MEKONG RIVER COMMISSION

THE COUNCIL STUDY

The Study on the Sustainable Management and Development of the Mekong River Basin, including Impacts of Mainstream Hydropower Projects

Macro-economic Assessment Report

(Final Report)

26 December 2017

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1 Executive summary

All lower Mekong countries have committed to *sustainable* development. Sustainability, however, is challenging as large investments come with a multitude of side effects or trade-offs that could lead to unsustainable outcomes. The integrated assessment of development strategies is a critical step towards evidence-based planning processes as it reveals likely impacts on a wide variety of economic, social, hydrological, and ecological indicators. Based on the improved understanding of trade-offs, unsustainable development strategies can be reconsidered and sustainable options designed to further improve development outcomes.

This report summarises the macroeconomic assessment of scenarios as defined by the MRC Council Study. These scenarios place at the forefront three main scenarios that combine investments in hydropower, irrigation, agriculture, and navigation:

- Main scenario M1: Early development situation of 2007, defines the baseline.
- Main scenario M2: Definite future as planned for 2020, including projects under construction.
- Main scenario M3: Planned development scenario that includes investments planned for 2040.
- Main scenario M3CC: M3 plus projected climate change, assuming more seasonal climate.

These *main* scenarios combine bundles of investments to assess the combined effect of all interventions, which has the advantage of considering synergistic effects. Synergies are critical where the combined effect differs from the sum of effects that individual interventions would have. Many scientific studies have emphasised the relevance of synergies. However, the downside is that the assessment of larger bundles of investments prevents clear attribution of outcomes to individual investments. Therefore, the Council Study considers in addition to these main scenarios thirteen sub-scenarios to assess the sector-specific variation of main scenario 3 (as planned for 2040). The design is focused on the comparison of the third main scenario that includes projected climate change (M3CC) with all sub-scenarios to reveal sector-specific impacts. However, within each sector considered in this study, up to a hundred projects or more (e.g. hydropower dams) are being considered as a bundle. This assessment does not allow for a project-specific attribution of impacts, only for a sector-specific assessment. Such an additional disaggregation would require a project-by-project assessment approach and would allow the effective design of sustainable development strategies.

This report presents the macroeconomic assessment and should be consulted in combination with other disciplinary and thematic reports. Many changes might appear positive from an economic perspective, but could lead to unacceptable outcomes for other indicators, for instance food security or biodiversity. The acceptability needs to be defined by policy makers in the Lower Mekong Basin. This study aims to support the discourse by providing evidence and recommendations.

The macroeconomic assessment is based on widely applied methodology. It utilises biophysical input information provided by other disciplinary and thematic teams and adds economic values relevant for each unit, thereby quantifying annual economic benefits and costs. Annual benefits between now and 2040 are being discounted employing hyperbolic discounting. Discounting assumes that profits and costs in the future have a lower value to people than the same profits or costs would have today. Hyperbolic means that people do not value profits or costs differently between two different years in the far future. In other words, this report adds all annual discounted values for the period until 2040, while discounting decreases over time. The combined (discounted) value of all benefits and costs in today's terms is referred to as the net present value (NPV).

This assessment is structured into three tiers. In a first tier, the NPV is calculated at the sector level, considering investments in hydropower, fisheries, agriculture and irrigation, and navigation. The comparison of results for these sectors identifies sector-specific gains and highlights the (changing) relevance of sectors. This tier is very narrow as it excludes wider macroeconomic effects. Hence, in a second tier, sector effects are embedded in a macroeconomic perspective to assess impacts on the Gross Domestic Product (GDP). Conventionally, this type of assessment requires appropriate economic modelling as changes in one sector are likely to affect other sectors. Sectors are linked because they require similar production factors as inputs (e.g. labour, capital, natural resources) and compete for the same household (or public) budget. Time and resource constraints precluded development of economic models capable of accounting for factor interdependence. Instead, for this second assessment tier, Input-Output data, household survey data, and population growth projections are combined with the sector-specific assessment results (assessment tier 1) to estimate ranges of possible GDP trajectories. The second tier revealed unexpected side effects resulting from sector-specific investments for the macroeconomic growth of lower Mekong countries. However, assessment tiers 1 and 2 only capture processes that are represented in existing and functioning economic markets and fail to consider impacts on factors that can be understood as the foundation of future economic activities. A third tier included in the assessment introduces the economic values of non-market processes to improve understanding of natural resource trade-offs and eventual incorporation into the economic calculus. The third tier takes a wider sustainability-focused perspective and includes effects on input factors to assess the long-term viability of development strategies. The assessment tier is focused on impacts on natural capital that are not represented on economic markets, an approach widely applied to qualify the sustainability of economic development as these changes affect future growth potential.

The first tier is focused on agriculture, hydropower, fishery and navigation. The macroeconomic results confirm that investments planned for the Lower Mekong Basin are likely to have profound impacts on the development of the basin and basin sustainability. Scenario M2 (2020 development plans) is likely to increase the combined NPV of the four foci sectors by 33%, and M3 (2040 development plans) by 67%. Agriculture is dominating the effects of M2 due to substantial expansion plans in Cambodia. The viability of these plans from a macroeconomic and sustainability perspective is discussed under tier 2 and 3. Hydropower has the largest impact in M3, and reveals that the main beneficiary of mainstream hydropower investment in Lao PDR is likely to be Thailand and the main beneficiary of mainstream hydropower investments in Cambodia is likely to be Vietnam. This is due to Thai investments in Lao PDR hydropower and the subsequent import of electricity at costs that are substantially below Thailand's domestic retail tariff, generating substantial profit margins in Thailand and increases in Thailand's GDP. The same benefit transfer unfolds in Vietnam, based on hydropower investments in Cambodia, and subsequent benefit transfers. A third substantial beneficiary of Mekong mainstream hydropower is investors from outside the Lower Mekong Basin (e.g. China, South Korea, Malaysia). Their profits from hydropower in the lower Mekong contributes to GDP in their respective countries. Within the boundaries of tariff estimate uncertainties, it is likely that both host countries (Lao PDR and Cambodia) would be able to convert 15-30% of hydropower profits into NPV for their national economies.

The fisheries sectors are likely to decline substantially in all four lower Mekong countries. Scenario M2 would trigger a decline of the NPV of the fisheries sector by $16.5 billion, while M3 would trigger a decline of $22.6 billion if compared with M1. Sub-scenario H1a quantifies that the combined effect of all planned and existing hydropower in the Lower Mekong Basin causes a loss in fisheries of about $19.4 billion in NPV. This is about 12% of the NPV of all planned and existing hydropower. Sub-scenario H1b distinguishes between mainstream hydropower and tributary dams, enabling quantification of the fisheries-related losses due to mainstream dams at about $8.6 billion in NPV, which is 5.4% of the NPV

of the hydropower sector. The majority of economic gains in the fisheries sector for these hydropower-focused sub-scenarios would eventuate in Lao PDR and Thailand. Under M3, fisheries would lose its economic relevance in both countries, and solutions would need to be found for the loss in related livelihoods and food security.

Analyses of the full range of sub-scenarios indicate that the second most relevant driver for fisheries (after hydropower) is climate change. Drier climate change would decrease the NPV of fisheries by nearly 10%. The majority of losses would occur in Cambodia.

Navigation has a surprisingly large economic potential, particularly for Vietnam and Cambodia. The NPV of navigation expansion in Vietnam in scenario M3 is about $55.5 billion and nearly as high as the combined effect of hydropower and agriculture. Cambodia ranks second in navigation-related benefits, associated with an estimated increase in NPV of $8.5 billion. This considers only navigation-specific revenue and costs and does not include the value of cargo or revenue from passenger transport (see the navigation report for a detailed assessment). Typically, improved infrastructure for trade multiplies with increasing value-add of exported goods. However, expected gains demand complementary investments in secondary (and tertiary) sectors, which leads to the second tier of this assessment.

The second tier embeds the narrow sector assessment into a macroeconomic perspective. This reveals if sector investments have negative impacts on one or multiple other sectors. Two elements have already been raised above, the impacts of hydropower on fisheries and the trade-related potential. In addition to these two important effects, a critical aspect emerges from linking agricultural expansion, population growth, and macroeconomic growth. Substantial investments in agriculture increase the demand in labour. If this demand outpaces workforce growth and productivity gains, other sectors will face increasing constraints in meeting labour requirements. Typically, salaries in secondary and tertiary sectors increase and workers move over time away from agricultural production, which would potentially leave newly developed farmland unproductive. The north-east of Thailand is an example for such effects. Mechanisation and farm consolidation are not always possible, which leaves large areas unproductive. This means that either agricultural production will increase as planned, but the demand for labour will reduce the overall growth of the national economies. Or, workers will move into secondary (and tertiary) employment, which would leave new investments in agriculture under-utilised or stranded. Agricultural expansion plans in Cambodia and Lao PDR (and to a much lesser extent in Vietnam) are likely to face this macroeconomic dilemma. As a corollary, large portions of the predicted increase in NPV of agriculture in for instance Cambodia ($65.3 billion for M2 and $67.3 billion in M3) may not eventuate. The risk of this development strategy will be amplified if the climate becomes drier than expected, as economic gains would substantially decline. It seems highly beneficial to disaggregate the bundle of proposed agricultural expansion projects and undertake a risk assessment of individual projects and how they perform against workforce and climate change–related risks.

The NPV derived from hydropower is also likely to benefit from a more disaggregated assessment. This study identifies a few hydropower projects that have low or negative benefits. If this coincides with negative externalities (i.e. side effects) for other sectors, underperforming projects could be cancelled and investment re-focussed on the most cost-effective projects, where cost effectiveness includes the benefits and costs of inter-sector side effects or externalities. This would require a project-by-project assessment approach to provide planning with a disaggregated, evidence-based prioritisation process. External effects within and between the economies of the Lower Mekong Basin are likely to be substantial. But not all projects are likely to trigger the same level of externalities. Eliminating the worst

performing projects in hydropower and any other sector is likely to substantially improve the macroeconomic development gains in the Lower Mekong Basin.

This study projects ranges for possible GDP growth in the absence of appropriate socioeconomic modelling. Table 1 summarises GDP results for all 16 scenarios. For each country, only areas that are within the basin are considered, which required the disaggregation of data for Vietnam and Thailand. For each country and for the Lower Mekong Basin, GDP values are provided as an upper range and a lower range of a potential growth trajectory, depending on how much of the workforce will remain in the agricultural sector. The greater the increase of labour transitions to secondary and tertiary sectors, the more realistic the upper bound becomes. The upper bound assumes that everybody in the workforce would find employment in secondary and tertiary sectors if leaving the agricultural sector, which is clearly too optimistic. However, long-term investments in education and effective development of innovative industries that meet national sustainability objectives would prepare the economic system towards this benchmark. This assessment tier aims to illustrate how macroeconomic growth potential changes for the selected development strategies for the four Lower Mekong Basin countries.

Important considerations for interpreting Table 1 correctly are

- these projections are largely based on workforce changes, while other input factors such as the availability of energy or capital could not be factored into these calculations;
- consequently, the results for H1a are likely to exaggerate GDP because it assumes substantial expansion of secondary and tertiary sectors, which implies the availability of energy (if provided by generating sources other than hydropower this would become more realistic);
- the upper bound requires full employment of labour not employed in agriculture, which is likely to be an overestimation of realistic GDP, hence “upper bound”; and
- the lower bound “forces” labour to meet the full utilisation of agricultural land, which is likely to lead to an underestimation of GDP.

Table 1 GDP ranges for 2040 under the various development scenarios for the Lower Mekong Basin

GDP in billion US$ (deflated to 2017 dollar)		M1 (2007)	M2 (2020)	M3 (2040)	M3CC (2040)	A1 (2007)	A2 (2020)	C2 (Wet)	C3 (Dry)	I1 (no IRR)	I2 (IRR)	F1 (no FPI)	F2 (FPI)	F3 (FPI)	H1a (noHPP)	H1b (noMain)	H3 (HPP)
Cambodia	Upper bound	$50.3	$45.6	$46.5	$47.7	$50.5	$46.7	$46.3	$46.2	$46.6	$46.0	$46.8	$47.2	$46.8	$48.5	$47.6	$47.4
	Average	$48.3	$41.8	$39.5	$38.5	**$48.0**	$40.8	$40.6	$40.7	$40.8	$40.3	$39.4	$39.4	$39.6	$40.2	$39.6	$39.5
	Lower bound	$46.2	$38.0	$32.6	$29.3	$45.4	$34.8	$35.0	$35.3	$35.1	$34.6	$32.0	$31.7	$32.3	$31.8	$31.5	$31.5
Lao PDR	Upper bound	$42.0	$40.4	$40.0	$39.7	$39.1	$40.0	$39.7	$39.9	$40.0	$39.8	$39.9	$39.9	$39.9	**$43.4**	$41.6	$39.8
	Average	$39.2	$35.1	$30.3	$30.3	**$36.3**	$30.2	$30.7	$30.7	$30.3	$30.1	$30.5	$30.5	$30.5	$32.5	$30.9	$30.4
	Lower bound	$36.3	$29.8	$20.5	$21.0	$33.5	$20.5	$21.6	$21.6	$20.6	$20.4	$21.0	$21.0	$21.0	$21.6	$20.3	$21.0
Thailand	Upper bound	$98.0	$101.6	$98.4	$98.2	$97.9	$98.4	$98.1	$98.4	$98.4	$98.3	$98.2	$98.4	$98.3	**$103.9**	$102.6	$97.9
	Average	$79.8	$73.7	$68.9	$70.5	**$78.3**	$69.0	$71.2	$71.0	$69.0	$69.0	$70.4	$70.5	$70.5	$73.2	$72.1	$70.3
	Lower bound	$61.5	$45.9	$39.5	$42.7	$58.6	$39.6	$44.3	$43.6	$39.5	$39.7	$42.7	$42.7	$42.7	$42.5	$41.5	$42.8
Vietnam	Upper bound	$92.3	$93.6	$92.9	$92.9	$93.3	$92.8	$92.4	$92.5	$92.5	$92.5	$92.6	$92.8	$92.6	**$94.3**	$93.6	$93.0
	Average	$82.3	$82.7	$82.5	$81.3	**$84.4**	$84.1	$83.8	$83.9	$83.8	$83.8	$82.7	$82.9	$82.9	$83.9	$84.0	$82.1
	Lower bound	$72.2	$71.7	$72.0	$69.7	$75.6	$75.4	$75.1	$75.3	$75.1	$75.2	$72.8	$73.0	$73.1	$73.5	$74.4	$71.3
LMB	Upper bound	$282.6	$281.2	$277.9	$278.5	$280.8	$277.9	$276.5	$276.9	$277.4	$276.5	$277.6	$278.3	$277.6	**$290.2**	$285.5	$278.1
	Average	$249.5	$233.3	$221.2	$220.6	**$247.0**	$224.1	$226.2	$226.3	$223.9	$223.3	$223.1	$223.3	$223.4	$229.8	$226.6	$222.3
	Lower bound	$216.3	$185.3	$164.6	$162.7	$213.1	$170.3	$176.0	$175.8	$170.3	$170.0	$168.6	$168.4	$169.1	$169.4	$167.7	$166.5

A few key insights emerge from Table 1:

- GDP for 2040 for scenario M1 is for most cases higher than most other scenarios because it assumes that the labour demand of agriculture does not increase, while M2 and M3 (and most sub-scenarios) assume an increase in agricultural demand for labour, which reduces the ability of secondary and tertiary sectors to grow;
- The comparison of M2, M3, A1 and H1a suggests that the macroeconomic optimum requires

    - lower agricultural expansion than assumed for M2;
    - some hydropower, but
        - fewer hydropower projects than assumed for M3; and
        - fewer mainstream dams than assumed for M2.
- The upper bound for GDP growth in M3 is lower than for M2 for all countries but Cambodia. However, Cambodia's lower bound decreases substantially when stepping from the M2 to the M3 development scenario. This indicates that a macroeconomic optimum is likely to be closer to M2 than M3.
- If alternate energy generation could be developed other than hydropower, growth potential would outpace all scenarios considered in this study. It is highly recommended to assess emerging energy technologies, including third generation biomass, offshore wind farms, tidal turbines, fusion, or transparent photovoltaic. However, any other power generation technology could also trigger negative externalities, which also need to be assessed.
- Flood protection projects benefit Vietnam and Cambodia more than Lao PDR and Thailand.
- Hydropower mitigation measures (comparing H3 and M3CC) are likely to create benefits of over $1.7 billion per year.

The main text of Section 7 (see Table 26) compares the 2040 scenario with 13 sub-scenarios and confirms that under M3CC conditions, over-investing in agriculture is likely to cause the largest economic reductions.

The analyses are based on simple calculations that combine Input-Output data, household survey data, population trends, and sector-specific valuation results. The approach neglects some key economic dynamics, as already mentioned. For instance, labour availability, mobility, and migration patterns emerges as important aspects, which could realistically translate into increasing salaries with the strongest increase in sectors with the highest labour productivity. It is critical for the macroeconomic development to capture sector-specific effects of relative price changes. Also, fish impacts are likely to be substantial, which means that fish prices are very likely to increase substantially. This means that there will be an increasing incentive to change land use and increase the development of aquaculture. National estimates of annual aquaculture increase over the projection horizon were held constant for the Council Study development scenarios. Expanding aquaculture is likely to affect water demands and water quality. These ripple effects are fundamental to designing sustainable development strategies. Due to the methodological constraints, the analytical interpretation focused on principle patterns and the relative comparison of scenarios instead of the absolute values.

Future scenario assessments with socioeconomic modelling that accounts for these complexities is a principle recommendation emerging from the macroeconomic assessment.

The third tier of this assessment places the economic system into the wider social-ecological system to identify important dependencies and the long-term viability of development strategies. One critical dependency is the need to sustain the functional integrity of natural resources as inputs for economic and social processes. The loss of natural capital (for instance in form of ecosystem services) would lead to a loss of economic growth potential. For instance, a continued investment in forestry would suddenly face negative growth rates if deforestation exceeds regrowth. This applies to all natural resources, even if it is a non-consumptive use, such as water for power plant cooling.

The economic valuation of natural resources functions and services relied on an assessment of over 500 economic valuation studies conducted in the Lower Mekong Basin over the past 20 years and applies these results as value ranges for each hectare of evergreen forest or each hectare of wetlands. Land use change is at the core of the value transfer approach. It is recommended to broaden this approach toward an Inclusive Wealth approach, which would add human capital, built capital and financial capital. However, natural capital changes are potentially the most immediate and relevant for the water resource focus of the MRC and the Member Countries. The results suggest that main scenario M2 would coincide with a mean loss of net present value of natural capital of $51 billion. M3 would increase this loss to a mean value of $110 billion. This is largely due to deforestation that already occurred between 2007 and 2015. This loss in natural capital is higher than the LMB-wide agricultural gains and equals about 35% of the combined annual economic gains from hydropower, fisheries, agriculture, and navigation. Most recent planning revisions foresee substantial reforestation in Cambodia, which would reverse the decline in natural capital and increase the net present value of natural capital by about $53 billion if compared with the 2007 scenario.

2 Background and scope of the study

The Council Study aims to assess the impacts of a variety of development investments on a range of indicators relevant to current decision-making processes. The Inception Report outlines the objectives. One assessment dimension is the macroeconomic perspective, which aims to analyse the effects of water infrastructure investments on individual sectors and on the broader economy.

The system boundary for the macroeconomic assessment is the Lower Mekong Basin. Effects are distinguished for the four countries within the basin. The inputs for this assessment have been drawn from the disciplinary studies, including the hydrological modelling, land use change plans, agricultural production projections, the BioRA study, the socioeconomic assessment, and the navigation assessment. Other data inputs have been provided by the thematic teams, including irrigation, land use, and navigation. This collaboration with disciplinary and thematic teams involved a series of iterative coordination steps to ensure a consistent implementation of the overall Council Study. Additional data were sourced from the MRC, the four member countries, or by international agencies.

Section 3 explains the scenarios applied during this assessment. These scenarios have been defined by the Member Countries and can be understood as two sets. The first set is the so-called main scenarios, which combine a variety of investments across various sectors, including hydropower, irrigation, navigation, and flood protection. The second set defines so-called sub-scenarios that assume sector-specific variations to isolate sector-specific impacts. Section 4 outlines the macroeconomic indicators, which capture three assessment tiers: the sector perspective, the whole-of-economy perspective, and a sustainability perspective. Section 5 summarises the assessment methodology. Section 6 provides all the results for the impacts for each scenario. Based on the comparison of the scenarios, Section 7 discusses the implications from a macroeconomic perspective.

3 Council Study scenarios

3.1 Main development scenario

The macroeconomic assessment will focus on the four main water resources development scenarios:

M1	Early Development Scenario (2007)
M2	Definite Future Scenario (2020)
M3	Planned Development Scenario (2040)
M3CC	Planned Development Scenario (2040) including more seasonal climate change

Each formulated scenario has a basin-wide scope and is composed of developments in each of the six thematic areas. These developments are as composite changes to an assumed *reference period*, which is defined by a 24-year time series from 1985–2008 of hydro-meteorological data (rainfall, evaporation, boundary water levels, etc.) broadly representative of historic natural flow conditions. This past period is corrected by a range of *exogenous drivers* that are not directly linked to the water infrastructure investments in the scenarios. Certain trends are assumed for these exogenous drivers, which include population growth and others. This combination of past hydro-meteorological data (or patterns) and predicted trends of exogenous drivers define the so-called *baseline*.

→ Early Development Scenario (2007) – Scenario M1

This scenario defines the state of water infrastructure development as it was in the year 2007 when the flow regime of the Mekong mainstream was considered to be still in its natural state. This scenario includes the infrastructure and the land use/cover changes in the thematic areas as of 2007. In addition to modelling with the Decision Support Framework, the impact assessment of the early development scenario is based on existing observations, studies, and assessments of historical changes in land use, development of (irrigated) agriculture, flood control structures, wetland areas, biodiversity, capture fisheries, etc. The assessment results allow the Member Countries to consider whether the benefits, impacts, and risks of new water resources development are reasonable and equitable.

→ Definite Future Scenario (2020) – Scenario M2

The main purpose of this scenario is to assess the distribution of the benefits, costs, impacts, and risks of water resources development in the Mekong Basin as predicted in 2020. This scenario includes all existing (before and after 2007), under-construction, and firmly committed development in the six thematic areas that are expected to be in place by 2020. The impacts (positive and negative) of this scenario are inevitable (but negative impacts can be mitigated).

→ Planned Development Scenario (2040) – Scenario M3

The main purpose of this scenario is to assess the distribution of the benefits, costs, impacts, and risks of water resources development in the Mekong Basin as of 2040. In addition to the development in the 2020 Scenario, the 2040 Scenario includes all water resources development that is planned in the six thematic areas in the Mekong Basin. On a timescale, the scenario covers the water resources development that would be in place by 2040 if these plans are fully implemented.

3.2 Development sub-scenarios

In order to respond rigorously to key policy questions arising from the stated objectives and assessment requirements of the Inception Report, additional sub-scenarios have been developed.

Impacts of climate change

Two sub-scenarios for 2040 are being prepared to explore the interactions between water resource development and changes in climate (Table 2). Comparisons between scenarios M3CC and C2 for instance measure the effect of water resources development at the level of 2040 under a climate that is even wetter than mean projections. Sub-scenario C3 defines a drier climate change. The sub-scenarios which assume climate change (M3CC, C2, and C3) are derived from statistical downscaling the outputs of a set of global circulation models driven with assumptions of intermediate levels of greenhouse gas emissions (RCP4.5) and using these estimates to adjust the reference 1985-2008 climate.

Table 2 Climate change sub-scenarios for analysis CIA

	Sub-scenarios	Level of Development for water-related sectors						Climate	Flood-plain
		ALU	DIW	FPF	HPP	IRR	NAV		
M3CC	Planned Development 2040 + more seasonal (mean projection)	2040	2040	2040	2040	2040	2040	More seasonal	2040
C2	Planned Development 2040 + Wetter Climate	2040	2040	2040	2040	2040	2040	Wetter	2040
C3	Planned Development 2040 + Drier Climate	2040	2040	2040	2040	2040	2040	Drier	2040

Impacts of individual sectors

To evaluate and report on the impacts and benefits of water resources development in each sector as requested in the Inception Report, it is necessary to analyse the contributions made by each sector. The best study design for doing this is to compare the main scenario with all sectors developed with a sub-scenario having all the developments apart from those in the target sector. In the following sections these comparisons are tabled for each sector.

→ Agricultural land-use sub-scenarios

To address the key policy goal in the Inception Report of reporting on the impacts and benefits of agriculture and land-use development, comparisons will be made between main scenario M3CC and sub-scenario A1 (Table 3) and an alternative scenario with more land-use changes (A2).

Table 3 Sub-scenario to better understand impacts of different assumptions about future agricultural land-use

Scenario		Level of Development for water-related sectors[1]						Climate	Flood-plain
		ALU	DIW	FPF	HPP	IRR	NAV		
M3CC	Planned Development Scenario 2040 with climate change	2040	2040	2040	2040	2040	2040	More seasonal	2040
A1	Planned Development 2040 without ALU	**2007**	2040	2040	2040	2040	2040	More seasonal	2040
A2	High level ALU implementation	**HIGH**	2040	2040	2040	2040	2040	More seasonal	2040

→ Flood protection sub-scenarios

To assess the positive and negative impacts of flood protection infrastructure, comparisons will be made between main scenario M3 and sub-scenario F1 (Table 4). Two other alternative flood protection strategies (F2 and F3) will also be compared with F1 or M3CC.

Table 4 Sub-scenarios to better understand impacts of different assumptions about future flood protection investments

Scenario and sub-scenarios		Level of Development for water-related sectors						Climate	Flood-plain
		ALU	DIW	FPF	HPP	IRR	NAV		
M3 CC	Planned Development Scenario 2040 with climate change	2040	2040	2040	2040	2040	2040	More seasonal	2040
F1	Planned Development 2040 without FPF	2040	2040	**2007**	2040	2040	2040	More seasonal	2040
F2	Planned Development 2040 with FP2	2040	2040	FPF2	2040	2040	2040	More seasonal	2040
F3	Planned Development 2040 with FPF3	2040	2040	FPF3	2040	2040	2040	More seasonal	2040

→ Irrigation sub-scenarios

To assess the positive and negative impacts of irrigation infrastructure, overall comparisons will be made between main scenario M3 and sub-scenario I1 (Table 5). Another sub-scenario with even more irrigation infrastructure (I2) will also be compared with I1 or M3CC.

Table 5 Sub-scenarios to test the effects of water resources development in the irrigation sector

Scenario and sub-scenarios		Level of Development for water-related sectors						Climate	Flood-plain
		ALU	DIW	FPF	HPP	IRR	NAV		
M3 CC	Planned Development Scenario 2040 with climate change	2040	2040	2040	2040	2040	2040	More seasonal	2040
I1	Planned Development 2040 without IRR	2040	2040	2040	2040	**2007**	2040	More seasonal	2040
I2	Planned Development 2040 with IRR HIGH	2040	2040	2040	2040	**HIGH**	2040	More seasonal	2040

→ Hydropower sub-scenarios

To assess the positive and negative impacts of hydropower development, comparisons will be made between main scenario M3 and sub-scenarios H1a and H1b (Table 6). Sub-scenario H1a assumes that no hydropower projects would be developed beyond what existed in 2007. H1b assumes that only tributary hydropower projects would be realised without mainstream dams. Sub-scenario H3 assumes the same level of hydropower investments as M3CC but with effective mitigation measures as detailed in the hydropower report.

Table 6 Sub-scenarios to test the effects of water resources development in the hydropower thematic sector

Scenario and sub-scenarios		Level of Development for water-related sectors						Climate	Flood-plain
		ALU	DIW	FPF	HPP	IRR	NAV		
M3 CC	Planned Development Scenario 2040 with climate change	2040	2040	2040	2040	2040	2040	More seasonal	2040
H1a	Planned Development 2040 without HPP	2040	2040	2040	**2007**	2040	2040	More seasonal	2040
H1b	Planned Development 2040 without mainstream HPP	2040	2040	2040	**Only tributary**	2040	2040	More seasonal	2040
H3	Planned Development 2040 with Mitigation	2040	2040	2040	**Mitigation**	2040	2040	More seasonal	2040

4 Assessment indicators

The promotion of economic development is key aim of the national plans for water resource development in Lower Mekong Basin countries as well as the MRC's coordination efforts. MRC operates in defined sectors, and it is important to monitor and assess the economic performance of MRC sectors with respect to current and future development plans, as well as to assess their contribution to the overall basin economy. The MRC Indicator Framework[1] guides the monitoring and assessment process for five dimensions, i.e. social, environment, economic, climate change, and cooperation, and comprises of strategic assessment indicators and discipline-specific monitoring indicators.

In order to evaluate the strategic economic indicators, namely (i) economic performance of MRC sectors and (ii) contribution to the overall basin economy, a series of assessment indicators have been specified based on the MRC Indicator Framework. These assessment indicators are presented in Table 7, and they will be evaluated in the assessment of the direct benefits, costs, and impacts of water resource developments across all main and all sub-scenarios.

Table 7: Economic assessment indicators

Strategic Indicators	Assessment Indicators	Unit
MRC sector focused indicators	Economic value of irrigated agriculture:	US$M/year
	Economic value of recession agriculture	US$M/year
	Economic value of lowland rain fed agriculture	US$M/year
	Economic value of hydropower production	US$M/year
	Economic value of mainstream navigation	US$M/year
	Economic value of flood damage	US$M/year
	Economic value of drought damage	US$M/year
	Economic value of capture fisheries	US$M/year
	Economic value of reservoir fisheries	US$M/year
	Economic value of aquaculture	US$M/year
	Economic value of river bank gardens	US$M/year
	Economic value of upland forestry	US$M/year
	Economic value of flooded forests	US$M/year
	Economic value of wetlands, key habitats and conservation areas	US$M/year
	Economic value of productive activities in areas affected by salinity	US$M/year
	Economic value of assets in locations affected by river bank erosion	US$M/year
	Aggregate economic value (from above)	US$M/year
GDP-focused indicators	Basin GDP changes	percent
	Natural capital changes (Economic value of Ecosystem Services)	percent
	Proportion of MRC sectors contribution to overall basin GDP	percent

[1] MRC Indicator Framework for managing the Mekong Basin (draft), June 2015.

5 Assessment methodology

5.1 Assessment tier 1: Sector-focused cost-benefit analysis

This part of the economic assessment sources biophysical information from disciplinary and thematic teams to define the conditions until 2040. Then, economic values are established for each biophysical unit (i.e. GWh, tons, ha) in close coordination with thematic and disciplinary teams, followed by quantifying all relevant costs. This approach ensures that the economic valuation is consistent with the disciplinary assessments of the overall Council Study. Figure 1 visualises these steps.

Figure 1: Approach for calculating annual cost-benefit values for all MRC sectors

	Biophysical state		Value per unit		Costs		Annual value
Fish	tons	*	$/tons	-	$	=	$
OAA	tons		$/tons		$		$
Hydropower	GWh		$/GWh		$		$
Irrigated agriculture	ha		$/ha		$		$
Rainfed agriculture	ha		$/ha		$		$
Wetlands	ha		$/ha		$		$
Navigation	tons		$/tons		$		$
Floods	ha		$/ha		$		$
Salinity changes	ha		$/ha		$		$
Riverbank erosion	ha & km		$/ha		$		$

The next step involves the calculation of aggregate value for the period 2007 until 2040. This is a standard approach and defines so-called *net present values*, which translates future benefits into today's values. This involves social discounting to consider the fact that people have a strong preference for present consumption (Rubinstein, 2003; Sozou, 1998). The longer in the future the benefit is placed, the less people value these benefits or costs. However, experiments have shown that the rate by which people discount future benefits drops the further one steps into the future. This means that people see a lot of difference between receiving a benefit now or in one year (hence the need to discount in the first place). But people do not distinguish (much) between receiving a benefit in twelve years or in thirteen years. Therefore, the social discount rate decreases the further we step into the future. This type of social discounting is referred to as hyperbolic discounting (Rubinstein, 2003; Sozou, 1998).
For this study we assume the following to approximate hyperbolic discounting:

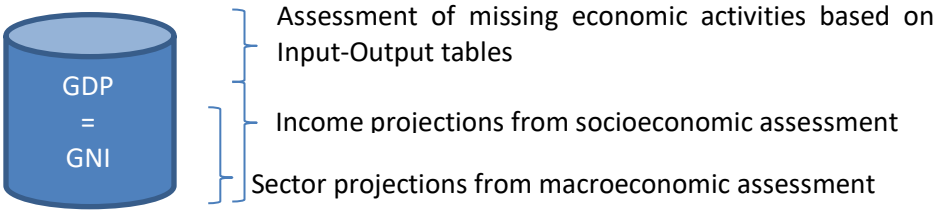
- *for the next 5 years: 6.5% discount rate*
- *for the ten years thereafter an annual drop of the discount rate by 0.65%*
- *for the ten years thereafter no further discounting is applied*

5.2 Assessment tier 2: Macroeconomic assessment approach

The macroeconomic assessment embeds sector-level results in the broader economy and quantifies possible impacts on GDP. GDP projections for the period 2017–2040 are calculated for all scenarios in three steps. In a first step, starting points are established for GDP and key sectors for 2017. This step is largely based on Input-Output data that has been published by the four countries and involves for Thailand and Vietnam the disaggregation of national data to estimate economic activities in Mekong

basin areas. In a second step, projections made by disciplinary assessments are implemented for all relevant scenarios (as described above). In a third step, income projections developed by the socioeconomic assessment to estimate income security effects are used to distinguish between primary, secondary, and tertiary sector income,[2] see Figure 2. The production-based GDP has to match the Gross National Income (GNI) corrected by income of non-residents.

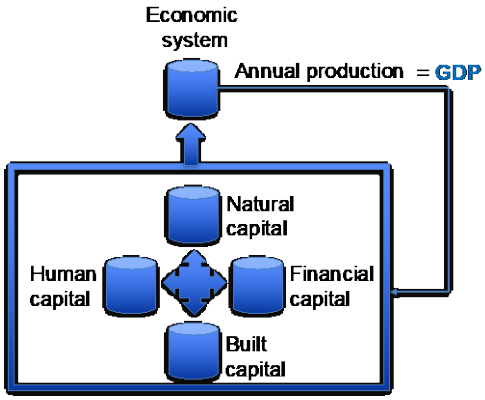
Figure 2: GDP projections based on MRC sector projections, household income projections and I/O data



5.3 Assessment tier 3: Sustainability and future growth potential

There are many criticisms concerning GDP and its value as a meaningful metric for the economy. Accordingly, this assessment analyses also impacts on production factors to understand future growth potential. Production factors include natural, built, capital, and financial capital. This study is focused on natural capital to evaluate the sustainability of GDP growth. This builds on well-established approaches, including the inclusive wealth theory.

Figure 3: Natural, human, built, and financial capital as the pillars for economic production (GDP)



Natural assets are provided as ecosystem services and are partly directly utilised for the production process. Natural capital values are based on the sector-specific cost-benefit analysis and a database of economic valuation results the Mekong Region Futures Institute (MERFI) compiled over recent years. This database combines over 500 valuation results into six broad ecosystem categories and derives value ranges. These value ranges are then applied to projected scenario changes, largely driven by land use change. Such an approach is typically referred to as a *transfer benefit* approach.

[2] Primary sectors include agriculture, forestry, fisheries, and mining. Secondary sectors include light and heavy manufacturing industries, often involving the processing of raw material. Tertiary sectors refer to service sectors.

In a final step, the changes of natural capital are compared across scenarios to approximate the sustainability of development plans. Sustainable development requires natural capital to remain stable or even increase because a decrease of natural capital (or any of the other capitals) constrains future potential if the dependency of economic growth on this input factor is not declining proportionately. Many economies have diminished their natural capital without decreasing their dependency on natural resources, which led to a collapse of the economy (i.e. Haiti).

6 Data gaps

The vast majority of data required for the aforementioned approach is provided by thematic and other disciplinary assessments. The thematic assessments defined the majority of baseline data while the disciplinary assessments provided responses for all scenarios. Only two data gaps remain, GDP-related information and the value of natural capital.

Historical data for GDP and inflation were sourced from the World Bank (http://data.worldbank.org/). Inflation is relevant to calculate real GDP and calculate the reference point for GDP at 2017 prices. This data was compared with national statistics, which resulted in no major differences.

Natural capital calculations are based on an online tool MERFI developed under the Mekong ARCC (Adaptation and Resilience to Climate Change) program. The tool is accessible under http://mekongarcc.net/ESV_tool/ESV.html. This valuation is based on over 500 results from economic valuations of ecosystems in the Lower Mekong Basin. Details are described in the report that describes the methodology for this macroeconomic assessment.

7 Main scenario impact assessment results

7.1 Assessment tier 1: Sector-specific assessments

Hydropower

The hydropower sector has the largest investment share across all main scenarios. The hydropower development situation as described by the main scenario M2 comes with substantial economic gains of about $72.3 billion in NPV for the 24-year period (approximating 2017 to 2040). The third main scenario would further increase the sector benefit and increase the NPV to $160.8 billion. Table 8 summarises the changes of NPV for the hydropower sector for the three main scenarios.

Table 8: Impacts on NPV of the hydropower sector for the main scenarios

		M1	M2	M3	M3CC
Lao PDR	B$	1.2	21.1	36.0	37.9
Thailand	B$	1.0	28.7	81.1	81.5
Cambodia	B$	0.0	6.6	12.0	11.9
Vietnam	B$	6.8	16.0	31.7	31.8
LMB	B$	9.1	72.3	160.8	163.1

Table 9 shows that Thailand would receive the highest increase in NPV equivalent to 44% of the additional economic gains. This is largely due to the difference between the cost for importing electricity from Lao PDR and the domestic retail prices. Lao PDR would receive about 31% of the Lower Mekong Basin (LMB)-wide NPV gain for scenario M2. Vietnam's share would be around 15% of the sector-specific increase in NPV, while Cambodia would gain about 10%.

Table 9: Share of increased economic benefit from hydropower investments as NPV

	M2	M3	M3CC
Lao PDR	31%	23%	24%
Thailand	44%	53%	52%
Cambodia	10%	8%	8%
Vietnam	15%	16%	16%
LMB	100%	100%	100%

Stepping hydropower investments further up, as defined by scenario M3, would more than double the economic benefit from hydropower if compared with M2, as Table 8 shows. The absolute increase would lead to substantial economic gains, particularly in Thailand. Table 9 indicates that about 53% of the LMB-wide increase in NPV would benefit Thailand. As explained above, this is based on the tariff difference between import costs and domestic retail tariffs. Lao PDR would obtain about 23% of the LMB-wide increase in NPV over the 24-year period. This share is surprisingly low despite the fact that most mainstream (and tributary) hydropower is planned to be installed in Lao PDR because most profits are made by investors in Thailand or by investors from outside the Lower Mekong Basin (e.g. China, Malaysia, South Korea). This is discussed in more detail further below. About 16% of increased NPV of hydropower in the Lower Mekong Basin would benefit Vietnam and about 8% would benefit Cambodia. Similar to the link between Thailand and hydropower investments in Lao PDR, substantial parts of profits derived from proposed hydropower projects in Cambodia would benefit Vietnam.

The additional consideration of climate change in the scenario for a 2040 development situation assumes that the climate becomes more seasonal with slightly wetter and warmer conditions. The increase of seasonality is likely to improve the economic returns from hydropower investments in most

parts of the Lower Mekong Basin. The largest benefits are likely to benefit Lao PDR, as shown in Table 8. Thailand and Vietnam would experience slight increases due to the expected climate change, while the NPV of economic benefits for Cambodia would slightly decrease.

Fisheries

The fisheries sector is likely to experience a substantial decline for scenarios M2 and M3 as the NPV is likely to drop by 22.7% and 31.1% respectively, see Table 10. For scenario M2, 39% of the economic loss would eventuate in Thailand, 29% in Cambodia, 22% in Lao PDR, and 10% in Vietnam.

Table 10: Impacts on NPV of the fisheries sector for the main scenarios

	M1 (2007)	M2 (2020)	M3 (2040)	M3CC (2040)	M2-M1 Diff		M3-M1 Diff		M3CC-M1 Diff	
	B$	B$	B$	B$	B$	%	B$	%	B$	%
Cambodia	30.5	25.8	24.2	23.6	-$4.7	-15.5%	-$6.3	-20.6%	-$6.9	-22.7%
Lao PDR	8.3	4.7	3.4	3.2	-$3.7	-44.2%	-$5.0	-59.9%	-$5.1	-61.4%
Thailand	15.0	8.7	6.9	6.6	-$6.4	-42.5%	-$8.2	-54.3%	-$8.4	-55.9%
Vietnam	18.9	17.2	15.7	17.7	-$1.7	-9.0%	-$3.2	-16.8%	-$1.2	-6.4%
LMB	72.9	56.3	50.2	51.2	-$16.5	-22.7%	-$22.6	-31.1%	-$21.7	-29.7%

The third main scenario (M3) results in an additional decline of the fisheries sector. The NPV for fisheries in the Lower Mekong Basin is likely to drop by nearly $23 billion if compared with M1, adding $6.1 billion to the impact of M2. The distribution of fisheries losses would be similar to scenario M2. The comparison of scenarios M2 and M3 reveals that 29% of the *additional* losses in fisheries would eventuate in Thailand and 21% in Lao PDR. About 25% of the additional losses in fisheries would be encountered in Cambodia and 24% in Vietnam. From a macroeconomic perspective, the fisheries sectors in Lao PDR and Thailand are likely to lose most of their economic relevance. Climate change in M3CC assumes a more seasonal and slightly warmer and wetter climate, which introduces some mitigating effects for fisheries sector as it reduces the LMB-wide loss by about $900 million.

Economically, these changes are substantial and likely to change the market structure for fish throughout the Lower Mekong Basin. This is likely to trigger substantial price increases. Considering the dominance of fish production in Cambodia, profit margins are likely to increase substantially during the assessment period. Cambodia's market share would increase from 42% (M1) to 46% (M2) and to 48% (M3), which is likely to further accelerate fish prices due to the shifts in the fish market structure.

The fish loss in combination with the substantial increase in fish prices is likely to put substantial pressure on food security throughout the region. The consequences within the corridor are assessed in detail in the socioeconomic study. Food security losses would affect mostly poor households in urban contexts. In rural areas, households are likely to lose substantial parts of their subsistence fisheries, which would need to be replaced by increasing income or other food (protein) sources. Poor households without necessary access to land are likely to face large challenges and are likely to be forced to migrate into urban areas to realise the necessary income increases. As experienced by many developing countries, such migration pressure would demand substantial public investments in urban infrastructure.

Agriculture

The NPV of economic benefits in the agricultural sector are likely to increase with the planned expansions. LMB-wide, the NPV of the agricultural sector would increase by about 26% for M2 and by about 29% for M3. The largest gains from agricultural investments in scenario M2 would occur in Cambodia as the NPV of agricultural production would increase by 105% to over $65 billion, as Table 11 shows. Vietnam would increase the NPV of its agricultural sector by $21 billion in M1 or about 7.5%. The NPV of Thailand's agricultural sector is likely to change only slightly by 1.4% or $2.2 billion.

Table 11: Impacts on NPV of the agricultural sector for the three main scenarios

	M1	M2	M3	M2-M1 Diff	M3-M1 Diff
	B$	B$	B$	%	%
Cambodia	62.2	127.5	129.5	105.0%	108.3%
Lao PDR	42.5	45.7	48.3	7.5%	13.6%
Thailand	154.8	157.1	159.0	1.4%	2.7%
Viet Nam	98.7	119.6	125.0	21.2%	26.7%
LMB	358.2	449.8	461.7	25.6%	28.9%

Scenario M3 would further add $2 billion to the substantial increase of NPV in the agricultural sector for Cambodia. Lao PDR would increase its NPV in agriculture to $48.3 billion, representing a similar increase to the benefit M2 provided. Vietnam's agricultural sector is likely to increase to $125 billion, which equals an increase of 26.7% if compared with M1. The agricultural sector in Thailand would grow by an additional $1.9 billion in NPV, a marginal increase of 2.7% if compared with M1.

Navigation

Macroeconomic impacts in the navigation sector involve three important components. The first component is the GDP contribution. The second component is the cross-sector impact due to the relative price difference to other modes of transport, in particular comparing ship-based transportation to road-based and railway-based options. The third component is the changes in total cargo value and total passenger numbers, which constitutes important flow-on effects for the broader economy.

The first component is presented in Table 12, which quantifies effects on the NPV of the navigation sector for the three main scenarios. The substantial expansion of capacity proposed by M2 and M3 is likely to lower prices.

Table 12: Impacts on NPV of the navigation sector for the three main scenarios

	M1 (2007)	M2 (2020)	M3 (2040)	M2-M1 Diff		M3-M1 Diff	
	B$	B$	B$	B$	%	B$	%
Cambodia	$0.9	$2.2	$9.5	$1.3	132%	$8.5	898%
Lao PDR	$0.3	$0.4	$2.2	$0.1	46%	$1.9	665%
Thailand	$0.5	$0.9	$3.4	$0.4	83%	$2.9	632%
Vietnam	$5.6	$13.8	$61.2	$8.2	146%	$55.5	990%
LMB	$7.3	$17.2	$76.2	$9.9	136%	$68.9	942%

The economic gains of nearly $10 billion for the M2 scenario are substantial and eventuate largely in Vietnam. The gains generated by M3 are even larger, providing nearly a ten-fold increase of the sector's NPV for the 24-year period. Vietnam would be the main beneficiary, followed by Cambodia.

7.2 Cross-sector comparison

The comparison of all four focus sectors suggests substantial economic improvements for scenarios M2, M3, and M3CC. This narrow sector perspective is only considering effects within each of these sectors and quantifies only effects for this first assessment tier, which needs to be understood in combination with results for the other two assessment tiers presented further below.

Table 13 summarises the NPV changes for all sectors and the percentage change compared to scenario M1. The combined investments for M2 across the four focus sectors are likely to create the largest benefits for Cambodia because of its substantial expansion of agricultural production. The combined benefit of all four sectors (including the economic value of subsistence production) would increase by 73% for M2 and 87% for M3. These economic benefits provide a seemingly convincing economic argument. However, as mentioned, these results are only representing a narrow sector perspective. The second tier assesses impacts on the national economy and provides a discussion of how realistic these potential sector benefits are. Considering the labour force requirements, the Cambodian economy might be able to realise only a small part of this agricultural potential, which means that Cambodia would be left with large losses in the fisheries sector and small gains in hydropower and navigation. Table 13 indicates that Cambodia is likely to experience the strongest trade-offs between hydropower and fisheries for M3, as the hydropower gains of $12 billion would coincide with a loss in fisheries of about $6.3 billion. This includes transboundary effects. The cumulative impact assessment analyses transboundary impacts in detail.

Vietnam's benefits of $103.6 billion are the largest gains for scenario M3, which is mainly created by the navigation sector. The second assessment tier below explains that the realism of this economic potential depends on the broader macroeconomic development, in particular the improvement of value-add production in the manufacturing industries and the increase of household income. However, investments in hydropower and agricultural would increase Vietnam's benefits for scenario M3, as shown in Table 13.

The combined economic benefit created by these four sectors in Thailand would experience a substantial increase for scenario M3 as NPV is likely to increase by $78.9 billion, which is about 46% more than the M1 baseline. The largest share of this possible gain is based on hydropower investments in Lao PDR, which are likely to amount to $80.1 billion in NPV over the 24-year time period. As a side effect, most of the fisheries sector would disappear with consequences for livelihoods and food security.

Lao PDR would gain from development plans. The combined NPV would increase by $37.5 billion for M3. This would include a substantial trade-off between hydropower and fisheries, see Table 13. The majority of economic benefits generated by mainstream hydropower is likely to move to investors from Thailand or other countries outside the Lower Mekong Basin. Nevertheless, the comparison of M3 and M1 suggests an increase in combined NPV of 72%.

The influence of climate change on these four sectors is positive for Lao PDR because of the additional economic gains from (tributary) hydropower as climatic conditions improve. Vietnam and Thailand would also benefit from the expected climate change while the combined NPV of these four sectors in Cambodia is likely to sustain marginal losses, as Table 13 suggests.

Table 13: Cross-sector comparison for NPV of hydropower, fisheries, agriculture, and navigation for the three main scenarios

Differences to M1		Hydropower B$	Fisheries B$	Agriculture B$	Navigation B$	SUM	%
M2	Cambodia	6.6	-4.7	65.3	1.3	68.4	73%
	Lao PDR	19.8	-3.7	3.2	0.1	19.5	37%
	Thailand	27.6	-6.4	2.2	0.4	23.9	14%
	Vietnam	9.2	-1.7	21.0	8.2	36.6	28%
M3	Cambodia	12.0	-6.3	67.3	8.5	81.6	87%
	Lao PDR	34.8	-5.0	5.8	1.9	37.5	72%
	Thailand	80.1	-8.2	4.1	2.9	78.9	46%
	Vietnam	24.9	-3.2	26.3	55.5	103.6	80%
M3CC	Cambodia	11.9	-6.9	67.3	8.5	80.8	86%
	Lao PDR	36.7	-5.1	5.8	1.9	39.3	75%
	Thailand	80.5	-8.4	4.1	2.9	79.1	46%
	Vietnam	25.0	-1.2	26.3	55.5	105.6	81%

It is essential to understand that these results can only represent a very narrow perspective as they only combine four sectors. Missing from this sectoral assessment level are (1) economy-wide implications and (2) the assessment of how sustainable these sectoral growth trajectories are.

Erosion as an important cost factor

Hydropower investments are predicted to cause substantial erosion, as the hydrological assessment points out. Some lengths of river have already been protected (Thailand: 56%; Lao PDR: 23%; Vietnam: 3%; Cambodia: 1%), but planned hydropower projects would require additional investments, see Table 14. Development scenario M3 would require an estimated $5.67 billion in investments in riverbank protection, largely in Vietnam and Cambodia.

Table 14: Required investment in river embankments to protect river banks for scenarios M2 and M3

In M$	Lao PDR	Thailand	Cambodia	Vietnam	LMB
Scenario M2	$228	$551	$15	$73	$866
Scenario M3	$990	$990	$1,608	$2,082	$5,670

Considering this as a direct result of hydropower would flag the need for a full internalisation of such costs into the planning of hydropower projects. The cumulative impact assessment discusses benefit-sharing mechanisms and explains that benefit sharing is as much about cross-sector effects and not only about transboundary (cross-country) compensation. However, erosion-related results shift the spotlight for burden sharing to the country level. Challenging remains the exact attribution of sediment loss for specific hydropower projects. This requires comparative simulations to quantify project-specific effects. In absence of project-level assessments, average impacts of the 2040 development scenario would convert to a levy of 1.2 % on profits from mainstream hydropower and 1.1 % for tributary dams.

7.3 Assessment tier 2: Macroeconomic assessment

Gross Domestic Product (GDP)

The projection of future GDP trajectories is challenging, particularly for longer periods. It requires more sophisticated modelling methodologies than available for the Council Study. Typically, an economic study would employ Computable General Equilibrium (CGE) models or micro-simulation models. Without adequate economic modelling this study is constrained to developing estimates from simple mathematical calculations. The following projections triangulate GDP projections in three steps.

First, a trend analysis is provided based on data for the past 10 years to provide a realistic range of possible GDP growth trajectories. The second approach derives potential labour growth from population growth. Growth of secondary and tertiary sectors can be estimated by combining

a. investments in primary sectors (as described in previous sections),
b. current labour requirements per output unit, and
c. historic improvements of labour productivity.

The combination of this growth potential and the value changes for primary sectors (as calculated in previous sections) provides the second estimate for GDP in 2040 and includes important labour constraints. It assumes that the investments in agriculture in particular will be met by the necessary labour requirements and therefore fully utilised. The results from this approach are likely to underestimate GDP growth because over the longer time frame people are more likely to seek employment in secondary and tertiary sectors due to higher income.

The third approach drops this assumption and assumes that only as much labour will seek employment in agriculture as needed to maintain food security. The remaining workforce transitions to secondary and tertiary sectors. This approach is more realistic considering sectoral income differences and resulting incentives for employees, especially over long time frames. However, estimates resulting from this approach are likely to underestimate agricultural employment because the competition for labour would typically trigger higher wages and thereby reduce sectoral income differences. Such price-driven processes and dynamic incentives are important reasons to improve economic modelling.

These three approaches triangulate GDP estimates. In summary, the first approach provides a range for historically based projections, which estimate typical upper and lower bounds. The second approach considers actual investments as defined by M1, M2, and M3, and connects them with labour force estimates and income changes provided by the socioeconomic study. The link between agricultural investments and labour demands assumes that all agricultural labour demands will be met, which is likely to underestimate GDP growth. The third approach is assuming a minimum allocation of labour to the agricultural sector and is therefore likely to (slightly) overestimate GDP growth.

Trend-based estimation

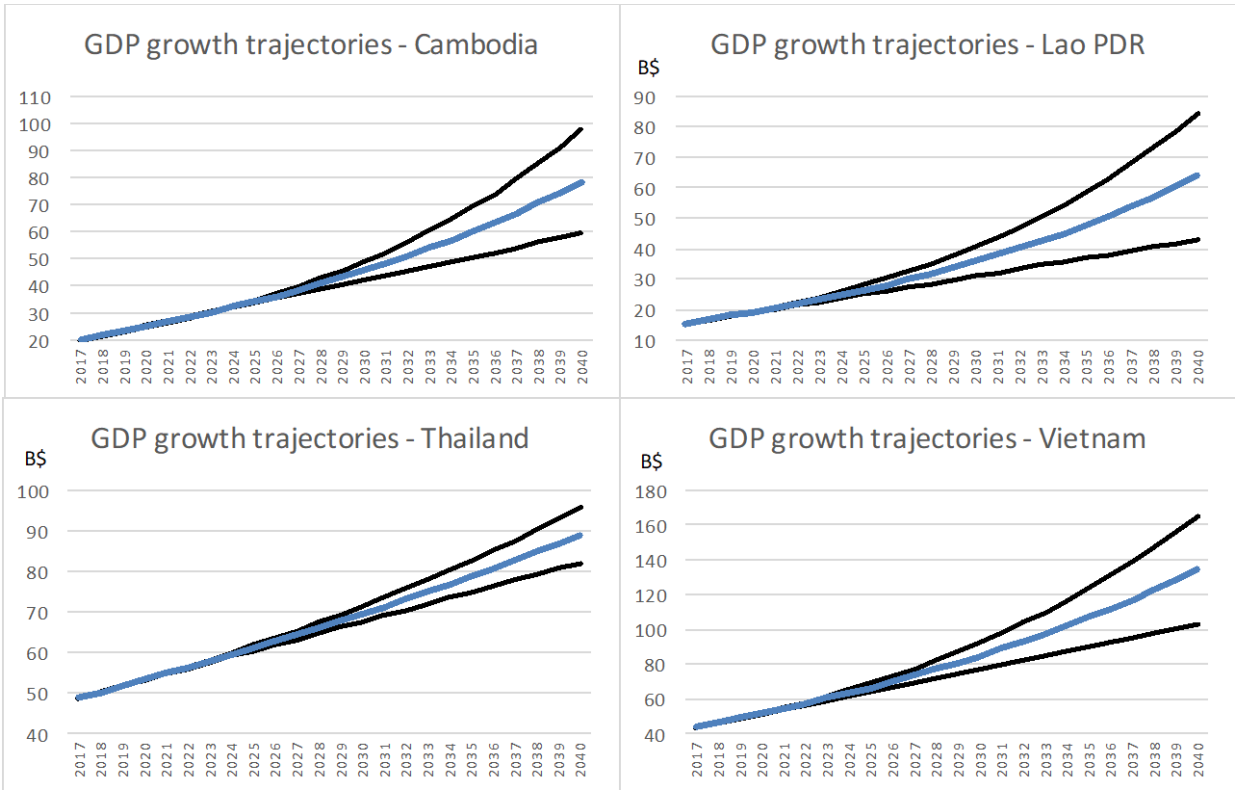
In preparation, official GDP data was sourced for 2003 to 2015. GDP calculations are focused on the Lower Mekong Basin area, which means that the values listed in Table 15 have been disaggregated and represent for Thailand only the north-eastern region and for Vietnam only the Mekong Delta. GDP calculations for Lao PDR and Cambodia represent the entire country. The disaggregation for Thailand and Vietnam could only be performed based on official 2015 data and not on more recent statistics. However, official GDP data was available for 2016, and for Thailand and Vietnam it is assumed that the areas within the Lower Mekong Basin grew at the same rate as the rest of the national economies. GDP

estimates for 2017 were estimated based on the average annual GDP growth rate for 2010-2015, see Table 15.

For the next step, two growth rates have been calculated based on the average growth rate for the period 2010-16. This average can be applied in two ways to the period 2017 to 2040. First, it could be assumed that the four economies grow exponentially at this rate. This would be a very rare case of economic development if considering the 24-year period. Thus, this growth path is the likely upper bound for economic development. Second, the absolute growth could be projected as a linear trend into the next 24 years. This would also be unlikely, particularly for countries that are in a development status as Lao PDR and Cambodia. Thus, this line is the lower bound for likely future trajectories.

As a first guidance and in absence of appropriate economic modelling, we assume that GDP will continue to grow over the next 24 years between these two bounds and is likely to range around the average of exponential and linear growth. This average is listed as a trend projection and as the blue growth path in Figure 4. Figure 4 displays GDP growth in nominal terms, whileshows GDP in real terms (at 2017 prices).

Figure 4: GDP growth path projections in B$ at constant 2017 prices



Bottom-up projections

The trend analysis provides a rough estimate based on economic conditions in the recent past. Several of these conditions are likely to change, including population growth (and workforce growth) as well as scenario-specific investments. Two bottom-up approaches link labour availability to scenario-based investments. Investments in agricultural production come with an increased demand in labour, which needs to be corrected by realistic productivity improvements. Agriculture is the key sector for the increased labour demand. Fishing is likely to release labour due to the projected reduction of the fishing

sector in all four countries. This is considered in the following projections. Hydropower and navigation have only small effects on the labour market due to their relative capital intensity.

As explained earlier in this section, it is assumed that in 2040, labour is first allocated to the agricultural sector to ensure full utilisation of agricultural production capacity and the allocated cultivated land. This labour demand grows according to the investments defined in scenarios. Under scenario M2, GDP would grow for Cambodia from $21.9 billion in 2017 to $38 billion in 2040 (deflated to 2017 prices). For scenario M3, GDP would only grow to $32.6 billion due to the effect of the additional development decisions made in this scenario and under the assumption of fully allocating labour to agricultural production. Both numbers are below the trend, which is due to the substantial increase of agricultural production under M2 and an even higher agricultural demand for labour under M3. This diminishes the ability for secondary and tertiary sectors to grow despite their higher factor productivity. Subsequently, this leads to suppressing GDP growth. This would also imply that the power generation expansion and the increase in export earnings from hydropower are unlikely to convert into the expected GDP growth. If the labour constraint on secondary and tertiary sectors is relaxed and agriculture receives only a minimum of required labour force (to maintain food security), secondary and tertiary sectors can grow at a higher rate. GDP estimates for 2040 would increase to $45.6 billion for M2 and $46.5 billion for M3. Realistically, the GDP growth will be between the “agricultural priority” assumption and the “agricultural minimum” assumption. Two main observations can be made for Cambodia. First, the substantial expansion of agriculture is likely to be unproductive in 2040. This would be similar to developments in north-east Thailand, where agricultural expansion did not convert into economic growth as workers followed incentives provided by higher income in secondary and tertiary sectors and lifestyle changes related to (peri-)urban living. Second, the substantial investment in hydropower under M3 is unlikely to trigger larger GDP gains.

GDP growth for Lao PDR is likely to be substantial, as Table 15 shows. Under the “agricultural priority assumption”, M2 investments would add to an economic development and increase 2017 GDP of $17.4 billion to $29.8 billion in 2040. This is slightly below the trend line ($30.6 billion). However, agricultural expansion causes a labour constraint under the “agricultural priority" assumption and thereby suppresses the growth of secondary and tertiary sectors. Once this assumption on labour allocation is relaxed under the “agricultural minimum” assumption, GDP is likely to grow by 2040 to $40.4 billion for M2 and $40 billion for M3. The key insight is similar to Cambodia: the agricultural expansion is likely to be beyond the macroeconomic optimum because it exceeds workforce growth, which is likely to involve that large areas of land would not be cultivated. The sub-scenario perspective further below indicates sub-optimal levels of other sectors for M3, including hydropower.

Thailand’s increase in GDP from 2017 to 2040 is rather small, as 5 quantifies. Thailand has the largest difference between the two agricultural assumptions, which range for M2 between $45.9 billion and $101.6 billion. This is largely because the current state of agriculture implies that about 30% of the area is unproductive. It also implies that the part of the labour force that is linked to this difference is already engaged in secondary and tertiary sector employment, but outside the Lower Mekong Basin area. Considering the current effort of the Thai Government to invest in secondary and tertiary sector in the north-eastern provinces, this would potentially realise the growth potential indicated by the GDP results for 2040 under the “agricultural minimum” assumption. This would require further analysis with appropriate economic modelling. However, workforce and income projections for 2040 indicate that GDP could increase to $101.6 billion under M2 and $98.4 billion under M3. This suggests that also for Thailand the macroeconomic growth potential for M3 drops below the potential of M2.

Vietnam's GDP projections under the "agricultural priority" assumption suggest $71.7 billion for M2 and $72.0 billion for M3. An important difference between Vietnam's Mekong Delta and the other Lower Mekong Basin countries is that agricultural expansion is very small, in parts even negative. Instead, large areas are likely to be converted partly into land uses with higher economic return. This means that even under this assumption, it is likely that labour is released from primary sector employment and available for secondary sector employment. This explains why these results are above the projected trend and assumes that secondary and tertiary sector employment will be realized within the Lower Mekong Basin area. Considering recent developments, it is more likely that large parts of this growth potential will benefit the wider Ho Chi Minh City area due to outmigration from the Mekong Delta. This argument is even more valid for the "agricultural minimum" assumption. This would imply that large agricultural surplus would not be available for export earnings, as labour would be allocated to secondary and tertiary sectors. Considering the outmigration incentive and prevailing income from trading agricultural produce, it is likely that the results for "agricultural minimum" is the more realistic prediction, possibly slightly overestimating realistic growth potential for the delta. From a policy perspective, results emphasise a growth potential for the delta region that could be harnessed by the appropriate investments in secondary and tertiary sector employment and agricultural land uses with high economic profit margins.

Sector contributions to GDP

Economic development trajectories typically imply a reduction of the relevance of agriculture and fisheries as GDP per capita continues to grow. This results from the fact that in the vast majority of cases income from secondary and tertiary sector employment is higher than from agriculture or fisheries. Large-scale enterprises divert from this rule. Typically, when entering the status of a middle-income country, the combined share of agriculture and fisheries in GDP drops under 20%, often under 15%. When developing further into a high-income country, this share would further drop well below 10%.

Table 6: GDP shares for agriculture, fisheries, and hydropower in 2040 under the "agricultural priority" assumption

GDP share in 2040	M2				M3			
	Agriculture	Fisheries	Hydro-power	Rest of Economy	Agriculture	Fisheries	Hydropower	Rest of Economy
Cambodia	18.9%	1.2%	1.2%	78.8%	22.4%	1.3%	2.4%	73.9%
Lao PDR	5.9%	2.0%	4.7%	87.4%	9.0%	0.6%	11.6%	78.7%
Thailand	14.5%	0.9%	4.1%	80.5%	17.1%	0.4%	13.6%	68.9%
Vietnam	9.5%	1.1%	1.5%	87.9%	9.9%	0.4%	2.9%	86.8%

Considering aforementioned GDP and sector projections allows for calculating the future importance of agriculture, fisheries, and hydropower under the various scenarios. Table 16 shows the results for 2040 under the "agricultural priority" assumption. Cambodia would maintain a very large share of the national economy in agriculture, which emphasises that the investments M2 and M3 include for the agricultural sector are likely to be beyond the macroeconomic optimum. The fisheries sector is losing its economic relevance with a share of 1.2% and 1.3%, respectively. Hydropower would increase to 1.2% (M2) and 2.4% (M3), but remain a small sector within the broader perspective of the national economy. Relaxing the labour-related constraint would lead to more realistic shares of Cambodian primary sectors, as Table 17 shows. Agriculture in M3 would drop under 10%, which is a realistic development and characteristic for the transition of labour from primary sector to secondary and tertiary sector employment. Ultimately, this transition is a core characteristic of economic development.

Results for M2 in Lao PDR indicate a substantial drop in the relevance of the agricultural sector even under the assumption of "agricultural priority". However, the additional investments in agriculture as assumed for M3 would increase the share of agricultural production in the national economy from 5.9% for M2 to 9% for M3. For the second situation, which allocates only enough labour to the agricultural sector as required to maintain food security, the agricultural share in the national economy would drop substantially. This assumes that secondary and tertiary sectors would actually grow at a rate that provides substantial new employment opportunities, which requires substantial investments in manufacturing and service sectors as well as the underpinning human and natural capital. Most realistically, the share of agriculture in Lao PDR's national economy is likely to lie between the values shown in Table 16 and Table 17. These tables also suggest that other components of primary industries are likely to decline as the fisheries sector is likely to become marginal and nearly disappear in the M3 scenario. The food security concerns related to this development are analysed in the socioeconomic assessment report.

Table 15: GDP shares for agriculture, fisheries, and hydropower in 2040 under the "agricultural minimum" assumption

GDP share in 2040	M2				M3			
	Agriculture	Fisheries	Hydro-power	Rest of Economy	Agriculture	Fisheries	Hydro-power	Rest of Economy
Cambodia	11.8%	1.0%	1.0%	86.3%	9.4%	0.7%	1.7%	88.2%
Lao PDR	2.2%	1.5%	3.4%	92.9%	1.6%	0.2%	6.0%	92.3%
Thailand	1.2%	0.4%	1.9%	96.6%	1.1%	0.0%	5.5%	93.4%
Vietnam	3.6%	0.8%	1.1%	94.4%	3.9%	0.2%	2.3%	93.7%

Thailand's share of agriculture under the "agricultural priority" assumption is unrealistic as it assumes that workers that are currently employed in secondary and tertiary sectors would transition back into agriculture, which is unlikely to happen due to substantial income differences. The realistic projection is likely to be between the results shown in Table 16 and Table 17, which points out the potential for north-east Thailand to be transformed into an area with high-income status. Results reported in Table 1 support this result. The share of hydropower is increasing substantially, which is likely to be an artefact because the benefits from Lao hydropower have been mapped into north-east Thailand. It needs to be taken into account that most benefiting companies locate in other parts of Thailand. The fisheries sector is likely to lose any economic significance, particularly under the M3 scenario, which highlights potential food security concerns as discussed in the socioeconomic assessment report.

The economic structure of Vietnam's Mekong Delta is likely to change substantially. Under the "agricultural priority" and under the "agricultural minimum" assumptions, the share of agriculture is likely to drop to under 5%. Similar to its upstream neighbours, Vietnam's fisheries sector is likely to lose most of its macroeconomic relevance. These results need to be understood under the constraints explained above: The rest of the economy results assume that the labour force remains in the geographical area of the Mekong Delta. In recent years, high growth rates of secondary and tertiary sectors have been achieved outside the Mekong Delta, involving substantial outmigration. Adding migration to this perspective, projections provided in in Table 16 and Table 17 would need to be corrected and might revert to current shares, based on a decreasing population in the Mekong Delta.

7.4 Assessment tier 3: Sustainability and future growth potential

Over the past four decades, economic policy has increasingly focused on the quality of economic growth instead of only being guided by GDP and GDP growth. This perspective acknowledges that only a small part of human benefits and well-being is represented in market transactions. The vast majority is not represented in market transactions and therefore not captured in GDP. One important dimension in understanding the quality of GDP growth is the understanding of those benefits derived by or available to the communities in the Lower Mekong Basin due to ecosystem services. These ecosystem services are provided for free and are therefore not all captured on markets or in GDP. The loss of these benefits translates either into economic losses (e.g. livelihoods) or requires replacement investments. These benefits include the provision of drinking water, flood protection, and the provision of food.

This assessment consolidated results of economic values of such ecosystem services from all assessments conducted over the past 20 years. Results are categorised for each type of ecosystem, which provides a set of ranges, see Table 18.

Table 16: Ranges of (annual) economic values for main ecosystem types in the Lower Mekong Basin

LMB	MIN	Mean	MAX
Deciduous Forest	$6,665	$13,306	$19,946
Evergreen Forest	$7,241	$17,578	$27,916
Wetlands	$9,906	$12,776	$15,646
Mangrove	$9,692	$20,324	$30,956

This approach gives an indication how ecosystems, their services, and natural capital respond to the development scenarios considered in this assessment. In addition to effect, we need to consider losses in the fisheries that are non-marketed but have economic potential and thereby an economic value. This refers to the proportion of fish stocks that is not caught and does not enter any market transaction or subsidence consumption. From an economic perspective, the remaining fish stocks, in particular juvenile fish and larvae, have an economic value as they constitute next year's catch. Considering this inter-annual value transfer a conservative ratio of 40-60% of catch is assumed as the value of uncaught fish biomass. Table 19 shows the NPV of natural capital in billion US dollars. This considers the ecosystem service component derived from land cover type and from the valuation of total fish stocks.

Table 17: Scenario results for economic value changes (compared with M1) in the LMB as Net Present Value

LMB NPV in B$	MIN	Mean	MAX
M2	-$64	-$105	-$145
M3	-$79	-$110	-$143
M2 (reforestation)	-$37	-$51	-$64
M3 (reforestation)	+$3	+$53	+$102

The comparison of M1 and M2 highlights that the net present value of natural capital is likely to drop between $64 billion and $145 billion, with a mean loss of $105 billion in NPV. This compares to over 5 years of GDP of Cambodia, over 6 years of GDP of Lao PDR, or about 80% of the 2017 GDP of the entire LMB. The results for scenario M3 involve substantial expansions of agricultural area and could lead to a drop of natural capital of about $110 billion if compared with scenario M1. However, most recent discussions with the Cambodian Government have initiated substantial reforestation plans and the

limitation of agricultural expansion to non-forest areas (e.g. old mine sites). This positive shift in Cambodia would trigger a considerable increase of natural capital and future growth potential of around $53 billion LMB-wide for scenario M3 as shown in Table 19.

The effects on natural capital are not evenly distributed if considering location and type of natural resource. Scenario M2 involves a large loss of deciduous forests in Cambodia, which already occurred between 2007 and 2015. Aforementioned reforestation ambitions would see Cambodia's natural capital recovering by around $80 billion if compared with baseline scenario M1. However, this implies an area of 439,000 ha, which seems challenging to reforest given the agricultural expansion plans and the ongoing urbanisation dynamics. Without the ambitious reforestation plans Cambodia would lose up to $83 billion if agricultural expansion plans were to be realised in forest areas, see Table 20. Recent decisions to stop the decline of forest area are economically promising and reforestation plans would increase the potential for third sector growth. Results provided in Table 20 include non-market values of fish stocks, which account in Cambodia for about $4.7 billion for scenario M2 and about $6.3 billion for scenario M3.

Table 18: Results for economic value changes for scenario M2 and M3 as Net Present Value

	Effects for **M2** in B$			Effects for **M3** in B$		
	MIN	Mean	MAX	MIN	Mean	MAX
Cambodia	-$44	-$82	-$120	-$46	-$83	-$121
(*reforestation*)	*-$17*	*-$28*	*-$39*	*+$36*	*+$80*	*+$124*
Lao PDR	-$11	-$12	-$15	-$13	-$14	-$15
Thailand	-$9	-$5	-$2	-$12	-$6	-$3
Vietnam	-$4	-$5	-$7	-$6	-$7	-$5

Lao PDR would experience some losses in natural capital of around $12 billion for M2 and $14 billion for M3. Land use planning based projections indicate large losses in natural capital in form of deciduous forests (M2: $25 billion; M3: $27 billion). However, the same planning assumptions indicate gains in natural capital due to expansions of evergreen forest areas (M2: $13 billion; M3: $16 billion) and wetlands (M2 & M3: $14 billion). Fish stock losses would be substantial (M2: $3.7 billion; M3: $5 billion).

If not considering the fisheries based losses, Thailand is likely to for M2 and M3 experience small gains in natural capital due to plans to expand evergreen forest areas. However, Thailand would suffer the largest absolute loss in fish related to natural capital (M2: $6.4 billion; M3: $8.2 billion), which results in an overall decline in natural capital.

Vietnam is likely to experience similar losses in natural capital as Thailand, which is due to a combination of planned expansion of irrigation area (M2: -$3.6; M3: -$3.6) and fish losses (M2: -$1.7; M3: -$3.2).

8 Sub-scenario assessment results

The main scenarios are defined as composites of various investments that combine changes in hydropower, irrigation, flood prevention, agricultural extension, and climate change. Such composite scenarios make it difficult to attribute effects to particular investments in individual sectors. The Council Study design assumes a series of 13 sub-scenarios. The comparison with main scenario M3CC reveals the sector contribution to the effect related to M3CC. This kind of sensitivity analysis reveals sector-specific implications and guides decision making towards prioritising and fine-tuning development strategies. The following provides a summary of each sub-scenario:

- A1: This sub-scenario assumes that the agricultural sector remains in the development state of 2007, while all other sectors are being expanded as assumed under M3CC.
- A2: For this scenario, it is assumed that the agricultural sector is being expanded even further than assumed for M3CC, while all other sectors are being developed to the planned development state of 2040.
- I1: This sub-scenario assumes that irrigation investments are not being made and that irrigation areas remain at the state of 2007, while all other sectors change to the state of 2040.
- I2: Similar to A2, this sub-scenario assumes additional expansion of irrigation areas beyond what is assumed for M3CC, while all other sectors change to the state assumed for M3CC.
- C2: For this sub-scenario, it is assumed that the period until 2040 will turn out to be wetter than assumed for M3CC.
- C3: For this sub-scenario, we assume a dryer climate than for M3CC.
- F1: This sub-scenario assumes that no investments in flood protection are being carried out (compared with 2007), while all other sectors are being developed according to M3CC.
- F2: This sub-scenario assumes additional urban flood protection and flood plain management.
- F3: This sub-scenario assumes in addition to urban protection and floodplain management also joint operation of mainstream dams and selected tributary dams.
- H1a assumes a situation without any hydropower in the Lower Mekong Basin.
- H1b assumes a situation in which all tributary dams would exist as defined in scenario M3CC (the 2040 development situation) but no mainstream dam would be build.
- H2 assumes the same level of hydropower development as assumed for M3.
- H3 defines a situation in which the operation and management of all mainstream dams is coordinated with all features of sustainable hydropower development, including regular coordinated flushing programs and effective fish ladders.

Sub-scenarios are based on the main scenario M3CC, which assumes the development status assumed for 2040 including a moderately wetter and warmer climate. The multi-sector changes M3CC entails are now being varied one by one, to reveal the impact of individual sectors. For instance, sub-scenarios H1a and H1b modify the assumed investment in hydropower expansion and shows how indicators such as GDP are affected. It is important to emphasise that the variations the sub-scenarios assume below do not go down to the project level. From a planning perspective, it would be most useful to understand which individual project has the highest benefit and which is likely to be most damaging. The sub-scenarios do not disaggregate scenarios to such a project level. Rather, they continue to assume larger bundles within sectors (e.g. multiple dams for the hydropower sector) and compare situations with and without such bundles of projects. As such, this approach allows attributing impacts to individual sectors but not to individual projects within each sector.

8.1 Sector-specific assessments

Hydropower

The most relevant sub-scenarios for the hydropower sector are H1a, H1b, H2, and H3 as these sub-scenarios assume different levels of investments in the hydropower sector. However, also other sub-scenarios have impacts on economic benefits generated by the hydropower sector, which raises the importance of cross-sector trade-offs and synergies. These cross-sector links are in more detail analysed by the cumulative impact assessment.

Table 19: NPV of the hydropower sector in billion US$ for ten sub-scenarios

Difference to M3CC in $B	Lao PDR B$	Thailand B$	Cambodia B$	Vietnam B$	LMB B$
A1 - M3CC	-$1.0	$0.0	$0.0	$0.0	-$1.0
A2 - M3CC	-$1.0	$0.0	$0.0	$0.0	-$1.0
C2 - M3CC	-$0.7	$1.2	$0.1	$0.0	$0.6
C3 - M3CC	-$2.1	-$1.9	-$0.2	-$0.3	-$4.5
I1 - M3CC	-$0.6	$0.6	$0.0	$0.2	$0.3
I2 - M3CC	-$1.1	-$0.2	$0.0	$0.0	-$1.4
H1a - M3CC	-$36.1	-$81.1	-$11.9	-$26.7	-$155.7
H1b - M3CC	-$17.1	-$61.8	-$4.4	-$15.2	-$98.4
H2 - M3CC	-$2.0	-$1.7	$0.0	-$0.2	-$3.8
H3 - M3CC	-$0.5	$5.7	$0.0	-$0.4	$4.8

Table 21 provides an overview of all sub-scenarios and how each variation is likely to impact on hydropower related benefits for all lower Mekong countries. This perspective compares the NPV for scenario M3CC with the NPV resulting under the assumptions of each sub-scenario. The agricultural variations under sub-scenario A1 and A2 cause a decline of $1 billion in hydropower benefits in Lao PDR. Thailand, Cambodia, and Vietnam are likely to experience only marginal impacts on hydropower benefits.

M3CC assumes a particular trajectory of climate change, which implies more seasonal effects and overall somewhat wetter and warmer conditions. The underpinning science emphasises the uncertainty of these assumption and the importance of scenario ranges. Sub-scenarios C2 and C3 acknowledge these uncertainties and assume, compared to M3CC, wetter and drier conditions, respectively. Sub-scenario C2 is likely to improve the conditions for hydropower-related benefits in Thailand, Cambodia, and Vietnam, but the economic benefit in Lao PDR declines by $0.8 billion. Drier conditions as assumed for sub-scenario C3 are likely to aggravate losses for Lao PDR if compared with M3CC (-$2.1 billion in NPV). Such drier climate change would also have a large impact on Thailand and could create a loss of up to $1.9 billion in NPV. Cambodia and Vietnam would also incur losses of $0.2 billion and $0.3 billion, respectively.

Variations in irrigation-related investments as defined by I1 and I2 would both cause lower returns from hydropower investments for Lao PDR, $0.6 billion for I1 and $1.1 billion for I2. Thailand's hydropower sector is likely to gain $600 million under I1 and lose $1.2 billion under I2, as shown by Table 21. Vietnam's hydropower sector would also benefit from I1 ($200 million) but would not be affected by I2. Cambodia's hydropower sector is likely to incur only marginal changes due to I1 and I2.

The core sub-scenarios for the hydropower sector are H1a, H1b, H2, and H3. Table 21 highlights that the main beneficiary of hydropower investments in the M3CC scenario is Thailand, with a NPV of economic benefits of $81.1 billion. Sub-scenario H1a assumes that all other investments are being carried out, but only hydropower remains at the level of 2007. This assessment puts hydropower benefits in Lao PDR second, which implies that reverting hydropower to the situation of 2007 would lower the overall benefit of M3CC by $36.1 billion. Vietnam would likely be losing 26.7 billion and Cambodia 11.9 billion. These values can be compared with the impact of M3CC as shown in Table 13. While the results in Table 13 quantify the impact of M3CC compared with M1, the results presented in Table 21 assumes that investments are taking place in all sectors apart from hydropower.

Sub-scenario H1b defines a situation in which only tributary dams are being realised in conjunction with all investments in the other focus sectors. The comparison of M3CC and H1b quantifies the economic impact of mainstream dams. The NPV of mainstream dams is substantial for the overall Lower Mekong Basin, as Table 21 shows. The combined NPV of economic returns from mainstream hydropower in the lower Mekong countries, without considering negative externalities, is $98.4 billion. This highlights the economic gravity of these projects from an investor's point of view. The side effects for fisheries and other sectors are typically not incorporated and will be discussed below. However, sub-scenario H3 assumes additional mitigation investments to reduce external effects caused by mainstream hydropower. Thus, these two sub-scenarios should be seen in combination.

Table 21 quantifies that the NPV in Thailand's hydropower sector would decline by about $61.8 billion, followed by Lao PDR ($17.1 billion) and Vietnam ($15.2 billion). Strikingly, sub-scenario H3 suggests that despite the installation of mitigation measures (e.g. fish ladders) and the implementation of sustainable operation procedures (e.g. regular sediment flushing), economic returns from hydropower would increase LMB-wide by about 4.8 billion. This surprising effect would largely benefit Thailand ($5.7 billion), while creating smaller losses in Lao PDR and Vietnam. This suggests that H3 might be an essential part of a sustainable development strategy if mitigation measures would indeed reduce negative externalities. This is considered in the following section on fisheries.

Fisheries

The comparison of the 13 sub-scenarios (see Table 22) allows for a sensitivity analysis and reveals which investments are likely to have the largest impacts on fish stocks and thereby on the NPV of the fisheries sector. Sub-scenario H1 has the largest positive impact and quantifies that the combined fisheries sectors in the Lower Mekong Basin could generate up to $70.6 billion in NPV if hydropower was not expanded beyond the 2007 situation. Table 23 emphasises this positive effect and shows that the fisheries sector in Lao PDR would increase by 124.2%. The fisheries sector in Thailand would nearly double its NPV.

Table 20: Economic benefit of the fisheries sector under the 13 sub-scenarios as NPV for the 24-year period in B$

in B$	**A1** no ALU	**A2** 2020	**C2** Wet	**C3** Dry	**I1** no IRR	**I2** high IRR	**F1** no FPI	**F2** FPI	**F3** FPI	**H1a** no HPP	**H1b** no Main	**H3** HPP
Cambodia	23.6	23.8	24.4	20.2	24.6	23.9	24.7	24.6	25.5	**30.1**	25.9	25.9
Lao PDR	3.2	3.2	3.2	3.0	3.2	3.2	3.3	3.2	3.2	**7.2**	5.3	3.3
Thailand	6.6	6.7	6.7	6.2	6.7	6.7	6.7	6.6	6.6	**13.1**	9.7	6.7
Vietnam	17.8	17.2	17.6	16.9	17.4	17.3	17.3	16.9	17.1	**20.2**	18.9	17.7
LMB	51.3	50.9	51.9	46.2	51.9	51.1	52.1	51.4	52.4	**70.6**	59.8	53.6

Table 22 shows that without any mainstream dams, but all tributary dams developed as planned for 2040 (H1b), the NPV is likely to range around $59.8 billion, which means that mainstream dams will cost the fisheries sector about $11 billion in NPV. The NPV of the fisheries sector in Lao PDR would increase by about 63.9% and in Thailand by 46.2%.

The assumption of joint operation of mainstream dams, including regular flushing programs and effective fish passages, would mitigate some of the losses triggered by M3CC. This analysis quantifies the NPV of the mitigation effect at about $2.4 billion, which leaves the fisheries sector with a total NPV of about $53.6 billion, about 4.7% more than under M3CC. The comparison of H3 and H1a shows that the fisheries losses in NPV would be about $17 billion, which compares the 2007 situation with the 2040 situation including mitigation measures.

Two interesting observations are worthwhile pointing out, see Table 23. First, measures assumed under H3 have the same effect on Cambodia's fisheries sector as not building any mainstream dams. The BioRA report explains that while the population of white and black fish drops substantially with the construction of mainstream dams (even with improved management assumptions under H3), the biomass of non-natives and grey fish increases even further, especially with the improved dam management of sub-scenario H3. The second surprising effect is that sub-scenario H3 adds to the negative impact of M3CC on Vietnam's fisheries sector. The BioRA report clarifies for this comparison that H3 would allow for a larger population of white fish but grey and black fish, marine and estuary fish, and non-natives would experience a further drop in biomass under H3 if compared with M3CC.

Table 21: Economic benefit changes in % of fisheries sector income compared to M3CC

%→M3CC	**A1** no ALU	**A2** 2020	**C2** Wet	**C3** Dry	**I1** no IRR	**I2** high IRR	**F1** no FPI	**F2** FPI	**F3** FPI	**H1a** no HPP	**H1b** no Main	**H3** HPP
Cambodia	+0.1%	+0.7%	+3.3%	-14.6%	+4.2%	+1.3%	+4.8%	+4.4%	+8.2%	**+27.5%**	+9.6%	+9.6%
Lao PDR	+0.5%	+0.5%	+0.7%	-7.9%	+0.6%	+0.5%	+1.3%	0.0%	-0.3%	**+124.2%**	+63.9%	+2.5%
Thailand	-0.2%	+0.6%	+0.6%	-7.2%	+0.2%	+0.5%	+1.4%	0.0%	-0.3%	**+97.3%**	+46.2%	+1.6%
Vietnam	+0.3%	-2.6%	-0.9%	-4.4%	-1.5%	-2.2%	-2.2%	-4.4%	-3.7%	**+13.8%**	+7.0%	-0.2%
LMB	+0.7%	-0.5%	+1.4%	-9.7%	+1.5%	-0.1%	+1.7%	+0.5%	+2.4%	**+37.9%**	+16.9%	+4.7%

Climate change–focused sub-scenarios reveal that climate is the second most important driver. The assumption of drier climates would have a substantial effect on the fisheries sector, as shown by Table 22 and Table 23 (column C3). The largest losses are likely to occur in Cambodia, where the fisheries sector could experience losses of up to 14.6%. This risk is important for any resilience analysis (see report on the cumulative impact assessment) and needs to be considered in any robust investment plan.

The fisheries sectors of the Lower Mekong Basin are likely to experience gains if the climate turns out to be wetter than assumed under M3CC, as quantified in Table 22 and Table 23. Again, Cambodia would see the largest impact with 3.3% increase of its sectoral NPV. Vietnam would experience a decline of 0.9% if compared with M3CC, due to a loss in marine fish and non-natives (see BioRA report).

Impacts of other sector investments on fisheries are small if compared with hydropower and climate change. Worth mentioning are positive impacts of changes in flood protection and changes in irrigation investments on the NPV of fisheries in Cambodia.

Agriculture

Four sub-scenarios have been considered for the assessment of impacts on the agricultural sector. The sub-scenario A1 assumes no expansion of agricultural activities beyond the situation of 2007. Table 24 indicates that if compared with scenario M3CC, the NPV of agriculture in the lower Mekong Basin would be about $111.3 billion lower. This emphasises the relevance of the agricultural sector and the weight of investments in the current development plans. The above assessment of main scenarios highlight the relevance of workforce demands that would constrain secondary and tertiary sectors, which typically grow faster than agriculture. This dimension will be further discussed below as this investment priority affects overall GDP growth.

Table 22: Economic benefit changes in % of fisheries sector income compared to M3CC

	A1 Difference		A2 Difference		I1 Difference		I2 Difference	
	B$	%	B$	%	B$	%	B$	%
Cambodia	-$70.0	-54.1%	+10.1	+7.8%	-$7.5	-5.8%	0.0	0.0%
Lao PDR	-$5.9	-12.3%	+15.3	+31.8%	-$5.9	-12.2%	+0.2	+0.5%
Thailand	-$9.9	-6.3%	0.0	0.0%	-$9.6	-6.1%	+2.4	+1.5%
Viet Nam	-$25.3	-20.2%	0.0	0.0%	$3.1	2.5%	0.0	0.0%
LMB	-$111.2	-24.1%	+25.4	+5.5%	-$19.8	-4.3%	+2.7	+0.6%

Sub-scenario A2 shows that the additional agricultural expansion would largely eventuate in Lao PDR and Cambodia, and would facilitate an increase in NPV of $15.3 billion and $10.1 billion, respectively. In relative terms, this change is substantial for Lao PDR as it increases the economic benefits in agriculture by nearly one third if compared with M3CC. However, these sector-specific advantages can impose a macroeconomic growth constraint due to higher labour demands.

The irrigation-focused sub-scenarios paint a very similar picture. Reverting the irrigation expansion to the situation of 2007, while developing all other sectors according to the assumptions of scenario M3CC, creates a difference of $19.8 billion. Surprisingly, avoiding these investments translates into a gain for Vietnam, which suggests that the costs of irrigation expansion are likely to outweigh the economic benefits by $3.1 billion in NPV.

Sub-scenario I2 sheds light on the option to increase investments into irrigation even further than defined by scenario M3CC. Thailand shows potential for further increasing economic benefits. However, these results are highly sensitive to the assumptions on costs for installing new irrigation areas. For this particular element of the council study cost information had to be derived from existing areas in absence of detailed studies of the irrigation extensions, which is not particular robust as new areas typically come at higher costs. Irrigation investments that go beyond M3CC assumptions do not seem to be promising for the other three Lower Mekong Basin countries, as Table 24 shows.

8.2 Cross-sector comparison

The comparison of all four sectors shows which investments have the largest economic effects. Focussing on these sectors and assessing individual projects would help identifying the most beneficial or the most harmful or risky investments. Table 25 shows on top the NPV for hydropower, fisheries, agriculture and navigation under main scenario M3CC in billion dollars. Below these shaded rows results are listed for all sub-scenarios as absolute difference to M3CC in billion dollars. The bold numbers are based on actual modelling of the respective sub-scenario. All other numbers are assumed to be identical or very similar to main scenario M3 in absence of specific modelling.

Table 25 confirms that the NPV of agriculture for scenario M3CC outweighs the other three sectors, even the NPV of hydropower. Focussing on the effects on sub-scenarios as a way to identify the relevance of single-sector variations reveals that proposed variations in the hydropower sector as defined by H1a, H1b, and H3 are likely to have the largest economic effect on the Lower Mekong Region if compared with M3CC. Considering the relevance of the hydropower sector, it is likely that the bundles of hydropower projects included in M3CC and the three sub-scenarios include a combination of economically highly beneficial and unbeneficial projects. Hence it seems important to conduct a project-level assessment and identify the best combination of projects for basin development planning. There is clear indication that from a narrow hydropower sector perspective, some projects are likely to create negative NPVs while others are likely to have (small) positive NPV, but cause larger negative externalities (or losses) in fisheries and potentially other sectors. Then again, there is likely to be hydropower projects with substantial economic benefits that outweigh all negative externalities. Distinguishing these three groups is essential for designing sustainable development plans.

Economic effects of agricultural expansion are also relevant, as Table 25 indicates, particularly for Cambodia and Lao PDR. The large effects emerging from sub-scenario A1 have to be taken with caution as large parts of potential increases in NPV are likely to be unrealistic if one considers the labour demand in the macroeconomic context.

Climate change emerges as the third priority with important impacts on fisheries. It can be expected that effects would also be substantial for agricultural production, which has not been modelled. Irrigation could be identified as a fourth priority of economic development in the Lower Mekong Basin.

Overall the majority of variations are likely to lead to lower economic returns from a narrow sector perspective if compared with M3CC. From a country perspective, some sub-scenarios are likely to increase the combined NPV across these four sectors, even further to what M3CC is likely to provide. This includes in particular sub-scenario A2 for Lao PDR and Cambodia, and H3 for Thailand and Cambodia. However, as explained for the main scenarios, these narrow sector results establish only the first assessment tier, and considering the next two assessment tiers is fundamental for sustainable development planning.

Table 23: Changes in NPV for hydropower, fisheries, agriculture, and navigation compared to M3CC (values for M3CC are provided as absolute values)

		Hydropower	Fisheries	Agriculture	Navigation	SUM	
M3CC	Cambodia	**11.9**	**23.6**	129.5	8.5	173.5	
	Lao PDR	**37.9**	**3.2**	48.2	1.9	91.4	
	Thailand	**81.5**	**6.6**	158.9	2.9	250.0	
	Vietnam	**31.8**	**17.7**	125.0	55.5	230.1	
A1	Cambodia	**0.0**	**0.0**	**-70.0**	0.0	-70.0	-40.4%
	Lao PDR	**-1.0**	**0.0**	**-5.9**	0.0	-6.9	-7.6%
	Thailand	**0.0**	**0.0**	**-9.9**	0.0	-10.0	-4.0%
	Vietnam	**0.0**	**0.1**	**-25.3**	0.0	-25.2	-11.0%
A2	Cambodia	**0.0**	**0.2**	**10.1**	0.0	10.3	5.9%
	Lao PDR	**-1.0**	**0.0**	**15.3**	0.0	14.3	15.7%
	Thailand	**0.0**	**0.0**	**0.0**	0.0	0.0	0.0%
	Vietnam	**0.0**	**-0.5**	**0.0**	0.0	-0.5	-0.2%
C2	Cambodia	**0.1**	**0.8**	0.0	0.0	0.9	0.5%
	Lao PDR	**-0.7**	**0.0**	0.0	0.0	-0.7	-0.7%
	Thailand	**1.2**	**0.0**	0.0	0.0	1.2	0.5%
	Vietnam	**0.0**	**-0.2**	0.0	0.0	-0.1	-0.1%
C3	Cambodia	**-0.2**	**-3.4**	0.0	0.0	-3.6	-2.1%
	Lao PDR	**-2.1**	**-0.3**	0.0	0.0	-2.3	-2.5%
	Thailand	**-1.9**	**-0.5**	0.0	0.0	-2.4	-1.0%
	Vietnam	**-0.3**	**-0.8**	0.0	0.0	-1.0	-0.5%
I1	Cambodia	**0.0**	**1.0**	0.0	0.0	1.0	0.6%
	Lao PDR	**-0.6**	**0.0**	0.0	0.0	-0.6	-0.6%
	Thailand	**0.6**	**0.0**	0.0	0.0	0.7	0.3%
	Vietnam	**0.2**	**-0.3**	0.0	0.0	-0.1	0.0%
I2	Cambodia	**0.0**	**0.3**	**0.0**	0.0	0.3	0.2%
	Lao PDR	**-1.1**	**0.0**	**0.2**	0.0	-0.9	-1.0%
	Thailand	**-0.2**	**0.0**	**2.4**	0.0	2.2	0.9%
	Vietnam	**0.0**	**-0.4**	**0.0**	0.0	-0.4	-0.2%
F1	Cambodia	0.0	**1.1**	0.0	0.0	1.1	0.7%
	Lao PDR	0.0	**0.0**	0.0	0.0	0.0	0.0%
	Thailand	0.0	**0.1**	0.0	0.0	0.1	0.0%
	Vietnam	0.0	**-0.4**	0.0	0.0	-0.4	-0.2%
F2	Cambodia	0.0	**1.0**	0.0	0.0	1.0	0.6%
	Lao PDR	0.0	**0.0**	0.0	0.0	0.0	0.0%
	Thailand	0.0	**0.0**	0.0	0.0	0.0	0.0%
	Vietnam	0.0	**-0.8**	0.0	0.0	-0.8	-0.3%
F3	Cambodia	0.0	**1.9**	0.0	0.0	1.9	1.1%
	Lao PDR	0.0	**0.0**	0.0	0.0	0.0	0.0%
	Thailand	0.0	**0.0**	0.0	0.0	0.0	0.0%
	Vietnam	0.0	**-0.7**	0.0	0.0	-0.7	-0.3%
H1a	Cambodia	**-11.9**	**6.5**	0.0	0.0	-5.4	-3.1%
	Lao PDR	**-36.1**	**4.0**	0.0	0.0	-32.1	-35.1%
	Thailand	**-81.1**	**6.5**	0.0	0.0	-74.6	-29.8%
	Vietnam	**-26.7**	**2.5**	0.0	0.0	-24.2	-10.5%
H1b	Cambodia	**-4.4**	**2.3**	0.0	0.0	-2.2	-1.2%
	Lao PDR	**-17.1**	**2.1**	0.0	0.0	-15.1	-16.5%
	Thailand	**-61.8**	**3.1**	0.0	0.0	-58.7	-23.5%
	Vietnam	**-15.2**	**1.2**	0.0	0.0	-13.9	-6.0%
H2	Cambodia	**0.0**	**1.2**	0.0	0.0	1.2	0.7%
	Lao PDR	**-2.0**	**0.0**	0.0	0.0	-2.0	-2.1%
	Thailand	**-1.7**	**0.0**	0.0	0.0	-1.6	-0.6%
	Vietnam	**-0.2**	**-0.4**	0.0	0.0	-0.5	-0.2%
H3	Cambodia	**0.0**	**2.3**	0.0	0.0	2.2	1.3%
	Lao PDR	**-0.5**	**0.1**	0.0	0.0	-0.4	-0.5%
	Thailand	**5.7**	**0.1**	0.0	0.0	5.8	2.3%
	Vietnam	**-0.4**	**0.0**	0.0	0.0	-0.4	-0.2%

8.3 Assessment tier 2: Macroeconomic assessment

The assessment of main scenarios considers three tiers, which explained that some investments seem positive at the level of individual sectors, while macroeconomic effects are likely to be negative or impacts on future growth potential (involving natural capital) are likely to be negative. This section applies the macroeconomic perspective as the second assessment perspective to sub-scenarios.

Table 24: GDP range projections for 13 sub-scenarios

GDP difference (M3CC) in billion US$ (deflated to 2017 dollar)		A1 (2007)	A2 (2020)	C2 (Wet)	C3 (Dry)	I1 (no IRR)	I2 (IRR)	F1 (no FPI)	F2 (FPI)	F3 (FPI)	H1a (noHPP)	H1b (noMain)	H3 (HPP)
Cambodia	Upper bound	$2.9	-$0.9	-$1.4	-$1.5	-$1.1	-$1.7	-$0.8	-$0.5	-$0.8	$0.9	$0.0	-$0.2
	Average	$9.5	$2.3	$2.1	$2.3	$2.4	$1.8	$0.9	$1.0	$1.1	$1.7	$1.1	$1.0
	Lower bound	$16.1	$5.5	$5.7	$6.0	$5.8	$5.4	$2.7	$2.4	$3.0	$2.5	$2.2	$2.2
Lao PDR	Upper bound	-$0.5	$0.3	$0.0	$0.2	$0.3	$0.1	$0.2	$0.2	$0.2	$3.7	$1.9	$0.1
	Average	$6.0	-$0.1	$0.3	$0.4	-$0.1	-$0.2	$0.1	$0.1	$0.1	$2.2	$0.6	$0.0
	Lower bound	$12.4	-$0.5	$0.6	$0.6	-$0.4	-$0.6	$0.0	$0.0	$0.0	$0.6	-$0.8	-$0.1
Thailand	Upper bound	-$0.3	$0.2	-$0.1	$0.1	$0.2	$0.1	$0.0	$0.2	$0.0	$5.6	$4.4	-$0.3
	Average	$7.8	-$1.4	$0.7	$0.5	-$1.5	-$1.5	$0.0	$0.1	$0.0	$2.7	$1.6	-$0.1
	Lower bound	$15.9	-$3.0	$1.6	$0.9	-$3.2	-$3.0	$0.0	$0.0	$0.0	-$0.2	-$1.2	$0.1
Vietnam	Upper bound	$0.4	-$0.1	-$0.5	-$0.4	-$0.5	-$0.4	-$0.3	-$0.1	-$0.3	$1.4	$0.7	$0.1
	Average	$3.1	$2.8	$2.4	$2.6	$2.5	$2.5	$1.4	$1.6	$1.6	$2.6	$2.7	$0.8
	Lower bound	$5.8	$5.7	$5.4	$5.6	$5.4	$5.5	$3.1	$3.3	$3.4	$3.7	$4.7	$1.6
LMB	Upper bound	$2.4	-$0.5	-$2.0	-$1.6	-$1.1	-$2.0	-$0.9	-$0.2	-$0.9	$11.7	$7.0	-$0.4
	Average	$26.4	$3.5	$5.6	$5.8	$3.3	$2.7	$2.5	$2.7	$2.8	$9.2	$6.0	$1.7
	Lower bound	$50.4	$7.6	$13.3	$13.1	$7.6	$7.3	$5.8	$5.7	$6.4	$6.7	$5.0	$3.8

Table 1 in the Executive Summary quantifies *absolute* GDP estimates for year 2040 for all main and sub-scenarios. Table 26 shows the *difference* between GDP projections for M3CC and all 12 sub-scenarios. The difference indicates if a particular sector investment is likely to shift the GDP range up or down, or if the GDP range widens or narrows down. Any shift up is positive as the macro-economic conditions improve. If the lower bound drops the risks are likely to increase. Consistent with Table 1, "lower bound" refers to the situation of utilising (or maximising) agricultural production capacity (in form of allocated land area). The "upper bound" of GDP growth potential refers to the situation in which labour is only allocated to the agricultural sector to maintain food security. As explained in earlier sections, the reality is likely to be between these two values, which is estimated by the average value. This simple method was applied in absence of appropriate economic modelling that would simulate GDP projections more robustly.

Table 26 provides a few insights. First, M3CC is likely to assume excessive investments in agricultural expansion. Focussing on strategies that expand secondary and tertiary sectors seems more effective, as column A1 suggests.

Second, the bundle of hydropower projects included in M3CC seems to result in more macroeconomic costs than benefits. This important assessment result has to be taken with caution as it assumes that electricity demands are met even if hydropower projects are not met. The growth projections employed by this method are mainly based on labour input. This implies that energy demands of secondary and tertiary sector growth are being met. This means that if hydropower projects are not being realised, other power generation options are being provided to allow for the economic growth. Otherwise the values provided in column H1a are not realistic. However, these values indicate a substantial macroeconomic growth potential if other energy sources are put in place. In other words, an alternative energy could cost up to $9.2 billion more than hydropower if it doesn't include side effects (see column

H1a in Table 26). It would be sensible to define and assess sub-scenarios with alternative power generation technologies and understand their side effects and their macroeconomic implications. Most likely, a combination of selected planned hydropower projects and alternative power generation options would lead to higher economic returns and to more sustainable outcomes. The comparison of H1a, H1b, and H3 with the main scenarios (see also Table 1) suggest that several hydropower projects embedded in the large bundles assumed for M2 and M3 are likely to be very beneficial, while others are likely to incur higher costs than benefits.

The combination of reduced agricultural expansion and reduced hydropower seems to converge to a macroeconomic optimum for all Lower Mekong Basin countries. It is surprising that from a macroeconomic perspective all four countries seem to benefit from similar changes, which indicates a much lower trade-off potential than widely expected.

8.4 Assessment tier 3: Quality of growth for the sub-scenario perspective

The third assessment tier introduces non-market values as shown for the main scenarios. Most sub-scenarios are likely to have some level of impact on ecosystems and ecosystem services. However, the assessment framework focuses on larger land use changes, which shifts the attention to sub-scenario A2. This sub-scenario assumes higher levels of agricultural expansion, but at the same time it also aims to focus on a more sustainable development. The proposed land use change plans were adjusted in regards to suitability and availability for maximal agricultural expansion to scope the limit for this sector. This approach converted into changes only for Lao PDR and Cambodia as shown in Table 27.

Table 25: Changes between scenario M3 and sub-scenario ALU 2 in area under forest, agriculture, and rice

	Forest (Excl. Wood and Shrub land)	Agriculture	Paddy Rice
Cambodia	(0)	+378,565	+257,873
Lao PDR	(0)	+266,630	+19,783

This approach suggests that forest areas in Lao PDR and Cambodia would remain unchanged. Fisheries, however, would be affected and thereby the fish-based dimension of natural capital. Based on DRIFT model results provided by the BioRA team (see sector assessment for sub-scenario A2), a natural capital loss of $900 million in NPV emerges for Vietnam if compared with the M3CC scenario. Cambodia would increase its NPV by $300 million and Thailand by $100 million, while Lao PDR would remain unchanged.

9 Implications

The above assessment considers scenarios M2 and M3 as compound scenarios that entail a variety of changes across multiple sectors. In addition, a series of 13 sub-scenarios are assessed to filter out the contribution of individual sectors. The results suggest a few policy implications.

First, the hydropower-focused interventions considered by the selected scenarios have the strongest influence on economic indicators. From a narrow sector perspective, growth potential seems substantial and substantially larger than any other investment considered in the list of development strategies included in the Council Study. However, realising this economic potential comes at a cost as the following points explain.

Second, substantial trade-offs need to be expected in the fisheries sector, which is likely to increase food security risks for various areas in the Lower Mekong Basin. The socioeconomic assessment report provides a deeper analysis of the food security risks and which areas are particularly at risk.

Third, a few key transboundary effects impact on the economic performance of the hydropower and fisheries sector. Within the hydropower sector, substantial benefits occur across the border as the import of cheap electricity generate large economic gains in Thailand and Vietnam. Lao PDR and Cambodia, the host countries of mainstream and tributary dams, are likely to receive the smaller fraction of economic returns. However, also the negative transboundary effect hydropower would have on the fisheries sector affects Thailand and Vietnam substantially, and would not remain constrained to Lao PDR and Cambodia, the host countries of hydropower development. Mitigation investments in coordinated fishing programs or fish ladders would therefore also benefit mostly Thailand and Vietnam. However, the remaining economic effects would still be substantial, and a narrow economic perspective is likely to distract from critical losses in food security for some areas along the Mekong, especially in Lao PDR and Cambodia as the socioeconomic report explains. Those areas that depend on fisheries and that will not benefit from the development changes would be hit the hardest, as their income would not replace the subsidence basis of their food security. This distributional effect entails the shift of economic benefits between different population segments, away from rural subsistence-based income receivers to those that are employed. Typically, the secondary effect is livelihood-driven and would involve many moving from rural areas into urban and peri-urban areas, a phenomenon that has been observed for more than three decades across Asia. Clearly, these ripple effects cannot be captured in the limited methodology employed during this study. However, migration, livelihoods, and poverty are key dimensions for the design of sustainable development programs.

Third, agricultural expansion seems to have very positive effects to a certain point. Expanding agriculture beyond that point is likely to impose constraints on secondary and tertiary sectors as increasing numbers of workers would be needed to convert the investments into economic growth. Thus, two possible situations unfold: Either the workforce does indeed stay in primary sector employment and cultivate the newly developed land, or the workforce follows monetary incentives and seeks employment in secondary and tertiary sectors where income levels are typically substantially higher. The first situation would slow down the macroeconomic growth, as labour is less available for faster growing secondary and tertiary sectors. These levels of investments in agriculture would therefore create substantial losses for the national economies. This type of situation is less likely to evolve because of the income incentives households perceive to work in manufacturing or service industries. Supplementary lifestyle reasons add to the incentive for younger generations to seek employment outside the agricultural sector. This second situation is a typical pattern of economic

development. However, excessive expansions of agricultural activities would mean that substantial parts of the new area would lack the necessary workforce for cultivation. Even mechanisation is not always an option for utilising the new investments efficiently, especially where land titles and cultural impediments make farm consolidation processes difficult. Northeast Thailand is an example for such agricultural expansion that replaced large forests for agricultural land, which is now partly not cultivated because of the lack of workforce, as younger people work in the manufacturing or service industry where they earn higher salaries. Now, Thailand invests in reforestation because with the increasing average income and the increasing urbanisation, people seek recreation in natural environments. These reforestation programs are very expensive. Understanding the effects of excessive expansion of agricultural areas would allow avoiding the costs and maintaining income opportunities in the tourism sector, which emerge with higher average income. This experience is connected to the fourth key result of this study.

Fourth, natural capital is essential for most economic activities but is in most cases not adequately considered in economic decision making. This is mostly because the economic costs and benefits eventuate indirectly, as explained in an earlier section. Results from this study suggest that the NPV of these losses (for a 24-year period) are likely to be as high as 56% of the GDP of the entire Lower Mekong Basin in 2017. The majority of these losses occurred between 2007 and 2015 due to agricultural expansion. Maintaining the natural capital would provide in the mid-term the critical basis for recreational activities, which will facilitate substantial income gains once the average income in Lao PDR and Cambodia increases. Already now there are many indicators for an increasing momentum of domestic tourism in both countries as income levels increase. Cambodia and Lao PDR consider substantial agricultural expansion in their planning, which are likely to have negative macroeconomic effects due to the workforce mechanism described above. Diverting these investments into the sustainable development of tourism (or other tertiary sector activities) is likely to provide higher economic gains for both national economies. Reforestation is likely to create additional benefits and improve future growth potential. The policy implication might be to select areas that are most efficient for agricultural production and those that are likely to provide the basis for tourism in the near future. The agricultural planning would benefit from a macroeconomic analysis of workforce trajectories and future livelihood scenarios. Cambodia and Lao PDR have the chance to avoid mistakes many countries made over the past decades.

Fifth, trade-related activities are likely to experience substantial growth as the navigation-related study suggests (see for details the navigation assessment report). The improvement of infrastructure is clearly a development strategy that needs a detailed analysis. Where environmental impacts can be avoided or mitigated, the Lower Mekong Basin countries are likely to generate substantial economic growth, in particular Vietnam. Environmental damages, however, are likely to add to the pressure of other sectors, hydropower in particular. Resulting cumulative effects for fisheries and the broader environment would exacerbate food security risks. Realising this economic trade potential efficiently and sustainably requires all four countries to cooperate, for which the MRC facilitated planning process provides an effective frame. In many other development situations trade growth was accelerating where the value-add of exports increased, which is another reason to prioritise secondary sector development over primary sector investments. The increasing value of exported goods would accelerate the growth in the navigation sector and other trade-focused sectors because of the lower cost proportion of the actual transportation. The current focus on the development of railway infrastructure emphasises the need and potential for trade and waterborne transport options have a clear cost advantage, as the navigation report explains.

10 Data gaps and contents of future study

In an ideal situation, these kinds of macroeconomic assessments would demand a methodology that is able to capture (1) cross-sector dynamics and (2) feedbacks between social, economic, and environmental variables. From an economic perspective, cross-sector dynamics are largely based on the fact that multiple sectors require the same input resources, including labour, capital, and land. This means that increasing demands by one sector for any of these inputs could increase prices and/or reduce availability of this input for other sectors. In addition to this connectivity through inputs, sectors are also connected as outputs of one sector become inputs of other sectors. Typically, these dynamics require either Computable General Equilibrium models (if defined highly aggregated from the top down) or agent-based modelling (if defined highly disaggregated from the bottom up). Depending on the methodology of choice, substantial data gaps would emerge for the Lower Mekong Basin.

The second important connectivity macroeconomic assessments would need to address concerns the feedbacks between environmental, social, and economic variables. For instance, the loss of forest goes often hand in hand with in- and out-migration, depending on the how requirements for certain livelihoods change. Migration is the critical driver for urbanisation or deforestation, which again is highly important for environmental conditions including water. These rather complex ripple effects require more advanced methodology, such as agent-based modelling.

The current approach is limited to spreadsheet tools that make some very simple assumptions about aforementioned dynamics. The main inputs for these spreadsheet tools for baseline, main scenarios, and all sub-scenarios are provided by

- the modelling team for hydrological conditions,
- the BioRA team for fisheries, and
- the socioeconomic team for household level changes.

One data gap emerged for fisheries, as the DRIFT model only provides percentage changes without an absolute value as a reference point. This required the BioRA team to establish a reference point with absolute values for 2015.

11 Conclusions and recommendations

The Council Study assumes a set of scenarios for a multi-disciplinary assessment. The macroeconomic assessment is only one dimension, in addition to the socioeconomic, the ecological, and the hydrological perspective. It needs to be stressed that from a policy perspective, all dimensions need to be considered because some non-economic indicators might drop below acceptable levels, which might not show up in the macroeconomic analysis. Thus, macroeconomic recommendations need to be considered in combination with other relevant indicators. For example, there might be a development strategy that leads to the highest macroeconomic results but as a side effect food security might drop under acceptable levels. The question of what is acceptable is part of the policy process and is not specified in this assessment.

The macroeconomic assessment approach considers three important tiers:

- the narrow sector perspective that quantifies impacts on individual sectors;
- the whole-of-economy economy view that quantifies GDP, and
- the quality of growth perspective, which includes non-market elements that are critical for a wide range of services that humans and economic production systems receive from ecosystems.

From a long-term development perspective, the third tier weighs most, as a degradation of ecosystems erodes the foundation of economic production. The narrow sector perspective is important for economic planning and to scope out growth potential but should only influence decision making in combination with the two other tiers.

The three main scenarios provide a relevant set of development strategies for the Lower Mekong Basin, which combine multiple investments in multiple sectors. The thirteen sub-scenarios provide a kind of sensitivity analysis to quantify if individual sectors were not developed as assumed in the main scenario. This allows separating sector specific impacts. In other words, main scenario M3CC, which specifies a development state planned for the year 2040 with a medium level of climate change, is the basis to predict the combined impact of multi-sector changes. The combination of investments does not allow for specifying which sector caused which portion of the overall impact. The sub-scenario approach varies sector by sector and isolates thereby sector-specific impacts. Thereby, the combination of main scenario M3CC and the sub-scenarios allows for understanding sector-specific impacts on relevant policy indicators.

It is critical to emphasise that for the macroeconomic assessment and the calculation of NPV, a period of 24 years needs to be determined. In this case, the design phase of the Council Study made the assumption that this assessment had to focus on a 24-year period from 2017 to 2040. Additionally, it was decided that the macroeconomic assessment needed to assume that the entire 24-year period is occurring for each scenario under the same conditions. This means that once a scenario is selected no change occurs within the 24-year timeframe apart from population growth. Hence, the only difference between scenarios are the development investments designed for each scenario. This is different from many other assessments that assess a sequence of interventions. To clarify this point further, this assessment assumes for main scenario M2 that all 24 years occur under the conditions expected for the year 2020 and all 24 years of the timeframe for scenario M3 unfold under the conditions expected or planned for 2040. There are no investment changes occurring between any of the years within M2 or within M3. This approach was selected during the design phase of the Council Study and allows for comparing development strategies on the basis of longer timeframes. It does not allow for the

assessment of sequences of investment options, which is likely to be a relevant aspect for an additional study.

The results of the combined investments emphasise the growth potential from a sectoral perspective (first assessment tier): The net present value of the 24-year period considered in this assessment (2017-2040) would increase under the conditions specified by main scenario M3 by $302 billion and by $148 billion for M2. This represents an increase of 67% for M3 and an increase of 33% for M2 if compared with M1.

Hydropower emerges as the sector with highest relevance for the lower Mekong basin under M3 with a share of 50% of the sector growth potential. Unfortunately, hydropower is also linked to the highest trade-offs: About 26% of the hydropower gains would be lost in the fisheries sectors under scenario M2 and about 15% for scenario M3. Sub-scenario H3 suggests that mitigation measures could reduce the fisheries losses for M3 by up to 11%. Surprisingly, the net present value for hydropower under H3 would also increase for Thailand and only trigger small losses for the other three countries. The combined net present value of hydropower in the lower Mekong basin in H3 would increase by over 2% if compared with M3CC.

The hydropower potential would benefit the four lower Mekong countries very differently. Thailand emerges as the main beneficiary of Lao mainstream dams and Vietnam as a key beneficiary of mainstream dams in Cambodia. For instance, Thailand's sector benefit would increase under M3 conditions by about $80 billion in net present value for the 24-year period while Lao's sector would increase by about $35 billion in net present value for the same period. Similarly, the net present value of Vietnam's hydropower would increase by $25 billion for scenario M3 while the net present value for Cambodia's hydropower sector would increase by $12 billion. This benefit transfer (from Lao PDR to Thailand and from Cambodia to Vietnam) is based on the power trading and cross-border investments in hydropower. It is important to emphasise that from a macro-economic perspective substantial profits related to mainstream hydropower would benefit non-Mekong countries (e.g. China, Malaysia, South Korea) as a result of their investments. This means that economic benefits from mainstream hydropower in the Mekong would increase GDP in those countries.

The most influential sector for scenario M2 (and second most influential for M3) is agriculture, with a potential to increase the NPV of the Lower Mekong Basin by up to $92 billion in M2 and $104 billion in M3. The majority of this potential is linked to expansion plans in Cambodia ($67 billion), followed by Vietnam ($26 billion). However, focussing on the second assessment tier reveals that economy-wide effects of such agricultural expansion involves risks. The substantial expansion of agriculture in Cambodia and also in Lao PDR would considerably exceed population growth. Even if labour intensity were declining, there would realistically still be an increase in demand for labour. This means that either parts of the new agricultural area would not be cultivated, as people decide to work in higher paid jobs in secondary or tertiary sectors. Or, agricultural production would flourish as planned, which would involve diverting labour from secondary and tertiary sectors, which typically grow faster. This faster growth is a distinctive characteristic of development success as the relevance of primary sectors for the labour market typically declines. Hence, excessive agricultural expansion is likely to slow down GDP growth, especially for Cambodia and Lao PDR, if scenarios M2 and M3 were fully realised.

The second side effect of agricultural expansion is the loss of natural capital, which adds to the erosion of future growth potential, particularly in tertiary sectors. Characteristically, an increase of average

income goes hand in hand with increasing expenditure in tourism and recreational activities. The urbanisation trend facilitates an increasing demand for natural environments for recreational purposes. Conserving these environments is likely to convert in the mid-term into substantial income sources, as already now experienced by the lower Mekong countries, in particular Thailand. If these areas are lost, people are likely to travel abroad and spend their money there, which would create an economic disadvantage. The restoration of natural habitats is very expensive and is often confronted with property rights–related impediments: Once converted into agricultural land and owned by private persons or by companies, any reforestation or restoration of wetlands becomes very challenging (and expensive). From a macroeconomic perspective, natural capital needs to be approached strategically and understood as existing investments in future growth potential. This means that Cambodia and Lao PDR would benefit from re-evaluating the agricultural expansion realised between 2007 and 2015.
Otherwise, around $51 billion could be lost in NPV of natural capital for scenario M2 and up to $101 billion for scenario M3.

The range of sub-scenarios provides a few additional insights. For instance, a drier climate than assumed for scenario M3CC would cause losses for all lower Mekong countries, especially for Cambodia (-$3.6 billion in NPV) and Thailand (-$3.4 billion in NPV). The fisheries sector would experience a decline of about $5 billion in NPV (over 5% of the sector value), of which more than $3.4 billion would eventuate in Cambodia. The hydropower sector would face even higher losses of about $5.6 billion that would mostly eventuate in Thailand (-$2.9 billion in NPV) and Lao PDR (-$2.2 billion in NPV).

Flood protection investments seem beneficial and would slightly increase benefits across sectors in the Lower Mekong Basin, with the exception of the fisheries sector in Vietnam, which would decline slightly. Cambodia would account for the largest gains from variations in flood protection, with $1.1 billion in NPV for sub-scenario F1.

The GDP-focused assessment of the second assessment tier emphasises two main points. First, agricultural expansion plans exceed macroeconomic optima for all four countries. Instead, development strategies would benefit from a stronger focus on secondary and tertiary sector employment. Second, the expansion of power generation is highly beneficial. However, scenarios M2 and M3 are likely to entail a number of (highly) unbeneficial hydropower projects that trigger higher costs than benefits. Assessing project by project and realising only the most beneficial projects seems highly promising as does focussing on alternative energy sources.

An additional insight emerging from this study is the trade-based growth potential. Macroeconomic gains seem substantial if infrastructure can be developed sustainably (for details, see the navigation report). This would align with development strategies that focus on secondary sectors and the increase of value-add within the Lower Mekong Basin countries.

Overall, the suggested portfolio of investments considered by the Council Study offers substantial potential for economic growth. Some strategies come with risks to erode future growth potential or to have negative transboundary impacts. Hydropower and agricultural investments are the most relevant to mention in the context. From a planning perspective, it would be crucial to decompose the scenarios even further to understand the impacts of individual projects and the relevance of implementation sequences. Not every hydropower project has the same negative externalities on other sectors or on neighbouring countries. Therefore, prioritising and selecting the most beneficial ones seems most promising. The current assessment of bundles of investments within each sector merges many benefits and losses and is not the most effective approach to design sustainable development strategies.

The three assessment tiers employed during this macroeconomic assessment demonstrated that some investments seem highly beneficial from a narrow sector perspective, but once considered in a wider macroeconomic context, negative side effects become visible and/or long-term erosion of economically critical input factors (e.g. natural capital) materialises.

Finally, it is important to emphasise that this study was conducted under a variety of constraints that did not allow for the development of adequate macroeconomic assessment methodologies. Typically, micro simulation or general equilibrium modelling would be employed to capture cross-sector dynamics, price dynamics, inflation, migration, and transboundary dynamics. Due to time constraints, this study needed to revert to spreadsheet tools that assume many important variables to be constant (e.g. prices and wages), or require exogenous specification (e.g. crop choice or population growth), or meant that some variables had to be ignored (e.g. human migration or trade). Some of the principle patterns revealed in this study are likely to remain stable but the absolute values would change if adequate methodologies were implemented.