IDENTIFYING SUSTAINABILITY INDICATORS OF STRATEGIC ENVIRONMENTAL ASSESSMENT FOR POWER PLANNING

ASIAN DEVELOPMENT BANK

IDENTIFYING SUSTAINABILITY INDICATORS OF STRATEGIC ENVIRONMENTAL ASSESSMENT FOR POWER PLANNING

ASIAN DEVELOPMENT BANK

6 ADB Avenue, Mandaluyong City, 1550 Metro Manila, Philippines
Tel +63 2 632 4444; Fax +63 2 636 2444
www.adb.org; openaccess.adb.org
OARsupport@adb.org; publications@adb.org

ISBN 978-92-9254-671-1 (Print), 978-92-9254-672-4 (PDF)
Publication Stock No. BKK146585-2

Cataloging-In-Publication Data

Asian Development Bank.
Identifying sustainability indicators of strategic environmental assessment for power planning.
Mandaluyong City, Philippines: Asian Development Bank, 2015.

1. Infrastructure. 2. Energy. 3. Environment. 4. Asian Development Bank.
I. Asian Development Bank.

Note: In this publication, "$" refers to US dollars.

Photo credits: Peter-John Meynell (front cover left image, pages 1, 11, 35, 43); Alexander Kenny (front cover center image, pages 5 and 15); ADB Photo Library (front cover right image). The left cover photo shows a section of the 44 MW Bangchak Solar PV Power Plant Project in Ayutthaya province, Thailand. The center cover photo shows transmission lines going through the Phou Khao Khouay National Protected Area in the Lao People's Democratic Republic, which shows the impacts of land take and fragmentation.

Printed on recycled paper

Contents

Box, Tables, Figures, and Maps iv

Acknowledgments v

Executive Summary vii

Abbreviations x

Introduction 1

How to Identify Indicators of Sustainability 5

- Defining Security Aspects 7
- Sustainability Statements 8
- Consultation Process 8

Finding the Best Indicators—Limitations and Assumptions 11

- Coverage and Reliability of Indicators 12
- Using Geographic Information Systems Analysis 13
- Scale of Analysis and Assumptions Required 14

Definition and Description of the Indicators Used 15

- Ecological Security 16
- Climate Security 20
- Food Security 20
- Social Security 25
- Health and Safety Security 26
- Good Governance and State Security 30
- Energy Security 30
- Economic Security 33

Analyzing Sustainability of Power Planning 35

- Integrating the Assessment of Security Aspects 36
- Qualitative Analysis 37
- Weighting the Security Aspects 38
- Quantitative Analysis—Monetization 38

Conclusions and Recommendations 43

References 47

Box, Tables, Figures, and Maps

Box

Methodology for Impacts on Fisheries 23

Tables

1 Security Aspects and Associated Sustainability Statements Used for the Strategic Environmental Assessment Study 9
2 Changes in Indicators between Existing (2012) and Current Power Development Plan (2025) with Significance Weighting 39

Figures

1 Benefits and Concerns Associated with Power Development as Expressed at Stakeholder Meetings 10
2 Cost–Risk Trade-Offs 32
3 Radar Diagram of Differences in Significant Impact by Security Aspect between Scenarios 37
4 Total Costs of Electricity Supply in the Lower Mekong Basin by Scenario, 2025 42

Maps

1 Network Degree of Regulation and River Connectivity Index for Different Scenarios in the Greater Mekong Subregion 19
2 Historic Storm Routes within the Greater Mekong Subregion with Locations of Existing and Planned Power Plants 21
3 Earthquake Risk Zoning Map for Power Plants in the Greater Mekong Subregion 29

Acknowledgments

This strategic environmental assessment (SEA) study for regional power planning was carried out under a regional capacity development technical assistance of the Asian Development Bank (ADB) on Ensuring Sustainability of the Greater Mekong Subregion Regional Power Development (TA 7764-REG), with financing from the Government of France through the Agence Française de Développement. The SEA was developed by the consultancy consortium of the International Centre for Environmental Management (ICEM) and Economic Consulting Associates (ECA).

Jong-Inn Kim, lead energy specialist at the Energy Division of ADB's Southeast Asia Department (SEEN), ably implemented the project. The peer reviewer of this report was Hyunjung Lee, energy economist at SEEN. The SEA team was led by Peter-John Meynell (SEA specialist) with the assistance of William Derbyshire (deputy team leader). The study team received strong support and guidance from ICEM, especially Jeremy Carew-Reid (director) and Tarek Ketelsen (technical director). The SEA team consisted of Tom Halliburton (power system analyst), Peter Meier (hydropower specialist), Jens Sjørslev (social specialist), John Sawdon (environment specialist), Tim Suljada (renewable energy specialist), Erin Boyd (energy economist), Mai Ky Vinh (GIS specialist), Dinh Hien Minh (energy economist), Nguyen Anh Tuan (energy planning specialist), Botumroath Sao (social specialist), Nguyen Quoc Khanh (renewable energy specialist), Phaivanh Phiapalath (environment specialist), Alexander Kenny (project manager and economist), Bernhard Lehner (river ecological connectivity study).

Staff at ADB ensured the smooth administrative implementation of the project, namely, Trinidad S. Nieto, Bui Duy Thanh, and Genandrialine Peralta from SEEN; and Lothar Linde, Iain Watson, and Sumit Pokhrel from the Environmental Operations Centre. Mark Kunzer, principal environmental specialist at the Environment and Safeguards Division, Regional and Sustainable Development Department, provided valuable comments in the vetting of this volume. Consultants Cherry Lynn Zafaralla edited the final volumes and coordinated publication, Jasper Lauzon designed the covers, and Principe Marin Nicdao designed and executed the interior layouts. Chong Chi Nai, SEEN director, and Ramesh Subramanian, Southeast Asia Department deputy director general, provided invaluable overall guidance and support throughout the project.

Many different people made suggestions, provided information, and helped with developing the study. These include more than 250 participants at the study's regional and national consultation meetings, attendees at four Regional Power Trade Coordination Committee (RPTCC) meetings, and those who commented on the various reports. The focal points of the RPTCC were instrumental in providing feedback at the country level, namely, Kong Pagnarith (Mines and Energy, Cambodia); Zhong Xiaotao (China Southern Power Grid Co., People's Republic of China); Sanhaya Somvichit (Department of Energy Policy and Planning, Lao People's Democratic Republic); Saw Si Thu Hlaing (Department of Electric Power, Myanmar); Panupong Sathorn (Electricity Generating Authority of Thailand); Trinh Quoc Vu (Electricity Regulatory Authority of Vietnam, Viet Nam); Voradeth Phonokeo (Mekong River Commission); Simon Krohn (Mekong River Commission); Chuenchom Sangarasri Greacen (Palang Thai); Ame Trandem (International Rivers); and Witoon Permpongsacharoen (Mekong Energy and Ecology Network).

Finally, the support of Carl Bernadac and Olivier Grandvoinet of Agence Française de Développement is gratefully acknowledged.

Executive Summary

This volume was developed from the Asian Development Bank (ADB) study ***Ensuring Sustainability of the Greater Mekong Subregion Regional Power Development*** (TA 7764-REG). This study shows how the strategic environmental assessment (SEA) process can be used for power planning. The study is the first in the world to incorporate SEA, which focuses on sustainability and policy making, into power development plans (PDPs). Specifically, the study incorporates SEA into the PDPs in the Greater Mekong Subregion (GMS) to arrive at an optimal power development trajectory for the GMS as a whole.

This volume is the second in a three-part series of knowledge products from this study. It shows how a wide range of possible indicators could measure the changes in different aspects of "security," or the degree of protection against danger, damage, or loss, which a sustainability-led SEA covers. Sustainable development encompasses environment, social, and economic dimensions. Sustainability issues were identified in terms of eight national and regional "security aspects" with an aggregate 46 indicators. The volume describes the chosen indicators and outlines the methods for measuring them. It shows how to combine and assess these indicators using both qualitative comparisons and monetization of cost and benefits. Monetization estimated the total net costs of generation under alternative power planning scenarios together with the costs of impacts, giving an overall cost of power supply under each scenario and the displacement case for the year 2025. Monetization included the costs of investment and fuel, and external impacts on the environment and society. Of the 46 indicators, six were monetized that had the largest significance in terms of total costs and benefits across different scenarios, and the greatest availability or accessibility to data within the time constraints and other resource limitations of the project.

The SEA used the following eight different "security aspects" for the power sector along with their associated sustainability statements and indicators. Only good governance and state security was described qualitatively with no specific quantitative indicators.

(i) Ecological security

- (a) pollution and air, water and land quality (e.g., emissions and pollutant discharges)
- (b) land take and terrestrial biodiversity (e.g., land take, land use change, and risks for protected areas and endangered species)
- (c) rivers and aquatic biodiversity (e.g., degree of regulation of rivers, ecosystem connectivity, and fish species diversity)

(ii) Climate security

- (a) greenhouse gas emissions
- (b) climate change risks from increased extreme storm events

- (ii) Food security
  - (a) agricultural land take
  - (b) potential for irrigation from hydropower
  - (c) changes in fish production
  - (d) contribution of fish and other aquatic animals to human nutrition
- (iii) Social security
  - (a) number of people potentially affected by hydropower
  - (b) resettlement of directly affected populations
  - (c) proximity of power plants to cultural and tourism locations
- (iv) Health and safety security
  - (a) numbers of people living in zones vulnerable to emissions from power plants
  - (b) numbers of people at risk in the zones of influence around power plants
  - (c) risks of catastrophic failure of dams due to earthquakes
  - (d) populations at risk of catastrophic failure of nuclear power plants
- (v) Good governance and state security
  - (a) social security in the power sector
  - (b) implementation of social policies
  - (c) corruption issues
  - (d) improving governance in the power sector
  - (e) environmental governance
  - (f) public consultation in the power planning process
  - (g) resettlement safeguards
- (vi) Energy security
  - (a) diversity of the fuel mix in electricity generation
  - (b) remaining life of domestic coal and gas reserves
  - (c) trade-off between cost and risk provided by different generation mixes
- (vii) Economic security
  - (a) costs of electricity supply
  - (b) numbers of jobs created
  - (c) resource rents

The methods for developing qualitative comparisons between all of the indicators and security aspects using a "radar diagram" approach illustrates how the assessment can highlight the strengths and weaknesses of the different power plan options. Application of a weighting process would increase the sensitivity of this approach. Monetization provided a clear comparison of the costs, benefits, and trade-offs of each scenario. However, monetization of many indicators to derive a much more comprehensive picture was not possible because the indicators do not lend themselves to such analysis; or the data to do so is not available or reliable. It is recommended that further studies be carried out to monetize more indicators that can enhance the sensitivity of SEA in power development plans.

The volume concludes with recommendations to establish a common set of indicators for power development in the Greater Mekong Subregion and to improve the methodologies and data requirements, especially for monetization.

Abbreviations

ADB	–	Asian Development Bank
DOR	–	degree of regulation
EIA	–	environmental impact assessment
EOC	–	Environmental Operations Centre
GHG	–	greenhouse gas
GIS	–	geographic information system
GMS	–	Greater Mekong Subregion
ha	–	hectare
km	–	kilometer
Lao PDR	–	Lao People's Democratic Republic
LMB	–	Lower Mekong Basin
MW	–	megawatt
PDP	–	power development plan
PRC	–	People's Republic of China
RCI	–	river connectivity index
SEA	–	strategic environmental assessment
TA	–	technical assistance

Water cooling at Bang Pakong combined cycle gas turbine power station, Thailand

Introduction

The Asian Development Bank's (ADB) project on ***Ensuring Sustainability of the Greater Mekong Subregion Regional Power Development*** is a $1.35 million technical assistance project (ADB 2010a). It has the following objectives:

(i) assess the impacts of alternative directions for the development of the power sector in the Greater Mekong Subregion (GMS) through a strategic environmental assessment (SEA);[1]

(ii) develop recommendations on how to minimize and mitigate harmful impacts in the power sector; and

(iii) provide capacity building for GMS countries in the conduct of SEA, and support its integration into the power planning process.

This project commenced in March 2012 with a series of three regional consultations. National consultations were also held in four countries of the Lower Mekong to contribute toward the development of sustainability indicators for use in assessing the impacts.[2] A baseline report was produced in January 2013, including a report setting out the alternative power planning

[1] The Greater Mekong Subregion includes Cambodia, the Lao People's Democratic Republic (Lao PDR), Myanmar, Thailand, Viet Nam, and Yunnan Province and Guangxi Zhuang Autonomous Region in the People's Republic of China (PRC).

[2] This strategic environmental assessment (SEA) study was "sustainability-led." Sustainability issues were defined in terms of national and regional "security"—the degree of protection against danger, damage, or loss. Eight security aspects that capture the essence of sustainability for power planning were identified, namely: (i) ecological security (pollution, land and biodiversity, rivers); (ii) climate security; (iii) food security; (iv) social security; (v) health and safety security; (vi) good governance and state security; (vii) energy security; and (viii) economic security. Associated with each "security aspect" is a series of indicators and sustainability statements that were developed through stakeholder consultation and literature review, and against which the contribution of the existing regional power plan was assessed.

scenarios (ADB 2013a).[3] The impact assessment report and summary report, complete with recommendations were finalized in December 2013.

A three-volume series of knowledge products prepared from the study captures significant aspects of the SEA process. These volumes are as follows.

(i) Integrating Strategic Environmental Assessment into Power Planning

(ii) Identifying Sustainability Indicators of Strategic Environmental Assessment for Power Planning

(iii) How Strategic Environmental Assessment can Influence Power Development Plans—Comparing Alternative Scenarios for Power Planning in the Greater Mekong Subregion

This volume aims to show how a set of indicators can be used to analyze power sector development plans in the GMS to achieve greater sustainability.[4] The volume explains why these particular indicators were selected for the study, why they are important, how they can be measured, and what the indicators reveal. The volume then describes the application of the SEA methodology to the GMS regional power development plan. Using the indicators established by the study, the volume shows how SEA may be applied to qualitatively and quantitatively compare different scenarios. The volume also presents monetization as a means of comparison across scenarios, and explains how selected indicators were monetized.

The first volume shows how the SEA process can be used for power planning and how capacity for conducting SEAs and the consultation process can be strengthened. It highlights the role of SEA in assessing the sustainability of polices and plans at a regional or national level.

The third volume applies SEA to compare different scenarios, and shows how a more sustainable power plan can be developed by incorporating the wider impacts considered during the SEA process. It also demonstrates how sustainability may be assessed in power planning, and how incorporating wider impacts might change decisions on the optimal power plan. The process of developing these scenarios starts from an updated version (as of 2012) of the existing GMS Power Transmission Master Plan under TA 6440-REG, and

3 The study had three power planning scenarios: (i) current power development plan (PDP), (ii) renewable energy, and (iii) energy efficiency. The current PDP scenario is an updated version (as of 2012) of the existing GMS Power Transmission Master Plan developed under the Asian Development Bank's (ADB) TA 6440-REG. The current PDP scenario incorporates the national PDPs of Cambodia, the Lao PDR, Thailand, and Viet Nam to 2025. The PDP for Myanmar as well as for Yunnan Province and Guangxi Zhuang Autonomous Region in the PRC were not available for this study. The current PDP is compared to the baseline situation of all power plants and regional interconnectors operational in 2012. Two displacement options are considered for the renewable energy and energy efficiency scenarios—a global impacts option in which some coal-fired power plants are displaced to reduce carbon emissions; and a regional and local impacts option in which some large hydropower, nuclear, and coal-fired power stations are displaced to reduce regional and local impacts. In the context of this SEA, the term "displacement" is used to indicate the option of removing a planned thermal, large hydropower, or nuclear plant from the PDP scenario and replacing it with greater contributions from renewable energy and energy efficiency.

4 The World Commission on Environment and Development (the Bruntland Commission) in 1987 defined sustainability as development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

serves as a baseline, henceforth referred to as "current PDP." The current PDP scenario then incorporates the national PDPs of Cambodia, the Lao People's Democratic Republic, Thailand, and Viet Nam to 2025 (the PDPs for Myanmar and Yunnan Province and Quangxi Autonomous Region of the People's Republic of China were not available for this study).

In addition, a series of SEA briefing papers produced earlier present the different stages of the SEA process in the format of case studies. An updated database of power plants in the GMS developed from a database provided by an earlier ADB project (TA 6440-REG) titled *Facilitating Regional Power Trading and Environmentally Sustainable Development of Electricity Infrastructure in the Greater Mekong Subregion. Component 2: Analysis of SEA in GMS Countries, and Identification of Gaps, Needs and Areas for Capacity Development* (ADB 2010b) is also available, together with an explanatory manual (ADB 2014).

The SEA process is usually conducted at a relatively high level and complements the more detailed environmental impact assessments (EIAs) necessary for specific developments. The SEA process has its own limitations and assumptions because of the scale at which it is conducted. Such assumptions must be made clear and transparent.

The development of more sustainable power plans must be underpinned by good governance.[5] Poor governance throughout the power planning process and operation of power plants in the GMS, along with the associated environmental and social impact assessment and monitoring, were major concerns of stakeholders consulted throughout this study. This volume shows how the SEA process can contribute to good governance in the power planning process, and how the capacity of national governments and stakeholders in the power planning process can be strengthened.

This study constitutes an attempt to introduce and incorporate a methodology for SEA in PDPs. The findings and recommendations are by no means exhaustive and final, but are meant to serve as a springboard for more in-depth SEA on individual national PDPs. The monetization of more indicators, in particular, is an area for future research.

[5] In this study, good governance covers policy making including laws and regulations, enforcement of environmental conditions and social safeguards, as well as issues of corruption and capacity of institutions to manage the process. It refers to oversight of policy making, planning, operations and management by government, state-owned enterprises, and private entities, and involves consultation with public, private, and civil society organizations. Good governance and capacity development is one of the five drivers of change that the Asian Development Bank (ADB), in its long-term strategic framework Strategy 2020 (ADB 2008), focuses on to better mobilize and maximize resources, the others being (i) private sector development and private sector operations, (ii) gender equity, (iii) knowledge solutions, and (iv) partnerships.

Fishing and tourism activities on Hoa Binh reservoir, Viet Nam

How to Identify Indicators of Sustainability

As SEA has evolved in the past 20 years, its differences with environmental impact assessment (EIAs) have become clearer. EIAs focus on how a proposed development project should take place in order to minimize and manage environmental and social impacts. By comparison, SEAs, which assess policies, plans, and programs, can have a real influence on the choice of possible development pathways, generation technologies to be prioritized, and other policy options. SEAs can ensure that environmental and sustainability considerations are taken into account at the early stages of the decision making process.

The International Association for Impact Assessment (IAIA 2002) notes that a good quality SEA must be integrated, sustainability-led, focused, accountable, participative, and iterative (Tetlow 2012, Bond 2012). There is a growing demand in many countries for sustainability assessments. This demand has been the driver for sustainability assessment, emerging as a separate tool to complement the establishment of national sustainable development strategies, e.g., the Earth Summit in Rio de Janeiro in 1992, Agenda 21, and Rio+20. Experience shows that EIAs and SEAs need to cover the three pillars of sustainable development—environment, society, and economy. Regional integration—one of the development agendas of ADB's Strategy 2020—lies at the heart of this SEA since it addresses regional power planning and interconnections for the trade in electricity.

Sustainability principles have been developed for national sustainability strategies, e.g., the Viet Nam Sustainable Development Strategy for 2011–2020; and for different sectors in many countries e.g., the Lao People's Democratic Republic's (Lao PDR) National Policy on Environmental and Social Sustainability of the Hydropower Sector, 2005. They represent the thinking and visioning of what is required for sustainable development in the country or for the sector. Some of the sustainability principles that guided the development of this SEA have been expressed in ADB (2009a), International Hydropower Association (2010), MRC (2010), and World Bank (2010).

Defining Security Aspects

The most commonly used definition of sustainable development comes from the World Commission on Environment and Development (the Bruntland Commission) in 1987 as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Since then, there has been considerable evolution in the understanding of sustainable development, but it remains a difficult concept to put into practice.

While the three pillars of sustainability enable understanding of what is required for sustainable development, these do not really help in making the necessary trade-offs. The result is that often, economic development proceeds as usual at the expense of, or with only limited attention to, social and environmental sustainability.

While it is clear that to be sustainable, development must consider these three main areas, ecological sustainability is regarded as the foundation for economic and social well-being. Without maintaining ecological processes, real sustainable development will never be achieved. Movement toward greater sustainability can be achieved by encouraging changes in the nature of production and consumption so that they can better satisfy human needs while using fewer raw materials and producing less waste.

This SEA study was "sustainability-led". Sustainability issues were defined in terms of national and regional "security"—the degree of protection against danger, damage, or loss. Eight "security aspects" [6]that capture the essence of sustainability for power planning were identified, as follows:

(i) ecological security (land, water, air);

(ii) climate security;

(iii) food security;

(iv) social security;

(v) health and safety security;

(vi) good governance and state security;

(vii) energy security; and

(viii) economic security.

Associated with each "security aspect" is a series of indicators and sustainability statements that have been developed through a process of stakeholder consultation and literature review, and against which the contribution of the existing regional power plan may be assessed. However, not all of the "security aspects" will be influenced by regional power development.

[6] The term "security aspect" has been developed as part of the methodology of the SEA. It is drawn from its usage in terms of food and energy security, and is used to denote groupings of aspects of sustainability.

Sustainability Statements

Sustainability principles are usually very general, and often rather idealistically phrased; it is not clear how they can be implemented. The challenge for an SEA is how to use them effectively. Sustainability statements help to add meaning and define the aim of the "security aspects" in relation to the PDP. Table 1 shows the "security aspects" and associated sustainability statements used in this study.

In the assessment process, the impacts of the GMS regional power plan and the alternative scenarios were compared against the chosen sustainability statements and their indicators, answering the question: "What contribution will the plan make toward maintaining sustainability of these "security aspects" and their application in the GMS?"

Consultation Process

Consultation is a fundamental part of an SEA, strengthening its relevance and credibility, and contributing toward ownership of the results. In this SEA study, a consultation and communication plan was developed to provide stakeholders at the national and regional levels the opportunity for comment and feedback during the main phases of the study—scoping, baseline and impact assessment, and recommendations.

Scoping is the most important phase for defining the indicators, and stakeholder consultation meetings provided an opportunity for identifying the most important "security aspects" and the most useful indicators for the SEA. Scoping is the phase in which the boundaries of the study are defined and the key strategic issues are identified. During the scoping meetings, participants discussed (i) the geographic scope—the six countries of the GMS, with a focus on the Lower Mekong Basin (LMB) countries; (ii) the temporal scope—from 2010 to 2025 in three 5-year blocks; and (iii) the technical scope—grid-connected power generation and regional interconnections.

The scoping consultations were held at the national level in four LMB countries,[7] with a fair representation of government, private sector, academic, and nongovernment organization stakeholders. Stakeholders were asked to identify their perceived main concerns and benefits associated with the PDP in their own country. These concerns and benefits were then grouped into the eight "security aspects". As expected, there were differences in perspective on these benefits and concerns for each (see Figure 1).

At the scoping meetings, stakeholders were also asked for suggestions for indicators to measure and monitor the benefits and concerns. These were used in the final development of indicators and methods of analysis, described below.

[7] Although the SEA covered all six of the GMS countries, more detailed analysis was carried out on four countries of the Lower Mekong Basin within the GMS, namely, Cambodia, the Lao PDR, Thailand, and Viet Nam. Consultation meetings were not held in Myanmar and Yunnan Province and Guangxi Zhuang Autonomous Region in the PRC.

Table 1. **Security Aspects and Associated Sustainability Statements Used for the Strategic Environmental Assessment Study**

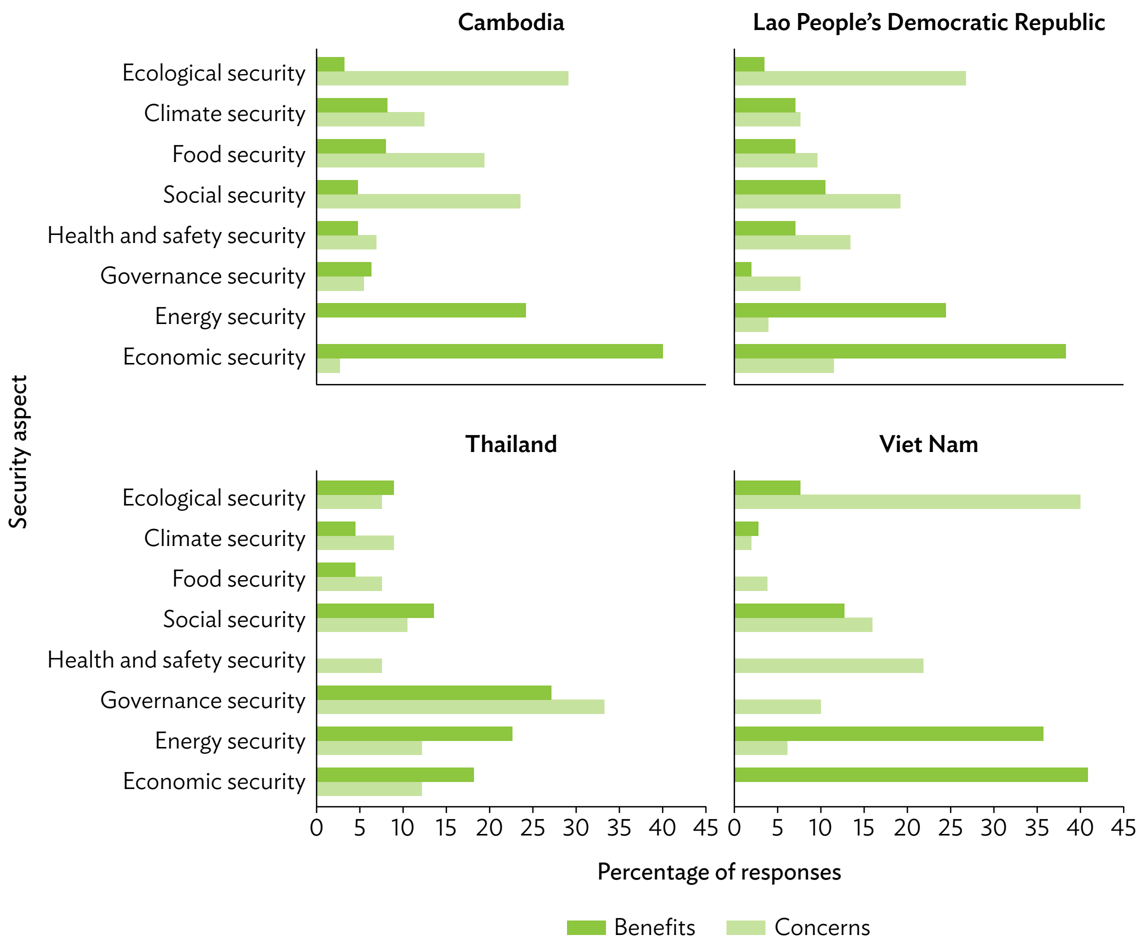
Security Aspect	Sustainability Assessment
1. Ecological security • Land • Water • Air	• Minimizing emissions, and ensuring the safe discharge and disposal of pollutants • Maintaining and improving the quantity and quality of land, water, and air resources • Maintaining and enhancing terrestrial, freshwater, and marine ecosystems throughout the GMS countries for conservation of biodiversity, connectivity, and ecosystem services and products
2. Climate security	• Reducing emissions of greenhouse gases within the GMS countries to mitigate global climate change • Maintaining and improving options and capacities of ecosystems and communities to adapt to climate change
3. Food security	• Maintaining and enhancing the diversity and productivity of the agricultural systems in the GMS countries • Maintaining and enhancing the diversity and productivity of the fisheries in the GMS countries • Ensuring balanced nutrition for the people of the GMS countries, especially for the poor and vulnerable
4. Social security	• Maintaining and enhancing employment and livelihoods for the people of the GMS • Ensuring the well-being of vulnerable and minority groups of the population of the GMS who may be affected by development • Maintaining the vital cultural diversity and heritage of importance to the GMS countries
5. Health and safety security	• Minimizing the risks to human health and safety from the disposal of polluting, toxic, and radioactive wastes • Minimizing the increased risks of flood and drought induced by development and climate change
6. Good governance and state security	• Ensuring transparent and accountable development action throughout the GMS • Preventing and resolving resource use conflicts within and between the countries of the GMS
7. Energy security	• Ensuring the availability of energy at all times in various forms, in sufficient quantities, and at affordable prices, without unacceptable or irreversible impact on the environment for each of the GMS countries • Increasing availability and access to electricity to communities in the GMS especially rural and urban poor
8. Economic security	• Maintaining and enhancing contributions to the wealth and economic well-being of the GMS and its constituent nations • Encouraging changes in the nature of production and consumption so that they can better satisfy human needs while using fewer raw materials and producing less waste • Ensuring equitable distribution of economic benefits of development, including long-term support to vulnerable and affected groups

GMS = Greater Mekong Subregion.

Note: This study uses national and regional "security aspects," which pertain to the degree of protection against danger, damage, or loss in specific areas, to determine sustainability.

Source: ADB. 2013c.

Figure 1. **Benefits and Concerns Associated with Power Development as Expressed at Stakeholder Meetings**



Source: ADB. 2012.

10 MW oil-fired power station,
Phnom Penh

Finding the Best Indicators—Limitations and Assumptions

Coverage and Reliability of Indicators

The long list of possible measurements that could be used should be limited to a few (at most five) indicators. To be useful and meaningful, the indicators should be representative of the "security aspect" or issue under consideration. They should also be measurable in some way, so that the changes can be quantified even if they cannot be monetized. The changes over the period or between the scenarios should also be clear so that the differences can be highlighted. They also need reliable data, but this is often one of the biggest constraints.

There is a considerable variation in the availability and quality of information about power plants, as well as environmental and social data between the different countries. In particular, more data is available about the LMB countries compared to the People's Republic of China (PRC) and Myanmar. This may mean that some indicators may not cover the whole of the GMS, but are restricted to LMB countries.

Using the OptGen power model, relevant data from the existing and proposed power plants are used to replace some of the capacity with increased power generation mixes of renewables; or to decrease the demand for power with increased energy efficiency.[8] The OptGen model requires detailed information on a monthly basis. Hydropower system inflow data for three specific scenarios are needed. Load shape within each month is essential. Modelling requires complete data in order to calculate overall system load and generation balance for each load level within each month. Hence it was possible to model only the LMB

[8] OptGen is a computational tool for determining the least-cost expansion (generation and interconnections) of a multi-regional hydrothermal system; see http://www.psr-inc.com.br/portal/psr/servicos/modelos_de_ apoio_a_decisao/studio_plan/optgen/

in OptGen as the necessary data was not available for other parts of the GMS, e.g., the PRC and Myanmar.

(i) **Uncertainty**

Power development plans change frequently. This happens because of changes in policies and external factors, delays in project development, and vagaries of negotiations. Power plants themselves are subject to significant changes as they progress from identification, to detailed design, to construction. The timing of when power projects will be commissioned is never exact. Therefore, the PDPs presented in this study are only representative of these plans at a given point in time. They are not necessarily the plans currently in place in each country.

(ii) **Significance**

It is not possible, within a study covering the whole GMS, to describe or measure every possible impact that might result from power sector development. In the scenario comparisons, therefore, the focus is on those impacts considered most significant for the region as a whole. These impacts are both large in magnitude (when monetized) relative to the costs of the power sector within the GMS, and may change noticeably across scenarios.

An inevitable consequence of this is that many localized impacts on communities from power sector development are not considered significant at the regional level and are not included in these comparisons. This should not be taken as implying that these impacts are not important; to the affected persons, they may be very significant. Such localized impacts should be considered in the analysis of individual projects.

Using Geographic Information Systems Analysis

Geographic information systems (GIS) provide one of the most useful tools for comparison of the different scenarios.

(i) **Locations**

Identifying the locations of power plants and interconnections is fundamental to carrying out an adequate impact assessment. However, this is a difficult exercise for new power plants. Often the power planning agencies do not know where a power plant will be built 10 years from now. In some cases, power planning agencies have been reluctant to identify possible sites due to the risk of premature public protests before the necessary analysis and consultation have been undertaken. In such instances, informed judgments may have to be made about the most likely locations of future power plants.

(ii) **Zones of influence**

One of the impact assessment approaches that have been adopted is the definition of zones of influence around the different types of power plants. Typically, circles with a radius of 1 kilometer (km), 5 km, and 10 km centered on the power plant location have been assessed for indicators such as land use, biodiversity, population, etc. This is an approximation, and the actual significant zone of influence will be tempered by factors such as prevailing wind direction and topography.

(iii) **Plant footprints**

Another approach uses standardized plant footprints of area per 1 megawatt (MW) installed for thermal plants. While actual plant sizes for existing plants are known, future plants' footprint areas are often not known. For both storage and run-of-river hydropower dams, the reservoir area is a critical piece of information for determining the land take and changes in land use, fishery production, and numbers of people to be resettled. Where the reservoir area is known, this may be used, but where it is not known, especially for hydropower plants still in the preliminary planning stage, an estimate based upon the typical power density for similar types of reservoirs in the country has been used.

(iv) **Population densities**

One of the critical pieces of data for this assessment is population density. This data helps to define the scale of the populations affected, such as by air pollution, or resettlement requirements, and by multiplication with the relevant areas within zones of influence. The LandScan population density database is used to estimate the populations affected in different ways.

Scale of Analysis and Assumptions Required

(i) **Broad-brush approach**

In trying to assess the impacts of PDPs covering six countries and over 400 major power plants, it is impossible to go into detail, or to focus on the impacts of specific plants. Therefore, a broad-brush approach is required. Impacts relevant to specific plants—which are ascertained in more detailed EIAs and cumulative impact assessments[9]—are not considered, instead, generic assumptions are applied. For example, impact analysis of thermal power plants assumes that these occupy a standard area for each unit of capacity. Impact analysis of nonhydropower renewable energy power plants assumes that these are a standard size. However, for hydropower plants, it is necessary to identify the characteristics of individual power plants in detail where these are available.

(ii) **Sensitivity analysis**

Given the number of assumptions in conducting an SEA, a wide range of possible outcomes exist. Many of these assumptions may be open to question and opinion. In some cases, the sensitivity of assessment results in testing of alternative assumptions (e.g., carbon pricing). However, it was not possible to carry out an extensive sensitivity analysis of these different assumptions in this SEA study.

[9] Cumulative impact assessment focuses on the combined impacts caused by one or more projects acting with existing or planned developments. Strategic environmental assessment also considers cumulative impacts, but from a strategic policy or plan perspective.

Burnt rice husks from biomass gasification plant, near Siem Reap, Cambodia

Definition and Description of the Indicators Used

This section provides an overview of the indicators used in the SEA study. It is drawn from ADB (2013c), which describes the methods used for each indicator. The baseline and impact assessment reports contain many tables with international standards and figures in the calculations (ADB 2013a and 2013b).

Ecological Security

Air, Soil, Water Pollution

Air pollutants, which are either directly or indirectly attributable to the power sector, are well defined including a range of emissions. Thermal plants potentially emit a large range of pollutants including sulfur oxide, nitrogen oxide, carbon monoxide, hydrogen sulphide, particulate matter of 10 microns or 2.5 microns or more, nonmethane volatile organic compounds, dissolved oxygen, total solids, as well as mercury, cadmium, arsenic, dioxins, furans, and other toxins. The SEA concentrated on the most common and important pollutants from the sector, namely emissions of sulfur dioxide, nitrogen oxide, and particulate matter in terms of tons per year by country and technology. In the absence of more detailed region- and country-specific emissions factors, emissions were estimated using standard European Union emissions factors. Emissions were estimated for conditions with and without pollution control equipment.

Similarly, there are many potential sources of pollution to soils from the power sector, including deposition of most emissions to the air; residual ash produced from fuel combustion; and oil, lubricants, and other chemicals used in the operation of power plants. As most of these pollutants had either been accounted for in emissions to air or, in the case of oil and chemical use at power plants, are only really emitted as a consequence of accidental spills, the most important indicator of potential for soil pollution was that of ash produced in terms of tons per year. This was estimated using the typical ash content of various fuels.

Pollutants to air and soil frequently end up in water. In addition, water and aquatic systems are also sensitive to a range of other effects from the power sector including emissions of heat, radioactivity, leachates from coal and ash storage, release of chemicals used to treat coolant water, etc. Hydropower in particular has important potential impacts on water quality, including changes to water temperature, turbidity, low levels of dissolved oxygen, and generation of pollutants such as ammonia and hydrogen sulfide, especially for recently inundated reservoirs. In recognition of these important impacts and the role of water more generally in environmental systems, the indicators developed for water pollution was a potential water pollution index weighted by electricity production. This gave qualitative scores for different types of water pollution indicators (pH, dissolved oxygen, total solids, oil and grease, ammonia and/or nitrate, hydrogen sulfide, suspended solids and/or turbidity, temperature, biological oxygen demand, and trace radioactivity) associated with each technology and weighted by the proportion of electricity generated using that technology. Thus, the index gives both the relative change in potential water pollution and allows a comparison between countries.

Finally, considering radioactive pollutants from nuclear power plants, nuclear plants produce a variety of wastes classified by radioactivity levels as low, intermediate, and high-level wastes. Low and intermediate level wastes have relatively short-lived and low levels of radioactivity, meaning they can be disposed of relatively easily, thus the indicator used for this type of waste was annual production of these wastes. High-level waste by contrast is highly radioactive and long-lived. It thus needs either to be reprocessed or safely stored for long periods. Thus, the appropriate indicator for high-level waste is cumulative waste production.

Land and Terrestrial Biodiversity

All power plants take up land, but the amount depends upon the type of technology. Thermal technologies typically have a much higher power density (in terms of land use per unit installed capacity) compared to hydropower and renewables. Moreover, power transmission infrastructure also covers large areas of land, although land use beneath the transmission line can often continue after construction. To calculate the land take from the power sector, estimates of the typical area per unit installed capacity occupied by different technologies was multiplied by the installed capacity of each plant. Land take for transmission lines was calculated by estimating the length and likely orientation of the line, modified for the land use corridor and footprint of transmission towers. In the case of hydropower, land take was estimated using GIS estimates of reservoir area, and where these were not available, using typical power densities for plants (in terms of unit capacity per unit area). GIS information also allowed an estimate of the land take by land use (forest, agricultural land, urban areas, etc.).

Achieving an indicator for impact on biodiversity is more difficult and data was not available to allow the direct estimation of likely biodiversity impacts. Risk to terrestrial biodiversity was assumed to depend on three spatial impacts of power infrastructure. First, land take by power plants and transmission lines within protected areas indicate habitat loss. Second, the development of power plants, which requires access roads, will allow illegal logging and hunting if the roads pass through protected areas within a 5 km "zone of influence" of power infrastructure. Third, power infrastructure (roads, reservoirs, and transmission lines) may result in fragmentation of ecosystems and/or habitats. In addition, indicators were modified based on the proximity of infrastructure to protected areas, and the location of key or endangered species within these areas. Indices were developed to incorporate these three aspects, identify numbers of affected protected areas, and identify which protected areas were most at risk.

Rivers and Aquatic Biodiversity

The indicators used for assessing the impacts upon rivers and aquatic biodiversity focused on the effects of hydropower dams upon hydrology and sediment transport, and the changes in ecological connectivity of the rivers. These in turn impact the diversity and distribution of fish species, for example, by blocking fish migration or changing the flowing riverine habitat into a lake.

The degree of regulation (DOR) of the rivers provides an indication of the changes in hydrology as a result of storage of water in the reservoirs. The DOR is calculated by estimating the total active storage in each of the hydropower dams, including both run-of-river and storage dams, and comparing this to the mean annual flows in the river. For an individual dam, it is expressed as the percentage of flow that can be withheld in the dam's reservoir. This can then be aggregated for all the dams in the river to give the network degree of regulation for the whole river (see Figure 2).

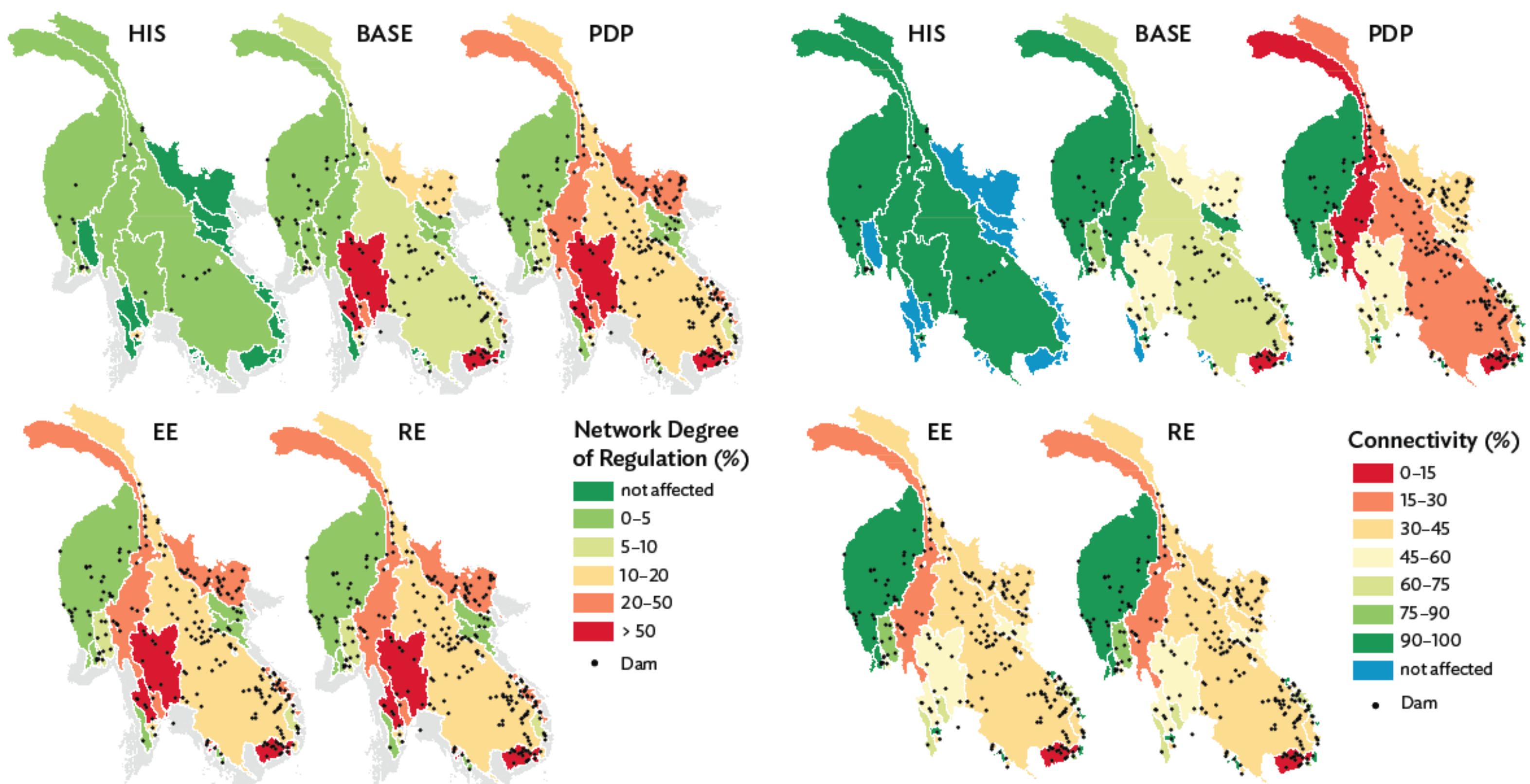
The DOR is an indicator of the changes in quantity and timing of water flows due to storage and release patterns, and is also indicative of altered water quality characteristics. An increase in water storage in a river basin is also indicative of increased rates of sediment trapping in the reservoir. It is also a measure of the amount of potential flood control that dams can provide by reducing peak flows.

The river connectivity index (RCI) is a measure of the degree of fragmentation of the ecosystems within each river. Fragmentation prevents effective ecological interchanges between the sections separated by a hydropower dam. If there are no barriers on a river, including irrigation dams as well as hydropower, the RCI has a value of 100. With increasing numbers of barriers, the RCI for each river will decrease. Originally, the Mekong had the greatest number of connected ecosystems of all the rivers in the GMS.

The RCI is calculated through a river classification system of all of the main rivers in the GMS. The RCI is calculated for each of the scenarios using GIS locations of all the projected hydropower dams, and estimating the ecosystems that remain connected over the whole river. The differences in RCI for each of the scenarios are shown in Map 1.

Fish species diversity in the GMS rivers is an indicator of changes in the character of aquatic ecosystems. While it is difficult to quantify these changes according to the scenarios, a qualitative description of impacts can be made. This shows that with greater density of hydropower projects on a river system, there will be a tendency for populations of migratory

Map 1. **Network Degree of Regulation and River Connectivity Index for Different Scenarios in the Greater Mekong Subregion**



EE = energy efficiency, PDP = power development plan, RE = renewable energy scenario.

Note: BASE refers to number of dams in 2010. HIS refers to historical development of dams as of 1970. At the time this study was written (April 2014), the base map was still under revision. The map was generated using ArcGIS, a platform for designing and managing solutions through the application of geographic knowledge (http://www.esri.com/software/arcgis).

Source: ADB. 2013b.

species to decrease and even to be lost; and for the fish that cannot survive in reservoirs to move away up to flowing water habitats, or to become extinct in that river system. The indicator can be used by considering the fish species diversity in a river or tributary; and identifying the species that are migratory and will not be able to move upstream to spawning grounds, and those that are unlikely to survive reservoir conditions. Some predictions place a cascade of dams to give rise to up to 60% loss of species diversity in a river.

Climate Security

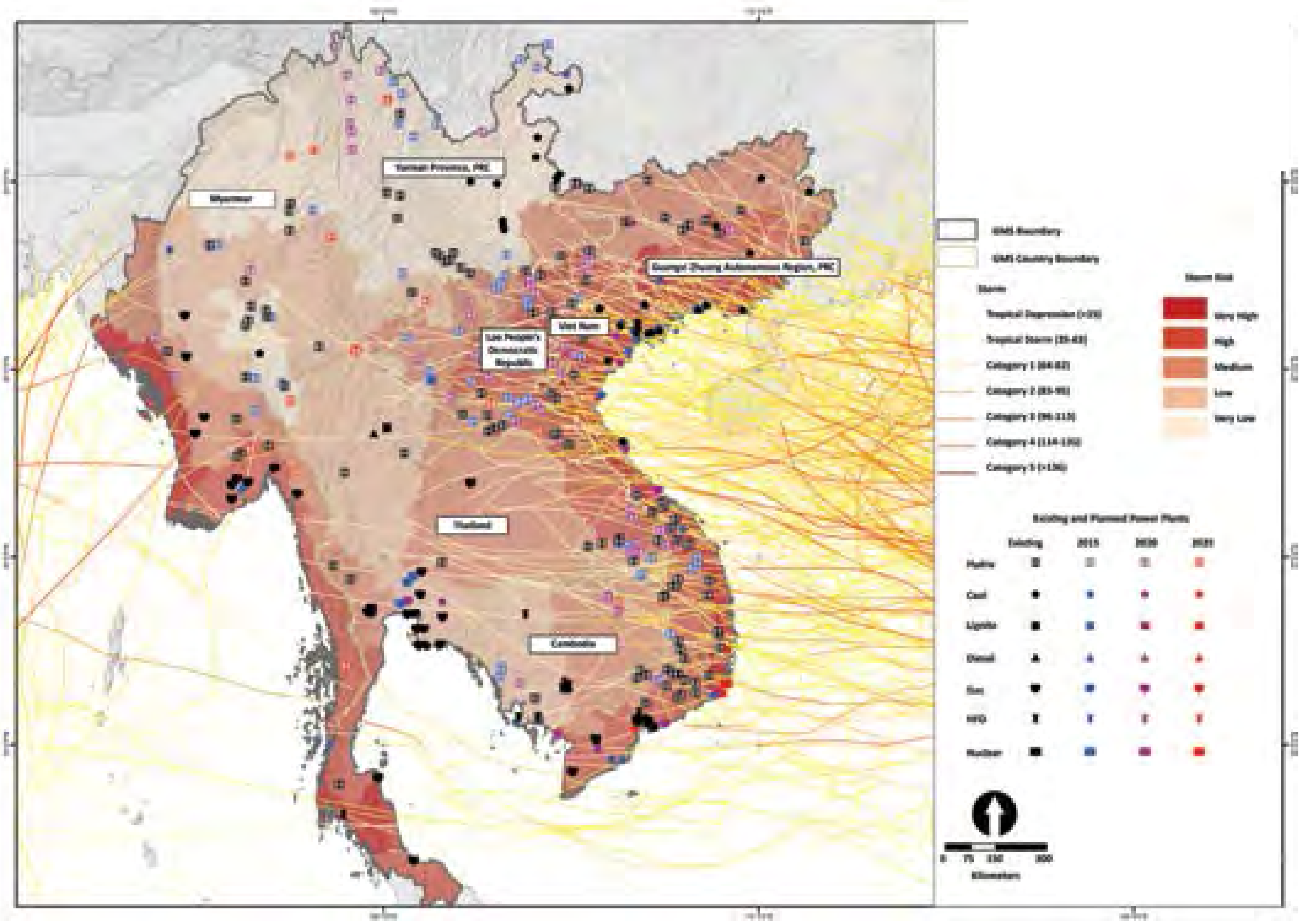
Climate security indicators considered both greenhouse gas (GHG) emissions and potential climate change impacts on power sector infrastructure. GHG emissions from the power sector were calculated for the main GHGs including carbon dioxide, methane, and nitrous oxide, expressed in terms of annual emissions of carbon dioxide equivalent using standard emissions factors (in the absence of region-specific factors) and fuel use data from the OptGen model. Methane emissions from hydropower were treated as a special case and emissions estimates were based on the highest values given in previous regional studies (e.g., Nam Leuk reservoir in the Lao PDR). These conservative figures err on the side of caution in order to identify potential negative environmental impacts.

The potential impacts of climate change on the power sector are wide ranging. Impacts cover the operational efficiency of power plants and transmission and distribution infrastructure; to water availability for cooling thermal plants and operating hydropower plants; to the potential impacts of extreme climatic events in terms of damage to power sector infrastructure or knock-on effects of extreme rainfall events in watersheds with significant amounts of hydropower development. While narrative accounts of these impacts can be developed, developing approaches amenable to quantification of likely climate risks would not be possible without more detailed rounds of climatic and power systems modelling. The climate risk indicator that was developed looked at the relative vulnerability of generation assets to extreme climatic events. The storm risk index was used as a relative ranking of the intrinsic vulnerability of different types of technology to storms (i.e., technological sensitivity). It assessed the exposure of power station locations to storms based on the past experience of storms (Map 2). It assumes that climate change will result in more extreme events of this type. This composite vulnerability index was multiplied by the electricity output attributable to different plants thus giving a generation-weighted storm vulnerability index. This allowed the comparison of vulnerability to climate change between different scenarios.

Food Security

Food security is a complex concept incorporating not only the average calorific value of food consumed over a period, but also achieving adequate nutrition from food and ensuring food supply in times of scarcity (for example, in the preharvest months). It was not possible to get directly at the likely food security implications of power development, as the pathways through which the development of the power sector can affect food security are indirect. Nevertheless, three indicators of direct impacts of power sector development on land availability, extent of irrigation, and impacts on fisheries were developed. Impacts on land

Map 2. **Historic Storm Routes within the Greater Mekong Subregion with Locations of Existing and Planned Power Plants**



GMS = Greater Mekong Subregion, Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China.

Note: At the time this study was written (April 2014), the base map was still under revision. The map was generated using ArcGIS, a platform for designing and managing solutions through the application of geographic knowledge (http://www.esri.com/software/arcgis).

Source: ADB. 2013b.

availability were based on agricultural land take applying the estimates described in land and terrestrial biodiversity section above. Estimates for changes in irrigated land were based on figures developed for the Mekong River Commission (MRC) basin development plans. Figures for the change in fisheries were also based on MRC estimates.

1. Aggregate productivity of agriculture

Power sector development may have multiple impacts on agricultural productivity in the GMS. The two indicators below were used.

(i) Agricultural land take for power sector development, for example, for transmission lines, using GIS mapping of the land take of developments with agricultural land use following FAOSTAT (2013).

(ii) Increased potential for irrigation as result of hydropower development using the MRC study on agricultural Impacts of basin-wide development scenarios (MRC 2010) for a rough and general application. In the MRC study, the irrigation areas were provided by MRC and were estimated in collaboration with riparian country partners. Water use was based on four irrigated cropping patterns involving rice and nonrice crops. The MRC study did not provide a basis for differentiating between the SEA scenarios and covered only the LMB; for other areas in the GMS, no data were available.

Land lost to power sector development is monetized at a uniform assumed cost. While simplistic, in that it does not recognize the differences between land areas lost, this is appropriate for a study covering such a large area in space and time. The valuation used was derived from the 2009 SEA conducted for Viet Nam's hydropower master plan (ADB 2009b), which used values of $5,600 per hectare (ha) for agricultural land; $16,100/ha for forest land, and $8,680/ha when aggregated. This is a lump sum for comparison with other cost and benefit streams expressed in annual terms. When annuitized, assuming a 10-year life and 12% discount rate, the final cost of land lost came to $1,536/ha/year. No allowance is made for the benefits of irrigation due to lack of reliable valuations as basis.

2. Changes in production in capture fisheries in rivers

Hydropower development has significant impacts on river fish and aquatic animals. Though the source study from MRC states that overall yields of inland fisheries and aquaculture combined are likely to stay at the current rate, or be only slightly reduced, due to hydropower development, negative effects on river and floodplain fisheries would be localized to stretches of river downstream of dams, and upstream of run-of-the-river hydropower plants, and probably to specific floodplains. However, according to a world review, losses in fish catch caused by any particular dam can range from 10% to 90%, so there is substantial uncertainty in assessment of impacts on fisheries from hydropower.

The calculation is based on an MRC study on impact on fisheries (Hortle 2010). The MRC assessment applied a number of development scenarios, defined by inclusion of different numbers and locations of hydropower dams. The MRC scenarios were somewhat different from the PDP and the alternative scenarios in the SEA, including a larger number of hydropower dams. The MRC 20-year plan scenario (for year 2030) without mainstream dams in the LMB most resembles the PDP scenario for the present SEA with 47 identical hydropower plant dams. However, the MRC scenario includes an additional 36 hydropower plants. It is found that the MRC and PDP scenarios are reasonably similar so the overall MRC assessment can be applied to the larger GMS with a view to obtaining orders of magnitude of expected impacts on inland fisheries from hydropower development planned in the PDP. A brief summary of the methodology for impacts on fisheries is shown in the box below.

The MRC's study on impact on fisheries calculates percentage increases and losses in production in for three cases: (i) "best case," i.e., with full and effective fisheries mitigation, development, and management measures in place; (ii) "mid case," with some mitigation; and (iii) "worst case" i.e., without any such measures and allowing fisheries to decline. These cases have been assigned to different power development scenarios and used to estimate the changes in total capture fisheries production between these scenarios. These differences are valued at $2,000/ton—the figure used in ICEM's (2010) SEA on the impacts of hydropower development on the Mekong mainstream.

Box. **Methodology for Impacts on Fisheries**

General approach: Estimate the size of the fishery, the sources of production, the areas of fisheries habitat available, and the likely effects of the scenarios on production in those habitats.

Assumptions: Food consumption is the main use of fisheries products in the basin. Consumption demand for fisheries products will increase proportionately to population by assuming constant per capita consumption. Aquaculture production will increase at conservative and declining rates based on recent trends in each country. Greater impact was assumed as more dams were built, up to the full development scenario, which would have the maximum impact. Impacts were assumed to increase by proximity; i.e., most of the impacts in the Lao PDR and Thailand accrue from upstream dams, whereas in the Cambodia and Viet Nam delta, more impacts accrue as dams are added downstream.

Estimating yield from capture fishery: Subtract the aquaculture component from consumption.

Source of capture fisheries production data: MRC's land-use GIS database and flood estimation. Three broad classes of habits were defined as follows:

(i) river-floodplain, comprising all habitats inside the major (year 2000) flood;

(ii) rainfed habitats, primarily rice fields as well as small water bodies (ponds, small reservoirs, canals, and modified streams) outside the river-floodplain habitats; and

(iii) other permanent water bodies outside these classes, primarily reservoirs.

Estimating yield from each habitat class: Multiply yield-per-unit-area estimates (based on literature values) by the areas of each habitat.

Basin-wide yield: "Forced" balance of basin-wide consumption figures by assuming certain levels of yield-per-unit-area in each habitat class in each country.

Baseline: Year 2000, which corresponded with the baseline consumption estimate.

Source: Hortle . 2010.

3. Changes in production in capture fisheries in hydropower reservoirs

This indicator is a subset of the total capture fisheries production. Fish production from reservoirs may increase due to construction of hydropower dams. Yields from reservoir fisheries resulting from impoundment by hydropower dams were estimated according to the reservoir area. Large reservoirs tend to have lower fish production compared to smaller, more intensively stocked and managed reservoirs. Fish production in hydropower reservoirs tends to be negatively affected by changes in water levels, e.g., seasonal drawdown in storage reservoirs, and daily drawdown in run-of-river reservoirs operated for peak power generation. Yields range from 500 kg/ha/year for reservoirs less than 100 ha, to 100 kg/ha/year for larger reservoirs over 100 square kilometers (km^2).

Reservoir sizes were taken from the actual figures for the areas of the known reservoirs, and from estimates of the sizes based on the ranges of power density (km^2/MW installed) for future reservoirs where the actual area has not yet been calculated. Changes in capture fisheries production in reservoirs are included in the monetization analysis conducted for other capture fisheries (as described above).

4. Contribution to nutrition of human population in each country of fish and other aquatic animals and plants

Fish and aquatic animals and plants are important sources of protein and calcium in the diet of people in the GMS countries. In many localities, these foods are essential for a large proportion of the population, especially the poor. In such areas, negative impacts on food security could be felt for a time until protein replacements, for example through aquaculture or exploitation of new fish habitats, including reservoirs, have been developed. This is a qualitative measurement of populations' food security sensitivity to energy development. It is based on the quantitative assessments of losses in capture fisheries due to hydropower development. The impact and/or risk assessment considered the following aspects:

(i) overall supply–demand balance of inland fish in the PDP scenario is assessed to remain positive;

(ii) reduced access to natural aquatic resources can be expected in some areas, and there could be potential severe impacts on river and floodplain fisheries;

(iii) reduced access to protein from natural aquatic resources is likely in some locations; and

(iv) food security for poor people dependent on river and floodplain fisheries is likely to be negatively impacted in some areas.

Monetization of the impacts on nutritional aspects of food security was not carried out. A risk and/or impact qualitative assessment was done based on the number of hydropower dams and sensitivity to impacts due to existing river and floodplain-dependent livelihoods. The scores applied were −3 for the highest negative impact, and 3 for the highest positive impact. Ideally, such assessment should include details on the location of dams (mainstream, tributary, closeness to floodplain) and reservoir area (for reservoir fisheries); however, generally this would be part of specific EIAs and would lie beyond the scope of this SEA.

Social Security

Because hydropower dams are the largest infrastructure built, assessing their impacts is exceedingly complex. There is a range of social and socioeconomic effects in several spatial and temporal dimensions: regional, national, and local; short-, medium-, and long-term. The number of "potentially affected people" by hydropower plants measures potential social impacts of hydropower on river water resources. This indicator is relevant because of the magnitude and importance of inland fisheries in the GMS countries.

At the scale of the present SEA, it was not possible to make a detailed assessment due to the lack of statistical data regarding subsistence fisheries and other dependencies on river aquatic resources. In areas where many households are dependent on natural river resources, the impacts from reductions in water flows and on river fish resources can be significant, requiring mitigation and compensation measures.

Emerging from this analysis, the number of "potentially affected people" is meant to provide a sense of scale of potential social impacts that would need to be considered in implementing the PDP. The figures should not be understood as the number of "project affected" people, which must be calculated through project-specific field surveys and social impact assessments.

The number of potentially affected people was calculated as follows. Corridors following the river for 50 km downstream of the hydropower plants were drawn on the GIS. Around the selected river stretches, 5 km buffer zones were made and these were overlaid on a population density grid of 1 x 1 km (data from LandScan 2011). The population living within these 5 x 50 km river corridors was then calculated.

Monetization of this indicator was not carried out since that would be exceedingly complex and would yield results with very large uncertainties. The number of "potentially affected people" is itself a measure of the scale of risk. The assumptions of the risks for people living in proximity to hydropower plants should of course be contextualized to specific circumstances in project EIAs.

1. **Resettlement of directly affected populations due to power plants (thermal, nuclear, hydropower)**

   Resettlement is among the most difficult and controversial of the social issues facing the development of the power sector. Resettlement has the potential to cause more social discontent than any other issue, and failures in the past have bred a legacy of distrust for the power sector. While any development that takes land may involve involuntary resettlement, the scale of the issue is likely to be greater for hydropower projects with large areas that will be flooded by reservoirs. Thermal plants are more likely to be located near urban areas where the population density is larger, but the land take areas involved are much smaller. Renewables that cover relatively large areas of land, such as solar and wind, may also have resettlement and compensation requirements.

For thermal and nuclear plants, the calculation is based upon the land take or area footprints, and the population densities of their locations. For medium and large hydropower, the available data for number of people resettled per megawatt is averaged and used for calculation of new hydropower plants. For small-scale hydropower, the approach has been to take a standard 10 MW plant with seven households of five persons each requiring relocation.

Average cost of resettlement was estimated using reported costs for the Trung Song hydropower project in Viet Nam supported by the World Bank (World Bank 2011); and the Nam Ngum 3 hydropower project in the Lao PDR, supported by ADB (ADB 2011). These costs include the direct costs of resettlement as well as compensation paid; expenditures on livelihoods development; and costs of communications, grievance handling, and program management. As this is a total value and benefits and costs streams in the analysis are expressed in annual terms, it was annuitized using a 10-year life for the stream of costs and a 12% discount rate. The average cost across the two projects of resettlement is $18,904 and the resulting annuitized cost was $3,345/person/year.

2. Proximity of cultural sites to power plants

The link between culture and power development is mainly through the effects of access to affordable electricity and all the technologies made possible through it—television, radio, lights, sounds, internet, mobile communication, computers, and so forth. Rural electrification makes an enormous difference in terms of access to information, with a great deal of impact on local culture. Only limited data is available regarding the location and character of cultural sites, mainly from the maps produced by ADB's GMS Environmental Operations Centre (GMS-EOC). The present analysis is therefore only indicative, not representative, due to nonavailability of data from large parts of the GMS.

Cultural sites in the four categories of history and culture, leisure, nature, and urban that are within 1 km, 5 km, and 10 km from power plants are identified. The physical cultural sites are assumed to represent cultural diversity. The indicator is based on the database of locations of 1,200 "tourism sites" of the GMS-EOC. Each power plant was assigned a score based on its proximity to one or more of these tourism sites. The scores for each power plant in the different scenarios were added up, and the totals for each scenario compared. No monetization was carried out for this indicator. Risk assessment would require more details about the types and characteristics of each site.

Health and Safety Security

Health and safety risks associated with the power sector relate to both impacts on human health from the everyday operations of the sector and the safety risks posed by the potential for catastrophic failure of hydropower and nuclear plants. Health impacts from power plant operations generally relate to pollution emissions to air. However, air quality rather than emission volumes *per se* determine health impacts, and it is therefore difficult to attribute likely impacts to the power sector based on emissions alone. Rather, the number of people living in zones vulnerable to emissions exposure around plants (i.e., in the typical stack shadow of a plant) were assessed as a proxy for health risks.

There are risks associated with living adjacent to all types of power plants. Impacts can be divided into incremental impacts caused by the day-to-day operation of power plants (e.g., emissions in the stack shadow of coal plants), and effects on human health due to accidents.

Risks to human health from thermal power plants are considered to be predominantly from air pollution, although water pollution may be important in some cases. Health impacts are related to air quality indicators rather than emission levels. Health impacts are seen when pollution levels in the air exceed certain thresholds. However, based on aggregate emission levels, it is not possible to ascertain and attribute health impacts. Weather conditions, the presence of other pollution sources, and population densities will be important for assessing the impact on air quality and therefore on health. Thus as a rough proxy of the population at risk from air pollution, populations living in the proximity of power plants are calculated based on populations in a typical stack shadow of these plants. The population exposed to potential health risk from power plants is calculated using international standards. The analysis is limited to the threats to health considered to be the most significant (shown in bold), i.e., populations within the typical stack shadow of coal and lignite plants, and populations within a likely affected radius of nuclear plants.

The number of people within the influence zones is calculated by applying GIS analysis whereby the location of different types of plants is overlaid on the LandScan population density grid of 1 x 1 km as shown in the example.

1. **Number of people in the "influence zone" of power plants according to the different scenarios**

   This is a measure of the potential risks that populations are exposed to when living adjacent to power plants. These risks will be different for different types of plants. Each type of plant is given a score from 1 to 5 depending on the potential risk to health of the people living around.

   The location of each specific plant enables estimation of the population at risk within a 10 km radius of each plant, using the LandScan population density database (i.e., multiplying the population density by 314.3 km^2). Size and power generation of each plant is also important, and this is factored in using the annual power production predicted in gigawatt-hours. The use of gigawatt-hours is considered better than installed capacity because it is related to the actual quantity of fuel used.

For each scenario, the numbers of people potentially at risk are then calculated for each plant according to the following equation:

$$\text{numbers of people potentially at risk} = (Pd \times A \times GWh)$$

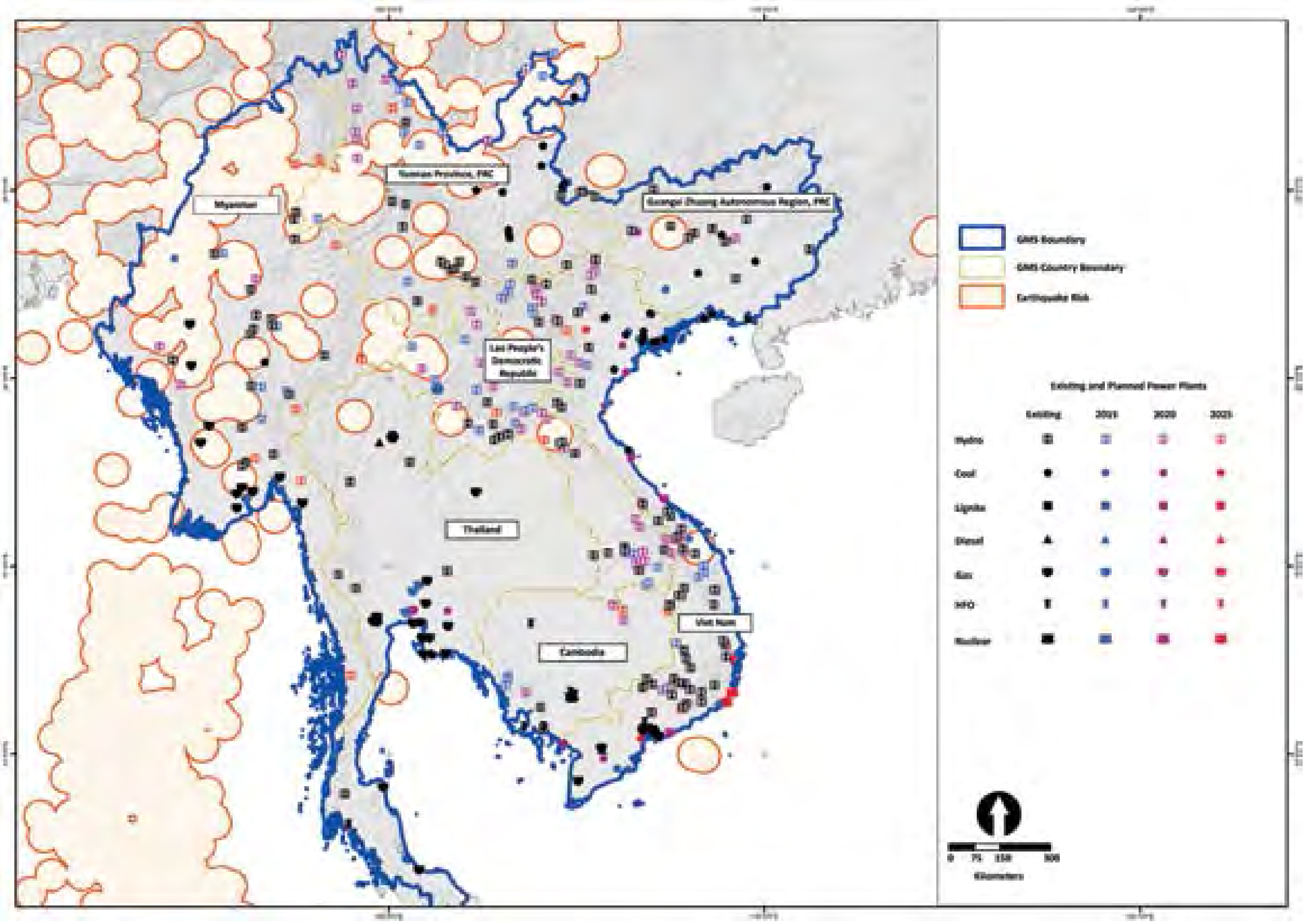
where Pd = population density, A = area of zone of 10 km, radius = 314.3 km^2, and GWh = annual gigawatt-hours produced. The numbers of people potentially at risk from every plant are added for each scenario, and then the totals compared. No monetization is attempted here. Mitigation costs to bring the health impact risks to acceptable limits are usually included in plant construction and operation costs. Studies on the costs of public health impacts have been done for some types of plants, but these are not included.

2. Risk of catastrophic failure of dams due to earthquakes

This was also deemed an important risk as a considerable number of dams have been built in areas that are prone to earthquakes. Some detailed analysis of earthquake risks and dams existed for the southwestern PRC, but otherwise a comprehensive data set giving the earthquake risk was not available. Earthquake maps of the United States Geological Survey were used to develop an idea of areas where earthquakes had happened more frequently in the past and are therefore deemed more vulnerable to earthquakes, then the location of power plants was overlaid on this to give an indication of where plants that were exposed to earthquakes under different scenarios are likely to be. Different scenarios were compared in terms of units of installed capacity of hydropower plants in zones vulnerable to earthquakes (see Map 3).

Finally, the risk of catastrophic failure at nuclear plants is well known, if rare. The risk relates to the release of dangerous radioactive elements over wide areas. As with the impacts of pollution, this was assessed in terms of the number of people potentially at risk in the event of such an accident based upon United States Nuclear Regulatory Commission emergency planning guidelines for emergency planning zones. The guidelines specify a 16 km plume exposure pathway within which exposure of the public to, and inhalation of, airborne radioactive contamination is a concern; and an 80 km ingestion pathway concerned with the ingestion of food or liquid contaminated with radioactivity. Based on these, the location of plants and data on population in the surrounding area potentially exposed populations were calculated.

Map 3. **Earthquake Risk Zoning Map for Power Plants in the Greater Mekong Subregion**



GMS = Greater Mekong Subregion, Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China.

Note: At the time this study was written (April 2014), the base map was still under revision. The map was generated using ArcGIS, a platform for designing and managing solutions through the application of geographic knowledge (http://www.esri.com/software/arcgis)

Source: ADB. 2013b.

Good Governance and State Security

Good governance and state security issues in the power sector are influenced by many national political and institutional factors, which are not primarily technology-specific. However, different technology mixes define the SEA scenarios. For this reason, the SEA does not apply indicators, nor does it formally differentiate and compare the scenarios in terms of governance issues. Instead, the SEA includes a narrative of issues that are applicable throughout the power sector without any distinction between the different technologies or power generation mixes. The issues covered are:

(i) social security in the power sector,

(ii) implementation of social policies,

(iii) corruption issues,

(iv) improving governance in the power sector,

(v) environmental governance,

(vi) public consultation in the power planning process, and

(vii) resettlement safeguards.

During the SEA process, the following potential indicators were raised by the stakeholders, but were rejected for the following reasons:

(i) World Governance Indicators—these were identified for the GMS countries but found to be too general for application to the different power sector SEA scenarios;

(ii) incidence of resource use conflicts or disputes associated with power plants—no data was available that could be extrapolated to the different scenarios;.

(iii) number of agreements and scope between countries as to sharing of resources for the power sector—no data was available that could be extrapolated to the different scenarios; and

(iv) existence of monitoring and evaluation frameworks for pollution control and enforcement for resettlement and compensation—such frameworks are not linked to the different scenarios and would likely not change from one to the next.

Energy Security

There is no simple or universally accepted definition of energy security. There is the obvious question of whether, for example, this means physical or financial (price) security. A country reliant on oil imports will generally always be able to obtain supplies (hence is physically secure), but may have to pay unexpectedly high prices to do so (so is not secure). A country dependent on gas imported through pipelines may have a fixed long-term gas price (so is financially secure), but is subject to the risk of interruptions due to pipeline failures, decisions by upstream producers to stop supplies, and so forth (so is not physically secure).

There also tends to be a presumption that domestic supplies are more reliable than imports. Again, this may not always be the case. As one example, reliance on a domestic coal industry that experiences frequent strikes may actually be less secure than importing fuels from a range of suppliers. Again, the question also arises as to what is meant by security in this context. If financial security is the aim then the implication is that prices for domestic fuels will move differently from those of world market prices to reduce volatility and price shocks. This imposes its own costs in terms of foregone government revenues, for example.

A further consideration is the extent of reliance on one technology or fuel: the greater the dependence, the greater the risk. Both Japan and the Republic of Korea have recently illustrated this with problems with individual nuclear reactors leading to shutdowns of the entire nuclear fleet, although nuclear power is often seen as a relatively secure source of supply given its lack of exposure to fuel price volatility.

Therefore, to try and capture the full range of aspects of energy security, a variety of indicators need to be used. In this SEA, the focus was on the following three (although there are other valid indicators):

(i) diversity of the fuel mix in electricity generation—the presumption is that a more diverse mix is more secure, other things being equal;

(ii) remaining life of domestic coal and gas reserves—the assumption is that domestic supplies will, generally, although not always, be more secure than imports of fossil fuels; and

(iii) trade-off between cost and risk provided by different generation mixes—in many cases, technologies offering reduced risk do so at higher expected costs.

Fuel diversity was measured using the Shannon-Weiner index, which captures both the number of different fuels and the distribution of the shares of each. For example, in a 10-fuel mix, the highest score of 1.0 would be realized where the share of the fuels are equally distributed (i.e., each has 10% of the mix). A situation where one fuel has 66% of the mix and the remaining nine are equally distributed would have the same score of 0.60 as would the case where there are four fuels equally distributed with 25% of the mix each. The index, therefore, recognizes that it is not just the number but also the relative contribution of individual fuels in the mix that is important to diversity.

Remaining lives of domestic coal and gas reserves were estimated using 2012 reserves data and total domestic consumption, from which estimated power sector consumption is deducted to give a baseline value for nonpower sector use.[10] This nonpower sector baseline value is assumed to remain constant over the study period, and projected power sector consumption is then added to it to obtain total consumption. From this, the remaining lives of existing reserves can be estimated.

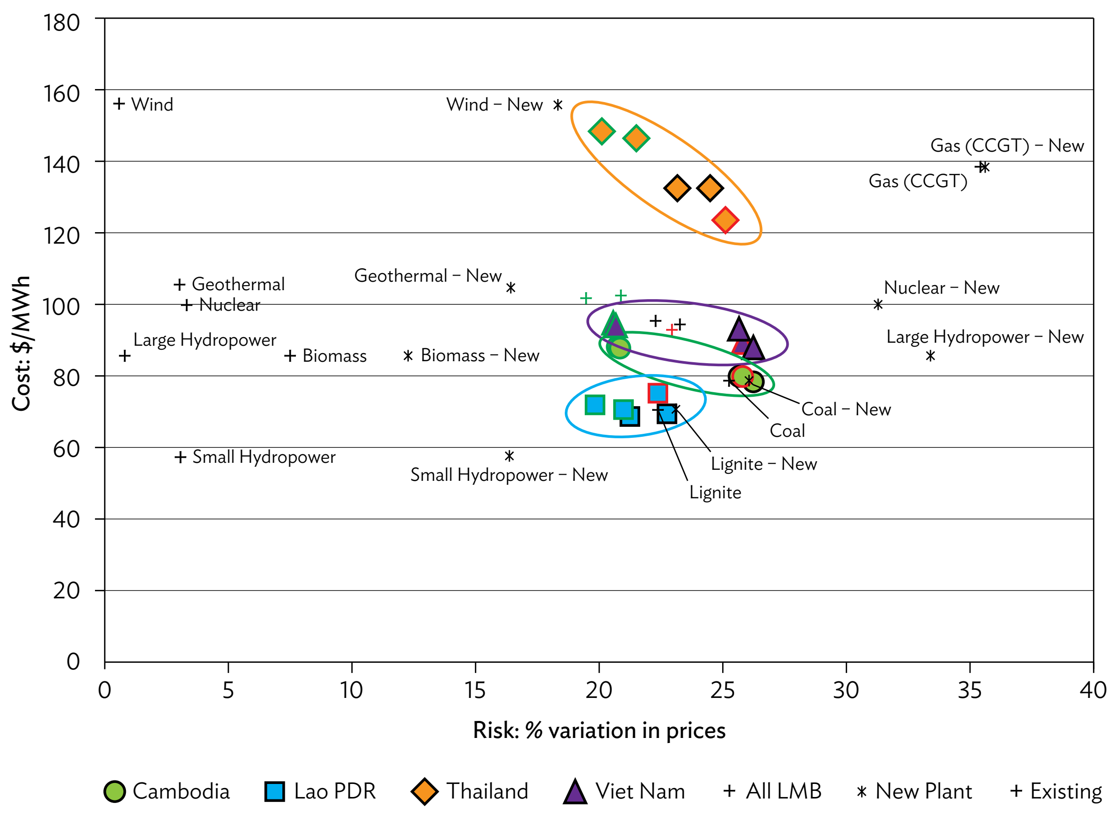
Cost–risk trade-offs were estimated for different generation mixes and different years using portfolio analysis techniques. In essence, this compares the expected cost of the generation

[10] Many different sources and definitions of reserves exist. For consistency, reserves levels were obtained from the United States Energy Information Administration.

mix (in US dollars per megawatt-hour) with its volatility or risk. Volatility is measured by the variance in costs around the expected cost level. These variances are themselves estimated using assumed probability distributions for key components of expected costs—notably capital costs, fuel costs, and operating costs. Where possible, probability distributions are estimated from historical cost data. Where this is not available, expert judgment is used. The concept is illustrated in Figure 2 using outputs from the study.

Energy security indicators are not easily subject to monetization. Monetization provides an estimate of the total net costs of generation under alternative scenarios together with the costs of impacts, giving an overall cost of power supply under each scenario and the displacement case for the year 2025.[11] Monetization includes the costs of investment and

Figure 2. **Cost–Risk Trade-Offs**



CCGT = combined cycle gas turbine, LMB = Lower Mekong Basin, MWh = megawatt-hour.
Source: ADB. 2013b.

[11] In the context of this SEA, the term "displacement" is used to indicate the option for removing a planned thermal, large hydropower, or nuclear plant from the PDP scenario and its replacement by greater contributions from renewable energy sources and energy efficiency measures. A global displacement option involved the displacement of some coal-fired thermal plants to address issues of carbon emissions. A regional displacement option involved the displacement of some planned large hydropower plants, nuclear plants in Viet Nam, and a few coal-fired plants.

fuel, and external impacts on the environment and society. As the analysis shows, there is often a trade-off between security (however measured) and expected costs of electricity supply. While expected costs can readily be compared, the associated levels of security or comparative risks cannot. Therefore, comparisons of energy security across scenarios generally tend to be qualitative.

Economic Security

In this SEA, economic security was compared in terms of the costs of electricity supply across scenarios and jobs created. The analysis conducted for the SEA made no allowances for the benefits of electrification in terms of improved well-being, income-generating activities, and productive potential. This is not because these impacts are considered to be unimportant but because they are expected to be the same across all scenarios assessed (all of which are assumed to meet the same demand for electricity).

For the Lao PDR only, which is the only economy within the GMS that is expected to be highly reliant on revenues from electricity exports, the potential levels of resource rents and the potential for "Dutch disease" was also assessed.[12]

Costs of electricity supply were estimated using the various PDPs and resulting projected generation by fuel and technology. The same assumed fuel costs, derived from projected world market prices, were used in all instances—consistent with an economic analysis excluding the impacts of taxes, subsidies, and other domestic price distortions. For consistency, the same capital and operating and maintenance cost assumptions were applied to all countries. These assumptions are those used in master planning in Viet Nam. The capital costs of large hydropower projects were estimated as the average of the costs of individual projects where these are known. A standard allowance for transmission and distribution costs was added to the resulting estimated generation costs.

The numbers of jobs created were estimated using ratios of the numbers of permanent and temporary construction jobs created for each unit of new generating capacity of different technology types constructed in the United States. For hydropower projects, estimates of jobs created were derived from various published studies of their impacts conducted for major financing agencies. These represent direct employment—there would also be indirect employment increases resulting from the increased income of those directly employed, but insufficient data is available to estimate the magnitude of these effects.

Resource rents were estimated from projected electricity exports by the Lao PDR. Only part of these resource rents would be retained in the Lao PDR; much would flow out to foreign lenders, equity investors, and skilled workers. Overall, using estimates for the Nam Theun 2 project, only around 10%–12% of project revenues are expected to remain in the Lao PDR.

[12] Dutch disease occurs where foreign revenues earned from the export of natural resources lead to rapid appreciation of a country's currency, a resulting loss of competitiveness of domestic agricultural and manufacturing industries, and resulting imbalances in how the benefits of the resources are shared within the country. It is named after the experience of the Netherlands following the discovery of the giant Groningen gas field.

This would mean resource rents by 2025 might represent around 1%–1.5% of gross domestic product—a substantial sum but unlikely to create Dutch disease.

Monetization of the costs of electricity supply is obviously straightforward—the total estimated costs are the monetary values used (provided these are adjusted for market distortions, as is appropriate for an economic cost–benefit analysis). Although it would be straightforward to monetize the additional jobs created by power sector development, this was not done for this SEA study as the benefits would be insignificant relative to the scale of other monetized costs and benefits.[13] The analysis of resource rents was limited to one country and is not amenable to monetization in any case, as its impacts would depend on assumptions on both the likelihood of Dutch disease resulting and the magnitude of its impacts.

13 For example, under the current PDP scenario, by 2025 an average of 96,000 jobs are estimated to be created annually among the four LMB countries as a result of new power generation development. Majority of these are in construction. If each job has average earnings (assumed to equal benefits) of $2,000 per month, the total benefits would be $2.3 billion annually compared to total electricity costs before considering externalities of $76 billion.

1040 MW PhaLai coal-fired
power station,
Viet Nam

Analyzing Sustainability of Power Planning

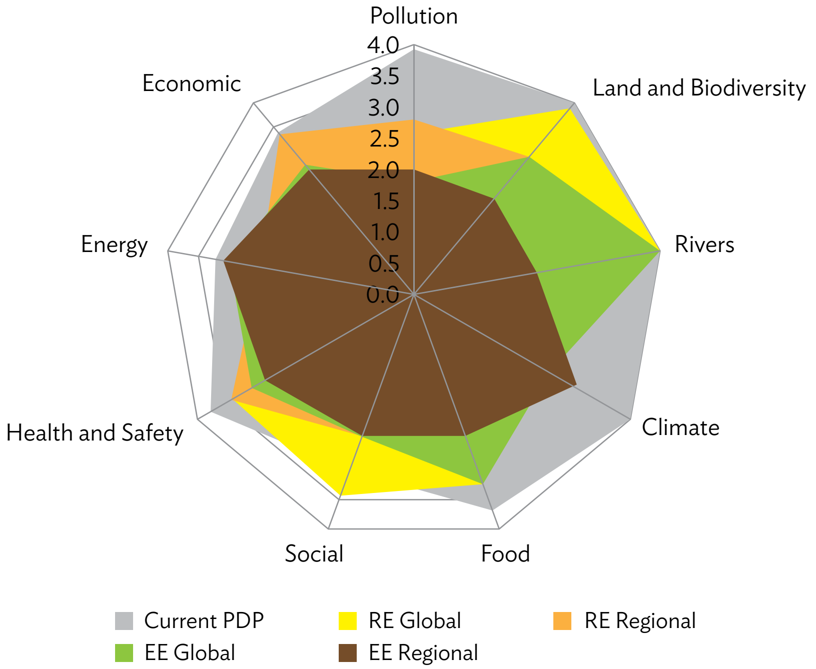
Integrating the Assessment of Security Aspects

The SEA process should allow for comparison of changes in the indicators of the eight "security aspects," relating these to the changes in the scale of power development over the 15-year time period. This allows a combined view of the total impacts across the alternative scenarios in order to identify which power development trajectory appears most sustainable for the GMS.

For such a comparison to be meaningful, a common unit of value is needed to allow trade-offs, for example, the reduced impacts on resettlement requirements of substituting renewable energy sources for large hydropower projects against the possible resulting increase in generation costs. As far as feasible, therefore, the study sought to convert the magnitudes of impacts under the different scenarios into US dollars by assigning a value to each unit of impact through monetization.

For many indicators, monetization is not possible. This is particularly so for those indicators where measures of the comparative magnitude of the impacts of different technologies and, therefore, power development scenarios, can be made, even though the values or costs of these impacts remain uncertain. Examples include the extent of fragmentation of ecosystems and the potential for water pollution. To allow comparisons of scenarios including these impacts, the study also conducted qualitative comparisons using radar diagrams. These provide a visual picture of the relative significance of the impacts in each "security aspect" for each scenario while, in effect, weighting all these impacts equally. An example of such a diagram is provided in Figure 3.

Figure 3. **Radar Diagram of Differences in Significant Impact by Security Aspect between Scenarios**



EE = energy efficiency, PDP = power development plan, RE = renewable energy.

Note: Pollution, land and biodiversity, and rivers are components under the ecological "security aspect." The aspect of good governance and state security is not included in the diagram, because no measurable indicators were found to compare the scenarios.

Source: ADB. 2013b.

Qualitative Analysis

There is no easy way to compare all these different parameters. However, the radar diagram approach can visually compare the scenarios in relation to the current PDP of the LMB countries. These differences can then be discussed more clearly. The radar diagrams highlight how the scenarios perform in each "security aspect" in comparison to each other. The higher the score, the less well they perform.

In order to develop the radar diagrams, the following process was applied to the numbers that can be attributed to the different indicators described earlier.

(i) For each indicator, identify the value in the scenario that represents the lowest performance and assign a score of 4 points. This may be the highest value, e.g., the scenario with the largest quantities of air pollutants or highest numbers of people to be resettled; or it may the lowest value, e.g., the scenario with the lowest numbers of jobs.

(ii) For the other scenarios, assign scores in relation to the percentage difference between the values of the indicator. Thus:

   (a) a scenario with a value between 95.1% and 100% of the highest value = 4,

   (b) a scenario with a value between 90.1% and 95% of the highest value = 3,

   (c) a scenario with a value between 80.1% and 90% of the highest value = 2, and

   (d) a scenario with a value between 70% and 80% of the highest value = 1

(iii) Indicators with values less than 70% are also scored 1.

(iv) Scores for all the indicators for one "security aspect" are averaged and used in the development of the radar diagram.

Other forms of averaging are used, e.g., when there are values for each LMB country, wherein the scores are assessed by country and then the scores for each scenario are averaged for all four countries.

Weighting the Security Aspects

As expected, not all impacts and benefits are equally important. In order to reflect this, the assessment should incorporate a weighting for each indicator or "security aspect". Weighting is a process that can be quite controversial depending upon the perception of the different stakeholders, and the weights accorded to each impact should not be unilaterally decided by one person or one group of people. This makes it ideal for a stakeholder consultation held toward the end of the SEA process when the main results of the assessment are known.

By according a scale of three weights (A = most important to C = least important) to each of the chosen indicators, the relative importance can be incorporated into the assessment and radar diagrams. Table 2 shows the weights accorded to the indicators selected for this SEA. Note that these weights were not subjected to a stakeholder consultation, and are used for illustration how the weights might appear.

Quantitative Analysis—Monetization

A fundamental problem in any SEA or any wider social or environmental analysis is the difficulty in finding a consistent basis on which to compare the resulting costs and benefits. Qualitative analysis of the type described above can provide some basis for comparison but, by its nature, does not create consistent valuations across different costs and benefits.

Monetization is the means used in the SEA to address this and to allow the streams of costs and benefits to be expressed in a consistent and comparable manner. It does so by placing a monetary value on each identified cost or benefit. Inevitably, these valuations are contentious and, in many cases, it can be difficult or impossible to find a means of valuing a cost or benefit. This will especially tend to place less weight on those impacts that are the most difficult to measure—for example, the loss of diversity among fish species—and more on impacts that can be readily costed, such as the different costs of electricity generation using different fuels.

Table 2. **Changes in Indicators between Existing (2012) and Current Power Development Plan (2025) with Significance Weighting**

Security Aspect	Indicator	Units	Existing	Current PDP	Percent Change	Significance
Ecological security—pollution	Air pollution—nitrogen oxide	MT/yr	0.15	0.355	236.7	A
	Air pollution—sulfur oxide	MT/yr	0.1	0.2	200.0	A
	Air pollution—PM10	MT/yr	0.4	1.5	375.0	A
	Solid waste	T/yr	150,000	725,000	483.3	B
	Potential water pollution	index	2.8	9.2	328.6	C
	Water withdrawal and consumption—thermal	M m^3/yr	210–650	310–900	148–139	B
	Water evaporation—hydropower	M m^3/yr	246	740	300.8	C
	Water consumption	M m^3/yr	456–739	1,347–2,169	283–164	B
	Radioactive waste LLW/HLW	M m^3/yr and T/yr	0	2,148–215		A
Ecological security—land and biodiversity	Land take, thermal	km^2	70	210	300.0	D
	Reservoir area	km^2	6,738	16,812	249.5	C
	Cropland and mixed agriculture—thermal	km^2		145		C
	Cropland and mixed agriculture—HPP	km^2		3,758		C
	Forest—HPP	km^2		10,096		B
	Land take—interconnectors	km^2		143		D
	PAs affected by power plants	# within 1 km	61	122	200.0	B
	PAs affected by interconnectors	# of PAs affected		20		B
	Habitat loss in PAs	km^2		1,016		A
	Number of PAs at risk	#PA very high/ high/medium		13 Very High, 6 High, 1 Medium		A
	Zone of influence of interconnectors in PAs	#PA/km^2		20/958		C
	Fragmentation in PAs	# of PA fragments		48		B
Ecological security—rivers and aquatic biodiversity	DOR (Mekong)	index (Mekong)	5.63	13.27	235.7	A
	DOR (Red River)	index (Red River)	14.79	22.53	152.3	B
	DOR (Salween)	index (Salween)	1.06	33.09	3,121.7	A
	RCI (Mekong)	index (Mekong)	68.77	15.32	22.3	A
	RCI (Red River)	index (Red River)	49.58	30.49	61.5	B
	RCI (Salween)	index (Salween)	98.7	12.37	12.5	A
	Sediment trapping (Mekong)	MT/yr	170	45	26.5	A
	Fish species diversity—percentage of species at risk	% of species numbers		40		B
Climate security	Greenhouse gas emissions from the power sector	MT/yr	148	459	310.1	A
	Reducing the risks of extreme events	storm vulnerability index	1.87	2.09	111.8	C

continued on next page

Table 2 *continued*

Security Aspect	Indicator	Units	Existing	Current PDP	Percent Change	Significance
Food security	Food production—loss of cropland or mixed agriculture	km^2		146		C
	Irrigated area	million ha	6.81	9.73	142.9	C
	Food production—fisheries yield, Mekong (with mitigation)	million tons/yr	2.034	2.295	112.8	B
	Food production—fisheries yield, Mekong (without mitigation)	million tons/yr	2.034	1.644	80.8	B
	Riverine floodplain fisheries (LMB)	million tons/yr	1.035	0.759	73.3	C
	Food production—reservoir fisheries (LMB)	million tons/yr	0.065	0.124	192.6	C
	Balanced nutrition—supply/ demand balance with fisheries	tons/yr	0	519,000		C
	Balanced nutrition—supply/ demand balance without fisheries	tons/yr	0	–132,000		C
Social security	Population within 50 km downstream of hydropower dams	# of people in GMS	8,968,030	10,502,306	117.1	C
	Potential resettlement thermal plants in GMS	# of people in GMS		140,662		B
	Potential resettlement requirement, HPP in GMS	# of people to be relocated	750,487	1,062,789	141.6	A
	Potential resettlement requirement, HPP in LMB countries	# of people to be relocated	387,493	515,389	133.0	A
Health and safety security	Health risks from power plants—people within 0.8 km of thermal plants		61,645	148,717	241.2	A
	Health risks from power plants—people within 1.6 km of thermal plants		125,747	333,038	264.8	B
	Flood control and safety risks	as per DOR				C
	Seismic risk—installed capacity within seismic zone	GW installed capacity	4.7	20	425.5	C
	Nuclear safety—populations within 16 km of nuclear plants	# of people in GMS	0	264,000		A
	Nuclear safety—populations within 80 km of nuclear plants	# of people in GMS	0	4,448,000		A
Economic security	Investment needs (LMB)	$ billion/yr	12.6	13.3		A
	Energy intensity	kWh/$000 GDP	667	890	133.4	A
	Jobs created—construction	# jobs/yr	84,000	67,000	79.8	C
	Jobs created—permanent	# jobs/yr	14,000	29,000	207.1	C

DOR = degree of regulation of rivers, GDP = gross domestic product, GMS = Greater Mekong Subregion, ha = hectare, HLW = high level nuclear waste, HPP = hydropower plant, km = kilometer , km^2 = square kilometer, kWh = kilowatt-hour, LLW = low level nuclear waste, LMB = Lower Mekong Basin, m^3 = cubic meter, MT = metric ton, PAs = protected areas, PDP = power development plan, PM10 = particulate matter of 10 microns, RCI = river connectivity index, yr = year.

Note: Significance is ranked from A (most important) to C (least important).

Source: ADB. 2013b.

Without monetization, any consistent comparison of costs and benefits and, therefore, drawing any conclusions on which scenarios offer the least total cost or greatest benefits to costs ratios is impossible. The solution to valuation problems is for more effort to be made on collecting the necessary data and improving the methodologies used for monetization—not to reject the entire process. Arguments that some impacts are too important to be monetized actually mean that the value to be placed on these impacts is very high. Unless a clear policy decision has been made that some technologies or fuels will not be developed, then there is always an option to develop a particular form of power supply and, in doing so, its costs and benefits relative to others forms need to be compared. No type of power supply, after all, is completely cost-free.

Because of the relatively small number of impacts that could be monetized using existing data and methodologies that could be applied within the relatively limited time frame and budget of the study, ultimately only six of 46 indicators identified could be monetized. The other 40 were not included because of their relative insignificance compared to total costs and benefits across the scenarios, or because they would not be expected to differ across scenarios. Most were not included because of a paucity of the necessary information to monetize them.

The six indicators that were monetized were:

(i) direct costs of power supply (generation investment, fuel costs, transmission and distribution);

(ii) costs of carbon emissions;

(iii) cost of other pollutants emitted;

(iv) costs of land take associated with power generation development;

(v) costs of resettling those people directly impacted by new power generation projects; and

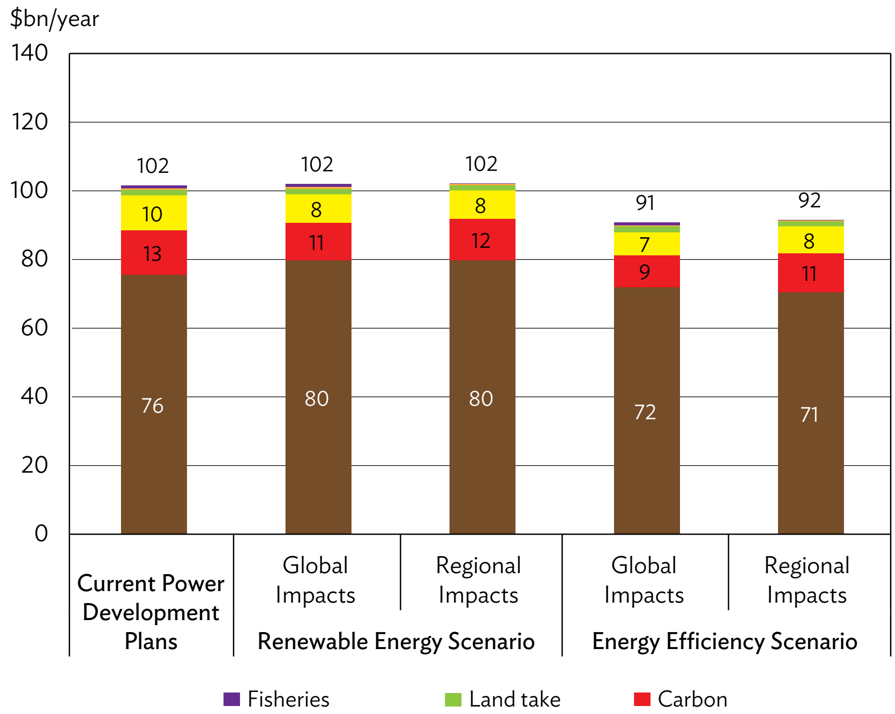
(vi) costs of lost production from capture fisheries.

The resulting monetized costs (no benefits were monetized) of the different scenarios investigated for 2025 are shown in Figure 4. These are annual cost streams, while costs that are of a one-off nature (such as resettlement costs) have been converted to an annuitized value.

What is readily apparent is that the slightly higher direct (or financial) costs of power generation with more renewable energy capacity than under current PDPs are offset by decreased carbon emissions and pollutants. However, greater use of energy efficiency technologies or measures is preferred over either of these routes, as it offers reductions in all costs.

It is also evident that the costs associated with land take, resettlement, and fisheries losses are relatively small. This reflects the regional nature of the analysis—that while these impacts are very important for the individuals directly affected, they are less so when considered in the context of the total population across the four LMB countries of 180 million people. This sort of comparison is an area where monetization can also help in evaluating the significance

Figure 4. **Total Costs of Electricity Supply in the Lower Mekong Basin by Scenario, 2025**
($ billion/year)



Source: ADB. 2013b.

of different impacts and the weights that should be attached to them in cost–benefit analyses. All the impacts monetized here were unweighted but often, for example, greater weights might be attached to impacts on the most vulnerable groups such as low-income households with little political influence.

Qualitative assessment can further enhance the conclusions regarding relative costs and benefits in a monetization assessment of different scenarios. For example, for indicators that were not monetized, the most significant in terms of their likely impacts on the conclusions are the impacts on biodiversity of different power generation technologies. Large hydropower projects would be expected to perform particularly poorly in this regard, given the land areas required for their reservoirs; their location in many cases in areas of ecological importance; and, for mainstream dams, their disruption of ecological connectivity. Where estimates of the value of other costs and benefits streams are broadly equal, as is the case for the current PDPs and renewable energy scenarios shown above, this additional qualitative assessment would lead to a bias away from those development paths that make the greatest use of large hydro projects.

1375 MW Ban Pakong combined cycle gas turbine power station, Thailand

Conclusions and Recommendations

This volume has shown how a wide range of sustainability indicators can be developed to assess different power planning scenarios. In choosing indicators, it is important to ensure that (i) the indicator is relevant to the sustainability aspect that is being considered; (ii) the measurements will show significant changes between different scenarios; and (iii) the data and information are available to allow these measurements and calculations to be made.

From the descriptions of the indicator methods, it is evident that many are dependent on the different types of generation technologies. Some indicators may be more relevant to one form of generation technology than the other, e.g., air pollution indicators are more relevant to thermal power than to hydropower, but the indicator must be applied across all the generation mixes in the scenarios.

Many of the indicators can be developed using standardized data or factors according to the installed capacity of a typical plant, and the overall value of the indicator can be measured by multiplying the total installed capacity of that type of plant. Other indicators are very size- and location-specific, as for hydropower, and may not be easily measured with standard values per megawatt of installed capacity.

Methods such as GIS are particularly adaptable for an SEA analysis using information such as population density, land use, forest cover, protected areas, etc. For application in an SEA, it is critical to know where the power plants and transmission lines are expected to be developed. In this way, the footprints of the plants (and reservoirs) can be superimposed over the GIS maps, and the impact assessed. Such indicators can then be aggregated for all of the plants in each scenario.

It is also important to appreciate that indicators do not tell the whole story—they are only a way of understanding the pressures on the particular sustainability aspects brought about by the different power development options. The radar diagram technique allows a comparison of the scenarios using all the indicators together and assessed in a similar method of relative change, which illustrates the strengths and weaknesses of each power scenario relative to each other.

It is clear in this study that many of the indicators chosen cannot be monetized easily. Monetization allows a clear comparison of costs and benefits, but even the process of monetization makes many assumptions that need to be explicit and may be challenged. Much more work is required to develop methods that will make the monetization process more comprehensive for all the sustainability "security aspects".

Recommendations and action points regarding choice of indicators, provision and storage of data, and methods of analysis for future sustainability-led SEAs to ensure that national and regional power sector planning consider environmental and social costs are given below.

1. **Agree on a common set of environmental and social indicators for the GMS to be included in comparisons of power development plans and their alternative options**

   The environmental and social indicators in this SEA study that may be used when assessing the impacts of power plans were developed through consultation and assessment of what are the most useful and feasible. They are by no means the only ones that could be used, and further work may identify more appropriate or measurable ones. It is essential that for both national and regional comparisons, the indicators should be agreed upon and consistently applied. This action point also refers to the recommendation on ensuring greater regional coordination.

   Some of the indicators chosen may have a higher priority than others, and it is necessary to develop an agreed weighting process for such assessments. In this SEA, an additional stakeholder consultation step would have been required to weight the different indicators and "security aspects".

2. **Agree on a common set of methodologies for the GMS to value these indicators to ensure that costs and benefits are captured in the overall least-cost analysis**

   Monetization of many of the environmental and social impacts in this SEA study was difficult and could only be applied effectively for a relatively few indicators. There is a need to develop and agree on valuation methodologies so that these can be used in similar cost–benefit analyses and incorporated into least cost comparisons of PDP options. In particular, methodologies for valuations of biodiversity impacts, nutrition, and cultural impacts are required.

3. **Develop improved methodologies for assessment of cumulative impacts of dispersed renewable technologies**

   The SEA highlighted concerns about the cumulative impacts of dispersed technologies such as construction of small-scale hydropower projects in a river basin, or land take of wind and solar projects. Such impacts may be cumulatively greater than one larger plant of equivalent size. Cumulative assessments would be required for increased deployment of such renewables.

4. **Encourage the use of cumulative impact assessment to inform power sector planning in the location of new power plants in the GMS, e.g., on river basins and wider urban areas**

   Cumulative impact assessment is also a useful tool for considering the impacts of power plants within a region in order to optimize the site selection process.

References

ADB. 2009a. *Building a Sustainable Energy Future—The Greater Mekong Subregion*. Manila.

———. 2009b. *Strategic Environmental Assessment (SEA) of Hydropower in Viet Nam*. GMS Environmental Operations Centre, Bangkok.

———. 2010a. *Ensuring Sustainability of Greater Mekong Subregion Regional Power Development*. Manila (TA 7764-REG, $1,350,000, approved on November 2010, financed by the Government of France through Agence Française de Développement).

———. 2010b. *Facilitating Regional Power Trading and Environmentally Sustainable Development of Electricity Infrastructure in the Greater Mekong Subregion. Component 2: Analysis of SEA in GMS Countries, and Identification of Gaps, Needs and Areas for Capacity Development*. Manila (TA 6440-REG, $5,000,000, approved on December 2007, financed by the Swedish International Development Agency)

———. 2011. *Nam Ngum 3 Hydropower Project: Resettlement and Ethnic Minority Development Plan*. http://www.adb.org/sites/default/files/projdocs/2012/40906-014-lao-remdp.pdf

———. 2012. *National Consultations Summary*. Consultant's report. Manila (TA 7764-REG, $1,350,000, approved on November 2010, financed by the Government of France through Agence Française de Développement).

———. 2013a. *Baseline Report*. Consultant's report. Manila (TA 7764-REG, $1,350,000, approved on November 2010, financed by the Government of France through Agence Française de Développement).

———. 2013b. *Impact Assessment Report*. Consultant's report. Manila (TA 7764-REG, $1,350,000, approved on November 2010, financed by the Government of France through Agence Française de Développement).

———. 2013c. *Indicator Descriptions for RETA 7764: Ensuring Sustainability of GMS Regional Power Development*. Consultant's report. Manila (TA 7764-REG, $1,350,000, approved on November 2010, financed by the Government of France through Agence Française de Développement).

———. 2014. *GMS Strategic Environmental Assessment Power System Analysis—Processes and OptGen Database*. Consultant's report. Manila (TA 7764-REG, $1,350,000, approved on November 2010, financed by the Government of France through Agence Française de Développement).

Bond, A., A. Morrisson-Saunders, and J. Pope. 2012. "Sustainability Assessment: The State of the Art." *Impact Assessment and Project Appraisal* 30(1, March):53–62.

Hortle, K. 2010. Impact on Fisheries. *MRC Technical Note 11*. Mekong River Commission, Vientiane.

IAIA. 2002. Strategic Environmental Assessment Performance Criteria. *International Association for Impact Assessment Special Publication Series No. 1.* http://www.iaia.org/publications/

International Hydropower Association. 2010. *Hydropower Sustainability Assessment Protocol*. London.

MRC. 2010. *Strategic Environmental Assessment of Mekong Mainstream Dams*. Mekong River Commission, Vientiane.

Power Systems Research Inc. OptGen. http://www.psr-inc.com.br/portal/psr/servicos/modelos_de_apoio_ a_decisao/studio_plan/ optgen/

Tetlow, M. F, and M. Hanusch. 2012. "Strategic Environmental Assessment: The State of the Art." *Impact Assessment and Project Appraisal* 30(1, March):15–24.

World Bank. 2010. *Criteria for Screening Coal Projects under Strategic Framework for Development and Climate Change*. Washington, DC.

———. 2011. *Trung Son Hydropower Project: Resettlement, Livelihoods and Ethnic Minorities Development Program*. http://siteresources.worldbank.org/INTVIETNAM/Resources/TrungSonRLDPmainreportfordisclosure.pdf

Identifying Sustainability Indicators of Strategic Environmental Assessment for Power Planning

This book is the second in a three-volume series of studies arising from the project Ensuring Sustainability of the Greater Mekong Subregion Regional Power Development. The project aimed to assess the impacts of alternative directions for development of the power sector in the Greater Mekong Subregion (GMS) through a strategic environmental assessment (SEA); develop recommendations on how to minimize and mitigate harmful impacts in the power sector; and provide capacity building for GMS countries in the conduct of SEAs, and support their integration into the power planning process. This volume shows how a set of indicators can be used to analyze power development plans in the GMS to achieve greater sustainability. It explains why these particular indicators were selected, why they are important, how they can be measured, and what the indicators reveal.

About the Asian Development Bank

ADB's vision is an Asia and Pacific region free of poverty. Its mission is to help its developing member countries reduce poverty and improve the quality of life of their people. Despite the region's many successes, it remains home to the majority of the world's poor. ADB is committed to reducing poverty through inclusive economic growth, environmentally sustainable growth, and regional integration.

Based in Manila, ADB is owned by 67 members, including 48 from the region. Its main instruments for helping its developing member countries are policy dialogue, loans, equity investments, guarantees, grants, and technical assistance.

Agence Française de Développement

The Agence Française de Développement (AFD) is a public development finance institution that has worked for 70 years to alleviate poverty and foster sustainable development in the developing world and in the French Overseas Provinces. AFD executes the French government's development aid policies and works on four continents. AFD provides financing and support for projects that improve living conditions, promote economic growth, and protect the planet.

The French Facility for Global Environment / Fonds Français pour l'Environnement Mondial

The French Facility for Global Environment / Fonds Français pour l'Environnement Mondial (FFEM) administered by the Agence Française de Développement is a bilateral public fund initiated by the French government in 1994. The FFEM co-finances projects that encourage the protection of the global environment in developing countries. FFEM's activities focus on biodiversity, international waters, climate change, land degradation and desertification, persistent organic pollutants, and the stratospheric ozone layer.

ASIAN DEVELOPMENT BANK
6 ADB Avenue, Mandaluyong City
1550 Metro Manila, Philippines
www.adb.org