Lao PDR is negative for much of the concession period and most of the Lao PDR benefit is gained after the concession period; Cambodia and Vietnam would suffer large negative impacts. Project developers and electricity importers would benefit but poor, farming and fishing communities in all LMB countries would suffer.

The forecast profitability of the Xayaburi project is modest even assuming no impact on capture fisheries and the environment. However, a small percentage loss of capture fisheries would result in a large, negative economic impact. The justification for the Don Sahong project is even more questionable as it is not essential for the security of Lao PDR electricity supply and the potential capture fisheries loss far exceeds the small hydropower benefit.

The planned Mekong projects would have a negative economic impact for the LMB region; they may provide income to the host countries but could cause a regional social and environmental disaster.

The following recommendations are proposed for further consideration:

(1) To delay construction of other mainstream dams until Xayaburi is completed and the effectiveness of mitigation measures (fish pass, sediment sluice gates) has been confirmed.
(2) To require hydropower development projects to include full cost accounting of social and environmental mitigation measures in the committed capital investment.
(3) To re-assess the net economic impact and forecast benefit to Lao PDR based on a ‘likely scenario’ for mainstream hydropower projects which have a high probability of going ahead.
(4) To develop a new LMB energy strategy taking into account less hydropower income than previously anticipated, updated forecast for LMB power demand and technology developments for improved energy efficiency & renewable energy.

2. BACKGROUND

The Mekong River is the largest freshwater fishery in the world (estimated fish catch about 2.3 million tons/year) and the third most bio-diverse river system (with approximately 800 fish species) after the Amazon and Congo rivers [1-3]. The estimated fish catch does not include 0.5 – 0.7 million/tons year fish catch from the Vietnam Delta coast which is dependent on Mekong River sediment/nutrient outflow and about 0.5 million tons/year of other aquatic animals (OAA) such as shrimps, crabs and frogs [4]. The annual fluctuation (water levels and flows) of the Mekong River is the main driver of the high productivity of the river and associated wetlands. However, this would change drastically if all planned hydropower projects (see map below) are constructed as fish migration routes would be blocked. The best available fish passage technology is unlikely to handle the huge volume of fish migration (up to 3 million fish/hour at peak migration) and the diverse migration patterns of different fish species [5-11]. The planned hydropower projects will also significantly change the hydrology of the Mekong River which will affect Tonle Sap and alter flood areas, riverine and Vietnam Delta coastal zone ecosystems [12-15].

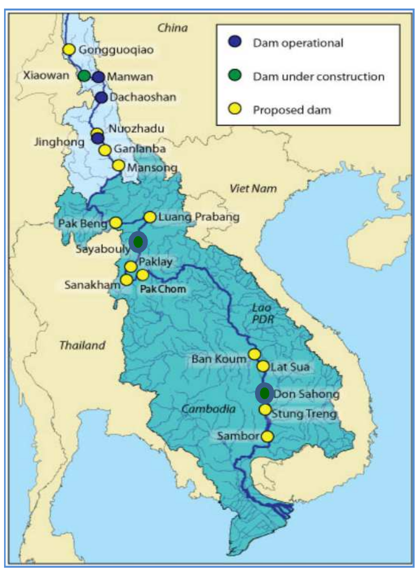


Figure 1. Location of mainstream dams on the Mekong River (Source: [16])

MRC has issued many reports related to development of water resources in the LMB and they formulated and assessed a wide range of basin-wide development scenarios described in BDP2 which was published in 2011 [16]. The assumptions in BDP2 were challenged in a report ‘Planning

Approaches for Water Resources Development in the Lower Mekong Basin' by Portland State University, Oregon and Natural Resources and Environmental Management Research and Training Center (NREM), Chiang Rai which is_hereafter referred to as the 'Costanza report' [17]. The Costanza report showed that the net economic impact of the planned hydropower projects would be negative in terms of NPV by changing some key assumptions (fish value, low discount rates for natural resources such as capture fisheries and wetlands) used in BDP2. Furthermore, the Costanza report highlighted the environmental/social risks of hydropower development and concerns about sustainable energy planning and rural livelihoods.

A previous NREM study, 'Working Paper on Economic, Environmental and Social Impacts of Hydropower Development in the Lower Mekong Basin' published in 2015 [18] was a revised, condensed version of the Costanza report. This paper assumed the same hydropower NPV benefit as BDP2 but it now seems that the BDP2 evaluation of hydropower benefits was based on some flawed assumptions:

(1) BDP2 assumed that the host countries would be the hydropower project owner/operator and receive 100% of the revenues and profits from electricity sales.
(2) The BDP2 evaluation was based on an economic model with large profits allocated to 'intermediary electricity trading' which mainly accrued to Lao PDR.
(3) Some capital investment data in BDP2 were low which lead to overstated NPV numbers.
(4) BDP2 assumed that the electricity export price would be 85% of replacement cost of electricity in the importing country (instead of using a market based electricity export price as now recommended by MRC). Furthermore, the estimated replacement costs turned out to be high as they were based on high forecast prices for crude oil, natural gas and coal which were expected in 2009/2010.

The **NREM Update** developed a more realistic hydropower economic model and used updated economic data to correct BDP2 flaws and to revise the forecast hydropower benefits. The **NREM Update** also used updated data on capture fisheries, wetlands value, social mitigation costs and sediment/nutrient flows to assess the overall economic impact.

3. ECONOMIC MODEL AND DISCOUNT RATES

The cost benefit analysis in the **NREM Update** used inputs from a recent MRC guideline [19] and hydropower economic evaluation manuals [20, 21]. A simplified evaluation basis is shown in Appendix 2 and the NPV calculations focused on two BDP2 scenarios:

(1) The '6 dams scenario' with six planned mainstream dams in Lao PDR plus 30 planned tributary dams
(2) The '11 dams scenario' with eleven planned mainstream dams (nine in Lao PDR and two in Cambodia) plus 30 planned tributary dams

The costs and benefits of planned hydropower project were evaluated in BDP2 in terms of Net Present Values (NPV) for a 50 years evaluation period (see Box below). BDP2 used a 10% discount rate which is typically used to evaluate major infrastructure projects. This study also used the same 10% discount rate and 50 years evaluation period with economic inputs adjusted to 2016 prices. The Costanza report argued that lower discount rates (such as 3%) and an Infinite Time Horizon are more appropriate for natural resources (such as capture fisheries, reservoir fisheries and wetland areas). Based on these assumptions, the net economic impact of the planned hydropower projects would be negative due to the large negative NPV (3) for capture fisheries.

> The Net Present Value (NPV) of a project is the sum of all future project discounted cash flows (investment, revenues, costs, loans) over the project evaluation period. The future cash flows are converted to a base time (usually today) by discount factors related to interest rates. A 10% discount rate is often used for project evaluations. If the project NPV(10) is positive, then the project is considered economically viable; if the project NPV(10) is negative, then it is not considered economically viable.

The NPV values used in this paper for Others (which are Irrigated Agricultural Production, Reduction in Eco-hotspot/Biodiversity, Forest Area Reduction, Recession Rice, Flood Damage Mitigation, Mitigation of Salinity Affected Areas, Losses in Bank Erosion Areas and Navigation) are the same as those in BDP2 (based on 10% discount rate and 50 years evaluation period) but adjusted to 2016 prices using World Bank inflation data [22].

The NPV calculations reported in the Summary and Appendix 3 are based on an Economic Internal Rate of Return (EIRR) method which assumes self-financed projects (no bank loan) and zero royalty and tax. However, additional calculations were carried out using a Financial Internal Rate of Return (FIRR) method (see explanation in [23]) to assess the net cash flow for Lao PDR.

As mentioned above, the **NREM Update** focussed on two BDP2 development scenarios (20 year period to 2030) which were based on LMB government water resources development plans rather than a wide range of independent scenarios. The ‘6 dams scenario’ and ’11 dams scenario’ were considered realistic when BDP2 was published in 2011 but may no longer be the most likely scenario. There are also limitations in the **NREM Update** due to the inclusion of parameters (e.g. social & environmental mitigation costs) which are difficult to quantify and calculation simplifications (e.g. no inflation, same electricity price for all projects). It is also recognised that the economic calculations in the **NREM Update** were based on many assumptions with varying degrees of uncertainties in the input data. The **NREM Update** tended to use conservative data to assess the two most important parts in this evaluation - hydropower generation benefits and capture fisheries loss. Also, sensitivity calculations were carried out for these two components (and other key parameters) as reported in Section 5.1.

4. KEY ASSUMPTIONS

4.1. Hydropower Generation

As shown in Appendix 1, the total capacity of the 11 planned mainstream projects is 13,000 MW which would produce 65,000 GWh – equivalent to about 8% of forecast LMB power demand for 2030 [24]. About 90% of the electricity from these projects would be exported to Thailand and Vietnam which account for the bulk of LMB power demand [25]. If all 30 planned tributary dams were built by 2030, they would produce an additional 44,000 GWh (from 10,000 MW capacity) which far exceeds the forecast power requirements of Lao PDR and Cambodia (each about 16,000 GWh).

The hydropower project basic data (capacity, capital investment, project ownership, electricity price, electricity market and operating & maintenance costs) for this study were collected from hydropower experts familiar with previous and planned Mekong projects [26]. Also, a capital injection of 10% initial capital investment is assumed following ownership transfer to the host country to pay for a major equipment overhaul after 25 years project operation. The data were adjusted to 2016 prices - a summary is shown in Appendix 1 and some salient points are noted below:

Project construction.

Construction of Xayaburi started in 2012 and commercial operation is expected in 2019. Construction of Don Sahong started in 2016 and construction of Pak Beng is expected to start in 2017. A project construction time of six years is assumed for mainstream projects (five years for tributary projects) and it is assumed that the other mainstream projects will start by 2030 in line with the BDP2 scenario (however, this may not be achieved according to hydropower experts).

Electricity price.

The price used in the NPV calculations is the electricity price available at the electricity generation site. This price is paid by the electricity company (either domestic or foreign importer) and does not take into account any capital investment or operating costs for electricity transmission and distribution in the importing country. Electricity prices vary due to different electricity markets (e.g. local sales price to Electricité Du Laos is slightly lower than export prices) and because tributary projects produce Primary Energy (peak demand hours) whereas mainstream projects are run-of-river schemes and produce electricity 24 hours/day. To simplify this evaluation, an electricity price of $ 0.07/kwh for all mainstream dams and tributary dams was used based on recent electricity sales agreements adjusted to 2016 prices. It is expected that future negotiated electricity export prices will be similar or lower than previous agreements due to competition from alternative energy and future Yunnan and Myanmar hydropower projects and an electricity price of $ 0.05/kwh (2016 price basis) was assumed for the period following ownership transfer to the host country. A NPV sensitivity calculation was carried out with an electricity price of $ 0.075/kwh for both mainstream projects and tributary projects. If all 11 planned mainstream projects were built, then it is estimated that 9% of the total electricity generation would be supplied to Lao PDR, 57% to Thailand, 4% to Cambodia and 30% to Vietnam.

Operating & Maintenance.

Annual cost equivalent to 1.5% of capital investment is assumed for the 25 year concession period based on experience from some recent, major Mekong tributary hydropower projects. The annual cost is assumed to increase to 2% of initial capital investment following the ownership transfer to the host country due to ageing equipment.

Allocation of benefits from hydropower operations.

A benefit split of 30% for the host country (i.e. country where the dam will be built which receives an equity share of profit plus royalty plus tax) and 70% for the country funding the project and/or importing the electricity was assumed for the 25-30 year concession period. This is based on existing large scale hydropower projects where the project owner is 80% Thailand 20% Lao PDR and 90-95% of the electricity will be exported to Thailand. This assumption results in a hydropower benefit split of 20% Lao PDR, 40% Thailand, 8% Cambodia and 32% Vietnam for the 11 dams scenario and 25% Lao PDR, 52% Thailand, 2% Cambodia and 21% Vietnam for the 6 dams scenario.

Electricity Import Benefit.

It is assumed that countries receiving hydropower electricity will benefit from using low cost hydropower instead of electricity generated from natural gas or coal. This benefit is estimated to be 10-15% of the value of total electricity generation from mainstream and tributary projects and a conservative figure of 10% was assumed in this study based on electricity generation, transmission and distribution data in Thailand [27]. The bulk of this benefit accrues to Thailand and Vietnam as they import most of the hydropower electricity.

4.2. Reservoir Fisheries

The capacity and storage area of hydropower reservoirs along the Mekong River would increase considerably with more dams and this should result in an increase in reservoir fish catch. This study used the same increase in catch for reservoir fisheries as BDP2 (64,000 tons/year for the 11 dams scenario) and assumed a fish value of $ 2.50/kg as discussed in Section 4.4. However, the assumed increase in reservoir fish catch may be optimistic as only nine Mekong fish species are known to breed in reservoirs [28-31]. Furthermore, poor reservoir water quality in tributary projects (development of anaerobic conditions from submerged biomass and stagnant waters) will adversely affect reservoir fish catch.

4.3. Aquaculture

Aquaculture production has expanded enormously throughout the Mekong Basin and current fish production is estimated to be about 2.4 million tons/year mainly from Thailand and Vietnam [32]. Additional aquaculture production would mitigate some lost capture fisheries but the largest increase is expected to be in Vietnam which would mainly be for export to countries outside the LMB. The Strategic Environmental Assessment (SEA) of Hydropower on the Mekong Mainstream reported that replacement of capture fisheries loss by aquaculture production is not considered realistic for two main reasons. First, a large proportion of aquaculture production depends on capture fisheries for feed. Second, aquaculture production is more costly than capturing wild fish. This study used the same assumption as the previous NREM study for the increase in aquaculture production (increase of 72,500 tons/year for the 11 dams scenario which is equivalent to 10% of capture fisheries loss) and a fish value for aquaculture is estimated at $ 2.50/kg.

4.4. Capture Fisheries

As discussed in the previous NREM study, it is difficult to estimate the annual Mekong River fish catch from the four LMB countries as government fish catch data do not cover small scale fishers, part (20-40%) of the fish catch is for own consumption by fishers and commercial fishers tend to under report. A literature review of fish catch estimates (see Appendix 3) combined with communications from Mekong fisheries experts were used to derive the estimates shown in the table below. A wide range (35-70%) has been reported for the percentage of Mekong fish species that are long-distance migrants [33]. This study conservatively assumed that 35% of Mekong fish are migratory and a sensitivity calculation was carried out for 40%.

It is also difficult to estimate the loss in capture fisheries if all the planned mainstream dams were built on the Mekong River due to many different fish species with different migration habits. The planned dams will alter fish habitats and affect fish breeding and life cycles [34]. A modelling study commissioned by MRC on the flow modifications and barrier affects caused by 1 to 3 Mekong dams concluded that a high percentage of migratory fish are vulnerable [35]. The fisheries sections in SEA and BDP2 forecast that migration of all long distance migrant fish species would be barred by a cascade of mainstream dams. However, some reports indicate that 5-10% of long-distance migratory fish would adapt to the new situation following construction of all mainstream dams. Also, some species may take advantage of new niches if other species leave. This study assumed 90% loss of migratory fish for the 11 dams scenario which resulted in a forecast fish loss of 725,000 tons/year. This is in line with recent estimates reported by MRC [36].

Table 1. Forecast Capture Fisheries loss due to planned hydropower projects

		6 Dams Scenario	11 Dams Scenario
	Current Fish Catch (tons/year)	**Forecast Fish Catch Loss** (tons/year)	**Forecast Fish Catch Loss** (tons/year)
Lao PDR	240,000	55,000	65,000
Thailand	920,000	60,000	60,000
Cambodia	770,000	200,000	430,000
Vietnam	370,000	85,000	170,000
Total	2,300,000	400,000	725,000

This paper assumed a fish value of $ 2.5/kg for aquaculture/reservoir fish and $ 3.5/kg for capture fisheries [37]. BDP2 assumed a fish value of $ 0.8/kg which resulted in a low NPV for the loss in capture fisheries. It is noted that these fish values do not include any multiplier effects for related economic activities such as fishing nets, processing and selling of fish.

4.5. Wetlands

The Mekong River and its associated wetlands (forests, marshes, and grasslands which are flooded during the rainy season) provide a wide range of ecosystem services. These services are essential in sustaining the livelihood and well-being of the local people. The wetlands provide food, medicinal plants, honey, insects, etc. which benefit local people directly and also nourish local spiritual and other cultural activities. Various studies indicate that local villagers depend greatly upon these services provided by this terrestrial-aquatic intermediary zone [38-41]. The economic benefits of the wetlands services must be taken into the trade-off equation to ensure a comprehensive and balanced basin development plan.

Global estimates of the economic value of ecosystem services provided by wetlands range from $ 3,300 to 25,680/ha/year [42]. A meta-analysis of South East Asian wetlands and mangrove ecosystem services estimated that the mean value of ecosystem services was $ 4,185/ha/year [43]. World Wildlife Fund report estimated the average value of ecosystem services in the Lower Mekong Basin countries at $ 1,639/ha/year for freshwater wetlands [44]. However, a recent report estimated the average value of wetlands ecosystem services in the Lower Mekong Basin countries to be $ 12,630/ha/year [45]. This report conservatively used the BDP2 wetland values adjusted to 2016 prices which results in values of $ 1,700/ha/year for forest wetlands, $ 1,400/ha/year for marshes, and $1,100/ha/year for grassland wetlands.

BDP2 reported that wetland areas will decrease for the 6 dams scenario as the six mainstream dams and tributary dams are located in higher elevation areas of Lao PDR and their storage reservoirs will hold back waters that normally flood lower level areas. However, the mainstream dams are run-of-river projects that do not retain floods so the impact should be minimal. The additional dams in the 11 dams scenario are located in low level areas of Lao PDR and Cambodia and may slightly increase flooded wetland areas.

4.6. Social Impact Cost

The mitigation costs of social/cultural impacts were not taken into account in BDP2. Hydropower construction on the mainstream and tributaries of the Mekong River will pose potential threats to the food security and livelihoods of all communities within the project footprint and for many more affected by transboundary impacts. Construction of the project structures, the reservoir, and associated facilities (e.g. physical plant and transmission lines, work and camp areas, access roads, quarries) will necessitate the relocation of thousands of households affecting their livelihoods, access to traditional food sources and social well-being [46]. The extent to which hydropower project developers provide adequate funds to cover resettlement costs and continue to fund social development programs after resettlement is the basis for evaluating social/cultural costs. Based on detailed studies of actual hydropower development costs in Lao PDR, the social/cultural mitigation costs required to achieve the goals of social wellbeing targeted in Concession Agreements amount to 3.0-8.0% of total project capital investment. A stable livelihood and income for resettled villagers is difficult to achieve in less than five years after commercial operation of the hydropower project. This goal takes a dedicated and well trained social development team, employed by the project proponents, including agricultural experts who are in daily contact with resettled villagers to achieve sustainable income goals. Previous research shows that social mitigation costs were 3.0-6.0% of total project costs [47, 48] New Concession Agreements covering hydropower projects in Lao PDR now state that the Project Proponent is responsible for Environmental and Social Safeguards and achievement of goals defined “by scope, not by budget”. This will surely add more costs to project operations and these costs will be paid for by the Project Proponent.

This study assumes that the capital investment data in Appendix 1 did not include realistic estimates for social impact costs so an additional cost item equivalent to 5% capital investment was included in the NPV calculations. It was further assumed that approximately 70% of total social mitigation costs will be spent during the 6 year construction period and the remaining 30% during the first three years of commercial operation. A sensitivity calculation was carried out assuming a social impact cost equal to 8% capital investment.

4.7. Environmental Impact Cost

Negative impacts of planned Mekong hydropower projects on biodiversity have not been properly assessed or mitigated in the past. The cost of forest land and forest loss is much higher than estimates for compensation plans in Environmental Impact Assessments. Habitat is lost due to the inundation of land for reservoirs and because land is needed for project construction and resettlement.

The environmental impacts of hydropower projects cover a wide range of issues [49]. Direct environmental impacts are most often covered by mitigation measures, proposed by the Project Proponent, in the EIA. Such mitigation measures are direct investments and expenditures on environmental protection or compensatory projects, such as new water supply or water treatment plants, wastewater and sewage collection and treatment plants, solid and hazardous collection, etc. The costs of the environmental management and monitoring office team are part of project investment and operation costs.

Based on economic reports and published documents covering a wide range of hydropower projects in the Lower Mekong Basin (mainly Lao PDR, Thailand and Vietnam), environmental costs range from 1.5 to 5% total capital investment [50]. Environmental costs are now based on mitigation requirements established by Lao PDR, stated in the Concession Agreement, costed by the Project

Proponent in the Environmental Management Plan and updated by Annual Implementation Plans based on scope (not on budget). New EIA regulations, climate change, greenhouse gas generation considerations, green issues, triple bottom line of economics and social responsibility are changing the costing of environmental issues which account for 3 to 5% total capital investment which is considered to be conservative. Environmental costs are paid for by the project proponent during the construction period and are assumed to be included in the capital investment data in Appendix 1. The operation costs of environmental protection facilities are a small proportion of normal annual operation costs and are not costed separately.

4.8. Sediment/Nutrients Loading

The recent Mekong Delta Study (MDS), prepared for the Vietnam government, [51] reported that the planned mainstream dams would significantly reduce the suspended sediment load and associated nutrients from the Upper Mekong Basin (known as the Lancang River in China). MDS expects severe adverse impacts on fishing and farming in Cambodia and Vietnam as a result of a combination of mainstream dam barrier effects (sediment trapped behind the dams) and the reduction in associated nutrient loading (phosphates and nitrates). The Chinese mainstream dams have already reduced the sediment load and its nutrient value by some 50% down from 160 million tons/year to about 80 million tons/year by the Upper Mekong Basin cascade of dam projects in China (as measured at the gauging station at Chiang Saen, Thailand) [52]. Construction of the planned mainstream dams in the Lower Mekong Basin and the Mekong tributary dams would cause a further 50% reduction of sediment load. The reduced sediments and nutrient flows would adversely decrease agriculture production in the Mekong floodplains as the Delta coastal areas become vulnerable to sea level rise and saline intrusion. The fish catch of Vietnam coastal fisheries (reported to be 0.5-0.7 million tons/year) which strongly depends on the suspended sediments and associated nutrients deposited by the Mekong plume in the shallow coastal shelf will also be affected [53]. This study used the following conservative impacts forecast in the MDS:

Table 2. Estimated Sedimentation loss due to planned hydropower projects

	Loss in tons/year	Loss in $ million/year
Vietnam inland fisheries	(included in capture fisheries loss)	
Vietnam rice production	550,000	220 (rice value $ 400/ton)
Cambodia rice production	200,000	80 (rice value $ 400/ton)
Vietnam coastal fisheries	50,000	150

The total economic impact (excluding Vietnam inland fisheries) is $ 450 million/year.

5. ECONOMIC CALCULATIONS

The hydropower benefit NPV and EIRR were calculated for each mainstream dam and the 30 tributary projects were combined using the data in Appendix 1. The average EIRR is about 11% for the eleven mainstream projects and the same for the tributary projects. This EIRR may seem reasonable for major infrastructure projects but it may be much lower in practice due to increased social and environmental costs which are passed on to the project developers in Lao PDR. The total NPV(10) for all mainstream and tributary projects in the 11 dams scenario is $ 6.6 billion comprised of $ 2.5 billion from hydropower operations and $ 4.1 billion from electricity import benefit. These numbers are much lower than BDP2 (total NPV $ 32.8 billion for 11 dams scenario) mainly due to the following factors:

Capital Investment – some BDP2 estimates were far too low (e.g. $ 1.9 billion for Xayaburi whereas current estimate is $ 3.8 billion) and other BDP2 estimates were not realistic ($ 4.9 billion for Stung Treng and $ 7.4 billion for Sambor) which would not make them viable.
Electricity Price – BDP2 assumed a high electricity export price based on forecast 85% replacement value in the importing country estimated with high natural gas and coal values.
Electricity Trading Model – The BDP2 evaluation was based on an economic model which allocated huge profits to an intermediary 'electricity trading organisation' in Lao PDR.

The hydropower NPV calculations were combined with updated NPV calculations for the other items (see Appendix 4.1 to 4.3) and summarised below for the 11 dams scenario:

Table 3. Summary of NPV calculations for 11 dams scenario

	BDP2 NPV ($ million)	Costanza Report NPV ($ million)	NREM Update NPV ($ million)
Hydropower	32,800	32,800	6,600
Reservoir fisheries	200	26,100	800
Aquaculture	1,300	4,000	900
Capture fisheries	-1,900	-133,600	-13,000
Wetlands	100	3,500	200
Social/Cultural	0	0	-1,600
Sediment/Nutrients	0	0	-2,300
Others	900	900	1,100
Total	33,400	-66,300	-7,300

Note. Numbers in BDP2 and NREM Update show NPV(10) whereas numbers in the Costanza report show NPV(3) for natural resources.

The above table shows that the NPV of forecast capture fisheries loss is much larger than the hydropower generation benefit using the same discount rate (10%) for all benefits and costs including natural resources. The NREM Update includes estimated costs for social, environmental and reduced sediment impacts - these were not taken into account in BDP2.
This results in a negative net economic impact for the planned mainstream and tributary projects. With 3% discount rate for natural resources (as proposed in the Costanza report), the negative NPV for the planned projects is huge – the total NPV in the **NREM Update** changes from minus $ 7,300 million to minus $ 47,200 million.

The forecast profitability of Xayaburi is modest (EIRR is 9.7% and NPV is minus $ 68 million) even assuming no impact on capture fisheries and the environment. If Xayaburi would cause a very small percentage loss (say 1%) of the Mekong fish catch, this would result in a large, negative economic impact (NPV minus $ 800 million). The economic justification for Don Sahong is even more questionable (EIRR is 11.7% and NPV is $ 96 million) - its capacity is small (240 MW) which would only provide about 0.2% of forecast LMB power demand. The electricity generation from Don Sahong to Lao PDR could easily be supplied by tributary dams (planned capacity 10,000 MW) so it is not essential for the electricity supply security of Lao PDR. Most importantly, the potential capture fisheries loss far exceeds the small hydropower benefit and this also holds for Pak Beng (EIRR is 9.7% and NPV is minus $ 51 million).

It is noted that the assumptions used for the above NPV numbers are very conservative – especially for social impacts, environmental impacts and the reduced sediment/nutrients loading. The Mekong Delta Study forecasts that decreased sediment/nutrients loading could reduce long-term Vietnam rice production by 2.4 million tons/year which is equivalent to a negative NPV(10) of about $ 8,000 million.

As shown above, the net economic impact of the planned hydropower projects is estimated to be NPV(10) of minus $ 7,300 million. The distribution of costs and benefits between individual LMB countries is difficult to estimate as other countries (China, France, Korea, Malaysia and Norway) are involved in project funding and operations. In order to simplify the distribution of costs and benefits between LMB countries, a benefit split of 30% for host country (i.e. country where the dam will be built which receives equity share of profit plus royalty plus tax) and 70% for the country funding the project and/or importing the electricity was assumed. These assumptions resulted in the LMB country split shown below for the 11 dams scenario and in Appendix 4.3 for the 6 dams scenario.

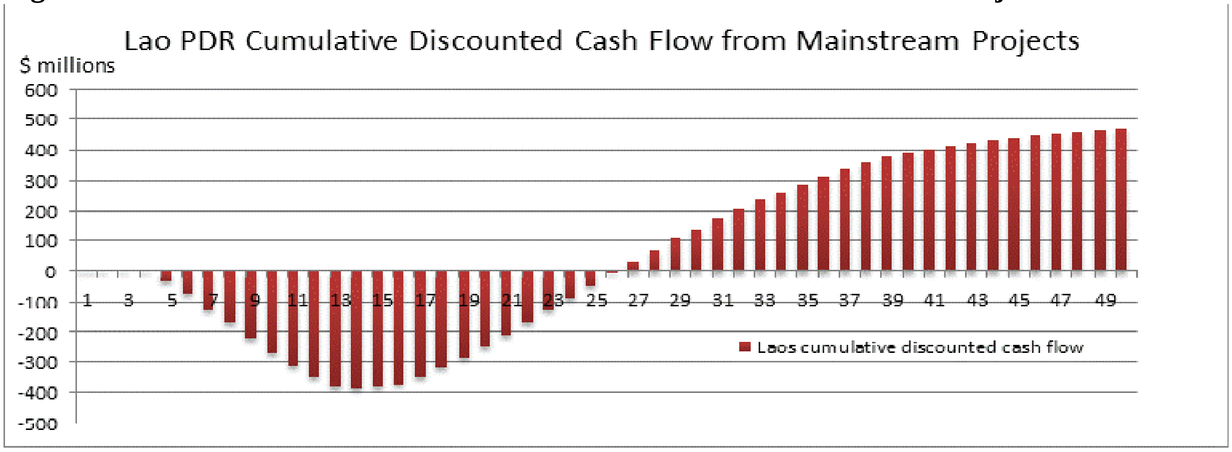
Table 4. Country cost/benefit split for 11 dams scenario

	BDP2 **NPV ($ million)**	**Costanza Report** **NPV ($ million)**	**NREM Update** **NPV ($ million)**
Lao PDR	22,600	20,400	700
Thailand	4,500	-39,100	1,300
Cambodia	2,600	-33,700	-6,500
Vietnam	3,700	-13,900	-2,800
Total	33,400	-66,300	-7,300

Note. Numbers in BDP2 and NREM Update show NPV(10) whereas numbers in the Costanza report show NPV(3) for natural resources.

As shown in the above table, Thailand is the main beneficiary and the net economic impact for Lao PDR is also positive but much lower than BDP2 estimates. It is noted that the economic impact for Lao PDR from the mainstream projects is negative for most of the 25 years concession periods and that most of the benefit to Lao PDR occurs after it gains project ownership (see Figure 2 below). A similar forecast is also expected for the large tributary projects with foreign funding. As shown above, Cambodia and Vietnam would have large negative economic impacts. Project developers/operators, project funders and electricity importers would benefit but poor, farming and fishing communities in Lao PDR, Cambodia and Vietnam would suffer. In contrast, BDP2 concluded that all LMB countries would benefit from hydropower development and that Lao PDR would be the main beneficiary.

Figure 2. Lao PDR Cumulative Discounted Cash Flow from Mainstream Projects



5.1. Sensitivity calculations

The summary of sensitivity calculations for the total economic impact (compared to Table 3 above for the 11 dams scenario) is shown below:

Table 5. Sensitivity calculations

	11 Dams Scenario
	NPV ($ million)
NREM Update (10% discount rate)	-7,300
5% Discount Rate for Natural Resources	-27,800
3% Discount Rate for Natural Resources	-47,200
Electricity price increased by 10%	-2,800
Electricity price decreased by 10%	-11,500
40% Migratory Fish; 90% loss due to dams	-9,100
40% Migratory Fish; 100% loss due to dams	-10,600
Fish value increased to $ 3/kg for farmed and $ 4/kg for wild	-8,800
Fish value decreased to $ 2/kg for farmed and $ 3/kg for wild	-5,800
Increase in Social Impact cost to 8% capital investment	-8,300

As shown above, all the sensitivity calculations resulted in negative NPVs. Clearly, NPV numbers are very sensitive to the selected discount rate for natural resources – as shown above using 5% discount rate (considered to be high for natural resources) there is a huge negative economic impact for the 11 dams scenario. This **NREM Update** used very conservative data for Social and Environmental Impact costs and expected increases would further reduce project viability.

6. RISK ASSESSMENT

The previous NREM study summarised concerns and risks of the mainstream hydropower projects described in SEA and the Costanza report. It also noted the considerable economic uncertainty due to poorly defined social and environmental impacts and mitigation measures which have either been excluded or under-estimated in many Mekong mainstream hydropower project proposals. Both SEA and the Costanza report recommended a ten year moratorium on dam construction in order to carry out transboundary Environmental Impact Assessments to better define project risks and assess mitigation measures and costs.

In addition to the social and environmental risks, there are also considerable financial risks for the project developers and operators. The assumption that all projects operate at 100% capacity after the start-up year may be optimistic and actual electricity generation could be much lower for several reasons:

(1) Forecast electricity demand for Thailand and Vietnam may be over-estimated especially the margin between capacity and peak demand. Also, improved energy-saving measures could reduce forecast demand by as much as 30% [54].

(2) Hydropower development in Myanmar (e.g. Salween River) has a huge potential which would introduce competition for electricity supply and project funding.

(3) Thailand's energy strategy could change from hydropower to increased used of new renewable technologies such as solar and biomass [55].

However, the most important risk is to food security in Lao PDR, Cambodia and Vietnam where many rural communities depend on fish from the Mekong River. The Mekong Delta currently provides 50% of Vietnam's rice production, and 60% of its seafood, both with export values of several billion US$ per year. Loss of food security and loss of protein for 30 million people would result in mass relocation of villagers and a huge social/cultural disaster.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 The net economic impact of planned Mekong hydropower projects is negative (NPV minus $ 7,300 million for the 11 dams scenario and NPV minus $ 1,900 million for the 6 dams scenario) using conservative assumptions and the same discount rate (10%) for all costs and benefits. With 3% discount rate for natural resources (as used in the Costanza report and previous NREM study) the negative NPV is huge; the NPV for the 11 dams scenario changes from minus $ 7,300 million to minus $ 47,200 million.

7.2 The negative economic impact is mainly due to the NPV(10) of the forecast loss of capture fisheries being much larger than the hydropower benefit but also due to the inclusion of social impact costs and decreased sediment/nutrients loading.

7.3 Assuming a split of 30% hydropower benefits for the host country and 70% for the country funding the project and/or importing the electricity, Thailand is the main beneficiary and the net economic impact on Lao PDR is positive but much lower than BDP2 estimates (net economic impact on Lao PDR is negative for most of 25 years concession period). Cambodia and Vietnam would experience large negative impacts. Project developers/operators, project funders and electricity importers would benefit but poor, farming and fishing communities in Lao PDR, Cambodia and Vietnam would suffer.

7.4 The forecast profitability of Xayaburi is modest even assuming no impact on capture fisheries and the environment; a small percentage loss of capture fisheries caused by Xayaburi would result in a large, negative economic impact. The justification for Don Sahong is even more questionable as it is not essential for Lao PDR electricity supply security and the potential capture fisheries loss far exceeds the small hydropower benefit. The forecast profitability of Pak Beng (project consultation process just started) is also modest.

7.5. If all 11 mainstream projects and 30 tributary projects are built by 2030, they would produce about 110,000 GWh which far exceeds the forecast power requirements of Lao PDR and Cambodia (both about 16,000 GWh). The 11 mainstream projects would provide about 8% of forecast LMB power demand. If the mainstream projects are not pursued, there would be minimal risk for electricity security in the LMB countries and the forecast electricity demand could be supplied by alternative energy sources (e.g. solar and biomass) and improved efficiency of energy use.

7.6 This **NREM Update** study clearly shows that the forecast hydropower benefit for Lao PDR will be much lower than BDP2 projections. Furthermore, the actual benefit to Lao PDR is likely to be even lower than forecast in this study as project profitability may be lower than expected (increased environmental and social impact costs paid by project developer, lower operational stream factor, lower electricity price due to increased competition) and several planned mainstream projects may not go ahead.

The following recommendations are proposed for further consideration:

(1) To delay construction of other mainstream dams until Xayaburi is completed and the effectiveness of mitigation measures (fish pass, sediment sluice gates) has been confirmed.
(2) To require hydropower development projects to include full cost accounting of social and environmental conservation mitigation measures in the committed capital investment.
(3) To re-assess the net economic impact and forecast benefit to Lao PDR based on a ‘likely scenario’ for mainstream hydropower projects which have a high probability of going ahead.
(4) (iv)To develop a new LMB energy strategy taking into account less hydropower income than previously anticipated, updated forecast for LMB power demand and technology developments for improved energy efficiency & renewable energy.

8. REFERENCES AND NOTES

1. Dudgeon, D., A. H. Arthington, M. O. Gessner, Z. Kawabata, D. J. Knowler, C. Lévêque, R. J. Naiman, P. Richard, AnneHélène, D. Soto and M. L. Stiassny, Freshwater biodiversity: importance, threats, status and conservation challenges. Biological reviews, 2006. 81(2): p. 163-182.
2. Welcomme, R. L., I. G. Baird, D. Dudgeon, A. Halls, D. Lamberts and M. G. Mustafa, Fisheries of the rivers of Southeast Asia. Freshwater Fisheries Ecology, 2016: p. 363-376.
3. Winemiller, K., P. McIntyre, L. Castello, E. Fluet-Chouinard, T. Giarrizzo, S. Nam, I. Baird, W. Darwall, N. Lujan and I. Harrison, Balancing hydropower and biodiversity in the Amazon, Congo, and Mekong. Science, 2016. 351(6269): p. 128-129.
4. ICEM, Strategic Environmental Assessment (SEA) of Hydropower on the Mekong Mainstream. 2010: Hanoi, Vietnam.
5. Bran, E., Fisheries Baseline Assessment for Mekong River Commission Strategic Environment Impact Assessment. 2010: Phnom Penh Hotel, Phnom Penh, Cambodia.
6. Baran, E., N. Van Zalinge, and N.P. Bun. Floods, floodplains and fish production in the Mekong Basin: present and past trends. in Contribution to the Asian Wetlands Symposium. 2001.
7. Van Zalinge, N., N. Thuok, and S. Nuov, Status of the Cambodian inland capture fisheries sector with special reference to the Tonle Sap Great Lake. Cambodia fisheries technical paper series, 2001. 3: p. 10-17.
8. Baumann, P. and G. Stevanella, Fish passage principles to be considered for medium and large dams: the case study of a fish passage concept for a hydroelectric power project on the Mekong mainstem in Laos. Ecological Engineering, 2012. 48: p. 79-85.
9. Orr, S., J. Pittock, A. Chapagain and D. Dumaresq, Dams on the Mekong River: Lost fish protein and the implications for land and water resources. Global Environmental Change, 2012. 22(4): p. 925-932.
10. Kang, B., D. He, L. Perrett, H. Wang, W. Hu, W. Deng and Y. Wu, Fish and fisheries in the Upper Mekong: current assessment of the fish community, threats and conservation. Reviews in Fish Biology and Fisheries, 2009. 19(4): p. 465.
11. Dugan, P., Mainstream dams as barriers to fish migration: international learning and implications for the Mekong. 2008.
12. Kummu, M. and J. Sarkkula, Impact of the Mekong River flow alteration on the Tonle Sap flood pulse. AMBIO: A Journal of the Human Environment, 2008. 37(3): p. 185-192.
13. Kummu, M. and O. Varis, Sediment-related impacts due to upstream reservoir trapping, the Lower Mekong River. Geomorphology, 2007. 85(3): p. 275-293.
14. Arias, M., T. Piman, H. Lauri, T. Cochrane and M. Kummu, Dams on Mekong tributaries as significant contributors of hydrological alterations to the Tonle Sap Floodplain in Cambodia. Hydrology and Earth System Sciences, 2014. 18(12): p. 5303.
15. Kondolf, G., Z. Rubin, and J. Minear, Dams on the Mekong: cumulative sediment starvation. Water Resources Research, 2014. 50(6): p. 5158-5169.
16. Mekong River Commission, Assessment of Basin-wide Development Scenarios – Basin Development Plan Programme, Phase 2. 2011: Vientiane, Lao PDR
17. Costanza, R., I. Kubiszewski., P. Paquet., J. King., S. Halimi., H. Sanguanngoi., N. L. Bach., R. Frankel., J. Ganjaseni., A. Intralawan. and D. Morell., Alternative Planning Approaches for Hydropower Develoment in the Lower Mekong Basin. 2011, USAID: Bangkok, Thailand.
18. Intralawan, A., D. Wood, and R. Frankel, Working paper on Economic, Environmental and Social Impacts of Hydropower Development in the Lower Mekong Basin. 2015, Natural Resources and Environmental Management Research and Training Center, Mae Fah Luang University: Chiang Rai, Thailand.
19. Mekong River Commission, MRC Initiative on Sustainable Hydropower. Guidelines for the Evaluation of Hydropower and Multi-Purpose Project Portfolios: Annex1. . 2015, Mekong River Commission.
20. International Finance Corporation, Hydroelectric Power: A Guide for Developers and Investors. 2015, WORLD BANK GROUP: Germany.
21. International Renewable Energy Agency, Renewable Energy Technologies: Cost Analysis Series. Volume 1: Hydropower 2012.
22. THE WORLD BANK. Inflation, consumer prices (annual %). 2015; Available from: http://data.worldbank.org/indicator/FP.CPI.TOTL.ZG.
23. Allen, K.R., New Venture Creation. 2012: South-Western College Pub.
24. Intelligent Energy Systems, Alternatives for power generation in the Greater Mekong Subregion: Volume 1 Power Sector Vision for the Greater Mekong Subregion. 2016.
25. Piseth, C. and C. Sophearin, Assessment of Power Trade Benefits from Hydropower Projects in Lower Mekong River Basin, in Energy Market Integration in East Asia: Energy Trade, Cross Border Electricity, and Price Mechanism, P.a.F.K. Han, Editor. 2014, ERIA Research Project Report FY2013: Jakarta. p. 193-239.
26. Anonymous Personal Communication with Mekong Hydropower Consultants 2016.
27. P Ruangrong. Power Tariff Structure in Thailand. in Economic Research Institute for ASEAN and East Asia. 2012. Singapore.
28. Ziv, G., E. Baran, S. Nam, I. Rodriguez-Iturbe and S. A. Levin, Trading-off fish biodiversity, food security, and hydropower in the Mekong River Basin. PNAS, 2012. 109(15): p. 5609-5614.
29. Barlow, C., E. Baran, A. S. Halls and M. Kshatriya, How much of the Mekong fish catch is at risk from mainstream dam. Catch and Culture, 2008. 14(3).
30. Baran, E. and B. Ratner, The Don Sahong Dam and Mekong Fisheries. Science Brief, 2007: p. 3.

31. Baran, E., P. Starr, and Y. Kura, Influence of built structures on Tonle Sap fisheries. Cambodia National Mekong Committee and the WorldFish Center, Phnom Penh, Cambodia, 2007.
32. Hortle, K.G.a.B., P., Fisheries Habitat and Yield in the Lower Mekong Basin MRC Technical Paper No. 47. 2015, Mekong River Commission, Phanon Penh, Cambodia.
33. Dugan, P. J., C. Barlow, A. A. Agostinho, E. Baran, G. F. Cada, D. Chen, I. G. Cowx, J. W. Ferguson, T. Jutagate and M. Mallen-Cooper, Fish migration, dams, and loss of ecosystem services in the Mekong basin. AMBIO: A Journal of the Human Environment, 2010. 39(4): p. 344-348.
34. Geheb, K. and I. Pukinskis, The Impacts of Dams on the Fisheries of the Mekong (English Language). 2012.
35. Halls, A. and M. Kshatriya, Modelling the cumulative impacts of mainstream dams on migratory fish populations in the lower Mekong basin. MRC Technical Paper, 2010(25).
36. Nam, S., S. Phommakone, L. Vuthy, T. Samphawamana, N. H. Son, M. Khumsri, N. P. Bun, K. Sovanara, P. Degen and P. Starr, Catch and Culture. 2015, Mekong River Commission, Fisheries Research and Development in the Mekong Region.
37. Personal communication and interview on fish price a in Vietnam and Thailand, 2016.
38. Hortle, K. and U. Suntornratana, Socio-economics of the fisheries of the lower Songkhram River Basin, northeast Thailand. 2008: MRC, Vientiane(Lao PDR).
39. Hall, D. and L. Bouapao, Social impact monitoring and vulnerability assessment in the Mekong corridor: Report on a regional pilot study. MRC Technical Paper No, 2010. 30.
40. Molle, F., T. Foran, and M. Kakonen, Contested waterscapes in the Mekong region: Hydropower, livelihoods and governance. Vol. 2. 2009: Earthscan.
41. Berg, H., A. E. Söderholm, A.-S. Söderström and N. T. Tam, Recognizing wetland ecosystem services for sustainable rice farming in the Mekong Delta, Vietnam. Sustainability Science, 2017. 12(1): p. 137-154.
42. De Groot, R., M. Stuip, M. Finlayson and N. Davidson, Valuing wetlands: guidance for valuing the benefits derived from wetland ecosystem services. 2006, International Water Management Institute.
43. Brander, L. M., A. J. Wagtendonk, S. S. Hussain, A. McVittie, P. H. Verburg, R. S. de Groot and S. van der Ploeg, Ecosystem service values for mangroves in Southeast Asia: A meta-analysis and value transfer application. Ecosystem Services, 2012. 1(1): p. 62-69.
44. Emerton, L., The Economic Value of Ecosystem Services in the Mekong Basin: What we know and what we need to know. 2013, World Wide Fund For Nature (WWF-Greater Mekong).
45. Mekong Region Futures Institute, Ecosystem Value Estimator: A Web-based Tool to Calculate Ecosystem Values in the GMS. 2015.
46. Mekong River Commission, Assessment of basin-wide development scenarios: Technical note 5 Social assessment. 2010: Vientiane, Lao PDR.
47. Laplante, B., Economic analysis of the environmental and social impacts of the Nam Theun 2 hydroelectricity power project: final draft report. Washington, DC: World Bank, 2005.
48. Maunsell Limited and Lahmeyer GmbH, Power system development plan for Lao PDR: Final Report, Volume A: Main Report. 2004.
49. MRC initiative on Sustainable Hydropower: Guidelines for the Evaluation of Hydropower and Multi-Purpose Project Portfolios; Annex 1 Economics Practice Guide Table 1, p.-.
50. See literature [19].
51. Ministry of Natural Resources and Environment; Government of Vietnam, Study on the Impacts of Mainstream Hydropower on the Mekong: Final Report. 2015.
52. See literature [15].
53. See literature [4].
54. Personal interview with official from Electricity Generating Authority of Thailand; August 2015.
55. WWF, Mekong River in the Economy. 2016.
56. Mekong River Commission, Assessment of basin-wide development scenarios: Technical Note 11 Impacts on Fisheries. 2010: Vientiane, Lao PDR
57. Van Zalinge N., P. Degen, C. Pongsri, S. Nuov, J.G. Jensen, V.H. Nguyen, X. Choulamany, The Mekong River system. in Proceedings of the Second International Symposium on the Management of Large Rivers for Fisheries, Vol. 1. 2004. FAO Regional Office for Asia and the Pacific, Bangkok, Thailand. .
58. Hortle, K.G., Consumption and the yield of fish and other aquatic animals from the Lower Mekong Basin. MRC Technical Paper No. 16. 2007, Mekong River Commission: Vientiane, Lao PDR. p. 87.
59. An, V.V., Death by a 1000 Cuts or Just Another Day at the Office, in American Fisheries Society. 2015: Portland, Oregon.
60. Nam, S., Importance of Inland Capture Fisheries in the Lower Mekong Basin, in American Fisheries Society. 2015: Portland, Oregon.
61. Cowx, I.G.K., W.; Sukumasavin, N.; Sirimongkolthawon, R.; Suksri, S. and Phila, N., Larval and Juvenile Fish Communities of the Lower Mekong Basin MRC Technical Paper No. 49. 2015: Phnom Penh, Cambodia.
62. Halls, A., Estimation of annual yield of fish by guild in the lower mekong basin. 2010, WorldFish center, Phnom Penh, Cambodia.
63. ICEM, Fisheries Baseline Assessment Working Paper. 2010.

Appendix 1. Lower Mekong Hydropower Projects

	Location	Capacity (MW)	Capital Investment ($ million)	Project Developer	Main Electricity Market
Pak Beng	Lao PDR	855	2,400	China	Thailand
Luang Prabang	Lao PDR	1,410	2,800	Vietnam	Vietnam
Xayaburi	Lao PDR	1,285	3,700	Thailand	Thailand
Pak Lay	Lao PDR	1,320	2,400	China	Thailand
Sanakham	Lao PDR	660	1,530	China	Thailand
Pak Chom	Lao PDR	1,080	2,700	Thailand	Thailand
Ban Khoum	Lao PDR	1,870	4,400	Thailand	Thailand
Lat Sua	Lao PDR	650	2,100	Thailand	Thailand
Don Sahong	Lao PDR	240	720	Malaysia	Lao PDR
Stung Treng	Cambodia	980	2,000	Vietnam	Vietnam
Sambor	Cambodia	2,600	4,900	China	Vietnam
Total Mainstream		12,950	29,650		
24 Trib. Dams	Lao PDR	9,700	19,900	See Note 5	Thailand
4 Trib. Dams	Cambodia	200	400		Vietnam
2 Trib. Dams	Vietnam	200	300		Vietnam
Total Trib.Dams		10,100	20,600		
Grand Total		23,050	50,250		

Note 1. The 6 dams scenario includes Pak Beng, Luang Prabang, Xayaburi, Pak Lay, Sanakham, Pak Chom and 30 tributary dams

Note 2. The 11 dams scenario includes the dams in Note 1 and Ban Khoum, Lat Sua, Don Sahong, Stung Treng and Sambor

Note 3. The total capital investment is estimated to be US $ 50 billion for all hydropower projects in the 11 dams scenario and US $ 34 billion for the 6 dams scenario in 2016 prices.

Note 4. Construction of Xayaburi started in 2012 and commercial operation is expected in 2019. Construction of Don Sahong started in 2016 and construction of Pak Beng is expected to start in 2017. It is assumed that the other mainstream projects will start by 2030 in line with BDP2 scenario.

Note 5. Several countries (China, France, Korea, Malaysia and Norway) have a share of project equity in both mainstream and tributary dams as well as LMB countries.

Appendix 2. Evaluation Basis for Hydropower Projects

ACTIVITY	TIMING	COSTS	BENEFITS
Construction	Year 1-6	Loss of forest and land. Reduced fish migration. Villagers resettlement and social mitigation cost. Environmental mitigation. Project infrastructure & hydropower investment.	Improved infrastructure and social facilities near project site*. Income for local labour*. Construction profit.
Hydropower Operations (During concession period)	Year 7-31	Reduced capture fisheries. Reduced sediment & nutrient flow. Impact on wetlands. Social mitigation cost (Year 7-9).	Host country income from equity share, tax & royalty Operator profit. Bank profit. Increased fish catch from reservoir and aquaculture.
Hydropower Operations (After concession period)	Year 32-57	Reduced capture fisheries. Reduced sediment & nutrient flow. Impact on wetlands.	Increased host country income from project ownership transfer. Increased fish catch from reservoir and aquaculture.
Electricity distribution	Year 1-6	Investment for transmission Loss of land for transmission*	
	Year 7-57		Profit for importer (use low cost hydropower instead of coal & gas). Improved electricity supply for host country.

*Not included in NPV calculations as data unavailable or considered secondary

Appendix 3. Mekong River Fisheries

Table 1. Estimated Mekong River capture fisheries

CAPTURE FISHERIES DATA	References
Capture fishery plus OAAs 2.304 million tons /year - Lao 166,000 Thailand 861,000 Cambodia 558,000 Vietnam 719,000 tons/year	[56]
Total fish catch 2.64 million tons/year - Lao 182,700 Thailand 932,300 Cambodia 682,150 Vietnam 844,850 tons/year	[57]
Total fish consumption estimate 2.63 million tons/year	[58]
Total fish catch 2.3 million tons/year	[16]
Total fish catch 2.5 million tons/year	[59]
Total fish catch 2.304 million tons/year. - Lao 166,000 Thailand 861,000 Cambodia 588,000 Vietnam 719,000	[60]
Total fish catch 2.6 million tons/year	[61]
Total estimate yield by guild for fish plus OAAs 2.55 million tons/year - Lao 208,450 Thailand 911,257 Cambodia 586,661 Vietnam 851,781 tons/year	[62]
The estimated range of LMB yield is 1.3-2.7 million tons/year. The figure of 2.3 million tons per year is the best available estimate of capture fish plus OAAs.	[32]

Table 2. Estimated loss of capture fisheries due to mainstream dams

ESTIMATED LOSS OF CAPTURE FISHERIES	References
The net loss to capture fisheries basin-wide estimated to be 295,000 – 964,000 tons/year	[16]
Loss estimated to be 270,000-600,000 for 6 dams 550,000 -880,000 for 11 dams	[63]
Loss of 280,000 tons/year for 6 dams 1,300,000 for 11 tons/year dams	[17]
<u>For the mid case Scenario</u> 285,000 tons/year for 6 dams 579,000 tons/year for 11 dams	[16]
Migratory fish resources comprise 71% (or 1.32 million tons/year) of the fisheries yield at US$1.89 /kg Loss estimate 1,270,000 – 1,570,000 tons /year 20,000 tons /year for upper Mekong 500,000 – 600,000 tons/year for middle Mekong 750,000 – 950,000 tons/year for Cambodia and Vietnam	[29]

Appendix 4. Economic Calculations

Appendix 4.1. Detailed summary of NPV calculations for 11 dams scenario.

	BDP2 **NPV ($ million)**	Costanza Report **NPV ($ million)**	NREM Update **NPV ($ million)**
Hydropower	32,823	32,823	6,650
Irrigated agriculture	1,659	1,659	1,832
Reservoir fisheries	215	26,058	822
Aquaculture	1,261	4,010	931
Capture fisheries	-1,936	-133,650	-13,030
Wetlands	101	3,536	238
Social/Cultural Impact	0	0	-1,665
Sediment/Nutrient	0	0	-2,311
Eco-hotspot/biodiversity	-415	-415	-458
Forest area reduction	-372	-372	-411
Recession rice	278	278	307
Flood mitigation	-273	-273	-301
Salinity mitigation	-2	-2	-2
Bank erosion losses	0	0	0
Navigation	64	64	71
Total	33,403	-66,284	-7,329

Note. Numbers in BDP2 and NREM Update show NPV(10) whereas numbers in the Costanza report show NPV(3) for natural resources.

Appendix 4.2. Detailed summary of NPV calculations for 6 dams scenario.

	BDP2 **NPV ($ million)**	Costanza Report **NPV ($ million)**	NREM Update **NPV ($ million)**
Hydropower	25,002	25,002	5,193
Irrigated agriculture	1,659	1,659	1,832
Reservoir fisheries	132	3,961	513
Aquaculture	1,261	854	513
Capture fisheries	-952	-28,476	-7,189
Wetlands	-178	-4,520	-312
Social/Cultural Impact	0	0	-1.197
Sediment/Nutrient	0	0	-1,027
Eco-hotspot/biodiversity	-240	-240	-265
Forest area reduction	-228	-228	-252
Recession rice	-175	-175	-193
Flood mitigation	360	360	397
Salinity mitigation	23	23	25
Bank erosion losses	0	0	0
Navigation	64	64	71
Total	26,728	-1,716	-1,890

Note. Numbers in BDP2 and NREM Update show NPV(10) whereas numbers in the Costanza report show NPV(3) for natural resources.

Appendix 4.3. Country cost/benefit split for 6 dams scenario

	BDP2 **NPV ($ million)**	Costanza Report **NPV ($ million)**	NREM Update **NPV ($ million)**
Lao PDR	17,600	16,600	900
Thailand	3,900	-1,400	1,700
Cambodia	1,400	-15,000	-3,500
Vietnam	3,800	-1,900	-1,000
Total	26,700	-1,700	-1,900

Note. Numbers in BDP2 and NREM Update show NPV(10) whereas numbers in the Costanza report show NPV(3) for natural resources.