The Economics of Climate Change in Southeast Asia: A Regional Review

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Asian Development Bank

Preface

The Economics of Climate Change in Southeast Asia: A Regional Review is the result of a 15-month long Asian Development Bank (ADB) technical assistance project, funded by the Government of the United Kingdom, which examines climate change issues in Southeast Asia, with a particular focus on Indonesia, Philippines, Singapore, Thailand, and Vietnam.

The study is intended to enrich the debate on the economics of climate change that includes the economic costs and benefits of unilateral and regional actions. It seeks to raise awareness among stakeholders of the urgency of the grave challenges facing the region, and to build consensus of the governments, business sectors, and civil society on the need for incorporating adaptation and mitigation measures into national development planning processes.

The study involves reviewing and scoping of existing climate studies, climate change modeling, and national and regional consultations with experts and policy-makers. It examines how vulnerable Southeast Asia is. to climate change, how climate change is impacting the region, what adaptation measures have been taken by the five study countries to-date, how great the region's potential is to reduce greenhouse gas (GHG) emissions in the future, how Southeast Asia can step up adaptation and mitigation efforts, and what the policy priorities are.

Although Southeast Asian countries have made significant progress on their own in addressing climate-related issues, there is need for closer cooperation and increasing use of existing mechanisms, both regional and global, for funding, technology transfer and capacity building to address future threats. Governments need to do more to fully integrate climate change concerns into their sustainable development policies. And further steps need to be taken to encourage all sector and stakeholders in mitigation and adaptation efforts.

As one of the world's most dynamic regions, the study shows that rapid economic growth in past decades has raised large numbers of people out of the extreme poverty trap in Southeast Asia. But incidence of income and non-income poverty is still very high, and achieving Millennium Development Goals (MDG) remains a daunting task. If not addressed adequately, climate change would have serious negative consequences for the region's sustainable development and poverty eradication policies and agenda.

The study observed that climate change is already affecting Southeast Asia, with rising temperature, decreasing rainfall, rising sea levels, increasing frequency and intensity of extreme weather events leading to massive flooding, landslides and drought causing extensive damage to property, assets, and human life. Climate change is also exacerbating the problem of water stress, affecting agriculture production, causing forest fires, degrading forests, damaging coastal marine resources, and increasing outbreaks of infectious diseases.

The report urges that Southeast Asian countries should treat adaptation as an extension of sustainable development practices. Its key elements include: adapting agricultural practices to changes in temperature and precipitation; adapting water management to greater risk of floods and droughts; adapting coastal zone management to higher sea levels; safeguarding forest areas from forest fires and degradation; adapting people to threats of vector-borne infectious diseases. Southeast Asia countries need to take timely action to adapt to climate change, build resilience, and minimize the costs caused by the impact driven by GHG emissions that have been locked into the climate system.

The report also argues that Southeast Asia should play an active role in global mitigation efforts. Compared to developed countries, the region's emissions on a per capita basis are relatively low. But they are considerably higher than the global average. In 2000, the region's major sources of emissions were the land-use change and forestry sector at 75%, energy sector at 15%, and the agricultural sector at 8%.

The report suggests that mitigation actions in Southeast Asia should put priority on efforts to avoid deforestation, encourage reforestation and afforestation, and promote sustainable forest management in the forestry sector; improve energy efficiency, promote renewable energy sources, increase investment in new and clean energy technologies in the energy sector; and improve land, livestock and waste management in the agriculture sector.

Climate change together with bio-diversity should not be treated in isolation from the general economic, social and environmental systems and must be dealt with in the context of sustainable development. It requires growth with economic stability, development with social equity and poverty eradication, and the continued functioning of eco-systems as life support systems to sustain development.

The world is experiencing the worse financial and economic crisis since the Great Depression, with serious consequences not only for the global economy, but to the economies of Southeast Asia and the five study countries as well. Growth is slowing, unemployment is rising, and the poor under the poverty line is increasing.

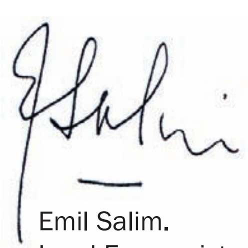
Under such circumstances, the priorities of development policy will shift away from addressing climate change, bio-diversity and other environmental issues. Allocating resources to cope with the economic slowdown may be considered more important. This, however, needs not be the case. Many countries are introducing green fiscal stimulus that creates jobs, shores up economies, and reduces poverty and, at the same time, spin-off activities of adaptation and mitigation to combat climate change. There is great scope for Southeast Asian countries to adopt such green stimulus programs.

This report is the outcome of a consultation process to agree on the scope and approach of the study, to discuss existing knowledge on climate change in the region, and to review policy developments. Seven national and regional dialogue sessions were held from April to November 2008, along with a Senior Policy Dialogue Meeting in October 2008.

Wide ranging ideas and valuable inputs were received from government officials, climate change researchers and experts, representatives of ADB's development partners, the civil society, business sector and other stakeholders. Feedback was received and formed an integral part of the study. We would like to convey our deepest appreciation and thanks to all those who have taken part in this endeavor.

We also extend our sincere thanks to the members of the advisory panel and steering committee that took part in this project. Without their valuable inputs, this study would not have been possible.

We hope that this review will provide impetus to all stakeholders of the five Southeast Asian countries and inspire other countries to cope with the challenges of climate change and other environmental issues through efforts that simultaneously address the daunting tasks of climate change, unemployment and poverty eradication through sustainable development.



Emil Salim.
Lead Economist of the Review
Jakarta, April 2009.

Foreword

Climate change will affect everyone but developing countries will be hit hardest, soonest and have the least capacity to respond. South East Asia is particularly vulnerable to the impacts of climate change with its extensive, heavily populated coastlines, large agricultural sectors and large sections of the population living under $2 or even $1 a day.

The study by the ADB on the economics of climate change for South East Asia is the first regional report on the impacts, vulnerabilities, costs, opportunities and policy options for South East Asia, and, on this regional scale, globally. It is a very welcome contribution for policymakers, businesses, academics and civil society. It increases the national understanding in each country of the challenge of development in the face of a more hostile climate. It provides important perspectives on the regional interdependencies of climate change impacts and policies and thus can help in the pooling of regional resources to address shared challenges; for example, the development of public goods for adaptation (including new technologies, disaster and risk management and water resource management) in the region. This is particularly important, given that the climate is likely to change significantly in South East Asia in the next 20 or 30 years.

But while it is right to develop our understanding of the economics of climate change for countries and regions of the world, it is important to keep the global context in mind. The science is continuing to develop rapidly and as it does further possible impacts will be revealed and risks re-assessed. Interactions between impacts can multiply their effects. Many of the impacts from climate change are not in traditional economic sectors with the result that valuations of their effect is difficult and many are likely to be missed. Further, some of the economic and social valuations, such as loss of life or ecosystem, can be contentious. It is important that the economic analysis on climate change measures what counts rather than merely counting what can easily be measured. It is a global deal, and not an Asian deal, that will be negotiated at the UNFCCC meeting in Copenhagen at the end of this year therefore, whilst Asia's role is crucial, it will be important to read this report with the wider, global science, costs and opportunities in mind.

That the governments of the Indonesia, Philippines, Singapore, Thailand and Viet Nam have supported this study, indicates that the policymakers in the region are increasingly clear, that not only is climate change, if left unmanaged, a severe, or insuperable challenge to their growth and poverty reduction goals, but also that action will lead to a wide range of business opportunities for growth and development. In the transition to a low-carbon growth path the markets for low-carbon, high-efficiency goods and services will expand, creating opportunities for farsighted policy makers and businesses to benefit from innovation and investment. The study both makes a major contribution to the understanding of climate change in the region, and greatly strengthens the global case for strong action.

I congratulate those who have commissioned and supported the study and those who carried it out. And I look forward to the leading role that I am convinced the region will play in action on climate change.

Nicholas Stern
IG Patel Professor of Economics & Government
London School of Economics and Political Science

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Southeast Asia is one of the most dynamic, fast growing regions in the world today. But with long coastlines, population and economic activity concentrated in coastal areas, reliance on agriculture in providing livelihoods for a large segment of the population—especially those living in poverty—and dependence on natural resources and forestry to drive development, it is highly vulnerable to the harsh impact of climate change.

Over the past few decades the region has seen higher temperatures and a sharp rise in the frequency of extreme weather events including droughts, floods and tropical cyclones. Without urgent action to address this pressing issue, the region will face a difficult future marked by declining freshwater and crop yields (affecting food security), increasing loss of forests and farmlands, rising sea levels threatening island dwellers and coastal communities, and a surge in infectious diseases such as dengue and malaria.

This study of five countries—Indonesia, Philippines, Singapore, Thailand and Viet Nam—involving extensive consultations with a wide range of stakeholders from the public and private sectors, examines in depth the climate challenges facing the region and makes policy suggestions.

Temperatures will continue to rise because of greenhouse gas (GHG) emissions already locked into the climate system. It is therefore of the utmost importance that Southeast Asian countries continue to take action to adapt to climate change. This is particularly important for poverty reduction and the achievement of Millennium Development Goals, since the poor are the most vulnerable.

But even with aggressive adaptation efforts, the negative impacts of climate change on economies, environment and health will continue to worsen. Only concerted global action to mitigate GHG emissions can ultimately steer the world off its current calamitous course. This requires all countries, developed and developing, to work together under the principle of common but differentiated responsibility. An essential component of a global solution to climate change would involve adequate transfers of financial resources and technological know-how from developed to developing countries for both mitigation and adaptation. The global climate change challenge cannot be effectively tackled without the participation of developing countries.

Southeast Asia produced 12% of the world's greenhouse gases at the turn of the century and, with the region's expanding population and economies, its global share of GHG emissions is likely to increase under "business-as-usual". Yet, Southeast Asia is among the regions of the world with the greatest potential for mitigating carbon dioxide by reducing deforestation and improving land management practices. It also has vast, untapped opportunities for energy efficiency improvements and for increasing the use of renewable energy sources, including biomass, solar, wind, hydro and geothermal—all leading to GHG emission reductions.

This study urges Southeast Asian countries to play their part in a global solution to climate change by introducing sustainable development policies that incorporate mitigation and adaptation activities. They should also do more to tap the wide array of global, regional and bilateral funding sources and initiatives that exist to help developing countries respond to climate challenges. Among these are ADB's Energy Efficiency Initiative and Carbon Market Initiative, as well as global-level programs such as the Clean Development Mechanism and the Global Environment Facility (GEF). These existing funding sources, albeit inadequate in view of the vast task at hand and need to scale up, provide initial support and can be used as a catalyst to raise co-financing.

Under the Bali Road Map concluded at the 2007 conference of parties to the United Nations Framework Convention on Climate Change, the international community agreed to step up efforts to combat climate change, and is now working toward a long term global climate change solution embracing mitigation, adaptation, technology development and transfer, and the provision of financial resources in support of developing countries' actions, with a view to stabilizing GHG atmospheric concentration at a safe level. Given its high vulnerability to climate change, Southeast Asia has a high stake in such a global solution.

Despite the global and regional economic downturn, the Earth is still warming and sea levels are rising. The world can no longer afford to delay action on climate change, even temporarily. Countries must act decisively. The global economic crisis provides an opportunity for the world, and Southeast Asia, to start the transition toward a climate-resilient and low-carbon economy.

ADB has put tackling climate change at the heart of its poverty reduction and development agenda and serves as a facilitator for active partnerships to meet the climate change challenge. It welcomes this comprehensive study as a valuable tool for policymakers and others, seeking to understand the issues, and how to respond to them.

Ursula Schaefer-Preuss
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An ADB Study Team, led by Tae Yong Jung (Senior Economist, Economics and Research Department [ERD]), implemented the project under the overall guidance of Juzhong Zhuang (Assistant Chief Economist, ERD) who was also fully involved in drafting the report. Other members of the study team included Suphachol Suphachalasai, Jindra Samson, Lawrence Nelson Guevara, Franklin de Guzman, Elizabeth Lat, Rina Sibal, Juliet Vanta, and Anneli S. Lagman-Martin.

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The Steering Committee members included two Economic Advisors to the UK Stern Team, Su-Lin Garbett-Shiels (UK-Office of Climate Change) and Chris Taylor (UK-Department for International Development) who also provided support to the study at various stages; Masakazu Ichimura (Chief, Environment Section, Environment and Sustainable Development Division, United Nations Economic and Social Commission for Asia and the Pacific [UNESCAP]); and from ADB, Tae Yong Jung, Herath Gunatilake (Senior Economist, ERD), and David McCauley (Principal Climate Change Specialist, Climate Change Program Coordination Unit, RSDD).

The ADB Study Team was assisted by a team of National Climate Experts and International Consultants. The National Climate Experts, who coordinated national consultations and prepared country reports, included Rizaldi Boer (Head of Climatology Laboratory, Bogor Agriculture University, Indonesia), Rosa Perez (Consultant/Researcher, Philippines), Ho Juay Choy (Professor, Department of Mechanical Engineering, National University of Singapore), Sitanon Jesdapipat (Associate, Climate Policy Initiative, Southeast Asia System for Analysis, Research and Training, Thailand), Nguyen Mong Cuong (Director, Research Center for Climate Change and Sustainable Development, Viet Nam), and Hoang Manh Hoa (Senior Expert, Climate Change Coordinator, International Cooperation Department, MONRE, Viet Nam).

The International Consultants, engaged to coordinate regional consultations, carry out modeling work, and prepare background reports, included Leandro Buendia (Lead Consultant), Keigo Akimoto (Senior Research Scientist, Research Institute of Innovative Technology for the Earth, Japan), Ancha Srinivasan (Principal Researcher and Manager, Climate Policy Project, Institute for Global Environmental Strategies), Agustin Arcenas (Assistant Professor, School of Economics, University of the Philippines), and Chris Hope (Faculty, University of Cambridge, UK).

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John Weiss, Eric Van Zant, Michael Clancy, and Cherry Lynn T. Zafaralla edited the report, and Joe Mark Ganaban was the graphics designer and typesetter.

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Abbreviations, Acronyms and Symbols

ADB	Asian Development Bank
APCF	Asia Pacific Carbon Fund
ASEAN	Association of Southeast Asian Nations
BAU	business as usual
CCF	Climate Change Fund
CCS	carbon capture and storage
CDM	Clean Development Mechanism
CEFPF	Clean Energy Financing Partnership Facility
CER	certified emission reduction
CF	carbon finance
CPF	Collaborative Partnership on Forests
CTI	Climate Technology Initiative
DMCs	developing member countries
DNE21+	Dynamic New Earth21+
ENSO	El Niño Southern Oscillation
ETS	Emissions Trading Scheme
ETTV	envelope thermal transfer value
FAO	Food and Agriculture Organization
FCF	Future Carbon Fund
GDP	gross domestic product
GEF	Global Environment Facility
GHG	greenhouse gas
GMS	Greater Mekong Subregion
HCMC	Ho Chi Minh City
HEV	hybrid-electric vehicles
IAM	integrated assessment model
ICEV	internal combustion engine vehicles
IPCC	Intergovernmental Panel on Climate Change
Lao PDR	Lao People's Democratic Republic
LDCF	Least Developed Countries Fund
LUCF	land use change and forestry
MAC	marginal abatement cost
MDG/s	millennium development goal/s
MONRE	Ministry of Natural Resources and the Environment (Viet Nam)
NCCC	National Climate Change Committee (Thailand)
OECD	Organization for Economic Co-operation and Development
OFDA	Office of US Foreign Disaster Assistance
ONEP	Office of Natural Resources and Environmental Policy and Planning (Thailand)
PAGASA	Philippine Atmospheric, Geophysical and Astronomical Services Administration
PEF	Poverty and Environment Fund

REDD	reduced emissions from deforestation and degradation
RITE	Research Institute of Innovative Technology for the Earth
RRECCS	Regional Review of the Economics of Climate Change in Southeast Asia
SCCF	Special Climate Change Fund
SEA-START	Southeast Asia System for Analysis, Research and Training
SME	State Ministry of Environment (Indonesia)
SOI	Southern Oscillation Index
SRES	Special Report on Emissions Scenarios
START	System for Analysis, Research and Training
TGO	Thailand Greenhouse Gas Management Public Organization
UNDP	United Nations Development Programme
UNEP	United Nations Environmental Programme
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
UNFCCC	United Nations Framework Convention on Climate Change

$	US dollar
%	percent
°C	degree Celsius
cc	cubic centimeter
cm	centimeter
CH_4	methane
CO	carbon monoxide
CO_2	carbon dioxide
CO_2-eq	carbon dioxide equivalent
cu m	cubic meter
dS/m	deciSiemens per metre
$GtCO_2$	gigaton of carbon dioxide
GtCO2-eq	gigaton of carbon dioxide equivalent
GWh	gigawatt hour
ha	hectares
kg	kilogram
kg/ha	kilogram per hectare
kg CO_2/m2	kilogram of carbon dioxide per square meter
km	kilometer
km/h	kilometer per hour
ktoe	kiloton of oil equivalent
m	meter
mt CO_2	metric ton of carbon dioxide
mt CO_2-eq	metric ton of carbon dioxide equivalent
$MtCO_2$	million ton of carbon dioxide
Mtoe	million ton of oil equivalent
MW	megawatt
N2O	nitrous oxide
NOx	oxide of nitrogen
ppm	parts per million
SF6	sulfur hexafluoride

sq km	square kilometer
SOx	oxide of sulfur
tC	ton of carbon
tC/ha	ton of carbon per hectare
tCO_2	ton of carbon dioxide
tCO_2-eq	ton of carbon dioxide equivalent
tCO_2/ha	ton of carbon dioxide per hectare
TWh	terawatt hour
W/m_2	watt per square metre

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Summary of Conclusions

Southeast Asia is highly vulnerable to climate change.

Climate change is happening now in Southeast Asia, and the worst is yet to come. If not addressed adequately, it could seriously hinder the region's sustainable development and poverty eradication efforts—there is no time for delay.

The review identifies a number of factors that explain why the region is particularly vulnerable. Southeast Asia's 563 million people are concentrated along coastlines measuring 173,251 kilometers long, leaving it exposed to rising sea levels.

At the same time, the region's heavy reliance on agriculture for livelihoods—the sector accounted for 43% of total employment in 2004 and contributed about 11% of GDP in 2006—make it vulnerable to droughts, floods, and tropical cyclones associated with warming. Its high economic dependence on natural resources and forestry—as one of the world's biggest providers of forest products—also puts it at risk. An increase in extreme weather events and forest fires arising from climate change jeopardizes vital export industries.

Rapid economic growth and structural transformation in Southeast Asia helped lift millions out of extreme poverty in recent decades. But poverty incidence remains high—as of 2005, about 93 million (18.8%) Southeast Asians still lived below the $1.25-a-day poverty line—and the poor are the most vulnerable to climate change.

The review has also assessed a wide range of evidence of climate change and its impact in Southeast Asia to date. It tells a clear story: mean temperature increased at 0.1–0.3°C per decade between 1951 and 2000; rainfall trended downward during 1960—2000; and sea levels have risen 1–3 millimeters per year.

Heat waves, droughts, floods, and tropical cyclones have been more intense and frequent, causing extensive damage to property, assets, and human life. Recorded floods/storms have risen dramatically, particularly in the Philippines, rising from just under 20 during 1960—1969 to nearly 120 by 2000—2008.

This report has also reviewed the existing studies that attempt to predict climate change impact in the region, all suggesting that it will intensify, with dire consequences. Modeling work undertaken under this review covering Indonesia, Philippines, Thailand, and Viet Nam confirms many of these findings. Indeed, it suggests that the region is likely to suffer more from climate change than the world average, if no action is taken.

Annual mean temperature is projected to rise 4.8°C on average by 2100 from 1990. Mean sea level is projected to rise by 70 cm during the same period, following the global trend. Indonesia, Thailand, and Viet Nam are expected to experience increasingly drier weather conditions in the next 2–3 decades, although this trend is likely to reverse by the middle of this century.

Global warming is likely to cause rice yield potential to decline by up to 50% on average by 2100 compared to 1990 in the four countries; and a large part of the dominant forest/woodland could be replaced by tropical savanna and shrub with low or no carbon sequestration potential.

For the four countries covered in the modeling work, the potential economic cost of inaction is huge: if the world continues "business-as-usual" emissions trends—considering all market and non-market impacts and catastrophic risks of rising temperatures—the cost to these countries each year could equal a loss of 6.7% of their combined gross domestic product by 2100, more than twice the world average.

Southeast Asia is among the regions with the greatest need for adaptation, which is critical to reducing the impact of changes already locked into the climate system.

The review demonstrates that a wide range of adaptation measures are already being applied. But much more needs to be done. Adaptation requires building adaptive capacity and taking technical and non-technical measures in climate-sensitive sectors.

Further strengthening adaptive capacity in Southeast Asia requires mainstreaming climate change adaptation in development planning, that is, making it an integral part of sustainable development, poverty reduction and disaster risk management strategies. Some of the immediate priorities are:

- Stepping up efforts to raise public awareness of climate change and its impact;
- Undertaking more research to better understand climate change, its impact, and solutions, especially at local levels;
- Enhancing policy and planning coordination across ministries and different levels of government for climate change adaptation;
- Adopting a more holistic approach to building the adaptive capacity of vulnerable groups and localities and their resilience to shocks; and
- Developing and adopting more proactive, systematic, and integrated approaches to adaptation in key sectors that are cost-effective and that offer durable and long-term solutions.

The review notes that many sectors have adaptation needs, but water, agriculture, forestry, coastal and marine resources, and health require particular attention. While many countries have made significant efforts, the review identifies the following priorities for further action:

- *Water resources*. Scale up water conservation and management; and widen use of integrated water management, including flood control and prevention schemes, flood early warning system, irrigation improvement, and demand-side management.

- *Agriculture*. Strengthen local adaptive capacity through better climate information, research and development on heat-resistant crop varieties, early warning systems, and efficient irrigation systems; and explore innovative risk-sharing instruments such as index-based insurance schemes.

- *Forestry*. Enhance early warning systems and awareness-raising programs to prepare for more frequent forest fires; and implement aggressive public-private partnerships for reforestation and afforestation.

- *Coastal and marine resources*. Implement integrated coastal zone management plans, including mangrove conservation and planting.

- *Health*. Expand or establish early warning systems for disease outbreaks, health surveillance, awareness-raising campaigns, and infectious disease control programs.

- *Infrastructure*. Introduce "climate proofing" in transport-related investments and infrastructure, starting with public buildings.

Southeast Asia also has great mitigation potential.

In 2000, the region contributed 12% of the world's GHG emissions, amounting to 5,187 MtCO_2-eq, up 27% from 1990. The land use change and forestry sector was the biggest source, contributing 75% of the region's total, the energy sector 15%, and the agriculture sector 8%. There is considerable scope for mitigation measures that can contribute to a global solution to climate change and bring significant co-benefits to Southeast Asia.

As the largest contributor to emissions, the forestry sector is the most critical. Major mitigation measures include reducing emissions from deforestation and degradation (REDD), afforestation and reforestation, and improving forest management.

The region's energy sector—as the fastest growing contributor to emissions—also holds vast, untapped potential for mitigation. Although Southeast Asian countries together contributed about 3.0% of global energy-related CO_2 emissions in 2000, this share is expected to rise significantly in the future given relatively higher economic and population growth compared to the rest of the world, if no action is taken.

"Win-win" options that would allow GHG emission reductions at a relatively low or even negative net cost could include, on the supply side, efficiency improvements in power generation, fuel switching from coal to natural gas, and use of renewable energy (including biomass, solar, wind, hydro and geothermal resources); and on the demand side, energy efficiency improvements and conservation in buildings (efficient lighting and electrical appliances, energy conservation, better insulation), industry sector (efficient equipment, heat/power recovery, recycling), and the transport sector (cleaner fuels, efficiency, hybrid/electric transport, rail/public transport).

In the case of the four countries' covered in the modeling work, such "win-win" options could mitigate up to 40% of their combined energy-related CO_2 emissions per year by 2020. Another 40% could potentially be mitigated by using positive-cost options such as fuel switching from coal to gas and renewable energy in power generation, at a total cost below 1% of GDP.

In the agriculture sector, the region is estimated to have the highest technical potential to sequester carbon. Major mitigation options in agriculture include better land and farm management. These will help reduce non-CO_2 emissions, reverse emissions from land use change, and increase sequestration of carbon in the agro-ecosystem.

Climate change mitigation is a global public good, and requires a global solution built on common but differentiated responsibility.

Addressing climate change requires all nations, developed and developing, to work together toward a global solution.

However, there is significant variation among countries in capacity and affordability when undertaking adaptation and mitigation, and climate change and its impact to date are largely the result of past emissions from developed countries. These raise the important issue of equitable division of responsibilities.

An essential component of an effective global solution would, therefore, involve adequate transfers of financial resources and technological know-how from developed to developing countries. Yet, emerging estimates of the additional investment needed for mitigation and adaptation in developing countries suggest that hundreds of billions of dollars per year are needed for several decades to come, far greater than the resources currently committed globally. This is a cause for serious concern.

Global climate change cannot be tackled without the participation of developing countries. In the coming decades, their GHG emissions will grow faster than the developed countries, and the developing countries hold significant potential for cost-effective emissions reductions.

As a highly vulnerable region with considerable need for adaptation and great potential for mitigation, Southeast Asia should play an important part in a global solution.

The region has in recent years taken encouraging actions to adapt to climate change impact and to mitigate GHG emissions. Each country in Southeast Asia has developed its own national plan or strategy, established a ministry or agency as the focal point, and implemented many programs supporting adaptation and mitigation. Going forward, the review identifies a number of policy priorities.

Adaptation. The priority is to enhance climate change resilience by building adaptive capacity and taking technical and non-technical adaptation measures in climate-sensitive sectors. While at a fundamental level, a country's adaptive capacity depends on its level of development, more effort in raising public awareness, more research to fill knowledge gaps, better coordination across sectors and levels of government, and more financial resources will go a long way toward enhanced adaptive capacity. In the key climate-sensitive sectors, including water resources, agriculture, coastal and marine resources, and forestry, the priority is to scale up action by adopting a more proactive approach and integrating adaptation.

Mitigation. While adaptation is hugely important, the region should also make greater mitigation efforts. Low-carbon growth brings significant co-benefits, and the costs of inaction far outweigh the costs of action. Implementation of mitigation measures requires the development of comprehensive policy frameworks, development and availability of low-carbon technology, incentives for private sector action, elimination of market distortions, and significant flows of finance, among other things. Some specific policy recommendations are:

Forestry sector. There is a need for strengthening the region's technical and institutional capacities to undertake forest carbon inventories and implement appropriate policies and measures to benefit from future global REDD mechanisms. Countries should also step up efforts to avoid deforestation, to encourage reforestation and afforestation, and to enhance national and local governance systems for sustainable forest management, including monitoring and controlling illegal logging. Since forests are also home to many indigenous communities, policies must be designed to fully recognize and respect their rights and priorities, and ensure their participation in the design and implementation of REDD policies.

Energy sector. To promote the adoption of "win-win' mitigation options in Southeast Asia, a priority is to identify and relax the binding constraints on the adoption of these options. These could include information, knowledge, and technology gaps; market and price distortions; policy, regulatory, and behavioral barriers; lack of necessary finance for upfront investment; and other hidden transaction costs. A prominent market distortion in the energy sector in many Southeast Asian countries involves general subsidies for the use of fossil fuels. Governments should work to gradually eliminate such subsidies and provide targeted transfers only for the poor and vulnerable.

Agriculture sector. The priority is to reduce emissions through better land and farm management, supported by a combination of market-based programs (taxes on the use of nitrogen fertilizers, and reform of agricultural support policies), regulatory measures (such as limits on the use of nitrogen fertilizers and cross-compliance of agricultural support to environmental objectives), voluntary agreements (such as better farm management practices and labeling of green products), and international programs that support technology transfer in agriculture.

Funding and technology transfer. International funding and technology transfers are essential for the success of adaptation and mitigation efforts in Southeast Asia. The region should enhance institutional capacity to make better use of the existing and potential international funding resources. Existing funding sources, albeit inadequate in view of the vast task at hand, provide initial support and can be used as a catalyst for raising cofinancing. Southeast Asia has not yet made full use of these funding sources, and its representation in the global carbon market is still limited. Governments need to facilitate access to these current and potentially available sources through better information dissemination and technical assistance. There is a need to increase the region's presence in making use of clean development mechanisms (CDM), REDD-related, and other financing mechanisms.

Regional cooperation. Because most countries in the region experience similar climate hazards, regional strategies are likely to be more cost-effective than national and subnational actions in dealing with many transboundary issues. These include integrated river basin and water resources management, forest fires, extreme weather events, threatened and shared coastal and marine ecosystems, climate change-induced migration and refugees, as well as regional outbreaks of heat-related diseases, such as dengue and malaria. Regional cooperation is also effective in pursuing some mitigation measures, for example: promoting power trade; using different peak times among neighboring countries to minimize the need for building new generation capacity in each country; developing renewable energy sources; promoting clean energy and technology transfer; and regional benchmarking of clean energy practices and performance. In the longer term, a regional voluntary emissions trading system could also be considered.

Policy coordination. Given that climate change is an issue that cuts across all parts of government, there is a need for involving not only environment ministries and related offices, but also economic and finance ministries, and for strong inter-governmental agency policy coordination. There is also a need for putting in place or enhancing central government–local authority coordination mechanisms (such as planning and funding) to encourage local and autonomous adaptation actions, and to strengthen local capacity in planning and implementing initiatives addressing climate change. For effective coordination, there is a strong case for the government agency responsible for formulating and implementing the development plan and strategy to take the lead. Addressing climate change requires leadership at the highest level of government.

Research. More research is required to better understand climate change challenges and cost-effective solutions at the local level and to fill knowledge gaps. Despite the emergence of more and more regional and country-specific studies on climate change in Southeast Asia in recent years, knowledge gaps remain huge.

The current economic crisis provides an opportunity.

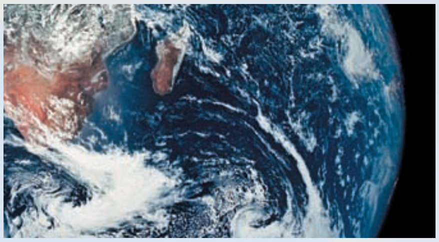
The world is experiencing its worst economic turbulence since the Great Depression of the 1930s, a fact which could make the task of combating climate change more difficult. This is not necessarily the case.

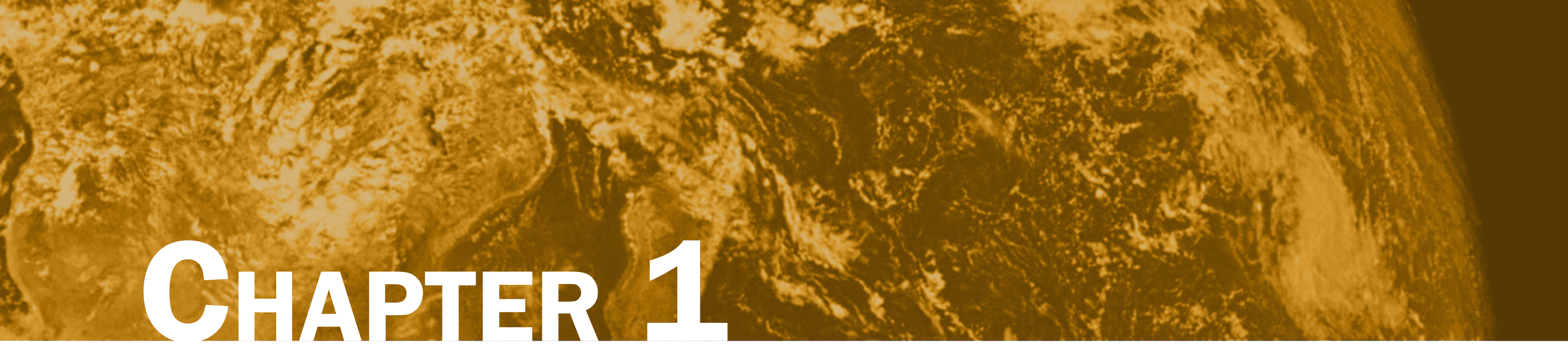
Leaders of the G20 at the 2009 London Summit agreed to make the best possible use of investment funded by fiscal stimulus programs toward the goal of building a resilient, sustainable, and green recovery, and to make the transition toward clean, innovative, resource-efficient, low-carbon technologies and infrastructure.

In Southeast Asia, too, the present crisis offers an opportunity to start the transition toward a climate-resilient and low-carbon economy. Indonesia, Philippines, Singapore, and Thailand are using fiscal stimulus to support domestic demand through tax cuts, investment in infrastructure, and to increase spending on social programs. There may also be scope for building “green investment” programs into such stimulus packages that combine adaptation and mitigation measures with efforts to shore up the economy, create jobs, and reduce poverty.

PART I

Background





Chapter 1

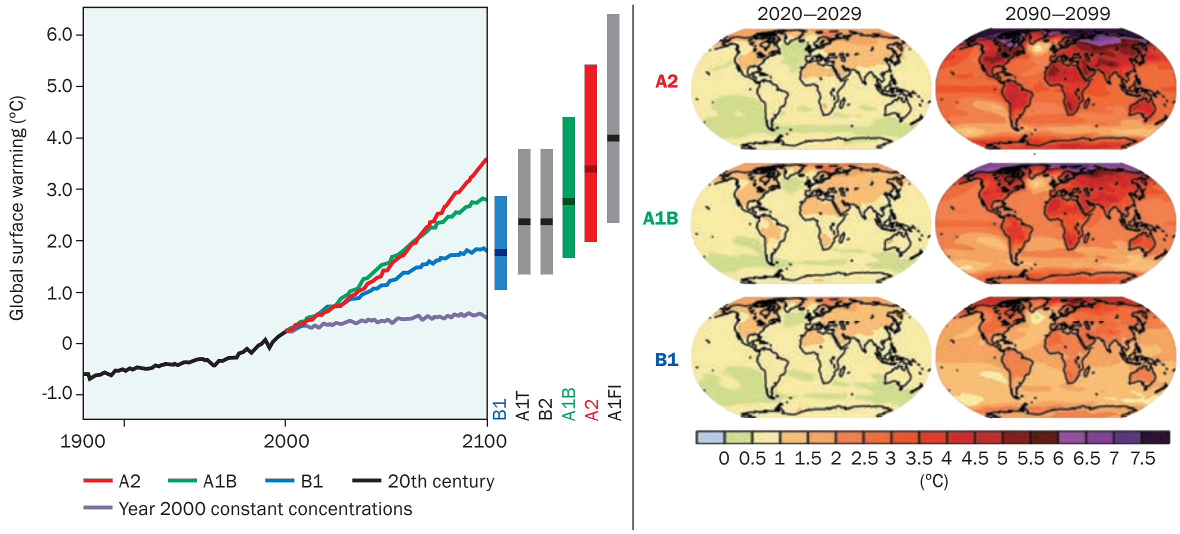
Background

A. Climate Change—A Global Problem

Over the past 150 years, global average surface temperature has increased 0.76°C, according to the Intergovernmental Panel on Climate Change (IPCC 2007). This global warming has caused greater climatic volatility, such as changed precipitation patterns and increased frequency and intensity of extreme weather events including typhoons, heavy rainfall and flooding, and droughts; and has led to a rise in mean global sea levels. It is widely believed that climate change is largely a result of anthropogenic greenhouse gas (GHG) emissions and, if no action is taken, likely to intensify. Under the most pessimistic emissions scenario developed in IPCC (2000), by the end of this century temperatures could rise to more than 4°C above 1980–1999 levels, ranging from 2.4–6.4°C (Figure 1.1). This would have serious consequences for the world's growth and development.

Climate change is a global problem and requires a global solution. In recent years, addressing climate change has been high on the international policy agenda. There is now a consensus that to prevent global warming from reaching dangerous levels, action is needed to control and mitigate GHG emissions and stabilize their atmospheric concentration within a range of 450–550 parts per million (ppm) (IPCC 2007). The lower bound is widely considered a desirable target and the upper bound a minimum necessary level of mitigation (Stern 2007). The international community is now working toward an international climate regime under the United Nations Framework Convention on Climate Change (UNFCCC) that aims to stabilize GHG atmospheric concentration and provide a long-term solution to the climate change problem through international cooperation based on the principle of common but differentiated responsibility. While the responses of the largest current and future GHG-emitting economies under UNFCCC hold the key, a successful global solution requires the participation of all countries, developed and developing.

Figure 1.1. Atmosphere-Ocean General Circulation Model Projections of Surface Warming



Note: B1, A1T, B2, A1B, A2, and A1FI represent alternative emissions scenarios developed by IPCC. A1 scenario family describes a world of rapid economic growth and population that peaks in mid-century and declines thereafter. Within the A1 family, there are three scenarios characterizing alternative developments of energy technologies: A1FI (fossil fuel intensive), A1B (balanced), and A1T (predominantly non-fossil fuel). B1 scenario describes a world with rapid changes in economic structures toward a service and information economy, the introduction of clean and resource-efficient technologies, and the same population path as in the A1 family. A2 scenario describes a world with slower per capita economic growth, continuously increasing population, and slower technological change than in other storylines. B2 scenario describes a world with intermediate economic development, continuously increasing global population at a rate lower than A2, and less rapid technological change than in B1 scenario (IPCC 2000).

Source: IPCC (2007).

While GHG mitigation is essential to preventing global warming from reaching dangerous levels, climate change adaptation is critical to reducing and minimizing the costs, often localized, caused by the unavoidable impacts of GHG emissions already locked into the climate system. Adaptation is particularly important for developing countries and their poverty reduction efforts because the poor—with limited adaptive capacity due to low income and poor access to infrastructure, services, and education—are often most vulnerable to climate change. They generally live in geographically vulnerable areas prone to natural hazards, and are often employed in climate-sensitive sectors, particularly agriculture, forestry, and fisheries, with virtually no chance of switching to alternative sources of income. Thus climate change adaptation, by building adaptive capacity, taking specific adaptation actions in key climate-sensitive sectors, and assisting the poor to cope with climate change impacts, should be a critical part of the development and poverty reduction strategies of every developing country.

B. Climate Change in Southeast Asia

Climate change is likely to be one of the most significant development challenges confronting Southeast Asia in the 21st century. Comprising 11 independent countries[1] geographically located along the continental arcs

[1] Brunei Darussalam, Cambodia, Indonesia, Lao People's Democratic Republic, Malaysia, Myanmar, Philippines, Singapore, Thailand, Timor-Leste, and Viet Nam.

and offshore archipelagos of Asia, the region is widely considered one of the world's most vulnerable to climate change. Home to 563.1 million people, its population is rising almost 2% annually, compared with the global average of 1.4%. It has long coastlines; high concentration of population and economic activities in coastal areas; heavy reliance on agriculture for providing livelihoods—especially those at or below the poverty lines—and high dependence on natural resources and forestry in many of its countries. As one of the world's most dynamic regions, rapid economic growth in the past few decades has helped lift millions out of extreme poverty. But the incidence of income and non-income poverty is still high in many countries, and achieving the Millennium Development Goals (MDGs) remains a daunting task. Climate change, if not addressed adequately, could seriously hinder the region's sustainable development and poverty eradication efforts.

Climate change is already affecting the region. IPCC (2007) reports an increasing trend in mean surface air temperature in Southeast Asia during the past several decades, with a 0.1–0.3°C increase per decade recorded between 1951 and 2000. Rainfall has been trending down and sea levels up (at the rate of 1–3 millimeters per year), and the frequency of extreme weather events has increased: heat waves are more frequent (an increase in the number of hot days and warm nights and decrease in the number of cold days and cold nights since 1950); heavy precipitation events rose significantly from 1900 to 2005; and the number of tropical cyclones was higher during 1990—2003. These climatic changes have led to massive flooding, landslides, and droughts in many parts of the region, causing extensive damage to property, assets, and human life. Climate change is also exacerbating water shortages in many areas, constraining agricultural production and threatening food security, causing forest fires and degradation, damaging coastal and marine resources, and increasing the risk of outbreaks of infectious diseases.

Southeast Asia, like any other developing region, need to take urgent action to adapt to climate change, build resilience, and minimize the costs of the unavoidable impact of GHG emissions already locked into the climate system.

While adaptation is the priority, the region also has an important role to play in contributing to global GHG mitigation efforts. In 2000, Southeast Asia contributed 12% of the world's GHG emissions, amounting to 5,187 $MtCO_2$-eq, an increase of 27% from 1990, faster than the global average. On a per capita basis, the region's emissions are considerably higher than the global average, although still relatively low when compared to developed countries. The land use change and forestry sector (LUCF) has been the major source of emissions from the region, contributing 75% of total regional GHG emissions in 2000. The other two key sources are the energy sector (at 15%) and the agriculture sector (at 8%), with emissions from the energy sector growing as much as 83% during 1990–2000, the fastest among the three sources. Southeast Asia needs to explore affordable and cost-effective mitigation measures and to pursue a low-carbon growth strategy.

C. About This Study

Recent years have seen the emergence of many studies aiming at quantifying the economic impacts of climate change and global warming and assessing costs and benefits of adaptation and mitigation options. Among the most influential is *The Economics of Climate Change: The Stern Review* (Stern 2007). On the basis of an extensive review of the existing studies (both economic and scientific) on climate change and global warming and modeling exercises using one of the latest integrated assessment models (IAM), the Stern Review concludes that for the world as a whole, an investment of 1% of gross domestic product (GDP) per year is required to avoid the worst effects of climate change. Failure to do so could risk having global GDP up to 20% lower than it otherwise would be. The Stern Review suggests that climate change threatens to be the greatest and widest-ranging market failure ever seen. It warns that people's actions over the coming few decades could risk disruptions to economic and social activity, later in this century and in the next, on a scale similar to those of the great wars and economic depression of the first half of the 20th century.

The Stern Review provides a global perspective on the economic effects of climate change and global warming. Since its release, there have been various efforts and initiatives to apply the Stern approach to specific regions and countries. As one such study, this review—The Regional Review of the Economics of Climate Change in Southeast Asia—is carried out as a Technical Assistance Project of the Asian Development Bank (ADB) and funded by the Government of the United Kingdom. Participated by five of ADB's developing member countries in Southeast Asia—Indonesia, Philippines, Singapore, Thailand, and Viet Nam—its purpose is to deepen the understanding of the economic and policy implications of climate change and global warming in the region. More specifically, the study aims to:

- contribute to the regional debate on economic costs and benefits of unilateral and regional actions on mitigation of, and adaptation to, climate change;

- raise awareness among stakeholders (for example, government, civil society, academia, media, nongovernment organizations, private sector, and aid agencies) on the urgency of climate change challenges and their potential socioeconomic impact on the study countries; and

- indirectly support government and private sector actions within the region that incorporate adaptation and mitigation into national development planning processes.

The study covers three main areas that serve as the basis for formulating climate change policies for Southeast Asia: impact assessment, adaptation analysis, and mitigation analysis. Impact assessment looks at how Southeast Asian countries have been and will be affected by climate change individually and collectively. Adaptation analysis then takes up the question of how they could individually and collectively best adapt to climate change and what adaptation options or strategies are needed to be incorporated into national sustainable development planning. The mitigation analysis assesses potential mitigation options and how the region can contribute to global GHG mitigation efforts.

The impact assessment, adaptation analysis, and mitigation analysis were carried out through: (i) scoping and literature review of existing climate change studies; (ii) regional, national, and policymaker consultations; and (iii) climate change modeling[2] for key sectors. On the basis of these, policy recommendations were formulated for the study countries.

The scoping and literature review covered observed and projected impacts of climate change, GHG emission profiles and trends, adaptation and mitigation practices that have been adopted, and their costs and benefits, where available. The review was based on published and unpublished material at the regional and country level as produced by academics, government agencies, research institutes, international organizations, and nongovernment organizations. These materials also included assessment reports and technical reports published by the IPCC, and National Communications submitted by countries to the UNFCCC. The tasks were carried out by national climate experts engaged by ADB from the respective countries.

The purpose of national and regional consultations is to introduce the study to major stakeholders; agree on its scope and approach; discuss existing knowledge on climate change in the region; review policy developments and initiatives in dealing with climate change at the regional and country levels; engage government officials in policy dialogue; gather and share information and knowledge; and discuss new findings under this study. From April to November 2008, two regional consultations and five national consultations (in Indonesia, Philippines, Singapore, Thailand, and Viet Nam) were conducted. In addition, a Senior Policy Dialogue meeting in October 2008 in Bangkok discussed policy recommendations from the study. These consultations were attended by government officials, climate change researchers and experts, representatives of development partners (World Bank, United Nations Economic and Social Commission for Asia and the Pacific, Japan Bank for International Cooperation, Government of the United Kingdom, and others), nongovernment organizations, the private sector, and other stakeholders.

Climate change modeling is based on an integrated assessment framework, using various complementary modules. A bottom-up global energy model that contains the energy supply and energy end-use sectors is used to project future energy mix, the adoption of mitigation technologies, and CO_2 emissions under different scenarios. A separate module is used to project non-CO_2 and other GHG emissions. A climate model is adopted to estimate future climate change, including temperature rise, precipitation change, sea level rise, and others, based on the projected GHG emissions and concentrations. A sectoral impact module is used to assess the physical impact of projected climate change on the water resources, agriculture, forestry, and health sectors. These modules were developed by the Research Institute of Innovative Technology for the Earth, a contributor to the IPCC Fourth Assessment Report. Consistent with Stern (2007), the study also made use of the PAGE2002 integrated assessment model to project the

[2] Modeling by the ADB study team covered only Indonesia, Philippines, Thailand, and Viet Nam.

economy-wide impact of climate change in monetary terms under different policy scenarios for the study countries.

D. Organization of the Report

The report is organized into four parts and consists of ten chapters. Part I introduces the background of the study (Chapter 1), highlights the unique features of Southeast Asia, and explains why it is vulnerable to climate change (Chapter 2). Part II—Climate Change, Its Impact, and Adaptation—consists of four chapters. It first reviews observed and projected climate change and its impact in Southeast Asia, particularly on water resources, agriculture, forestry, coastal and marine resources, and human health, documented in the existing studies (Chapter 3). It then reports results of an integrated assessment of future climate change and its impact on key climate-sensitive sectors in Southeast Asia using an IAM under alternative scenarios, focusing on Indonesia, Philippines, Thailand and Viet Nam. This is followed by an integrated assessment of future economy-wide impacts of climate change in the region using a more aggregated IAM under alternative scenarios, also focusing on the same set of countries (Chapter 5). The last chapter of Part II examines climate change adaptation options and practices employed in the region and those yet to be employed (Chapter 6).

Part III—Climate Change Mitigation Options and Practices—consists of two chapters. It first examines the measures being practiced in Southeast Asia to reduce GHG emissions and those not yet employed but that could become feasible in the future, and assesses the potential and costs of alternative mitigation measures (Chapter 7). It then assesses the potential and cost effectiveness of mitigation options in the energy sector in the four countries covered in one modeling work (Chapter 8).

Part IV—Policy Responses—consists of two chapters. It first reviews the existing policies, initiatives, and institutional arrangements for climate change adaptation and mitigation, and global and regional financing mechanisms that have been established to address climate change (Chapter 9). It then concludes the report and provides policy recommendations for Southeast Asia to combat climate change (Chapter 10).

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Chapter 2

Regional Circumstances

Key Messages

Southeast Asia is one of the world's most vulnerable regions to the impact of climate change because of its unique economic and social characteristics, long coast lines, and mostly tropical climate.

It has been one of the world's most dynamic and fastest growing regions in past decades. But it still faces the daunting task of eradicating income and non-income poverty. The poor are the most vulnerable to climate change impact.

Agriculture remains an important sector—despite rapid economic growth and structural transformation—accounting for 11% of gross domestic product (GDP) in 2006 and providing 43.3% of employment in 2004. And increasing demand for food and industrial crops has intensified agricultural production and competition for land and water resources.

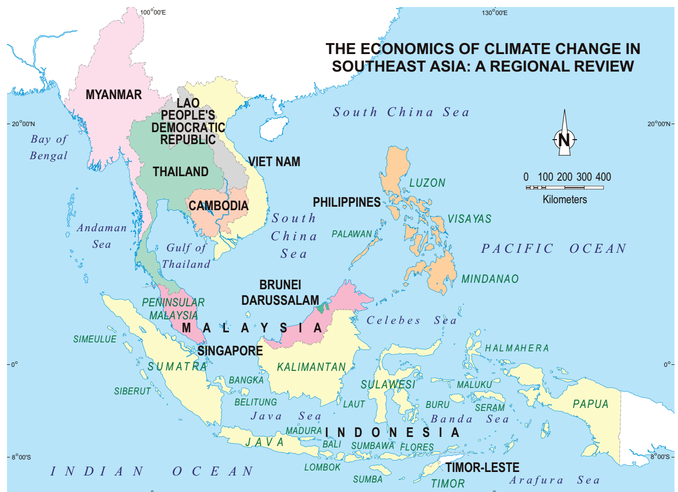
Much of the region's growth is also dependent on natural resources, particularly forestry, putting considerable pressure on the environment and ecosystems.

At the same time, urbanization is among the fastest in the world and mostly in coastal areas—with about 80% of the population living within 100 kilometers (km) of the coast—leading to an over-concentration of economic activity and livelihoods in coastal mega cities.

A. Introduction

Southeast Asia comprises the 10 independent members of the Association of Southeast Asian Nations (ASEAN) and newly independent Timor-Leste[1] (Figure 2.1). With a total land area of 4,330,079 square kilometers (3.3% of the world total) and mainly tropical climate, it is home to 563 million people (8.5% of the world population). Its 173,251 kilometers of coastline rank it third in the world behind North America and Western Europe. Alongside its economic, demographic, and social characteristics, its unique geographic and climatic conditions make Southeast Asia one of the world's most vulnerable regions to climate change impact.

Figure 2.1. Southeast Asian Countries



Source: ADB.

B. Economic and Social Development

Southeast Asia has been one of the world's most dynamic and fastest growing regions in recent decades.

During 1990–2007, the region's GDP grew 5.5% annually, compared to the world's 2.9% (Table 2.1). In per capita terms, annual GDP growth reached 3.6%, compared to the global average of 1.5%. In 2007, the region's average per capita income was estimated at $4,020.3 (at 2000 constant prices), slightly higher than developing Asia.[2] High levels of investment in physical and human capital, pragmatic trade and industrial policies, a vibrant external sector and, especially after the 1997/98 Asian financial crisis, structural reforms supported this favorable economic performance. The crisis sparked a wave of recession in many directly affected economies, but this was short-lived and recovery was swift.

[1] Timor-Leste (formerly East Timor) is pursuing ASEAN membership and became a member of the ASEAN Regional Forum in July 2005.

[2] Developing Asia means ADB developing member countries.

Table 2.1. Selected Economic and Social Indicators

Indicator	Indonesia	Philippines	Singapore	Thailand	Viet Nam	Southeast Asia	Developing Asia	World
GDP growth, 1990–2007 (annual average, %)	4.9	3.8	6.8	5.2	7.5	5.5	7.0	2.9
GDP per capita, 2007 (constant 2000 US$)	1,033.6	1,216.2	28,964.2	2712.7	617.0	4,020.3	3,802.5	5,964.3
Shared of agriculture in GDP, 2006 (%)	12.9	14.2	0.1	10.7	20.4	11.0 [a]	22.4	4.1
Poverty incidence								
1990 headcount ratio (%)								
$1.25-a-day poverty line	54.3	29.7	–	9.4	34.2	39.1	–	–
$2.00-a-day poverty line	84.6	54.9	–	30.5	65.3	66.0	–	–
2005 headcount ratio (%)								
$1.25-a-day poverty line	21.4	22.6	–	0.4	22.8	18.8	27.1	25.2
$2.00-a-day poverty line	53.8	45.0	–	11.5	50.5	44.6	54.0	69.4
Total population, 2007 (million)	225.6	87.9	4.6	63.8	85.1	563.1	3,519.7	6,612.0
Population growth, 1990–2007 (annual average, %)	1.4	2.1	2.5	1.0	1.5	1.9	1.5	1.4
Population density, 2007 (people per square km)	124.5	294.8	6,659.8	124.9	274.6	781.5	901.6	51.0
Urban population growth, 2000–2005 (annual average, %)	4.0	3.5	1.5	1.5	3.1	3.5	2.6	2.1
Share of population within 100 km of coast, 2005 (%)	98.4	88.6	84.4	39.5	77.9	80.2	34.3	38.0
Employment in agriculture, 2004 (% of total employment)	43.3	37.1	0.3	42.3	57.9	43.3 [b]	36.8	–

a This excludes Brunei Darussalam and Myanmar.
b This excludes Brunei Darussalam, Cambodia, Lao PDR, and Myanmar.
– = data not available, Developing Asia = ADB Developing Member Countries.
Sources: World Bank's World Development Indicators online database, World Bank's PovcalNet Database (2008).

But the region still faces the daunting task of eradicating income and non-income poverty.

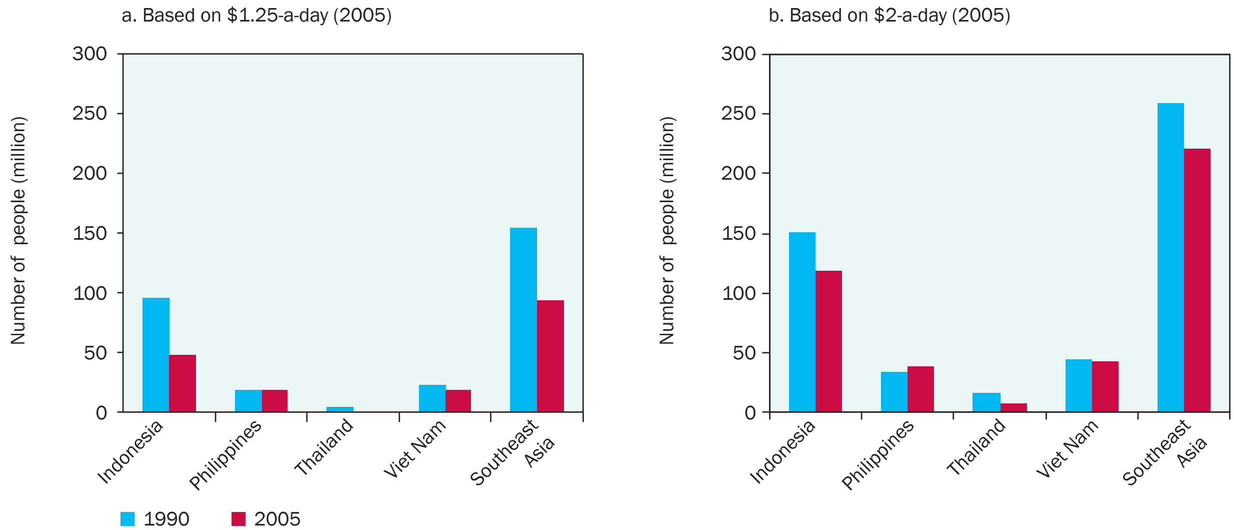
Rapid economic growth and structural transformation has helped lift millions of Southeast Asians out of extreme poverty. During 1990–2005, poverty incidence[3] in Indonesia declined 32.8, Philippines 7.0, Thailand 9.0, and Viet Nam 11.4 percentage points. But as of 2005, about 93 million (18.8%) Southeast Asians still lived below the $1.25-a-day poverty line, and 221 million (44.6%) below the $2-a-day poverty line (Figures 2.2a, 2.2b). Although most Southeast Asian countries are on their way to achieving the income Millennium Development Goals (MDG) by 2015, many face great challenges in achieving the non-income MDGs.

Despite rapid economic growth and structural transformation, agriculture remains a major economic sector.

Agriculture contributed to a significant part of GDP in 2006: 12.9% in Indonesia, 14.2% in the Philippines, 10.7% in Thailand, and 20.4% in Viet Nam. In 2004 the sector accounted for 43.3% of the region's total employment: it accounted for 57.9% of employment in Viet Nam, 43.3% in Indonesia, 42.3% in Thailand, and about 37.1% in the Philippines. Most Southeast Asian poor live in rural areas and rely on the agriculture sector for their livelihoods. As

[3] measured at the $1.25-a-day poverty line at 2005 purchasing power parity.

Figure 2.2. Poverty Estimates in Southeast Asia



Sources: World Bank PovcalNet Database (2008).

such, agriculture provides a safety net for the poor.

The region has one of the fastest rates of urbanization globally, with economic development often concentrated on coastal cities and areas.

By 2005, 44.1% of Southeast Asia's population was urban, well up from 31.6% in 1990, with the annual average increase in 2000–2005 reaching about 3.5%. Rapid development has focused on major coastal areas, concentrating population, economic activity, and livelihoods in coastal mega cities. In 2005, about 80% of the region's population lived within 100 km of the coast.

C. Land Use and Natural Resources

Increasing demand for food and industrial crops in recent years has led to intensification of agricultural production, generating considerable environmental pressure.

Growing population, rising incomes, and changing consumption patterns have boosted demand for food and industrial crops from within and outside the region, and to rising food prices on a global scale. In response, the region has intensified production of grains, animal feed, and industrial crops. Table 2.2 summarizes some of Southeast Asia's environmental and natural resource indicators.

From 2002 to 2007, the region produced about 140 million tons of milled rice per year. Southeast Asia has been a major producer and supplier of grain in the world, led by Viet Nam and Thailand. The region is also one of the world's largest producers of palm oil and natural rubber. The average annual production of palm oil almost doubled from 86 million tons during 1996—2001 to 139 million tons during 2002—2007. Natural rubber

Table 2.2. Environmental and Natural Resource Indicators in Southeast Asia

Indicator	Indonesia	Philippines	Singapore	Thailand	Viet Nam	Southeast Asia	Developing Asia	World
Total land area, 2007 (million hectares)	181.1	29.8	0.1	51.1	31.0	433.0	–	13,013.5
Agricultural land area (% of land area)	26.4	40.9	1.2	36.4	30.9	26.5	–	38.2
Forest area, 2005 (% of land area)	48.9	24.0	2.9	28.4	41.7	46.9	–	30.4
Change in extent of forest and other wooded land, 1990—2005 (annual, %)	-2.4	-3.2	–	-0.9	3.8	-1.3	-0.2	–
Length of coastlines (‘000 km)	95.2	33.9	0.3	7.1	11.4	173.3	274.5	1,478.7
Access to improved water sources, 2006 (% of population)	80.0	93.0	100.0	98.0	92.0	85.2	80.4	86.2
Access to improved sanitation, 2006 (% population)	52.0	78.0	100.0	96.0	65.0	71.4	65.3	60.0
Nitrogen use for agriculture, 2005 (ton per hectare)	0.07	0.05	–	0.06	0.12	0.05	–	0.02
Agricultural production, 2002—2007 (annual growth, %)								
Milled Rice	2.7	4.8	–	0.1	3.0	3.2	–	1.9
Natural Rubber	8.0	45.3	–	3.4	10.2	6.2	–	5.4
Palm Oil	11.8	12.8	–	11.7	–	8.3	–	7.1
Fishery and marine resource production, 1991—2007 (annual growth, %)	–	–	–	–	–	4.7	5.1	2.4
Forest production, 1991—2007 (annual growth, %)								
Industrial roundwood (cu m)	-1.4	-2.8	–	9.1	0.5	-1.3	-0.6	0.1
Paper and paperboard (ton)	11.1	12.2	0.6	9.6	23.2	11.7	8.8	2.8
Pulp and paper (ton)	16.9	1.8	–	29.8	20.2	15.2	4.5	0.8

– = data not available.

Sources: World Bank's World Development Indicators online database, FAOSTAT (2008), Global Forest Resource Assessment (FAO 2005), United Nations Environment Programme (2006).

production increased from 5 million tons per year during 1996–2001 to 7 million tons per year during 2002–2007. The combined output of Indonesia, Malaysia, and Thailand in natural rubber production now accounts for around 75% of the world total. Intensified agriculture production has led to:

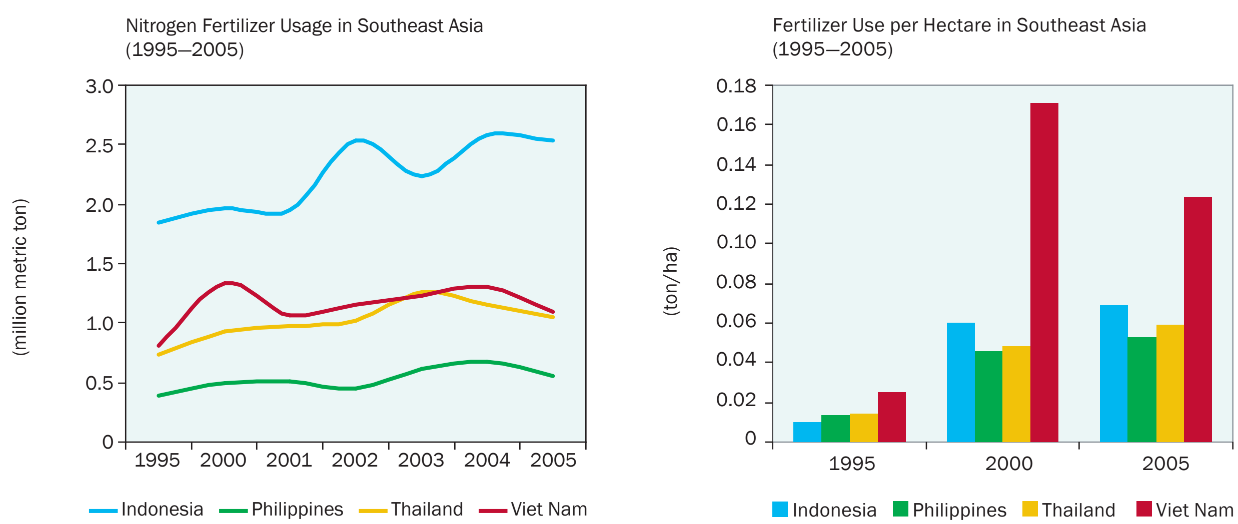
- Increases in land conversion. Huge nonagricultural areas (for example, forestlands, grasslands, and wetlands or peatland) have been converted to cropland for the production of beans, coffee, natural rubber, palm oil, rice (paddy), sesame seed, soybean, and vegetables. This has helped intensify competition for land use due to industrialization and urbanization, as well as emissions of CO_2 from biomass (below ground and above ground) and soils. Burning of biomass in the process of land conversion also causes emissions of CO_2 and other gases such as methane (CH_4), nitrous oxide (N_2O), carbon monoxide (CO), and oxides of nitrogen (NO_x).

- Increases in use of farm inputs. To increase yields, Southeast Asian countries have to use modern crop varieties, improved farming techniques, and farm inputs including fertilizers and chemicals for pest and disease control. During 1995—2005, nitrogen usage increased 44% in Thailand, 41% in the Philippines, 37% in Indonesia, and 35%

in Viet Nam (Figure 2.3). Fertilizer use has intensified most in Viet Nam, at 0.16 ton per hectare in 2000 and a slightly lower 0.13 ton per hectare in 2005. The increase in nitrogen fertilizer usage, if not efficiently managed or applied, could result in N_2O emissions. And the greater use of chemicals, if not handled properly, will have significant adverse impacts on the environment, including on water resources.

- Increases in livestock production. The output from Southeast Asia's livestock sector has grown dramatically and at a rate much faster than that of food crops and pasture in recent years (FAO 2006). As shown in Table 2.3, over the last 4 decades, the population of major farm animals has increased significantly. The cattle population has increased by 98% since 1965 while pig and chicken populations have increased two-fold and seven-fold, respectively. The increase has put further pressure on agricultural areas to service growing requirements for animal feeds.

Figure 2.3. Consumption Trend and Intensity of Fertilizer Use in Southeast Asia



Sources: FAOSTAT Database (2008), ADB Bank Staff estimates.

Table 2.3. Livestock Production in Southeast Asia

Animals	Unit	1970	1990	2000	2005	2007
Buffaloes	(million)	19.00	18.17	14.45	15.18	41.53
	% of world	17.71	12.26	8.80	8.69	20.52
Cattle	(million)	24.01	33.90	38.20	41.87	45.68
	% of world	2.22	2.61	2.91	3.05	3.29
Pigs	(million)	30.19	40.58	52.37	66.87	69.14
	% of world	5.52	4.74	5.85	6.93	6.98
Goats	(million)	8.55	18.19	21.33	24.15	23.32
	% of world	2.27	3.10	2.94	2.88	2.74
Chickens	(million)	293.52	937.92	1,546.10	1,969.90	2,182.30
	% of world	5.64	8.79	10.67	11.73	12.65

Source: FAOSTAT database (accessed 4 December 2008).

Rising agriculture production puts considerable pressure on water resources already under stress from high population and economic growth.

Southeast Asia is known for its many natural inland water systems and tributaries vital to industrial and agricultural production. Its predominantly tropical climate is characterized by seasonally heavy rainfall, recharging most of its water resources. For the region as a whole, the renewable internal freshwater resource is estimated at 5,674.2 billion cubic meters (cu m), 13% of the world's total (Table 2.4) and twice the world average on a per capita basis. During the last decade, however, many parts of the region have been experiencing increasing water stress, including water shortages and deterioration of water quality due to rapid population and economic growth and climate change. Misuse and overexploitation of water resources has depleted aquifers, lowered water tables, shrunk inland lakes, and diminished stream flows, some to ecologically unsafe levels. Deforestation in some of its important watersheds has also contributed to the reduction of water levels in rivers, especially during dry seasons, while demand for irrigation is another important contributing factor to water shortages.

The withdrawal of freshwater by countries in Southeast Asia varies greatly as shown in Table 2.4. Available freshwater resources per capita are highest in Indonesia, followed by the Philippines. Thailand has the highest ratio of annual freshwater withdrawal to total internal water resources (41.5%), followed by Viet Nam (19.5%). This indicates the vulnerability of Thailand and Viet Nam to changes in water resources. Most of the water withdrawals are used for agriculture production, except for the Philippines and Viet Nam, where a considerable share of the available freshwater supply is used for domestic (settlements or residential) and industrial purposes.

Much of the region's growth is dependent on natural resources, particularly forestry.

Southeast Asia has one of the largest and most biologically diverse forest ecosystems in the world (UNEP 2001). The region is a major producer and exporter of forest products, including industrial roundwood, paper and paperboard, pulp for paper, and wood-based panels. Collectively, in 2005, forestlands in Southeast Asia covered 203 million hectares (ha), representing 5.1% of the world total.

Table 2.4. Freshwater Resources in Southeast Asia

Country/region	Total freshwater resource (billion cu m)	Available freshwater per capita (cu m)	Total annual freshwater withdrawals (% of internal resources)	Annual freshwater withdrawal by sector use (% of total freshwater withdrawal)		
				agriculture	domestic	industry
Indonesia	2,838.0	12,867.4	2.9	91.3	8.0	0.7
Philippines	479.0	5,664.2	6.0	74.0	16.6	9.4
Singapore	0.6	138.2	–	–	–	–
Thailand	210.0	3,333.2	41.5	95.0	2.5	2.5
Viet Nam	366.5	4,410.1	19.5	68.1	7.8	24.1
Southeast Asia	5,674.2	13,237.6	–	–	–	–
World	43,507.0	6,778.3	–	–	–	–

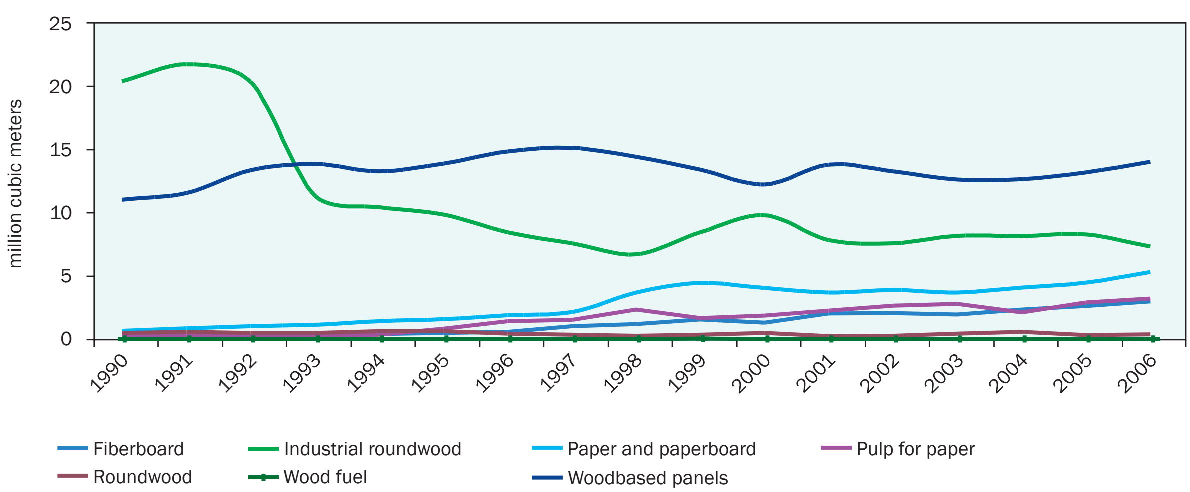
– = data not available.
Source: World Bank's World Development Indicators online database (2008).

The region's exports of industrial roundwood peaked in the early 1990s at 20 million cu m and stabilized thereafter at an annual average of about 7.7 million cu m from 2001 to 2006. Export of wood-based panels has been increasing steadily, from 10 million cu m in 1990, to 12 million cu m in 2000, and 13 million cu m in both 2005 and 2006. Exports of other forest products including paper, pulp, and fiberboard, are also increasing. Indonesia registered the largest share of exported wood-based panels in the early 1990s, and remains the largest exporter, although its share has decreased over the years (Figures 2.4, 2.5 and 2.6). The region's forest sector plays a very important role in providing livelihoods to a large segment of the population (especially the relatively poor), and in maintaining biodiversity, stability of the ecosystem, and quality of life.

But the sustainability of the forest sector is under increasing threat due to:

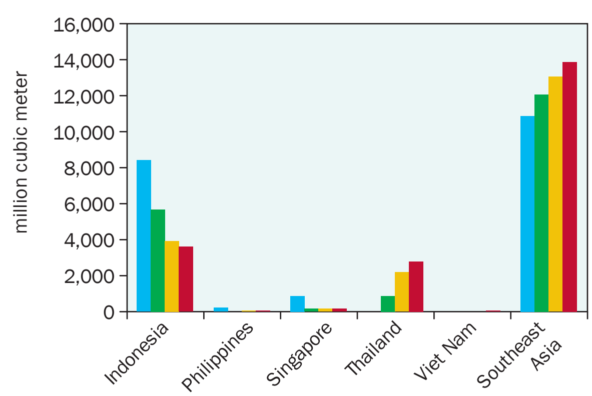
- Continued conversion of forestland to cropland. Between 1990 and

Figure 2.4. Regional Exports of Forest Products (1990–2006)



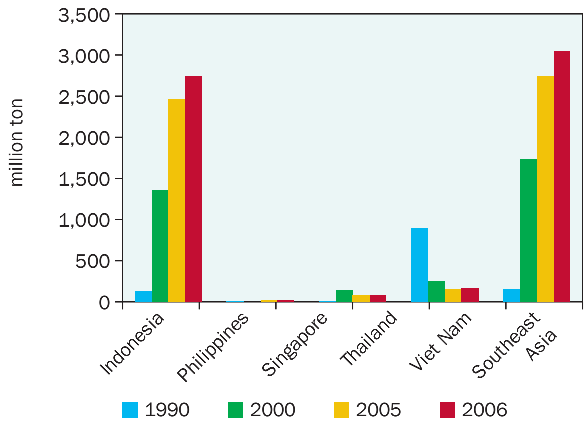
Source: FAOSTAT (2008).

Figure 2.5. Exported Wood-based Panels in Southeast Asia



Source: FAOSTAT (2008).

Figure 2.6. Exported Pulp for Paper in Southeast Asia



Source: FAOSTAT (2008).

2005, about 41 million ha of forestlands were converted to other land use. Sizeable conversion of forestland has taken place in Cambodia, Indonesia, Myanmar, and Philippines. For the last 15 years, forest areas decreased in all countries in Southeast Asia, except for Viet Nam, where forestland is increasing at a rate of 3.8% per year (FAO 2005).

- Conversion of primary forest to plantation forest. Many countries continue to convert their primary forest to other land uses (Table 2.5). Between 1990 and 2005, the area of primary forest in Southeast Asia was reduced overall by 27%. While the primary forest area has decreased, the area of forest plantations has increased, but not proportionately. Between 1990 and 2005, forest plantations increased from 10 million to 13 million ha, with most of the increase contributed by Indonesia and Viet Nam (Table 2.6).

- Increased frequency of forest fires. Over the past several decades, droughts accompanying the El Niño Southern Oscillation (ENSO) have triggered recurring forest fires in the region, which threaten not only the livelihood of workers and families relying on the forest sector, but also the sustainability of the ecosystem.

- Unsustainable harvesting practices and illegal logging induced by high prices due to increasing demand for forest products. If not managed sustainably, primary forestlands in Southeast Asia will continue to decrease, to the detriment of water resources and ecosystems. The loss of forest cover, which serves as a natural ecological temperature control, protective cover, and watershed for the vast areas of Southeast Asia, will increase the exposure of the region to potential consequences of extreme events including typhoons, landslides, flash floods, drought, biodiversity loss, and other impacts resulting from the change of the ecological balance.

Coastal and marine resources provide livelihoods for many Southeast Asians.

Table 2.5. Primary Forest in Southeast Asia (1990–2005)

Country	Primary forest ('000 ha)			As % of total forest Area			Annual change (ha/year)	
	1990	2000	2005	1990	2000	2005	1990–2000	2000–2005
Brunei Darussalam	313	288	278	100.0	100.0	100.0	-2,500	-2,000
Cambodia	766	456	322	5.9	4.0	3.1	-31,000	-26,800
Indonesia	70,419	55,941	48,702	60.4	57.2	55.0	-1,447,800	-1,447,800
Lao PDR	1,490	1,490	1,490	8.6	9.0	9.2	0	0
Malaysia	3,820	3,820	3,820	17.1	17.7	18.3	0	0
Myanmar	–	–	–	–	–	–	–	–
Philippines	829	829	829	7.8	10.4	11.6	0	0
Singapore	2	2	2	100.0	100.0	100.0	0	0
Thailand	6,451	6,451	6,451	40.4	43.5	44.4	0	0
Viet Nam	384	187	85	4.1	1.6	0.7	-19,700	-20,400
Total	84,474	69,464	61,979	–	–	–	–	–

– = data not available.
Source: Global Forest Resource Assessment (FAO 2005).

Table 2.6. Forest Plantations in Southeast Asia (1990–2005)

Country	Forest plantations ('000 ha)			As % of total forest area			Annual change (ha/year)	
	1990	2000	2005	1990	2000	2005	1990–2000	2000–2005
Brunei Darussalam	–	–	–	–	–	–	–	–
Cambodia	67	72	59	0.5	0.6	0.6	500	-2,600
Indonesia	2,209	3,002	3,399	1.9	3.1	3.8	79,300	79,400
Lao PDR	4	99	224	n.s.	0.6	1.4	9,500	25,000
Malaysia	1,956	1,659	1,573	8.7	7.7	7.5	-29,700	-17,200
Myanmar	394	696	849	1.0	2.0	2.6	30,200	30,600
Philippines	1,780	852	620	16.8	10.7	8.7	-92,800	-46,400
Thailand	2,640	3,077	3,099	16.5	20.8	21.3	43,700	4,400
Viet Nam	967	2,050	2,695	10.3	17.5	20.8	108,300	129,000
Total	10,017	11,507	12,518	–	–	–	–	–

– = data not available.
Source: Global Forest Resource Assessment (FAO 2005).

Southeast Asia's excellent coastlines and rich marine ecosystems have been a distinctive economic advantage in trade, fishery production, and tourism. For example, coastal and marine economic activities are estimated to account for some 25–30% of Indonesia's GDP and provide employment to about 20 million people (ADB 2008).

- Between 2000 and 2005, the region attracted about 261 million visitors, mostly intraregional and from the Americas (North, Central, and South) and Europe (Table 2.7).

- The shelf area is rich in demersal resources, including penaeid shrimp and small pelagic resources, and its oceanic waters are rich in tuna, with Indonesia and the Philippines being the main tuna fishing countries in the whole of the Western Central Pacific (FAO 2005). Indonesia's coastal zone, for instance, is home to 2,500 species of mollusk; 2,000 species of crustacean; six species of sea turtle; 30 species of marine mammal; and over 200 species of fish. With its 70 genera and 450 species of coral covering 16.5% of the global area of coral reefs, Indonesia is considered the coral biodiversity center of the world.

- Coastal aquaculture is the most important fishery activity in some countries, dominated by shrimp farming, which constitutes about

Table 2.7. Tourist Arrivals in Southeast Asia (2000–2005)

Country	2000	2001	2002	2003	2004	2005
Brunei Darussalam	984,093	840,272	–	–	–	815,054
Cambodia	351,661	408,377	786,526	701,014	1,055,202	1,421,615
Lao PDR	737,208	673,823	735,662	636,361	894,806	1,095,315
Malaysia	10,221,582	12,775,073	13,292,010	10,576,915	15,703,406	16,431,055
Myanmar	207,665	204,862	217,212	205,610	241,938	232,218
Indonesia	5,064,217	5,153,620	5,033,400	4,467,021	5,321,165	5,002,101
Philippines	1,992,169	1,796,893	1,932,677	1,907,226	2,291,352	2,623,084
Singapore	7,691,399	7,522,163	7,567,110	6,127,288	8,328,658	8,943,029
Thailand	9,578,826	10,132,509	10,872,976	10,082,109	11,737,413	11,567,341
Viet Nam	2,140,000	2,330,050	2,627,988	2,428,735	2,927,873	3,467,757
Study Countries	26,466,611	26,935,235	28,034,151	25,012,379	30,606,461	31,603,312
Southeast Asia	38,968,820	41,837,642	43,065,561	37,132,279	48,501,813	51,598,569

– = data not available.
Source: UN Statistics Division Common Database (as of September 2008).

three-fourths of the total coastal aquaculture output. Shrimp and tuna are the main export commodities. More than 30,000 households earn their livelihood from shrimp farming, which covers an area of more than 64,000 ha in three main areas. Since the early 1990s, Thailand has been one of the world's leading exporters of shrimp and shrimp products.

But coastal and marine resources have come under serious threat in recent decades.

During the 1970s, rapid expansion of coastal urban centers, paddy rice cultivation, and aquaculture production contributed significantly to the reduction of coastal habitats, particularly mangrove forests. In the Mekong basin, mangrove forests have been degraded drastically, both in area and in quality, particularly in the southern Mekong Delta. In Viet Nam, for example, mangrove forests shrank from 400,000 ha in 1950 to just 269,150 ha in 1980 and then to 157,000 ha in 2005 (FAO 2007). This has indirectly affected the commercial demersal fisheries that rely on mangroves as nursery areas.

The region's coastal environment has also been affected by silt from unsound agricultural and logging practices.

Two-thirds of the world's total sediment transported to oceans occurs in Southeast Asia. This is the result of a combination of active tectonics, heavy rainfall, and the steep slopes characteristic of local terrain prone to soil erosion (UNEP 2001). All coastal areas in Asia are facing an increasing range of stresses and shocks, the scale of which now poses a threat to the resilience of both human and environmental coastal systems. This threat is likely to be exacerbated by climate change. The projected future sea level rise could inundate low-lying areas; drown coastal marshes and wetlands; erode beaches; exacerbate flooding; and increase the salinity of rivers, bays, and aquifers. With higher sea levels, coastal regions would also be subject to increased wind and flood damage due to storm surges associated with more intense tropical storms. In addition, warming of the ocean due to increasing atmospheric temperature would have far-reaching implications for Southeast

Asia's marine ecosystems.

D. Summary

Southeast Asia is one of the world's most vulnerable regions to climate change impact such as droughts, floods, typhoons, sea level rise, and heat waves. This is because of its long coastlines; large and growing population; high concentration of human and economic activities in coastal areas; importance of the agriculture sector in providing jobs and livelihoods for a large segment of people, especially those living in poverty; and dependence of some countries on natural resources and the forestry sector for growth and development. Climate change poses significant threats to the sustainability of the region's economic growth, its poverty reduction endeavors, the achievement of the MDGs, and long-term prosperity.

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PART II

Climate Change, Its Impact, and Adaptation

CHAPTER 3

Climate Change and Its Impact: A Review of Existing Studies

Key Messages

Southeast Asia's average temperature has increased at a rate of 0.1–0.3°C per decade and sea level has risen at 1–3 millimeter (mm) each year over the last 50 years or so. The region also experienced a downward trend in precipitation during 1960–2000.

The increasing frequency and intensity of extreme weather events such as heat waves, droughts, floods, and tropical cyclones in recent decades are also evidence that climate change is already affecting the region. Climate change is worsening water shortages; constraining agricultural production and threatening food security; and causing forest fires, coastal degradation, and greater health risks.

Without global action, climate change is likely to intensify in the decades to come. The region is projected to warm further, following the global trend; become drier still in the coming decades in many parts, particularly in Indonesia, Thailand, and Viet Nam; and experience further rises in sea level.

Southeast Asia is likely to suffer more from climate change than the global average, in terms of increased frequency and intensity of extreme weather events; declining crop yields; loss of rich forests; damage to coastal resources; increased outbreaks of diseases; and associated economic losses and human suffering. The region therefore has a high stake in taking action against climate change.

A. Introduction

Over the past 150 years, the global average surface temperature has increased 0.76°C (IPCC 2007). Global warming has caused greater climatic volatility—such as changes in precipitation patterns and increased frequency and intensity of extreme weather events—and has led to a rise in mean global sea levels. These changes have affected many regions of the world, including Southeast Asia.

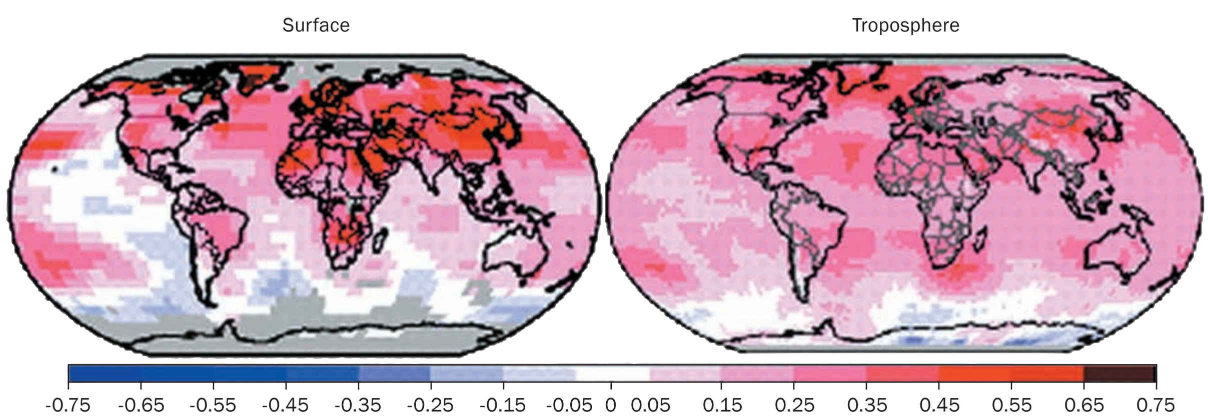
This chapter reviews evidence of how climate is changing in Southeast Asia (changes in temperature, precipitation, extreme weather conditions, and sea level rise), and how that is affecting water resources, agricultural production, forestry, coastal and marine resources, and human health. The review is based on an extensive literature survey and scoping exercise covering the findings of the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 2007) and other studies carried out by concerned governments, research institutions, international organizations, academics, and nongovernment organizations. The review also draws on information collected during regional and national consultations and provided by national climate experts engaged under this study.

B. Observed and Projected Climate Change in Southeast Asia

The average temperature in Southeast Asia has increased 0.1–0.3°C per decade over the last 50 years (Figure 3.1).

There is also evidence that temperature increases became more pronounced in recent years compared to the first half of the 20th century. Country-specific studies report that temperature has increased in all the Southeast Asian countries reviewed in this study (Table 3.1).

Figure 3.1. Patterns of Linear Global Temperature Trends (1979—2005) °C per decade



Source: IPCC (2007).

- In Indonesia, Rataq (2007) reported that the mean temperature recorded in Jakarta increased about 1.04°C per century in the month of January (the wet season) and 1.40°C per century in July (the dry

Table 3.1. Observed Temperature Changes in Southeast Asia

	Temperature change (°C)	Source
Indonesia	Increase of 1.04–1.40°C per century	Rataq (2007)
Philippines	Increase of 1.4°C per century	IPCC (2007)
Singapore	Increasing by about 0.3°C per decade as observed between 1987—2007	Ho (2008)
Thailand	Increase of 1.04–1.80°C per century	Jesdapipat (2008)
Viet Nam	Increase of 1.0°C per century	Cuong (2008)

Source: Compiled by ADB study team.

season). The disappearance of snow covering Mount Jayawijaya of Irian Jaya is seen as clear evidence that warming has occurred.

- In the Philippines, since 1971, mean, maximum, and minimum temperatures have increased 0.14°C per decade according to IPCC (2007). Studies by Tibig (2004) and Manton et al. (2001) support this finding, showing departures from the annual mean, maximum, and minimum temperatures in recent years of 0.61°C, 0.34°C, and 0.89°C, respectively, from the 1961–1990 normal values, indicating an increase in temperature. The frequency of hot days and warm nights has also increased and the number of cold days and cool nights decreased.

- In Singapore, temperature increased 0.6°C between 1987 and 2007 or about 0.3°C per decade. This appears to be consistent with the global trend.

- In Thailand, temperature increased, ranging from 0.10–0.18°C per decade over 5 decades of observation. The country has at sometime in the past experienced an average daytime temperature of up to 40°C, especially during the month of April.

- In Viet Nam, the annual average temperature increased 0.1°C per decade from 1900 and 2000, and 0.7°C, or 0.14°C per decade, during 1951—2000, suggesting temperature rose faster in the latter half of the century. Summers have become hotter in recent years, with average monthly temperatures increasing 0.1–0.3°C per decade.

Southeast Asia is projected to warm further during this century, following the global trend increase in mean surface air temperature.

Under a high emissions scenario (that is, A1FI), developed in IPCC (2000), by the end of this century temperatures could be more than 4°C above 1980–1999 levels, ranging from 2.5–6°C (Box 3.1). This trend could be seriously amplified in different regions of the world. According to IPCC (2007) projections, the mean surface air temperature in Southeast Asia would increase between 0.75–0.87°C by 2039, 1.32–2.01°C by 2069, and 1.96–3.77°C by 2100, depending on which business-as-usual (BAU) baseline scenario is assumed (Table 3.2). While in most parts of Asia the greatest warming occurs from December to February, future warming in Southeast Asia is projected to occur throughout the year. There is a tendency for warming to be stronger over mainland Southeast Asia and the larger land masses of the archipelago.

Box 3.1. The IPCC Special Report on Emissions Scenarios

A1: The A1 storyline and scenario family describes a future world of very rapid economic growth, a global population that peaks mid-century and declines thereafter, and a rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building, and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family is further developed into three groups that describe alternative directions of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: fossil-intensive (A1FI), non-fossil energy sources (A1T), or balanced across all sources (A1B) (where balanced is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end use technologies).

A2: The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing populations. Economic development is primarily regionally oriented and per capita economic growth and technological change are more fragmented and slower than other storylines.

B1: The B1 storyline and scenario family describes a convergent world with the same global population, which peaks mid-century and declines thereafter as in the A1 storyline, but with rapid change in economic structures toward a service and information economy, with reductions in material intensity and introduction of clean- and resource-efficient technologies. The emphasis is on global solutions to economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives.

B2: The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

An illustrative scenario was chosen for each of the six scenario groups, A1B, A1FI, A1T, A2, B1 and B2. All should be considered equally sound.

The SRES scenarios do not include additional climate initiatives, which means that no scenarios are included that explicitly assume implementation of the United Nations Framework Convention on Climate Change or the emissions targets of the Kyoto Protocol.

Source: IPCC (2000).

Table 3.2. Projected Change in Mean Surface Air Temperature for Southeast Asia under A1FI and B1 (with respect to baseline period of 1961—1990), °C

Season	2010—2039		2040—2069		2070—2099	
	A1FI	B1	A1FI	B1	A1FI	B1
December to February	0.86	0.72	2.25	1.32	3.92	2.02
March to May	0.92	0.80	2.32	1.34	3.83	2.04
June to August	0.83	0.74	2.13	1.30	3.61	1.87
September to November	0.85	0.75	1.32	1.32	3.72	1.90
Mean	0.87	0.75	2.01	1.32	3.77	1.96

Source: IPCC (2007).

- Boer and Faqih (2005) projected that temperature in Indonesia will increase 2.1°C and 3.4°C by 2100 under the B2 and A2 scenarios, respectively.

- Hulme and Sheard (1999) projected a temperature increase of 1.2–3.9°C in the Philippines by 2080, using all the IPCC emission scenarios.

- Temperature rise in Singapore by the end of this century, according to IPCC (2007), is likely to be similar to the projected global mean temperature rise of 2.5°C with a range of 1.7–4.4°C.

- Thailand's temperature, based on the climate data generated by a global circulation model, is projected to increase 2–4°C by the end of this century (TEI 2000).

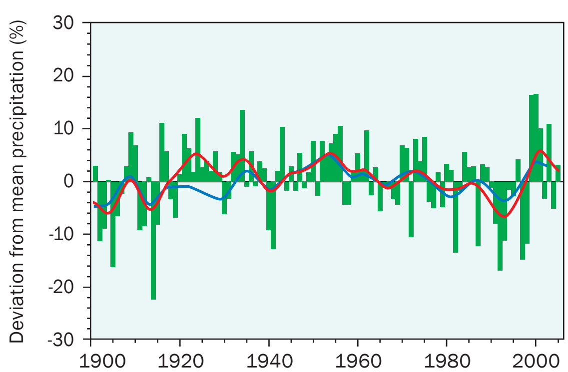
- Most regions in Viet Nam are projected to experience an increase in temperature of 2–4°C by 2100 (Cuong 2008).

Precipitation in Southeast Asia trended downward from 1960 to 2000.

During the second half of the last century, Southeast Asia's precipitation patterns changed inter-seasonally and inter-annually, with an overall trend toward decreasing rainfall until 2000 (Figure 3.2) and a declining number of rainy days. Table 3.3 summarizes the changes in precipitation patterns.

- On the basis of 43 years of historical annual rainfall data from 63 stations since 1950, Aldrian (2007) reported that Indonesia's rainfall decreased in recent decades, except in the Lesser Sunda Islands, the eastern coast of Java, and the northern part of Indonesia including Sumatra. The extent of the decrease varies among locations. Between 1968 and 1997, a significant decrease of rainfall of 71.79 mm per

Figure 3.2. Annual Precipitation in Southeast Asia (1901–2005)



Note: Mean precipitation (2455 mm) is computed from 1961 to 1990. Green bars indicate annual variations in precipitation. Colored lines highlight decadal variation. The blue line used Global Historical Climatology Network data from the National Climatic Data Center. The red line used data from the Climatic Research Unit.

Source: IPCC (2007).

year was observed in Bengkulu in Sumatra and 29.71 mm/year in Ketapang in Kalimantan.

- Rainfall in Thailand and Singapore also decreased in the past 3–5 decades compared to the first half of the last century. In most areas of Viet Nam, average monthly rainfall has decreased, particularly between the months of July and August, and has increased between September and November. Rainfall intensity has also increased considerably (Cuong 2008).

- In contrast, since 1960 mean annual rainfall and the number of rainy days in the Philippines has increased. But as in other places the country has experienced similar variability in the onset of the rainy season. The trend has been toward decreasing rainfall over Luzon and parts of Mindanao and increasing rainfall over the central western part of the country (the Visayan islands) (Anglo 2006).

Under the A1FI scenario, precipitation in Southeast Asia is projected to decrease in the first half of the century, but to increase by the end of the century, with strong variation expected between March and May.

By 2050, Southeast Asia's precipitation will increase 1% under A1FI and 2.25% under B1, with the strongest rise starting in December and ending in May (Table 3.4). Localized climatic change patterns are likely to show significant variation from the regional average due to the very complex topography and maritime influences within Southeast Asia. The strongest increase in rainfall will follow the inter-tropical convergence zone, which could occur between December and May in some parts. Away from the inter-tropical convergence zone, precipitation will decrease. Broadly, the projected precipitation pattern is that the wet season will become wetter and the dry season drier.

- Indonesia's studies on projection of future rainfall are still limited. Some findings suggest seasonal rainfall would increase consistently in the period between 2020 and 2080 under B1 and A2 scenarios, except in September to November (Boer and Dewi 2008).

- Rainfall in the Philippines would continue to be highly variable, as influenced by seasonal changes and climate extremes (for example, El Niño Southern Oscillation [ENSO] events),[1] and be of higher intensity (Perez 2008).

- Changes in annual precipitation for Singapore would range from –2% to +15% with a median of +7%. Extreme rainfall and winds associated with tropical cyclones are likely to increase (Ho 2008).

- In Thailand, there would be a shift in precipitation from north to south

[1] El Niño Southern Oscillation (ENSO) is a periodic phenomenon of climatic inter-annual variability which causes floods in some areas (during La Niña periods) and drought in other areas (during El Niño periods). ENSO has also caused tropical cyclones in Southeast Asia to be more intense and longer-lasting during El Niño years than in La Niña years (Camargo and Sobel 2004).

as predicted by impact studies conducted under the United States Country Studies (TEI 1999) and Boonyawat and Chiwanno (2007).

- Viet Nam's rainfall pattern will be greatly affected by the Southwest monsoon. A recent study on Viet Nam's future rainfall showed that annual rainfall in most areas world increase by 5–10% toward the end of this century (Cuong 2008). Southern Viet Nam would become drier.

Table 3.3. Observed Change in Precipitation in Southeast Asia

	Change in precipitation	Reference
Indonesia	Decrease in annual rainfall during recent decades in some areas	Aldrian (2007)
Philippines	Increase in annual rainfall and in the number of rainy days	Anglo (2006)
Singapore	Decrease in annual rainfall in the past three decades	Ho (2008)
Thailand	Decreasing annual rainfall for the last five decades	Jesdapipat (2008)
Viet Nam	Decrease in monthly rainfall in July-August and increase in September to November	Cuong (2008)

Source: Compiled by ADB study team.

Table 3.4. Projected Change in Precipitation for Southeast Asia under A1FI and B1 (with respect to baseline period 1961—1990), %

Season	2010—2039		2040—2069		2070—2099	
	A1FI	B1	A1FI	B1	A1FI	B1
December–February	-1	1	2	4	6	4
March–May	0	0	3	3	12	5
June–August	-1	0	0	1	7	1
September–November	-2	0	-1	1	7	2
Mean	-1.00	0.25	1.00	2.25	8.00	3.00

Source: IPCC (2007).

Extreme weather events in Southeast Asia have increased in the past several decades.

IPCC (2007) has reported changes in temperature extremes such as heat waves, an increase in the number of hot days and warm nights, and a decrease in the number of cold days and cold nights in Southeast Asia since 1950, consistent with a general warming. The report also highlights a significant increase in the number of heavy precipitation events in the region from 1900 to 2005. Further, the number of tropical cyclones recorded increased markedly during the summer (July to August) and autumn (September to November) of strong ENSO years. In 2004, the number of tropical depressions, tropical storms, and typhoons reported in the region reached an all-time high, with 21 reported typhoons, well above the median of 17.5 for the period 1990—2003. The changes are summarized in Table 3.5. These extreme events, for instance, have led to massive flooding and landslides in many parts of the region, causing extensive damage to property, assets, and human life (Figure 3.3)

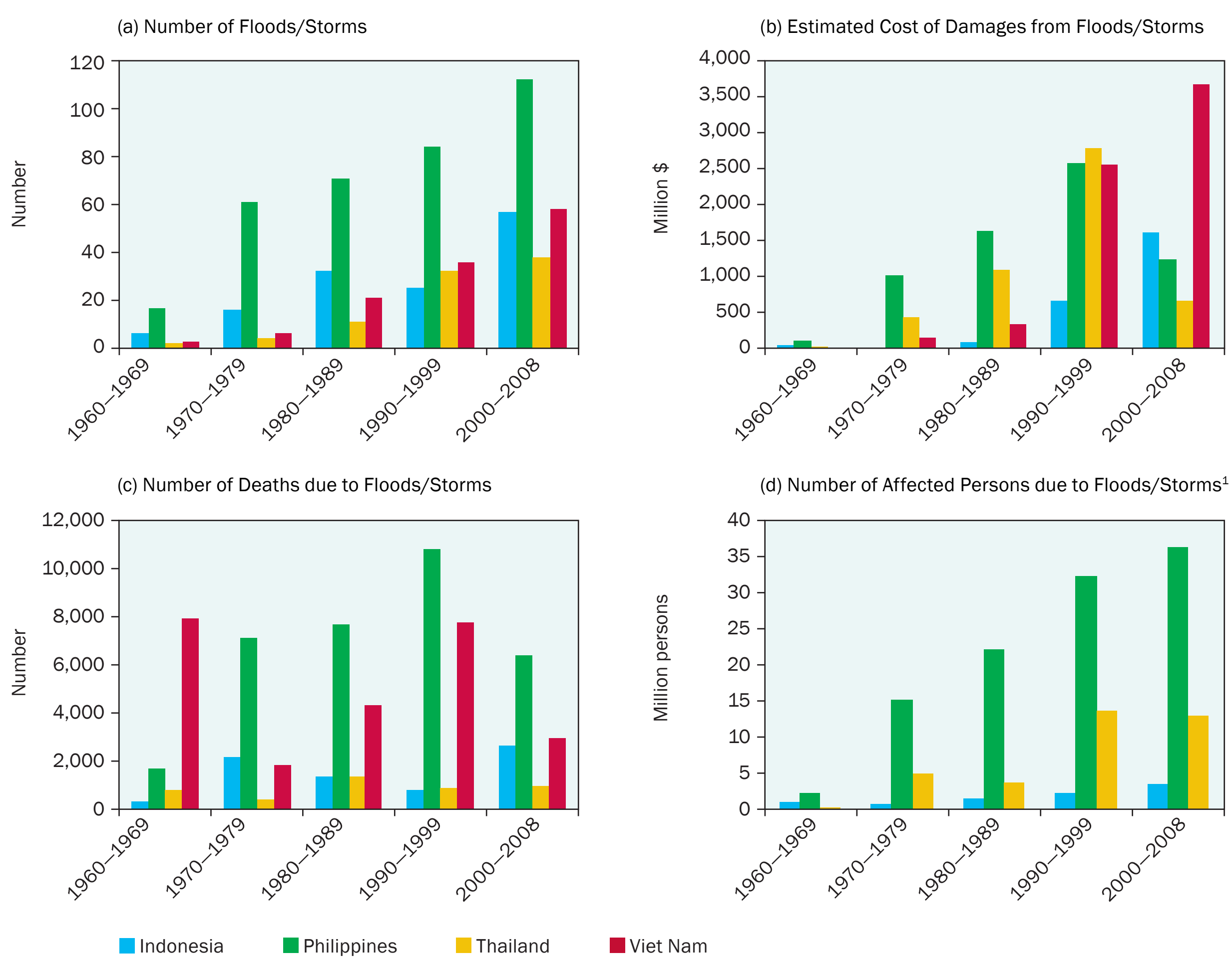
- Extreme climate events in Indonesia are normally associated with ENSO. The ENSO signal is very strong in the country, particularly in those regions that have a monsoonal climate, such as Java, Bali, and Nusa Tenggara. The decrease in dry season rainfall on these islands was twice that of the other islands (Irawan 2002). In recent years,

Table 3.5. Observed Changes in Extreme Events and Severe Climate Anomalies in Southeast Asia

Extreme Events	Key Trends	Reference
Heat waves	Increase in hot days and warm nights and decrease in cold days and nights between 1961 and 1998	Manton et al. (2001), Cruz et al. (2006), Tran et al. (2005)
Intense rains and floods	Increased occurrence of extreme rains causing flash floods in Viet Nam; landslides and floods in 1990 and 2004 in the Philippines, and floods in Cambodia in 2000	FAO/WFP (2000), Environment News Service (2002), FAO (2004a), Cruz et al. (2006), Tran et al. (2005)
Droughts	Droughts normally associated with El Niño years in Indonesia, Lao PDR, Myanmar, Philippines, and Viet Nam; droughts in 1997 and 1998 causing massive crop failures and water shortages as well as forest fires in various parts of Indonesia, Lao PDR, and Philippines	Duong (2000), Kelly and Adger (2000), Glantz (2001), PAGASA (2001)
Typhoons	On average, 20 cyclones cross the Philippine area of responsibility with about eight or nine making landfall each year; an average increase of 4.2 in the frequency of cyclones entering the Philippine area of responsibility during the period 1990—2003	PAGASA (2005)

Source: IPCC (2007).

Figure 3.3. Extent of Damages due to Floods/Storms (1960—2008)



Note: 1 Data not available in Viet Nam for the number of affected persons due to floods/storms.
Sources: CRED (2008), CCFSC (2005).

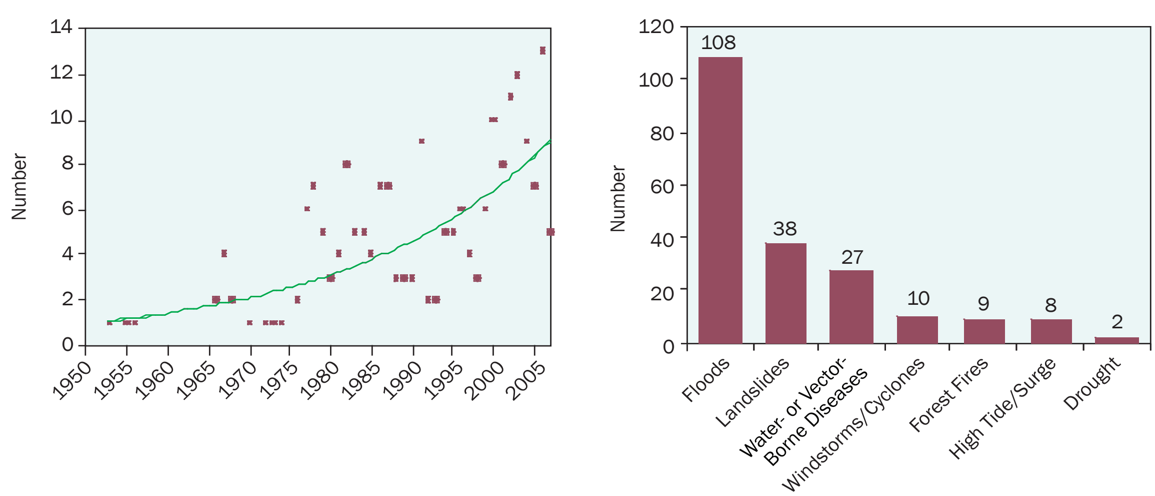
El Niño events have become more frequent as global temperature anomalies have increased (Hansen et al. 2006). Based on a study by Boer and Perdinan (2008) using data for 1907–2007 from the International Disaster Database (OFDA/CRED 2007), it is clear that climate-related hazards have increased over the past 5 decades (Figure 3.4). The most frequent hazard is flooding, followed by landslides and water- or vector-borne diseases.

- In the Philippines, the frequency of typhoons entering its area of responsibility increased more than four-fold during 1990–2003. On average, 20 tropical cyclones, most of them originating in the Pacific, frequented the area each year, with nine (on average) making landfall. Most of these tropical cyclones pass over the central Visayas region of the country. Observations have increasingly supported the scientific claim that rising sea surface temperatures are already enhancing the destructiveness of tropical cyclones worldwide (Emanuel 2005). During the past 15 years, the country was hit by the strongest typhoon ever recorded, the most destructive typhoon, the deadliest storm, and the typhoon that registered the highest recorded 24-hour rainfall. According to Amadore (2005), extreme events in the Philippines are usually accompanied by persistent torrential rains that cause landslides and flash floods, killing people and destroying property as well as the environment. Almost 80% of disasters occurring in the country over the past 100 years have been weather-related, with typhoons and floods contributing to the two highest event categories (Figure 3.5).

- Singapore also faces extreme weather events such as high air temperatures and heavy rainfall, usually from November to January of each year when strong winds from the northeast and heavy cloud cover prevails (Ho 2008).

- In Thailand, extreme events include prolonged flood and drought, landslides, and strong storm surges. These extreme events have

Figure 3.4. Number of Climate-Related Hazards Occurence by Type in Indonesia (1950—2005)

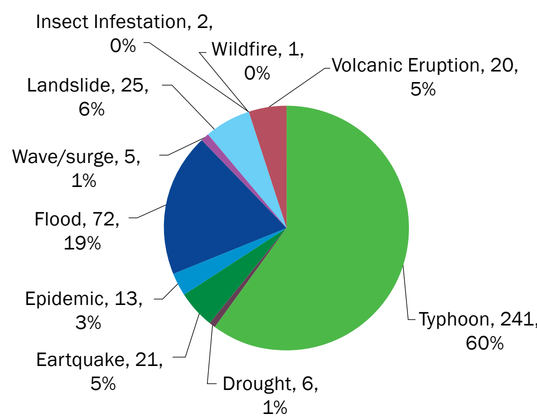


Source: Boer and Perdinan (2008).

become more frequent and more damaging. Storms have become more intense but so far not more frequent (Jesdapipat 2008).

- Extreme events in Viet Nam take the form of typhoons, droughts and flooding, as well as heat waves. Over the last 50 years, the peak month for typhoon landfalls has shifted from August to November, and most of the storms now occur later in the year. Typhoons have also tended to move to lower latitudes. In the Thùa Thiên Huê region, from 1952 to 2005, the area was hit directly by 34 typhoons (about seven per decade). The effect of ENSO has become stronger in various parts of Viet Nam. Droughts and floods now occur with greater frequency than before and affect mostly the central coastal provinces. In the northern lowland part of the country, heat waves occur mainly in the summer, while in the south they occur in the spring-summer period (Cuong 2008).

Figure 3.5. Disasters in the Philippines (1905—2006)



Source: Perez (2008).

The frequency and intensity of extreme weather events in Southeast Asia is likely to increase further, including more heat waves and drought, more flooding, and more tropical cyclones.

Alongside such events, IPCC (2007) also projects an increase in intense precipitation events and an increase in the inter-annual variability of daily precipitation in the Asian summer monsoon. Changes in ENSO and its effect on monsoon variability will greatly influence rainfall variability. ENSO will also affect changes in the occurrence, intensity, and characteristics of tropical cyclones and their inter-annual variability. Northern Southeast Asia will be most affected by changes in tropical cyclone characteristics, which are likely to manifest themselves in an increase in intensity (precipitation and winds).

Likewise, IPCC (2007) projects an increase of 10–20% in tropical cyclone intensity due to a rise in sea surface temperature of 2–4°C relative to the current threshold temperature. Amplification in storm-surge heights could result from the occurrence of stronger winds, with the increase in sea surface temperatures and low pressure associated with tropical storms, resulting in an enhanced risk of coastal disasters.

Sea levels have also risen in Southeast Asia in the last few decades, between 1 and 3 mm per year on average, marginally higher than the global average.

IPCC (2007) cites several studies reporting rises in sea level, with the rate of increase accelerating in more recent years relative to the long-term average. At the upper end of observations are those of Arendt et al. (2002) and Rignot et al. (2003), both highlighting a rise of 3.1 mm per year over the past decade compared to 1.7–2.4 mm per year averaged over the entire 20th century, with the rate of increase varying by location (Table 3.6).

- In Indonesia, the State Ministry of Environment (SME 2007) reported that mean sea level increased by 1–8 mm per year, with the highest increase registered in the area of Belawan (Figure 3.6). A phenomenon called "rob", which refers to the inundation of coastal areas during the spring tide, has been observed in a number of coastal areas in the country. In Demak, the first rob occurred in 1995 and then followed in other districts such as Banten, Jakarta, and other regions.

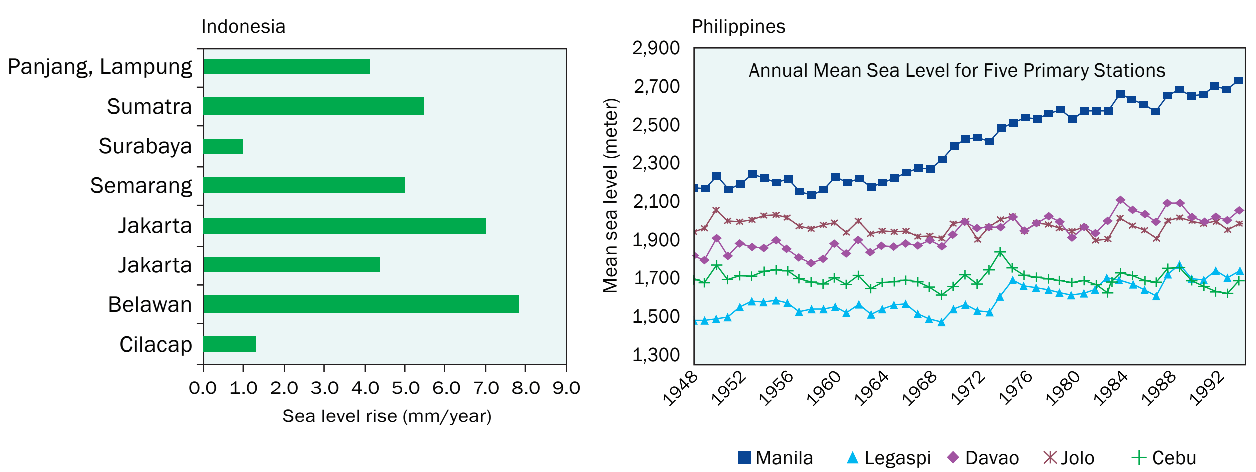
- In the Philippines, studies on rising sea levels in major coastal cities show a slight upward trend (Yanagi and Akaki 1994). The Manila area has exhibited a particularly strong increase in mean sea levels, probably due to a combination of local subsidence as well as a global rise in sea levels (Perez 1999, Hulme and Sheard 1999).

Table 3.6. Observed Change in Sea Level in Southeast Asia

	Change in sea level	Source
Indonesia	Increased by 1–8 mm/yr depending on location	SME (2007)
Philippines	Increasing in major coastal cities with Manila exhibiting the highest increase	Yanagi and Akaki (1994), Perez (1999), Hulme and Sheard (1999)
Singapore	No observable trends toward higher mean sea level so far	Ho (2008)
Thailand	Trending higher in recent years	Jesdapipat (2008)
Viet Nam	Increasing by 2–3 mm/yr	Cuong (2008)

Source: Compiled by ADB study team.

Figure 3.6. Sea Level Rise in Indonesia and the Philippines



Sources: Boer and Dewi (2008) for Indonesia, Perez (2008) for Philippines.

- An analysis of the data for the past 13 years of tide levels at Tanjong Pagar, Singapore shows an average tide level of 3.3 meters and no observable trend toward higher mean sea levels so far. Because Singapore is a small country, this measurement at one location may be taken as representative of the whole country.

- Thailand reports that mean sea levels have been trending higher in recent years.

- In Viet Nam, an upward trend in mean sea level has also been observed, at an average increase of 2–3 mm per year.

Sea levels are projected to rise 40 cm in Southeast Asia by 2100, which will likely increase the loss of small islands.

IPCC (2007) predicts sea levels will continue to rise 1.3±0.7 mm per year over the next several decades. By the end of the century, across all scenarios, the global mean sea level is projected to increase by 0.18–0.59 meters relative to the mean sea level in 1980—1999 (Table 3.7). It could be even higher than 1 meter, as suggested by some climate experts, if the rapid melting of ice sheets and glaciers is taken into account (Guardian 2009). For Southeast Asia, the most conservative scenario estimate is that sea level will be about 40 cm higher than today by the end of the 21st century (IPCC 2007).

- Limited studies exist regarding projection of sea level in the Southeast Asian countries. However, it has been reported that Indonesia could lose 2,000 small islands by 2030 due to a rise in sea level as a result of climate change (Terra Daily 2007).

- Hulme and Sheard (1999) projected an increase in sea level in the Philippines of 0.19–1.04 meters by 2080 relative to mean sea level during 1961—1990.

- In Singapore, as reported in the country report (Ho 2008), sea level rise is likely to be close to the global mean of 0.21–0.48 meters by the end of the century.

Table 3.7. Projected Global Average Surface Warming and Sea Level Rise in 2100

Case	Termperature change (°C) (in 2090–2099 relative to 1980—1999) [a]		Sea level rise (meter) (in 2090—2099 relative to 1980—1999)
	Best estimate	Likely range	Model-based range excluding future rapid dynamic changes in ice flow
At constant year 2000 GHG concentration [b]	0.6	0.3–0.9	—
B1 scenario	1.8	1.1–2.9	0.18–0.38
A1T scenario	2.4	1.4–3.8	0.20–0.45
B2 scenario	2.4	1.4–3.8	0.20–0.43
A1B scenario	2.8	1.7–4.4	0.21–0.48
A2 scenario	3.4	2.0–5.4	0.23–0.51
A1FI scenario	4.0	2.4–6.4	0.26–0.59

– = not available.
a These estimates are assessed from a hierarchy of models that encompass a simple climate model, several Earth Models of Intermediate Complexity, and a large number of Atmosphere-Ocean Global Circulation Models (AOGCMs).
b Year 2000 constant composition is derived from AOGCMs only.
Source: IPCC (2007).

- In Viet Nam, based on A2 and B2 scenarios and using the Dynamic Interactive Vulnerability Assessment tool developed by DINAS-COAST[2] consortium (http://www.dinas-coast.net/), mean sea level for Vung Tau near the mouth of Sai Gon-Dong Nai River will rise by 0.26 meters for A2 and 0.24 meters for B2 (relative to the 1995 baseline level) in 2050.

C. Observed and Projected Climate Change Impact

Water Resources

Southeast Asia has extensive natural inland water systems, its rivers and tributaries playing a vital role in its economic development, particularly in support of industrial and agricultural production. The Mekong River, Red River, and Chaophraya River cradle much of the region's productive rice-growing areas. About 60 million people live in the lower Mekong Basin and are intimately attached to the river's natural cycles for their way of life. The rivers nurture inland fisheries and supply most of the dwellers' protein needs.

Table 3.8 summarizes the observed impact of climate change on water resources in Southeast Asia. With an increase in temperature, the rate of evaporation and transpiration increases. This in turn affects the quantity and quality of water available for agricultural production and human consumption. Erratic precipitation patterns cause irregular stream flows in rivers, which in turn affect the quantity of water for storage, power generation, and irrigation. While El Niño years bring reduced stream flows, the La Niña years bring heavy and intense rainfall, which results in excessive runoff and water flows that cause severe erosion of river banks and sedimentation of transported soils in water reservoirs. Sedimentation reduces the capacity of water reservoirs to store water for future use. Rising sea levels cause intrusion of salty water into freshwater resources and aquifers, which aggravate the water shortage in some parts of the region.

Table 3.8. Summary of Observed Impact of Climate Change on Water Resources Sector in Southeast Asia

Climate Change	Observed Impact
Increasing temperature	— Increased evapotranspiration in rivers, dams, and other water reservoirs leading to decreased water availability for human consumption, agricultural irrigation, and hydropower generation
Variability in precipitation (including El Niño Southern Oscillation)	— Decreased river flows and water level in many dams and water reservoirs, particularly during El Niño years, leading to decreased water availability; increased populations under water stress — Increased stream flow particularly during La Niña years leading to increased water availability in some parts of the region — Increased runoff, soil erosion, and flooding, which affected the quality of surface water and groundwater
Sea level rise	— Advancing saltwater intrusion into aquifer and groundwater resources leading to decreased freshwater availability

Sources: Boer and Dewi (2008), Cuong (2008), Ho (2008), Jesdapipat (2008), Perez (2008).

[2] See http://www.dinas-coast.net/.

Water stress has increased in Southeast Asia, particularly during El Niño years, causing damage to crops, shortages of drinking water, and a drop in electricity production.

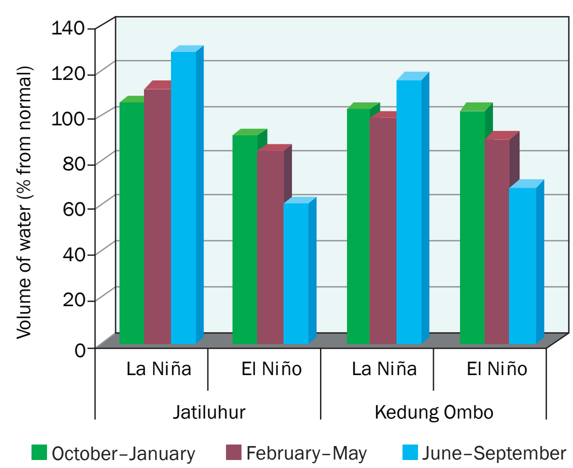
In recent years, Southeast Asia's water resources have come under increasing strain not only from rapid population and industrial growth, but also from decreasing precipitation and increasing temperatures commonly associated with ENSO. The ENSO events have increased water shortages in areas already under water stress.

- In Indonesia, ENSO events have significantly affected river flows and water reservoirs (Figure 3.7), particularly during the dry season from June to September (Las et al. 1999). Flow data from 52 rivers across the country show a significant increase in the number of rivers in which minimum flow was caused by drought. Similarly, the number of rivers in which the peak flow caused floods has also significantly increased. Due to such changes, many dams have not been able to function optimally, causing damage to crops, shortages of drinking water, and reduction in electricity production from hydro sources.

- In the Philippines, the worst drought in the 1997–1998 El Niño years resulted in severe water shortages at the Angat dam, the main source of water for Metro Manila and surrounding areas. These reduced its storage by 10%, resulting in water rationing (daily service shortened by about 4 hours) in some areas. The falling water levels affected the operation of hydroelectric plants that provide power to major cities and surrounding areas. Rising sea levels have also aggravated the already water-stressed areas. Advancing seawater in parts of Northern Luzon has affected groundwater resources, the main source of drinking water and water for irrigation (Perez 2008).

- In Singapore, due to limited domestic availability of water resources, water is crucial when considering the effects of climate change. With

Figure 3.7. Changes in Volume of Water in Reservoirs in Java, Indonesia during La Niña and El Niño Years



Source: Las et al (1999).

half of the country's land area serving as a catchment to collect water for its reservoirs, any significant reduction in rainfall immediately brings considerable impact on supplies. Rising global temperatures have changed rainfall patterns, which affect the amount of water collected and stored in reservoirs.

- Thailand has abundant water resources, but with the onset of climate change, the water balance has become a common annual problem and, in recent years, an increasingly critical one. Changes in rainfall patterns and the frequency and intensity of rainfall have affected the quantity and quality of water resources from some watersheds (for example, Chaophraya Basin) down to rivers and estuaries (Jesdapipat 2008).

- In Viet Nam, as in other countries of Southeast Asia, the increase in evapotranspiration (loss of water from the soil both by evaporation and transpiration by plants) due to increased temperature has reduced the availability of water for irrigation and other purposes (Cuong 2008).

La Niña (associated with heavy rains) and tropical cyclones have caused massive flooding in major rivers in Southeast Asia; the events have become more frequent and have caused extensive loss in livelihoods, human life, and property.

Extreme events like La Niña and tropical cyclones have brought heavy and intense rainfall in Southeast Asia, resulting in excessive runoff and water flows to already fragile ecosystems (that is, due to poor land use planning and unsustainable use) that cause massive flooding, landslides, severe erosion of river banks, and sedimentation.

- In Indonesia, floods caused by La Niña in 2003–2005 damaged houses, public facilities, roads, bridges, dams, channels, dikes, water resources buildings, settlements, and rice areas, resulting in total damage to infrastructure of about $205 million (BPSDA 2004).

- Heavy rainfall, particularly brought about by tropical cyclones, has caused severe runoff, flooding, and damaging landslides in many parts of the Philippines. Between 1991 and 2006, around 10,000 people died as victims of flash floods and landslides. Based on the report by Amadore (2005a), from 1975 to 2002, intensified tropical cyclones caused an annual average of 593 deaths and annual damage to property worth $83 million, including damage to agriculture of around $55 million.

- Thailand was also not spared from the impact of flooding due to heavy rainfall. In 2001, 920,000 households were affected by floods. In a report by Greenpeace (Amadore 2005a), the country claimed to have suffered more than $1.75 billion in economic losses related to floods, storms, and droughts in the period 1989—2002. The majority of these losses came from the agriculture sector where crop yield losses amounted to more than $1.25 billion during 1991—2000.

- Viet Nam reports considerable damage and loss brought about by extreme flooding in the Red River Delta, Mekong Delta, and Central Region. From 1996 and 2001 alone, millions of houses were damaged by floods including thousands of classrooms and hundreds of hospitals. At least 1,684 people were reported to have died. Rice growing areas ranging from 20,690 ha to 401,342 ha were flooded and damaged. Thousands of hectares of farmland were also damaged and fish and shrimp ponds were flooded and destroyed, with total estimated damage at $680 million. During the last decade, death and injuries due to flash floods and landslides in mountainous areas of Viet Nam have become more frequent. On average, about 9.3 people per million die annually due to climate-related disasters.

Projected maximum and minimum monthly flows in major river basins in Southeast Asia suggest increased flooding risk during the wet season and increased water shortages during the dry season by 2100.

Compared with 1960—1990 levels, the maximum monthly flow of the Mekong River is projected to increase between 35% and 41% in the basin and between 16% and 19% in the delta. The lower value is projected to occur between the year 2010 and 2038 and the higher value between 2070 and 2099 (IPCC 2007). The minimum monthly flow, on the other hand, will fall by 17–24% in the basin and by 26–29% in the delta. These suggest the possibility of increased risk of flooding during wet seasons and increased water shortages in dry seasons (Hoanh et al. 2004).

- Jose et al. (1999), in a study of the impact of changes in temperature and precipitation in the Angat water reservoir in the Philippines, projected that a 6% decrease in precipitation and a 2°C increase in temperature will result in a 12% decrease in runoff. However, if precipitation increases by 3–15% and the temperature increases by 2.4–3.1°C, runoff will increase by 5–32%. This projection suggests that water availability will fluctuate more severely in the future and that conservation and water management during times of high precipitation will become critical in order to cope with periods when rainfall is inadequate.

Areas under severe water stress are projected to increase in Southeast Asia, affecting millions, challenging the region's attainment of sustainable growth.

The areas under severe water stress are likely to increase substantially, posing the most challenging impact of climate change on water resources. Under the full range outlined in the Special Report on Emissions Scenarios (IPCC 2000), about 120 million to 1.2 billion people in Southeast and South Asia will experience increased water stress by 2020, and 185 million to 981 million by 2050 (Arnell 2004). By the end of the 21st century, the annual flow of the Red River is projected to decline by 13–19% and the Mekong River by 16–24%. This could exacerbate water stress in the region (ADB 1994).

Proper management of water resources will be crucial to the attainment of sustainable growth and poverty alleviation in Southeast Asia. Water demands from growing population and industries, if not managed sustainably, will lead to further degradation of riparian areas, intensification of land and water use, and increase in the discharge of pollutants. With the increasing demand for water, the already stressed environment, and the threats of climate change, the region faces the challenge of how best to manage its water resources to ensure future water demands can be met.

Agriculture

Agriculture remains a major economic sector throughout Southeast Asia. The region has about 115 million ha of agricultural land planted, mainly to rice, maize, oil palm, natural rubber, and coconut. It is a major producer and supplier of grains and the largest producer of palm oil and natural rubber. It also raises a considerable amount of livestock, which in recent years has grown dramatically in importance and at a much faster rate than croplands and pasture. In recent years, due to climate change coupled with growing populations and emerging industries, the agriculture sector in Southeast Asia has been under considerable environmental pressure.

Increasing temperature amplifies the rate of evapotranspiration, which intensifies stress in crops, particularly in those areas with limited water supply. The combined effect of heat stress and drought reduces crop yields. Erratic precipitation patterns affect land preparation and planting times and alter the life cycle of major pests and diseases affecting agricultural crops. Drought during the El Niño years causes water stress to crops and increases pest and disease infestation. These insects (also acting as pathogens) feed heavily on major agricultural crops rather than the natural vegetation in the surrounding areas. Heavy rains during La Niña years bring severe flooding, massive runoff, and soil erosion, reducing soil fertility and productivity. Rising sea levels amplify soil salinity in many low-lying agricultural areas and even expand the intrusion of seawater into groundwater resources and aquifers. Higher sea levels also cause the loss of arable lands in the region. The impact on Southeast Asia's agriculture sector is summarized in Table 3.9.

Increasing temperature (and heat stress) has been undermining the agricultural production potential of Southeast Asia.

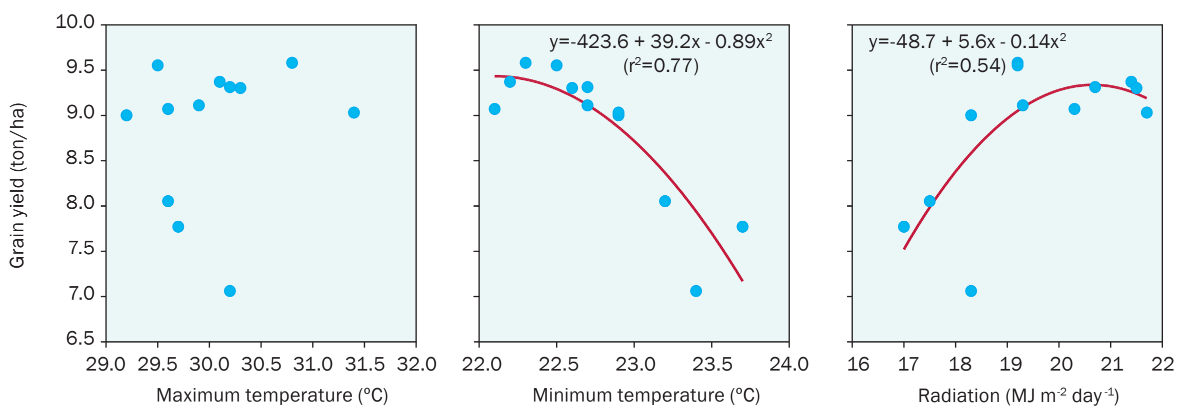
Temperature and rainfall are the key factors affecting agricultural production in Southeast Asia. The production potential of major crops such as rice and maize has declined in many parts of the region due to the increase in heat stress and water stress. A study conducted by the International Rice Research Institute (Peng et al. 2004) found that rice yield decreases by 10% for every 1°C increase in growing season minimum temperature (Figure 3.8). In Thailand, it is reported that increasing temperature has led to a reduction in crop yield, particularly in non-irrigated rice. This has been attributed to the effect of drought at critical stages of growth, such as the flowering period. In a study conducted by the Office of Natural Resources & Environmental Policy and Planning (ONEP 2008), negative impacts on corn productivity ranged from 5–44%, depending on the location of production.

Table 3.9. Summary of Observed Impacts of Climate Change on Agriculture Sector in Southeast Asia

Climate change	Observed impacts
Increasing temperature	— Decreased crop yields due to heat stress — Increased livestock deaths due to heat stress — Increased outbreak of insect pests and diseases
Variability in precipitation (including El Niño Southern Oscillation)	— Increased frequency of drought, floods, and tropical cyclones (associated with strong winds), causing damage to crops — Change in precipitation pattern affected current cropping pattern; crop growing season and sowing period changed — Increased runoff and soil erosion caused decline in soil fertility and consequently crop yields
Sea level rise	— Loss of arable lands due to advancing sea level — Salinization of irrigation water affected crop growth and yield

Sources: Boer and Dewi (2008), Cuong (2008), Ho (2008), Jesdapipat (2008), Perez (2008).

Figure 3.8. Relationship between Crop Yield and Climate (1991—2003)



Source: Peng et al. (2004).

Increased frequency and intensity of extreme events have brought considerable economic damage to agricultural production.

Southeast Asia in recent years has been frequented by many strong tropical cyclones and intensified ENSO events, with significant effects on agricultural production. Planting time and growing season have been changing due to erratic patterns of precipitation. Farmers, particularly those who depend on rainfall for water supply, have to take more risks in growing crops. When hit by El Niño in the middle of the growing season, the shortage of water will impair crop growth and consequently reduce its potential yield. During the El Niño period, agricultural crops become vulnerable to pest attacks and diseases. La Niña years bring heavy rain, causing massive runoff, severe erosion of fertile soils, and inundation of agricultural areas and aquaculture farms.

- In Indonesia, a delay in the onset of the wet season beyond 20 days has upset the established crop cycle in some locations. A one-month delay in the onset of the rainy season during El Niño years reduces the production of wet season rice (January–April) by 6.5% in West/Central Java, and 11.0% in East Java/Bali (Naylor et al. 2007).

- Also in Indonesia, the occurrence of ENSO has affected many agricultural areas. The drought in 1991 affected more than 800,000 ha of rice (with about 25% completely damaged); about 30,000 ha each for maize and soybean; and around 12,000 ha of peanuts. ENSO has influenced changes in major crop pests and diseases. The major rice pest, brown plant hopper population (Nilaparvata lugens) has increased significantly in La Niña years due probably to higher rainfall. The pink rice stem borer (Sesamia inferens) has become a major problem in some parts of the country compared to the yellow rice stem borer (Scirpophaga incertulas), and white rice stem borer (Scirpophaga innotata). In the past, the pink rice stem borer was not a major problem in Indonesia (Nastari Bogor and Klinik Tanaman IPB 2007). Similar phenomena have also been observed in crop diseases. Before 1997, twisting disease, caused by Fusarium oxysporum was not for the red onion crop but, in recent years, has become very important not only in the lowlands but also in the highland areas (Wiyono 2007).

- In the Philippines, there are reports of cropping seasons during El Niño years during which farmers had to totally give up rain-fed rice farms due to water shortages. The recurrence of extreme drought has resulted in a significant decline in agricultural production in some areas. The sharpest fall in gross value added and in volume of production in the agricultural sector came about in the El Niño years of 1982–1983 and 1997–1998 (Amadore 2005b). The decline in gross value added was noted in four major crops: rice, maize, sugarcane, and coconut. Between 1975 and 2002, Amadore (2005a) reported that intensified tropical cyclones in the country caused damage to agriculture amounting to 3 billion pesos (around $55 million).

- In Thailand, Boonpragob (2005) noted that the country suffered more than 70 billion baht (around $1.75 billion) in economic losses due to floods, storms, and droughts between 1989 and 2002. These losses came mainly from the agriculture sector, where crop yield losses amounted to more than 50 billion baht (around $1.25 billion) between 1991 and 2000.

- What could be most disturbing is the impact of extreme weather events in Viet Nam. In recent years, thousands of hectares devoted to rice production have been damaged by frequent flooding in the Red River Delta, Central Region, and Mekong Delta. These also included areas devoted to fish and shrimp farming. The Mekong River Delta flood in 2000 brought severe damage to 401,342 ha of rice paddy; 85,234 ha of farmland; and 16,215 ha of fish and shrimp farms. Rice areas affected by drought doubled from 77,621 ha in 1979–1983 to 175,203 ha in 1994–1998 (the latter included the impact of one of the worst El Niño years in 1997–1998) (Cuong 2008).

- Singapore's agriculture sector contributes less than 1% to the country's GDP. Given the low level of food production within Singapore due to limited land and water resources, Singapore relies mainly on imports to satisfy domestic demand. Therefore, any significant damage to crops in neighboring countries will affect agriculture and food supplies (Ho 2008).

Rising sea levels have accelerated saline water intrusion and soil salinity in the region's agricultural areas, causing a decline in potential production and considerable loss in arable lands.

Advancing sea levels encroach on coastal farm areas affecting groundwater resources and making soil saline and less favorable for crop production. Grattan et al. (2002), Maas and Hoffman (1977), Maas and Grattan (1999), and Hanson et al. (1999) reported evidence of the negative effect of increasing soil salinity on rice. Grattan et al. (2002) found that yield starts to decrease when salinity in field water increases above 1.9 dS/m.[3]

- Increased soil salinity has affected rice production in Indonesia since many rice fields are located in the coastal zone (accounting for about 15% of total rice production).
- Rising sea levels have contributed to the loss of arable lands in low-lying coastal areas of the Philippines. This rise has intensified saltwater intrusion in groundwater resources in the northern part of Luzon, which is predominantly an agricultural region. Saltwater intrusion has also affected many agricultural areas in the coastal regions of Thailand.
- Viet Nam has also suffered from severe saltwater intrusion in agricultural areas. In 1998, seawater intrusion caused severe soil salinization up to 10–15 km inland. About 100,000 ha of agricultural land in the provinces of Ben Tre, Tra Vinh, Tien Giang, and Ca Mau (the Mekong Delta region) were salinized in 1999 (CECI 2004, Chaudhry and Ruysschaert 2007).

Several studies have predicted a possible decline in agricultural production potential in Southeast Asia due to climate change.

Murdiyarso (2000) predicted a decline of 3.8% in rice yields by the end of the 21st century as a consequence of the combined influence of fertilization effects and accompanying thermal stress and water scarcity. Under the A1FI scenario, for the warming projection of 0.83–0.92°C, decreases in crop yields of 2.5–10% in 2020 could be expected. In 2050, warming is projected to be in the range of 1.32–2.32°C, which could result in 5–30% yield decreases. A more recent study by Cline (2007), however, predicts that crop yields in Asia could decline by about 7% with CO_2 fertilization and 19% without CO_2 fertilization towards the end of this century.

- According to Naylor et al. (2007), a one-month delay in the onset of the rainy season during El Niño years will reduce the production of wet season rice (January–April) in West/Central Java, Indonesia by about 6.5% and in East Java/Bali by 11.0%.
- Escaño and Buendia (1994) in a United States Environmental Protection Agency Modeling Project predicted that an increase in temperature of +2°C (at 330 ppm CO_2 concentration) would reduce

[3] The measurement dS/m, which means deciSiemens per meter, is a unit of measure of electrical conductivity. Seawater has an electrical conductivity of about 55 dS/m.

rice yield by 22% in the Philippines. Centeno (1995), using the Goddard Institute for Space Studies model of a doubling of CO_2, predicted a yield decrease of 14% due to a higher increase in temperature, which reduces spikelet fertility and consequently lowers yields.

- In Viet Nam, the Dynamic-Ecological simulation model, a tool developed by the DINAS-COAST consortium, predicts a decrease in spring rice yield of 2.4% by 2020 and 11.6% by 2070 under the A1B scenario (Table 3.10). Summer rice will be less sensitive to climate impact than spring rice, but the yield will also decrease by 4.5% by 2070. Rice planted in northern and central Viet Nam will be affected more than rice grown in the southern part of the country. In the case of maize, the projected decrease in yield is small as compared to rice (Table 3.11). However, across the region, the projection is that maize grown in northern areas will experience increased yield while maize grown in central and southern areas will have reduced yields.

Climate change constitutes a significant challenge to Southeast Asia's status as a major producer of grain and industrial crops.

Heat stress, water stress (drought), climate-associated pests and diseases, flooding, and typhoons will all contribute to the decline in the production of rice, maize, soybean and other crops in Southeast Asia. Industrial crops such as rubber trees, oil palms, coconut, and fruit trees will not be spared the threat of heat and water stresses as well as wildfires. Consequently, the decline in grain production and industrial crops will impact the livestock industry and emerging industries very much dependent on natural resources. A rise in sea levels also adds to the burden, claiming fertile agricultural areas near the coast (coastal erosion) and reducing arable lands by soil salinization.

Table 3.10. Rice Yield Change in Viet Nam (comparison with base year, 1980–1990), %

Location	Spring Rice			Summer Rice		
	2020	2050	2070	2020	2050	2070
Ha Noi (Northern Viet Nam)	-3.7	-12.5	-16.5	-1.0	-3.7	-5.0
Da Nang (Central Viet Nam)	-2.4	-6.8	-10.3	-1.2	-4.2	-5.7
Ho Chi Minh City (Southern Viet Nam)	-1.1	-6.0	-8.1	-0.2	-1.7	-2.8
Mean	-2.4	-8.4	-11.6	-0.8	-3.2	-4.5

Source: Cuong (2008).

Table 3.11. Maize Yield Change in Viet Nam (comparison with base year, 1980–1990), %

Location	2020	2050	2070
Ha Noi (Northern Viet Nam)	+0.7	+7.2	+7.1
Da Nang (Central Viet Nam)	-0.7	-3.1	-4.2
Ho Chi Minh City (Southern Viet Nam)	-1.6	-6.4	-8.5
Mean	-0.53	-0.77	-1.87

Source: Cuong (2008).

If these negative impacts on the region's agricultural production continue, with the increasing population of Southeast Asia, it is very likely that millions of people in the region will be left unable to produce or purchase sufficient food. Food insecurity and loss of livelihood are likely to be exacerbated further by the loss of arable land and fisheries to inundation and coastal erosion in low-lying areas. More people will be at risk of hunger and malnutrition, which will cause more deaths. The possibility of local conflicts may increase.

On the supply side, future farming will be a challenge, as farmers will need to adapt to new farming technologies (that is, heat-tolerant and pest-resistant crop varieties, drought-resistant and waterlogging-resistant crops, adjusted planting dates, and others). If these technologies are not available and readily accessible to farmers, it is likely that agricultural productivity will continue to decline in Southeast Asia.

Rising temperatures will also lead to a reduction in fish production, threatening the entire region's potential as the world's largest producer of fish and marine products.

The Asia and Pacific region is the world's largest producer of fish, both from aquaculture and capture fishery sectors. Recent studies suggest primary production of fish will decrease in the tropical oceans due to changes in oceanic circulation in a warmer atmosphere. A large-scale change of the skipjack tuna habitat is projected in the equatorial Pacific under a warming scenario (Loukos et al. 2003). A measurable decline in fish larvae abundance in the coastal waters of Southeast Asia is predicted due to the increased frequency of El Niño events. With future changes in ocean currents as well as sea levels, seawater temperature, salinity, wind speed and direction, strength of upwelling, mixing layer thickness, and predator response to climate change, the region's potential as the world's largest producer of fish and marine products would be challenged.

Forestry

Forestlands in Southeast Asia covered 203 million ha (as of 2005), 5.1% of total world forest. Traditionally, the region has been a major producer of industrial roundwood, paper and paperboard, pulp for paper, and wood-based panels. It has been the main exporter of forest products accounting for 50% of the total from Asia and the Pacific (UNESCAP 2005). Many of the region's inhabitants rely on forests for their livelihood, as do those industries in need of forest products.

Southeast Asia's forests have been under mounting pressure as more

Table 3.12 Summary of Observed Impacts of Climate Change on Forestry Sector in Southeast Asia

Climate Change	Observed Impacts
Increasing temperature	— Increased frequency of forest fires as well as area of burnt forests — Increased pest and disease infestation in forests
Variability in precipitation (including El Niño Southern Oscillation)	— Increased forest fire, and pest and disease infestation due to drought — Change in precipitation pattern, affecting survival of seedlings and saplings — Increased soil erosion and degradation of watershed due to intermittent drought and flooding — Increased population of invasive plant species
Sea level rise	— Loss of mangrove forests due to advancing sea levels

Sources: Boer and Dewi (2008), Cuong (2008), Ho (2008), Jesdapipat (2008), Perez (2008).

areas are converted to other land uses to cater to the growing demand for food, feed, and forest products, as well as the need to provide for the growing industrial sector. In recent decades, forests were also affected by climate change, as summarized in Table 3.12.

Over the past 20 years, the intensity and geographic spread of forest fires has increased, causing significant economic damage.

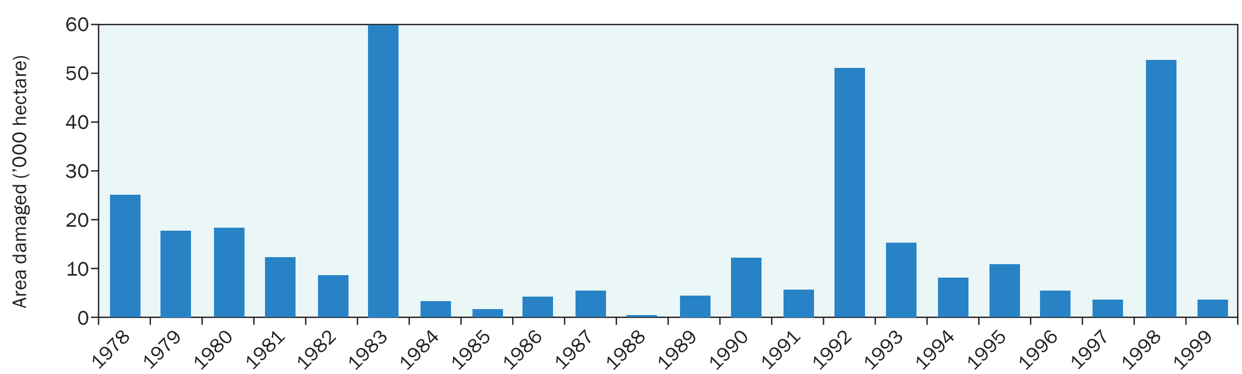
Forest fires in Southeast Asia have brought health problems and caused serious environmental damage. In the past decades, the areas of burned forest have generally shown an increasing trend. This is attributed largely to the combined effects of rising temperatures, declining precipitation, and increasing intensity of land use (Murdiyarso et al. 2004, Murdiyarso and Adiningsih 2006).

- In Indonesia, past data show that total forest areas burned have increased significantly during El Niño years. In East Kalimantan alone, during the 1982–1983 El Niño, the total area burned by wildfires was 3.5 million ha (Lennertz and Panzer 1984). During the 1994 El Niño, the total area burned was 5 million ha (Goldamer et al. 1998). The 1997—1998 El Niño event triggered forest and brush fires in Indonesia's extensive forests, causing serious domestic and cross-border pollution. Forest fire damage, which resulted in economic losses to agriculture, forestry, and other sectors, was estimated to be between $662 million and $17 billion in the 1997 El Niño alone. Peatlands were also affected: during 1997–1998, over 2 million ha of peatlands were consumed by fire (Page et al. 2002).

- In the Philippines, the highest recorded forest fire damage occurred in the El Niño years of 1983, 1992, and 1998 when fire destroyed between 50,000 and 65,000 ha of forests (Figure 3.9). Thousands of hectares of secondary growth and over-logged forests were also burned during the 1997–1998 ENSO events (Glantz 2001, PAGASA 2001).

- Forest fires in Thailand occur annually during the dry season in the

Figure 3.9. Forest Fire Destruction in the Philippines (1978—1999)



Source: Perez (2008).

deciduous forests of drier environments. In recent years, the prolonged and hotter dry season, the decline in rainfall, and the availability of combustible herbaceous fuels have accelerated the spread of forest fires, causing enormous economic damage. Before, it was only the drier environments that were affected. Currently, even moist and evergreen forests are affected, and double burning (burning twice per year) on dry sites has become a regular feature.

- Viet Nam's forest fires have also increased in recent years. Between 1995 and 1999, about 5,000–8,000 ha of forests were burned during El Niño years. This has increased to about 9,000 and 12,000 ha during 2002–2005 (General Statistics Office of Viet Nam 2006).

Heavy rains and tropical cyclones have caused massive landslides in already degraded forest areas, damaging livelihoods and taking lives.

La Niña years bring heavy and widespread rainfall to some parts of Southeast Asia, causing runoff and erosion in watersheds and eventually massive landslides. Landslides cause significant damage not only to forestlands but also to properties and the lives of neighboring settlements and communities. For instance, the 2001 Camiguin flash flood in the Philippines, which was triggered by tropical typhoon Nanang, affected more than 35,000 people and killed 157. Total damage was estimated at $96 million. The 2006 Guinsaugon, Leyte landslide, which was triggered by super typhoon Reming, killed 1,126 people. The 2006 Legazpi, Albay mudslide, also brought about by typhoon Reming, killed 1,399 people and brought significant damage to the communities of the area, many of which have had to be completely rebuilt or relocated. These two landslides, affecting more than 800,000 families, were considered the world's second and third deadliest disasters of 2006.

Endemic flora and fauna have been disappearing in Southeast Asia due to shifting rainfall patterns and climate-related pest infestation and disease.

One tree species common in Southeast Asia and known to be sensitive to variations in climate is the teak (IPCC 1997). This important wood product, commonly found in Java of Indonesia (Tectona grandis) and the Philippines (Tectona philippinensis), has been threatened by the increase in temperature and shifting precipitation patterns.

The distribution of forest types closely follows rainfall distribution patterns. In some parts of Southeast Asia, shifting patterns have led to the disappearance of endemic or common flora and fauna and caused the invasion not only of pests and diseases but also of invasive plant species. Increases in temperature and irregular rainfall pattern have changed forest types and affected the survival of seedlings and saplings in some parts of the region.

Advancing sea level and coastal erosion have been affecting many mangrove forests of Southeast Asia.

Rising sea levels linked to global warming have threatened economically, ecologically, and culturally important mangrove forests in Southeast Asia (UNEP 2008). These mangrove forests, which act as protectors against storm surges and coastal erosion, have been reduced in size by advancing sea water and by the damaging impact of coastal erosion.

- The monsoon season in Thailand, which brings heavy rains and coastal erosion, has caused much of the country's mangrove forests to vanish. Bang Khunthian, which is Bangkok's only seaside district and which once comprised 5 km of muddy coastline with abundant mangrove forests as well as rare and diverse species of plants and marine life, has lost more than 483 ha of mangrove forests over the last 30 years.

- In Viet Nam, sea level rise, together with monsoons and storms, accelerated the speed of coastal erosion resulting in the destruction of many rich mangrove forests, particularly along the east coast of the Ca Mau cape. Erosion has destroyed the shelter of a great many tidal and forest animals as well as the spawning grounds of some fish and shrimp species.

Climate change could trigger the replacement of subtropical moist forests by tropical dry forests in some parts of Southeast Asia.

Malcolm et al. (2006) predicts that doubling the pre-industrial level of CO_2 concentration (at 550 ppm) could lead to about 133 to 2,835 plant species becoming extinct in the Indo-Burma region. Boonpragob and Santisirisomboon (2004) reported that a doubling of atmospheric CO_2 concentrations over the next century could trigger the replacement of subtropical moist forests by tropical dry forests. Subtropical moist forests will decline significantly from 48% of total forest area to 12%, and subtropical wet forests will drop from 5% to 1%. These projections were made using three different types of global climate model scenarios. Each model produced similar outcomes.

In Viet Nam, under the A1B scenario, the area of semideciduous broad leaf forest is projected to decrease by 41% in 2020, 66% in 2050, and by 69% in 2100. In the case of plantation forest such as Churkasia talbularis and Pirus merkusii, the area planted to these species will increase by 21% and 7%, respectively, by 2020. Thereafter that will decrease by up to 76% for Churkasia talbularis and 56% for Pirus merkusii by the end of the century (Table 3.13).

Table 3.13. Projected Change in the Area of Natural and Plantation Forests in Viet Nam

Forest Type	Baseline Area ('000 hectare)	2020	2050	2100
Semideciduous broad leaves	3,827	2,251 (-40.8%)	1,307 (-65.8%)	1,179 (-69.2%)
Churkasia talbularis	1,000	1,214 (+21.4%)	686 (-31.4%)	245 (-75.5%)
Pirus merkusii	5,360	5,757 (+7.4%)	4,237 (-20.9%)	2,338 (-56.4%)

Source: Cuong (2008).

In terms of the effects of rising sea levels on forest cover, it has been projected that a one-meter rise in mean sea level in Viet Nam will affect 1,731 sq km of mangrove forests (almost 70% of the total) due to inundation, especially in the Mekong Delta region (MHC 1996). IPCC (2007) projected that with a one-meter rise in sea level, about 2,500 sq km of mangroves in Asia are likely to be lost.

Coastal and Marine Resources

A large percentage of the region's population lives in coastal areas and on the many low-lying offshore islands. In 2005, the estimated population living within 100 km of the coast reached about 452 million people, equivalent to about 79% of the total population. Most of these people depend on coastal and marine resources for their livelihoods. Coastal aquaculture has been the most important fishery activity in Southeast Asia with more than 30,000 households, in more than 64,000 ha, earning their livelihood from shrimp farming. In recent decades, however, all coastal areas and marine resources in Southeast Asia have been affected by global warming, extreme events, and rising sea levels as shown in Table 3.14.

Coral bleaching has significantly increased in recent years due to global warming.

Coral bleaching is the most commonly reported impact of climate change on marine resources, caused by various types of environmental stress including temperature extremes, pollution, and exposure to air. Coral bleaching has increased significantly since 1979. The most significant mass-bleaching event on record was associated with the 1997–1998 El Niño, when vast and diverse coral reefs in Southeast Asia were reported to have been lost (Wilkinson 2000, 2002; Arceo et al. 2001). According to Wetland International, the 1997–1998 El Niño damaged about 18% of the coral ecosystems in region (Burke et al. 2002).

- Coral bleaching was observed in many parts of Indonesia, such as in the eastern part of Sumatra, and in Java, Bali, and Lombok. In Thousand Islands (north of the Jakarta coast), about 90–95% of corals 25 meters below the surface were bleached.

- In the Philippines, the recent sea surface temperature increase of 0.5°C above the normal summer maximum temperature, coupled with the associated El Niño periods, started coral bleaching in many areas of the country. Amadore (2005a) and Arceo et al. (2001) have reported massive coral bleaching in various reefs caused by elevated

Table 3.14. Summary of Observed Impact of Climate Change on Coastal and Marine Resources Sector in Southeast Asia

Climate change	Observed impacts
Increasing temperature	— Increased coral bleaching and degeneration of coral reefs
Variability in precipitation (including El Niño Southern Oscillation)	— Increased loss of land due to erosion and flooding of coastal areas — Increased damage from floods and storm surge including damage to aquaculture industry
Sea level rise	— Accelerated salt water intrusion inland

Sources: Boer and Dewi (2008), Cuong (2008), Ho (2008), Jesdapipat (2008), Perez (2008).

sea temperatures also during the severe 1997–1998 ENSO episode. Coral bleaching has been reported in the Masinloc Fish Sanctuary (Zambales Province, Northern Luzon), where almost 70% of the corals have been bleached. Bleaching has also occurred in some parts of Luan, Megalawa Island, and Oyon Bay. The Tubbataha Reef in the center of Sulu Sea—which in 1993 was declared a World Heritage site by the United Nations Educational, Scientific, and Cultural Organization and is known as one of the richest areas of marine biodiversity in the world—was also greatly affected by the 1997–1998 El Niño, where more than 20% of the corals were bleached, causing dramatic impact on the fish ecosystem.

- Coral reefs in Thailand have been similarly affected by climate change. Severe coral bleaching was reported in the summer of 1991 in the Andaman Sea off Phuket, Phangnga, and Krabi. The warm water temperatures of April 1998 caused widespread coral bleaching in the Gulf of Thailand from Narathivat province (south) and Trat province (east), up to Chonburi province (the inner part of the Gulf). The 1998 El Niño year also proved disastrous for coral reefs in Thailand.

Coastal flooding and erosion in Southeast Asia have intensified in recent years due to the combined effect of extreme climatic and non-climatic events.

Mangrove forests play a critical role in the protection of coastlines in Southeast Asia. Many of the mangrove forests, however, have been converted into aquaculture and other related projects, and in some cases are converted into human settlements where gathering of mangrove trees for charcoal making and construction materials are practiced unsustainably. As a consequence, many areas have been exposed to tidal waves and coastal erosion.

Coastal flooding and erosion have been accelerated by the destabilization of coastlines due to advancing sea levels and extreme events (such as La Niña and tropical cyclones), causing significant damage in many parts of the region. The tropical cyclones that hit Southeast Asia in recent years, together with storm surges, have accelerated the erosion of beaches, steep bluffs, deltas, and mangrove swamps. This has led to substantial economic losses, loss of lands, and even premature deaths of inhabitants.

- The rob phenomenon, or the inundation of coastal areas during spring tide, has affected a number of coastal areas of Indonesia. In Demak, the first observed rob, in 1995, affected more than 650 ha of coastal areas in six villages of Sriwulan, Bedono, Timbul Seloka, Surodadi, Babalan, and Beran Wetan. It also damaged infrastructure such as roads and railways, and brought considerable problems to the country's transportation system as well as the economy (Boer et al. 2007).

- Coastal erosion has been observed in key cities and areas in the Philippines including Cebu and La Union. This was confirmed by the University of the Philippines National Institute of Geological Sciences-Marine Geology Laboratory in a study that found that sea level rise contributed to coastal erosion. Siringan et al. (2004)

also identified the factors that may have caused coastal erosion in La Union, including relative sea level rise, decrease in precipitation, increase in storm, watershed erosion, beach sand mining, and destruction of coral reefs, mangroves and sand dunes. Even activities that are meant to prevent erosion, such as building of sea walls and ripraps, were found to have contributed to the problem.

- Thailand's 2,667-km shoreline is under serious threat from coastal erosion, which is occurring at the rate of 15–25 meters per year in some places. Coastal erosion is a significant problem along the Gulf of Thailand from Trat province in the east to Narathiwat province in the south. A serious case has been reported in the small coastal village of Khun Samutchine, in Samut Prakan province south of Bangkok. The people of the Khun Samutchine settlement previously enjoyed living in a diverse natural habitat with wetlands, mangrove swamps, and marshes that were home to a wide variety of flora and fauna. Due to coastal erosion and an advancing sea, most of these areas are now deforested, degraded, and devastated, and groundwater resources are already contaminated with seawater. Many families have been forced to abandon their coastal homes, as few people can afford to continue rebuilding houses washed away regularly by the sea.

- Also in Thailand, storm surges have become stronger and more frequent. Certain spots along the inner gulf (for example, areas along the upper south around Prachuab Khirikan province in southern Thailand) and the eastern tip of the south (in Narathiwas and Songkhla provinces) have been eroded by strong winds and the changing direction of seawater flows.

- Coastal land loss is also a major concern to Singapore. Increased coastal erosion has already affected some recreational areas along the coast such as those at the East Coast Park (Figure 3.10).

- Frequent and extreme flooding has also threatened coastal

Figure 3.10. Coastal Erosion at East Coast Park, Singapore

Source: Ho (2008).

communities in Viet Nam. Coastal erosion is getting severe and has already impacted its aquaculture industries.

Rising sea level has caused saltwater intrusion into both coastal freshwater and groundwater resources.

Rising sea levels have caused saltwater intrusion into coastal freshwater and groundwater resources in many areas of Southeast Asia, aggravating water shortages brought about by declining rainfall. Rising sea levels have also accelerated inundation and land subsidence in coastal cities and communities, resulting in considerable losses to tourism and aquaculture industries.

- In Indonesia, groundwater resources in a number of metropolitan areas near the coast of Jakarta, Surabaya, and Semarang have been affected by saltwater intrusion. This problem has existed in Jakarta since the 1960s. Saltwater intrusion in the shallow and deep aquifers of Jakarta has reached inland up to 10–15 km from the coastline. The problem has been exacerbated by overexploitation of groundwater, which has caused land subsidence. Penetration of saltwater in deeper aquifers (40–140 meters) has been noted up to 5–13 km inland in the area of the Soekarno Hatta airport; and 8–10 km in the areas of Cengkareng, Grogol, and Kelapa Gading.

- Viet Nam, considering all sea level rise impact indicators, ranks among the top five countries most affected by rising sea levels. This conclusion is based on the study conducted by the World Bank on the potential impact of rising sea levels on 84 coastal, developing countries (Dasgupta et al. 2007). Salinity intrusion has advanced in the country affecting the lives and livelihoods of the people living in the coastal areas.

By 2100, rising sea levels are predicted to severely affect millions of Southeast Asians.

Wassmann et al. (2004) and the Stern Report (Stern 2007) state that millions of people living in the low-lying areas of the People's Republic of China, Bangladesh, India, and Viet Nam will be affected by rising sea levels by the end of this century. By 2100, under the most common predictions, global mean sea level is projected to increase by 40 cm, which could mean an increase in the average annual number of people flooded within coastal regions, or from 13 million to 94 million people worldwide. About 20% of them will live in Southeast Asia, particularly Indonesia, Philippines, Thailand, and Viet Nam.

- In Indonesia, rising sea levels, in combination with land subsidence due to overexploitation of ground water, will definitely move the coastline inland, with an associated higher risk of flooding. A study conducted by Pusat Pengembangan Kawasan Pesisir dan Laut, Institut Teknology Bandung (2007) showed that with a sea level rise of 0.25, 0.57, and 1.00 cm per year, the total area of north Jakarta that will be affected by inundation in the year 2050 would be about 40, 45, and 90 sq km, respectively. This is expected to increase further if land subsidence continues.

- A similar study conducted by Dasanto and Istanto (2007) also indicated that when the mean sea level increases by about 0.5 meters and land subsidence continues, parts of six sub-districts of North Jakarta and Bekasi will be permanently inundated. With a sea level rise of about 1 meter, it was estimated that about 405,000 ha of coastal land including small islands will be inundated. The impact may be severe in certain coastal areas such as the north coast of Java, the east coast of Sumatra, and the south coast of Sulawesi (Subandono 2002).

- The disappearance of small islands due to changing sea levels will also have serious implications for the Indonesian state border. At least eight of 92 outermost small islands that serve as a baseline for the Indonesian sea territory (Kepala, Dolangan, Manterawu, Fani, Fanildo, Brass, Laag and Nipah islands) are very vulnerable to a rise in mean sea level (Hendiarti 2007).

- A projected 30-cm rise in sea level in the Philippines by 2045, under B2-mid and A1-mid scenarios, is seen to affect 2,000 ha and about 500,000 people (Hulme and Sheard 1999). An A2-high scenario, which shows a 100-cm rise in sea level by 2080, will inundate over 5,000 ha of the Manila Bay coastal area and will affect over 2.5 million people. These risks will be further intensified if sea surges associated with intense storm activity increase. A1-mid and A2-high scenarios for 2080 indicate an increase in typhoon intensities in the western Pacific by 5% and 10%, respectively. More intense typhoon activity will also pose threats to inland areas where frequent mudslides are triggered by torrential rains associated with typhoons.

Increasing temperatures, rising sea level, and extreme weather will continue to threaten coastal and marine resources in Southeast Asia, including industries and activities that rely on these resources.

Sea level rise in combination with land subsidence due to overexploitation of groundwater will definitely move the coastline inland in many key cities in Indonesia and the Philippines, with an associated higher risk of floods.

- It is likely that the waters of the Sulu Sea in the Philippines will continue to warm in the future. For the region around the Tubbataha Reef, mean annual sea surface temperatures for B1-low and A2-high scenarios will increase 1.5° and 3.5°C in 2100, respectively (Hulme and Sheard 1999). Coral reef ecosystems will be threatened by increasing levels of atmospheric CO_2, which is projected to increase by 2 ppm (B1-low) and 4 ppm by volume per year (A2-high).

- For Singapore, a projected sea level rise of up to 59 cm (under the worst case scenario) may result in some coastal erosion and consequent land loss. This rise in sea level would also lead to loss of mangroves, which will not only represent a loss of biodiversity, but will also further aggravate coastal erosion rates.

- An increase in coastal erosion in Thailand is expected, leading to further deterioration of natural resources, with consequent loss for the tourism industry. Settlements along rivers and coastal areas will be at risk from the threat of sea level rise and coastal storm surges.

- Tran et al. (2005) predicts that a one-meter rise in sea level could lead to flooding of 5,000 sq km of Red River Delta and 15,000–20,000 sq km of Mekong Delta. About 6,276 sq km of rural residential areas will experience annual flooding and about 4,000 sq km of fruit trees and mangrove plantations will be affected.

Human Health

Southeast Asia is home to about 563 million people. Population growth is high by global standards, averaging 2.2% annually over the last decade. As of 2005, about 93 million (18.8%) people still lived below the $1.25-a-day poverty line, and 221 million (44%) below the $2-a-day poverty line.

Many of the region's poor live in coastal areas and in the low-lying deltas. Most often, these are smallholder farmers, fishermen, and poor households most vulnerable to risk of climate change, as their marginal income provides little or no access at all to health services or other safety nets to protect against the threats posed by changing conditions.

Some of the possible direct threats that climate change could pose on human health in Southeast Asia include morbidity and mortality due to thermal stress (that is, caused by heat stress or cold stress); vector-borne infectious diseases (for example, malaria and dengue); diarrhea; and malnutrition. Indirectly, climate change could cause injury, and in the worst case, deaths, as a result of landslides, flashfloods, and tropical cyclones (strong winds). Respiratory diseases brought about by worsening air pollution (for example, from forest fires) and ill health due to social dislocation and migration could be attributed indirectly to climate change (Table 3.15).

Outbreaks of vector-borne infectious diseases linked to climate change have been increasing in recent years in Southeast Asia.

Many studies suggest that outbreaks of human diseases such as malaria, dengue, diarrhea, cholera, and other vector-borne diseases coincide with the

Table 3.15. Observed Impacts of Climate Change on Health Sector in Southeast Asia

Climate Change	Indonesia	Philippines	Singapore	Thailand	Viet Nam
Increasing temperature and variability in precipitation	Significant increase in dengue cases in La Niña years; illness and deaths due to heat stress	Increased dengue outbreak; illness and deaths due to heat stress	increasing cases of dengue; spreading to areas not previously found	Impacts of dengue fever significant and increasing	Increased number of dengue cases
Sea level rise	Spread of water-borne infectious diseases	Spread of water-borne infectious diseases		Spread of water-borne infectious diseases	Spread of water-borne infectious diseases

Sources: Boer and Dewi (2008), Cuong (2008), Ho (2008), Jesdapipat (2008) Perez (2008).

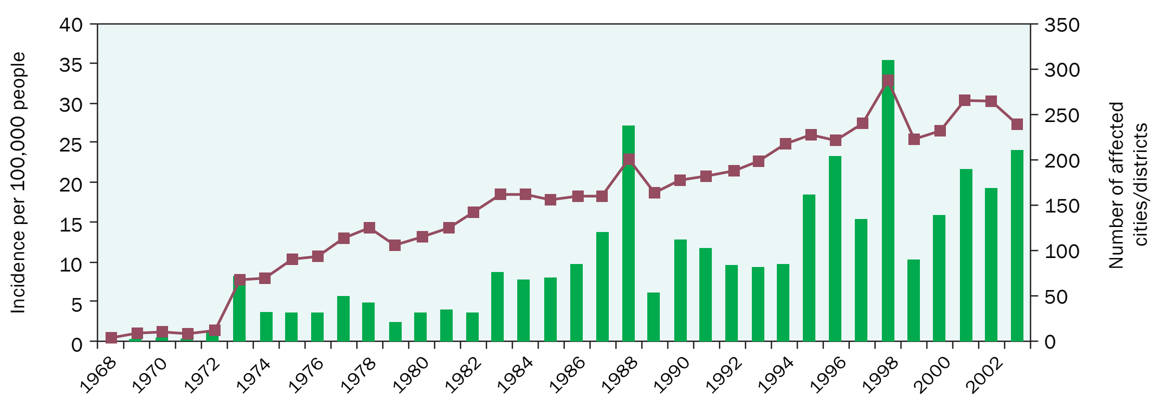
occurrence of extreme climate events such as droughts and flooding. This is true for Southeast Asia where increased dengue outbreaks and malaria cases are reported to be strongly correlated with the ENSO years.

- Dengue cases in Indonesia increased significantly in La Niña years, as shown in Figure 3.11, when seasonal rainfall increased above normal. The number of cities and districts affected also increased considerably over the past 3 decades.

- In the Philippines, a study by Flavier et al. (1998) on the characteristics of notifiable diseases such as malaria, dengue, diarrhea, and cholera showed a 10–58% association between health and climate variables. The study also revealed that non-infectious diseases are also affected by climate change, variability, and extremes such as shellfish poisoning, cardiovascular diseases, and respiratory problems. Amadore (2005a) reported that extreme heat, water shortages, and flooding brought about by ENSO events have triggered a number of health-related problems in the Philippines. The 1997 El Niño, which was followed by a La Niña year (1998), caused several outbreaks of cholera, dengue, malaria, and typhoid fever in various parts of the country. Dengue cases have significantly increased since the early 1990s when the number of recorded dengue cases then averaged only about 5,000 per year. In 1998 and 2003, the number of dengue cases rose by six- to seven-fold to 35,500 and 30,000, respectively.

- Dengue outbreaks happen in cycles in Singapore, peaking every 6–7 years. During the last peak in 2005, 14,209 people were infected and 25 died. That year's total was almost three times the previous peak of 5,258 in 1998. The dengue numbers have been observed to rise even during the low-point years. The last low point, in 2006, saw more than 3,000 fall sick. This was more than three times the number infected in previous low years. In 2007, more than 8,800 people were taken ill, which is considered the third highest number ever, and 20 people died. In 2008, the number of infections from January to April

Figure 3.11. Incidence of Dengue (histogram) and Affected Cities and Districts (line) in Indonesia



Note: 1973, 1988, and 1998 are La Niña years.
Source: Depkes RI in www.tempointeratktif.com

increased by 60%, higher than in the same period in 2007. Dengue seems to be spreading to areas of Singapore where it previously was not found (The Straits Times 2008). From 2004 to 2007, for example, it became predominant in Bukit Batok, an area where it had not previously been a significant problem.

- Thailand has also reported an increasing trend in dengue cases since 2000. The impact of dengue fever has become a greater concern in Thailand since the reduced forest areas and the rapid urbanization of the country have together created a suitable environment for dengue outbreaks that have become more frequent and damaging.

- Dengue fever has become an annual epidemic in the plains and central coast of Viet Nam. The outbreaks are closely associated with the El Niño index. On average, and based on 25 years of statistics (1976–1999), morbidity and mortality due to dengue fever in Viet Nam was 124.5 persons per 100,000 population (Tran Viet Lien 1997, Tran Thanh Xuan 2001).

An increase in morbidity and mortality is predicted to occur in most Southeast Asian countries due to water-borne diseases, primarily associated with floods and droughts.

IPCC (2007) predicted an increase in endemic morbidity and mortality in Southeast Asia due to diarrheal disease, primarily associated with climate change. The occurence of water-borne diseases in the region is likely to increase with global warming due to precipitation changes, contamination of fresh water supplies, and sea level intrusion into freshwater areas. Floods contaminate shallow groundwater and stream waters, which in some areas are the main source of drinking water. During drought periods, sea water advances inland, which leads to contamination of groundwater resources.

McMichael (2004) notes that the risk of mortality and morbidity due to climate change (attributable to diarrhea and malnutrition) in some parts of Southeast Asia is already the largest in the world, and predict that this would remain so in 2030. Flooding and sea level rise could result in poor water quality leading to more water-related infectious diseases such as dermatosis and gastrointestinal diseases. A few of the many gastrointestinal epidemic diseases that could be transmitted by poor sanitation and contaminated water supplies are amoebiasis, cholera, giardia, shigellosis, and typhoid fever.

Pascual et al. (2002) found that phytoplankton blooms are excellent habitats of infectious bacterial diseases such as cholera. These phytoplankton blooms are projected to benefit from warmer sea-surface temperatures along the coastlines of Southeast Asian countries.

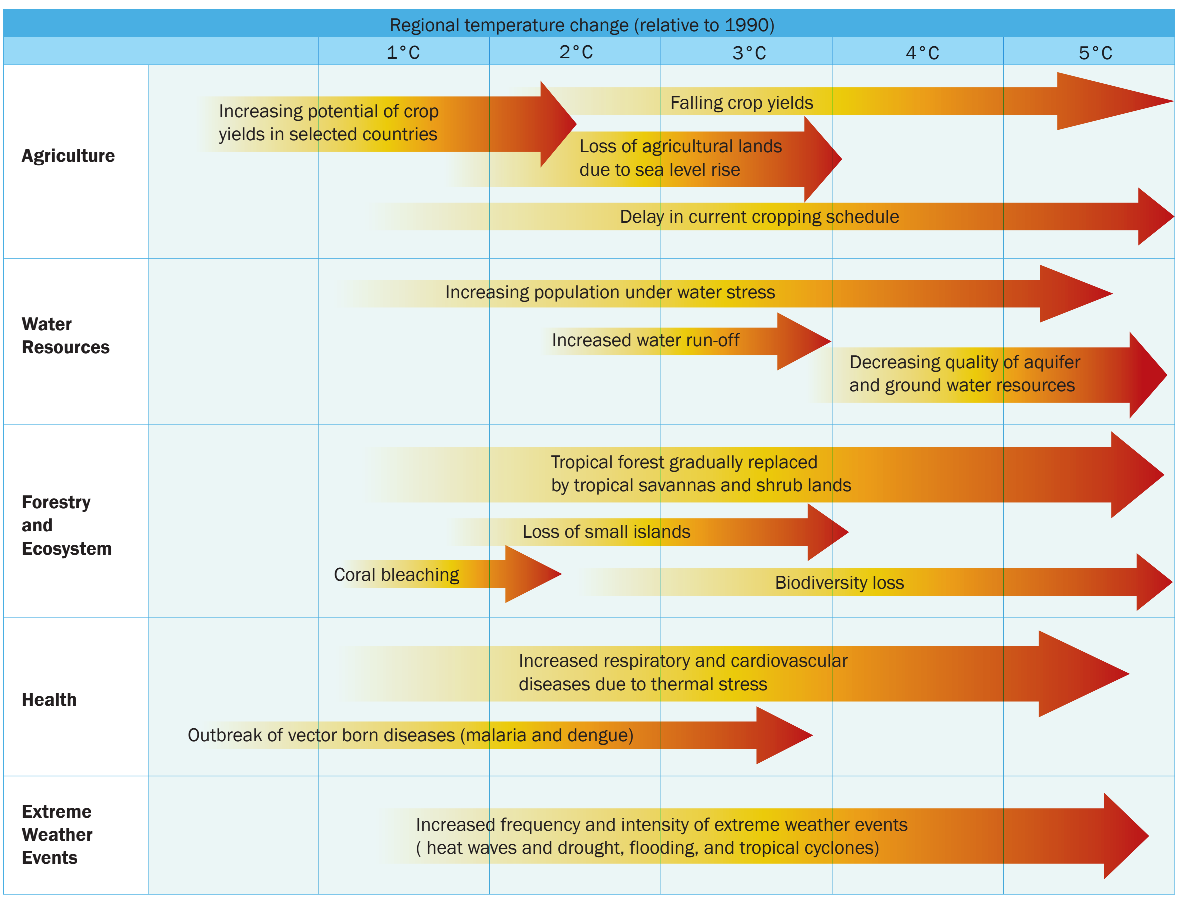
D. Conclusion

Overall, this review of the various impacts of climate change supports the claim that Southeast Asia is highly vulnerable to its consequences.

Climate change is already affecting Southeast Asia and impacting many sectors. It has affected the quantity and quality of water resources. Extreme weather events such as drought, flooding, and tropical cyclones are increasing in frequency and intensity, and have contributed to a decline in the production of grains and industrial crops, fish supply, and forest harvests. The region is struggling against the loss of its arable lands and coastal areas due to a rise in sea levels, more frequent storm surges, heightened coastal erosion, and soil salinization. A significant proportion of the population has been affected by the outbreak of malaria and dengue. All these impacts are predicted to worsen due to increased warming, changes in precipitation patterns, and sea level rise, as illustrated in Figure 3.12.

Southeast Asia, as a tropical region, has endured climate extremes that include the monsoon, tropical cyclones, El Niño and La Niña events, extreme variability in rainfall, and very high temperatures. Further climate change is predicted to make these conditions more acute and challenging with regard

Figure 3.12. Potential Impact of Climate Change on Key Sectors



Source: Adapted from Stern (2007).

to the physical impact on people, their livelihoods, and the environment as a whole. As projected by the IPCC (2007), Southeast Asia is likely to experience increased exposure to extreme events, including fire risk, typhoons and tropical storms, floods, and landslides, as well as water-borne and vector-borne diseases. The heat and water stresses brought about by climate change are likely to disrupt the ecology of mountain and highland systems in the region. Rising sea levels will cause large-scale inundation along the extensive coastlines and will lead to a recession of flat sandy beaches. The ecological stability of mangroves and coral reefs is also under threat.

The region is sensitive to the direct impacts of climate change, in view of the heavy dependence of its economies on natural resources, particularly agriculture, forestry, and coastal and marine resources (including as a tourism destination). At risk is the region's large and fast-growing population; the large proportion of its labor force employed in agriculture; the long coastlines with high concentration of human and economic activity in coastal areas; and the many people still living below the poverty line with poor access to a healthy and safe environment.

It is the poor of Southeast Asia that are most vulnerable to climate change. Its impact will exacerbate poverty—particularly the income and earning capacity of the poor, opportunities for progress, and effects on health. Southeast Asia is challenged as to how to manage these impacts and how to build resilience against the future impacts of climate change in a sustainable way and without falling short of achieving the Millennium Development Goals and beyond.

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Chapter 4

Modeling Climate Change and Its Impact

Key Messages

Climate change modeling carried out under this study using an integrated assessment model confirms many of the findings documented in existing studies and provides new estimates of climate change and its likely impact in coming decades, with a particular focus on Indonesia, Philippines, Thailand, and Viet Nam.

Climate patterns in Southeast Asia are likely to change significantly, with impact on the environment and economies expected to be more severe than the world average. The actual extent of climate change and impact depends on the assumed future emission scenarios, and on the level of global mitigation action.

The region's mean temperature by 2100 is projected to increase 2.5°C under B2—a medium emissions scenario—and 4.8°C under A1FI—a high emissions scenario—from 1990, without global mitigation. With stabilization under A1FI, from 1990, temperature will only increase 2.3°C at 550 parts per million (ppm) and 1.8°C at 450 ppm.

Increasingly drier weather conditions are projected to afflict Indonesia, Thailand, and Viet Nam over the next 2–3 decades although this trend is projected to reverse by mid-century.

Global mean sea level is projected to rise 70 cm by the end of this century relative to the 1990 level under A1FI, and Southeast Asia is to follow this global trend, threatening economic activity and population in coastal areas and islands.

Climate change is likely to worsen water stress in parts of the region, particularly Thailand and Viet Nam, in coming decades; water resources in Indonesia, Thailand and Viet Nam are projected to be most vulnerable.

Under A1FI, rice yield potential in the four countries is projected to decline about 50% by 2100 on average, relative to 1990, without adaptation or technical improvements. Part of the decline could be offset by productivity improvements and adaptation.

Southeast Asia's dominant tropical evergreen, semideciduous and deciduous forests/woodlands—all with great carbon sequestration potential—are projected to be slowly replaced by tropical savanna and tropical xerophytic shrub, with lower or no such potential. Thailand and Viet Nam would be hurt most, with high-quality forest areas projected to decline 60% and 28%, respectively, by 2100, under the A1FI scenario.

Climate change is likely to lead to more deaths from cardiovascular and respiratory diseases, due to thermal stress, and from malaria and dengue. Stabilization could significantly reduce the number of additional deaths. Overall, under the most pessimistic scenario, it is projected that global warming would increase the number of deaths from heat-related cardiovascular and respiratory diseases in the four countries by 2.9% and 12.4% of the total number of deaths by 2050 and 9.2% and 20.4% by 2100.

A. Introduction

Understanding past climate change patterns and monitoring climate change impact are important for identifying vulnerable areas and designing appropriate adaptation measures. If no action is taken, rising populations and economic growth in the coming years and decades will cause more greenhouse gas (GHG) emissions and hence global warming and other environmental damage. Projecting future climate change and its impact is therefore critical to the design of effective climate change policies and adaptation and mitigation actions.

Environmental scientists and economists have made considerable efforts to develop economic and scientific models to predict the patterns of future climate change and its impact. The most common approaches are the integrated assessment models (IAM) to simulate human-induced climate change from emissions of GHGs to the socio-economic impact. Numerous IAMs have been developed in the last two decades, each differing in several dimensions. These range from the objective of the modelers (climate change and impact assessment, policy evaluation, or policy optimization); the nature of policy options evaluated (regulatory or economic, single or multiple); the complexity of the economic and climate sectors; the geographical coverage (global, regional, country-specific, highly aggregated, fairly disaggregated); the treatment of uncertainty (Box 4.1); and the responsiveness of agents to climate change policies within the model.

As part of this study, an IAM was employed to project climate change and its impact in Southeast Asia for the coming decades. The model was developed by the Research Institute of Innovative Technology for the Earth (RITE) based in Japan. The model takes into account emissions of various GHGs including carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), 27 types of halocarbon emissions, as well as oxides of sulfur (SOx). These emissions are translated into atmospheric concentrations of gases, which are then used to calculate the radiative forcing of the different gases and, consequently, estimates of global annual mean temperature change, change in precipitation, and sea level rise, and their impact on water resources, agriculture, forestry, and human health.

Box 4.1. The Uncertainties of Modeling Climate Change

Estimating precisely how climate change would evolve is subject to considerable uncertainty. Some of the well recognized uncertainties are:

Emissions uncertainty
Emissions are a function of projected population growth, technological innovation, and patterns of production and consumption. These determine the level of production and its degree of carbon intensity. Emissions are difficult to accurately project over a period of five years, let alone a century.

Uncertainty over atmospheric concentrations and sinks
The ultimate mapping from emissions to concentrations is subject to great uncertainty. This is because the duration of greenhouse gases in the atmosphere itself depends on the rate at which so-called carbon sinks such as oceans and vegetation extract carbon from the atmosphere, and these sink processes are subject to a number of complex feedback mechanisms.

Uncertainty over solar radiation and the effect of other gases
Other gases such as anthropogenic and natural aerosols (for example, volcanic), or changing intensity of solar radiation also affect the climate. Uncertainty about their effect on temperature contributes further to uncertainty about future warming.

Model uncertainty
There are a number of uncertainties in climate model specification. These include the functional form of key equations, the specification of key parameters, data inputs, the scale and resolution, and the nature and interpretation of the empirical estimation properties. Differences in models inevitably yield differences in results but models are constrained by underlying theoretical physical properties and observed data.

Parameter and functional form uncertainty
Parameter estimation is determined by theoretical science and observed data, but is inevitably estimated with error. The overarching parameter driving all climate models is so-called “climate sensitivity” which relates the physical ‘climate forcing’ (or greenhouse gas effect) from increased concentrations of greenhouse gases to the temperature change. Estimation of this parameter from observed data needs to account for concentrations of other industrial aerosols, a key driver of parameter uncertainty.

Damage uncertainty
At the global level, total climate change damage is often simplified as a direct function of temperature change, and the parameter behind this is subject to uncertainty. This modeling simplification is intended to capture a vast array of impacts and cannot adequately reflect the detailed nature of the climate problem.

Uncertainty about climate change should not be seen as a reason for inaction, or for failing to model likely risks. In fact, policy options that provide protection against low-probability, highly damaging events can yield substantial expected benefits; it is important that modeling exercises appropriately quantify and warn of such risks. To fully appreciate the dangers ahead, economic analysis therefore must look beyond the average expectation and consider the entire probability distribution rather than just the mean. Models and projections that do not take full account of uncertainties and the possibility of extreme events tell only part of the story and mark a subset of the total expected damages. Chapter 5 of this study explicitly models uncertainty and catastrophic risks.

Source: Zenghelis (2009).

To predict human-induced climate change and assess its consequences, this study considers three timelines: the short term (2020), the medium term (2050) and the long term (2100). It also considers two emission scenarios with three cases each: reference (also called business as usual or baseline), stabilization at 550 ppm (S550), and stabilization at 450 ppm (S450). The two emission scenarios are taken from the Special Report on Emissions Scenarios (SRES) of the Intergovernmental Panel on Climate Change (IPCC) (2000). The IPCC report developed six emission scenarios for use in climate change impact assessment based on four specific storylines of social, economic, and technological development (see Box 3.1 in Chapter 3). These storylines are known as A1, A2, B1, and B2. A1 is further divided into three groups describing the directions of technological change in the energy system: A1FI is fossil-intensive, A1T focuses on non-fossil energy sources, and A1B is balanced across all energy sources.

The A1FI and B2 emission scenarios are considered in this chapter. A1FI assumes (i) a future of very rapid economic growth; (ii) global population that peaks in 2050 and declines thereafter; (iii) rapid introduction of new and more efficient technologies; and (iv) primary reliance on fossil fuels. B2 assumes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability, with an intermediate increase in population, economic and technology development, and balanced use of energy sources. In terms of GHG emissions, climate change, and its impact, A1FI represents the most pessimistic scenario, and B2 represents a medium case.

The IPCC SRES emission scenarios do not consider explicit policy options to reduce GHG emissions, such as might be adopted under the United Nations Framework Convention on Climate Change (UNFCCC), despite the fact that differences in socio-economic and technological trends considered by these scenarios lead to considerable differences in GHG emissions among them. For this reason, they are considered the reference cases. S550 and S450 are the two commonly agreed stabilization levels required to prevent global warming from reaching dangerous levels. According to Stern (2007), under S450 there would be about a 5–20% chance of global mean temperature ultimately rising more than 3°C above pre-industrial levels: under S550 that chance increases to 30–70%. Stabilization at levels below 450 ppm would require immediate, substantial, and rapid cuts in emissions—that are likely to be extremely costly. Stabilization at above 550 ppm would imply climatic risks that are extremely large and likely to be generally viewed as unacceptable. For each targeted stabilization level, required stabilization efforts will differ depending on which reference emission scenario is considered.

In the rest of this chapter, section B describes the key assumptions associated with B2 and A1FI emission scenarios at the global level, and reports findings on projected global climate change. Section C reports the key assumptions associated with B2 and A1FI emission scenarios for Southeast Asia and reports findings on projected climate change in the region under alternative scenarios and cases generated from the RITE model for 2020, 2050, and 2100. Section D presents findings on projected climate change impact in the region, focusing on water resources, agriculture, forestry, and human health. Section E concludes.

B. Projected Global Climate Change

As seen in Table 4.1 the B2 and A1FI emission scenarios represent two very different worlds. Under B2, global population is projected to rise to 10.4 billion by 2100, from 5.2 billion in 1990, with the proportion of those aged 60+ rising to about 27%, from below 10%. Per capita real GDP (in 1990 constant prices) would increase to US$21,400, from US$4,400 during the same period. Under A1FI, global population would increase from 1990 to 2050, and decline during the second half of the 21st century, with the proportion of those aged 60+ rising to about 41% by 2100. Per capita real GDP would rise more than 18-fold to US$81,900 by 2100.

Table 4.1. World Population Growth and Economic Growth under B2 and A1FI

	1990	2020	2050	2100
B2 Scenario				
Population (billion)	5.2	7.6	9.4	10.4
Population aged 60 or more (%)	9	14	20	27
GDP (billion $/year)	23,100	51,800	106,700	222,400
World average GDP per capita ($)	4,400	6,800	11,400	21,400
A1FI Scenario				
Population (billion)	5.2	7.4	8.7	7.1
Population aged 60 or more (%)	9	14	26	41
GDP (billion $/year)	23,100	62,500	198,000	578,400
World average GDP per capita ($)	4,400	8,400	22,800	81,900

Note : GDP data are based on the IPCC B2 and A1FI scenarios. World GDP per capita grows by 1.7% annually under B2 and 3.3% in A1FI from 2020 to 2050. from 2050 to 2100, world GDP per capita grows by 1.3% annually in B2 and 2.6% in A1FI.

Sources: IPCC (2000), For B2, percentage of population <60 years of age is based on United Nations (1998); for A1FI, based on IIASA (1996).

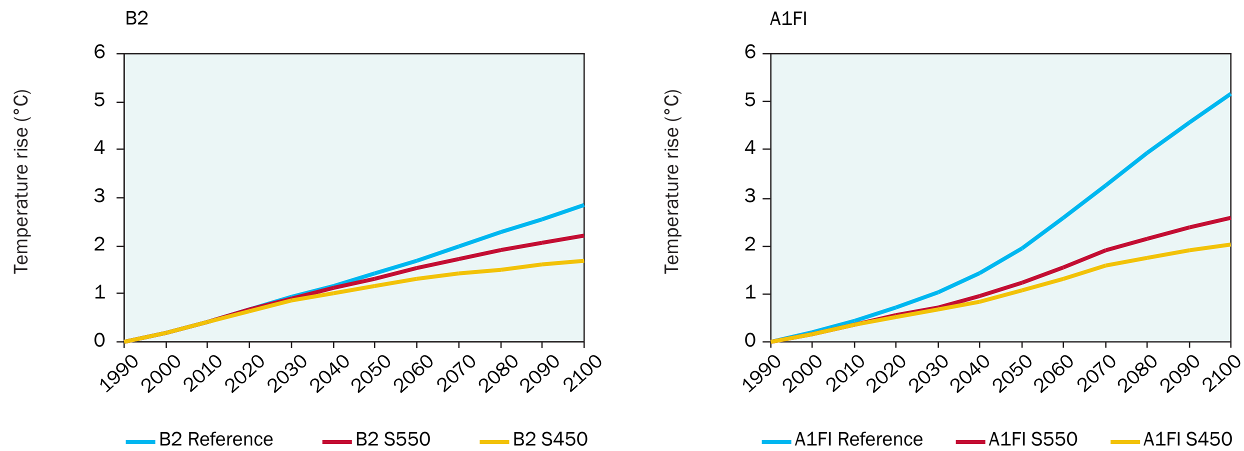
Key results on the projected GHG emissions, CO_2-eq concentration, and global climate change under the four scenarios from the RITE model are more or less in line with IPCC findings:

- From 1990 to 2100, without stabilization, global mean temperature is projected to increase 2.85°C under B2 and 5.16°C under A1FI (Figure 4.1). With S550, under B2, temperature would increase 2.22°C and under A1FI 2.59°C. With S450, the B2 increase would be 1.68°C and A1FI increase 2.04°C. The difference in temperature increase between the two reference emission scenarios with stabilization is due to differences in non-CO_2 emissions (including SOx emissions). The cooling effect of SOx results in lowering of temperature for A1FI with stabilization.

- Global mean precipitation by the end of this century is projected to increase by 0.13 mm/day under B2 and by 0.38 mm/day under A1FI (Figure 4.2). Under S550, the projected increase is 0.10 mm/day for B2 and 0.11 mm/day for A1FI. Under S450, the increase in global mean precipitation would be 0.07 mm/day under B2 and 0.09 mm/day under A1FI.

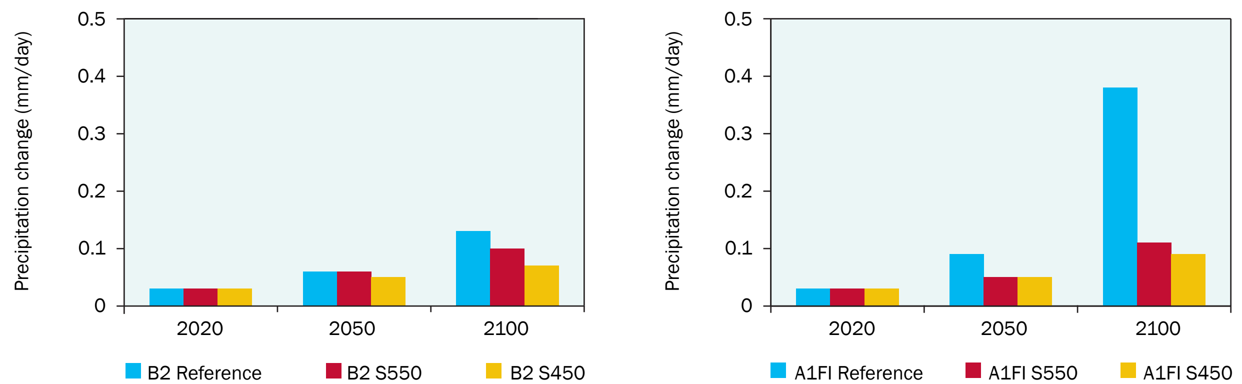
- Without stabilization, by 2100, global mean sea level is projected to have increased by 0.5 meter under B2 and 0.78 meter under A1FI. With S550, it would increase 0.43 meter under B2 and 0.47 meter under A1FI; with S450, the increase is projected to be 0.36 meter under B2 and 0.40 meter under A1F (Figure 4.3).

Figure 4.1. Global Mean Temperature Increase Relative to the 1990 Level



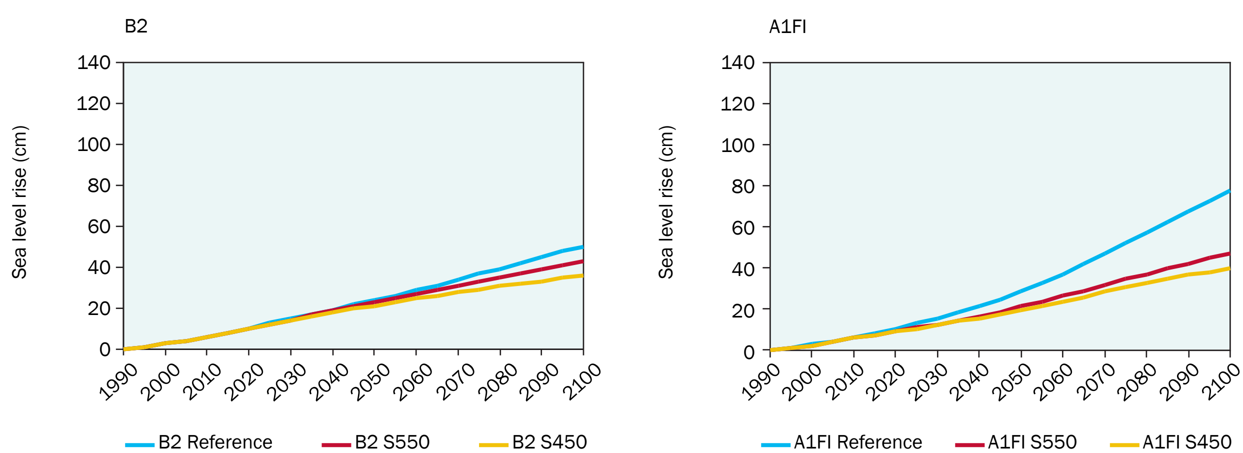
Source: ADB study team.

Figure 4.2. Global Mean Precipitation Change (2100 Relative to 1990)



Source: ADB study team.

Figure 4.3. Global Mean Sea Level Rise Relative to 1990 Levels



Source: ADB study team.

Table 4.2. Population Growth and Economic Growth under B2 and A1FI

Country	Population (million)				GDP (billion $/year)			
	1990	2020	2050	2100	1990	2020	2050	2100
				B2 Scenario				
Indonesia	182	264	318	302	122	730	2,455	5,845
Philippines	61	100	131	124	58	308	1,036	2,466
Thailand	55	68	73	69	98	594	2,000	4,762
Viet Nam	66	104	130	133	12	86	248	553
Total	364	536	652	628	289	1,718	5,740	13,626
				A1FI Scenario				
Indonesia	193	262	297	209	122	1,020	5,636	19,891
Philippines	64	101	121	83	58	491	2,711	9,568
Thailand	58	75	81	64	98	819	4,524	15,966
Viet Nam	65	95	104	59	12	124	551	1,586
Total	380	533	603	415	289	2,454	13,422	47,012

Note: Since there is no country-specific data available beyond 2100 for Southeast Asia, for the B2 scenario, population growth up to 2150 was estimated by multiplying the country population in 2100 by the ratio of regional population in 2150 relative to the level in 2100. For the A1FI scenario beyond 2100, the population was extrapolated based on the assumption that the population growth rate up to 2125 is equivalent to half that in the period from 2075 to 2100, and declines by half again every 25 years after 2125.

Sources: For both scenarios, the country-level population projection was taken from the Center for International Earth Science Information Network database (CIESIN 2002). The regional population up to 2150 was obtained from the population projections developed by the United Nations (1998), which are consistent with the IPCC (2000) B2 scenario.

C. Projected Climate Change in Southeast Asia

For the four countries—Indonesia, Philippines, Thailand, and Viet Nam—under B2, total population is projected to increase from 364 million in 1990 to 652 million (17% aged 60+) by 2050 and then decline to 628 million (24% aged 60+) by 2100 (Tables 4.2 and 4.3). Under A1FI, total population would increase to 603 million (24% aged 60+) by 2050 and then decline to 415 million (41% aged 60+) by 2100. Both scenarios project large increases in urban population, from 37% in 1990 to 89% by 2100 (Table 4.3).

Table 4.3 Population Aged 65 Years and above and Urban Population in the Four Countries

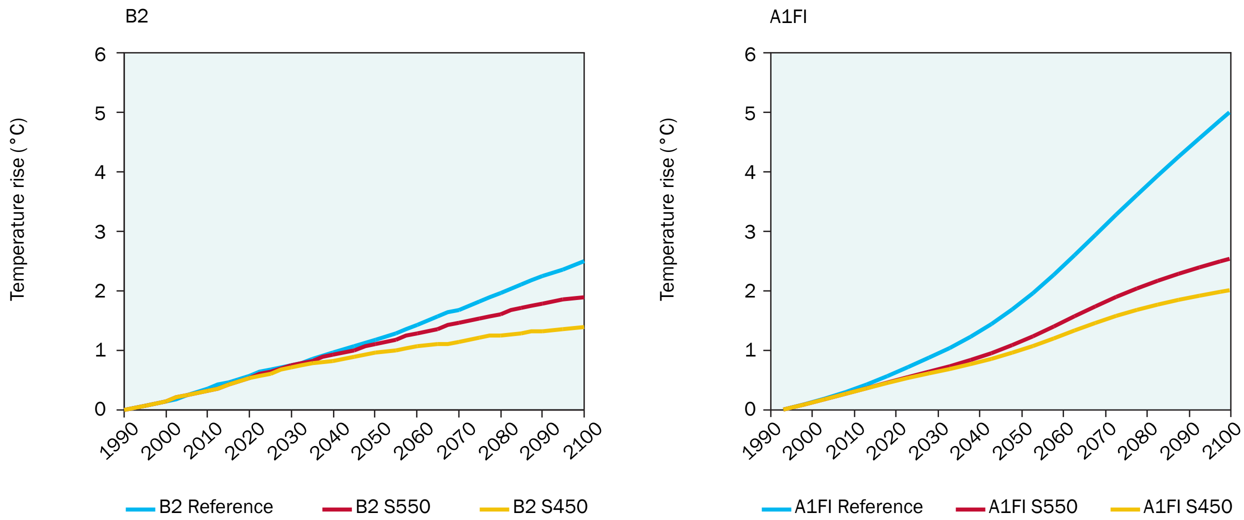
Reference Scenario	1990	2020	2050	2100
		Proportion of population aged 65 years and above (%)		
B2	6	11	17	24
A1FI	6	13	24	41
		Proportion of urban population (%)		
B2/A1FI	37	48	70	89

Sources: The proportion of elderly population in B2 was projected by the United Nations (1998); in A1FI by the International Institute for Applied Systems Analysis (IIASA 1996). The estimated proportion of the urban population up to 2030 was derived from United Nations estimates (UN 2004). In the absence of any estimate beyond 2030, it was assumed that from 2030 to 2050 the rate of increase continues. After 2050, the rate of increase is assumed to halve every 25 years (Tol 2004).

The region's mean temperature toward the end of this century is projected to increase 2.5°C under B2 and 4.8°C under A1FI, over 1990, without global mitigation.

Overall, the projected increases in mean temperature under the B2 and A1FI scenarios are in line with the projected increases in global mean temperature (Figure 4.4). Under the B2 reference scenario, the projected increase would range from 2.41°C to 2.62°C by 2100. Under A1FI, the increase would be more significant, ranging from 4.61°C to 5.0°C by the end of this century. By 2100, average annual temperatures in western Southeast Asia will be hotter than the eastern part of the region.

Figure 4.4. Annual Average Temperature Increase Relative to 1990 in the Four Countries



Source: ADB study team.

With stabilization under the most pessimistic scenario, the projected mean temperature increase in Southeast Asia by 2100 would be substantively lower at only 2.3°C at 550 ppm and only 1.8 °C at 450 ppm, relative to 1990.

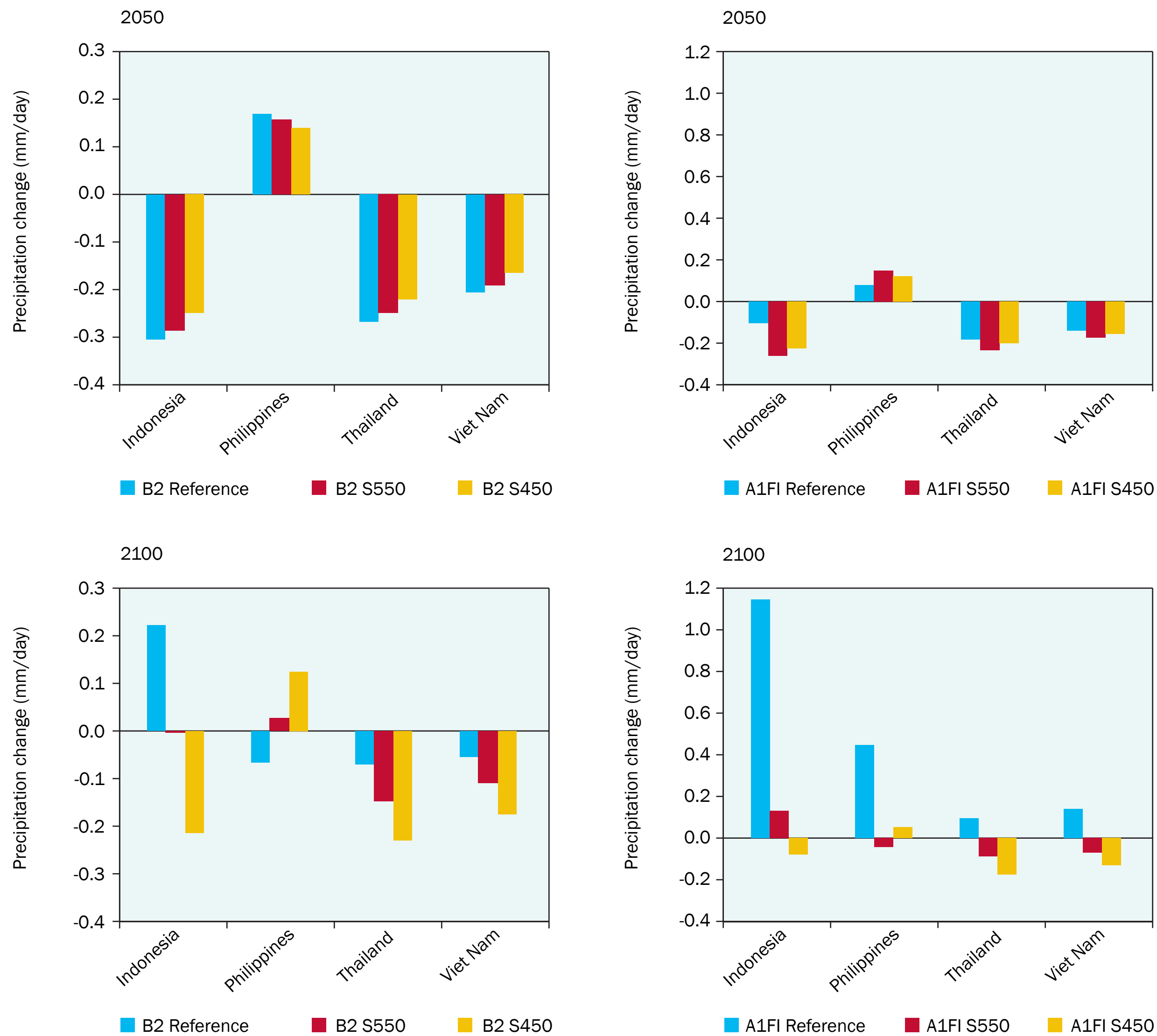
With S550, under B2, the mean temperature increase by 2100 would range from 1.85°C to 2.0°C relative to the 1990 temperature level. Under A1FI, the corresponding increase would range from 2.18°C to 2.36°C. With S450, the projected mean temperature increase by 2100 would be less, ranging from 1.36°C to 1.45°C under B2 and 1.69°C to 1.82°C under A1FI. Among the four countries, Thailand would experience the highest increase in mean temperature and the Philippines the lowest.

Indonesia, Thailand, and Viet Nam will experience increasingly drier weather conditions in the next 2–3 decades, although this trend is projected to reverse by mid-century.

The modeling results show that, by 2050, with the exception of the Philippines, the decrease in precipitation from the 1990 level will range from 0.20 mm/day to 0.34 mm/day under the B2 scenario, and from 0.11 mm/day to 0.26 mm/day under A1FI (Figure 4.5).

By 2100, the trend in precipitation will be reversed, with most countries experiencing an increase in precipitation. Under the B2 scenario, Indonesia would experience an increase in precipitation of 0.22 mm/day from its 1990 level, while all the other countries would see a decrease in precipitation from the 1990 level ranging from 0.05 mm/day to 0.16 mm/day. Under the A1FI scenario, on the other hand, most countries would experience an increase in precipitation, ranging from 0.09 mm/day to 1.14 mm/day. In general, by the end of this century, it is projected that precipitation will likely be higher than the 1990 precipitation level.

Figure 4.5. Annual Average Precipitation Change Relative to 1990 in the Four Countries



Note: The scale used for B2 is smaller than A1FI to emphasize the difference in precipitation changes.
Source: ADB study team.

Precipitation patterns appear little different under the two scenarios and stabilization cases before 2050, but become significantly different after, underscoring the difficulty of predicting precipitation.

The change in precipitation under the scenarios (B2 or A1FI) appears similar to the stabilization cases (S550 or S450) before 2050 (Figure 4.5). Beyond 2050, however, the change in precipitation with stabilization would be very different than without it. For example, Indonesia would experience an increase in precipitation of 0.22 mm/day without stabilization by 2100 under B2; with S550, on the other hand, the country would experience no change in precipitation from its 1990 level. This makes clear that predicting precipitation is more difficult and challenging than predicting temperature.

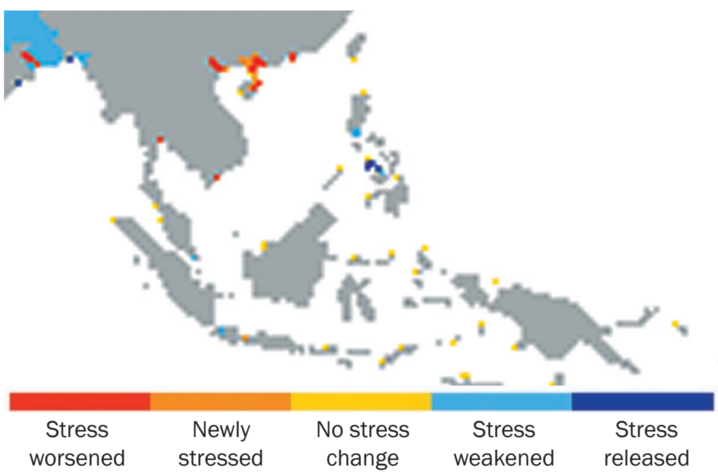
D. Projected Climate Change Impact in Southeast Asia

Water Resources

Global warming is likely to worsen water stress in some parts of the region, particularly in Thailand and Viet Nam, in the coming decades.[1]

Under the B2 scenario, most river basin areas in Indonesia are projected to experience no change in water stress by 2050 as indicated by the yellow color in Figure 4.6. In the Philippines, the projection is that some river basins will experience no water stress; some river basins will have the stress weakened; while other basins will have the water stress released. However, river basin areas in Thailand and Viet Nam are projected to experience an increase in water stress due to global warming, as indicated by the red color.

Figure 4.6. Water Stress in River Basin Areas due to Global Warming under B2 (2050)



Source: ADB study team.

Water resources in Indonesia, Thailand, and Viet Nam are projected to be most vulnerable to climate change, threatening the lives and livelihoods of millions.

The modeling results suggest that 12.2 million people in Viet Nam, 8.6 million in Indonesia, and 3.6 million in Thailand would experience either

[1] The impact of global warming on water resources-related stress are evaluated in terms of available per capita annual water resource for a given river basin as defined by Arnell (2004). The runoff, which corresponds to the amount obtained by subtracting the amount of evapotranspiration from precipitation, is used as the basis of the water resource. A river basin in which the annual runoff per capita is less than 1000 cu m is considered 'water-stressed". The Total Runoff Integrating Pathways (TRIP), developed by Oki (2001), was used for the data on river basins. A "water stressed population" is defined as "a population living in a water-stressed river basin area". The types of water stress (for example, stress worsened, new stressed, stress weakened, and stress released) are explained by the relationship between changes in population and changes in runoff. To estimate the number of people that will be affected by water stress, the population distribution was estimated for the four countries by multiplying the population increase rate (based on CIESIN 2002) by 0.5° x 0.5° population distribution developed by Kanae (2002).

worsening water stress or new water stress by 2050. In contrast, under both B2 and A1FI, significant numbers of Indonesians and Filipinos would benefit from weaker water stress in 2020 and beyond. This could be explained by the fact that the countries' population growth (or population distribution) will be matched by increases in water runoff (the amount obtained from subtracting the amount of evapotranspiration from precipitation). It should be noted that water stress in this study was evaluated with respect to annual water resources. Even in the event that there is an increase in the frequency of heavy rain to annually increase available water resources, there remains a possibility that such rain may not be captured or used effectively, or that flooding and other problems might occur instead of the capture of the water to recharge aquifers and other groundwater resources.

Agriculture

The impact of climate change on agriculture is likely to vary across crops and over time, and also depend on countries and emission paths. Given the importance of rice in Southeast Asia, this chapter focuses only on rice production.

Under the most pessimistic scenario, rice yield potential is likely to decline about 50% by 2100, from 1990, in the four countries, without adaptation or technical improvements.[2]

The four countries would continue to see rice yield potential decrease in the coming years under both scenarios. Under B2, rice yield potential would decline about 20% on average by 2100, from 1990, ranging from 4% to 40% (Figure 4.7). Under A1FI, however, by 2100 the rice yield potential decline wound range from 34% in Indonesia to 75% in the Philippines (about 50% on average). This is much lower than the expected average world decline. With stabilization, whether at 550 ppm or 450 ppm, the decline in rice yield potential would be significantly smaller, or avoided.

Declining rice yield potential could be partly offset by productivity improvements and adaptation.

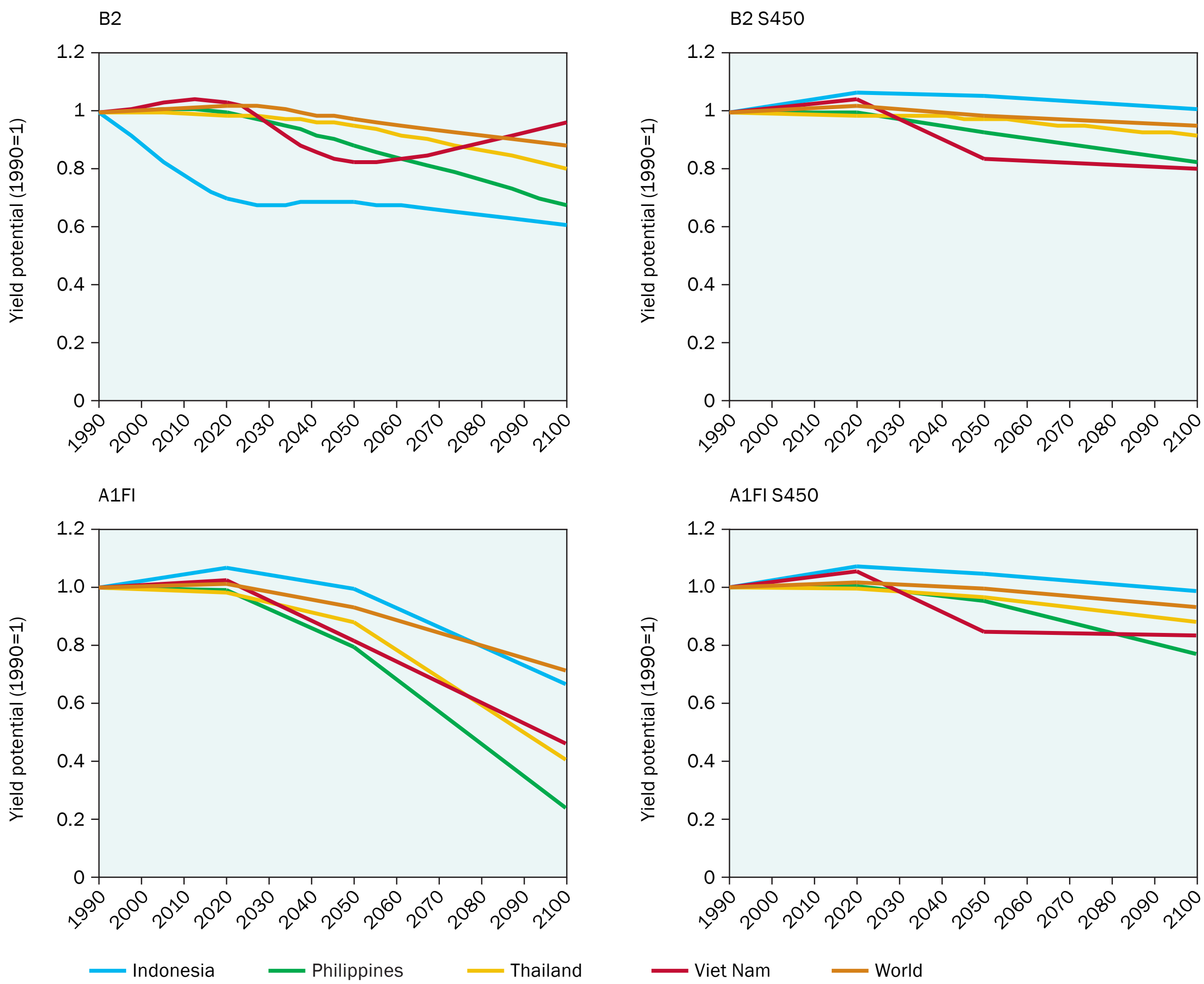
Through productivity improvements[3] and adaptation measures[4] the projected declines in rice yield potential could be partly avoided. In Indonesia, for example, under the A1FI scenario, improved productivity would increase rice yield potential by 115% per year and adaptation would result in an additional 29% increase by 2050. The corresponding figures are 160% and 126% for Viet Nam; 110% and 21% for the Philippines; and 56% and 20%

[2] The Agro-ecological Zones model was used in the agriculture sector to evaluate the impact of adaptation measures (such as variation of crop type) and adjustment of planting month on the crop yield potential. Variation of crop type considered biomass and yield parameters which included growth cycle, harvest index, and leaf area index. The model estimated yield potential based on meteorological data including temperature, precipitation, wind speed, sunshine hours, and geographical data, such as gradient (slope) and soil type. The model does not take into account the effect of CO_2 fertilization in predicting the crop yield potential.

[3] In this study, the model assumes three categories of productivity improvement measures: high, intermediate, and low inputs, for which the parameters of productivity include harvest index and leaf area index. These two parameters can be changed through technology improvements or inputs.

[4] Adaptation measures, in this study, refer to optimization of crop variety and planting month, which maximize the yield under the given climate scenario.

Figure 4.7. Rice Yield Potential in the Four Countries and World



Source: ADB study team.

for Thailand. A similar pattern is observed in the B2 scenario, although the magnitudes differ.

But even with productivity improvements and adaptation, the declines in rice yield potential would remain significant without stabilization.

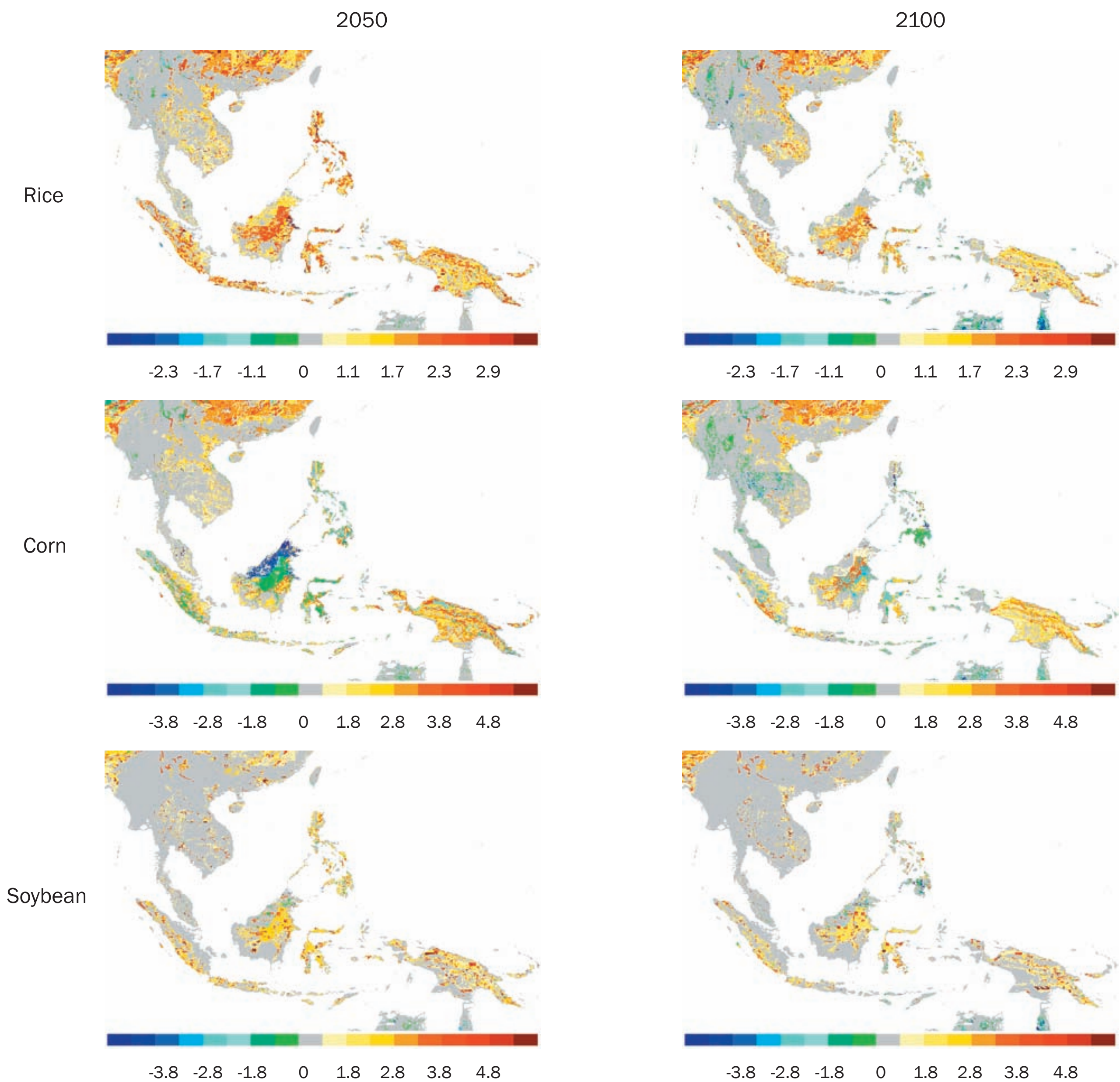
By 2050, under A1FI, with productivity improvement and adaptation measures, rice yield potential in a large part of Southeast Asia is projected to increase from 1990 levels by as much as 2.9 tons/ha/year (red shade), with productivity improvement and adaptation (but without stabilization) (Figure 4.8). This includes certain parts of the rice-growing areas in Indonesia (central Kalimantan), Philippines (Luzon), Thailand, and Viet Nam. But by the end of this century, under the same scenarios, there would be a trend toward decreasing rice production potential with areas such as Mindanao in the Philippines and the northern part of Kalimantan likely to be most affected. This is shown in Figure 4.9 by the change in color from yellow/red in 2050 to gray/green in 2100. Most rice growing areas in Thailand will experience decreased yields (from yellow to gray). The major growing areas of the Mekong

Delta in Viet Nam will be similarly affected.

Overall, the assessment suggests that climate change will significantly undermine crop production in Southeast Asia, posing a serious threat to future food security.

The study also assessed the impact of climate change on corn and soybean yield potential, the results more or less the same as for rice (Figure 4.8). To maintain or increase the level of production and to cope with the impact of climate change, technological improvements and adaptation

Figure 4.8. Change in yeild Potential in Southeast Asia Relative to 1990 Level (A1FI, with productivity improvement and adaptation measures, in tons per hectare per year)



Source: ADB study team.

Figure 4.9. Territorial Biome Distribution in Southeast Asia (1990—2100)

Note: Definition of biome type is described in Table 4.4.
Source: ADB study team.

measures will be required. Technological improvement will mean strong support for research and development, technology transfer, and capacity building. However, there is a limit to what adaptation measures can achieve, as shown in the figures, and stabilization of CO_2 concentrations will be needed to ensure future adequate food supply.

Forestry (Ecosystems)

Climate change will also impact forest ecosystems in Southeast Asia. This study focuses on the impact of climate change on (i) the biome distribution and (ii) territorial biodiversity loss (Table 4.4).[5]

Southeast Asia's dominant tropical evergreen, semideciduous, and tropical deciduous forest/woodland—all with greater carbon sequestration potential—will be slowly replaced by tropical savanna and tropical xerophytic shrub land (with lower or no carbon sequestration potential) because of climate change.

In 1990, 93% of Southeast Asia's total forest area was covered by high-quality forests (that is, with high carbon sequestration potential). But due to climate change, this is projected to fall to 92% by 2050 and 88% by 2100 under the B2 scenario; and to 90% by 2050 and 75% by 2100 under the A1FI scenario (Figure 4.9). It should be noted that these figures do not take into account the impact of direct human-induced land use changes such as deforestation. Considering such impact would mean even greater change in the biome distribution. Across the four countries, forests in Thailand and Viet Nam are projected to be most severely affected. Under the A1FI scenario, the high-quality forest area is projected to decline by 60% by 2100 in Thailand, from 1990, and by 28% in Viet Nam.

Table 4.4. Definition of Biome Type

No.	Biome Type	No.	Biome Type
1	Tropical evergreen forest	2	Tropical semideciduous forest
3	Tropical deciduous forest/woodland	4	Temperate deciduous forest
5	Temperate conifer forest	6	Warm mixed forest
7	Cool mixed forest	8	Cool conifer forest
9	Cool mixed forest	10	Evergreen taiga/montane forest
11	Deciduous taiga/montane forest	12	Tropical savanna
13	Tropical xerophytic shrubland	14	Temperate xerophytic shrubland
15	Temperate sclerophyll woodland	16	Temperate broadleaved savanna
17	Open conifer woodland	18	Boreal parkland
19	Tropical grassland	20	Temperate grassland
21	Desert	22	Steppe tundra
23	Shrub tundra	24	Dwarf shrub tundra
25	Prostate shrub tundra	26	Cushion-forbs, lichen and moss
27	Barren	28	Land ice

[5] The BIOME4 model (Kaplan et al. 2003) was used to estimate territorial biodiversity loss due to global warming. The model estimates the potential biome distribution mainly based on climatic condition. To identify the biome distribution, the model ranked the plant functional types (PFTs) according to a set of rules based on the computed biogeochemical variables which include net primary productivity (NPP), leaf area index (LAI), and mean annual soil moisture. The resulting ranked combinations of PFTs resulted in the categorization of distribution for the 28 biomes listed in Table 4.4.

Stabilization will slow the replacement of high-quality forests with low-quality forests.

With CO_2 concentration stabilized at 550 ppm, under the most pessimistic scenario, the high-quality forests would fall to 89% in 2100, from 93% in 1990: at 450 ppm, the high-quality forest area in Southeast Asia would only fall to 91% by 2100. These figures suggest stabilization will be essential to maintaining a high-quality forest and ecosystem in Southeast Asia.

Loss of high-quality forests is likely to lead to significant biodiversity loss.

With severe changes in biome distribution, Thailand and Viet Nam are expected to suffer more than others from biodiversity loss due to the impact of future climate change. Thailand is projected to experience a biodiversity loss of about 5% relative to 1990. It should also be recognized that the impact on biodiversity due to direct human-induced land use changes could be larger than the climate change impact.

Health

Possible impacts on human health due to global warming could include increased thermal stress, and an increase in the numbers affected by vector-borne infectious diseases, diarrhea, and malnutrition. In assessing the impact of climate change on human health, this study focused on cardiovascular diseases and respiratory diseases caused by thermal stress and vector-borne diseases (malaria and dengue).[6]

Deaths from cardiovascular and respiratory diseases are likely to rise under climate change.

In 1990, the number of deaths in the study from cardiovascular and respiratory diseases due to thermal stress was estimated at about 0.24% (range 0.23–0.25%) of the four countries' total population of 383 million. The total number of deaths from the two diseases is projected to reach 0.76% of total population by 2050 and 1.11% by 2100 under the A1FI emission scenario, without considering global warming.[7] Global warming, on one

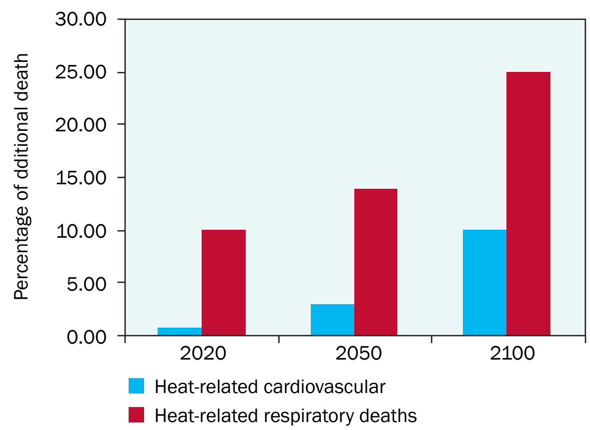
[6] The model used to evaluate impact is based on a thermal stress impact evaluation model and a vector-borne infectious diseases evaluation model developed by Tol (2002a,b). The model takes into account the positive impact of rising income on human health (because of better access to health services and facilities) and negative impact of population growth and aging (which tend to increase the number of deaths). The results reported refer to additional numbers of additional deaths due to global warming. In the models, "number of additional deaths due to global warming" is basically formulated by a product of global mean temperature rise relative to 1990 and the regional parameters which had been developed by Tol based on literatures (Martens et al. 1998; Martens et al.1997; Martin et al.1995; Morita et al. 1994). The "number of additional deaths due to global warming" means an increase in the estimated number of deaths due to global warming relative to the estimated number of deaths when only the change in social and economic parameters such as population or income is considered (termed "the baseline number of deaths").

[7] "Without considering global warming" means that only the change in social and economic parameters such as population or income is considered (that is, human health has a strong correlation with factors other than global warming such as social infrastructure, age, and social customs). Deaths not considering global warming, in this report, is also termed "baseline deaths".

hand, will increase the number of deaths due to heat-related cardiovascular diseases and respiratory diseases; on the other, it will reduce the number of deaths due to cold-related ailments.

Overall, under the most pessimistic scenario, it is projected that global warming would increase the number of deaths from heat-related cardiovascular and respiratory diseases in the four countries by 2.9% and 12.4% by 2050 and 9.2% and 20.4% by 2100. With CO_2 stabilization, the number of additional deaths is reduced (Figure 4.10).

Figure 4.10. Addtional Deaths from Cardiovascular and Respiratory Diseases Due to Global Warming in the Four Countries



Source: ADB study team.

Deaths from malaria and dengue are also likely to rise due to climate change.

In 1990, an estimated 24,632 people in the four countries died from malaria and dengue. The total number of deaths is projected to decline to 9,223 by 2020, due to better access to health services and facilities, and under the assumption that these countries follow the B2 emission scenario (but without considering global warming). With global warming, additional deaths of 18% in 2020 is projected under B2.

E. Conclusion

In the coming decades, Southeast Asia's climate patterns are likely to change significantly, with impact on the environment, economies, and other human activities more severe than the world average. This is partly because the region's population, GDP, and per capita incomes are growing more rapidly than the world average.

The modeling work carried out under this study has shown that the region's average temperature could increase 4.8°C by 2100, from 1990 levels, under the most pessimistic emission scenario, with average annual temperatures hotter in western than eastern regions. Most of the four countries—Indonesia, Philippines, Thailand, and Viet Nam—could experience a decrease in precipitation toward the middle of this century with the pattern reversing beyond 2050. Due to the lack of baseline data, no projection was made as to possible rises in sea levels in Southeast Asia. But global projections suggest a possible increase of 0.5 meters in the mean sea level under the low emission scenario (B2), or a much higher increase of 0.8 meters under the high emission scenario (A1FI). These changes in climate will hurt many sectors in Southeast Asia.

Climate change would have an impact on water resources. Millions could experience worsening water stress, with the tendency increasing as the century progresses, while new areas could come under water stress. For some, such as Indonesia and Philippines, the net effect would be a decrease in the water-stressed population, while for Thailand and Viet Nam, the net effect would be an increase in the water-stressed population, particularly beyond 2050.

The agriculture sector would suffer severely under climate change. In the four countries, the yield potential for rice will decline by about 50% on average, relative to 1990, toward the end of this century. Corn and soybean production would also decline. Water stress or shortage and the decline in agricultural production would pose a serious threat to the region's long-term food security and to lives and livelihoods, especially of the poor.

Climate change would have a significant impact on forestry. The modeling results show that the region would experience a decrease in the area of tropical evergreen forest associated with high-temperature, high-rainfall climate and an increase in the area of tropical savanna and tropical xerophytic shrub land associated with drier climates. Indonesia and Philippines, having the highest proportion of high-temperature, high-rainfall climate conditions, would experience limited change in biome distribution (tropical evergreen forest) while Thailand and Viet Nam will experience large changes in biome distribution. The impact on forests would have considerable implications for the conservation of biodiversity and water resources.

Climate change would have significant impact on human health. Modeling results show that the number of deaths from thermal stress causing cardiovascular and respiratory diseases would increase in the region. The increase in heat-related deaths would be greater than the decrease in cold-related deaths. Those most affected are likely to be the elderly (above 65 years of age). Modeling results also show that the number of deaths due to vector-borne infectious diseases (malaria and dengue) in Southeast Asia is likely to increase.

But technological improvements and adaptation measures could play a significant role in mitigating the effects (for example, through adjustment in planting dates) of climate change, suggesting a crucial role for research and development. But there is a limit to what can be achieved by adaptation. Such measures should be complemented with efforts to reduce GHG emissions.

The modeling results show that the harmful effects of climate change would be far greater under the business-as-usual or "no action" cases than under the stabilization cases, with active mitigation efforts to stabilize CO_2 concentrations in the atmosphere at a safer level. Model predictions show that stabilization at S550 or S450 would result in much smaller increases in temperature and sea levels. Stabilization could help to avoid agricultural yield losses, maintain forest ecosystems, lessen the problem of water shortages, and reduce heat-related deaths.

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Chapter 5

Modeling the Economy-wide Impact of Climate Change

Key Messages

Economic modeling carried out under this study using the same model as in The Stern Review (2007), PAGE2002, confirms that Southeast Asia is more vulnerable to climate change than the world as a whole.

Without further mitigation or adaptation, the four countries—Indonesia, Philippines, Thailand, and Viet Nam—are projected to suffer a mean loss of 2.2% of gross domestic product (GDP) by 2100 on an annual basis, if market impact only (mainly related to agriculture and coastal zones) are considered, well above the world's 0.6%.

The mean impact could be dramatically worse, equivalent to 5.7% of GDP each year by 2100, if non-market impact (mainly related to health and ecosystems) is included; and 6.7% if catastrophic risks are also considered. These are far higher than the world's 2.2% and 2.6%, respectively.

Adaptation can help: at a cost of just 0.2% of GDP for investment in such things as sea walls and drought- and heat-resistant crops, the four countries could avoid damage amounting to 1.9% of GDP by 2100, on an annual basis.

But adaptation alone is not sufficient: concerted global action to mitigate GHG emissions is needed. Global stabilization of GHG concentrations at 450–550 parts per million (ppm) would significantly reduce the potential losses to the four countries.

A. Introduction

This chapter complements Chapter 4, which projected the physical impact of climate change at a sector level in the four countries (Indonesia, Philippines, Thailand, and Viet Nam). As stated, such projections are useful for understanding and anticipating the potential damage of global warming in the region and essential for designing future sector-specific adaptation measures. This chapter examines the economy-wide impact of climate change in monetary terms, expressed in losses as a portion of gross domestic product (GDP). Estimates of potential losses from climate change in monetary terms allows aggregation of sector-specific impacts into a single measure. For this purpose, and to be consistent with the Stern Review (Stern 2007), this study used the PAGE2002 integrated assessment model.

B. Model and Scenario Assumptions

The Stern Review used the PAGE2002 model, as described in Hope (2006), to evaluate the long-term global impact of climate change. The model is stochastic and designed to encompass the uncertainties of the best available knowledge of climate science and economics. The coefficients and data ranges used are based on the Third Assessment Reports of the Intergovernmental Panel on Climate Change (IPCC 2001a and IPCC 2001b). Two types of impact are considered: (i) market impact (on the agriculture sector and coastal zones) and (ii) non-market impact (on health and ecosystems). The possibility of future large-scale discontinuity is also incorporated to reflect the increased risk of climate catastrophes, such as the melting of the West Antarctic ice sheet. Greenhouse gas (GHG) emissions include CO_2 (energy-related and due to land use change and forestry), CH_4, and SF_6, while cooling from sulphate aerosols is also taken into account. Box 5.1 describes the PAGE2002 model in detail.

The model is applied using a global development path under the A2 scenario as developed by IPCC (2000). The A2 storyline and scenario describes a very diverse world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in a continuously increasing population at a rate higher than that in the A1 and B2 scenarios. Economic development is primarily regionally oriented, and per capita economic growth and technological change are more fragmented and slower than in the other scenarios (IPCC 2000). Emissions under A2 are relatively high—lower than A1FI which is the most pessimistic, but higher than B2, which is considered a medium-emission scenario in this study. Table 5.1 presents the key assumptions underlying the A2 scenario.

This study modified the original PAGE2002 model to allow for analysis of the four countries. In addition to the A2 scenario reflecting the business-as-usual (BAU) case, two global CO_2 stabilization scenarios, S450 and S550, are simulated to assess the avoided damage to the four countries resulting from global stabilization efforts. Moreover, an adaptation scenario is simulated for the four countries to estimate the cost and benefits of adaptation. Drawing upon a number of uncertain climate and impact parameters, the model generates probability distributions of results with a range of possible outcomes, based on 30,000 simulations using the Latin Hypercube sampling

Box 5.1. PAGE2002 Model

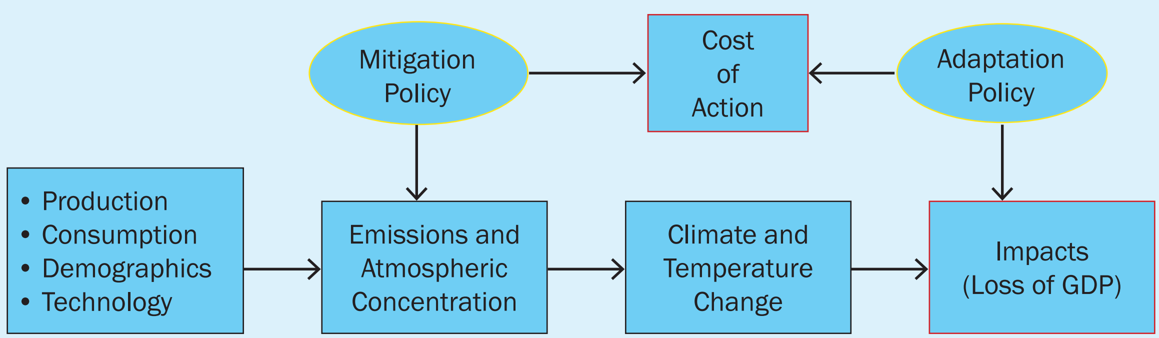
PAGE2002 is a top-down, global integrated assessment model developed at the University of Cambridge for climate policy evaluation and used by the Stern Review (2007) to provide estimates (in terms of gross domestic product loss) of the future economy-wide impact of climate change. The model divides the world into eight regions, but this study modifies and applies it to the four countries by explicitly treating them as separate regions.

It incorporates the most up-to-date knowledge on climate science and economics, in particular, how emissions, climate change, and impacts are interlinked (Box Figure 5.1). Model parameters were drawn from numerous studies documented in IPCC (2001a and 2001b), each having a probability distribution reflecting the uncertainties. The model estimates impacts through a damage function linking GDP loss with temperature rise. The impacts are driven mainly by three factors: (i) region-specific temperature rise, which is determined by radiative forcing from global GHG concentration (including CO_2 from energy-related and land-use change and forestry, CH_4, and SF_6) and regional sulphates; (ii) regional impact parameters which are a function of region-specific geographical characteristics; and (iii) region-specific adaptive capacity which is determined by the level of per capita income.

The possibility of future large-scale discontinuity is modeled through a linearly increasing probability of occurring as the global mean temperature rises above a threshold. By construction, the model is calibrated to the IPCC A2 BAU scenario in terms of anthropogenic GHG emissions, GDP, and population growth. It allows broad mitigation and adaptation policy evaluation.

To evaluate mitigation policy, the model estimates GDP loss due to temperature rise under the BAU scenario, and compares it with the GDP loss under alternative levels of global stabilization, namely, 450 parts per million (ppm) and 550 ppm. To evaluate adaptation policy, the model simulates the cost required for investment in measures that enhance a region's adaptive capacity, including the construction of sea walls and development of drought and heat resistant crops, in order to avoid a certain level (90%) of potential market impact without mitigation, and compare it with the benefit in terms of the avoided market impact. The cost parameters are obtained through bottom-up studies and are in line with UNFCCC (2007) estimates.

Box Figure 5.1. Chain of Impact and Policy Analysis of PAGE2002 Model



Source: Hope (2006), ADB study team.

method. The global results from the modified PAGE2002 are in line with those reported in the Stern Review. It is important to note that there are currently great uncertainties associated with both the scientific and economic aspects of climate change. Therefore, the results in this study should be taken as insights into the direction and the orders of magnitude of the potential climate and policy impact, and not as precise forecasts of the future.

Table 5.1. Key Assumptions Underlying A2 Scenario

	Population (billion)	World GDP (trillion $, 1990)	Annual CO_2 Emissions ($GtCO_2$)	Annex-I to Non-Annex-I per Capita Income Ratio
2020	8.2	41	41.1	9.4
2050	11.3	82	63.8	6.6
2100	15.1	243	106.7	4.2

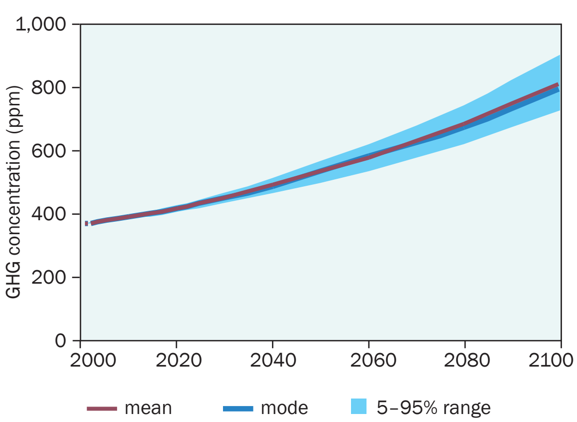
Source: IPCC (2000).

C. Modeling Results

By 2100 global mean temperature would rise 3.4°C above its 2000 level, with a 5% chance it would rise beyond 5.5°C.

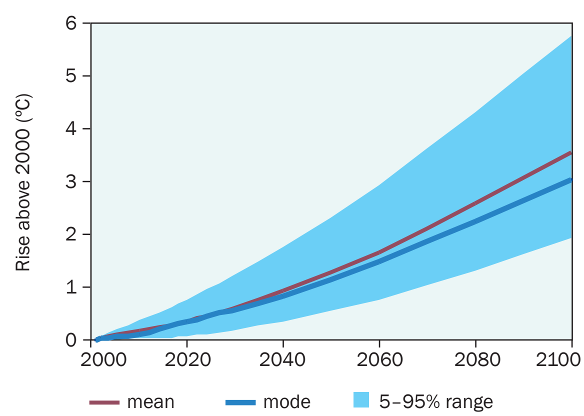
World production would increase about 2% per annum on average under A2, with world population projected to double by 2100. Annual GHG emissions would rise rapidly as a result, increasing from 37 $GtCO_2$-eq in 2000 to 128 $GtCO_2$-eq by 2100. GHG concentration would likely rise beyond the safe level (450–500 ppm) by 2040 and to above 800 ppm by 2100 (Figure 5.1). Due to the complexity of the climate system, there is uncertainty about what the temperature level might be in the long run. But PAGE2002 projects that global mean temperature would rise by 3.4°C above the 2000 level by 2100 on average, with a 5% chance it will rise beyond 5.5°C by then (Figure 5.2).

Figure 5.1. Global GHG Concentration under A2 Scenario



Note: 'mean' indicates the average outcome of the simulations, 'mode' indicates the most likely outcome, and the range of estimates from the 5th to the 95th percentile is shaded area.
Source: ADB study team.

Figure 5.2. Global Mean Temperature Rise under A2 Scenario

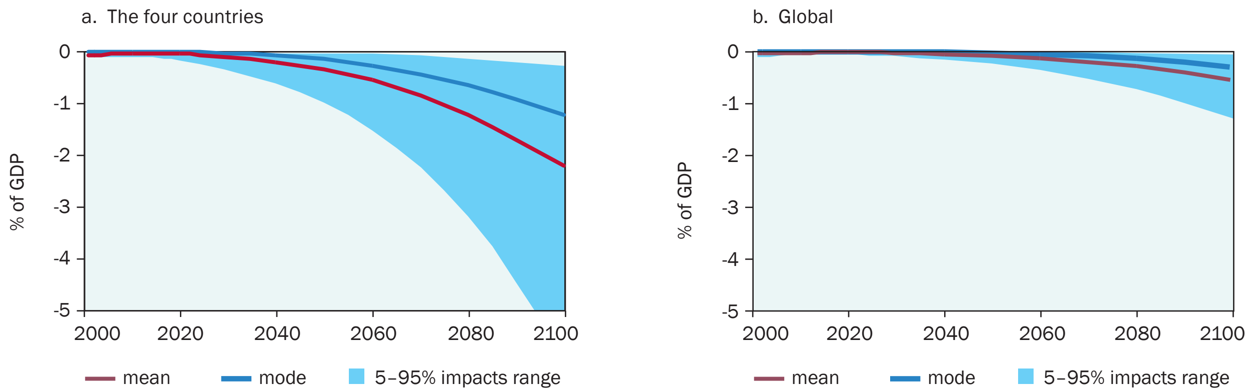


Note: 'mean' indicates the average outcome of the simulations, 'mode' indicates the most likely outcome, and the range of estimates from the 5th to the 95th percentile is shaded area.
Source: ADB study team.

Without further mitigation and adaptation, the model projects a mean GDP loss of 0.6% by 2100 for the world as a whole, if considering market impact only: the losses increase dramatically, when non-market impact and catastrophic risks are also considered.

As shown in Figure 5.3b considering market impact only, the mean global GDP loss is projected to reach 0.6% by 2100, with the mode (or most likely) loss at 0.3%. The model estimates a 5% probability that the market

Figure 5.3. Loss in GDP (market impact only) under A2 Scenario



Note: 'mean' indicates the average outcome of the simulations, 'mode' indicates the most likely outcome, and the range of estimates from the 5th to the 95th percentile is shaded area.
Source: ADB study team.

GDP loss would reach 1.3% by 2100. But when potential non-market impact such as those on health and ecosystems are considered, projected losses rise dramatically: when market, non-market impact, and catastrophic risks are accounted for mean global loss reaches as high as 2.6% of global GDP (Figure 5.4b).

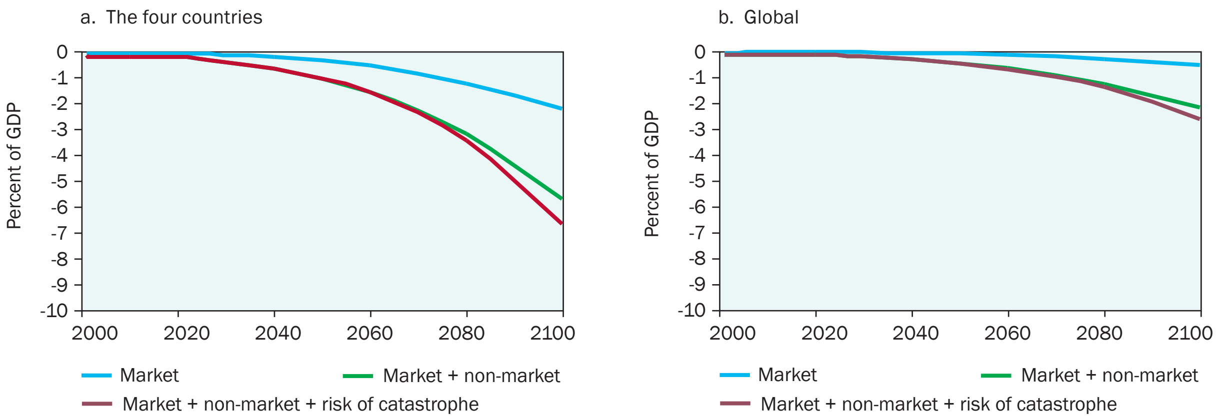
Southeast Asia is projected to suffer more from climate change than the global average.

For the four countries, without considering non-market impact and catastrophic risks, mean GDP loss is projected to reach 2.2% by 2100, with the mode at 1.2%, and a 5% chance that market loss would reach 5.8% (Figure 5.3a). The mean impact is three times the global mean GDP loss of 0.6% because, compared to the rest of the world, the four countries have relatively long coastlines, high population density in coastal areas, high dependence on agriculture and natural resources, relatively low adaptive capacity, and mostly tropical climates. This finding is consistent with those described elsewhere in this study. It is also worth noting that the distribution of the losses for the four countries is wider than for the global average, as indicated by the difference between the results at mean, mode, and 5% probability level.

The four countries could lose 6.7% of GDP by 2100, if non-market impact and catastrophic risks are also taken into account.

Climate change will also have non-market impact that would become highly significant over the longer term. The impact of climate change on ecosystems and health (non-market impact) in the four countries is likely to be greater than the impacts on agriculture and coastal resources (market impact), with the gap growing larger over time as shown in Figure 5.4a. Under the BAU scenario with no further mitigation and adaptation, combined mean GDP losses from market and non-market impact could reach 5.7% by 2100: if the chance of catastrophic events is also considered, they could reach 6.7% of GDP.

Figure 5.4. Mean Impact under A2 Scenario

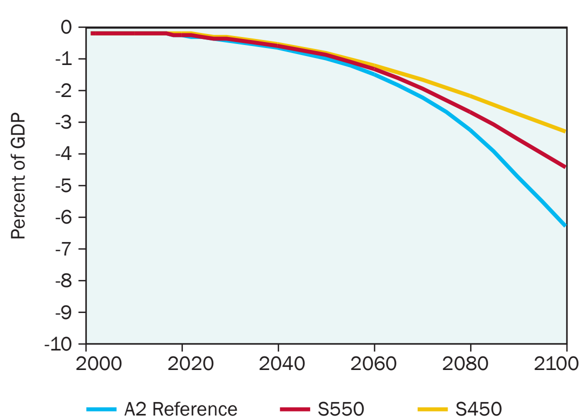


Source: ADB study team.

Stabilizing CO_2 concentrations between 450–550 ppm would significantly reduce the potential losses to the four countries

The model shows that, with stabilization, the potential mean losses in GDP due to climate change are likely to be much lower: 4.6% at S550 and 3.4% at S450 by 2100, compared with 6.7% under the BAU scenario, when considering market impact, non-market impact, and catastrophic risks combined. The savings of several percentage points of GDP suggest significant benefits from global mitigation for the four countries (Figure 5.5). Such benefits would be even greater beyond 2100. The results also show that the differences between the reference and the stabilization scenarios would become apparent only after 2050, partly because of the significant time lag between mitigation action and its impact on the climate system. Early global mitigation is urgently needed.

Figure 5.5. Mean Total Loss under Different Scenarios in the Four Countries



Note: Total loss includes market impact, non-market impact and catastrophic risks
Source: ADB study team.

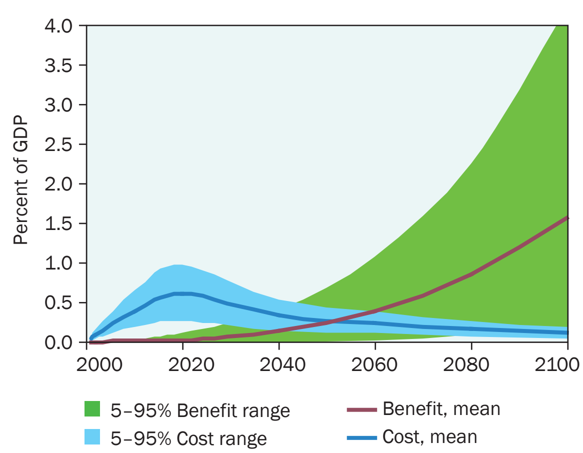
Adaptation can help reduce harmful climate change impact at a cost far lower than the ultimate benefit.

Understanding the cost and benefit of adaptation is important for planning. Existing cost estimates vary significantly from one study to another. UNFCCC (2007) estimates that the combined cost of adaptation in the agriculture, coastal zone, forestry, fisheries, health, infrastructure, and water supply sectors could reach $44 billion to $166 billion per year by 2030 for the whole world, and $28 billion to $67 billion for developing countries. UNDP (2007) projects adaptation cost for developing countries of around $86–109 billion per year by 2015. To meet developing countries' current adaptation needs, the World Bank (2006) estimates it would require investment in the range of $9–41 billion per year.

Studies of adaptation cost and benefit for Southeast Asia are still limited. The PAGE2002 model allows cost-benefit analysis of adaptation by comparing the cost associated with different levels of adaptation efforts with benefits from avoided climate change impact. The result shows that, for the four countries, the cost of adaptation for the agriculture and coastal zones (mainly the construction of sea walls and development of drought- and heat-resistant crops) would be about $5 billion per year by 2020 on average, and that this investment is likely to pay off in the future: the annual benefit of avoided damage from climate change is likely to exceed the annual cost by 2060 (Figure 5.6). By 2100, the benefit could reach 1.9% of GDP, compared to the cost at 0.2% of GDP.

Figure 5.6 also indicates the risks, with a 5% chance that the annual benefit from adaptation would not exceed the annual cost before 2080. Further, adaptation cannot entirely remove the projected damage of climate change, and thus must be complemented with global mitigation of CO_2, as analyzed above, in order to avoid the greater impact of future climate change. As mentioned, there are currently great uncertainties associated with the economic aspects of climate change. The results presented are meant to be illustrative and should only be taken to provide the orders of magnitude of the

Figure 5.6. Cost and Benefit of Adaptation



Note: 'mean' indicates the average outcome of the simulations and the range of estimates from the 5th to the 95th percentile is shaded area.
Source: ADB study team.

potential policy impacts. But the modeling results indicate that interventions to adapt to and mitigate climate change have significant long-term economic benefits in avoided damage.

D. Conclusions

This chapter has shown that the global mean temperature would rise 3.4°C above the 2000 level by 2100 under the A2 scenario, with a 5% chance that temperature could rise beyond 5.5°C when climate uncertainties are considered. Under business-as-usual and no further mitigation and adaptation efforts, the PAGE2002 model projects a mean global GDP loss due to market impact alone of 0.6% each year by 2100. When non-market impact and catastrophic risks are also considered, annual global GDP loss could equal 2.6% of GDP by 2100. Moreover, Southeast Asia is likely to suffer more from climate change than the global average—about 2.2% loss of GDP on average by 2100, when considering market effects only, and 6.7% when non-market and catastrophic risks are also taken into account. Global stabilization at 450–550 ppm would significantly reduce the potential damage to the four countries. Based on the best available information, the benefit from adaptation is projected to outweigh the costs of implementing adaptation measures in the long term. However, adaptation alone is not sufficient. Global CO_2 mitigation will be needed to complement adaptation efforts in the four countries.

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Chapter 6

Climate Change Adaptation Options and Practices

Key Messages

The future climate poses challenges outside historical experience. Building and improving adaptive capacity and taking technical and non-technical adaptation actions in key climate-sensitive sectors must be an urgent priority for Southeast Asia.

There exist “win-win” measures that address climate change and are also good sustainable development practices. Government has a vital role to play in providing incentives and an effective policy framework for individuals and firms to adapt to climate change and to enhance their adaptive capacity.

Southeast Asian countries have made significant efforts to build adaptive capacity. There remains a need for enhancing policy and planning coordination across ministries and different levels of government for climate change adaptation. There is also a need for adopting a more holistic approach to building the adaptive capacity of vulnerable groups and localities and their resilience to shocks, including developing their capability to diversify local economies, livelihoods, and coping strategies.

Southeast Asian countries have also made encouraging efforts in taking adaptation actions in key sectors including water resources, agriculture, forestry, coastal and marine resources, and health. But most implemented to date have been reactive not proactive, autonomous not well-planned, and developed to address climate variability not change.

In water resources, the priority is to scale up existing good practices of water conservation and management, and apply more widely integrated water management, including flood control and prevention schemes, flood early warning systems, irrigation improvement, and demand-side management.

In the agriculture sector, the priority is to strengthen local adaptive capacity by providing public goods and services, such as better climate information, research and development on heat-resistant crop varieties and other techniques, early warning systems, and efficient irrigation systems; and explore innovative risk-sharing instruments such as index-based insurance schemes.

In the forestry sector, the priority is to enhance early warning systems and awareness-raising programs to better prepare for potentially more frequent forest fires as a result of climate change; and implement aggressive public-private partnerships for reforestation and afforestation.

In the coastal and marine resources sector, the priority is to implement integrated coastal zone management plans, including mangrove conservation and plantation.

In the health sector, the priority is to expand or establish early warning systems for disease outbreaks, health surveillance, awareness-raising campaigns, and infectious disease control programs.

In the Infrastructure sector, the priority is to introduce “climate proofing” of transport-related investments and infrastructure.

A. Introduction

The two means of coping with human-induced climate change and its impact are adaptation and mitigation. Adaptation involves adjustments in natural or human systems in response to actual or expected climate change impacts to reduce harm or exploit beneficial opportunities. Adaptation action is taken by individuals, households, communities, businesses, and governments. Many actions are taken autonomously by private actors in reaction to actual or expected climate change without policy interventions and are known as “autonomous” adaptation. Other actions, “planned” or “policy-driven” adaptation, are taken as a result of deliberate policy decisions. Adaptation can also be “reactive” or “proactive”, the former in response to actual climate change impact and the latter to anticipated climate change. Adaptation can operate at two broad levels: building national and local adaptive capacity, and delivering specific adaptation actions.

Adaptation reduces vulnerability and increases resilience. It is essential for managing and reducing the unavoidable impacts of GHG emissions already locked into the climate system. It helps to reduce the risks associated with climate change and is now widely recognized as an equally important and complementary response to greenhouse gas mitigation. It also offers an opportunity to adjust economic activity in vulnerable sectors and to support sustainable development and poverty reduction. Adaptation, therefore, should be a vital part of Southeast Asia countries’ response to a problem that will disproportionately affect the poor.

This chapter reviews the need for building adaptive capacity in Southeast Asia and the adaptation options and practices underway in the region in key climate-sensitive sectors, including water resources, agriculture, forestry, coastal and marine resources, and health.

B. Building Adaptive Capacity

Building adaptive capacity involves creating the information and conditions—regulatory, institutional, managerial, and financial—needed to support adaptation actions. While building a country's adaptive capacity requires the effort of all segments of society, the government has a particularly important role to play. This includes putting in place an effective policy and institutional framework, filling information and knowledge gaps, creating the right incentives, and allocating adequate public resources for adaptation.

The future climate poses challenges outside historical experience. Improving adaptive capacity must be an urgent priority for Southeast Asia.

While Southeast Asia has a long record of dealing with weather-related incidents, future climate change and its variability are expected to increase the frequency of extreme events and intensify impacts in ways that are outside the realm of historical experience. The region's vulnerability to climate change has necessitated the development of adaptation practices to cope with climate impacts. These include reactive/responsive measures such as changing the pattern and timing of the cropping system, emergency response to disasters, and migration; as well as proactive/anticipatory adaptation like crop and livelihood diversification, climate forecasting, community-based disaster risk reduction, famine early warning systems, insurance, water storage, supplementary irrigation, and so forth. Enhancing adaptive capacity has been high on the development agenda in Southeast Asia. Although uncertainty remains about the extent of climate change impacts in the region, there is sufficient information and knowledge available to implement adaptation activities now. Table 6.1 summarizes major adaptation options that are available and have been practiced in developing countries as reported in UNFCCC (2007). This chapter reviews the adaptation practices implemented and proposed in Southeast Asian countries against this framework.

Adaptation decisions should be based on a sound economic foundation. Although uncertainty may make it difficult to fine-tune adaptation, there exist "win-win" measures that address climate change and are also good sustainable development practices.

Planning for coping with the observed and anticipated impacts of climate change requires decisions based on sound economic considerations. It is necessary to know what adaptation would cost, and to what extent it would help avoid climate change damage. However, studies on adaptation costs and benefits for Southeast Asia are still limited—this is an area for further research.

The long-term nature of climate change makes timing crucial to adaptation decisions. Despite the uncertainties, one of the best adaptation

Table 6.1. Adaptation Options

	Reactive/Responsive	Proactive/Anticipatory
Water Resources	• Protection of groundwater resources • Improved management and maintenance of existing water supply systems • Protection of water catchment areas • Improved water supply • Groundwater and rainwater harvesting and desalination	• Better use of recycled water • Conservation of water catchment areas • Improved system of water management • Water policy reform including pricing and irrigation policies • Development of flood controls and drought monitoring
Agriculture	• Erosion control • Dam construction for irrigation • Changes in fertilizer use and application • Introduction of new crops • Soil fertility maintenance • Changes in planting and harvesting times • Switch to different cultivars • Educational and outreach programs on conservation and management of soil and water	• Development of tolerant/resistant crops (to drought, salt, insect/pests) • Research and development • Soil-water management • Diversification and intensification of food and plantation crops • Policy measures, tax incentives/subsidies, free market • Development of early warning systems
Forestry	• Improvement of management systems including control of deforestation, reforestation, and afforestation • Promoting agroforestry to improve forest goods and services • Development/improvement of national forest fire management plans • Improvement of carbon storage in forests	• Creation of parks/reserves, protected areas and biodiversity corridors • Identification/development of species resistant to climate change • Better assessment of the vulnerability of ecosystems • Monitoring of species • Development and maintenance of seed banks • Including socio-economic factors in management policy
Coastal and Marine Resources	• Protection of economic infrastructure • Public awareness to enhance protection of coastal and marine ecosystems • Building sea walls and beach reinforcement • Protection and conservation of coral reefs, mangroves, sea grass, and littoral vegetation	• Integrated coastal zone management • Better coastal planning and zoning • Development of legislation for coastal protection • Research and monitoring of coasts and coastal ecosystems
Health	• Public health management reform • Improved housing and living conditions • Improved emergency response	• Development of early warning system • Better and/or improved disease/vector surveillance and monitoring • Improvement of environmental quality • Changes in urban and housing design

Source: Adapted from UNFCCC (2007).

measures available would be to extend ongoing efforts toward sustainable development, as these are adaptations that are justifiable even without climate change. Better health care, access to safe drinking water, better sanitary conditions, and improved standards of education and infrastructure are “win-win” measures that, while useful in their own right, will also enhance the region’s adaptive capacity.

Government has a vital role to play in providing incentives and a policy framework for individuals and firms to adapt effectively to climate change and enhance their adaptive capacity.

Adaptation decisions are largely decentralized, unlike mitigation, which requires global cooperation. Some adaptations will have local public good characteristics and as such may be provided by the state, also called policy-driven adaptation. However, a majority of decisions will be taken by private agents, individuals, households, and firms with local benefits, known as autonomous adaptation. Because adaptation is a decentralized process, there is the question of how incentives can be provided to support it through private agents. The literature on climate change has so far paid relatively little attention to the role of market and regulatory mechanisms in scaling up and enhancing the efficiency of adaptation efforts. This is a critical gap, because most adaptations are undertaken by private actors, and the scope of the adaptation will likely be far greater than the government budgets available to address it (OECD 2008).

Southeast Asian countries have made encouraging efforts to build adaptive capacity, but much more is needed.

Strengthening efforts requires mainstreaming climate change adaptation into development planning. This means that adaptation must be considered not only as a technical solution focused on natural systems, but more importantly, as an integral part of sustainable development and poverty reduction strategies. Among the immediate priorities for Southeast Asian countries in mainstreaming climate change adaptation identified by the study are:

- Step up efforts to raise public awareness of climate change and its impact, with a view to building consensus for public action and engaging all stakeholders including households, businesses, government agencies, nongovernment organizations, civil society, and development partners in combating climate change.

- Undertake more research to better understand (i) climate change and its impact at the local level; (ii) cost-effective technical solutions that focus on natural systems (water resources, agriculture production, forestry, coastal and marine resources, and others); and (iii) sound adaptation strategies beyond technical solutions (migration, social protection mechanisms, livelihoods of small-scale farmers and fishermen, and governance of adaptation at all levels).

- Step up efforts in information and knowledge dissemination.

- Put in place or enhance multi-ministerial coordination and planning mechanisms to promote multi-sector approaches to climate change adaptation, including linking climate change adaptation with disaster risk management. Given that climate change is an issue that cuts across all parts of government, it requires the attention of not just the ministries of the environment and the key agencies. Climate policy should be led by heads of state and the economics and finance ministries.

- Put in place or enhance central government-local authority coordination, planning, and funding mechanisms to encourage local and autonomous adaptation actions, and to strengthen local capacity to plan and take adaptation initiatives.

- Adopt a more holistic approach to building vulnerable groups' and localities' adaptive capacity and resilience to shocks beyond technical solutions, including developing their capacity to diversify local economies, livelihoods, and coping strategies.

At a more fundamental level, a country's adaptive capacity depends on its economic, social, and human development, which is closely related to levels of income, inequality, poverty, literacy, and regional disparity; capacity and governance of public institutions and public finance; availability or adequacy of public services including education, health, social protection and social safety nets; capacity of economic diversification especially at local levels. In all these aspects, there is wide variation across Southeast Asia and significant gaps between Southeast Asia and the developed world. Eliminating these gaps by keeping growth strong and making development sustainable and inclusive will go a long way toward improving the region's adaptive capacity.

The rest of this chapter reviews adaptation options and practices undertaken by Southeast Asian countries in response to the impacts of climate change in key sectors, including some case studies on adaptation in the region.

C. Adaptation Options and Practices in the Water Resources Sector

Climate change phenomena, such as erratic rainfall patterns, El Niño episodes, and drought, have exacerbated growing water stress in key economic sectors of the region.

In recent years, the region's major rivers have been under threat not only due to diversion to hydropower energy and to freshwater needs of the growing urban population, but also to climate change. Most countries in the region have experienced growing water shortages due to changes in rainfall patterns and the effect of El Niño. Consequently, water quantity and quality have deteriorated. Overexploitation of water resources has depleted aquifers, lowered water tables, and reduced stream flows, which in some cases have already reached ecologically unsafe levels. For example, in Indonesia, Sutardi (2007) found that the water demand from some islands already exceeded the volume that available water resources could provide (Table 6.2). This deficit affects not only the agriculture sector but also domestic and industrial users.

Table 6.2. Supply and Demand of Raw Water in Indonesia, by Island (2003)

Island	Demand		Supply		Ratio
	Volume (billion cu m)	Share (percent)	Volume (billion cu m)	Share (percent)	Supply/Demand
Sumatera	11.6	17.5	96.2	19.9	8.29
Java and Bali	38.4	57.8	25.3	5.2	0.66
Kalimantan	2.9	4.3	167	34.6	57.59
Nusa Tenggara	4.3	6.5	4.2	0.9	0.98
Sulawesi	9.0	13.6	14.4	3.0	1.60
Maluku	0.1	0.2	12.4	2.6	124.00
Papua	0.1	0.1	163.6	33.9	1636.00

Source: Sutardi (2007).

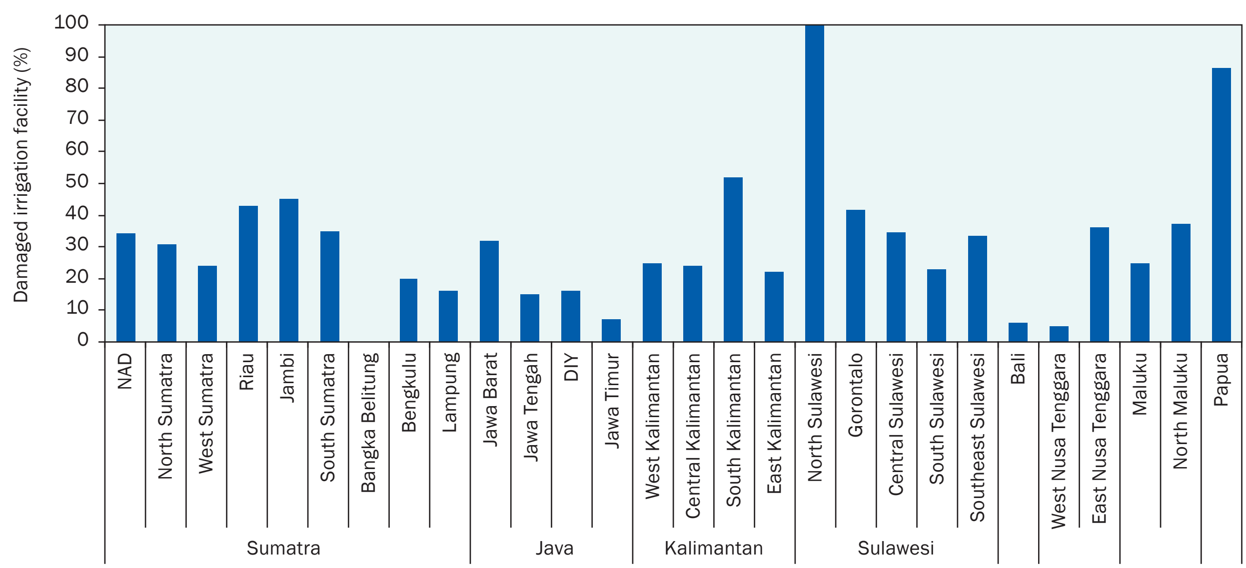
To improve the water shortage situation, the Southeast Asian countries have used supply-side measures, such as water harvesting technologies and renovation of irrigation facilities, and demand-side measures, including promotion of efficient use of water resources and better water management practices.

Amid increasing water stress due to climate change, growing water demand has led to a shortage of water in several areas in Southeast Asia. Damaged irrigation facilities contribute to difficulties in meeting water demand from agriculture. For example, in 2003 a high and significant percentage of irrigation facilities in several districts of Indonesia were damaged (Figure 6.1). Governments have taken steps to address this by repairing existing facilities and implementing innovative adaptation measures. Farmers in a number of drought-prone districts in Indonesia have been trained to develop rain harvesting technologies to absorb surplus water from irrigation and rainfall (Figure 6.2). The Government of Viet Nam has planned for the extension of small-scale irrigation schemes in Ninh Thuan province (see Box 6.1). On the demand side, Thailand has promoted the combined use of surface and groundwater resources to maximize the yield of water resources, while farmers in Indonesia and Viet Nam have been trained in the better management of water including efficient and effective use of irrigation water and other water resources.

As climate change causes extreme weather events such as floods and storm surges, flood control facilities have been installed and communities have been trained to cope with floods.

Southeast Asia has already suffered from floods and storm surges brought on by climate change. Several areas, particularly in the Philippines, Thailand, and Viet Nam, are flood-prone, making these countries particularly vulnerable to extreme weather events. In response, flood control and

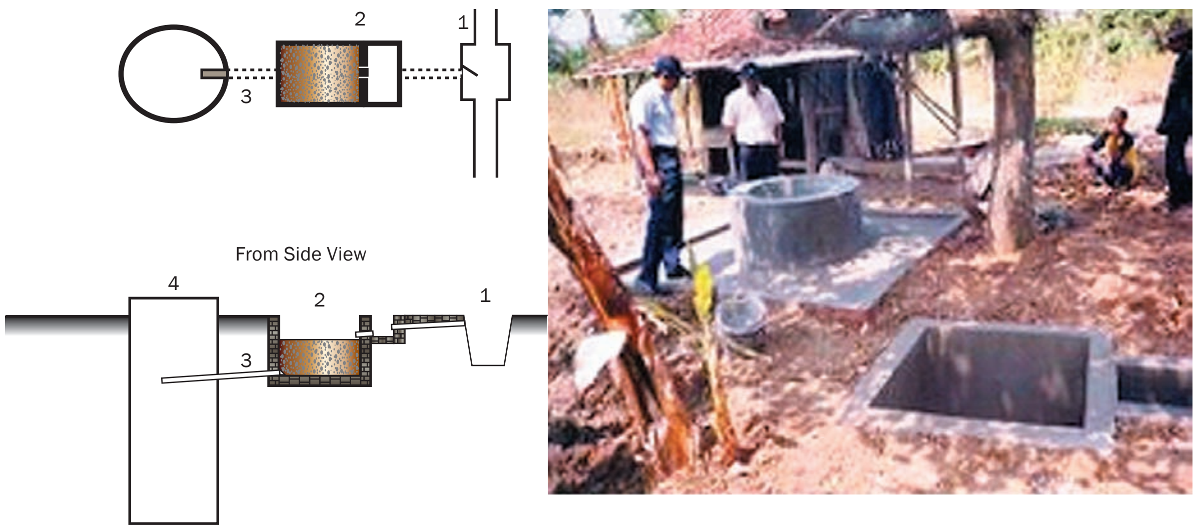
Figure 6.1. Damaged Irrigation Facilities in Indonesia by Province (2003)



NAD = Nanggroe Aceh Darussalam, DIY = Daerah Istimewa Yogyakarta
Source: Boer and Dewi (2008).

prevention facilities have been put in place in these locations. For example, the Bangkok Metropolitan Administration has established pumping stations in strategic areas of the city to regulate water in canals and rivers that tend to overflow during the rainy season. Water gate facilities have also been installed for flood control as well as for the prevention of saline water intrusion in Thailand. Upgrading of existing drainage systems has been proposed in Viet Nam, particularly in the Red River and Mekong River Deltas, and has already been implemented in Singapore. Experience from the Lower Songkhram River Basin in the northeastern region of Thailand also shows that an effective way to prepare for floods is to provide training to the local communities in flood-

Figure 6.2. Wells to Absorb Surplus Water from Irrigation and Rainfall at Grobogan



Note: 1 = Irrigation canal, 2 = control pond, 3 = pipe, 4 = well.
Sources: Photo documentation from Ditgen Land and Water Management, Ministry of Agriculture (2007), Boer and Dewi (2008).

Box 6.1. Climate Change Adaptation Strategies on Water Resources in Ninh Thuan Province, Viet Nam

The central coast is the area most severely affected by drought, with an estimated 1.0–1.3 million people classified as "drought affected" in the nine central provinces of Viet Nam. Ninh Thuan province is situated in the typhoon belt and has both the lowest average annual rainfall in the country, as well as the highest temperatures.

A study on supporting local government efforts to adapt to the impacts of drought by extending irrigation facilities and establishing deep wells, open wells, and other longer-term adaptation measures shows how communities have adapted to climate change. For example, people use more drought-resistant seed varieties and have made changes in the cropping calendar to deal with the effects of drought. The communities involved have also adjusted their animal husbandry practices by changing animal breeds and exploring drought-resistant fodder sources (Kyoto University 2007). On the other hand, the study found a need for increased investment to support the livelihood of communities and the natural resources on which they depend.

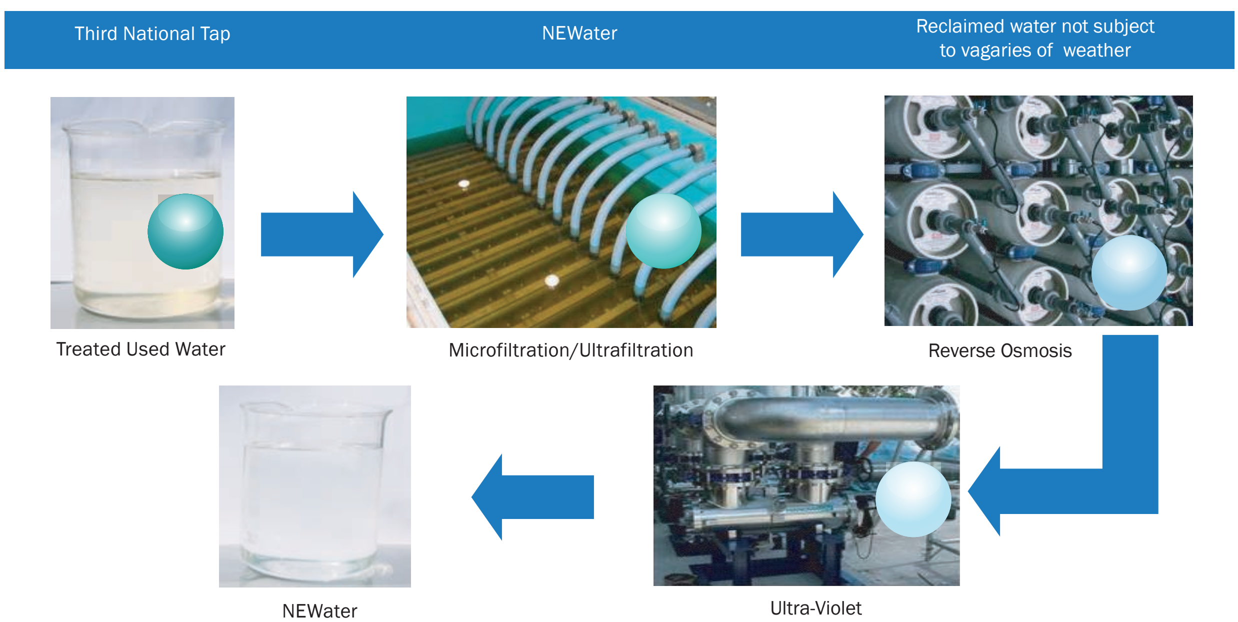
Source: Kyoto University and Oxfam UK (2007).

prone areas, for instance, how to build rice storage silos on high ground and how to prepare for moving livestock. Viet Nam is considering a more proactive approach to flood control by establishing flood warning systems for local communities.

In the face of increasing water stress due to climate change, experience and lessons can be shared among communities in the region.

Innovative technologies have proven to be the key to enhancing water supply in a resource-constrained country like Singapore. Until recently, Singapore's water supply was dependent on rainfall and water imported from Johor, Malaysia. Singapore's daily water consumption is currently about 350 million gallons and has been increasing steadily because of population growth and economic activity. To respond to the increasing water consumption and in order to reduce reliance on water imports, Singapore has recently implemented several projects to expand and diversify its domestic water supply, one of which is reclaiming used water through NEWater[13] technology (Figure 6.3). The NEWater installations currently provide about 15% of Singapore's water consumption and capacity will be increased to

Figure 6.3. NEWater: Reclamation of Water from Waste and Sewerage



Source: Ho (2008).

[13] NEWater is the high-grade water produced after treated used water has been further purified using a three-step process involving advanced membrane technologies like microfiltration, reverse osmosis, and the final disinfection of the product water using ultraviolet light (see www.pub.gov.sg/newater/PlansforNEWater/Pages/default.aspx).

meet 30% of Singapore's water needs by 2011. A seawater reverse osmosis project has been implemented to produce 136 million liters of fresh water a day. Moreover, the government plans to increase the water catchment area from half to two-thirds of the nation's land area through three new reservoir schemes—Marina, Punggol, and Serangoon Reservoirs.

Integrated water management is needed to capture multiple benefits, including flood prevention, efficient use of water supply, and clean power generation.

Rainfall patterns in the Philippines have become erratic, particularly during the El Niño Southern Oscillation years. There is excessive water during La Niña periods, causing intense runoff and soil erosion, massive flooding, and damage to riverbanks and many irrigation systems. During El Niño periods, water is scarce, causing water shortages for irrigation of agricultural crops. In response, the government has developed the Small Water Impounding Project aimed at reducing flood damage, making more effective use of water resources, and generating electricity. The project consists of a water harvesting and storage structure with earth embankment spillways, outlet works, and canal facilities (Figure 6.4). It is designed for soil and water conservation and flood control by holding as much water as possible during the rainy season. The reservoir, with its stored water, serves as an important supplementary source of water for irrigation, inland fisheries, and recreational purposes. The watershed is developed for land use that enhances water infiltration and minimizes soil erosion. The farmer-beneficiaries of the irrigation water and those of the watershed are organized into an association that maintains the system and protects the watershed by practicing sustainable agriculture. A similar holistic approach has been considered in Viet Nam, with high priority given to the southeast region, the central highlands, and the mountainous area in the north; and in some districts of Indonesia such as Indramayu in Java through the construction of multipurpose dams and reservoirs.

Figure 6.4. Small Water Impounding System in the Philippines

Sources: Bureau of Soil and Water Management (2005), Perez (2008).

Table 6.3 summarizes key adaptation options for water resources in Southeast Asian countries indicating the scale of adoption, types, beneficiary sector, and countries where they are practiced. To improve the water shortage situation, many countries have used both supply-side and demand-side measures including rain harvesting technologies, improved irrigation facilities, training in the efficient use of water, reclamation of used water, and better water management practices. These practices should be scaled up, and experience and lessons should be better shared among communities within each locality, region, country, and among countries in the region. Integrated water management, including flood control and prevention schemes, early warning systems, irrigation improvement, and demand-side management, should be applied more widely to capture multiple benefits.

Table 6.3. Summary of Key Adaptation Options in Water Resources Sector

Practice	Reduced Impact	Scale	Reactive/ Proactive	Planned/ Autonomous	Beneficiary Sector	Example
Rehabilitation of damaged irrigation and drainage facilities	Water shortage, drought, erratic rainfall	Local/ Sub-regional	Reactive	Planned	Agriculture	Indonesia, Singapore, Thailand, Viet Nam
Extension of small-scale irrigation schemes						Viet Nam
Flood warning system	Extreme events, e.g. floods, storm surges	Local/ Sub-regional	Proactive	Planned	Agriculture, Coastal, Household, Industry	Viet Nam
Improved flood control facilities, such as pumping stations, water gate		Regional			Agriculture, Household, Industry	Thailand
Multi-purpose reservoirs, dams, water-impounding system	Drought, flood, erratic rainfall pattern, water shortage	Regional	Proactive	Planned	Agriculture, Household, Industry, Power generation	Philippines, Viet Nam
Integrated river basin development, water catchment areas					Agriculture, Household, Industry	Singapore, Thailand
Rain harvesting technologies	Water shortage, drought, erratic rainfall pattern	Local	Reactive	Autonomous	Household	Indonesia
Conjunctive use of water, training for efficient use of water from irrigation					Household, Agriculture	Indonesia, Thailand, Viet Nam
Metering and pricing to encourage water conservation	Water shortage	Local	Reactive	Autonomous	Household	Philippines, Singapore
Reclamation of used water	Water shortage	Regional/ National	Proactive	Planned	Household, Industry	Singapore
Sea water osmosis plant						

Sources: Boer and Dewi (2008), Cuong (2008), Ho (2008), Jesdapipat (2008), Perez (2008).

D. Adaptation Options and Practices in the Agriculture Sector

Agricultural productivity in several pockets of Southeast Asia has declined, largely due to heat and water stress as well as climate variability, threatening food security in the region and beyond as populations grow.

For the past several decades, agriculture in Southeast Asia has been under considerable environmental pressure due to increasing demand for food, feed, and industrial crops. The growing population and increasing industrialization have triggered intensification of agricultural production to meet growing demand. However, the productivity of major crops has declined in many parts of the region due to increasing average temperatures, resulting in water shortage and heat stress, erratic rainfall patterns that have affected yields and the planting season, frequent typhoons with strong winds causing soil erosion, and flooding that has destroyed many production areas through inundation and siltation (ONEP 2008, Naylor et al. 2007). In addition, rising sea levels have reduced arable land through soil salinization. Agriculture is one of the most climate-sensitive sectors in the region and has been hurt by the multifaceted impact of climate change.

The most commonly used adaptation techniques in the region's agriculture are changes in cropping patterns and the cropping calendar, and improved farm management.

Farmers across Southeast Asia have a long record of adjustment of farm management practices and cropping techniques to cope with the impacts and variability of climate change. The adaptation measures include changing cropping calendars and patterns (for example, from rice-rice to rice-maize cropping pattern to optimize the use of available water for crop growth); improved farm management; and use of drought-resistant and heat-resilient crop varieties. In Viet Nam, future forecasts suggest there will be a need to change rice crop sowing dates and management procedures to optimize rice yields under changing climate conditions. In the northern part of Viet Nam, the sowing date of spring rice will be earlier by 15–25 days while the sowing date of summer rice will be 20–25 days later. With climate change, the rice growing period in Viet Nam will be expanded. Farmers in Thailand have also adopted similar adaptation practices, as well as intercropping, diversified farming, and variation of crop rotation patterns.

Farm-level adaptation practices are helpful in coping with climate variability, but their effectiveness can be enhanced by institutional and policy support from government.

The various farm-level adaptation techniques have helped individual farmers reduce the extent of productivity decline. The Organisation for Economic Co-operation and Development (OECD 2008) reports that many studies have shown that adaptation efforts can be made more effective with enhanced coordination and institutional support from government. Box 6.2 presents case studies showing how farmers were able to manage climate risks through different technological and institutional arrangements.

Box 6.2. How Farmers Manage Climate Risks in the Lower Mekong Countries

Case 1: Kula Field and Ubonratchathani Province, Thailand

Farmers in Thailand tend to rely on household and national measures for reducing climate risk. The former focuses on income diversification, primarily from off-farm sources, which are not as sensitive to climate variation as income from rice. Generally, farmers migrate seasonally to the cities for employment, at times permanently. Rice farmers in Thailand use such on-farm measures as changing seedling techniques, using hired machinery, growing alternative crops between seasons, and raising livestock. They sometimes make investments in small-scale irrigation to secure water sources for mid-season dry spells or for crops in the main season. They also construct embankments to protect fields from flood damage.

Case 2: Mekong River Delta, Viet Nam

Farmers of rainfed rice in Viet Nam tend to rely on measures implemented at the household level and aimed mainly at on-farm actions to protect against climate hazards. These include efforts and investments to increase and sustain the productivity of farms, such as construction and maintenance of small-scale irrigation systems or embankments to protect farmlands from floods. But investment costs and limited finances limit wider use of these measures. Using an alternative strategy, some farmers in the study sites have adapted to floods by accepting these as part of the ecosystem of their farmland, adjusting their crop calendar accordingly, thereby gaining advantage from deposited nutrients that enhance soil fertility, and the washing away of pollutants. Alternative crops and seed varieties are also common adaptation measures in Viet Nam's Mekong River delta.

Because the rainy season in the delta is usually 7 months long, two crop cycles of rainfed rice can be grown in a year. A two-crop cycle is facilitated by the availability of short-cycle rice varieties that are suitable for growing.

Source: Chinvanno et al (2006).

Table 6.4. Adaptation Options in the Philippine Agriculture Sector

Economic	Technological	Institutional
Liberalization of agricultural trade barriers Changes in existing subsidies Extensive review/ analysis of and appropriate action on economic incentives, subsidies, taxes, pricing, and trade barriers	• Changes in agricultural management practices • Natural rainfall management including water impounding dams and evaporation control • Cropping pattern adjustment according to the onset of the rainy season and observed frequency of tropical cyclones, including information dissemination to farmers and timely provision of farm weather services/advisories, early warning systems • Access to available data on soil fertility from the Bureau of Soil and Water Management particularly in relation to: – Improved water management – Developing heat-resistant varieties/genetic breeding – Improved farm management – Organic farming, diversified farming – Safe and judicious use of fertilizers/chemicals – Optimum/efficient use of fertilizers/chemicals – Increasing effectiveness and flexibility of irrigation – Introduction of new least-cost technologies such as hydroponics – Improvement of post harvest and bulk handling facilities (i.e., installation of grain drying facilities in strategic areas)	Institutionalizing agricultural drought management through: • Collaboration between managers of weather data, water resources, farmers, policymakers • Passage of legislative measures including those on land use conversion • Strengthening of extension services at the local government unit level – Upgrading the food storage distribution system – Promoting and implementing judicious land use planning

Source: The Philippines' Initial National Communication on Climate Change (1999).

A number of adaptation measures have also been put in place in the Philippines, both technological and institutional (Table 6.4). Technological adaptation strategies such as natural rainfall management, cropping pattern adjustment, and improved access to available information such as soil fertility and taxonomy were chosen primarily because they are low-cost options, while policy-level measures have been devised to provide an adequate incentive framework to promote private adaptation. Furthermore, government can help strengthen technical adaptive capacity that is beyond the capacity of individual farmers. For instance, the government of Viet Nam has planned to increase irrigation efficiency by shifting from low-performing surface and overhead systems, to high-performance ones such as center pivot and drip irrigation.

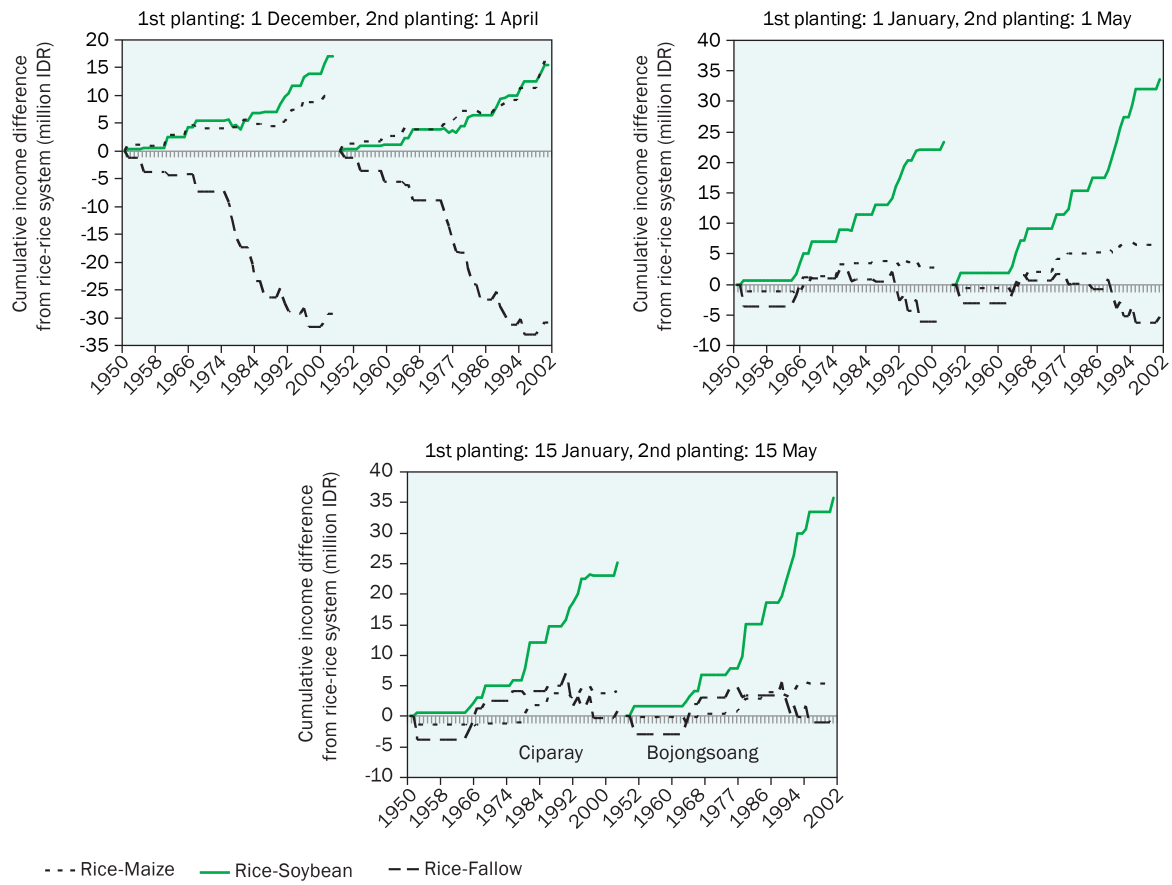
Government has a major role to play in augmenting adaptive capacity by providing public goods and services, such as weather information forecasts and development of early warning systems.

Agricultural crops are very sensitive to temperature and precipitation during the growing period and it is important for local farmers to be able to plan the growing season according to detailed, time-specific information about temperature and precipitation. Seasonal weather forecasts are one type of information source that can help farmers respond appropriately to weather parameters. This requires that relevant information is given to farmers, and that they know how it can be used in relation to planting of crops and production strategies. Coping strategies, including appropriate seeds, fertilizers, irrigation systems, pesticides, and various tools and machinery, should likewise be available to farmers. For example, in Indonesia, it is reported that the consistent use of the Southern Oscillation Index (SOI) information in designing cropping strategy helps improve farmers' income during El Niño Southern Oscillation years (Boer and Surmaini 2006). Government can help enhance farmers' adaptive capacity by establishing an information sharing network and training programs for farmers. The main challenge found in the Indonesian context is how to encourage farmers to use climate information consistently in making cropping decisions, and local authorities on how to mobilize the resources needed to support farmers in implementing their decisions. Figure 6.5 shows the income difference between farmers that use and do not use SOI information in Indonesia. Farmers who normally plant rice twice a year, in the wet and dry season, get higher income in the long term if they switch their second crop to non-rice (May planting) whenever April SOI Phase is 1 or 3.

While innovative risk-sharing instruments are being developed and tried in Southeast Asia, experience and expertise of the private sector should be brought in to complement public sector efforts.

Recently, index-based insurance was implemented on a pilot basis in Thailand and Viet Nam. It is thought to reduce moral hazard since payment and actual damage are not directly linked. As the insured party receives a payout irrespective of the losses experienced, the incentive to prevent and mitigate risk is preserved. There is no need for an assessment or verification of actual damage so the transaction costs are lowered and the speed of payout is improved. By basing contracts on publicly available information, the

Figure 6.5. Income Difference Between Farmers that Use and Do Not Use SOI Information



SOI = Southern Oscillation Index, IDR = Indoneasian rupees.
Source: Boer and Surmaini (2006).

Table 6.5. Summary of Index-based Insurance Schemes in Asia

Country	Risk Event	Contract Structure	Index Measure	Target
Bangladesh	Drought	Index insurance linked to lending	Rainfall	Smallholder farmers
China, People's Republic of	Low, intermittent rainfall	Index insurance	Rainfall and storm day count	Smallholder watermelon farmers
India	Drought and flood	Index insurance linked to lending and offered directly to farmers	Rainfall	Smallholder farmers
Mongolia	Large livestock losses due to severe weather	Index insurance with direct sales to herders	Area livestock mortality rate	Nomadic herders
Thailand	Drought	Index insurance linked to lending	Rainfall	Smallholder farmers
Viet Nam	Flooding during rice harvest	Index insurance linked to lending	River level	Smallholder rice farmers; the state agricultural bank

Source: Adapted from OECD (2008).

asymmetries associated with traditional insurance are reduced, encouraging greater participation. Moreover, index insurance will give an incentive for greater measurement of weather patterns and the development of more sophisticated models. While the market for index insurance is currently little developed, further developments are required in order to encourage more extensive participation from the private sector. This type of instrument is an example of mobilizing the resources and experience available in the private sector to supplement government and individual farmers' efforts in adapting to climate change impacts. Table 6.5 summarizes index-based insurance schemes that have been put in place in Thailand, Viet Nam, and other countries in Asia in recent years.

Table 6.6 summarizes key adaptation options in the agriculture sector in Southeast Asian countries indicating the scale of adoption, types, and countries where they are practiced. The most commonly used adaptation measures in the region are adjustment in cropping calendars and patterns,

Table 6.6. Summary of Key Adaptation Options in Agriculture Sector

Practice	Scale	Reactive/Proactive	Planned/Autonomous	Example
Adjustment of cropping calendar and pattern	Local	Reactive	Autonomous	Widely used
Changes in management and farming techniques	Local	Reactive	Autonomous	Widely used
Use of heat-resistant varieties	Local/Sub-regional	Proactive	Autonomous	Widely used
Diversified farming, inter-cropping, crop rotation	Local	Proactive	Autonomous	Widely used
Utilization of SOI in designing cropping strategy	Local/Sub-regional	Proactive	Planned	Indonesia
Implementation of index-based insurance	Local/Regional	Proactive	Planned	Thailand, Viet Nam
Development of early warning systems	Local/Regional	Proactive	Planned	Philippines, Thailand, Viet Nam
Improvement of irrigation efficiency	Local	Reactive	Planned	Viet Nam

SOI = Southern Oscillation Index.
Sources: Boer and Dewi (2008), Cuong (2008), Ho (2008), Jesdapipat (2008), Perez (2008).

changes in management and farming techniques, use of heat-resistant varieties, diversified farming, intercropping and crop rotation, among others. Farm-level adaptation practices are helpful in coping with climate variability, but there is a need for government to strengthen local adaptive capacity by providing public goods and services, such as better climate information, research and development on heat-resistant crop variety and other techniques, early warning systems, and water-efficient irrigation systems. Innovative risk-sharing instruments for the agriculture sector such as index-based insurance schemes are being developed and tried in Southeast Asia, and experience and expertise of the private sector should be brought in to complement the public sector efforts.

E. Adaptation Options and Practices in the Forestry Sector

Forest fires, coupled with rising temperature, have degraded and destroyed biodiversity-rich forest resources in Southeast Asia, which in the past had helped store a substantial amount of carbon.

Southeast Asia has 203 million ha of forestland (as of 2005) representing 5.1% of the total world forest. It has been a major producer of forest products, accounting for 50% of total forest product exports from the Asia and Pacific region (UNESCAP 2006). Many people in the region rely on forests for their livelihoods as well as way of life. For the past several decades, forestlands have been under mounting pressure as more areas are converted to croplands and grasslands to meet the demand for food and raw materials. In addition, forestlands have been affected by increasing temperature, heat stress, and drought, which cause forest fires and consequently loss of tree species and degradation of forests. In turn, deforestation releases CO_2 and reduces the potential for its sequestration.

Early warning systems of dry spells have been established, in parallel with awareness-raising programs, as a means to prevent forest fires.

Forest fires count among the main factors contributing to biodiversity and forest loss in Indonesia and the Philippines, and normally occur during El Niño years. To cope with the fire risk, the provincial government of Central Kalimantan in Indonesia has used climate information to develop an early warning system on the likelihood of fire outbreaks. This system can, 2 or 3 months in advance, inform local government or the communities affected about conditions expected in the coming season, allowing them to prepare for the outbreak of fires. In a season where a prolonged dry spell is expected, the local government warns farmers not to engage in burning to clear land. To encourage farmers to follow instructions, local governments have established an incentive system to reduce fire activity in high-risk years. Similar early warning systems, together with awareness-raising programs, adjustment in silvicultural treatment, and construction of fire barriers, have also been planned in other parts of the region, including the Philippines and Viet Nam.

Aggressive plans for reforestation and afforestation are being implemented to substitute forest resources damaged by climate change and extreme events.

Thailand has already felt the impact of forest loss, mainly due to unpredictable rainfall, more frequent and prolonged droughts, flash floods, as well as hotter summer days and nights. This is crucial because forests in Thailand also have important ecological functions, especially in regard to water regulation and microclimate. A number of reforestation and afforestation projects have already been implemented. Efforts have also been made to monitor changes that are taking place. For example, the Sakaerat station in the eastern forest complex has long been used as a monitoring station, the data used in studies of forest change and the carbon cycle. In Viet Nam, major national programs for forestation, reforestation, and improved forest management have been developed. In 1993, the government of Viet Nam commenced Program 327 for the period 1993—2000, which aimed to create forest on open treeless hills throughout the country. In 1998, the National Assembly agreed to adopt an ambitious 5-Million hectare Reforestation Program for the period 1998–2010, the main objective being to increase forest cover to 43% by 2010. Forest coverage in Viet Nam increased from 27.8% in 1990, to 33.2% in 2000, and to 37.3% in 2004.

Table 6.7 summarizes key adaptation options in the forestry sector in Southeast Asia, indicating the scale of adoption, types, and countries where they are practiced. The most common adaptation practices are reforestation, afforestation, and improved forest management; establishment of early warning systems; use of appropriate silvicultural practices; awareness-raising regarding forest fire prevention; and monitoring of degraded forests. Early warning systems and awareness-raising programs should be enhanced for the communities to better prepare for potentially more frequent forest fires as a result of climate change. Furthermore, aggressive public-private partnerships for reforestation and afforestation should be pursued to offset forest and biodiversity losses due to the adverse effects of climate change and extreme climatic events.

Table 6.7. Summary of Key Adaptation Options in Forestry Sector

Practice	Reduced Impact	Scale	Reactive/ Proactive	Planned/ Autonomous	Example
Reforestation, afforestation, improved forest management	Forest degradation, biodiversity loss	Local/Sub-regional	Reactive	Planned/ autonomous	Widely used
Establishment of early warning system	Forest fire	Regional	Proactive	Planned	Indonesia, Philippines, Viet Nam
Use of appropriate silvicultural practices	Forest fire	Regional/ National	Reactive	Autonomous	Philippines, Viet Nam
Awareness-raising regarding forest fire prevention among communities	Forest fire	Regional/ National	Proactive	Planned	Indonesia, Philippines, Viet Nam
Monitoring of degraded forests	Forest degradation, biodiversity loss	Regional/ National	Proactive	Planned	Thailand

Sources: Boer and Dewi (2008), Cuong (2008), Ho (2008), Jesdapipat (2008), Perez (2008).

F. Adaptation Options and Practices in the Coastal and Marine Resources Sector

Coastal regions are an important source of development, and the risk of sea level rise and occurrence of extreme events, if not managed, could result in catastrophic impacts.

The region's coastlines provide rich marine ecosystems and economic activity. A large percentage of the population lives in coastal areas and many depend for their livelihoods on coastal and marine resources. But recently, climate change has brought adverse impacts to the region's coastal and marine resources. Increasing temperatures have bleached coral reefs; rising sea levels have caused massive coastal erosion, destruction of mangrove plantations, and flooding in many areas including major cities near the coast. Rising sea levels have also affected many aquaculture industries and caused saltwater intrusion of inland freshwater and aquifer resources. Future climate change will intensify these impacts and potentially jeopardize the development of parts of the region.

Mangrove conservation and plantation are highly effective in reducing the impact of tropical storms and cyclones. Co-benefits are substantial, including ecosystem services on which local communities depend.

Coastal mangrove plantation or conservation is a highly effective form of coastal protection. For example, restored mangroves in the Kien Thuy District, Thai Binh province of northern Viet Nam reduced a four–meter storm surge in 2005 to a 0.5–meter wave, causing no harm in the area. Establishment of mangrove forests in the coastal zone is essential to upgrading the coastal protection system and preparing for the more severe impacts of climate change in the future. At the same time, mangrove plantations increase the amount of habitat for various plant and animal species and also help diversify the livelihoods of local communities by providing other business opportunities, such as fisheries.

Box 6.3 Mangrove Reforestation in Southern Thailand

Mangrove forests are located in 23 coastal provinces in Thailand. These forests used to cover 368,000 ha in 1961, but dropped to 240,000 ha by 2002. The major causes of the loss of mangrove forests are timber and charcoal industries, and conversion of some areas for urbanization, agriculture, and aquaculture especially shrimp farming. In 2004, a 5-year Action Plan for Mangrove Management in the Gulf of Thailand was established to preserve mangrove forests as well as to promote the sustainable use of mangrove resources.

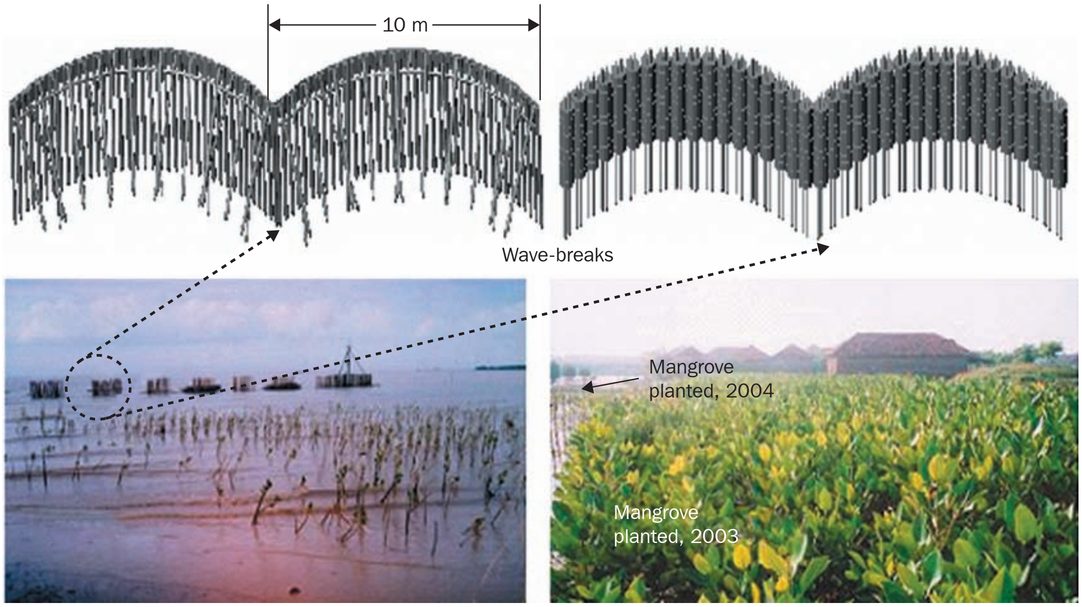
Following the 2004 tsunami, many local communities became interested in mangrove reforestation as protection against disasters such as storm surges. The Department of Marine and Coastal Resources established a program to conserve and rehabilitate mangrove forests. Four mangrove development stations located in Trang support the program's activities, including reforesting and maintaining mangroves by:

- Providing training to
  - build capacity for community forestry management and volunteer network
  - increase partnerships between the local community, government, and nongovernment organizations
  - reduce illegal wood harvesting and land cultivation
- Setting up mangrove protection zones.

The community mangroves operate with established rules. For example, wood cannot be taken from protected areas (violators are fined 5,000–10,000 baht, or $125–250, depending on the amount taken). Only villagers who participate in conservation activities are allowed to present requests to the local committee. However, locals are allowed to catch small aquatic animals such as fish and crabs. So far, the mangrove protection zones cover approximately 2,240 ha and provide habitats to protect and increase biodiversity. The community nurseries have produced 225,000 mangrove seedlings, which serve government and nongovernment organization plantation activities and provide plants for reforestation. Families are able to supplement their incomes by catching and selling aquatic animals in the mangrove areas. The average household income from this activity ranges from 20,000 to 66,000 baht ($500–1,650) per year per household. Households also earn income from gathering charcoal, fuelwood, medicinal plants, tree bark for tanning production, and honey.

Source: Jesdapipat (2008).

Figure 6.6. Wave Break to Protect Mangrove Seedling from Big Waves



Source: Directorate of Disaster Mitigation and Environmental Pollution, Ministry of Marine and Fishery (2007).

Box 6.4. Albay in Action on Climate Change

Agenda

The province of Albay in the Philippines is highly exposed to various climate risks such as tropical cyclones and storm surges. This could worsen as a result of climate change. Having communities along the coastline and in the uplands, Albay must be prepared to meet these challenges to the environment and to their livelihood. Albay needs to develop strategies to adapt to the threat of climate change.

Strategy: Provincial Disaster Risk Management Approach

Albay is the only province in the Bicol region with an operational management office that has successfully implemented sustainable disaster management programs. In July 1994, the Albay Provincial Safety and Emergency Management Office was created by virtue of Sanguniang Panlalawigan Resolution No. 155-94. The Office is an independent department that serves as the technical secretariat and administrative arm of the Provincial Government of Albay (PGA) in terms of public safety and disaster management. The PGA is implementing a pioneering prototype for local climate change adaptation called the "Albay in Action on Climate Change (A2C2)" that aims to embed disaster risk reduction and to enforce climate-proofing and disaster-proofing practices.

Components

The A2C2 program has three major components:

- Policies: The provincial legislative board has passed several resolutions in support of the province's agenda on mainstreaming climate change adaptation through local government action, an example of which is SP Ordinance 2007-51: Updating and Review of the Comprehensive Land Use Plan for disaster risk reduction and climate change adaptation.
- Programs and Projects: The PGA, having proclaimed climate change adaptation as a governing policy, has created various programs and projects involving stakeholders that in one way or another help address climate change.
  - The LINIS KALOG or the Linis Kanal at Ilog (clean-up of rivers and creeks) aims to promote environmental conservation and at the same time function as a "food for work" program for river cleanup in two cities and one municipality (Legazpi and Tabaco City, Ligao City, Daraga and Polangui).

Box 6.4. *continued.*

Box 6.4. *continued.*

— The Albay Integrated Agricultural Rehabilitation Program establishes farm clusters to assist farmers.

Achievements

The PGA spearheaded the first-ever "National Conference on Climate Change Adaptation" in October 2007. A key output of the conference was the "Albay Declaration on Climate Change Adaptation" mainstreaming climate change into local and national development policies. The declaration has the following major resolutions: (a) prioritizing climate change adaptation in local and national policies; promoting "climate-proofing" development; (b) advocating the creation of oversight bodies in the government; (c) mainstreaming climate change adaptation through local and regional partnerships for sustainable development; (d) information, education, communication, and research and development; (e) sourcing funds for activities and programs that will directly benefit local communities; and (f) promoting environmentally sustainable practices.

- The Barangay Level Composting project aims to reduce the volume of garbage dumped at landfills by processing compost into organic fertilizer, thus reducing methane emissions from agricultural lands.
- The establishment of 10 ha of mangrove plantations in the coastal areas of Manito, Albay aims to adapt to the impact of storm surges. The P30,000/ha ($638/ha) project is in partnership with the Philippine National Oil Company-Energy Development Corporation and Department of Environment and Natural Resources.
- The implementation of watershed management seeks to adapt to the impact of heavy rain on soils.

Source: Provincial Government of Albay (2008).

Thailand also has an aggressive plan for mangrove plantations as part of its national strategy for reforestation and afforestation (Box 6.3). Indonesia has planted mangroves further into the sea to create wave breaks and to allow mangrove invasion toward the sea (Figure 6.6). A local initiative is being undertaken in the province of Albay in the Philippines. The Albay in Action on Climate Change, or A2C2 project, was established for mangrove plantations in the coastal areas of Albay to adapt to the impact of storm surges (Box 6.4). Similarly the Government of Indonesia has set a target to protect 10 million ha of marine area by 2010 and 20 million ha by 2020 and is planting mangroves in coastal areas to safeguard against the impact of climate change.

Upgrading existing coastal prevention infrastructure such as dikes, sea walls, and revetments prevents further damage from rising sea levels.

Countries in the region have constructed dikes, sea walls, and revetments to prevent coastal erosion and saline water intrusion. However, in the face of sea level rise, this infrastructure will have to be strengthened and upgraded. The Government of Singapore plans to strengthen and reinforce existing revetments while natural areas such as mangroves will be protected using coastal defense systems. Viet Nam is particularly at risk of sea level rise. It is estimated that a total of 2,700 km of sea and estuary dikes need to be upgraded with design standards that specify a height increase of 1.5–2.0 meters in the north, 1.0–1.5 meters in the south, and 0.3–1.0 meters in the central provinces. In the Mekong Delta, in order to protect crops against early floods, some 3,300 km of ring embankments need to be raised to about 0.5 meters (Cuong 2008).

The case of Bang Khun Thian District in Bangkok is a good example of the erosion that threatens coastal areas of Thailand. As adaptation measures, farmers built stone walls, bamboo revetments, and breakwaters; reconstructed some parts of the pond walls/breakwaters; and abandoned their water gates

Box 6.5. Adaptation Strategies on Coastal Erosion and Flooding in Thailand: A Case Study of Bang Khun Thian District, Bangkok

Current Situation

Bang Khun Thian is the only district of Bangkok province that is located on the coast, with a coastline stretching up to 4.7 km. The subdistrict area of Ta Kam is the nearest to the sea and has about 38,000 residents, most of whom rely on aquaculture of shrimp and cockles for livelihood. Over the past 3 decades, studies have shown that more than 500 meters of the Bang Khun Thian coast have already been eroded. The level of erosion has been equal to a loss of about 400 hectares of land in total. Most severe erosion is experienced around the mouth of the canal. Based on analysis of aerial photography taken between 1952 and 1991, the rate of erosion was approximately 7–12 meters per year at the beginning of the period, and increased to 33.1 meters per year in 1987—1991 (Isaraporn 2001). Further analysis revealed that the retreat of the coast was accompanied by a significant change in the shape of the coastline, from being regular and smooth to very irregular (Winterwerp et al. 2005). Coastal erosion in Bang Khun Thian district is the result of a decrease in sediment yield, natural land subsidence, rising sea level, and impact of waves and storms (Winterwerp et al. 2005, Thanawat 2006, Isaraporn 2001). Clear evidence of the seriousness of the situation can be seen in the deserted old water gates, which were once part of farmers' shrimp ponds. In recent years, aquaculture ponds have retreated further inland.

Future Scenario

Thanawat (2006) estimates that the sea level in the upper Gulf of Thailand will rise by 10–100 cm in the next 50 years. When the effects of land subsidence are integrated into the calculation, the coastal area is projected to be inundated up to 6–8 km inland from the current shoreline during the next 100 years.

Adaptation Strategies

Aquaculturists in Bang Khun Thian district have been trying to help the local community protect their shrimp ponds for more than 30 years. Surveys revealed that households have responded autonomously to the situation so that they can cope with coastal erosion. The households used three types of adaptation measure:

(i) Protection Strategies — These make use of stone breakwaters, bamboo revetments, and heightening of dikes (see figures below) to protect the coast against erosion.
(ii) Accommodation – Farmers have rebuilt/renovated their existing coastal protection in order to avoid the impacts of coastal erosion or flooding.
(iii) Retreat — Farmers have abandoned their old water gates and built new ones further inland.

(a) stone

(b) bamboo

(c) breakwaters

Cost of Adaptation

From 1993 to 2007, aquaculture farmers in Bang Khu Thian already spent an accumulated $117,420 to protect their farms against coastal erosion and flooding. The annual adaptation cost ranges from $163 to as high as $8,387 per household, or a mean annual adaptation cost of $3,130 per household, 23% of annual household income.

Source: Rawadee and Areeya (2008).

when they were covered by water. Details of these measures, including the estimated cost of adaptation are given in Box 6.5.

Design of houses, buildings, and development areas has been adjusted to cope with climate change, and future planning will have to take into account potential climate risks.

Inundation of coastal areas during the spring tide has affected large coastal areas of Indonesia. It has caused damage to infrastructure, including roads and railways, which impacts on the country's economy (Boer et al. 2007). The impact of inundation has been amplified by subsiding coastal land, as observed in a number of cities in Indonesia. To cope with future threats, the Ministry of Marine and Fishery has introduced a new housing design for coastal areas (Figure 6.7), which raises houses 160 cm above the ground (Dit. Mitigasi Bencana dan Pencemaran Lingkungan 2007).

The Philippines, as an archipelago, has 17,000 km of coastline that is home to rich and diverse coastal and marine resources. These resources are already under threat due to climate change. Sea level rise has caused seawater intrusion into freshwater and groundwater resources, flooding and erosion of coastal areas, bleaching of coral reefs, and destruction of mangrove forests. Rising sea levels could increase storm surges, tsunami damage, and land subsidence. The projected impact of a 1 meter sea level rise is that it would cause vast inundation of many coastal settlements in Luzon, such as in Cavite, Metro Manila, and Bulacan (Perez et al. 1999). Tropical cyclones could exacerbate the impact of sea level rise with its strong winds and heavy rain, which have caused massive flooding in coastal settlements. A typhoon-resistant housing project was implemented to enhance the adaptive capacity of those living in typhoon-prone areas (see Box 6.6). A number of capacity building programs have been proposed to support adaptation measures (Table 6.8).

In Viet Nam, new lands for special industrial areas will be raised above danger levels, involving 1,800 ha at an estimated cost of $72 million. In the Mekong Delta and some central coast locations, raising houses rather than constructing new dikes is preferred as it costs less. The total number of hectares considered for priority attention for raising houses is 128,550

Figure 6.7. New Housing Design in Coastal Areas in Indonesia

Source: Directorate of Disaster Mitigation and Environmental Pollution, Ministry of Marine and Fishery (2007).

Box 6.6. Typhoon-Resistant Housing in the Philippines

After Typhoon Sisang in 1987, which completely destroyed over 200,000 homes, the Department of Social Welfare and Development instigated a program of providing typhoon-resistant housing for those living in the most typhoon-prone areas.

Core shelter houses are designed to withstand windspeeds of 180 km/h and have the following typhoon- resistant features:

- anchorage tying the roof to the ground through cement footings to achieve continuity
- a four-sided roof design strengthened by roof trusses
- extra bracing and anchoring on walls and ceilings to ensure stability

The shelter itself is quite small, measuring 3 x 3.5 m. There are four wooden corner posts attached to concrete pedestals partially sunk in the ground, and four wooden side posts situated midway on each wall, similarly attached to concrete pedestals partially sunk in the ground. These firm footings, together with secure anchorage of the superstructure, help to ensure that the dwelling remains firm during typhoons. Costs are kept down by using cheap, locally available materials for roofing, walling, and flooring, since these units are not essential to the wind resistance of the dwelling.

An essential aspect of the design is that it should be easy to understand and build. It is thus acceptable to local people who can be trained in the simple construction methods. The technology can be easily transferred without the need for lengthy and complicated training courses. All aspects of the house design and appearance, apart from the essential design aspects relating to wind resistance, are left to the individual beneficiaries to develop as they wish.

Source: Perez (2008).

Table 6.8. Measures to Enhance Adaptive Capacity of the Coastal Sector in the Philippines

Adaptation Measures	Capacity-Enhancing Measures
• Modification of setback policies to address climate change/sea level rise • Conduct research studies on salt water intrusion, fisheries and aquaculture • Strengthening of the Disaster Management Program • Improved typhoon warning system • Flood prevention/protection • Shoreline stabilization/preparation of hazard and vulnerability maps to floods and to probable sea level rise • Stop further conversion of mangroves for fishpond development • Putting in place Integrated Coastal Management and expansion of Coastal Environment Program • Massive upland and coastal reforestation, including the expansion of community-based mangrove reforestation program • Information, education and communication, awareness program • Monitoring sea level rise and climatological data: Tidal gauge stations vs. indigenous methods • Installation of Geographical Information System	• People empowerment in the management of coastal resources • Inventory and survey of coastal resources • Provincial environmental and natural resource accounting • Requirement of industries to install desalination facilities for water sources, instead of groundwater withdrawal • Regulation of installation of water pumping systems • Expansion of coverage for artificial reefs, marine sanctuary, marine reserves • Strengthening coordination between Department of Environment and Natural Resources and local government units • Appropriate land use and zoning • Strict monitoring and enforcement of mining laws (sand and corals) and other coastal management policies, laws and regulations • Formulation of comprehensive coastal development plan • Develop/improve watershed management, including identifying and developing potable water sources • Reactivate/re-orient Environment and Natural Resources Committee in the coastal municipalities • Implementation of Poverty Alleviation Program • Strengthening/enhancement of integrated waste management program, including adoption of coastal clean-up movements • Provision of alternative livelihood and resettlement program

Source: Perez (2003).

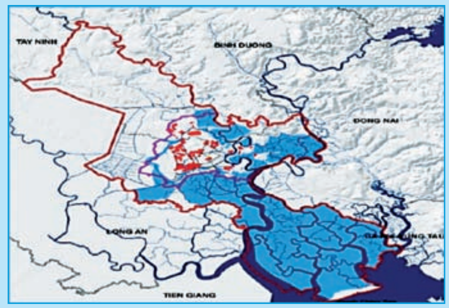
Box 6.7 *continued.*

Box 6.7. Cost of Adaptation to Sea Level Rise in Ho Chi Minh City

Ho Chi Minh City (HCMC) has been shaped and defined by climate and water (Box Figure 6.1). The city is located just above the mouth of Viet Nam's third largest river basin, the Dong Nai, which spreads out across a delta of complex channels and mangrove forests. A significant part of HCMC is regularly flooded due to a combination of tides, storm surges, rains, floods, and manmade structures (Box Figure 6.2).

Box Figure 6.1. HCMC, Viet Nam

Box Figure 6.2 Areas Frequently Flooded in HCMC



Impact analysis showed that the impacts of climate change are likely to affect a large part of the HCMC population. The poor will be affected more by flooding given the poorer environmental conditions and infrastructure. The close association between social marginalization of the poor and geographical marginalization compound their vulnerability.

Valuing the Cost of Climate Change Impacts: Infrastructure

The indicative overall infrastructure value at risk is around 1,130 billion Viet Namese dong (VND) ($71 million). But this estimate only considers the risk to hospitals, electricity substations, and road intersections and would substantially increase with the consideration of a wider range of infrastructure.

Land Values

For areas affected by minor flooding, land values are quite large, in excess of VND140,000 trillion ($8.75 trillion) for regular flooding and VND200,000 trillion ($12.5 trillion) in extreme events—values exceeding national nominal gross domestic product. For more serious flooding, land values at risk would range from VND500 trillion ($31.25 billion) to VND710 trillion ($44 billion). But the figures are quite high and may suggest that land values are overestimated.

Cost of Adaptation Measures

In November 2008, the HCMC government committed to spend $750 million on a new flood defense system that will enclose much of the city with dikes. The design considered sea level rise (70 cm by 2010) and once-in-30-years storm events. However, the dike and drainage system failed to take account of two climate change parameters that the HCMC study found to be the most influential in flooding: heavy monsoon rains and storm surge.

Adaptation Options

Adaptation for each sector and each area will involve a combination of the following:

- Engineering options (dikes and drainage systems)
- Social responses (including resettlement and "autonomous" actions of commitments)
- Land use planning (zoning and development controls)
- Economic instruments (subsidies and tax incentives)

continued.

- Natural systems management (rehabilitation, natural flood areas)
- Agricultural practices (adjustment of species and regimes)

Principles for HCMC Adaptation

Based on the study, a number of principles can guide HCMC's adaptation to climate change, including:

- Build on experience in natural disaster response
- Rehabilitate and maintain natural flexibility and resilience in city design
- Promote autonomous responses among communities
- Maintain and enhance natural systems
- Maintain and enhance biodiversity for greater stability and resilience
- Keep rivers and canals free-flowing and clean
- Ensure that the poor would not be worse off with climate change
- Locate strategic infrastructure away from vulnerable areas
- Locate sensitive industrial and commercial functions away from vulnerable areas
- Adapt at every level

Source: ADB (2009).

ha (1.3 million homes) with an estimated cost of $4.7 billion (Cuong 2008). Details of adaptation plans to prevent flooding in Ho Chi Minh city are given in Box 6.7.

Table 6.9 summarizes key adaptation options in the coastal and marine resources sector in Southeast Asia indicating the scale of adoption, types, and countries where they are practiced. The common adaptation practices are mangrove conservation and plantation; strengthening and reinforcing existing revetments, dikes, and sea walls; relocation of aquaculture farms, and coastal infrastructure; better design and standards for construction of houses and industrial areas; provision of information and awareness-raising programs; monitoring of sea level rise; pumping to relieve flooding; and preparation of hazard and vulnerability maps. The implementation of these adaptation measures in the region is still scattered, and there is a need for integrated coastal zone management plans that take into account future climate risks and vulnerabilities. Mangrove conservation and plantation are highly effective in reducing the impact of tropical storms and cyclones and this adaptation practice has to be sustained in the future. The co-benefits from this are substantial in terms of ecosystem services and livelihoods on which local communities depend.

Table 6.9. Summary of Key Adaptation Options in Coastal and Marine Resources Sector

Practice	Reduced Impact	Scale	Reactive/ Proactive	Planned/ Autonomous	Beneficiary Sector	Example
Mangrove conservation and plantation	Storms, cyclones, coastal erosion	Local	Reactive	Planned/ Autonomous	Agriculture, Forestry Household	Widely used
Strengthening and reinforcing existing revetments, dikes, sea walls, etc.	Sea level rise, coastal erosion	Regional	Reactive	Planned	Agriculture, Household, Industry	Widely used
Relocation of aquaculture farms, coastal infrastructure	Sea level rise	Local	Reactive	Autonomous	Agriculture	Thailand, Viet Nam
Better design and standard for construction of houses, industrial areas, and infrastructure	Storms, cyclones, coastal erosion	Local/ Sub-regional	Proactive	Planned/ Autonomous	Household, Industry	Indonesia, Viet Nam
Provision of information and awareness, raising program	Storms, cyclones, coastal erosion, sea-level rise	Regional/ National	Proactive	Planned	Agriculture, Household, Industry	Philippines
Monitoring sea level rise	Sea level rise	Regional/ National	Proactive	Planned	Agriculture, Household, Industry	Thailand
Pumping to relieve flooding	Storms, cyclones	Local	Reactive	Autonomous	Agriculture, Household	Viet Nam
Preparation of hazard and vulnerability maps	Storms, cyclones,	Local/ Sub-regional	Proactive	Planned	Agriculture, Household	Philippines

Sources: Boer and Dewi (2008), Cuong (2008), Ho (2008), Jesdapipat (2008), Perez (2008).

G. Adaptation Options and Practices in the Health Sector

A number of reactive measures exist in the health sector, but a more proactive approach, such as an early warning system, improved surveillance, and awareness-raising programs are necessary

Adoption of adaptation measures to vector-borne disease carried by mosquitoes, such as dengue, are under way in the region. For instance, the Ministry of Health in Thailand campaigns to control dengue. Advice on control and avoidance measures is passed on to villagers via health workers, village leaders, and the media. Some good housekeeping measures such as regular emptying of all refuse containers and avoiding direct exposure to mosquitoes are being implemented. However, more proactive and aggressive policy initiatives require better information. Box 6.8 describes an innovative preventative approach to dengue fever as piloted in Viet Nam. Most programs to manage these diseases in Indonesia are reactive rather than proactive. Nevertheless, efforts have been made to develop an early warning system for disease outbreaks by looking at patterns in climate data (Sukowati 2004, Sasmito et al. 2006, Sintorini 2006). This system is expected to assist local health officers in setting up anticipatory management of possible disease outbreaks. However, up to now, such systems remain rudimentary and their potential has not yet been fully utilized.

Table 6.10 summarizes key adaptation options in the health sector in Southeast Asia indicating the scale of adoption, types, and areas where they

Table 6.10. Summary of Key Adaptation Options in Health Sector

Practice	Scale	Reactive/ Proactive	Planned/ Autonomous	Example
Coordination with other groups	Local/Sub-regional	Reactive	Autonomous	Widely used
Rebuilding and maintaining public health infrastructure	Local	Reactive	Planned/ Autonomous	Widely used
Establish green, clean, and beautiful areas	Local	Reactive	Autonomous	Widely used
Enhancing short-range and long-range forecasting and warning systems and improved surveillance (e.g., risk indicators, infectious disease outbreaks, etc.)	Local/Sub-regional	Proactive	Planned	Used in some countries in the region
Education and awareness (public information drive, capacity building)	Local/Sub-regional	Proactive	Planned	Widely used
Enhanced infectious disease control programs (vaccines, vector control, case detection and treatment)	Local/Sub-regional	Proactive	Planned	Widely used
Disaster preparedness (climate-proofed housing design; etc.)	Local/Sub-regional	Proactive	Planned	Used in some countries in the region

Sources: Boer and Dewi (2008), Cuong (2008), Ho (2008), Jesdapipat (2008), Perez (2008).

Box 6.8. Dengue Fever Prevention in Viet Nam: Using Mesocyclops to Combat the Larvae of *Aegis aegyptiaca*

Dengue fever is a potentially lethal vector-borne disease affecting 50 million people worldwide annually. The major global vector for dengue fever is the container-breeding mosquito, *Aedes aegypti*, which breeds predominantly in urban areas in tropical regions. The mosquitoes prosper in poor, densely inhabited areas that lack adequate water infrastructure. In such areas, water is often stored in standing containers, which provide an optimal breeding site for dengue mosquitoes. The A. aegypti mosquito is particularly susceptible to climatic changes. Future patterns of distribution are thus likely to change and potentially vulnerable communities need to be aware of preventive measures.

In order to control dengue fever, it is necessary to concentrate on preventing of the breeding of *A. aegypti* in water containers. There are various measures to do this, such as covering the containers adequately or introducing chemical insecticides. However, such measures have been inadequate to reduce breeding on a larger scale. A novel solution has been tested in Viet Nam by Brian Kay and Vu Sinh Nam. The method involves introducing a local predatory crustacean species, the mesocyclops, into the infected water containers. The mesocyclops, once introduced, eat the *A. aegyptis* larvae, effectively destroying the population. The project was implemented between 1998 and 2003 in cooperation with national, regional, local, and communal health officials in 10 Vietnamese provinces. The strategy has apparently succeeded in eliminating the *A. aegypti* larvae almost completely in the test communities, and has later been adopted by the Government of Viet Nam in its national dengue fever mitigation program.

An important dimension of the implementation was the mobilization of communal human resources for performing the various stages of implementation. Communal health workers, health collaborators, as well as school teachers and pupils participated in the implementation by monitoring, promoting awareness of the method, distributing the mesocyclops, and organizing periodic clean-up campaigns as well as various other activities. The project was funded and supported by the Australian Foundation of Peoples of Asia and the Pacific, Queensland Institute of Medical Research, Queensland University of Technology, and the Vietnamese National Institute of Hygiene and Epidemiology. Different species of cyclopodes are generally predacious to *A. aegyptis* larvae and have been used in other similar projects, for example, in Australia, Japan, and French Polynesia. Various other biological agents, such as the Wolbechia bacteria, can be introduced to reduce *A. aegyptis* populations.

Source: UNFCCC (2007).

are practiced. A number of reactive adaptation measures exist, including rebuilding and maintaining of public health infrastructure, coordination with relevant organizations, and establishing green and clean areas. However, a more proactive approach, such as establishment of early warning systems for disease outbreaks, health surveillance, awareness-raising campaigns, and infectious disease control programs, has to be adopted or extended to better deal with the health impacts of climate change.

Other sectors where adaptation actions are needed but less attention has been devoted in many Southeast Asian countries are hydropower, building, and tourism. Efforts have to be advanced in these sectors to develop links and synergies with adaptation actions. For instance, on tourism, climate change is likely to have serious negative impact on economies. At risk are the region's efforts to develop and implement sustainable tourism while promoting wildlife conservation and protecting biodiversity.

H. Conclusion

Adaptation should be seen as part of the region's sustainable development strategy. Southeast Asian countries have already made significant efforts to implement adaptation measures to minimize the impacts of climate change. However, most adaptation measures implemented to date have been reactive rather than proactive, autonomous rather than well-planned, and largely developed to address climate variability rather than climate change. The current level of adaptation is still inadequate to cope with the future challenge of climate change. Only few countries have developed adaptation plans while others are still in the process of finalizing them; and despite the urgent need, many countries lack the resources and the financial capacity to do them on their own. The region has recognized the importance of monitoring climate change, but the efforts made so far are still inadequate to enable proper, long–term planning.

Adaptation has always occurred in response to changes in climatic conditions. However, adaptation by private agents will have to be bolstered by government support in a variety of ways, if countries and regions are to rise to the challenge of climate change. Governments have a specific role in establishing the policy framework to encourage adaptation by private individuals, households and firms, in particular by addressing information uncertainties, conducting effective land use planning, ensuring that major planning and public sector investment decisions take into account climate change, and aligning incentives for private agents with broader social costs and benefits.

Finally, mal-adaptations should also be considered in dealing with adaptation measures. These are measures that do not succeed in reducing vulnerability but increase it instead. Adaptation could be successful at a specific spatial or temporal scale but could become mal-adaptation at a different spatial and temporal scale. For example, the construction of a reservoir or hydro power station in upstream areas to enhance adaptive capacity of communities often leads to suffering of communities downstream. This issue could be important, particularly in areas that involve regional cooperation such as water resources, and coastal and marine resources.

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PART III

Climate Change Mitigation

CHAPTER 7

Climate Change Mitigation Options and Practices

Key Messages

Southeast Asia contributed 12% of the world's total greenhouse gase (GHG) emissions in 2000, an increase of 27% over 1990, twice as fast as the global average rate of increase.

Emissions from the land use change and forestry (LUCF) sector were 75% of the total, energy 15%, and agriculture 8%. Emissions rose fastest in the energy sector (83% during 1990—2000), while about 59% of total emissions came from Indonesia, largely from LUCF.

As the largest source of emissions, the region's forestry sector holds the key to the success of mitigation efforts, and has great potential to sequester carbon through reduced emissions from deforestation and degradation (REDD), afforestation and reforestation, and forest management.

Southeast Asia also has great potential for reducing GHG emissions in the energy sector, through such things as energy efficiency improvements in buildings and industry; by harnessing renewable resources, including biomass, solar, wind, geothermal resources; and by using more efficient and cleaner transport.

Southeast Asia has the highest technical mitigation potential to reduce GHG emissions from agriculture of any region. Its vast area of croplands, through cropland management, could be an important area for sequestering carbon in soils. As a major world rice producer, the region could also contribute to a reduction of methane emissions while ensuring food security.

GHG mitigation has been high on Southeast Asia's climate change policy agenda. Given its high stake in preventing further global warming, the region should make greater effort at mitigation. There is a need for more action to support research and development; provide reliable information and high-quality data; allocate more financial resources; and strengthen international and regional cooperation for funding, technological transfer, and capacity building.

A. Introduction

It is widely agreed that there is a limit to what adaptation can achieve, and that mitigation measures must be undertaken in parallel to prevent GHG concentrations in the atmosphere from reaching dangerous levels. This chapter reviews mitigation measures that have already been implemented in Southeast Asian countries and those that could become feasible in the future.

Mitigation measures focusing on reducing GHG emissions typically require large investment and financial resources. However, mitigation is a global public good. Once implemented, its benefits will be shared by the global population: those who fail to pay for it cannot be excluded from enjoying the benefits, and one person's or one country's enjoyment of the improved climate does not diminish the capacity of other persons or other countries to enjoy it. Markets do not automatically provide the right type and quantity of public goods, because in the absence of public policy there are limited or no returns to private investors for doing so. This, plus the global nature of the problem, means that addressing climate change needs public policy not only at the national level, but more importantly, at the global level. Further, climate change observable now is the result of past emissions, largely by developed countries, raising an important equity issue. These issues will be discussed in Chapter 9.

While the responses of the largest current and future GHG-emitting economies under the United Nations Framework Convention on Climate Change (UNFCCC) hold the key to a successful global solution, Southeast Asian countries should also be an important part. This is because with the rapid pace of economic and population growth the region's GHG emissions are likely to grow further, and because a low-carbon growth path brings significant co-benefits. In the rest of this chapter, section B reports GHG emission levels and their sources in Indonesia, Philippines, Singapore, Thailand, and Viet Nam. Section C reviews the mitigation options and practices of the key sectors in these countries. Section D concludes.

B. Southeast Asia's GHG Emissions

Given the region's rapid economic growth, its GHG emissions have been rising twice as fast as the global average.

In 2000, Southeast Asia contributed 12% of global GHG emissions, amounting to 5,187.2 Mt CO_2-eq, including emissions from LUCF (Table 7.1). The region's total emissions increased 27% during 1990–2000, faster than the global average. On a per capita basis, the region's emissions are considerably higher than the global average, but are still relatively low when compared to developed countries.

Table 7.1. Greenhouse Gas Emissions ($MtCO_2$-eq.)

	1990	1995	2000	World (%)	Per Capita Emission (tons CO_2)	% Increase over 1990
Southeast Asia	4,091.20	4,944.90	5,187.20	12.0	10.2	27
Annex I countries	14,645.10	16,628.20	17,001.90	39.5	13.9	16
World	37,736.20	41,481.80	43,058.20	–	7.2	14

Note: Annex I countries (industrialized countries): Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechtenstein, Lithuania, Luxembourg, Monaco, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, UnitedKingdom, United States of America (based on the United Nations Framework Convention on Climate Change grouping).

Source: CAIT Database (WRI 2008).

The region's land use and forestry sector has been a major source of GHG emissions from the region, contributing 75% of the total in 2000.

The region in 2000 accounted for almost 51% of global LUCF GHG emissions. Sources included the decrease in biomass stocks of forestland through deforestation, logging, fuel wood collection; and the conversion of forestland to other uses such as cropland, grassland or pasture, and settlements (Table 7.2). The energy sector is another key source in the region (15%), including burning of fossil fuels for electricity generation and fuel emissions from transportation. For agriculture (8%), emissions come chiefly from livestock production, rice cultivation, use of nitrogen fertilizer, and burning of agricultural residues.

Table 7.2. Global GHG Emissions by Sector in 2000 ($MtCO_2$-eq.)

Sector	Southeast Asia	Annex 1 Countries	World
Energy	791.8	14,728.1	2,6980.4
Industrial process	50.8	628.6	1,369.4
Agriculture	407.0	1,445.8	5,729.3
Land use change and forestry	3,861.0	-274.0	7,618.6
Waste	76.6	473.4	1,360.5
Total	5,187.2	17,001.9	43,058.2

Source: CAIT Database (WRI 2008).

Southeast Asia's GHG emissions from the energy sector increased by 83% during 1990—2000, the highest among the major emission sources.

Greenhouse gas emissions from the energy sector have increased significantly since 1990 (Table 7.3), and are expected to continue increasing rapidly as the region's demand for energy and food grows and as the region seeks to maintain high growth through industrialization. Agriculture-related emissions increased by a more modest 21% during 1990—2000, while total emissions from the LUCF sector increased 19%.

Table 7.3. Trend of GHG Emissions in Southeast Asia ($MtCO_2$-eq.)

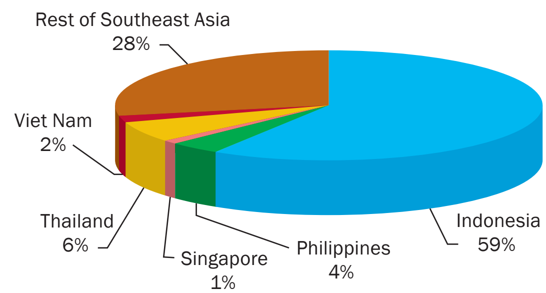
Sector	1990	1995	2000	% Increase over 1990
Energy	432.6	635.5	971.8	83
Industrial process	25.4	46.4	50.8	100
Agriculture	336.7	369.3	407.0	21
Land use change and forestry	3,232.4	3,823.2	3,861.0	19
Waste	64.1	70.5	76.6	20
Total	4,091.2	4,944.9	5,187.2	27

Source: CAIT Database (WRI 2008).

About 59% of Southeast Asia's GHG emissions in 2000 came from Indonesia, mainly due to LUCF emmission.

Covering almost 42% of the region's land area and 40% of its population, Indonesia is the biggest contributors of GHG emissions (Figure 7.1) and is therefore one of the key players in the struggle against the adverse impacts of climate change.

Figure 7.1. GHG Emissions in Southeast Asia



Note: Total GHG emissions = 5,187 MtCO_2-eq.
Source: CAIT Database (WRI 2008).

C. Mitigation Options and Practices

Land Use Change and Forestry

Forests cover about 47% of Southeast Asia's total land area. In terms of sustainable development, the sector is recognized as an important resource base that creates environmental services, including biodiversity, as well as employment and livelihoods. From the perspective of climate change, the sector has two critical functions: as a source of carbon stock and as a carbon absorber. This dual role is crucial to the future development of the region.

Options to reduce GHG emissions or to increase carbon storage in the sector are summarized in Table 7.4. According to Nabuurs et al. (2007), forestry mitigation options include:

- maintaining or increasing the forest area through reduced deforestation and degradation and through afforestation and reforestation;
- maintaining or increasing carbon density (tons of carbon per hectare) through forest management, forest conservation, longer forest rotations, fire management, and protection against insects; and
- increasing off-site carbon stocks in wood products and enhancing product and fuel substitution using forest-derived biomass.

Table 7.4. Mitigation Options for the LUCF Sector in Southeast Asia

Practice	Relative Mitigation Potential (unit of production)	Challenges/Barriers (policy, poverty, knowledge, extension)	Opportunities (feasibility, cost effectiveness, synergy with adaptation)	Co-benefits and Contribution to Sustainable Development
Reducing deforestation and degradation	Could store carbon of about 350–900 tCO_2/ha	Protecting forests could result in maintained or increased forest carbon but may reduce wood and land supply to meet other societal needs	Depending on the cause of deforestation (e.g., timber or fuelwood extraction, conversion to cropland), cost effectiveness analysis can take into account the associated returns from non-forest land use, returns from alternative use of forests, and any incentives that may be given to change land use practices	Improve water and soil quality, enhance biodiversity and wildlife habitat, and improve the aesthetic/amenity value of the area
Afforestation/ Reforestation	Depending on tree species and site, afforestation/ reforestation can sequester carbon in the range of 1–35 tCO_2/ha/year	High initial investment; long payback period	Costs of forest mitigation projects rise significantly when opportunity costs of land are taken into account	Reduce soil erosion, improve water and soil quality, enhance biodiversity and wildlife habitat, and improve the aesthetic/amenity value of the area
Forest management	–	Retaining additional carbon on-site delays revenues from harvest; trade-off in carbon gain due to increased GHG emissions from fertilizer use and drainage	Alternative use of forest and incentives in maintaining forest growth	Reduce soil erosion, improve soil and water quality, and conserve biodiversity
Increasing off-site carbon stocks in wood products and enhancing product and fuel substitution	Using wooden instead of concrete frames can reduce lifecycle net carbon emissions by 110–470 kg CO_2/sqm floor area	In areas of limited supply of wood products, the cost will be restrictive. Also, durability of wood products (e.g., against termites) will pose a challenge	When used as bioenergy to replace fossil fuels, woodfuels can provide sustained carbon benefits; significant carbon sequestration from wood products that displace fossil-fuel intensive construction materials such as concrete, steel, plastic, etc.	Energy conservation through the use of bioenergy

Source: Nabuurs et al. (2007).

There is great potential to sequester carbon through REDD and through afforestation and reforestation.

Increasing carbon storage in existing carbon reservoirs (trees and soils) is highly applicable in the region. This is done by protecting these carbon reservoirs from carbon losses through deforestation, forest and land degradation, urbanization, and other land management practices. Parties to the UNFCCC have recognized the significant amount of emissions coming from deforestation activities and that through REDD, a greater amount of carbon could be stored in the forests with other environmental benefits (Box 7.1).

Box 7.1. Reducing Emissions from Deforestation and Degradation (REDD) in Developing Countries

What is REDD?

REDD was first introduced in the agenda of the Conference of the Parties of the United Nations Framework Convention on Climate Change (UNFCCC) at its 11th session in Montreal (December 2005). Under the UN-sponsored REDD, developed world governments and investors would pay developing countries and their forest stakeholders to not cut down their forests. REDD would offer an alternative revenue stream to those relying on forests for their livelihood. This proposal received wide support, with agreement on its importance in the context of climate change, particularly of the developing countries' large contribution to global GHG emissions from this activity.

Why is REDD important to global mitigation efforts?

The Food and Agriculture Organization (FAO 2005) reports that deforestation—that is, the conversion of forest to other uses such as cropland or grassland—continued at an alarming rate of about 13 million hectares per year from 1990 to 2005. Southeast Asia alone converted 41 million hectares of forest in that period. Forest degradation, on the other hand—unsustainable harvesting and land-use practices such as selective logging, fuelwood gathering, forest fires and other anthropogenic disturbances—have also contributed to a substantial reduction in forest carbon. Deforestation and forest degradation have resulted in the immediate release of carbon from the burning of biomass and decay of organic matter in biomass and soils. IPCC (2007) estimated that deforestation from developing countries alone released about 5.8 $GtCO_2$/year in the 1990s.

Among mitigation options, REDD has the largest and most immediate impact in sequestering carbon (IPCC 2007). In the short term, the carbon mitigation benefits of reduced deforestation are greater than the benefits that could be attained with afforestation. In the longer term, the combined effects of REDD, forest management, agro-forestry and bio-energy have the potential to increase forest carbon from the present to 2030 and beyond. REDD is already getting attention as a low-cost mitigation option with significant positive side-effects (Stern 2007).

REDD Status and Future

The UNFCCC Subsidiary Body for Scientific and Technological Advice has been working on REDD issues related to (i) scientific, socio-economic, technical and methodological issues; and (ii) policy approaches and positive incentives. Its work program will depend on guidance from the Ad Hoc Working Group on Long-term Cooperative Action under the UNFCCC.

Some REDD initiatives in Southeast Asia

Regional:

- The Southeast Asia Indigenous Peoples Regional Consultation on REDD, 9–11 November 2008, Baguio City, Philippines was convened[1] to provide an opportunity for indigenous people (IP) from Myanmar, Cambodia, Indonesia Malaysia, Philippines, Thailand and Viet Nam to discuss the possible impacts and opportunities from these developments, and to develop an IPs REDD strategy for the region. The meeting came up with the following elements to become part of REDD strategy: (i) consider REDD under the framework of human rights; (ii) recognize land tenure and resource rights for IPs, and develop democratic forest governance structures; (iii) empower IPs to participate effectively in REDD by raising awareness, capacity building, consultation, and information sharing.

- The United Nations Reduced Emissions from Deforestation and Forest Degradation Programme (UN-REDD) was launched in September 2008 to be carried out by three UN agencies (including UNDP) with the Government

[1] By the United Nations University – Institute of Advanced Studies (UNU-IAS) and Tebtebba - Indigenous Peoples' International Centre for Policy Research and Education, with the assistance of the David and Lucile Packard Foundation.

Source: http://UNFCCC.int

of Norway financing the $35 million initial phase. Nine countries including Indonesia and Viet Nam have expressed interest. The UN-REDD will support these countries as part of an international move to include REDD in new and more comprehensive UN climate change arrangements to kick-in after 2012.

National:

- In March 2009, Indonesia applied to join the World Bank's Forest Carbon Partnership Facility, which has raised $350 million to support REDD projects and to protect its forest. Indonesia already has more than 20 REDD projects in development, mostly in Kalimantan, Papua, and Sumatra.

The Intergovernmental Panel on Climate Change (IPCC 2007) estimated the potential of Southeast Asia to sequester carbon through avoided deforestation. The relative competitiveness of different regions as a source of carbon sequestration varies with the carbon price (Figure 7.2). A carbon price above $5.4/t$CO_2$ would make Southeast Asia the most competitive source of carbon store in all the regions considered, an advantage that grows as the carbon price increases. A carbon price of $27/t$CO_2$ is sufficiently high to make it financially attractive to halt deforestation in the region. Over 50 years, this would mean a net cumulative sequestration of 278 GtCO_2 relative to the baseline and an additional 422 million ha in forests. The region is projected to have the largest mitigation potential, estimated at 109 GtCO_2 at that carbon price, followed by South America, Africa, and Central America.

Grieg-Gran (2009) studied eight tropical countries that collectively are responsible for 70% of land-use emissions today, including Indonesia, and found the average opportunity costs of avoided deforestation to be in the range of about $1.2 to 6.7/t$CO_2$-eq depending on the scenario under consideration.

At the country level, Makundi and Sathaye (2004) showed that the mitigation potential of Indonesia’s forestry sector by 2012 could reach about 2,670 MtCO_2 (equivalent to 70% of the country’s total projected emissions in that year). This would increase to 9,200 MtCO_2 in 2030 provided the price of carbon is $27.3/t$CO_2$. This could be achieved through aggressive protection of 1.1 million ha of existing forests as well as accelerated forestation covering an additional 30 million ha by 2030. The same study estimated that the mitigation potential for the forestry sector in the Philippines would be about 92 mtCO_2 by 2012; and 280 mtCO_2 by 2030. These numbers will be equivalent to 35% and 77% of the country’s total GHG emissions in 2012 and 2030, respectively.

In the case of mitigation through afforestation and reforestation, a review of the existing studies by IPCC (2007) indicates that, for a carbon price up to $20/t$CO_2$, Southeast Asia is likely to have the potential to mitigate about 300 MtCO_2 per year by 2040, rising to 875 MtCO_2 when the carbon price increases to $100/t$CO_2$.

Southeast Asian countries have already implemented significant measures to sequester carbon in forests.

Many programs have been implemented in the region primarily to protect forests against further degradation and to prevent further loss of biodiversity and wildlife. These also enhance the storage of carbon.

- Indonesia has reduced pressure on its forests by introducing permanent agriculture systems to farmers practicing shift cultivation. It has implemented several land and forest rehabilitation programs such as the afforestation of private community lands, reforestation in highly degraded state forest lands, and introduction of industrial forest plantations in unproductive forests.

- Indonesia has also sought to reforest its degraded mangrove forests. Between 1980 and 2000, the rate of mangrove reforestation was about 2,286 ha per year (Secretariat General of Ministry of Forestry and Estate Crops, as cited in Rosalina et al. 2003). In 2003, the government launched a program known as National Movement for the Rehabilitation of Forests and Lands, aiming to rehabilitate about 5 million ha of forestland by 2009. There were also a number of planting movements conducted by the community, local governments, and the private sector, which by May 2008 had planted about 100 million trees.

- The Philippines' Master Plan for Forestry Development serves as the government's blueprint for managing forest and woodland resources, including the establishment of forest plantations.

- Thailand is also implementing forest protection and reforestation measures for GHG reduction and enhancement of carbon sequestration. Almost every local administration has tree-growing projects for combating climate change. The Bangkok Municipal Authority's signing a memorandum of understanding in 2007 to cooperate with 35 national agencies to combat climate change is a high-profile example.

- In 1998, the Viet Nam National Assembly adopted an ambitious 5 Million Hectare Reforestation Program (5MHRP) that aims to establish and restore 2 million ha of protection forests and 3 million ha of production forests, and to increase the total forest cover to 43% of the country by 2010, while ensuring environmental protection requirements are met. As of 2003, the 5MHRP had achieved the restoration of about 2 million ha, largely protection and special use forests.

These mitigation measures, however, require large investments. The land available for this type of mitigation activity will depend mainly on the price of carbon in the carbon trading market as compared to the financial returns from existing or other land use alternatives. On the other hand, the co-benefits of implementing this type of mitigation are very substantial.

Afforestation and reforestation will improve the quality of the environment, soil erosion and soil degradation will be reduced, and water quality and quantity will be enhanced.

With about 200 million ha of forests (about 5% of the world total) Southeast Asia could contribute significantly to CO_2 emission reduction through forest management.

This mitigation measure can be achieved through introducing forest harvesting systems that maintain partial forest cover, minimize losses of dead organic matter (litter and dead wood), minimize losses of soil carbon by reducing soil erosion, and prevent high-emission activities such as slash and burn farming.

According to the existing studies reviewed by IPCC (2007), for a large part of Asia (including Southeast Asia but excluding non-Annex I countries in East Asia), the mitigation potential of forest management could reach 960 $MtCO_2$ per annum by 2030 at a carbon price up to \$100/tCO_2.

Boer et al. (1999) reported that forest protection in Indonesia, if properly applied, has the potential to sequester carbon in the range of 55–220 tC per ha while reduced logging can store carbon at 49 tC per ha and enrichment planting at 70 tC per ha.

Many countries in the region have been implementing some of these measures to protect their forestland from further degradation. In the Philippines, for instance, the Master Plan for Forestry Development includes a number of forest management activities that support GHG mitigation, including the RUPES Kalahan Project (Box 7.2). This project promotes soil and watershed conservation and forest protection, and enhances community-based forestry activities. The drawback is in the delay in forest revenues due to partial harvesting, which are necessary to provide a form of payment to forest workers for maintaining the forest and to compensate them for their loss in harvest revenue.

Southeast Asia can also reduce GHG emissions from forests by increasing off-site carbon stocks and by enhancing fuel substitution.

This is achievable through harvesting practices that allow the maintenance or increase of forest carbon stocks while meeting the need for fiber, timber, and energy from forest harvesting. In some instances, biomass in the form of wood products can be used in place of fossil fuels, as well as fossil-fuel intensive construction materials such as concrete, steel, aluminum, and plastic. Within the region, the potential benefits from bioenergy technology are considerable, although fairly limited in practice at present. In Indonesia, for example, the use of biomass for generating electricity (bioelectricity) is still in its infancy, but some private sector firms (such as PT. Ajiubaya, a plywood manufacturer in Sumatra) use small (4–6 MW) biomass energy plants. Smaller power plants called bioner, with individual capacities of around 18 kW, have been installed in a number of rural areas in Kalimantan, Sumatra, and North Sulawesi Province (Martono 1998, Ridlo et al. 1998).

Box 7.2. Forest Management as Carbon Mitigation Option: The RUPES Kalahan, Philippines Case Study

Long before the concept of Kyoto Protocol and terms like "carbon sequestration" were popularised in the Philippines, the Ikalahans (literally, "people of the broadleaf forest") practiced conservation measures. The Ikalahans are the indigenous people in the province of Nueva Vizcaya in the northeast of the Philippines belonging to the Kalanguya-Ikalahan tribe, which inhabits the Ikalahan ancestral domain. The domain includes the Kalahan Forest Reserve covering about 38,000 ha in Nueva Vizcaya and about 10,000 ha in Nueva Ecija. For generation after generation, the Ikalahan's indigenous knowledge and environmentally sustainable practice systems have been key in the preservation of the Kalahan Forest Domain and have protected it from deforestation and further land conversion.

Box Figure 7.2.1. Study Area in Kalahan Forest Reserve, Philippines

In 1973, Ikalahan tribal elders organised the Kalahan Educational Foundation Inc. (KEF) to protect communities from possible eviction by land grabbers. Since then, KEF has pioneered and stood as legal representative during the Community-Based Forest Management Agreement with the Philippine government. They promoted Forest Improvement Technology to expedite the growth rate of indigenous trees within the forest to improve carbon sequestration. In 2003, Kalahan was chosen to be the first pilot site in the Philippines for the development of a carbon sequestration payment mechanism. KEF, together with the World Agroforestry Centre developed and implemented the Rewarding Upland Poor for Environmental Services (RUPES) Program aimed to enhance the livelihood and reduce the poverty of the upland poor, while supporting environmental conservation, biodiversity protection, watershed management, and carbon sequestration.

RUPES built on working models of best forest practices of the Ikalahan. The program helped to continue the carbon sequestration study set up by KEF in 1994 and assisted the foundation in examining the rate and extent of the carbon sequestration potential of the Kalahan Forest Reserve. Through RUPES, the local capacity to assess and understand the tools used to measure possible market-based rewards for environmental services were developed and strengthened. Potential buyers were sought within the Kyoto Protocol market after the Philippines ratified the treaty and got the national approval processes working. RUPES Kalahan has also pursued the voluntary market where the rules for generating carbon credits are more negotiable.

In 2002, KEF estimated around 38,383 tons of carbon dioxide were recycled by the Kalahan forests. To date, the KEF is analyzing 1994—2004 data using improved formulas to quantify carbon stocks. Also, forest inventories are being carried out in an area of about 10,000 ha. It is a huge task but the Ikalahans are confident that by the time they finish the project, they will be able to compare the growth rates of three forest types (dipterocarp, pine and oak forests) and the carbon sequestration rates of 15 indigenous tree species.

Five Key Strategies of RUPES Kalahan

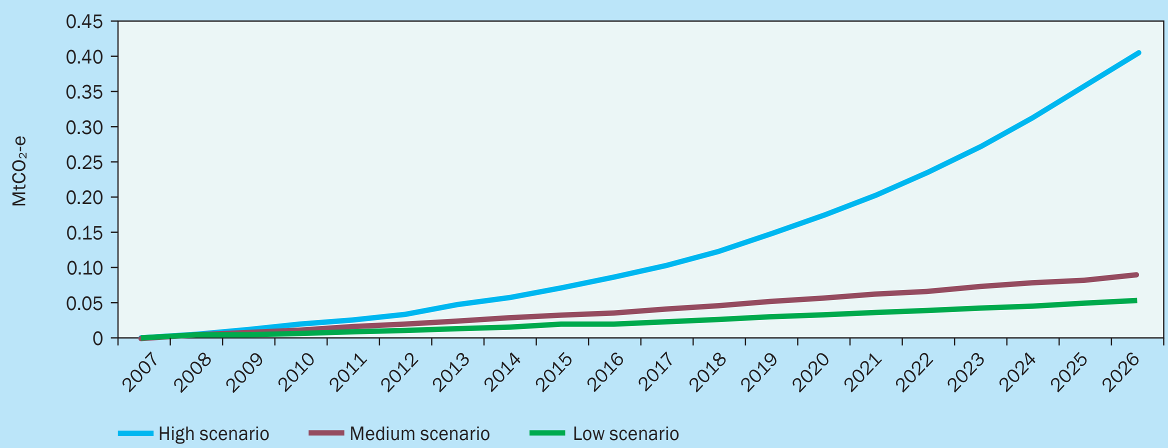
- Quantifying environmental services
- Developing environmental service agreements
- Supporting on enabling policy environment
- Raising awareness on the value of environmental services
- Forming effective partnership

continued

continued Box 7.1

In the meantime, the RUPES Kalahan team is preparing the CDM Project Design Document for the Kyoto market. The Kalahan forestry team, with technical assistance from ICRAF, also prepared the 'Forestry Project Idea Note (PIN) on Sequestration Project in the Ancestral Domain of Ikalahan'. The PIN proposes a carbon sequestration project on the 900 ha grassland portion of the domain. Among the activities conducted was the field measurement of carbon stocks in the grassland areas, which was carried out by the Kalahan forestry team. The grassland areas to be reforested have been covered with grasses at least since 1990, and without the project activity they are expected to remain so. Thus the project sites are expected to regenerate as they have for decades, at a level considered insignificant under the CDM. For cropland areas, a similar baseline situation applies. These areas have been under cultivation with annual crops for decades and are expected to be planted with annual crops (Lasco et al. forthcoming). The environmental service (carbon sequestration) to be provided by the project has been estimated under three rates of growth scenarios (Box Figure 7.2.2).

Box Figure 7.2.2 Estimated Net Cumulative CO_2 Removals by the Kalahan Reforestation Project



The simulation was done based on the tree growth rates using the Philippine derived values (Lasco et al. 2004) plus other assumptions and projected them using on MS Excel program. The main purpose of the exercise was to assist the Kalahan indigenous people in obtaining funding for the carbon sequestration services they could provide. For this purpose the estimated carbon sequestration rates will suffice since the objective is to show potential buyers the expected range of benefits. In 2004, the KEF established two nurseries producing seedlings of various tree species for reforestation within the Kalahan Reserve and the adjacent communities covered by the ancestral domain. A total of 89,702 assorted, mostly indigenous forest trees were planted on approximately 40 ha within the ancestral domain, and enrichment plantings were done in many other portions of the forest. The Kalahan Forestry team initiated reforestation and rehabilitation activities in the grasslands, brushland and open areas.

The Ikalahans initiated all the project activities described for their aspiration of sustainable development of forests on mountainous terrain. They are working hard to achieve rewards from this environmental service. The next step is to begin dialogue with the beneficiaries of the forest services to convince them to pay for the services rendered. Although monetary payments are not yet realized, KEF's hard work is nevertheless well recognized. With the RUPES project, it builds the capacity of indigenous communities to begin negotiations. It will also increase awareness and participation in carbon sequestration and other related issues in and around ancestral domain communities through public education programs.

Source: Villamayor and Lasco (2006).

The Energy Sector

Although Southeast Asian countries together contributed about 3% of global energy-related CO_2 emissions in 2000, this share is expected to rise in the future, given their relatively higher pace of economic and population growth compared to the rest of the world. The implementation of mitigation measures in the energy sectors in these countries could therefore contribute to global CO_2 stabilization efforts in the coming decades. Many options also bring significant co-benefits such as improved local environmental quality.

Mitigation strategies are available in both the energy supply and demand sectors. On the supply side, major options include efficiency improvements in power generation, fuel switching from coal to natural gas, and the use of renewable energy including biomass, solar, wind, hydro and geothermal resources. On the demand side, the key sources of GHG emissions are the residential and commercial building, industry (steel, cement, pulp and paper, and others), and transport sectors, with several key options.

- *Residential and commercial building sector*: Use of more efficient lighting and electrical appliances, energy efficiency standards and rating programs, improved insulation, and behavioral change.

- *Industry sector*: Use of more efficient boilers, motors, and furnaces, improved management practices such as energy auditing and benchmarking, heat and power recovery, fuel switching, and material recycling and substitution, particularly in energy-intensive sectors, such as iron and steel, cement, paper and pulp, and chemicals.

- *Transport sector*: Switching to cleaner fuels, use of fuel-efficient vehicles, use of hybrid/electric options in road transport, better traffic management, modal shifts from road transport to rail and public transport systems, promotion of non-motorized transport, and land use and transport planning.

Southeast Asia has great potential for reducing GHG emissions through greater energy efficiency.

IPCC (2007) identified a list of key mitigation technologies and practices for improving energy efficiency that are currently commercially available and could be adopted in the region, as well as those projected to be commercialized before 2030 (Table 7.5). Some of those currently available are already being practiced:

- In the power generation sector in Indonesia more efficient technologies such as circulated fluidized bed combustion and coal integrated gasification combined cycle have already been introduced. Similarly, increased energy efficiency has been obtained in oil refineries through revamping and reduced gas flaring. Nonetheless, there are opportunities for obtaining more energy efficiency savings in both industrial and residential uses.

- In the Philippines, the Department of Energy has taken the lead in implementing mitigation-related initiatives. The Power Patrol was launched nationwide in January 1994 through radio, television, and print, aiming to promote efficient and sensible use of electricity by targeting a reduction of at least 10% in power demand in the household, commercial, and industry sectors. Through its Fuels and Appliance Testing Laboratory, the department has implemented energy standards and labeling, and undertaken energy performance testing and certification of specific household appliances and electrical equipment.

- Singapore's Energy Efficiency Program is a key strategy in mitigating GHG emissions and addressing climate change, emphasizing the sharing of knowledge and expertise in energy efficiency. Programs supporting research and development for energy efficiency include the Innovation for Sustainability Fund, Going Upstream, Beyond Test-bedding, and Demonstration. To reduce the energy used for air-conditioning, the Building and Construction Authority and the National Environment Agency are implementing measures to improve energy efficiency in buildings. For example, under the Building Control Act, air-conditioned buildings must be designed with a high-performance building envelope that meets the prescribed envelope thermal transfer value (ETTV), currently set at 50W per square meter. The authority, with the National University, reviewed ETTV standards and explored the possibility of extending ETTV regulations to residential buildings. Study findings were used to create minimum Green Mark standards for new buildings, which came into effect in early 2008 (Box 7.3).

- In Thailand, financial incentives for promoting improvements in energy efficiency are being undertaken through a subsidy program for energy efficiency investments, based on concessionary loans and tax incentives. The government promotes energy efficiency-related information services such as handbooks, e-learning programs in energy conservation, energy clinics, and energy display centers. The Thailand Greenhouse Gas Management Organization initiated "eco-labeling", which gives carbon labels to industrial products.

Table 7.5. Key Energy-efficient Mitigation Technologies and Practices

Subsector	Currently Commercially Available	Projected to be Commercialized before 2030
Buildings	• Efficient lighting and use of daylight • More efficient electrical appliances and heating and cooling devices • Improved cooking stoves • Improved insulation • Passive and active solar design for heating and cooling • Alternative refrigeration fluids and recovery and recycling of fluorinated gases	• Integrated design of commercial buildings including technologies such as intelligent meters that provide feedback and control • Solar Photovoltaic integrated in buildings
Industry	• More efficient end-use electrical equipment • Heat and power recovery • Material recycling and substitution • Control of non-CO_2 gas emissions • A wide array of process-specific technologies	• Advanced energy efficiency • Carbon capture and storage for cement, ammonia, and iron manufacture; inert electrodes for aluminium manufacture

Source: IPCC (2007).

Box 7.3. Green Mark Ratings

The BCA Green Mark Scheme was launched in January 2005 as an initiative to move Singapore's construction industry towards more environment-friendly buildings. It is intended to promote sustainability in the built environment and raise environmental awareness among developers, designers and builders when they start project conceptualisation and design, as well as during construction.

Criteria and Scoring System

BCA Green Mark is a green building rating system to evaluate a building for its environmental impact and performance. It is endorsed and supported by the National Environment Agency. It provides a comprehensive framework for assessing building performance and environmental friendliness. Buildings are awarded the BCA Green Mark based on five key criteria:

- Energy efficiency
- Water efficiency
- Site/Project development & management (building management & operation for existing buildings)
- Good indoor environmental quality & environmental protection
- Innovation

Under the Green Mark assessment system, points are awarded for incorporating environment-friendly features which are better than normal practice. The assessment identifies designs where specific targets are met. Meeting one or more indicates that the building is likely to be more environment-friendly than buildings where the issues have not been addressed. The total number of points obtained provides an indication of the environmental friendliness of the building design.

Green Mark Award Rating

Green Mark Points	Green Mark Rating
85 and above	Green Mark Platinum
80 to <85	Green Mark Gold PLUS
70 to <80	Green Mark Gold
50 to <70	Green Mark Certified

The assessment process consists of an initial assessment leading to the award of the Green Mark. Subsequently, buildings are required to have triennial assessment. This is to ensure that the Green Mark building continues to be well-maintained. Buildings are awarded Platinum, GoldPLUS, Gold or Certified rating depending on the points scored. Apart from achieving the minimum points in each rating scale, the project has to meet all prerequisites, and score a minimum of 50% of the points in each category, except the Innovation category.

New buildings assessed under the Green Mark will require triennial assessment to maintain their Green Mark status. They will be assessed under the existing buildings criteria during the triennial assessment. The same criteria apply to existing buildings, unless they are undergoing a major refurbishment program.

Source: Building and Construction Authority (2009).

- In Viet Nam, the government is giving priority to efficiency improvements in coal-fired industrial boilers. There are currently 485 such boilers registered throughout the country, more than 90% of which have a burn capacity of 10 ton/hour or less. The efficiency of coal-fired industrial boilers is in the range of 50–75%. It is estimated that around 52% of existing boilers will need to be replaced and 10% rehabilitated.

Southeast Asia has considerable potential to harness renewable resources, including biomass, solar, wind, and geothermal resources; and to use emerging technologies on oceanic energy resources, such as tidal power.

IPCC (2007) has also identified key mitigation technologies and practices on renewable and cleaner energy that are now commercially available and could be adopted in the region (Table 7.6). Some have already been adopted.

- The use of renewable energy in Indonesia is still limited. While the country has been using biomass for electricity, the use of bioelectricity remains limited. Presidential Decree No. 5 (2006) has set the goal of increasing the share of renewable energy (biomass, geothermal, wind, solar energy, and others) and new or clean energy such as nuclear power or hydrogen to 15% of the primary energy mix by 2025. As part of this initiative the Ministry of Energy and Mineral Resources Decree 1122/2002 for small-scale energy generating installations and Decree 02/2006 for medium-scale energy generating installations mandate Indonesia's national public utilities to purchase renewable energy generated from small- and medium-scale installations.

- In the Philippines, under the Philippine Energy Plan (PEP), the use of new and renewable energy sources is seen contributing significantly to the country's electricity requirements. Backing up the PEP are policies and laws such as the Philippine Clean Air Act of 1999, Biofuels Act of 2006, and the Renewable Energy (RE) Act of 2008. Through incentives, the RE Act of 2008 encourages local entrepreneurs to go into the development of alternative energy resources and help decrease dependence on imported fuel. The RE Act of 2008 directs the Department of Energy, National Power Corporation, and other government agencies to develop and institute a framework for propagating renewable energy, and seamlessly interconnecting these sources into the national power grid. In the short term, new

Table 7.6. Key Mitigation Technologies and Practices on Renewable and Cleaner Energies

Subsector	Currently Commercially Available	Projected to be Commercialized before 2030
Energy supply	• Fuel switching from coal to gas • Biofuels • Nuclear power • Renewable heat and power (hydropower, solar, wind, geothermal and bioenergy) • Combined heat and power • Early applications of CCS (e.g., storage of removed CO_2 from natural gas).	• CCS for gas, biomass, and coal-fired electricity-generating facilities • Second generation biofuels • Advanced nuclear power • Advanced renewable energy, including tidal and wave energy, concentrating solar, and solar Photovoltaic

Source: IPCC (2007).

and renewable energy sources such as solar, wind, micro-hydro, and biomass are expected to reach a capacity of 92.3 million barrels of fuel oil equivalent in 2009 (as compared with 71.2 million barrels of fuel oil equivalent in 2000).

- Singapore has shifted toward the use of less carbon-intensive fuels, principally natural gas. Efforts are under way for Singapore's first liquid natural gas terminal to be ready by 2012. Efforts in promoting renewable energy such as biomass and solar energy are focused on research and development, while the government is reviewing how electricity generation using renewable energy sources can be increased, and at the same time ensuring that this does not cause disruption to the network. Singapore is also one of the few countries in the world that incinerates almost all of its solid waste. As such, landfills generate negligible methane. At present, five such waste-to-energy plants are in operation and electricity from the incineration plants contributes 2–3% of Singapore's energy supply.

- Thailand has developed the Alternative Energy Development Plan, which covers a wide range of power generation and heat from renewable energy sources, including biofuels. The government target is to increase the share of renewable energy to 8% by 2011. There is an active biofuel program and a target for biomass energy of 2800 MW by 2011. Table 7.7 provides details of targets for all renewables and alternative fuels in Thailand. There are currently nine operating ethanol plants with a production capacity of 1.25 million liters/day and the government has approved the construction of an additional 45 ethanol plants (20 sugar mills and 25 cassava mills) with a total capacity of 12 million liters/day. Community-based biodiesel production commenced in 2005.

- In Viet Nam, the Energy Law of 2005 aims to improve energy efficiency and promote the development of renewable sources, including solar and wind power. As yet there has been little development of renewables, despite the huge potential for renewable energy (estimates range between 1100 to 1900 MW). The development of small, localized hydropower units to replace the present reliance on generation from coal-fired power plants is now being considered.

Table 7.7. Targets for Renewable Energy and Alternative Fuels in Thailand

	Power Generation		Process Heat	Alternative fuels	
	(MW)	(ktoe)	(ktoe)	(millions litres/day)	(ktoe)
Targets in 2011	3,276	1,047	4,035	5.4	1,606
Solar	45	4	5	–	–
Wind	115	13	–	–	–
Hydropower	156	17	–	–	–
Biomass	2,800	941	3,660	–	–
Municipal solid waste	100	45	–	–	–
Biogas	60	27	370	–	–
Ethanol	–	–	–	2.4	653
Biodiesel	–	–	–	3.0	953
Existing in 2006	1,621	530	2,424	0.5	

– = data not available.
Source: Ministry of Energy (2008).

Southeast Asia has considerable potential to reduce GHG emissions by using more efficient transport and traffic management systems.

IPCC (2007) identified key mitigation technologies and practices for transport systems and road traffic management that are currently commercially available and could be adopted in the region (Table 7.8). Some are already being implemented.

- Indonesia considers the development of mass rapid transportation (a dedicated bus line and mono rail) an important measure to reduce GHG emissions in urban areas. The Blue Sky Programme was designed to improve air quality in Indonesia's five largest cities through, among other means, increasing the capacity and quality of public transportation. Indonesia has also introduced plans for the use of alternative fuels (liquefied natural gas and liquefied petroleum gas for public transport and taxis), inspection and maintenance programs, and stronger vehicle emission standards. The government has developed the Strategic Plan for the Transportation Sector in response to climate change, which aims to ensure that climatic considerations are incorporated in planning for the sector.

- A Road Transport Patrol Program was launched in April 1998 in the Philippines, through Executive Order No. 472: Institutionalizing the Committee on Fuel Conservation and Efficiency in Road Transport. The program promotes efficient use of fuel through a media campaign on fuel conservation for drivers, vehicle operators, and fleet owners. The Philippine Clean Air Act of 1999 mandates the Philippine Atmospheric, Geophysical and Astronomical Services Administration to regularly monitor meteorological factors affecting environmental conditions, including GHG emissions. Executive Orders 396 and 397 of 2004 provide for import duty reductions for hybrid and compressed natural gas vehicles.

- Singapore is improving the energy efficiency of its transport sector through managing vehicle usage and traffic congestion, improving and promoting the use of public transport, improving fuel economy, and promoting green vehicles. The transportation sector accounts for around 20% of GHG emissions, and government plans target an increase in public transport as a share of total traffic from 63% in 2004 to 70% in 2020. A vehicle quota system and electronic road pricing are already used to reduce traffic congestion. A "green vehicle"

Table 7.8. Key Mitigation Technologies and Practices for the Transport System and Road Traffic Management

Subsector	Currently Commercially Available	Projected to be Commercialized before 2030
Transport	• More fuel-efficient vehicles • Hybrid vehicles • Cleaner diesel vehicles • Modal shifts from road transport to rail and public transport systems • Non-motorized transport (cycling, walking) • Land use and transport planning	• Higher efficiency aircraft • Advanced electric and hybrid vehicles with more powerful and reliable batteries

Source: IPCC (2007).

rebate scheme to encourage the use of hybrid and compressed natural gas vehicles has been in operation since 2001. The rebate for such vehicles was increased from 20% to 40% of their market value in 2006. Likewise, a fuel economy labeling scheme for vehicles, launched as a voluntary program in 2003, became mandatory for all passenger cars from April 2009.

- Policies in Thailand to mitigate GHG from transport include the development of a master plan in large cities, promotion of the mass transit system in Bangkok, encouragement of car pools, use of economic incentives to encourage mode switching, retrofitting and improvement of engine efficiency, and promotion of the use of natural gas in vehicles.

- In Viet Nam, the government plans to improve fuel efficiency in transport through the wider use of cars with "lean burn" engines. The aim is to substitute existing small gasoline cars (less than 1,500 cc) with cars of the lean burn type. This new engine improves fuel efficiency by about 20% and also emits less air pollutants per kilometer.

Costs associated with mitigation options vary greatly, but there remains low-cost potential that Southeast Asia should exploit.

IPCC (2007) reviewed the existing studies on the potential and costs of various energy sector mitigation options, focusing mostly on those with an abatement cost below $100/tCO_2$-eq. The results show that abatement cost estimates vary greatly depending on underlying assumptions regarding emission scenarios, time horizons, cost parameters, and technology specifications, among others. In the case of fuel switching from coal to gas-power plants, for instance, the abatement cost is estimated to range from zero to $11/tCO_2$ by 2030 for developing countries. Some mitigation options have much higher abatement costs. For example, it can go up to $50–100 or even higher per tCO_2-eq in the case of solar power plants and CCS technologies.

There are, however, win-win mitigation options, that is, CO_2 emissions reduction could be achieved at a negative cost. According to IPCC (2007), developing countries by 2020 could mitigate a total of 1.5 $GtCO_2$ from the residential and commercial building sector and, by 2030, depending on the projected oil prices, 88 to 146 $MtCO_2$ from automobiles, on an annual basis at a negative cost. According to McKinsey (2007), a total of about 5 $GtCO_2$-eq emissions could be mitigated by 2030 on an annual basis at a negative net cost globally through measures including building insulation; use of high-efficiency appliances (air conditioners and water heaters) and lighting in the residential sector, fuel efficiency in vehicles, and biofuels; and reduction of industrial non-CO_2 emissions.

A number of studies have reported mitigation potential with a negative net cost in the Southeast Asian energy sector.

- On the energy supply side, efficiency improvements in system loss reduction in power plants have the potential to mitigate about 227 $MtCO_2$ in the Philippines during 2000—2020 (ADB 1998a). Switching from oil to gas power plants is projected to have the potential to mitigate about 4 $MtCO_2$ in Viet Nam by 2010 (MONRE 2004).

- On the energy demand side, Thailand has the potential to mitigate 31 $MtCO_2$ emissions from the residential and commercial building sector from 1997—2020 (ADB 1998). The same study reports that the Philippines and Thailand could reduce a total of 18 $MtCO_2$ and 89 $MtCO_2$, respectively, in the period up to 2020, through the use of efficient boilers and motors in the industry sector. The Philippines has the potential to mitigate about 40 $MtCO_2$ through the use of high-efficiency transport systems during the period 2000—2020, and Thailand could mitigate about 30 $MtCO_2$ during the period 1997—2020 through improvement of fuel efficiency in vehicles.

The Agriculture Sector

Agriculture remains a major economic sector in the region, with its share in GDP, although declining, still high. Most of the region's poorest people, living in rural areas, still rely on agriculture for their livelihood and as a safety net. A variety of options exist for mitigation of GHG emissions in the agriculture sector. These include (i) reducing fertilizer-related emissions; (ii) reducing CH_4 emissions from rice paddies; (iii) reducing emissions from land use change; (iv) sequestering carbon in agro-ecosystems; and (v) producing fossil fuel substitutes. Table 7.9 summarizes these agriculture-related mitigation options.

IPCC (2007) classified the mitigation potential for agriculture into technical and economic potential. Technical potential refers to the possible amount of GHG mitigation possible by implementing a technology or practice (such as the efficient use of nitrogen fertilizer) that has already been demonstrated successfully. This considers only practical constraints with no reference to cost. Economic potential, on the other hand, considers the costs.

Estimates exist, though limited, on the range of economic mitigation potential of agricultural practices in Southeast Asia.

Empirical estimates of mitigation potential of the agriculture sector are limited. The United States Environmental Protection Agency (2006) estimates the economic potential for reducing net emissions of nitrous oxide and soil carbon from cropland in South and Southeast Asia at zero cost would be 2.1 $MtCO_2$-eq in 2010 and 2.3 $MtCO_2$-eq in 2020. Increasing the carbon cost to \$30/tCO_2-eq would increase the potential by 20% in 2010 and 35% in

Table 7.9. Mitigation Options in Agriculture in Southeast Asia

Practice	Relative Mitigation Potential (unit of production)	Challenges/Barriers (policy, poverty, knowledge, extension)	Opportunities (feasibility, cost effectiveness, synergy with adaptation)	Co-benefits and Contribution to Sustainable Development
Cropland management • agronomy • nutrient management • tillage/residue management • water management	Potential to sequester soil carbon by 0.55–1.14 tCO_2/ha/year Potential to reduce N_2O emissions by 0.02–0.07 tCO_2-eq/ha/year	This option could be costly to implement and would need considerable effort to transfer, diffuse, and deploy. Also, some measures may challenge existing traditional practices.	Use of improved varieties with reduced reliance on fertilizers and other inputs provides opportunity for better economic returns. Reduced tillage will reduce the use of fossil fuel thus less CO_2 emissions from energy use.	Increases productivity (food security); improves soil, water, and air quality; promotes water and energy conservation; and supports biodiversity and wildlife habitat.
Rice management	In continuously flooded rice fields, potential to reduce CH_4 emission by 7–63% (with organic amendment) and 9–80% (with no organic amendment)	The benefit may be offset by the increase of N_2O emissions and the practice may be constrained by water supply	More effective rice straw management to reduce methane emission (e.g., as a biofuel).	Promotes productivity (food security) and conservation of other biomes. Also enhances water quality.
Agroforestry, set-aside, land use change	Potential to sequester carbon by 0.70–3.04 tCO_2/ha/year; reduce CH_4 emission by 0.02 tCO_2-eq/ha/year; and reduce N_2O emission by 0.02– 2.30 tCO_2-eq/ha/year.	Cropland conversion reduces areas intended for food production. Also, the fate of harvested wood products would need to be accounted for.	Harvest from trees (fuelwood) could be used for bioenergy; additional returns to farmers. Set-aside is usually an option only on surplus agricultural land or on croplands of marginal productivity.	This practice promotes biodiversity and wildlife habitats; energy conservation; and in some cases poverty reduction. Improves the quality of soil, water, and air; promotes water and energy conservation; supports biodiversity, wildlife habitats, and conservation of other biomes.
Grassland management • grazing management • fertilization • fire	Potential to sequester carbon by 0.11–1.50 tCO_2/ha/year	Nutrient management and irrigation might increase the use of energy; introduction of species might have an ecological impact.	Improves productivity	This measure increases productivity (food security); improves soil quality, promotes biodiversity and wildlife habitats; and enhances aesthetic/amenity value.
Petland management and restoration of organic soils	Potential to sequester carbon by 7.33–139.33 tCO_2/ha/year; and reduce N_2O emission by 0.05–0.28 tCO_2-eq/ha/year	Need better knowledge of the processes involved to avoid double counting.	Avoiding row crops and tubers; avoiding deep ploughing; and maintaining a shallower table are strategies to be explored.	Improves soil quality and aesthetic/amenity value; promotes biodiversity, wildlife habitats, and energy conservation.
Restoration of degraded lands	Potential to sequester carbon by 3.45 tCO_2/ha/year	Where this practice involves higher nitrogen application, the benefit of carbon sequestration may be partly offset by higher N_2O emissions.		Increases productivity (food security); improves soil and water quality and aesthetic and amenity value; and supports biodiversity, wildlife habitats, and conservation of other biomes.

Table 7.9 *continued.*

Practice	Relative Mitigation Potential (unit of production)	Challenges/Barriers (policy, poverty, knowledge, extension)	Opportunities (feasibility, cost effectiveness, synergy with adaptation)	Co-benefits and Contribution to Sustainable Development
Bioenergy (soils only)	Potential to sequester carbon by 0.70 tCO_2/ha/year; and reduce N_2O emission by 0.02 tCO_2-eq/ha/year.	Competition for other land uses and impact on agro-ecosystem services such as food production, biodiversity, and soil moisture conservation.	Technical potential for biomass; technological developments in converting biomass to energy.	Promotes energy conservation.
Livestock management feeding practices	Improved feeding can reduce CH_4 emissions from enteric fermentation by 1–22% for dairy cattle; 1–14% for beef cattle; 4–10% for dairy buffalo, and 2–5% for nondairy buffalo.	The effect varies depending on management of animals, i.e., whether confined animals or grazing animals.	The measure depends on soil and climatic conditions, especially when dealing with grazing animals.	Reduced pressure on natural resources (such as soils, vegetation, and water) allow a higher level of sustainability.
Manure management	Up to 90% of CH_4 emitted can be captured and combusted 10–35% of CH_4 can be reduced by composting 2–50% reduction in N_2O emission by improved soil application.	Lack of incentives for the broad application of this measure would be a challenge.	Applicable to all waste management systems particularly swine production.	Fewer odors and less environmental pollution.

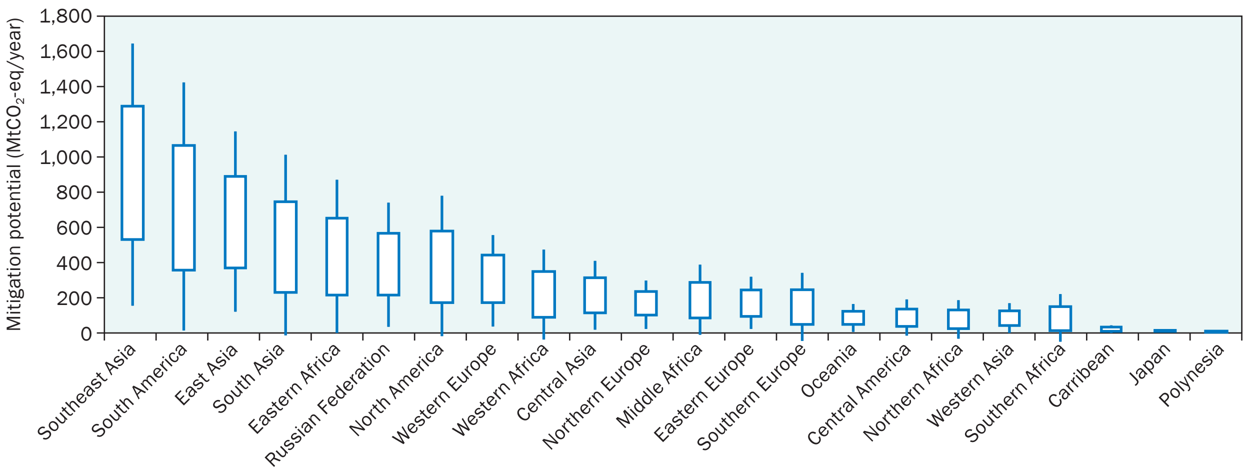
Source: Smith et al. (2007).

2020. The study also estimates that the same regions' economic potential in reducing GHG emissions from rice fields at zero cost would be about 60.6 $MtCO_2$-eq in 2010 and 72 $MtCO_2$-eq in 2020. Increasing the carbon cost to \$30/tCO_2-eq would significantly increase the potential, by about 60% in both 2010 and 2020.

Southeast Asia has the highest technical mitigation potential to reduce GHG emissions from agriculture than of any other region.

Smith et al. (2007) report that the technical potential for emissions reduction from using all technically feasible practices and covering all GHGs (carbon dioxide, methane, nitrous oxide, carbon monoxide, and others) ranges from 550 to 1,300 $MtCO_2$-eq per year for Southeast Asia by 2030, the highest among regions in the world (Figure 7.3). The study also estimates that by 2030 the global economic potential for agricultural GHG reduction could reach 28% of its total technical potential at a carbon price of up to \$20/tCO_2-eq and 46% at a carbon price of up to \$50/tCO_2-eq. Roughly applying these proportions to Southeast Asia implies that by 2030 the region's economic potential for GHG mitigation in the agriculture sector would be about 152 $MtCO_2$-eq per year at a carbon price of up to \$20/tCO_2-eq and about 414 $MtCO_2$-eq per year at a carbon price of up to \$50/tCO_2-eq. However, these estimates are derived from a strong assumption that the composition of Southeast Asia's mitigation practices approximates that at the global level, and should be taken to provide only very rough orders of magnitude.

Figure 7.2. Total Technical Mitigation Potential in Agriculture (all practices, all GHGs) for Each Region (2030)



Source: IPCC (2007).

Southeast Asia's vast area of croplands, through cropland management, could be an important channel to sequester carbon in soils.

Proper cropland management has the potential to sequester soil carbon by 0.55–1.14 tCO_2/ha per year and to reduce N_2O emissions by 0.02–0.07 tCO_2-eq/ha per year. This mitigation measure can be achieved by improved agronomic practices that enable crops to increase yield and generate higher inputs of carbon residue, resulting in higher carbon storage (Follet 2001). Examples of improved agronomic practices include use of improved crop varieties, extending crop rotations, particularly of perennial crops, and avoidance of cultivation of bare unplanted or fallow land (West and Post 2002, Smith 2004a and 2004b, Lal 2003 and 2004a, Freibauer et al. 2004).

The challenge in using improved crop varieties, with a view to increasing yield and biomass as carbon residue input, is in the management of nitrogen fertilizer requirements so as not to offset gains in soil carbon with the emission of N_2O from fertilizer application. However, this mitigation measure, if implemented, will contribute to increases in crop productivity and improved soil quality due to increased soil carbon storage.

Nutrient management also reduces GHG emission from agriculture. Improving efficiency in nitrogen use can reduce the emissions of N_2O and indirectly reduce GHG emissions from nitrogen fertilizer (Schlesinger 1999). This also reduces off-site N_2O emissions from leaching and volatilization. Practices that improve the use of nitrogen fertilizer include the use of slow- or controlled-release fertilizer, precision farming or applications based on precise estimation of crop needs, and precise application of fertilizer to the soil to make it more accessible to plant roots (Robertson 2004, Dalal et al. 2003, Paustian et al. 2004, Cole et al. 1997, Monteny et al. 2006).

A study in Indonesia, on the use of slow- or controlled-release nitrogen fertilizer in rice fields, showed that applying non-prilled urea such as tablet urea, polymer-coated urea and nutralene can result in a reduction of N_2O emissions (Setyanto 1997). Use of polymer-coated urea could reduce N_2O emissions by 4–16% as compared with prilled urea and can also increase yield significantly more, from 17–25% in some cases (Table 7.10).

Table 7.10. Effects of Different Types of Nitrogen Fertilizer on N_2O Emission in Rice Fields in Central Java, Indonesia (1997)

Treatment	N_2O emission (kg/ha)	Grain Yield (kg/ha)	Effect of Technology on N_2O Emission (%)	Grain Yield Difference (%)	Benefit per kg Reduction of N_2O ('000 x Rp)
			Dry Season		
Prilled urea	225	3953	–	–	–
Tablet urea	194	5172	-13.8	30.8	58.9
Prilled urea + sulfur	182	3908	-19.1	-1.1	1.5
Nutralene	215	4154	-4.4	5.1	30
CRM	165	4634	-26.7	17.2	17
			Wet Season		
Prilled urea	73	4008	–	–	–
Tablet urea	73	4698	0	17.2	0
Prilled urea + sulfur	47	4114	-35.6	2.6	6
Nutralene	61	4279	-16.4	6.8	33.8
CRM	64	5021	-12.3	25.3	168.8

Source: Setyano, (1997).

Tillage and residue management in croplands could promote carbon gain since soil disturbance often results in carbon losses through decomposition and soil erosion (West and Post 2002, Ogle et al. 2005, Gregorich et al. 2005, Alvarez 2005). Water management could also reduce GHG emissions by using more effective irrigation measures that enhance soil carbon storage, crop yields, and residue return (Follett 2001, Lal 2004a).

As a major world rice producer, Southeast Asia can contribute to a reduction of methane emissions while ensuring food security.

In a continuously flooded rice field, rice management has the potential to reduce the emission of methane by 7–63% (with organic amendment) and by 9–80% (with no organic amendment) (Table 7.11). This can be achieved by a combination of water management and management of organic and mineral fertilizer inputs.

- Intermittent irrigation techniques, which are known to reduce methane emission, are already being practiced by farmers in Indonesia, not for the specific purpose of reducing methane emission, but as part of normal management practices. Setyanto et al. (1997) found that intermittent irrigation reduced methane emissions by 83% as compared to continuous flooding. The yield, however, was also reduced by 24%. Other potential mitigation options available to Indonesian farmers are the use of the direct seeding method as opposed to the transplanting method, and use of slow-release nitrogen fertilizer. Direct seeding in irrigated rice fields has been found to reduce methane emissions by

8–32% as compared with the baseline technique of transplanting rice (Makarim and Setyanto 1995). With the same amount of inputs, yields increased by 21%.

- In the Philippines, Corton et al. (2000) found that the use of ammonium sulfate as nitrogen fertilizer in place of urea resulted in a 25–36% reduction in CH_4 emissions. The use of phosphogypsum when applied in combination with urea fertilizer reduced CH_4 emissions by 72%. Mid-season drainage, which is associated with the influx of oxygen into the soil, reduced methane emission by 43%. The practice of direct seeding rice instead of transplanting reduced methane emissions by 16–54%. The addition of composted rice straw increased CH_4 emissions by only 23–30%, as compared to the 162–250% increase in CH_4 emissions that occur with the use of fresh rice straw.

- Wassmann et al. (2000) found that methane emission rates in rice fields vary over a very wide range from 5 to 634 kg CH_4/ha depending on the season and management practices. Field drying at mid-tillering can reduce CH_4 emissions by 15–80% compared to continuous flooding without a significant effect on grain yield.

- Research institutions in Thailand have evaluated methane emissions from deepwater rice fields. Chareonsilp et al. (2000) found that methane emissions were highest with raw straw incorporation, followed by straw compost incorporation, then zero-tillage with straw mulching, and last with straw ash incorporation. Other mitigation options have been introduced slowly into practice, while others are still to be tested before farmers can be convinced that the benefits outweigh the costs.

- A study in the Dien Ban district of Viet Nam between 2002 and 2004 developed a model for reducing methane emissions from paddy rice cultivation through an innovative water management regime. It found that a reduction in CH_4 emission of 40kg/ ha/ year could be obtained with an increase in rice yield of 0.3 ton/ ha.

The challenge in using rice management as a mitigation measure is to ensure that the gains in reducing CH_4 emissions are not offset by the increase in N_2O emissions due to the application of nitrogen fertilizer. Residue management can also be a challenge to farmers, since the burning of rice straw, which is often seen as a preferred practice due to the ease of implementation, causes emissions of non-CO_2 gases. Composting rice straw, instead of burning, would be a better management strategy, but this would entail additional costs to farmers. Water management may also be a challenge since this will require efficient irrigation and drainage systems. However, implementing this measure could promote greater rice productivity (and thus contribute to food security) and could enhance water quality through efficient use of water resources and mineral inputs.

Table 7.11. Potential Options for the Reduction of CH_4 Emissions in Rice Fields

Management Practice	Continuous Flooding, Organic Amendment	Mid-season Drainage, Organic Amendment	Continuous Flooding, No Organic Amendment
Water regime	Mid-season drainage (7–44%)		Mid-season drainage (15–80%)
	Alternate flooding/drying (59–61%)	Alternate flooding/drying (21–46%)	Alternate flooding/drying (22%)
		Early/dual drainage (7–46%)	
Organic amendments	Compost (58–63%)	Biogas Residues (10–16%)	
Mineral amendments	Phosphogypsum (27–37%)		Phosphogypsum (9–73%)
			Ammonium sulphate (10–67%)
			Table urea (10–39%)
Straw management		Fallow incorporation (11%)	
		Mulching (11%)	
Crop establishment	Direct wet seeding (16–22%)		

Note: Values in parentheses are reduction effects for each mitigation practice or modified crop management.
Source: Wassmann et al. (2000).

Other potential mitigation options tested under Southeast Asian conditions could boost agricultural production (and help reduce poverty), while at the same time help stabilize GHGs.

Agroforestry, Set-Aside[1], and Land Use Change

This mitigation measure has the potential to sequester carbon by 0.70–3.04 tCO_2/ha per year, reduce CH_4 emission by 0.02 tCO_2-eq/ha per year, and to reduce N_2O emissions by 0.02–2.30 tCO_2-eq/ha per year. This can be achieved by growing food crops or producing livestock on land that also grows trees for timber, firewood, or other tree products. This practice includes planting trees as shelterbelts, riparian zones, and buffer strips. Soil carbon is enhanced by planting trees and other woody species on cropland and grassland. This mitigation measure could entail high investment, but it promotes conservation of biodiversity and wildlife habitat, and improves the water holding capacity of the soil. Woody biomass from trees (fuelwood) can be used as bioenergy to replace fossil fuels that would have otherwise been used to generate energy or to power farm operations. Boer et al. (1999) found that in Indonesia, planting of fruit trees could sequester carbon in the range of 53–254 tC/ha and provide farmers with a high-value crop.

Grassland Management

Grassland management has the potential to sequester carbon by 0.11–1.50 tCO_2/ha per year. This can be achieved by controlling grazing intensity through regulation of the animal stocking rate, by enhancing rotational

[1] Land left fallow.

grazing, and by limiting grazing time by season over the year. Increasing pasture productivity through increased above-ground biomass density could also increase carbon storage in grasslands. Nutrient management could be applied to reduce N_2O emissions from nutrient application while at the same time maintaining the productivity of grasslands. Fire management can also reduce emissions of non-CO_2 gases while increasing tree and shrub cover that can provide a CO_2 sink in soil and in biomass (Scholes and van der Merwe 1996).

The challenge with this option is the proper regulation of grazing intensity to avoid overgrazing of grassland that could result in even more GHG emissions. With appropriate grazing management, soil quality will be enhanced by the increase in soil carbon, and desertification will be prevented. There will be promotion of biodiversity and wildlife habitat, as well as the enhancement of aesthetic and amenity values of lands. Co-benefits would include the reduction of soil erosion and degradation, which would help in rural poverty reduction.

Peatland Management and Restoration of Organic Soils

This mitigation practice has the potential to sequester carbon by 7.33–139.33 tCO_2/ha per year and reduce N_2O emission by 0.05–0.28 tCO_2-eq/ha per year. The sequestration of carbon can be achieved by avoiding the drainage of organic or peaty soils that are known to contain high densities of carbon, or by re-establishing a high water table in the area (Freibauer et al. 2004). Furthermore, emission of GHGs from drained organic soils can be reduced by avoiding the planting of row crops and tubers, avoiding deep ploughing, and maintaining a shallower water table (IPCC 2007). Restoring peatland areas or organic soils can reduce the runoff from agricultural fields and settlements, which causes eutrophication, algal blooms, and hypoxic dead zones in lakes, estuaries, bays, and seas. It can also reduce flood damage; stabilize shorelines and river deltas; retard saltwater seepage; recharge aquifers; and improve wildlife, waterfowl, and fish habitat. Restoration of organic soils can also improve soil quality and aesthetic and amenity values, promote biodiversity and wildlife habitats, and support energy conservation.

Restoration of Degraded Lands

Restoration of degraded lands has the potential to sequester carbon by 3.45 tCO_2/ha per year. This can be achieved using practices that reclaim productivity, such as revegetation (that is, planting grasses); improving fertility through nutrient management; use of organic substrates such as manures, biosolids, and composts; tillage management; and retaining crop residues and water management (Bruce et al. 1999, Lal 2001, Lal 2004b, Olsson and Ardö 2002, Paustian et al. 2004). The challenge with this option is to ensure that the benefit of carbon sequestration is not offset by the additional N_2O emissions from the use of nitrogen inputs in the soil. This mitigation measure, if implemented, would increase soil productivity (thus improving food security); improve soil and water quality and aesthetic and amenity value; and support biodiversity, wildlife habitats, and the conservation of other biomes.

Bioenergy

This mitigation measure has the potential to sequester carbon by 0.70 tCO_2/ha per year, and reduce N_2O emission by 0.02 tCO_2-eq/ha per year. This can be achieved by using agricultural crops and residues that can be burned directly to produce energy or which can be processed to generate liquid fuels such as ethanol or diesel. Such fuels, when burned, release biogenic CO_2 (that is, CO_2 of recent atmospheric origin taken by plants via photosynthetic carbon uptake), which displaces CO_2 that otherwise would have come from fossil carbon. The challenge with this option is the competition between land use for dedicated energy crops against food crops. On the other hand, implementing this option will promote energy conservation.

- Bioelectricity is already being tested in Indonesia. According to Boer et al. (1999), bioelectricity—using biomass as a source fuel for generating electricity—has the potential to mitigate CO_2 emissions by 50–185 tC/ha.

- In Thailand, with its strong agricultural sector particularly in the production of cassava and sugarcane, early adoption of gasohol as a substitute for Benzene 95 has proved to be a good test case for the use of bioenergy.

Livestock Management and Manure Management

Livestock management through improved feeding practices can reduce CH_4 emissions from enteric fermentation by 1–22% for dairy cattle; 1–14% for beef cattle; 4–10% for dairy buffalo, and 2–5% for non-dairy buffalo. This can be achieved by providing animals with an enriched diet that would lower the enteric methane emissions per output or input unit. Farmers can implement this measure by managing their grain supplementation, using higher-quality forages, using forage from plants containing some natural methanogenic depressors, and using mineral supplements to overcome any possible nutrient deficiencies (DEFRA 2007, de Klein and Eckard 2008, and IPCC 2007). This measure when implemented will reduce pressure on natural resources and increase the profitability of livestock production systems.

Manure management can also be used to mitigate GHG from livestock. The measure can reduce GHG emissions of CH_4 emitted through capture and combustion by up to 90%, reduce CH_4 through composting by 10–35%, and reduce N_2O emissions through improved soil application by 2–50%. Manure management can be achieved by enhancing CH_4 production in closed environments (such as biodigestors, covered manure piles, and lagoons) and then collecting and using it as biogas, applying aerobic treatments of manure such as composting, aerobic animal waste treatment systems, or applying manure to soil under aerobic conditions (Hao et al. 2008). The challenge with this option is the lack of financial incentives to support the investment needed by farmers for the broad implementation of this mitigation practice.

- Under its National Action Plan on Climate Change, the Government of the Philippines has proposed the use of tubular polyethylene biodigesters and urea-molasses mineral blocks as nutrient supplements in animal production.

- Manure management and improved feed are commonly practiced in Thailand. Waste-to-energy has been developed on a commercial scale, especially in providing energy for pig farms.

D. Conclusions

With an estimated 12% of world total GHG emissions in 2000 coming from Southeast Asia, mitigation has been high on the agenda of many countries in the region, particularly with regard to its key emission sources—land use change and forestry, energy, and agriculture. The region's total GHG emissions have been growing at a faster rate than the global average because the region's GDP growth is higher. A growing and increasingly affluent population, together with further industrial growth, will result in even more emissions in the future as well as a greater share for the region in global emissions. Recognizing the limitation of adaptation practices, the region will need to contribute to the global reduction of GHGs to stabilize CO_2 concentrations in the atmosphere by pursuing mitigation options.

A number of studies have shown that Southeast Asia has considerable potential to sequester carbon through avoided deforestation, protection of existing forests, afforestation and reforestation, and forest management. Similarly, there is considerable potential to increase off-site carbon stocks through enhancement of fuel substitution and use of bioenergy. The region has large areas devoted to agriculture and pasture where mitigation of GHGs can be achieved in a sustainable manner and with co-benefits and synergies with adaptation efforts. The increasing population and the growing demand for energy pose both a challenge and opportunity to reduce GHG emissions.

There are a number of mitigation practices that can already be applied in Southeast Asia. However, options would differ widely between countries, and while some of them will be country-specific, others could have broader application. There is an opportunity for the countries of the region to learn from each other and adapt national policies accordingly. There may also be a need for certain countries to provide more information publicly as to current efforts and results, so as to better benchmark the progress being made.

Currently, most mitigation efforts in the region have focused on improving energy efficiency, developing renewable sources of energy, promoting urban mass transit systems, rehabilitating forests, and restoring degraded land. There are several practices already implemented in crop and livestock management, which are known to reduce GHG emissions, although, originally, their introduction was not intended for mitigation purposes. Those that are already tested and validated need to be promoted throughout the region for broad implementation.

The challenges are many for mitigation measures to be effective, but the need is immediate. Meeting the challenge will require support for research and development, provision of reliable information and high-quality data, technology transfer, capacity building, as well as additional financial resources. In this regard, international and regional cooperation as well as the efforts of individual governments—from national to local levels—will play an important role in providing policy and economic incentives that will support the promotion and sharing of innovative and effective mitigation technologies in Southeast Asia.

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CHAPTER 8

Energy Sector Mitigation Options

Key Messages

Energy modeling carried out under this study confirms that without mitigation action, Southeast Asia's energy-related emissions will continue to grow. At the same time, the region has significant mitigation potential for reducing such emissions.

Under a business-as-usual scenario, the four countries—Indonesia, Philippines, Thailand, and Viet Nam—as a whole are likely to rely heavily on dirty fossil fuels as primary energy sources, with energy-related CO2 emissions projected to increase four-fold during 2000–2050.

Reducing energy intensity and improving energy efficiency and moving towards cleaner energy sources such as natural gas and renewable would be among the key elements of the region's low-carbon growth strategy for contributing to global mitigation efforts.

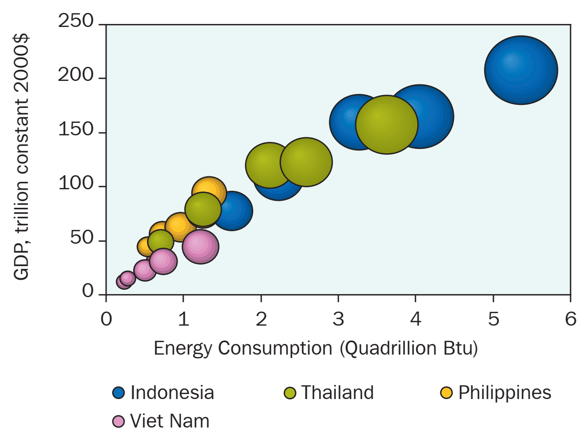
The marginal abatement cost (MAC) analysis suggests that the four countries have significant potential for reducing energy-related CO_2 emissions. As a ballpark estimate, the total mitigation potential at a carbon price up to US$50 is projected to be 903 million tons of carbon dioxide ($MtCO_2$) each year, equivalent to 79% of total energy-related CO_2 emissions expected in 2020 under business-as-usual.

Many energy efficiency improvement measures are win-win options that could mitigate up to 40% of the four countries' total energy-related CO_2 emissions by 2020 each year under the same scenario, and at the same time bring in cost savings. Another 40% could be mitigated using options with a positive cost, such as fuel switching from coal to gas and renewable energy in power generation, at a total cost below 1% of GDP in 2020.

A. Introduction

Energy is key to achieving Southeast Asia's sustainable development and poverty reduction goals. Energy use and the economy grow in tandem and growing fossil fuel production and consumption have led to emissions of large quantities of greenhouse gases (GHGs), causing global warming with grave environmental damage. Climate change forces us to find ways to decouple energy use from economic growth and GHG emissions (Figure 8.1), and to put in motion a transition to a low-carbon growth path, without at the same time hindering economic and social development.

Figure 8.1. Nexus Between Energy Consumption, GDP, and CO_2 Emissions



Note: Size of bubble indicates CO_2 emissions. Data shown for 1985, 1990, 1995, 2000, and 2005.
Source: EIA (2008) and World Bank (2007).

A number of mitigation options are available towards a low-carbon growth path, including energy efficiency improvement on both demand and supply sides, switching to clean and renewable energy—including hydro, wind, solar, geothermal, among others—and application of new technologies such as carbon capture and storage (CCS).

This chapter looks at the mitigation options available for the energy sector in the four countries —Indonesia, Philippines, Thailand, and Viet Nam—and assesses the mitigation potential of these options and their cost-effectiveness, using the DNE21+ model developed by the Research Institute of Innovative Technology for the Earth (RITE) Japan. The four countries together contributed about 3% of global energy-related CO_2 emissions in 2005 (EIA 2008); but this share is expected to rise in the future amid relatively faster economic growth compared to the rest of the world. The implementation of mitigation measures in these countries is therefore important for global CO_2 stabilization efforts in the coming decades (see Appendix 1 for country-specific projections under different scenarios).

DNE21+ is a bottom-up cost-minimization linear-programming model of the global energy balance system containing detailed energy supply technologies and end-use sectors, with the world divided into 54 regions/countries. The model was adapted to this study by treating each of the four countries as a separate region. With exogenously given parameters such as population and gross domestic product (GDP), the existing cost levels and assumptions on likely trends in various energy technologies and CCS, and energy users, among others—and by allowing energy flows and technology transfer across regions—the model estimates primary energy consumption and its sources, electricity generation and its technologies, and CO_2 emissions for each region from 2000 to 2050 in such a way that the global energy system cost is minimized. DNE21+ projects CO_2 emissions from the energy sector, while those from land use change and forestry are exogenously given and assumed to follow the IPCC B2 scenario for the reference and stabilization scenarios in this study. In this chapter, mitigation options for the four countries are assessed up to 2050 with the following steps.

- First, the DNE21+ model is used to project primary energy consumption and its sources, electricity generation and its technologies, the use of CCS, and CO_2 emissions for the four countries as a whole and individually under a business-as-usual scenario (BAU) with no mitigation action. The BAU scenario largely follows the B2 reference case used in Chapter 6.

- Second, the model is used to project these variables and quantities under two stabilization scenarios with CO_2 concentration being kept at 450 ppm (S450) and 550 ppm (S550), respectively. This is done by including the cost of carbon emissions in energy costs so that high-emission energy technologies become relatively more expensive than low- or zero-emission energy technologies, leading to the former being replaced by the latter, including through the use of CCS in order to minimize the global energy system costs, inclusive of carbon cost.

- Third, primary energy consumption and sources, electricity generation and technologies, the use of CCS, and CO_2 emissions under the BAU scenario are compared with those under the two stabilization scenarios. The differences indicate the required adjustments and strategies for the four countries as part of the global least-cost mitigation solution to keep the CO_2 concentration at 450 ppm or 550 ppm.

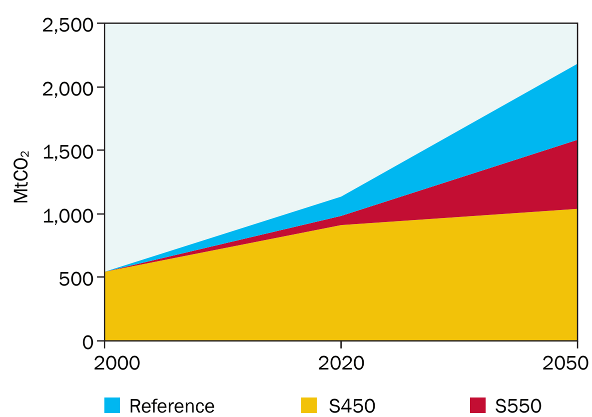
- Fourth, the DNE21+ model is used to generate marginal abatement cost curves for the four countries and, on the basis of these, to assess the mitigation potential and estimate funding requirements of mitigation actions for the four countries in total and individually in year 2020.

B. Mitigation Options in the Energy Sector

The global least-cost mitigation solution would involve cutting the four countries' energy-related CO_2 emissions by up to half by 2050 compared to the business-as-usual scenario

In 2000, the four countries emitted a total of 544 Mt of energy-related CO_2. The modeling results show that, under the BAU scenario where these countries would be heavily reliant on coal and oil, their total energy-related CO_2 emissions are likely to grow 3% a year on average during 2000–2050, reaching 1,140 $MtCO_2$ in 2020, and 2,191 $MtCO_2$ in 2050. With stabilization, however, as part of the global mitigation solution, the total energy-related CO_2 emissions from the four countries would be 990 $MtCO_2$ in 2020 (13% lower than the BAU level) and 1,587 $MtCO_2$ in 2050 (28% lower than the BAU) under S550, and only 911 $MtCO_2$ in 2020 (20% lower than the BAU) and 1,041 $MtCO_2$ (52% lower than the BAU) in 2050 under S450 (Figure 8.2). These figures suggest that there would be significant room for the four countries to contribute to global stabilization efforts, and such contribution could involve cutting their BAU per year emissions as much as 50% on an annual basis by 2050. Such a cut would not only contribute to global mitigation efforts, but also benefit the four countries themselves through more efficient use of energy as well as improved local environmental quality.

Figure 8.2. Energy-related CO_2 Emissions in the Four Countries

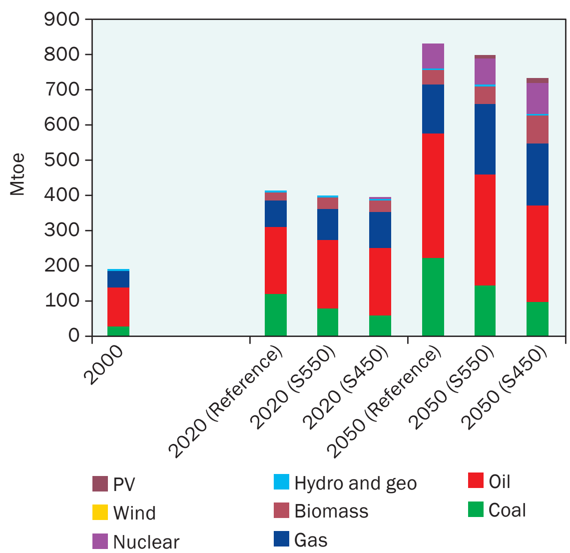


Note: Reference = business-as-usual without action; S450 = stabilization at 450 ppm; S550 = stabilization at 550 ppm.
Source: ADB study team.

Reducing energy intensity and improving energy efficiency, while moving towards cleaner energy sources such as natural gas and renewable and away from dirty fossil fuels (coal and oil), would be key elements of a mitigation and low-carbon growth strategy contributing to global stabilization efforts in coming decades.

In 2000, the four countries consumed a total of 193 Mtoe of primary energy, including primarily 30 Mtoe of coal (16%), 113 Mtoe of oil (58%), and 47 Mtoe of natural gas (24%), with an energy intensity at 0.48 Mtoe per unit of GDP. Under the BAU scenario, these countries are projected to become more coal-dependent. The share of coal consumption in total primary energy consumption is likely to rise from 16% in 2000 to 27% by 2050 (Figure 8.3). Although the share of oil consumption is expected to decline, oil is likely to remain the most prominent primary energy source, with its share staying above 40% by 2050. The use of biomass and nuclear energy is projected to increase over time, while the share of wind energy is likely to remain small. Under the BAU scenario, energy intensity is projected to decrease to 0.2 Mtoe per unit of GDP by 2050.

Figure 8.3. Primary Energy Consumption in the Four Countries

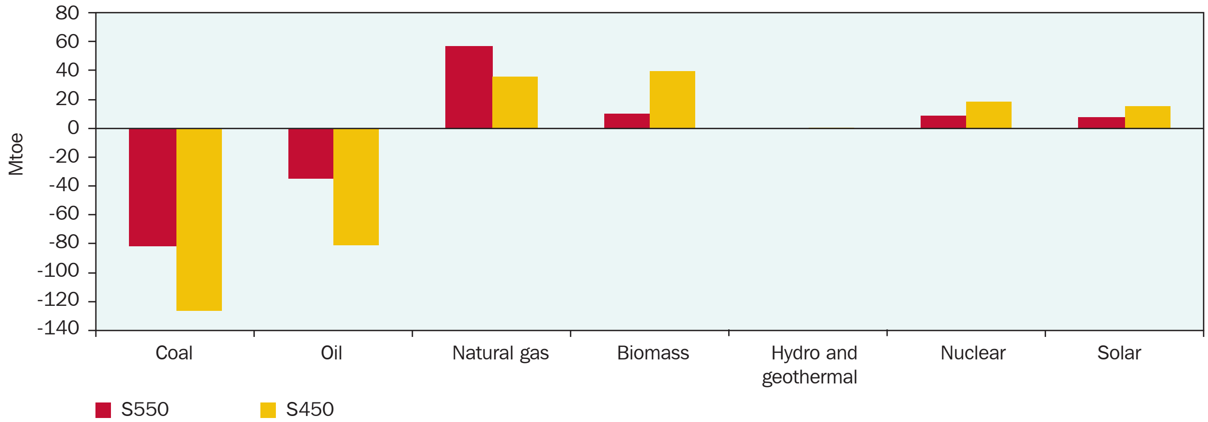


Source: ADB study team.

Under the stabilization scenarios, as part of the global mitigation solution, total primary energy consumption by the four countries would be 4–12% lower than the BAU level in 2050, depending on which stabilization level is considered, and the following adjustments in their primary energy consumption pattern would be required:

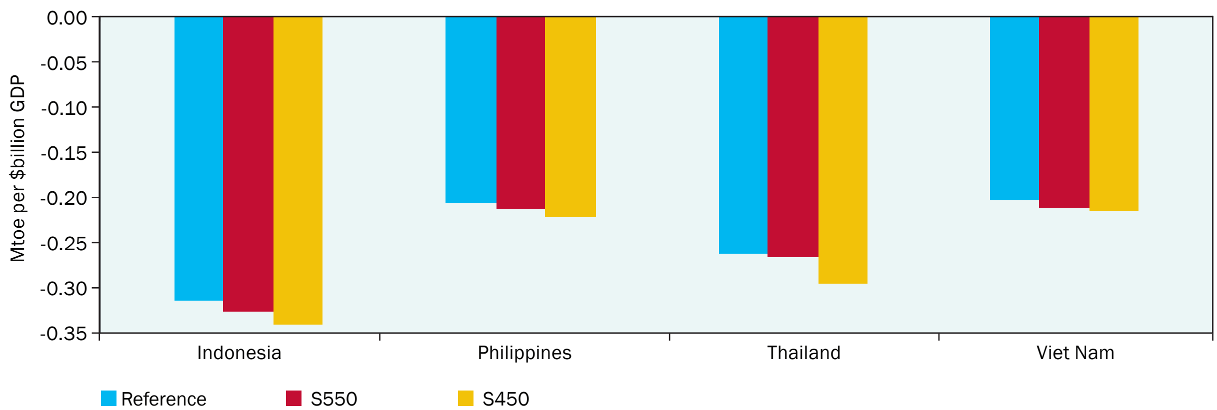
- The amount of annual coal consumption would be reduced. The four countries are projected to reduce annual coal consumption by 82 Mtoe (or 36%) with S550 and 127 Mtoe (or 56%) with S450, from the BAU level in 2050 (Figure 8.4);
- Petroleum consumption would also be cut back—about a 10% cut from the BAU level in 2050 with S550 and 23% cut with S450; and
- The primary energy mix would move toward more aggressive use of natural gas, biomass, solar, and nuclear energy (Figure 8.4). At the same time, energy intensity is projected to improve over time as compared to the BAU, especially Indonesia and Thailand (Figure 8.5).

Figure 8.4. Primary Energy Consumption Adjustment in 2050, Relative to Reference Scenario, in the Four Countries



Source: ADB study team.

Figure 8.5. Change in Primary Energy Consumption per Unit of GDP, 2050 Relative to 2000, in the Four Countries

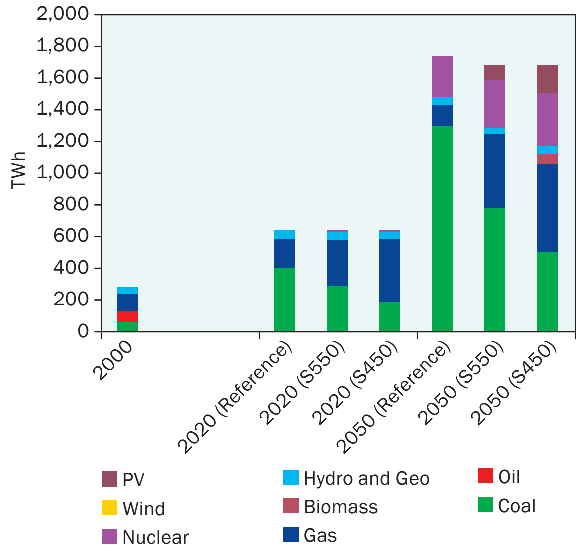


Source: ADB study team.

Contributing to the global mitigation efforts would also mean that coal-based power generation in the four countries under the BAU scenario be replaced with cleaner fuels such as natural gas, renewable (particularly solar), and nuclear power.

In 2000, gas was the most important source of energy for electricity generation in the four countries (39%), followed by coal (29%), oil (18%), and hydro and geo-thermal (16%). Under the BAU scenario, the share of gas is projected to decline to 29% in 2020 and 8% by 2050, but coal is projected to become more and more important given its lower cost (when ignoring carbon cost), with its share projected to reach 63% in 2020 and 74% in 2050 (Figure 8.6). At the same time, the share of oil is projected to be phased out completely by 2050 under the BAU scenario. Electricity generation based on renewable resources such as hydro, geo-thermal, and wind power is projected to increase only slightly and the share is likely to remain insignificant. Under the BAU scenario, electricity consumption per unit of GDP is projected to

Figure 8.6. Electricity Generation in the Four Countries

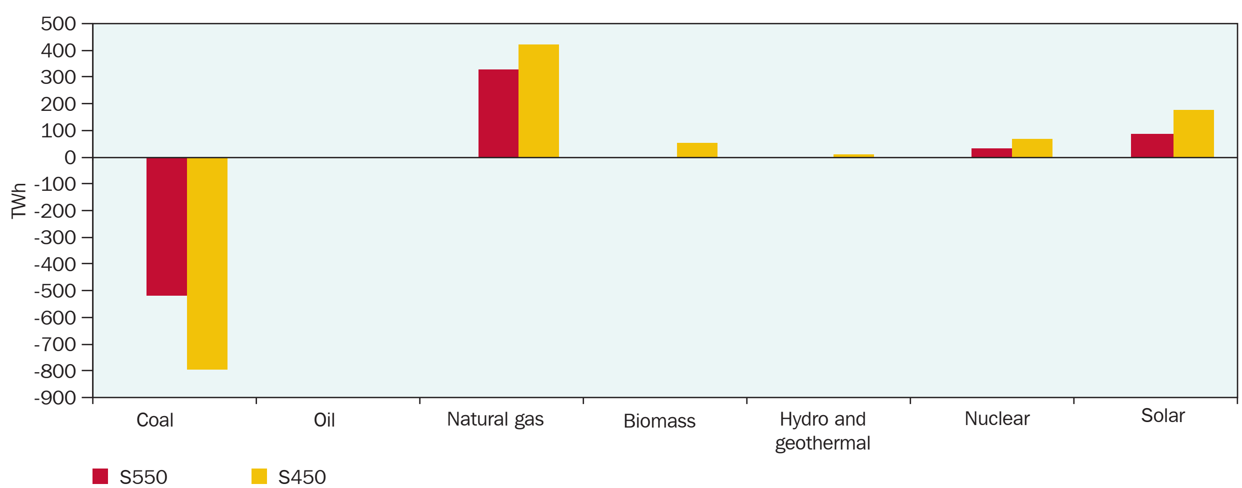


Source: ADB study team.

decline in 2050 compared to the 2000 level (Figure 8.8)

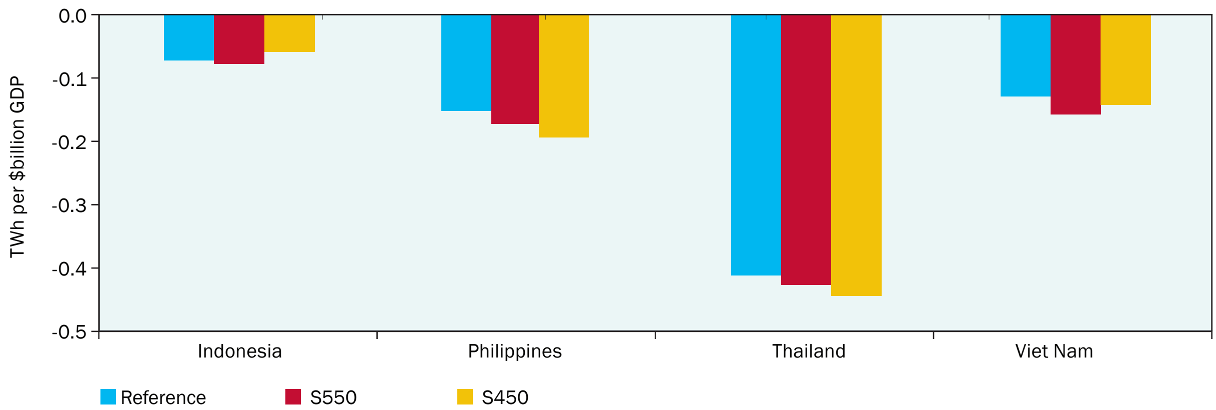
Under the stabilization scenarios, coal use would be far less important compared to the BAU scenario, and there would be a switch to natural gas, nuclear power and renewable energy including photovoltaics, wind, hydro and geothermal, as well as biofuels (Figure 8.7). The modeling results show that, by 2050, electricity consumption per unit of GDP with stabilization would be lower than with business-as-usual (BAU) in most four countries (Figure 8.8). Although the total electricity consumption is projected to be higher under S450 than the BAU in Indonesia, higher electricity demands would be met by cleaner forms of power generation that result in lower CO_2 emissions.

Figure 8.7. Electricity Generation Adjustment in 2050 Relative to Reference Scenario, in the Four Countries



Source: ADB study team.

Figure 8.8. Change in Electricity Generation per Unit of GDP, 2050 Relative to 2000, in the Four Countries

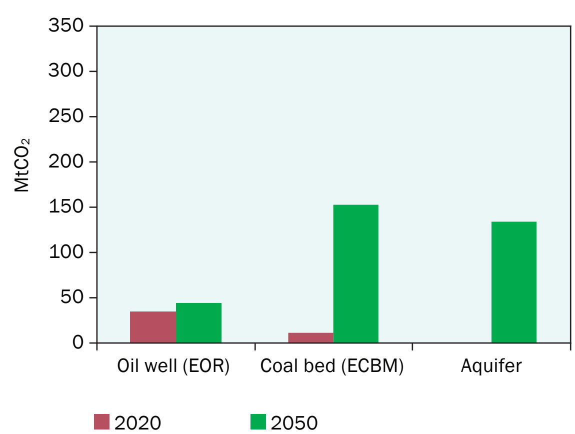


Source: ADB study team.

Mitigation through CCS could become feasible as the carbon price rises toward 2050, with reduction potential of up to 22% of their emissions under the business-as-usual scenario.

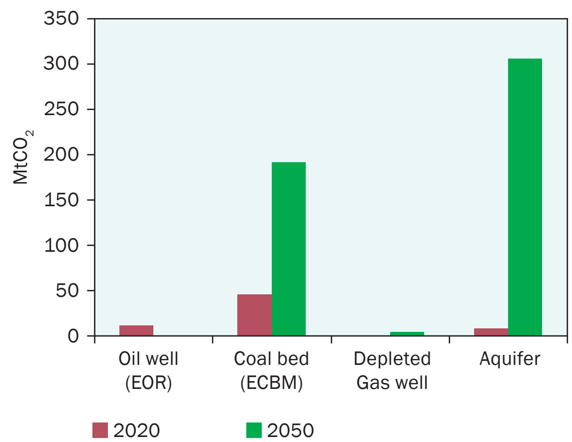
In addition to changes in the primary energy consumption pattern and fuel switching in electricity generation, mitigation options for the four countries in the coming decades could also include CO_2 reduction through CCS technologies. Under S550, with the carbon price projected to be \$6.7/ tCO_2, geological storage of CO_2 in oil wells (EOR) and coal beds (ECBM) is projected to become economically feasible by 2020 for the four countries, mainly Indonesia; when the carbon price rises to around \$25.5/tCO_2, injection of CO_2 into deep saline aquifers is projected to become economically feasible by 2050 and would help capture as much as 133 $MtCO_2$ per year, 6% of the BAU emission in that year (Figure 8.9). Under S450, with the carbon price projected to be above \$80/tCO_2 by 2050, CCS is likely to play an even more important role in emissions reductions in all the four countries with coal beds

Figure 8.9. CO_2 Capture and Storage under S550, in the Four Countries



Source: ADB study team.

Figure 8.10. CO_2 Capture and Storage under S450, in the Four Countries



Source: ADB study team.

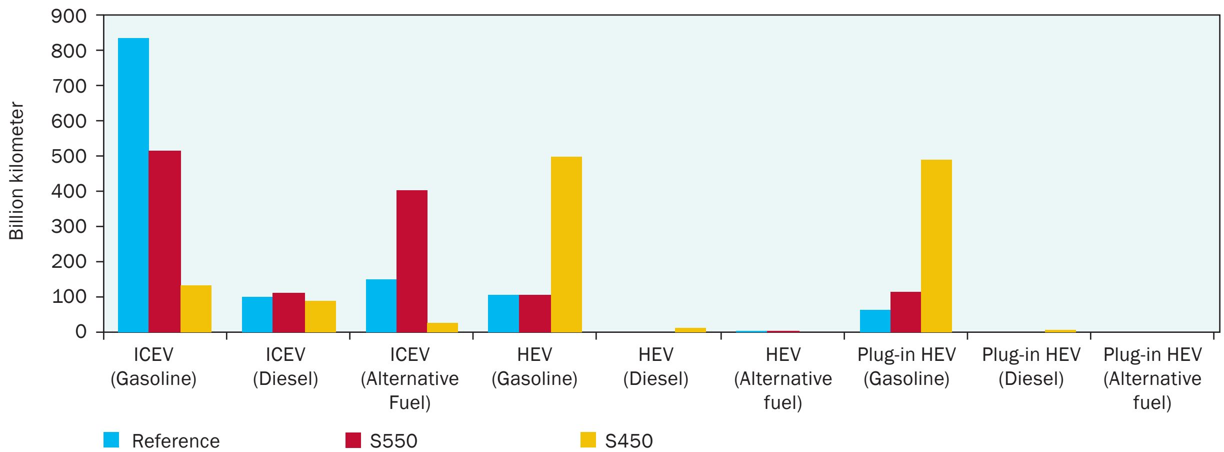
and deep saline aquifers projected to store about 192 $MtCO_2$ (9% of the BAU emission) and 310 $MtCO_2$ (14% of the BAU emission) by 2050, respectively (Figure 8.10), and total CO_2 storage using all available options projected to be about 506 $MtCO_2$ in 2050. This would be equivalent to 22% of total CO_2 emissions from the four countries under the BAU scenario in 2050. This confirms the importance of CCS technologies in mitigating CO_2 emissions in the four countries in the coming decades.

The four countries' contribution to global mitigation would also involve switching from dominant gasoline-powered vehicles to innovative low-carbon options.

In 2000, gasoline-powered internal combustion engine vehicles (ICEV) dominated road transportation in the four countries. The modeling results show that they would continue to dominate the sector in 2020 under all scenarios (BAU, S550, and S450). However, if the stabilization targets are to be achieved the picture must change dramatically by 2050. Figure 8.11 shows that the use of ICEV using gasoline declines sharply by 2050 under both S550 and S450, relative to the BAU. Under S550, the road transport sector would see fuel switching from gasoline to cleaner ICEV alternatives by 2050.

Under S450, different types of hybrid-electric vehicles (HEV) are likely to replace ICEV. For instance HEV (gasoline) and plug-in HEV (gasoline) together are expected to constitute about 77% of total distance traveled by passenger cars in Indonesia by 2050, while the share of ICEV (gasoline and diesel) would drop from 78% under the BAU scenario to 23%. A similar trend is likely in Thailand and the Philippines: in Thailand, about 80% of total distance traveled in 2050 could be by HEV and plug-in HEV, while this share could be as high as 90% in the Philippines. In Viet Nam, it is predicted that about 58% of total distance traveled in 2050 could still be by ICEV (gasoline and diesel),

Figure 8.11. Projection of Kilometers by Car by 2050 in the Four Countries



Source: ADB study team.

with the rest covered by ICEV (alternative fuel) and plug-in HEV (gasoline). However, this is a significant improvement from the BAU scenario, where ICEV (gasoline and diesel) would grow to account for about 92% of total distance by that time.

C. Marginal Abatement Cost Curves for the Four countries

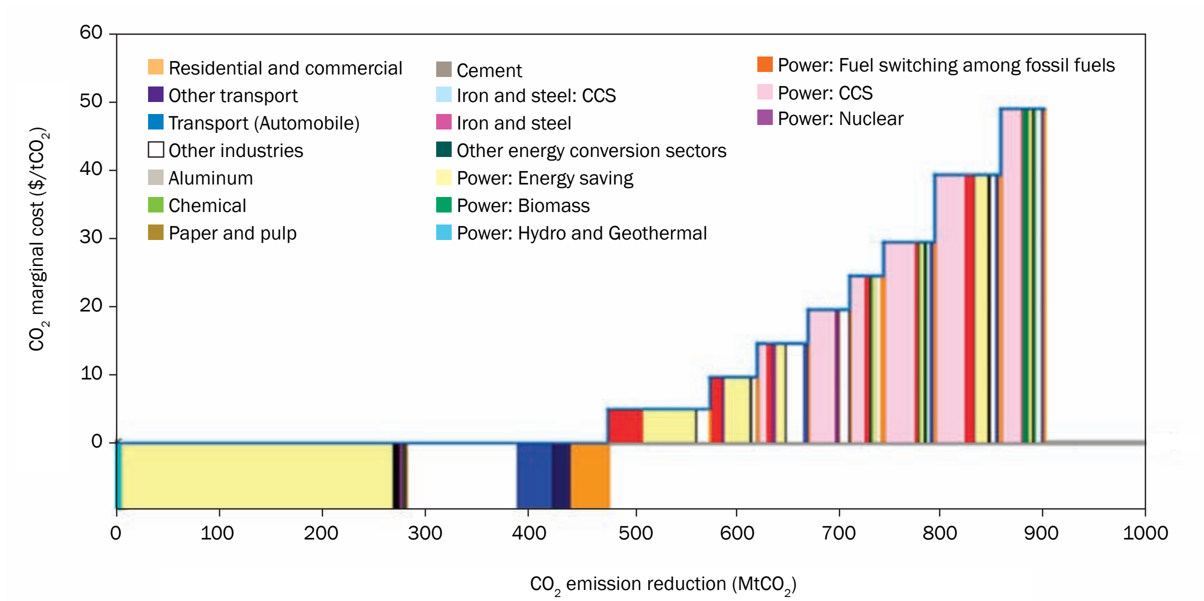
The cost of CO_2 mitigation varies across countries and among different options. Numerous studies have estimated the marginal abatement cost (MAC) curves for the world, various regions and individual countries. Consistent with other studies, MAC curves are generated in this study to show the estimated marginal mitigation cost per ton of avoided emissions, as well as the mitigation potential of these options. The mitigation cost is estimated as the additional incremental cost of adopting a particular mitigation option compared to the BAU scenario. For instance, the mitigation cost of fuel switching in power plants is the additional cost of producing electricity using, say, natural gas instead of coal. Some mitigation measures have negative net cost because the mitigation expenditure is outweighed by the benefits from energy cost savings. In general, as the level of mitigation efforts increases, more expensive options would have to be deployed.

This study constructed the MAC curves for the four countries as a whole and individually using the DNE21+ model, with a view to assessing the potential of various mitigation options and their cost effectiveness in 2020. The analysis is based on two key assumptions (see Appendix 2 for country-specific marginal abatement cost curves in 2020). First, it is assumed that technologies are frozen at the 2005 level such that the future energy and CO_2 intensity by sector is fixed at the value in that year. Second, no mitigation measures are taken from 2005 onwards until 2020 when MAC is generated. It should be noted that the analysis does not take into account existing transaction costs and adoption barriers, such as people's preference, social/cultural norms, and market-related barriers (such as incomplete information and subsidies on energy price). These barriers are important reasons why many of the win-win options are not being adopted. Furthermore, the MAC analysis in this study only considers the mitigation measures related to the energy supply and demand sectors and does not include those available in non-energy sectors such as land use, forestry and the agriculture sector.

There would be significant potential for CO_2 reduction for the four countries in the coming decades, about half achievable with possible net cost savings. This is greater than the CO_2 reduction estimated as their contribution to the global mitigation solution under S450 in 2020.

The MAC analysis projects that the total emission reduction potential in the four countries is likely to be about 903 $MtCO_2$ by 2020, equivalent to 79% of total energy-related CO_2 emissions under the BAU scenario in the same year. About 53% of which, amounting to 475 $MtCO_2$, could be achieved by "win-win" mitigation options—that reduce CO_2 and at the same time bring in net cost savings (Figure 8.12). The "win-win" options are largely energy efficiency improvement measures. The greatest potential would be from the electricity generation sector, particularly from efficiency improvement of existing coal, oil, and gas power plants. Considerable potential with net negative cost also exists in the industry sector, achievable mainly through the adoption of more efficient technologies in iron and steel, cement, paper and pulp, chemical, and other energy-intensive industries (Table 8.1). Furthermore, mitigation through efficiency improvement of ICEV and increased use of bio-ethanol in

Figure 8.12. Marginal Abatement Cost Curve for the Four Countries (2020)



Source: ADB study team.

Table 8.1. Key "win-win" Mitigation Potential in the Four Countries (2020)

Efficiency Improvement Option	Mitigation Potential ($MtCO_2$)
Power sector	264
Energy conservation sector	6
Industry sector	115
Transport sector	51
Residential sector	39
Total	475

Source: ADB study team.

the transport sector, as well as enhanced efficiency in electrical appliances in the residential sector, is also projected to bring in net cost savings by 2020. Achieving these, however, requires policies and institutions that would help eliminate the existing market failures and implementation barriers, and reduce transaction costs.

Significant mitigation potential, equivalent to about a third of BAU emissions, would be available in the four countries at a positive cost (below \$50/tCO_2) by 2020. Achieving it would require investment amounting to about 0.9% of GDP.

There would also be other technically feasible mitigation options in the four countries by 2020; however, these would come with a positive cost. About 144 $MtCO_2$, amounting to 13% of the BAU emissions could be cut at a cost lower than \$10/tCO_2. Fuel switching from coal to gas and energy savings in power generation are among the options within this cost range. Meaningful potential from CCS technologies is likely to materialize at the price level of \$20/tCO_2 or above. The reduction potential from wind and solar power generation is projected to be very small in the four countries by 2020. This is because the cost of implementing these new technologies is projected to still be relatively high in 2020. To realize the total potential with a positive cost below \$50/tCO_2, it is estimated that the four countries would have to invest about \$9.5 billion—approximately 0.9% of GDP in 2020.

D. Conclusion

Energy is a vital source of sustainable development. Energy use in the four countries will grow in parallel with the continued expansion of the region's economy. Without further mitigation, fossil fuel consumption will continue to increase and the region is likely to become more coal-dependent over the coming decades, leading to a large amount of CO_2 emissions, and adding to concerns about global warming and its impacts on future economic development, globally and in the region. There are a number of mitigation options that are—or will become—available to the four countries. Many of these are relatively low-cost options, with some bringing in net energy cost savings such as efficiency improvement in energy supply (power plants) and demand sectors (that is, industry, residential, commercial, and transport), and have significant potential.

Efficiency improvement and energy saving/conservation measures will have to be complemented by other low-carbon technologies such as CCS, and clean and renewable forms of power generation. CCS is expected to provide large CO_2 reduction potential in the longer term, and its development is still at an early stage. Wind and solar power generation technologies are still relatively costly to developing regions such as the four countries. Scaling up their use in the region will be a major challenge. Expansion of the global market for low-carbon alternatives will be critical to the success of global GHG reduction in the long term. An appropriate carbon price can also be set, for example, through tax, trading, or regulation, so that consumers and producers face up to the social cost of their emissions. This will provide the right incentives for the switch to cleaner and more energy-efficient technologies.

The adoption and diffusion of low-carbon technologies requires policies and institutions that will help eliminate the existing implementation barriers, lower transaction/hidden costs, as well as a large sum of additional financial resources for investment in new technologies. The much needed regional and global cooperation, particularly through technological and financial support from developed to developing countries, is a key element to the success of the ambitious CO_2 stabilization target, and financing mechanisms will have to be put in place in order to facilitate this global action.

Appendix 1: Results by Country[1]

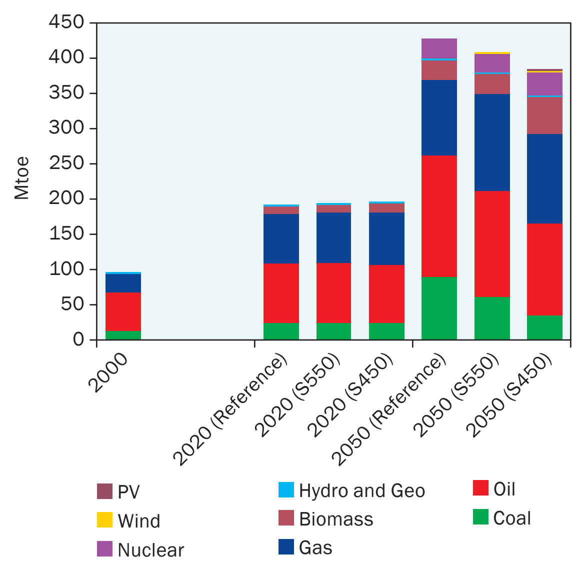
Country-specific Projections under Different Scenarios

Appendix 1 presents modeling results with regard to primary energy consumption, electricity generation, and CO_2 emissions and storage for the four countries towards 2050 under different scenarios, and their Marginal Abatement Cost curves in 2020

Indonesia

Indonesia's energy sector will continue to be the largest among the four countries. The country's total consumption of primary energy is projected to increase from 96 Mtoe in 2000 to 192 Mtoe in 2020 and 428 Mtoe in 2050 under the BAU scenario (Figure A1). Even though the room for adjustment appears to be limited, by 2020, significant opportunities for CO_2 reduction are projected to emerge by the middle of this century. By 2050, Indonesia's total consumption of primary energy and coal consumption are projected to decrease as part of the global mitigation solution. The share of coal-based power generation would decline dramatically under each of the stabilization scenarios (Figure A2). Total electricity generation in 2050 under S450 is expected to be higher than that of the BAU and S550 because more CCS would be adopted under S450 and would demand more electricity. It is likely that, in 2050, electricity production from coal will be reduced by 37% under the S550 relative to the reference scenario, and by 68% under the S450. Natural gas would, for the most part, provide the alternative to coal. Nuclear, solar, and methanol would also be used to facilitate Indonesia's shift from the reference to the S450.

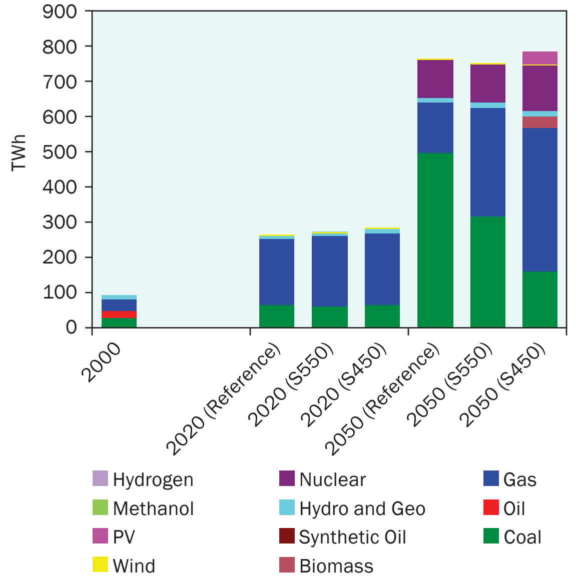
Figure A.1 Indonesia – Primary Energy Consumption



Source: ADB study team.

1 All figures and charts are from ADB study team.

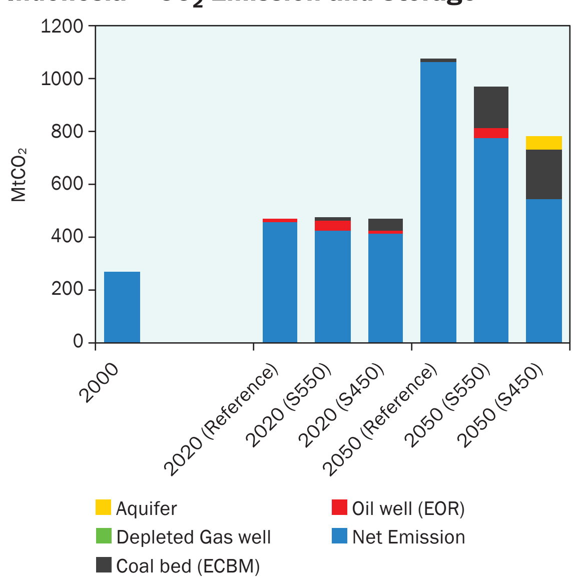
Figure A.2 Indonesia – Electricity Generation



Source: ADB study team.

Indonesia is the only country among the four countries where CO_2 storage in coal beds is feasible and, by 2050, its economic potential is projected to reach 155 $MtCO_2$ per annum under the S550 scenario, and 192 $MtCO_2$ per annum under the S450 scenario (Figure A3). By 2050, about 40 $MtCO_2$ would be injected into oil wells (EOR) per year under the S550 scenario and approximately 50 $MtCO_2$ would be stored in deep saline aquifer under the S450 scenario. Switching to cleaner fuels and CCS would, in combination, help Indonesia cut down the emissions in 2050 by nearly 290 $MtCO_2$ under the S550 scenario and 522 $MtCO_2$ under the S450 scenario relative to the reference case. Without mitigation efforts, Indonesia's CO_2 emissions are projected to increase three times relative to 2000, and would reach 1,075 $MtCO_2$ per annum by 2050.

Figure A.3. Indonesia – CO_2 Emission and Storage

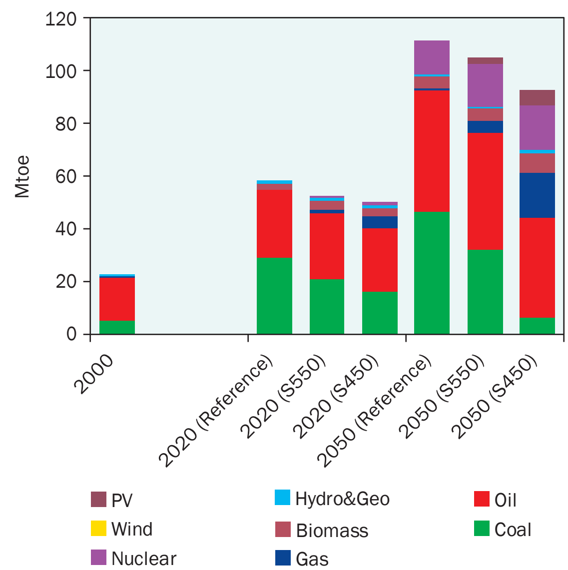


Source: ADB study team.

The Philippines

Oil constitutes 75% of the total 23 Mtoe of primary energy consumed in the Philippines in 2000. It is projected that it will consume more oil in the future (Figure A4). The country imported about 17.2 Mtoe of crude oil and petroleum products in 2005 (IEA 2005). Oil consumption is expected to reach 26 Mtoe per year in 2020 and 46 Mtoe per year in 2050 under the reference scenario. Coal would be called in to serve the fast growing energy demand that will rise to 111 Mtoe per year by 2050. Greater supply of biomass energy would be seen over time, but it would contribute only a small proportion of the total. Under the stabilization scenarios, coal use is likely to be much lower than under the reference scenario, particularly in the longer term—6 Mtoe for the S450 ppm scenario versus 47 Mtoe for the reference scenario in 2050. CO_2 reduction in the Philippines is expected to come from lower total energy demand, less consumption of coal and oil, and more aggressive use of biomass, gas, and solar energy.

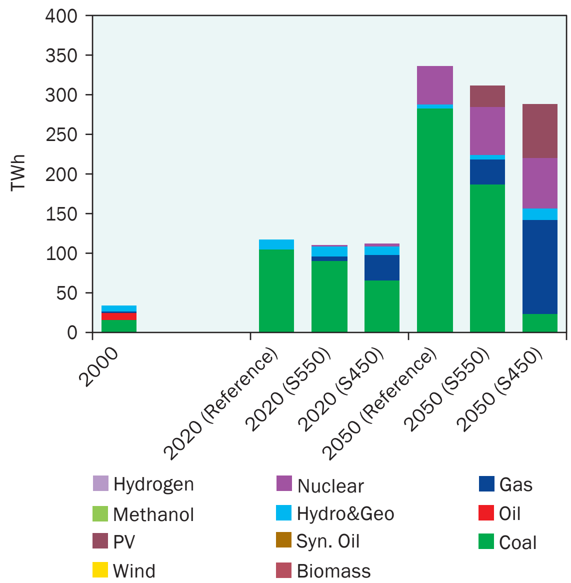
Figure A.4. Philippines – Primary Energy Consumption



Source: ADB study team.

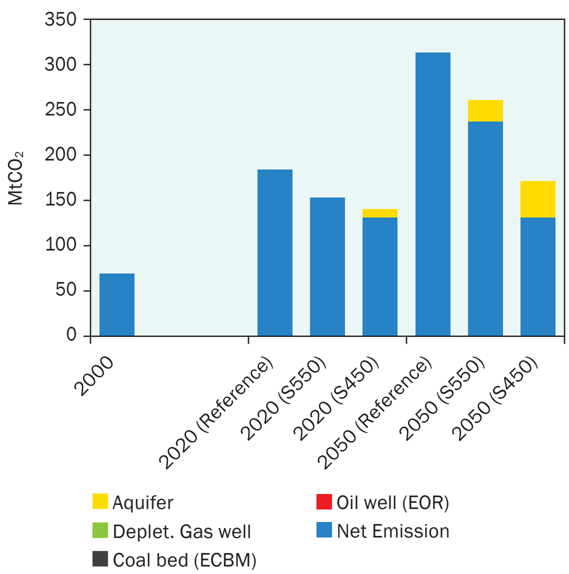
Under the reference scenario, 90% of electricity would be generated from coal by 2020 (Figure A5). By 2050, nuclear power would become available, yet 84% of power generation will still be coal-based. Under the stabilization scenarios, however, the Philippines would see a substantial reduction of coal-based power generation: under the S450, about 259 TWh of coal-based electricity will be replaced by extensive use of natural gas, and augmented nuclear, solar, and hydro and geothermal power generation. These measures and deep saline aquifer storage together are expected to help cut about 183 $MtCO_2$ per annum by 2050 under the S450 (Figure A6). The Philippines would not see CCS opportunities at all unless carbon is priced. Some scope for CCS will be possible by 2050 under the S550, and perhaps as early as 2020 under the S450.

Figure A.5. Philippines – Electricity Generation



Source: ADB study team.

Figure A.6. Philippines – CO_2 Emission and Storage

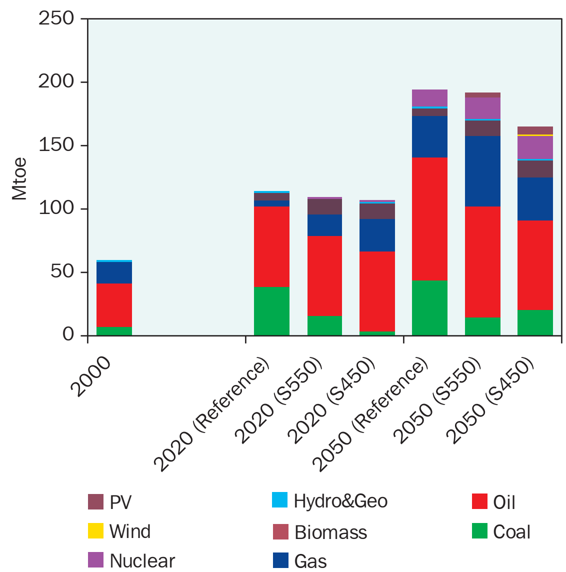


Source: ADB study team.

Thailand

Under the reference scenario, Thailand is projected to consume more coal and oil as primary energy demand grows—it is likely to expand more than threefold by 2050 relative to the base year (Figure A7). Electricity generation would also grow very rapidly, from 95 TWh in 2000 to 150 TWh in 2020 and 316 TWh by 2050. As in other four countries, Thailand's power sector would be supported mostly by coal (Figure A8). Under the stabilization scenarios, the level of coal consumption is projected to be much lower, and coal would be replaced largely by natural gas. Nuclear and solar power are likely to become significant sources of energy by 2050, if a global CO_2 stabilization target materializes.

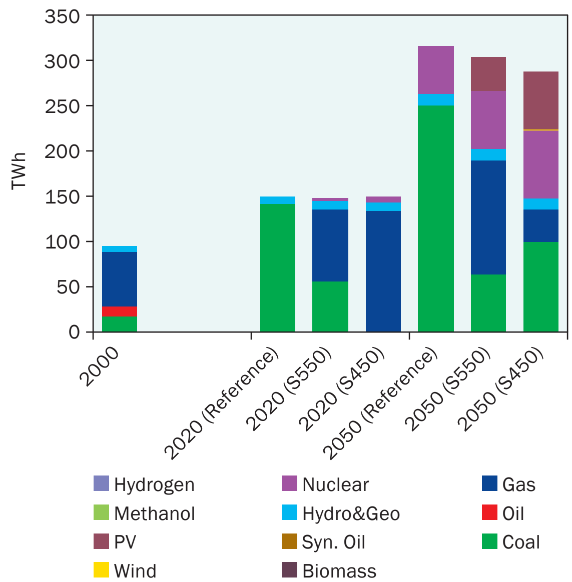
Figure A.7. Thailand – Primary Energy Consumption



Source: ADB study team.

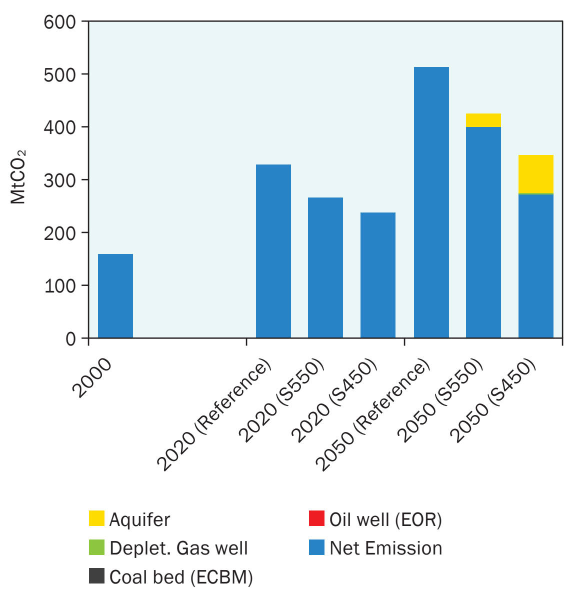
As a consequence of growing fossil fuel consumption under the reference scenario, Thailand's CO_2 emissions are projected to be more than triple during 2000—2050, rising from 158 $MtCO_2$ in 2000 to 512 $MtCO_2$ in 2050 (Figure A9). An increase in carbon price, as stabilization targets tighten, would induce the switch to cleaner energy such as natural gas in the mid-term, and solar and nuclear in the longer term. CCS opportunities are unlikely to emerge in Thailand, unless there is a price on carbon, sufficient to make CCS financially attractive. In which case, storage of CO_2 emissions in deep saline aquifers is expected to be available by 2050, with a sizeable potential under the S450 scenario. The CCS would complement the fuel switching efforts and collectively, by 2050, would have the potential to reduce 112 $MtCO_2$ per annum under the S550 and 240 $MtCO_2$ per annum under the S450.

Figure A.8. Thailand – Electricity Generation



Source: ADB study team.

Figure A.9. Thailand – CO_2 Emission and Storage



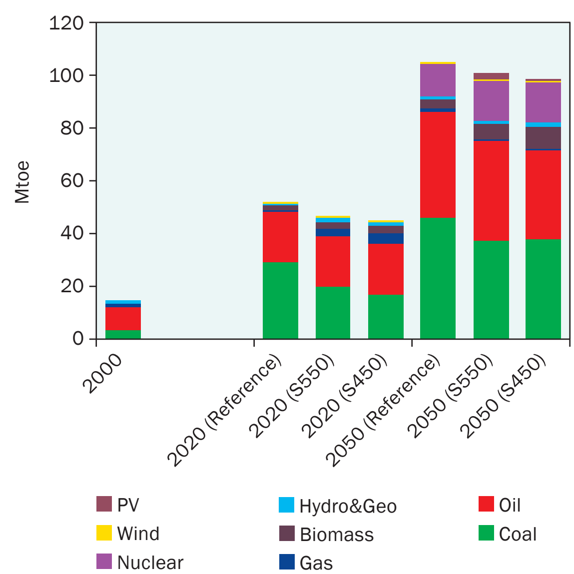
Source: ADB study team.

Viet Nam

Viet Nam currently has the fastest growing energy sector among the four countries. Its primary energy demand is projected to grow at 13% per annum on average during 2000–2020 (Figure A13). Viet Nam's electricity generation is expected to climb from 28 TWh per annum in 2000 to 114 TWh per annum in 2020, and 344 TWh per annum in 2050 (Figure A10). As expected, coal and oil consumption would expand significantly under the reference scenario towards 2050, since Viet Nam has large coal and crude oil reserves. Biomass would be used more aggressively, and fossil fuel consumption is expected to decline slightly under the stabilization scenarios.

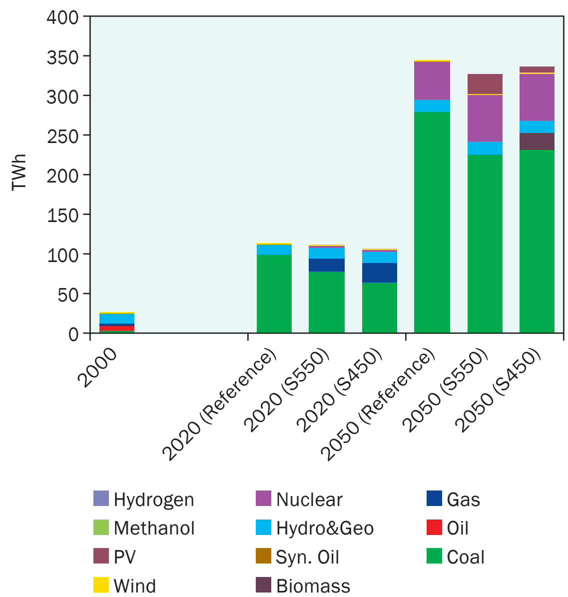
With abundant domestic coal resources, Viet Nam's electricity generation sector would be dominated by coal in all future scenarios (Figure A11). Although the country has the largest potential for hydro-electric power among the four countries, hydropower would remain insignificant in the share of total power generation in Viet Nam. The implication of this is that there would be a swift growth of CO_2 emissions under the reference scenario. In this case, the emissions are projected to rise from 48 $MtCO_2$ in the base year to 172 $MtCO_2$ in 2020 and to over 300 $MtCO_2$ in 2050. Under the stabilization scenarios, injection of CO_2 into deep aquifers is possible with relatively large potential and is likely to become available by 2050 (Figure A12). CCS could potentially be the most significant source of CO_2 mitigation in Viet Nam by 2050. Under the S450 scenario, CCS could contribute as much as 74% of total possible CO_2 reduction in 2050 relative to the reference scenario.

Figure A.10. Viet Nam – Primary Energy Consumption



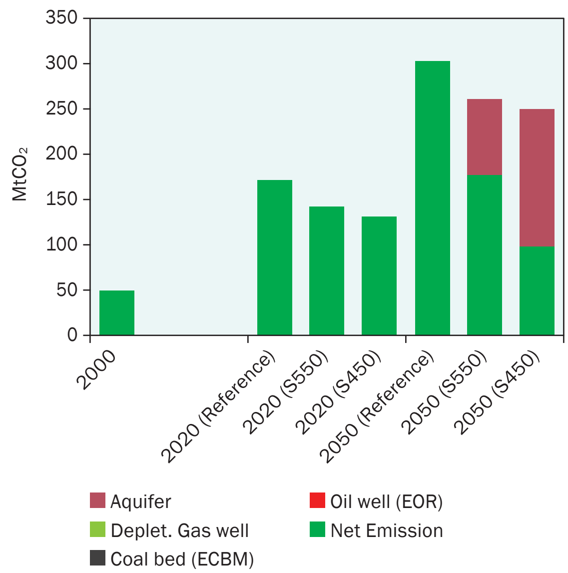
Source: ADB study team.

Figure A.11. Viet Nam – Electricity Generation



Source: ADB study team.

Figure A.12. Viet Nam – CO_2 Emission and Storage



Source: ADB study team.

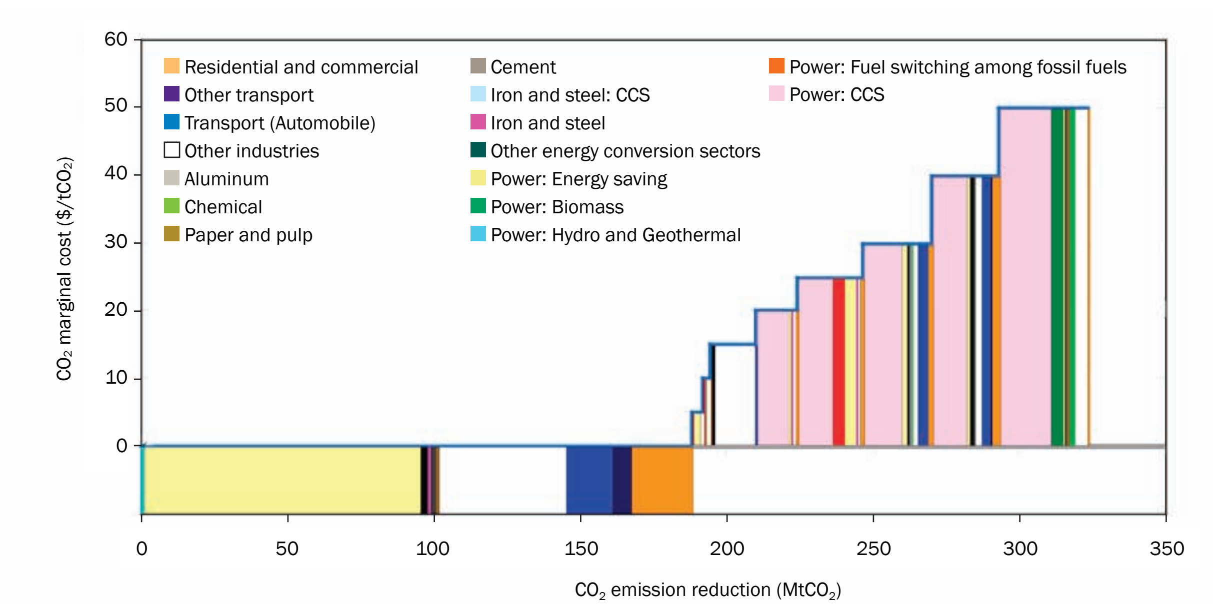
Appendix 2

Country-specific Marginal Abatement Cost Curves in 2020

Indonesia

By 2020, the total energy-related CO_2 reduction potential in Indonesia is projected to be about 344 $MtCO_2$. About 38% of the four countries' net negative-cost potential would be in Indonesia (amounting to 194 $MtCO_2$, 47% of its BAU emissions). The CO_2 reduction potential from efficiency improvement of coal and gas power plants is projected to be 97 $MtCO_2$ in 2020, while that from energy efficiency improvement in the industry, transport, and the residential sectors together would constitute as much as 93 $MtCO_2$ (Figure A13). CCS potential would still come at a price of at least $20/$tCO_2$. There would be very little CO_2 reduction potential achievable at a carbon price below $10/$tCO_2$. Capturing the total CO_2 reduction potential at a positive cost (below $50t/$CO_2$) in 2020 would require Indonesia to invest $4.3 billion in clean technologies, amounting to about 1% of GDP in 2020.

Figure A13. Indonesia – Marginal Abatement Cost Curve (2020)

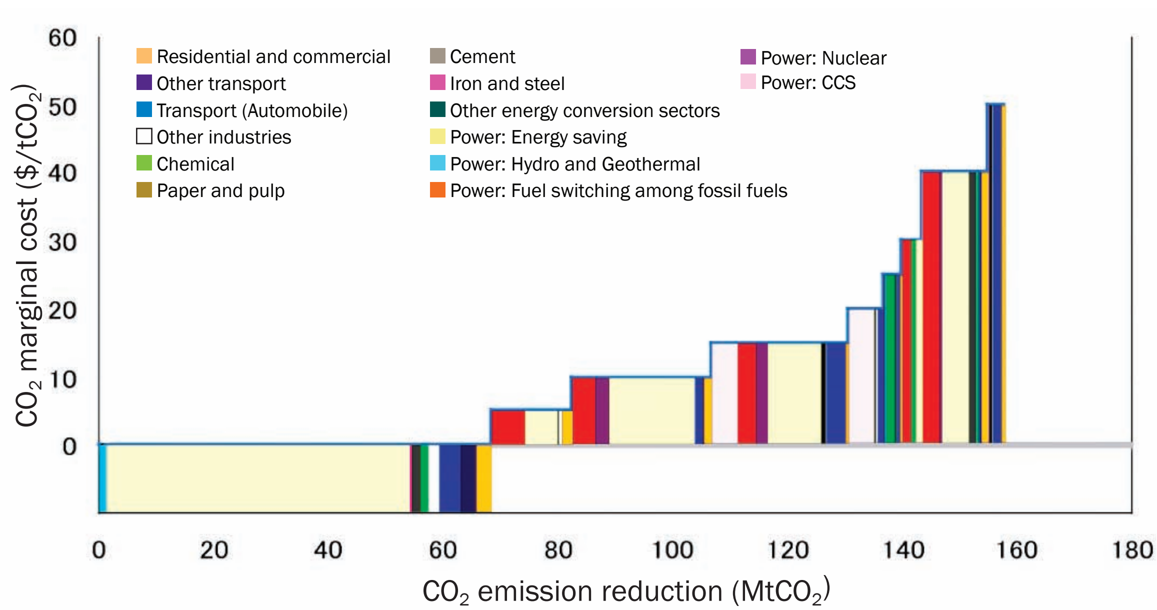


Source: ADB study team.

The Philippines

The Philippines would have fairly large CO_2 reduction potential at a relatively low cost. A number of net negative cost options exist in the power, industry, transport, and residential and commercial sectors, with total potential of 68 $MtCO_2$ (amounting to 37% of the BAU emissions) in 2020 (Figure A14). The potential with positive cost below $10/$tCO_2$ is projected to be about 38 $MtCO_2$ in 2020 to be achieved mainly through a combination of fuel switching from coal to gas-based power generation and energy efficiency improvement in power plants. Mitigation at a price below $10/$tCO_2$ is also possible through wider use of high efficiency air-conditioning and television in the residential and commercial sector, and diffusion of bio-ethanol use, plus efficiency improvement of ICEV in the transport sector. It is projected that CCS would become economically feasible at a price below \$20/tCO_2, but the reduction potential is somewhat limited. The total potential with a positive cost below \$50/tCO_2 in the Philippines is estimated to be 89 MtCO_2 in 2020: achieving this would require the Philippines to invest up to \$1.6 billion, amounting to about 0.6% of its GDP in 2020.

Figure A14. Philippines – Marginal Abatement Cost Curve (2020)

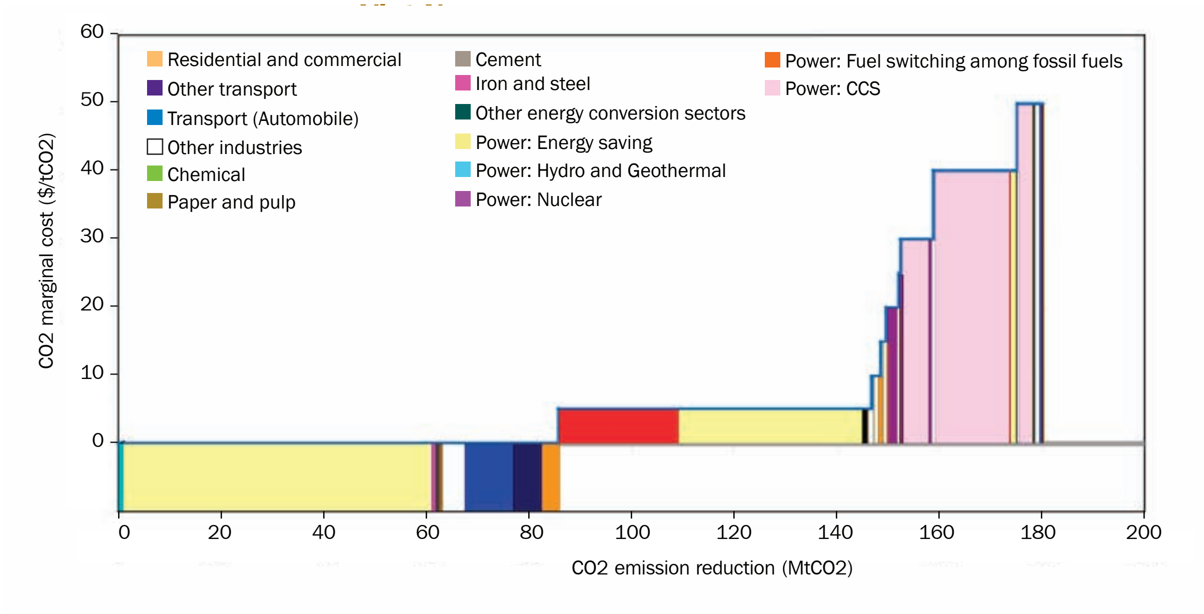


Source: ADB study team.

Thailand

Thailand's total CO_2 reduction potential in 2020 is projected to be around 180 MtCO_2 (55% of the BAU emissions), about 83% of which would emerge at a price below \$10/tCO_2 including a net negative price (Figure A15). A substantial amount of CO_2 reduction, about 101 MtCO_2, would be achievable through efficiency improvement of power plants at a net negative cost. Relatively large mitigation potential in Thailand could also be captured through fuel switching from coal- to gas-based power generation: this option is projected to be available at the cost of \$5/tCO_2 or lower in 2020. There is great potential for CCS in Thailand, but most is likely to come at a price of \$30/tCO_2 or above. Capturing total reduction potential with a positive cost (around 94 MtCO_2) in 2020 would require Thailand to invest up to \$1.5 billion—about 0.5% of GDP—in several clean technologies, mostly in the power supply sector.

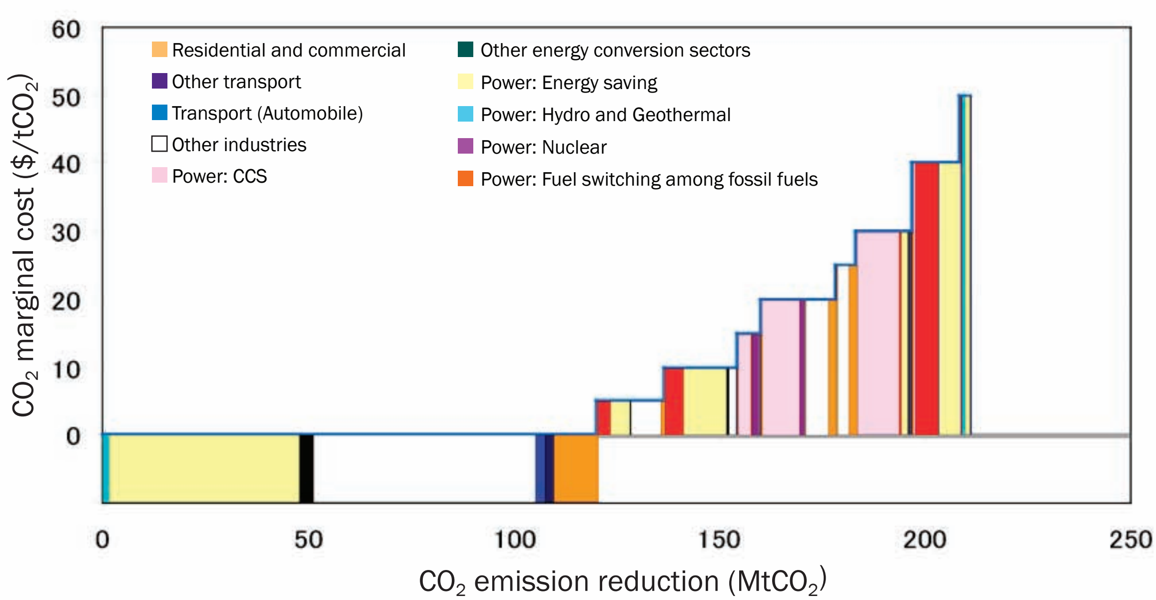
Figure A15. Thailand – Marginal Abatement Cost Curve (2020)



Source: ADB study team.

Table A1 summarizes the emission mitigation potential from the energy sector and the estimated upper-bound investment requirement in 2020 for each study country

Figure A16. Vietnam – Marginal Abatement Cost Curve (2020)



Source: ADB study team.

Table A.1. Mitigation Potential in Energy Sector and Total Cost in 2020

Country	Total mitigation potential $MtCO_2$	Mitigation potential at negative cost $MtCO_2$	Total investment cost in $ billion	Share of GDP in 2020 %
Indonesia	342	207	4.27	1.0
Philippines	157	68	1.58	0.6
Thailand	180	100	1.49	0.5
Viet Nam	211	120	1.83	1.3

Note: Investment cost covers only mitigation expenditures where there is a positive cost prices are 2000 constant prices, and GDP in 2020 is forecast by the DNE21+ model.

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PART IV

Policy Responses

CHAPTER 9

Climate Change Policy: A Review

Key Messages

All governments in the region have developed plans for addressing climate change challenges and designated key agencies to implement such plans.

As Non-Annex I parties, Southeast Asian countries have no obligation to set quantitative targets for emissions reduction, but they have developed policies, programs, and measures for adaptation and mitigation.

Multilateral institutions and United Nations agencies support climate change initiatives in the region through: sector-specific international initiatives from which the region could benefit to enhance its mitigation efforts and access to low-carbon technologies; institutions and programs that support climate change capacity building and development; international funding sources and mechanisms available for mitigation and adaptation.

Going forward, Southeast Asian countries should integrate adaptation and mitigation actions more closely into their sustainable development poverty reduction strategies and policy-making processes.

While the existing international funding sources available for supporting adaptation and mitigation actions in developing countries fall far short of what is required, and need to be scaled up, the region should enhance institutional capacity to make better use of existing and potential international funding sources.

A. Introduction

Climate change is the most serious market failure the world has ever witnessed. Like any market failure it can only be resolved through the intervention of public policy. As a global public good, its solution requires the intervention of both individual national governments and the world community. In recent years, Southeast Asian countries have established their own national plans and institutions to deal with climate change and its impacts, and to support adaptation and mitigation activities. This chapter looks at the policies, initiatives, and institutional arrangements that exist in the region; at the action plans and programs developed for adaptation and mitigation; and the finance available internationally to fund climate change initiatives.

B. National Policy and Actions in Southeast Asia

All governments in the region have developed climate change plans and designated key agencies to implement them.

As signatories to the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol and as part of their commitment to the convention process, each study country has developed its own national plan or strategy for climate change and has established a ministry or agency as the focal point for climate change policy (Table 9.1).

- In Indonesia, the Ministry of Environment's (MoE) Climate Change Division is the focal point serving as the designated national authority for the Clean Development Mechanism (CDM). A National Committee on Climate Change and a related Steering Committee were established to offer broad policy guidance and to make funding allocation decisions. The Steering Committee is served by an advisory panel and a technical committee headed by the MoE and the National Development Planning Agency (BAPPENAS).

- The Philippines, in early 2007, created the Presidential Task Force on Climate Change to be the focal point for all climate change-related activities. It is composed of the Secretary of the Environment and Natural Resources as chair, with the Secretaries of Energy, Science and Technology, Agriculture, and Interior and Local Government, with two representatives from the private sector/civil society as members.

Table 9.1. Government Agencies and Climate Change Key Plans

Country	Focal Point	Key Plans/Strategy
Indonesia	Ministry of Environment, Climate Change Division	National Climate Change Action Plan 2007
Philippines	Presidential Task Force on Climate Change	Philippines Energy Plan 2004–2014
Singapore	Ministry of Environment and Water Resources	National Climate Change Strategy 2006, part of Singapore Green Plan 2012
Thailand	Ministry of Natural Resources and Environment, Office of Natural Resources and the Environmental Policy and Planning	National Strategic Plan on Climate Change 2008—2012
Viet Nam	Ministry of Natural Resources and Environment, Office for Climate Change and Ozone Protection	National Target Program in Response to Climate Change (draft close to completion)

Sources: Boer and Dewi (2008), Cuong (2008), Ho (2008), Jesdapipat (2008), Perez (2008).

- Singapore's Ministry of Environment and Water Resources, which leads the climate change program, developed in 2006 a National Climate Change Strategy as part of the Singapore Green Plan 2012. The strategy requires that climate change response must be sustainable, based on multi-stakeholder efforts, and developed through a consultative approach. In addition, the Ministry of National Development leads an inter-agency task force to review existing infrastructure adaptation measures, and the National Environment Agency has established the Energy-Efficiency Singapore Program Office. The Strategy document targets reducing carbon intensity by 25%, from 1990 levels, by 2012.

- In Thailand, the Ministry of Natural Resources and Environment has responsibility for government policy, within which the Office of Natural Resources and Environmental Policy and Planning (ONEP) is the national focal point to the UNFCCC. The National Climate Change Sub-committee was established under the National Environmental Board after the country ratified the UNFCCC. In July 2007, the government upgraded the National Climate Change Sub-committee to the National Climate Change Committee (NCCC), chaired by the prime minister. Technical subcommittees are also established under the national committee to support different aspects of climate change issues, including mitigation and vulnerability and adaptation. Thailand has already developed the country strategic plan on climate change and is currently developing its 10-year climate change plan. Thailand also established the Thailand Greenhouse Gas Management Public Organization (TGO) in July 2007. While NCCC sets policy, the TGO aims to cover all aspects of implementation of climate change projects, including CDM projects. A key policy aim is to strengthen the links between measures to address sustainable development and those to address climate change. Important areas of overlap include improvements to energy efficiency, and promotion of carbon sequestration.

- In Viet Nam in July 2007, the National Steering Committee for implementing the UNFCCC and the Kyoto Protocol was established. The Department of Meteorology, Hydrology and Climate Change under the Ministry of Natural Resources and Environment (MONRE) is the focal point for climate change activities in the country. A number of financial mechanisms and policies were instituted to support climate change activities through the Prime Minister Decision No. 130 August 2007. In December 2007, the prime minister tasked MONRE, in coordination with other relevant ministries, to establish a national target program in response to climate change.

As Non-Annex I[1] parties, Southeast Asian countries have no obligation to set quantitative targets for GHGs, but they have developed policies, programs, and measures for adaptation and mitigation.

1 Non-Annex I parties are mostly developing countries and recognized by the UNFCCC as especially vulnerable to the adverse impacts of climate change, including countries with low-lying coastal areas and those prone to desertification and drought. Others (such as countries that rely heavily on income from fossil fuel production and commerce) feel more vulnerable to the potential economic impacts of climate change response measures.

- Indonesia released its National Climate Change Action Plan in 2007, which calls for greater integration between mitigation, adaptation, and national development goals through better coordination between relevant agencies (energy, transportation, forestry, agriculture). It also called for incorporating climate-related funding decisions into all development plans, with the most promising signs of institutional coordination in medium- and short-term development plans. The plan is based upon "pro-poor, pro-job, pro-growth and pro-environmental" principles. It is also apparent that many sectors treat mitigation or adaptation as a climate co-benefit of developmental policies. Table 9.2 lists selected policies and measures in various sectors in

Table 9.2. Sectoral Policies, Programs, and Measures Relevant to Mitigation and Adaptation in Indonesia

Sector	Policies, Programs, and Measures
Climate Change	• Act No. 23/1997 Environmental Management • Act No. 6/1994 Ratification of UNFCCC • Act No. 17/2004 Ratification of the Kyoto Protocol • Decree No. 206/2005 Afforestation and Reforestation (A/R) CDM projects • Decree No. 14/2004 Afforestation and Reforestation (A/R) CDM projects
Energy	• National Energy Law/Presidential Decree No. 5/2006 (Perpes) • National Energy Conservation Plan 2002 (RIKEN) • MEMR Decree No. 2/2004 (Green Energy Policy) • MEMR Decree No. 1122/2002 • MEMR Decree No. 02/2006 • Presidential Instruction No. 10/2005 • Ministerial Regulation No. 031/2005
Transportation	• The Blue Sky Programme • Indonesia Area Traffic Control System • Ministry of Energy and Mineral Resources Decree No. 1585/K/32/MPE (1999) on Criteria for Marketing of Gasoline and Diesel in Indonesia • Act No. 14 on Traffic and Land Transportation • Government Regulation No. 44 regarding vehicles and vehicle operation • Minister of Environment Decree No. Kep-35/MENLH/10/1993 on Emission Limit for Gas Waste of Motor Vehicles • Governor of DKI Jakarta Decree No. 1041 on Motor Vehicle Emission Standards for DKI Jakarta • President Instruction No. 1/2006 on biofuels • President Instruction No. 10/2006 on biofuels
Forestry	• Reduced Emissions from Deforestation and Degradation in Indonesia • Regulation PP6/2006 on Forest Management and Utilization • Ministerial Decree SK. 159/Menhut-II/2004 related to the restoration of degraded ecosystem in production forest areas • Presidential Instruction Inpres 4/2005 on illegal logging • Presidential Decree Keppres 32/1990 prohibiting development on peat >3m deep • Presidential Instruction Inpres 2/2007 on rehabilitation of the ex-Mega Rice Project in Central Kalimantan • Ministerial Decree KepmenEkuin 14/2001 on Integrated Water Resources • Regulation PP 4/2001 on Forbidding the Use of Fire • Ministerial Decree KepMenHut 260/1995 Guidelines for Fire Control/ Prevention
Agricultural	• Climate Field Schools • National Climate Information System for Agriculture Development
Water and coastal	• Law 27/2007 on Coastal Zone and Small Island Management Conduct • Coral Reef Rehabilitation and Management Programme • Coral Triangle Initiative

Source: Boer and Dewi (2008).

Indonesia, which have implications for climate change mitigation and adaptation.

- The Philippines has initiated many adaptation measures in agriculture, water resources, and coastal areas that also aim to enhance food security, water security, and coastal security (Table 9.3). On mitigation, the government has initiated various strategies through sectoral policies, and other initiatives at the national and local levels (Table 9.4).

- Singapore's national policy on adaptation is embodied in the Singapore National Climate Change Strategy 2008 (Table 9.5). In the water sector, policies and measures for integrated water resources management, expansion and diversification of water sources (local water, NEWater, imported water, desalinated water); water conservation; and for demand-side management (for example, through pricing and an efficiency labeling scheme) have been introduced. In health, a comprehensive infectious disease surveillance program is also in place to prevent an outbreak of disease due to climate change. On mitigation, an inter-ministerial energy policy group has developed a national energy strategy to increase energy efficiency in all sectors of the economy, as a means to improve energy security, reduce CO_2 emissions, improve air quality, and reduce energy costs for companies and consumers.

- Thailand has taken adaptation measures in several sectors, including agriculture, water resource management, coastal defense, and forest, as shown in Table 9.6. On mitigation, the country has been tapping several policy areas where the link between sustainable development and climate change mitigation can be strengthened. Such policy areas include energy efficiency improvement, promotion of renewable energy, transportation policy, and promotion of carbon sequestration (Table 9.7).

Table 9.3. National Policies in the Philippines Related to Adaptation

Sector	Title of Law/Policy
Agriculture and fisheries	RA 9281 "The Agriculture and Fisheries Modernization Act of 1997" — An Act to Strengthen Agriculture and Fisheries Modernization in the Philippines by Extending the Effectivity of Tax Incentives and Its Mandated Funding Support, Amending for This Purpose Sections 109 and 112 of RA 8435 (March 30, 2004)
Water	RA 9275 "The Philippine Clean Water Act of 2004" — An Act Providing for a Comprehensive Water Quality Management and for Other Purposes (March 22, 2004)
	RA 8041 "The National Water Crisis Act of 1995" — An Act to Address the National Water Crisis and for Other Purposes (June 7, 1995)
	EO 222, Series of 1995 — Established the Committee on Water Conservation and Demand Management (January 24, 1995)
	PD 1067 "The Water Code of the Philippines" (December 31, 1976)
Fisheries	RA 8550 "The Philippine Fisheries Code of 1998" — An Act Providing for the Development, Management and Conservation of the Fisheries and Aquatic Resources, Integrating All Laws Pertinent Thereto, and for Other Purposes (February 25, 1998)
Waste	RA 9003 "Ecological Solid Waste Management Act of 2000" (January 31, 2001)
Coastal	PD 600 "Marine Pollution Decree of 1976" (August 18, 1976)

RA = Republic Act, EO = Executive Order, PD = Presidential Decree.
Source: Perez (2008).

Table 9.4. National Policies in the Philippines Related to Mitigation

Sector	Title of Law/Policy
Energy	RA 9367 "Bio fuels Act of 2006" — An Act to Direct the Use of Bio fuels, Establishing for this Purpose the Bio fuel Programme, Appropriating Funds Therefore, and for Other Purposes (January 12, 2007) Philippine Energy Plan 2004—2014 — Emphasizes Energy Independence and Savings, and Power Sector Reforms
	RA 9136 — An Act Ordaining Reforms in the Electric Power Industry, Amending for the Purpose Certain Laws and for Other Purposes (June 4, 2001) EO 462, Series of 1997 — Enabling Private Sector Participation in the Exploration, Development, Utilization and Commercialization of Ocean, Solar and Wind Energy Resources for Power Generation and Other Energy Uses (December 29, 1997) EO 123 — Institutionalizing the Committee on Power Conservation and Demand Management (September 8, 1993) RA 7638 "Department of Energy Act of 1992" — An Act Creating the Department of Energy Rationalizing the Organization and Functions of Government Agencies Related to Energy and for Other Purposes (December 9, 1992)
	RA 7156 "Mini-Hydroelectric Power Incentives Act" — An Act Granting Incentives to Mini-hydroelectric Power Developers and for Other Purposes (September 12, 1991) EO 433, Series of 1990 — Directing the Immediate Implementation of Additional Energy Conservation Measures (November 2, 1990) EO 418, Series of 1990 — Directing the Immediate Implementation of an Energy Conservation Program (August 13, 1990)
	EO 412, Series of 1990 — Institutionalizing the Energy Conservation Inter-Agency Committee (July 13, 1990) PD 1068 — Directing the Acceleration of Research, Development and Utilization of Non-Conventional Energy Sources (January 12, 1977) RA 5092 "Geothermal Energy, Natural Gas and Methane Gas Law" — An Act to Promote and Regulate the Exploration, Development, Exploitation and Utilization of Geothermal Energy, Natural Gas and Methane Gas; to Encourage its Conservation; and for Other Purposes (June 17, 1967)
Transportation	RA 8749 "The Philippine Clean Air Act of 1999" (January 23, 1999) EO 396, Series of 2004 — Reducing Rates of Import Duties on CNG Vehicles EO 397, Series of 2004 — Reducing Rates of Import Duties on Low-Displacement/Hybrid Vehicles
Forestry	RA 7586 "The National Integrated Protected Areas System (NIPAS) Act" (June 1, 1992) EO 263 — Adopting a Community-Based Forestry Management as the National Strategy to Ensure the Sustainable Development of the Country's Forestlands Resources and Providing Mechanisms for its Implementation (July 19, 1995) PD 705 — Revised Forestry Code of the Philippines, Revising PD 389 (May 19, 1975)

RA = Republic Act, EO = Executive Order, PD = Presidential Decree.
Source: Perez (2008).

Table 9.5. National Climate Change Adaptation Plans and Implementation in Singapore

Sector	Adaptation Plans and Implementation
Water	• Increase reclaimed water to meet 30% of national needs • Installation of 136 million liters/day of water using reverse osmosis (RO) technology • Increase water catchment from half to two-thirds of national land area • Water conservation strategy through pricing • Mandatory measures to reduce excessive flow and wastage
Flooding and sea-level rise	• Further reduction of flood areas from current 98 ha to 56 ha in 2011 • Land reclamation policy (1991) minimum of 125 cm above highest tide level • Key infrastructure to be at least 1 meter above recorded flood levels • Review of storm water design criteria • Building of rain forecasting capabilities
Energy	• Displacement of oil in power generation by natural gas • Development of liquefied natural gas terminal by 2012 to further promote use of natural gas in all sectors of the economy • Promotion of research and development capabilities and manufacturing capacity in renewable energy, for example in biofuels and solar photovoltaic cells

Table 9.5. National Climate Change Adaptation Plans and Implementation in Singapore *(continued)*

Industry	• Energy Efficiency Improvement Scheme providing 50% of cost of energy audits of buildings and industrial processes • Grant for Energy Efficient Technology to provide funding to private sector companies to offset part of their investment costs for energy efficient equipment • Design for Efficiency Scheme has been introduced to help companies incorporate energy efficiency considerations during the conceptual design phase by co-funding cost of design workshops • Singapore Certified Energy Manager Training Grant has been introduced to equip facilities owners and technical staff with the knowledge and skills to manage energy services
Transport	• Land transport policies are focused to encourage public transport • Car ownership is discouraged through imposition of taxes on vehicle ownership • Vehicle congestion is managed through road pricing system and integrated land-use planning
Buildings	• Standard to reduce external heat transfer to air-conditioned buildings has been introduced, Envelope Thermal Transfer Value of such buildings is currently set at 50 W/m2 • Green Mark Scheme, a building rating scheme, has been introduced to encourage incorporation of environment-friendly and energy-saving features. From 2008, all new buildings and existing buildings with gross floor area greater than 2,000 m2 must meet this standard • From 2008, all household refrigerators and air-conditioners must be energy labeled.
Public health	• Improve health care system through raising standards of healthcare, increase capacities and resources of hospitals • Vector control and surveillance system and programme and research and development

Source: Ho (2008).

Table 9.6. National Climate Change Adaptation Plans and implementation in Thailand

Sector	Adaptation Plans and Implementation
Agriculture	• Germplasm banks for major crops • Increase use of degraded land for flood control • Specific policy on food security • Improve water efficiency in cropping and appropriate use of land • Experiment crops in marginal land areas • Financial and technological support for local communities in adaptation • Forest-set aside program
Water	• Reforestation in key watershed areas, with participation from rural communities • Introduce economic incentives for water management, especially for recreation and industry • Supply mapping, water balance • Research on climate change and water to gain better understanding of the issues • Research and capacity enhancement for local communities • Monitor use and sustainability • International cooperation, including with the Mekong River Commission (MRC) • Support community-level management of water • Enhance the capacity of water management agencies to comprehend and manage the potential impacts of climate change on water resources • Research the possibility of inter-basin transfer to enable Thailand to manage water resources
Forest	• Research and development on adaptation of forests • Monitoring of degraded forests • Ex situ and in situ conservation of tree species • Human intervention in forest management in key watersheds • Stop forest destruction and promote private sector forestation
Coastal areas	• Research, development and monitoring of sensitive areas • Financial support for area-based management • Climate proof design of public infrastructure • Monitoring of existing infrastructure in sensitive areas • Plan and monitor long-term use of coastal areas
Health	• National study on climate change and malaria • Monitoring and preventive measures for malaria • Regional training for preventive measures to malaria • Investigate other health-related impacts of climate change

Source: ONEP (2008).

Table 9.7. National Mitigation Plans and Implementation in Thailand

Issue	Mitigation Policy/Plan
Energy efficiency improvement	• Improve process efficiency in the industrial sectors • Efficient motors • Cleaner technology in small and medium enterprises through incentives
Renewable energy and other alternative energy	• Promote renewable energy, including rhododendron energy • Private sector–government sector partnership in renewable energy as a pilot phase • Revise pricing schemes to reflect the true cost of fuels • Fuel switching (toward bioethanol and biodiesel)
Transportation	• Master plan in large cities • Promoting use of mass transit systems in Bangkok • Car pool in government and private sectors • Use of economic incentives to encourage mode switching • Invest in mode supplies • Enhance co-benefits of energy use • Retrofitting and improvement of engine efficiency • Promote natural gas in vehicles
Non-energy sector: Rice	 • Soil, water, and fertilizer management • Research and development for GHG reduction in the rice sector • Local knowledge and rice technology • Improve efficiency in rice production • Inter-agency coordination to implement plans
Waste	• Waste from livestock sector • Waste from household and industrial sectors • Policy coordination
Forest	• Master plan • Community forest law • Management plan for mangrove land • Reform of forest-related agencies
Other initiatives	• Secure natural gas supply by the state • Integrate the environmental aspects in fuel use • Promote environmentally friendly electricity production, especially in rural areas • Expand demand-side management • Reduce GHG emissions at source using economic incentives and technology • Revise the energy plan to enable technology transfer, research and development, and local knowledge

Source: ONEP (2008).

- In Viet Nam, there is scope for further addressing adaptation to climate change in policies on agriculture and water. On mitigation, Viet Nam introduced the Energy Law in 2005, aiming at improved energy efficiency and promotion of renewable sources of energy. Table 9.8 provides the country's climate change adaptation and mitigation policy initiatives in the context of its Agenda 21 priorities.

Tables 9.9 to 9.11 summarize the policies on energy efficiency, renewable energy, and use of biofuels in Indonesia, Philippines, Singapore, Thailand, and Viet Nam.

Table 9.8 Priority Areas of Viet Nam's Agenda 21 and Current State of Related Laws and Regulations *(continued)*

Area	Priority Areas Envisaged in Viet Nam Agenda 21	Laws/Regulations/Mechanisms/Studies
Mitigation		
Overall	• Shift in economy characterized by extensive exploitation and utilization of raw materials into one characterized by more skillful goods and processing capacity with a view to increasing added value for each unit of exploited natural resources • Save resources in the development process, effectively and efficiently utilize scarce natural resources, control consumption so that it will not encroach upon the welfare of future generations	• Asia least cost GHG abatement strategy (study, 1995—1997) • Economics of GHG limitation (study, 1996—1998) • Preparation of initial national communication (program, 1999—2002) • National strategy study on CDM (study, 2002—2004) • Capacity development for CDM (program, 2004—2006) • National Target Programme as a basic strategy to respond to climate change was established under MONRE (program, 2007) • Viet Nam second national communication (program)
Energy efficiency and renewable energy	• Study and incorporate environmental and social aspects into the system of national accounting • Application of environmentally friendly and cleaner technologies • Healthy lifestyle and reasonable consumption pattern • Regulate inappropriate consumption patterns through economic instruments • Clean industrialization process through legislation, technologies, and economic instruments	• The electricity law (2005) • Decree for energy saving and efficiency (2003) • Developing a model of vertical brick kiln with high energy efficiency (2001—2003) • Energy efficiency in public lighting (2005—2009) • Promoting energy conservation in small- and medium-scale enterprises (2005—2009) • Promotion of renewable energy, energy efficiency, greenhouse gas abatement (2002—2004) • Demand-side management and energy efficiency (2004—2007)
Forestry		• Law on forest protection and development (2005) • Strategy on forestry development for 2006—2020 (2007)
Land use		• Decree No. 70 requiring all documents registering family assets and land use rights to include the names of wives as well as husbands (2001)

Table 9.8 Priority Areas of Viet Nam's Agenda 21 and Current State of Related Laws and Regulations *(continued)*

Area	Priority Areas Envisaged in Viet Nam Agenda 21	Laws/Regulations/Mechanisms/Studies
Adaptation		
All sectors	• Improve agriculture sustainability through agroforestry, sustainable water management methods, expanding organic agriculture and other sustainable practices • Development of regions and localities through capacity building for better planning and management in all spheres of life, participatory planning • Eradication of extreme poverty, narrow the gap between economic classes and rural and urban areas, empower women and other social groups • Control population growth rate • Sustainable urban growth through better local and regional planning • Enhanced health care facilities with a focus on disadvantaged sections of the society • Sustainable land and water management through legislative, economic, and technical means • Protection of marine, coastal, and island environments • Forest protection and development	• Environmental protection law (1993 and amendments in 2005) • National strategy on environmental protection to 2010 and vision to 2020 (2003) • Strategic orientation for sustainable development (VA21) • Socio-economic development strategy 2001–2010 • Directive to the implementation of KP to the UNFCCC (2005) • The comprehensive poverty reduction and growth strategy through Document No. 1649/Cp-QHQT dated 26 November 2003 (2003) • 2nd national strategy and action plan for disaster mitigation and management 2001–2020 (2001) • Climate change in Asia: Viet Nam (program, 1992–1994) • CC:TRAIN for formulating climate policy (1994–1996) • Socio-economic and physical approaches to analyzing climate change impacts in Viet Nam (study, 1996–1998) • Disaster preparedness and climate change (2003–2005)
Agriculture and water		• The water resources law (1999) • Developing a model to reduce methane emission from paddy rice cultivation through innovative water management (program, 2002–2004)
Coastal resources		• Viet Nam coastal zone vulnerability assessment (program, 1994–1996) • Viet Nam–Netherlands integrated coastal zone management project (2000–2003) • Viet Nam coastal wetlands protection and development project (project, 2001–2006) • Climate change impacts in Huong river basin and adaptation in its coastal district Phu Vang (program, 2005–2008)

Source: Cuong (2008).

Table 9.9. Comparison of Policies on Energy Efficiency

Policy Type	Indonesia	Philippines	Singapore	Thailand	Viet Nam
National energy efficiency strategy					
Energy audits and conservation fund					
Financial subsidies					
Tax incentives					
Regulatory Instruments					
Energy performance standards					
Mandatory product labels					
Voluntary labels					
ISO certified companies	369	312	573	974	–

– = data not available.
Source: IGES (2008).

Table 9.10. Comparison of Renewable Energy Policies

Policy Type	Indonesia	Philippines	Singapore	Thailand	Viet Nam
Renewable energy targets					
Independent power producer frameworks					
Net metering regulations					
Public–private partnerships					
Research, development, and deployment					
Investment incentives					
Tax measures					
Feed-in tariffs					
Voluntary corporate efforts					

Source: IGES (2008).

Table 9.11. Comparison of Biofuel Policies

Policy Type	Indonesia	Philippines	Singapore	Thailand	Viet Nam
Numerical target	Biofuel use: 2% of energy mix by 2010	No target (Biofuel Act of 2006)	1 million tons biodiesel per year by 2012 and 3 million tons by 2015	To replace 20% of fuel consumption with biofuels and natural gas by 2012	500 million liters of ethanol by 2020; and 50 million liters of biodiesel by 2020
Blending mandate	Blending is not mandatory but blended (2–5%) fuels are sold	Gasoline: at least 5% ethanol; 10% by 2010 Diesel: 1–5% coconut blend	No	2% palm oil for all diesel vehicles from April 2008	Targets biofuel production of 100,000 tons of 5% ethanol blend and 50,000 tons of 5% biodiesel blend each year
Economic measures	No special incentive	Tax incentives; income tax holiday; duty-free imports	No	Taxes and levies for E10 are lowered	Government plans to create favorable conditions for the development of biofuels and promote investments, including tax incentives and low-interest loans
Policy for new biofuels	Considering jatropha and cassava	Considering jatropha	Yes	Yes	Yes

Sources: APEC Biofuels (2008), Boer (2008), Ho (2008), Jesdapipat (2008), Perez (2008).

C. Global and Regional Initiatives in Southeast Asia

Multilateral institutions and United Nations agencies are active in supporting climate change initiatives in the region.

There are strong reasons why regional financial initiatives have an important role in climate change policy. As a regional development bank, the Asian Development Bank (ADB) has several dedicated funds for financing climate change mitigation and adaptation in Asia and the Pacific (Sharan 2008). These perform a variety of functions, including mobilizing concessional resources, catalyzing private capital, and using market mechanisms to address environmental issues. The following are the key regional funds available:

Climate Change Fund (CCF)

The CCF was established in May 2008 to provide grant financing for projects, technical assistance, research, and other activities to address the causes and consequences of climate change in ADB's developing member countries (DMCs). ADB has provided an initial $40 million to CCF, with $25 million made available for clean energy development, $5 million for sustainable forestry and other land use, and $10 million for adaptation. There are several technical assistance projects being developed across ADB to be supported by the fund. The fund is open for further contributions from countries, other development organizations, foundations, the private sector, and other sources.

Clean Energy Financing Partnership Facility (CEFPF)

Established in April 2007, the CEFPF provides financing to DMCs to improve energy security and transition to low-carbon economies through cost-effective investments in technologies and practices that result in GHG mitigation. The CEFPF also finances policy, regulatory, and institutional reforms that encourage clean energy development. It has a target size of $250 million and has received donor commitments amounting to about $90 million from Australia, Japan, Norway, Spain, and Sweden as of April 2009.

Asia Pacific Carbon Fund (APCF)

The APCF was operationalized in May 2007 as part of ADB's Carbon Market Initiative (CMI). It provides upfront co-financing to projects eligible for the Clean Development Mechanism in return for a proportion of GHG emission reduction to be generated until 2012. The APCF has received funding commitments of $151.8 million from seven European countries—Belgium, Finland, Luxembourg, Portugal, Spain, Sweden, and Switzerland. It has committed over $50 million in several CDM projects across the region and expects to commit the entire fund in projects by end of 2009.

Future Carbon Fund

An integral part of ADB's CMI, the FCF was approved in July 2008 and operationalized in January 2009. The FCF provides upfront financing to project developers through purchase of post-2012 carbon credits. As of April

2009, the Fund is capitalized by contributions from three European sovereign and public bodies and is expected to have additional public and private sector participants by the Fund closing before March 2010. The initial target size of $100 million is expected to be surpassed in the first half of 2009.

Water Financing Partnership Facility (WFPF) and the Poverty and Environment Fund (PEF)

Two smaller funds are the Water Financing Partnership Facility (WFPF) and the Poverty and Environment Fund (PEF). The WFPF provides financial resources and technical support for rural water services, urban water services, and river basin management. For 2007/2008, the WFPF had secured donor commitments for a total of $26 million from Australia, Austria, Netherlands, and the Norway Fund. The PEF is a $3.6 million multidonor trust fund administered by ADB that promotes the mainstreaming of environmental and climate change issues into development plans.

Regional Other Initiatives

ADB also operates a range of programs supporting climate change initiatives in relation to specific sectors. It has sought to promote energy efficiency savings and the development of renewable energy sources. It has set up a $250-million facility, the Energy Efficiency Initiative, to finance energy efficiency projects; and its Carbon Market Initiative aims to fund clean energy projects. In terms of waste management ADB has joined the United States Environmental Protection Agency's Methane to Markets Partnership. In the transportation sector, ADB has launched the Sustainable Transport Initiative to ensure that climatic effects are incorporated in the design of future transport projects. In support of this goal, ADB is funding the development of energy efficient public transport systems in Bangkok, Ho Chi Minh City, and Manila. In contrast to energy and transportation, ADB has made relatively less progress in the forestry and land use sectors. It has assisted several forestry-based initiatives through the Greater Mekong Subregion (GMS), acting as an executing agency for the Global Environment Facility (GEF). It has also supported investments to prevent forest loss and degradation for more than 3 million ha of forest in Viet Nam. In Indonesia, it has provided technical assistance to the Ministry of Environment to implement forestry-based CDM projects. However, more remains to be done in this area.

In coastal and marine resources, ADB has launched the Coral Triangle Initiative to protect the region's coral resources from further degradation. In relation to coastal resources, ADB has worked with the GEF on the Coral Triangle Initiative to preserve some of the world's most valuable coral resources. It has also co-funded the Coral Reef Rehabilitation and Management Program to develop decentralized community-based resource management systems in Indonesia.

ADB also encourages private sector involvement in climate change initiatives. For example, it is making equity investment of up to $20 million each in three regional private equity funds focused on clean energy—the Asia Clean Energy Fund, Global Environment Fund Management Corporation South Asia Clean Energy Fund, and MAP Clean Energy Fund. It is also trying to use private sector expertise in the pricing of risk to create insurance products for countries facing the risk of climate-related natural disasters. In collaboration with the World Bank, ADB is developing a Pacific Catastrophe Risk Pool Initiative, which will ensure short-term liquidity to Pacific island states after a natural disaster.

World Bank

The World Bank, recognizing the primacy of the UNFCCC process, has adopted a Strategic Framework for Development and Climate Change in 2008 based on six areas that address adaptation and mitigation: (i) support climate actions in country-led development processes; (ii) mobilize additional concessional and innovative finance; (iii) facilitate the development of market-based financing mechanisms; (iv) leverage private sector resources; (v) support the acceleration of the development and deployment of new technologies; and (vi) step up policy research, knowledge, and capacity building. This framework will provide better support to developing countries in achieving poverty reduction and growth objectives, while recognizing the adverse impacts of climate change.

On adaptation, the World Bank work covers climate-sensitive sectors, such as agriculture and natural resources, water, energy and health. The World Bank develops tools for climate data dissemination and mapping, screening of climate risk to projects, and pilot insurance programs for protection against bad weather. On mitigation, World Bank activities are directed to supporting operations of its clients to reduce GHG emissions in the energy, urban, transport, and forestry sectors. Such operations provide benefit from carbon revenues through the carbon finance (CF) program or access to GEF cofinancing.

- In March 2008, the World Bank signed an innovative Emission Reduction Purchase Agreement with PT Gikoko Kogyo Indonesia (Gikoko) to reduce GHG emissions, improve solid waste management, and provide funding for local communities in the Municipality of Bekasi. Under this agreement the World Bank serves as the trustee of the Netherlands Clean Development Mechanism Facility to purchase Certified Emissions Reductions. This kind of public–private sector partnership removes the barrier that restricts private sector involvement in solid waste management. The initiative can be seen as a catalyst to develop similar CDM projects in the municipal solid waste sector.

- The World Bank has developed a technical assistance program called CF Assist that enhances the capacity of developing countries in climate change and CF to enable them to effectively participate in the carbon market. The program supports institutional strengthening, engagement of financial and new industrial sectors, project portfolio development and knowledge sharing, and information outreach. The earliest CF Assist programs were launched in Cambodia, People's Republic of China, Indonesia, and Philippines. New programs have been launched in Mongolia and Viet Nam.

- The World Bank has developed some carbon offset programs/initiatives in the region including: (i) Philippine Ethanol Plant Wastewater Biogas Project; (ii) Makassar–TPA Tamangapa Landfill Methane Collection and Flaring in Indonesia; (iii) Livestock Waste Management in Thailand; and (iv) Kota Kinabalu Composting Project in Malaysia.

United Nations Environment Programme (UNEP)

UNEP has developed climate change strategy on four themes: (i) facilitating a transition toward low-carbon societies; (ii) adapting by building resilience; (iii) improving understanding of science; and (iv) communicating and raising public awareness. In Southeast Asia, UNEP was involved in projects such as (i) integrating climate change adaptation measures into the Mangroves for the Future Initiative; (ii) capacity building to integrate disaster risk reduction into coastal zone management; (iii) enhancing capacity to adapt to climate change in the Philippines under the Millennium Development Goal (MDG) Fund; (iv) developing tools and methodologies for national and city assessments for Viet Nam and Thailand; (v) holding a series of national workshops with the aim of building the capacity of policymakers in developing and implementing national climate change laws and policies to combat climate change challenges in Cambodia, Lao People's Democratic Republic (Lao PDR), Myanmar, and Viet Nam.

UNEP also launched the project Capacity Development for the Clean Development Mechanism, with the aim of generating a broad understanding of the opportunities offered by CDM in participating developing countries, and developing the necessary institutional and human capabilities that allow them to formulate and implement projects under the CDM. In Asia, during Phase I of this project, capacity and project development activities were completed in Cambodia, Philippines, and Viet Nam.

United Nations Development Programme (UNDP)

UNDP has been active in the region through its country offices as well as regional office in Bangkok. In June 2007, UNDP launched the MDG Carbon Facility, an innovative support scheme for the development and commercialization of CDM projects. In the coming years it is expected to play a key role in mobilizing the potentially significant benefits of CF for the developing world including Southeast Asia. The key objectives of the MDG Carbon Facility are to broaden access to CF by enabling more developing countries to participate; and to further promote CDM emissions reduction projects that contribute to the MDGs, by yielding additional sustainable development and poverty reduction benefits.

United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP)

UNESCAP has been working on four areas related to climate change in Southeast Asia: (i) advocacy of the concept of "green growth"; (ii) promotion of a regional approach to achieving climate-friendly and climate change-resilient society; (iii) promotion of voluntary participation of developing countries in Asia and the Pacific in global GHG emission reduction through preparation of guidebooks for promoting unilateral CDM; and (iv) promotion of a regional perspective on a post-2012 climate framework.

Through a combination of these four-track activities, UNESCAP promotes the integration of climate change policies into national development planning with emphasis on environmental and socio-economic co-benefits. In particular, it ensures the policy compatibility of national climate actions and sustained economic growth/recovery. It offers various forms of support to member states, such as regional/subregional policy dialogue, leadership training and tailor-made national capacity building events focusing on tackling climate change issues through a green growth approach, upon request from member countries.

The Association of South East Asian Nations (ASEAN)

During the 13th ASEAN Summit in November 2007, ASEAN reaffirmed the need to tackle climate change based on the principles set out by the UNFCCC through the Singapore Declaration on Climate Change, Energy and Environment. The declaration aims, among other things, to deepen the understanding of the region's vulnerability to climate change and to implement appropriate mitigation and adaptation measures. These include intensifying ongoing operations to improve energy efficiency and the use of cleaner energy, promoting cooperation in afforestation and reforestation, and continuing support and initiatives under the UNFCCC. Among concrete measures, the 41st ASEAN Ministerial Meeting in July 2008 delegated the responsibility of mainstreaming climate change actions into ASEAN programs to the ASEAN sectoral bodies on energy efficiency, transportation, and forestry.

- On energy generation, the Memorandum of Understanding on the ASEAN Power Grid, should it materialize, could harmonize the region's power generation potential and benefit the region in a more environmentally friendly manner. This is in line with the ASEAN Plan of Action for Energy Cooperation 1999—2004 adopted at the 17th ASEAN Ministers on Energy Meeting, and the ASEAN Plan of Action for Energy Cooperation 2004—2009 adopted at the 22nd ASEAN Ministers on Energy Meeting.

- On the adaptation front, the Ministerial Understanding on ASEAN Cooperation in Rural Development and Poverty Eradication of 1997 forms the basis for cooperation. The important strategies identified were capacity building, sharing of experiences, promoting networking, and developing a common position on matters related to rural development and poverty eradication. The ASEAN Ministers on Rural Development and Poverty Eradication was established to oversee initiatives undertaken in line with this cooperation.

- On technology cooperation, the ASEAN Science and Technology Ministers endorsed the Plan of Action on Science and Technology 2007–2011. The plan identified six areas of thrust and 24 supporting actions for science and technology cooperation among member countries. The cooperation also includes a science fund with contributions from member and non-member countries.

- ASEAN was also instrumental in launching an ASEAN Climate Change Initiative (now dormant), ASEAN Haze Action Plan, ASEAN Agreement on Trans-boundary Haze, ASEAN Disaster Response Programme, ASEAN Peat Land Management Initiative, European Union–ASEAN agreements, ASEAN+3 cooperation, and others.

All these regional initiatives have some relevance to integrating climate change concerns in sustainable development policy, but many opportunities for collaboration have not been explored.

The GMS confirmed its commitment to environmental protection at recent ministerial summits.

Comprising two provinces of the People's Republic of China, Cambodia, Lao PDR, Myanmar, Thailand, and Viet Nam, the GMS has agreed to a strategy of "greening the corridors" through carbon sequestration in its economic and road corridor projects. As yet, however, relatively little has been achieved in this regard.

Southeast Asia could benefit from sector-specific international initiatives to enhance its mitigation efforts and access to low-carbon technologies.

On Land-Use Change and Forestry

- The Collaborative Partnership on Forests (CPF) acts as an umbrella organization for 14 international forest-related organizations, institutions, and convention secretariats that support the work of the United Nations Forum on Forests. The CPF has adopted a non-legally binding instrument on all types of forests to create an international instrument for sustainable forest management. There are significant synergies between the work of the CPF and REDD (reduced emissions from deforestation and degradation) initiatives in the post-2012 climate regime that could be exploited.

- The Asia Forest Partnership could be a good forum for information sharing. It hosts annual meetings intended to facilitate joint identification of new programs and research on issues relevant to Southeast Asia, such as illegal logging, fire prevention, land rehabilitation, and REDD-related issues.

On Energy

- The Climate Technology Initiative (CTI) could also improve the region's access to climate-friendly technologies. The CTI fosters cooperation in the development and diffusion of climate-friendly technologies by building partnerships between developed countries and developing countries. The CTI works closely with the UNFCCC and other international organizations. The CTI may have implications for energy security and GHG mitigation in Southeast Asia, but its current emphasis tends to be on information exchange and technical support.

- The Future Gen Alliance is another initiative that could have longer-term implications for energy security and GHG mitigation in Southeast Asia. It is a consortium of 13 power producers and electric utilities (11 from the United States) that pooled their resources to build the first zero-emissions coal-fired power plant. FutureGen has advanced coal-based technologies that generate electricity for families and businesses, and also produce hydrogen to power fuel cells for transportation and other energy needs. The technology also integrates the capture of carbon emissions with carbon sequestration, helping to address the issue of climate change as energy demand continues to grow. These technologies could play a potentially sizable role as governments in Southeast Asia contemplate expanding coal use.

There are institutions and programs that support climate change capacity building and development in the region.

The global System for Analysis, Research and Training (START) provides an international framework for improving scientific knowledge and technology to conduct regional and local research and to inform and influence decision makers. The Southeast Asia START Regional Center (SEA-START), established in 1996, is one of the regional research nodes of the Southeast Asia Regional Committee for START. SEA-START supported many scientific studies on climate change such as Southeast Asia Regional Vulnerability to Changing Water Resource and Extreme Hydrological Events Due to Climate Change.

The Japan-based Institute for Global Environmental Strategies has established a program that increases the capacities of Asian countries related to institutional and operational aspects of CDM. The Institute organizes training workshops for government officials to prepare the approval procedure for CDM projects, and initiates study groups to conduct research on sector-wide project formulation. In Southeast Asia, activities have been implemented in Cambodia, Indonesia, Philippines, and Thailand.

D. Financing Climate Change Mitigation and Adaptation Activities

Implementing climate change mitigation and adaptation measures requires investment, technologies and know-how, and financial resources. For Southeast Asia, many mitigation and adaptation technologies are still relatively costly to deploy, posing a considerable challenge (Box 9.1).

There are a large number of international funding sources and

mechanisms available for mitigation and adaptation by developing countries, but Southeast Asian countries have barely tapped these sources.

Table 9.12. Multilateral Financial Schemes

Name of Fund	Institution	Date	Objective	Budget
Prototype Carbon Fund (PCF)	World Bank	April 2000	Provision of finance and piloting production of emissions reductions within the framework of CDM and Joint Implementation. The fund is designed to support projects addressing urgent and immediate adaptation needs in less developed countries identified by National Adaptation Plans of Action. Target areas include water, agriculture, and public health.	$180 million
BioCarbon Fund (BioCF)	World Bank	November 2002	Provision of finance for projects that sequester or conserve carbon in forests and agro-ecosystems and GHG mitigation.	Tranche One: $53.8 million Tranche Two: $38.1 million
Community Development Carbon Fund (CDCF)	World Bank	March 2003	Provision of funds to support projects that combine community development with emission reductions to create “development plus carbon” credits.	Tranche One: $128.6 million
Carbon Partnership Facility (CPF)	World Bank	2008	Provision of funds to support the purchase of emissions reductions for at least 10 years after 2012. The CPF is comprise of two trust funds: (i) the Carbon Asset Development Fund (CADF) to prepare emissions reduction programs, and (ii) the Carbon Fund (CF) to purchase carbon credits from the pool of emissions reduction programs.	~$500 million
Forest Carbon Partnership Facility (FCPF)	World Bank	December 2007	Provision of funds to developing countries for their REDD efforts. The FCPF has two components: 1) Readiness Mechanism Provision of technical assistance in calculating opportunity costs of possible REDD interventions, designing and adopting REDD strategy. 2) Carbon Finance Mechanism Implementation and evaluation of pilot incentive programs for REDD based on a system of compensated reductions.	$300 million

Table 9.12. Multilateral Financial Schemes *(continued)*

Name of Fund	Institution	Date	Objective	Budget
Prototype Carbon Fund (PCF)	World Bank	April 2000	Provision of finance and piloting production of emissions reductions within the framework of CDM and Joint Implementation. The fund is designed to support projects addressing urgent and immediate adaptation needs in less developed countries identified by National Adaptation Plans of Action. Target areas include water, agriculture, and public health.	$180 million
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Forest Carbon Partnership Facility (FCPF)	World Bank	December 2007	Provision of funds to developing countries for their REDD efforts. The FCPF has two components: 1) Readiness Mechanism Provision of technical assistance in calculating opportunity costs of possible REDD interventions, designing and adopting REDD strategy. 2) Carbon Finance Mechanism Implementation and evaluation of pilot incentive programs for REDD based on a system of compensated reductions.	$300 million

Tables 9.12 to 9.14 summarize some of the financial opportunities for mitigation and adaptation available to Southeast Asian countries from both the public and private sectors.

- The UNFCCC has established the Least Developed Countries Fund (LDCF) and Special Climate Change Fund (SCCF) to support adaptation activities. While the LDCF is aimed at helping the least developed countries meet their immediate adaptation needs as identified in their National Adaptation Plans of Action, the SCCF was created to not only support adaptation but also to support technology transfer, energy and infrastructure, and activities related to energy-intensive products and consumption of fossil fuels. Priority areas for funding

Table 9.12. Multilateral Financial Schemes *(continued)*

Name of Fund	Institution	Date	Objective	Budget
Climate Investment Fund (CIF)	World Bank	July 2008 (approved by Board)	Provision of interim funds to assist developing countries achieve their development goals through a transition to a climate-resilient economy and a low-carbon development path. The CIF is composed of two segments. 1) Clean Technology Fund Investment in projects/programs (large-scale) to demonstrate, deploy, and transfer low-carbon technologies. The fund is also used for realizing environmental/ social co-benefits. 2) Strategic Climate Fund Used for programs for climate resilience, green energy access, and sustainable forest management. The Financing Pilot Program for Climate Resilience is designed to complement existing sources for the Adaptation Fund by assisting transformation of national development plans to make them more climate-resilient.	$5 billion (planned)
Asia Pacific Carbon Fund (APCF)	Asian Development Bank	May 2007	Provision of upfront capital for CERs and technology support for enabling clean energy projects among member countries based on the Carbon Market Initiative. Aims to foster long-term partnerships between project developers in developing member countries, carbon investors in developed countries, and ADB.	$152 million
Clean Energy Financing Partnership Facility (CEFPF)	Asian Development Bank	April 2007	Provision of grant financing for improving energy security and for moving to a low-carbon economy.	$250 million (target)
Water Financing Partnership Facility (WFPF)	Asian Development Bank	2007	Provision of financial resources and technical support for rural water services, urban water services, and river basin management	$26 million
Poverty and Environment Fund (PEF)	Asian Development Bank	2007	Promote mainstreaming of environmental and climate change issues into development plans	$3.6 million
Future Carbon Fund	Asian Development Bank	July 2008 (approved)	Provision of long-term financial incentives to scale up clean energy projects that will continue to generate CERs after 2012. Complementary to the Carbon Market Initiative.	~$100 million
Climate Change Fund (CCF)	Asian Development Bank	May 2008	Provision of a more holistic financing program for activities in mitigation and adaptation. Provision of Grant financing for technical assistance, investment projects, research.	~$40 million

Table 9.12. Multilateral Financial Schemes

Name of Fund	Institution	Date	Objective	Budget
Asia-Pacific Fund for Energy Efficiency (APFEE)	Asian Development Bank	Proposed	Provision of finance for energy efficiency projects among developing member countries, in accordance with the Energy Efficiency Initiative of ADB.	$200–500 million
Special Climate Change Fund (SCCF)	GEF (UNFCCC)	2001	Provision of finance for projects relating to adaptation; technology transfer and capacity building; energy, transport, industry, agriculture, forestry and waste management; and economic diversification.	$34.7 million
Least Developed Countries Fund (LDCF)	GEF (UNFCCC)	2001	Provision of grants to support preparation and implementation of National Adaptation Programs of Action.	$27.8 million
Adaptation Fund	GEF (Kyoto Protocol)	2001	Established under Kyoto Protocol with 2% share of proceeds from CDM. Provision of finance for concrete adaptation projects and programs in developing countries that are parties to the Kyoto Protocol.	€ 37 million (expected to be $80–300 million in 2008–2012)
Thematic Trust Fund (TTF) on Energy and Environment	UNDP	2001 (two funds merged in 2005)	• Provision of funds to activities at the country and global level leading to optimum development impacts from affordable and accessible energy services. • Disbursement of funds for 43 projects from 2001 to 2004. • Combination of TTF on Environment and TTF on Energy for Sustainable Development.	$ 15 million~
MDG Carbon Facility	UNDP	June 2007	• Provision of funding for portfolio of projects that yield tangible sustainable development and poverty reduction toward MDG, such as methane, renewable energy, energy efficiency, carbon sequestration, transport, and clean fuel. • Provision of an assistance for designing, implementing, managing, and monitoring GHG emission reduction projects, i.e., preparation of PDD and guidance on the application of baseline methodologies.	

Source: Compiled by ADB study team.

under SCCF include water resource management, land management, agriculture, health, infrastructure development, fragile ecosystems, and integrated coastal zone management.

- A separate Strategic Priority on Adaptation fund has been created under GEF to reduce vulnerability and to increase adaptive capacity to the adverse effects of climate change in the focal areas that the GEF addresses. The Strategic Priority on Adaptation fund will support pilot and demonstration projects that address local adaptation needs and generate global environmental benefits in all GEF focal areas.

- The Adaptation Fund was established under the Kyoto Protocol from a 2% share of proceeds from CDM project activities and from other sources. Recently, the Adaptation Fund Board was created to support the implementation of the fund, with GEF providing secretariat services and World Bank serving as the trustee of the fund.

Table 9.13. Bilateral Financial Schemes

Name of Funds	Institution	Date	Objective	Budget
Cool Earth Partnership	Japan	2008 –2012 (5 years)	Provision of funds to developing countries making efforts to reduce GHG emissions and achieve economic growth in a compatible way. The fund is allocated on the basis of policy consultations between Japan and beneficiary countries. The fund has the following two components. 1) Assistance for Adaptation and Clean Energy The fund is allocated for access to clean energy, feasebility study on rural electrification projects with geothermal energy and "cobenefit" projects by means of environment program grant aid, technical assistance, and aid through international organizations 2) Assistance for Mitigation Climate change Japanese official development assistance loan with preferential interest. Yen 500 billion is allocated for projects to reduce GHG emissions. Capital and guarantees are shared by JBIC, NEXI, NEDO, and by the ADB Clean Energy Fund. A $300 million loan to Indonesia was provided in July 2008.	
Enhanced Sustainable Development of Asia (ESDA)	Japan (ADB)	May 2007	1) Accelerated Co-Financing Scheme with ADB provision of a Yen 2 billion loan for 5 years. 2) Investment Climate Facilitation Fund Promotion of funds to facilitate investment climate and required infrastructure. 3) Asia Clean Energy Fund Provision of funds to promote energy efficiency in Asia.	¥ 2 billion $100 million
Global Initiative on Forests and Climate (GIFC)	Australia	July 2007 (5 years)	Provision of funding for projects to reduce deforestation, encourage reforestation, and promote sustainable forest management. Establish a comprehensive and consistent approach to forest carbon monitoring through GCMS. Close coordination with the World Bank's new Global Forest Alliance (provision of $10 million to the Alliance). Setting Indonesia as a key partner country ($40 million), and other countries in the Mekong subregion and the Philippines.	$200 million

Source: Compiled by ADB study team.

Table 9.14. Other Financial Schemes—Private Sector

Name of Fund	Institution	Date	Objective and Target Sector	Budget
FE Clean Energy Services Fund (Asia ESCO Fund)	FE. Co.,Ltd. (funded by JBIC, etc.)	2004 (10 years)	Provision of capital to invest in energy efficiency and RE initiatives (ESCOs) in small and medium-size enterprises in Asian countries. Focusing on India, Malaysia, Philippines, and Thailand.	$150 million (currently $50 million)
MAP Clean Energy Fund (MAP)	MAP Capital (funded by ADB)	Proposed	Provision of investment (~$15–40 million per project) in a portfolio of clean energy projects in Asia with focus on Indonesia and Southeast Asia. Geothermal projects in Indonesia being considered.	$400 million
Asia Clean Energy Fund (ACE)	KTIC, KPMG/ SIA (funded by ADB)	Proposed	Provision of investment in clean technology, RE, energy efficiency in Asia. Portfolio of projects includes palm oil projects, solar project expansions, replacement of used transformers, and solar photovoltaic business in Indonesia.	$200 million

Source: Compiled by ADB study team.

- Additional financial support is also available through different bilateral funding sources such as the Organization of the Petroleum Exporting Countries Fund for International Development, Japan International Cooperation Agency, United States Agency for International Development, and United Kingdom Department for International Development. Nearly $2 billion was made available by the Government of Japan for adaptation activities.

- A large number of funding mechanisms for mitigation have been established in recent years, in particular after the adoption of the Kyoto Protocol in 1997. The most important of these for developing countries is the CDM which allows emission reduction or removal projects in developing countries to earn certified emission reduction (CER) credits, each equivalent to one ton of CO_2. These CERs can be traded and used by industrialized countries to meet a part of their emission reduction targets under the Kyoto Protocol. The CDM provides a way for developed countries to invest in "clean" projects in developing countries while the latter are achieving sustainable development targets. The region's share of the global carbon market is still very limited however.

E. Conclusion

A review of climate change policies in the region suggests that while considerable progress has been made, there is a need for more closely integrating climate change concerns into sustainable development policy making. There are various international and regional initiatives and programs that Southeast Asian countries can benefit from in terms of funding, technology transfer, and capacity building. However, the tapping of these resources by the region appears to be limited. There is a need to find ways to increase the

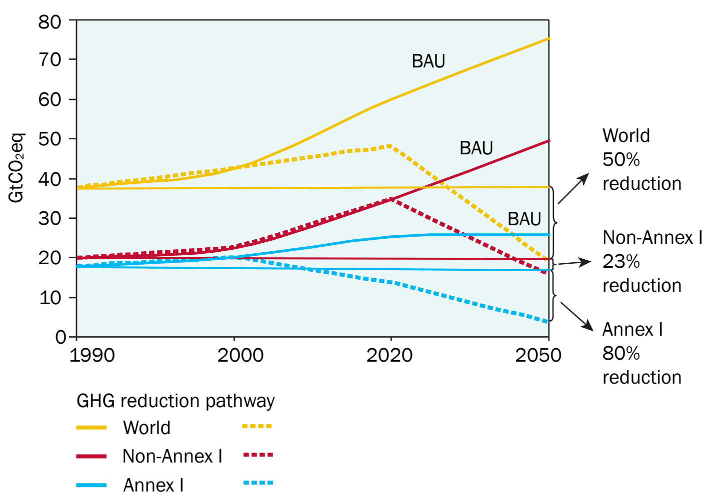
Box 9.1. Funding Requirement by the Four Countries to Achieve Target under a Hypothetical Global Deal

There exist several low-carbon options that can help reduce emissions from what would occur by following a business-as-usual trajectory. However, stabilizing GHG concentration at a safe level to avoid extreme climate risks and impacts requires both widespread diffusion and adoption of currently available low-carbon technologies, as well as development of new technologies. Stern (2007) suggests that, in order to stabilize GHG concentration around 450–500 ppm and thus limit the risks associated with severe climate change, global emissions will have to be cut by at least half of the 1990 level by 2050 and even further thereafter. Furthermore, Annex I countries will have to reduce their emissions by at least 80% relative to the 1990 level by 2050, while Non-Annex I countries should be able to commit to their own national targets for reduction starting from 2020.

Box Figure 9.1a. depicts the GHG mitigation scenario suggested by Stern (2007) against the BAU emission projection. Under the IPCC (2007) B2 marker scenario, a 50% global emission cut, with 80% reduction from Annex-I countries by 2050, implies that Non-Annex-I countries will collectively be responsible for a reduction of about 23% from their 1990 level by the same year. Box Figure 9.1b shows that the total GHG reduction from the four countries—Indonesia, Philippines, Thailand, and Viet Nam—will be approximately 3.6 GtCO_2e in 2050, while that from other Non-Annex-I countries would be about 30.6 GtCO_2e (assuming that the proportion of the four countries GHG emissions in total Non-Annex-I's emissions remains unchanged at 10.5% from 2000). If GHG mitigation cost is $10/t$CO_2$e on average, then the total investment required for the reduction in the four countries would be about $36 billion (Box Figure 9.1c.). If the unit cost is $15/t$CO_2$e, the total financial requirement would amount to about $54 billion. Clearly, an enormous amount of investment will have to be made in new mitigation technologies, which in fact are still relatively costly to the four countries and also to developing countries in general.

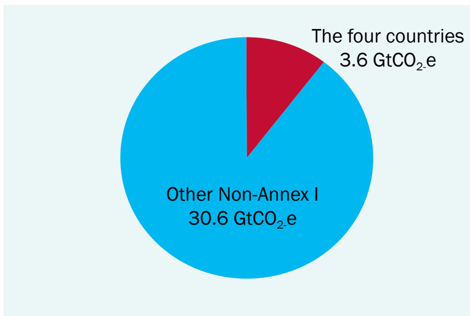
Technological and financial support from developed to developing countries is one of the key elements to the success of the GHG stabilization target.

Box Figure 9.1a. GHG Emission Reduction by 2050 (50% Reduction from 1990 World Level)

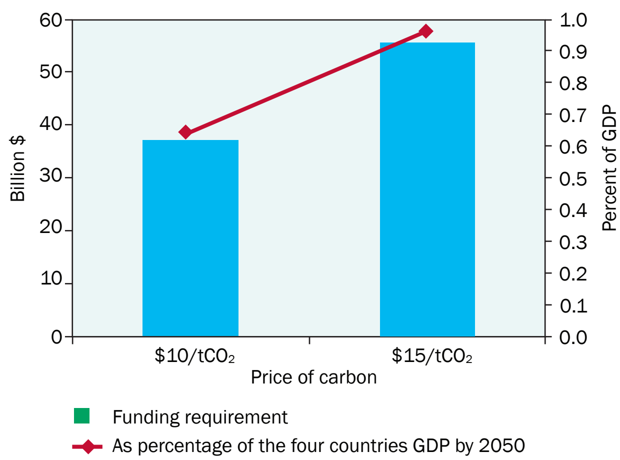


Box 9.1. Funding Requirement by the Four Countries to Achieve Target under a Hypothetical Global Deal *(continued)*

Box Figure 9.1b. Emission Reductions for Non-Annex I Countries



Box Figure 9.1c. Funding Requirement by the Four Countries



Source: ADB study team.

region's presence in making use of these initiatives. Moreover, the current level of international financial transfer to address the region's adaptation and mitigation challenges is far short of what is required.

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CHAPTER 10

Conclusions and Policy Recommendations

Key Messages

Southeast Asia is already suffering the effects of climate change and the worst is yet to come. According to IPCC (2007), without global mitigation, by the end of this century, the global mean temperature increase–from 1980—1999 levels–could be more than 4.0°C. The modeling work carried out under this study suggests that the region's mean temperature by 2100 could reach 4.8°C from the 1990 level under the same emissions scenario.

Combating climate change is a global issue and requires a global solution built on a common but differentiated responsibility. Given its high stake in actions against global warming, great adaptation needs and significant mitigation potential, Southeast Asia should contribute to the global solution, by implementing both adaptation and mitigation measures.

The five countries—Indonesia, Philippines, Singapore, Thailand, and Viet Nam—have made significant efforts in adapting to climate change impact, but more is needed to mainstream adaptation in development planning; to enhance/build adaptive capacity, especially of the poor; and to implement proactive measures in key climate-sensitive sectors.

While adaptation is the region's priority, Southeast Asia should make greater mitigation efforts–low-carbon growth also brings significant co-benefits, in particular, by reducing emissions from deforestation and degradation, implementing "win-win" mitigation options in the energy sector, and exploring the mitigation potential of the agriculture sector.

International funding and technology transfer are essential for the success of adaptation and mitigation actions in Southeast Asia. The region should enhance its capacity to make better use of existing and potential international funding sources.

Regional cooperation offers an effective means to deal with many cross-boundary issues, such as water resources management, forest fires, extreme weather events, and disease outbreaks, as well as for learning and knowledge sharing.

Climate change issues cut across many sectors, and Southeast Asian countries should strengthen policy and planning co-ordination among different ministries and levels of government.

There is an urgent need in Southeast Asia for more research to better understand climate change challenges, in particular at the local level, and cost effective adaptation and mitigation solutions.

The economic crisis and the fiscal stimulus packages designed to combat climate change offer an opportunity to start a transition towards a climate-resilient and low-carbon economy in Southeast Asia.

A. Climate Change and Its Impact in Southeast Asia

Southeast Asia—highly vulnerable to climate change—is already suffering from its effects, and the worst is yet to come.

This study confirms that climate change has already had an impact on the region, as evidenced by increasing mean temperature, changing precipitation patterns, rising sea level, and increasing frequency and growing intensity of extreme weather events. Climate change is exacerbating water shortages in many parts of the region, straining agriculture production, causing forest fires and degradation, damaging coastal and marine resources, and increasing the risk of outbreaks of infectious diseases.

Southeast Asia is projected to suffer more from climate change in the years to come, with the impact likely to be worse than the global average. If not adequately addressed, climate change could seriously hinder the region's sustainable development and poverty eradication efforts. The study shows that a wide range of adaptation measures are already being applied, and that the region has great potential to contribute to global mitigation actions. The cost to the region and globally of not addressing climate change now far exceeds the cost of adaptation and mitigation: there is no time for delay.

If no action is taken, the four countries—Indonesia, Philippines, Thailand, and Viet Nam—could suffer a loss equivalent to more than 6% of GDP annually by 2100, more than double the global average loss.

The results of an integrated assessment of the economy-wide cost of climate change show that for the four countries as a whole, while the cost is relatively low in the medium term, each year it rises very significantly beyond that; by 2100, the cost could reach 2.2% of GDP each year if one considers market impact only, 5.7% of GDP if non-market impacts related to health and ecosystems are included, and 6.7% of GDP if catastrophic risks are also taken into account. This is more than double similar estimates for the global average and, more importantly, would occur annually.

B. The Need for a Global Solution

Addressing climate change requires a global solution built on a common goal but differentiated responsibility.

Climate change is the most significant market failure the world has ever witnessed. Like any market failure it can only be resolved through the intervention of public policy. Governments need (i) to put in place effective national climate change policy frameworks; (ii) devise cost-effective implementation strategies; (iii) mobilize sufficient resources from both external and domestic sources including the private sector and ensure their efficient allocation; (iv) create strong incentives for implementing adaptation and mitigation actions and eliminate various market distortions that impede such actions; (v) fill knowledge and information gaps; (vi) and raise public awareness of the urgency of addressing climate change. But government interventions alone are not enough. Successfully tackling climate change problems requires the participation and action of all stakeholders, including households, firms, individuals, nongovernment organizations, and civil society.

As a global public good addressing climate change requires all nations in the world, developed and developing, to work together on a global solution.

Large income gaps among different parts of the world today imply that there are significant variations among countries in capacity and affordability when undertaking adaptation and mitigation actions. Further, the observed climate change and its impacts are a result of past emissions largely by developed countries. These considerations raise an important issue of equitable burden sharing, and point to the need for a common goal but differentiated responsibility. Developing countries need to be aware that without adequate global effort in reducing GHG emissions their prospects of income growth and poverty reduction would be under serious threat. Developed countries should also recognize the need and legitimacy of developing countries to narrow their income gaps with the developed world, and appreciate their desire to ensure that addressing the climate change challenge would not come at the cost of a slower pace of development. These considerations also highlight the importance of including both mitigation and adaptation in any global solution to the climate change problem.

An essential component of an effective global solution would, therefore, involve adequate transfers of financial resources and technological know-how from developed to developing countries.

Estimates of financing needs for climate change mitigation and adaptation vary widely, reflecting the uncertainties associated with potential climate change scenarios and their likely impact. However, emerging estimates of the additional investment needed for mitigation and adaptation in developing countries indicate a financial gap of hundreds of billions of dollars per annum for several decades to come. This is far greater than the resources that have been committed or established by developed countries through global financing mechanisms, such as the Clean Development Mechanism (CDM), the Global Environment Facility (GEF), the various dedicated funds such as the Clean Energy Investment Framework and Climate Investment Fund, and other regional and bilateral mechanisms. This is cause for serious concern.

Global climate change cannot be tackled without the participation of developing countries.

This is because, first, there is greater potential for cost-effective emissions reductions in developing countries than in developed countries; second, GHG emissions by developing countries are expected to grow faster than those by developed countries in the coming decades, given their more rapid growth of population and economy. An effective global solution would therefore inevitably involve developing countries mainstreaming climate change considerations in their policy-making and integrating adaptation and mitigation actions into strategies for economic growth, poverty eradication, and sustainable development.

The international community has now agreed to the Bali Road Map to step up efforts to combat climate change.

The past few years have witnessed the emergence of a consensus on the urgency of addressing climate change, culminating in the formulation of the Bali Action Plan by the 13th Conference of Parties (COP13) of the United Nations Framework Convention on Climate Change (UNFCCC) in December 2007 in order to enhance the implementation of the UNFCCC and to initiate negotiations toward comprehensive, long-term cooperation. The Bali Action Plan has set the COP15 in Copenhagen in December 2009 as the deadline for agreeing to the terms of an international climate regime beyond 2012. The terms will embrace climate change mitigation, including reducing emissions from deforestation and degradation (REDD), adaptation, technology development and transfer, and provision of financial resources in support of developing countries' actions. In July 2008, the Group of Eight rich nations agreed to adopt the goal of achieving at least a 50% reduction of global emissions by 2050, recognizing that the global challenge can only be met by a global response, in particular, by contributions from all major economies, consistent with the principle of common but differentiated responsibilities and respective capabilities.

C. What Should Southeast Asia Do?

Southeast Asia has in recent years taken encouraging action to adapt to climate change impacts and to mitigate GHG emissions.

Each country in Southeast Asia has developed its own national plan or strategy for climate change, established a ministry or agency as the focal point to deal with climate change and its impact, and implemented many programs supporting adaptation and mitigation activities. But more action is needed. There is urgent need for (i) raising awareness of climate change impacts and risks; (ii) mainstreaming climate change considerations in development planning and policymaking; (iii) putting in place an effective institutional framework for better policy coordination; (iv) investing more resources in climate adaptation and mitigation; (v) providing adequate information on "win-win" adaptation and mitigation; (vi) addressing market failures and eliminating market distortions that impede the implementation of such options; (vii) strengthening international and regional cooperation in knowledge, technology, and financial transfers; (viii) undertaking more research and filling knowledge gaps on climate change-related challenges and solutions at local levels; and (ix) making more capacity building efforts.

(i) Adaptation toward enhanced climate resilience

Southeast Asian countries should continue efforts to enhance climate change resilience by building adaptive capacity and taking technical and non-technical adaptation measures in climate-sensitive sectors.

A country's resilience to climate change depends first and foremost on its adaptive capacity. At a more fundamental level, a country's adaptive capacity depends on its economic, social, and human development, which are closely related to (i) income, inequality, poverty, literacy, and regional disparity; (ii) capacity and governance of public institutions and public finance; (iii) availability or adequacy of public services including education, health, social protection, and social safety nets; and (iv) capacity for economic diversification, especially at local levels. In all these aspects, there are wide variations across Southeast Asia and significant gaps between the region as a whole and the developed world. Eliminating these gaps by keeping growth strong and making development sustainable and inclusive will go a long way toward improving Southeast Asia's adaptive capacity.

Strengthening adaptive capacity also requires mainstreaming climate change adaptation in development planning. This means that adaptation should be considered an integral part of sustainable development and poverty reduction strategies. In this context, the study identified some immediate priorities: (i) stepping up efforts to raise public awareness of climate change and its impact; (ii) undertaking more research to better understand climate change, its impact, and solutions, especially at the local level, and stepping up efforts in information and knowledge dissemination; (iii) enhancing policy and planning coordination across ministries and different levels of government for climate change adaptation, including linking climate change adaptation with disaster risk management; (iv) adopting a more holistic approach to building the adaptive capacity of vulnerable groups and localities and their resilience to shocks, including developing their capability to diversify local economies, livelihoods, and coping strategies beyond tackling the natural systems; and (v) developing and adopting more proactive, systematic, and integrated approaches to adaptation in key sectors that are cost-effective and that offer durable and long-term solutions.

Many sectors have adaptation needs but water, agriculture, forestry, coastal and marine resources, and health require particular attention.

Adaptation action has been taken in a number of key sectors where climate change impacts are most visible or damaging in Southeast Asia, including in these sectors. But adaptation inherently suffers from several market failures. The market failures arise because of uncertain information associated with large scale and long-term investment such as climate proofing of building and defensive infrastructure; the positive spillover effects and the public goods nature of certain adaptive measures such as research and coastal protection; and the need for coordination among many multiple stakeholders. As a result, private markets and autonomous actions alone will not lead to an adequate level of adaptation.

Many measures need to be driven by public policy and government interventions. Box 10.1 describes areas of adaptation for scaling up in the key sectors.

Box 10.1. Policy Recommendations on Adaptation

- Enhance adaptive capacity by keeping growth strong, sustainable, and inclusive; and by mainstreaming climate change adaptation in development planning.
- Step up efforts at raising public awareness of climate change and its impact.
- Undertake more research to better understand climate change, its impact, and solutions, especially at the local level, and step up efforts in information and knowledge dissemination.
- Enhance policy and planning coordination across ministries and different levels of government for climate change adaptation, including linking climate change adaptation with disaster risk management. Addressing climate change requires the leadership at the highest level of government.
- Adopt a more holistic approach to building the adaptive capacity of vulnerable groups and localities and their resilience to shocks, including developing their capability to diversify local economies, livelihoods, and coping strategies.
- Develop and adopt more proactive, systematic, and integrated approaches to adaptation in key sectors that are cost-effective, offer durable and long-term solutions, and are relevant to each country's circumstances.
    - *Water resources sector*: scale up existing good practices of water conservation and management, and apply more widely integrated water management, including flood control and prevention schemes, early warning flood systems, irrigation improvement, and demand-side management.
    - *Agriculture sector*: strengthen local adaptive capacity by providing public goods and services, such as better climate information, research and development on heat-resistant crop variety and other techniques, early warning systems, and efficient irrigation systems, and explore innovative risk-sharing instruments such as index-based insurance schemes.
    - *Forestry sector*: enhance early warning systems and awareness-raising programs to better prepare for potentially more frequent forest fires as a result of climate change; and implement aggressive public-private partnerships for reforestation and afforestation.
    - *Coastal and marine resources sector*: implement integrated coastal zone management plans, including mangrove conservation and planting.
    - *Health sector*: expand or establish early warning systems for disease outbreaks, health surveillance, awareness-raising campaigns, and infectious disease control programs.
    - *Infrastructure sector*: introduce "climate proofing" of transport-related investments and infrastructure.

(ii) Mitigation toward a low-carbon economy

Southeast Asia should be an important part of the global solution to stabilize GHG concentrations in the atmosphere.

While the response of the largest current and future GHG-emitting economies under the UNFCCC is key to a successful global solution, Southeast Asian countries should also be an important part of this global solution given that its rapid economic and population growth will see its GHG emissions likely to grow further, and because a low-carbon growth path brings significant co-benefits. This study has shown that Southeast Asia has considerable potential for GHG emission reduction. Based on the contribution of different sectors, mitigation should target the land use change and forestry sector, the energy sector, and the agriculture sector (Box 10.2).

As Southeast Asia's largest contributor to emissions, the forestry sector is key to their successful reduction.

Major mitigation measures for the forestry sector include maintaining or increasing forest areas through REDD; afforestation and reforestation; and improving forest management. Reducing and/or preventing deforestation is the mitigating option with the largest and most immediate carbon stock impact in the short run. Since REDD also provides significant sustainable development co-benefits, Southeast Asia's countries should address the causes of deforestation relevant to their own national circumstances. The creation of global financial mechanisms that are effective, predictable, sustainable, performance-based, and supported by diversified resources, including market and non-market mechanisms, is an urgent priority for REDD. In order to benefit from a future global REDD mechanism, the region's technical and institutional capacities to undertake forest carbon inventories and implement appropriate forest policies and measures should be strengthened.

Southeast Asian countries should also step up efforts in reducing deforestation, supporting reforestation and afforestation, and enhancing national and provincial governance systems for sustainable forest management. These require policy reforms appropriate to national and local circumstances, such as monitoring and controlling illegal logging, increased government rent capture for forest concessions, lengthened concession cycle and tenure security, and enhanced competition for access to concessions. Since forests are also home to many indigenous communities, policies must be designed to fully recognize and respect their rights and priorities, and ensure their participation in the design and implementation of REDD policies.

Mitigation in the energy sector should start with win-win options with which GHG emission reductions can be achieved at a relatively low cost or even a negative net cost.

Although Southeast Asian countries together contributed about 3.0% of global energy-related CO_2 emissions in 2000, this share is expected to rise in the future given relatively higher economic and population growth compared to the rest of the world. Southeast Asia has considerable mitigation potential in both the energy supply and demand sectors. On the supply side, major mitigation options include efficiency improvement in power generation, fuel switching from coal to natural gas, and use of renewable energy including biomass, solar, wind, hydro and geothermal resources. On the demand side, the key sources of GHG emissions are the residential and commercial building, industry (steel, cement, pulp and paper, and others), and transport sectors.

There are many win-win mitigation options in Southeast Asia, with cost savings from mitigation exceeding expenses. Energy efficiency improvement measures fall in this category. A policy priority is to identify the binding constraints to the adoption of these options. Such binding constraints could include information, knowledge, and technology gaps; market and price distortions; policy, regulatory, and behavioral barriers; lack of necessary finance for upfront investment; and other hidden transaction costs. A thorough review of these possible constraints is needed in order to eliminate them. A prominent market distortion in the energy sector in many Southeast Asian countries involves general subsidies for fossil fuels and electricity generated from such fuels. Governments should cut general fuel subsidies and provide subsidies only for the poor and vulnerable.

Given its rapid economic and population growth, Southeast Asia's energy demand is likely to continue to expand, and new sources of energy supply will have to be developed in the longer term. With the support of existing financial transfer and technology cooperation mechanisms and those to be agreed in the near future, Southeast Asian countries should step up their efforts in developing and switching to clean, renewable, and low-carbon energy sources as well as clean and sustainable transport. Governments should encourage this switch by putting in place an appropriate policy framework or further strengthening it, creating appropriate financial and tax incentives, and supporting research and development. Public sector energy investment should incorporate the negative externalities of GHG emissions in cost-benefit analysis. Southeast Asia should join the global effort in moving toward a low-carbon economy.

Southeast Asia is estimated to have the highest technical potential to sequester carbon in agriculture in the world.

Being the third largest source of GHG missions in Southeast Asia, the agriculture sector also provides significant potential for mitigation. Major mitigation options in agriculture include improved crop and grazing land management; restoration of organic soils (including peatland) that are drained for crop production, and restoration of degraded lands; livestock management; manure and bio-solid management, and bio-energy use (IPCC 2007). These measures can lead to a reduction of fertilizer and methane-related emissions, reversal of emissions from land use change, and increased sequestration of carbon in the agro-ecosystem. Currently, however, progress in implementing these measures in the region has been slow.

Measures for reducing GHG emissions from the agriculture sector could be explored through the combination of market-based programs, regulatory measures, voluntary agreements, and international programs. Examples of market-based programs are taxes on the use of nitrogen fertilizers, and reform of agricultural support policies. Regulatory measures could include limits on the use of nitrogen fertilizers and cross-compliance of agricultural support to environmental objectives. Voluntary agreements on better farm management practices could be promoted, alongside labeling of green products. International programs could support technology transfer in agriculture.

Box 10.2. Policy Recommendations on Mitigation

- Target key sources of the region's emissions, namely, the land use change and forestry sector, the energy sector, and the agriculture sector.
- Land use change and forestry sector.
    - Address key drivers of deforestation, and strengthen technical and institutional capacities to undertake forest carbon inventories and implement appropriate forest policies and measures, in order to benefit from the future global REDD mechanism. Step up efforts in reducing deforestration.
    - Step up efforts in reforestation and afforestation.
    - Enhance national and local governance systems for sustainable forest management by implementing context-specific policy reforms, such as monitoring and controlling illegal logging, increased government rent capture for forest concessions, lengthened concession cycle and tenure security, and enhanced competition for access to concessions.
    - Design policy to fully recognize and respect rights and priorities of indigenous communities and ensure their participation in the design and implementation of REDD policies.

- Energy sector.
    - Explore mitigation options both on the demand and supply sides.
    - On the supply side, improve efficiency in power generation, promote fuel switching from coal to natural gas, and encourage the use of renewable energy, including biomass, solar, wind, hydro and geothermal resources.
    - On the demand side, improve energy efficiency and promote energy conservation in the residential and commercial building, industry (steel, cement, pulp and paper, and others), and transport sectors.
    - Explore and implement win-win mitigation options—involving mainly energy efficiency improvement—by identifying and eliminating the binding constraints to the adoption of these options, including information, knowledge, and technology gaps; market and price distortions; policy, regulatory, and behavioral barriers; lack of necessary finance for upfront investment; and other hidden transaction costs.
    - Cut general subsidies on the use of fossil fuels, and provide targeted transfers to the poor and vulnerable groups.
    - Step up efforts in developing and switching to clean, renewable, and low-carbon energy sources as well as clean and sustainable transport by putting in place an appropriate policy framework including creating incentives and supporting research and development, with the support of existing and future international financial and technology transfer mechanisms.
    - Incorporate the negative externalities of GHG emissions in cost-benefit analysis of public sector energy investment.

- Agriculture sector.
    - Improve land and farm management.
    - Promote emissions reduction through a combination of market-based programs, regulatory measures, voluntary agreements, and international programs.

(iii) Funding, Technology Transfer, and International/Regional Cooperation

International financial and technology transfers are essential for the success of adaptation and mitigation efforts in Southeast Asia.

The region should enhance institutional capacities to make better use of the existing and potential international funding resources. Existing funding sources, albeit inadequate in view of the vast task at hand, provide initial support and can be used as a catalyst for raising cofinancing. Southeast Asia has not yet made full use of these funding sources, and its representation in the global carbon market is still limited. Government needs to facilitate access to these current and potentially available sources through better information dissemination and technical assistance. There is a need to increase the region's presence in making use of CDM, REDD-related, and other financing mechanisms (Box 10.3).

Technology needs vary greatly within and across Southeast Asian countries. The international climate regime will need to do more to facilitate the transfer of technologies that have been identified, while key performance indicators for transfer of low-carbon technologies should be developed. A regional framework should also be established to support south-south technical cooperation and information sharing among neighboring countries in Southeast Asia, as it is likely easier to apply mitigation and adaptation measures introduced by neighboring countries that successfully utilize locally available materials and traditional environmental management skills. Opportunities for technological leapfrogging, especially in the energy, infrastructure, and waste management sectors, should be effectively explored.

In the longer term there is also a need to explore innovative forms of financing, such as risk-sharing instruments like catastrophe bonds, weather derivatives, and micro-insurance index-based schemes through partnerships involving the private sector. Following the example of the International Financial Facility for Immunisation Company, a regional financial facility for supporting adaptation initiatives could be considered. Private investment in the form of venture capital and mutual funds focusing on low-carbon and energy efficiency technologies could also play a role in funding adaptation and mitigation.

Southeast Asian countries could also consider creating a regional emissions trading scheme (ETS) in the longer term.

Besides making use of international funding mechanisms and participating in the international carbon market through effective use of mechanisms such as programmatic CDM and possibly sectoral approaches and policy-based CDM likely to become part of the future climate regime, the region could also consider creating a regional ETS in the longer term. Such a scheme would help reduce costs associated with emissions reduction and facilitate faster deployment of low-carbon technologies. The scheme would also help create a mechanism to consider environmental externalities, thereby encouraging energy-intensive firms to adopt low-carbon technologies in an incremental manner. The experiences of Republic of Korea and Hong Kong,

Box 10.3. Funding, Technology Transfer, and International/Regional Cooperation

- Funding.
  - Promote the region's use of CDM, REDD-related, and other international financing mechanisms, existing or likely to become available in the future, by facilitating access through better information dissemination and technical assistance and by enhancing institutional capacities for using such mechanisms.
  - Explore innovative forms of financing, such as catastrophe bonds, weather derivatives, and micro-insurance index-based schemes through public-private partnerships. Private investment in the form of venture capital and mutual funds focusing on low-carbon and energy efficiency technologies could also play a role in funding adaptation and mitigation.

- Technology Transfer.
  - Facilitate the transfer of technologies of low-carbon technologies.
  - Establish a regional framework to support south-south technical cooperation and information sharing among neighboring countries in Southeast Asia.
  - Explore opportunities for technological leapfrogging, especially in the energy, infrastructure, and waste management sectors.
- Regional Cooperation.
  - Consider creating a regional emissions trading scheme in the longer term, after meeting several functional prerequisites including enhancing institutions and governance systems.
  - Adopt regional strategies in dealing with transboundary issues, including integrated river basin and water resources management, forest fires, extreme weather events, threatened and shared coastal and marine ecosystems, climate change-induced migration and refugees, as well as regional outbreaks of heat-related disease and vector-borne infectious diseases such as dengue and malaria.
  - Improve regional cooperation toward effectively addressing climate change mitigation challenges, for example, by promoting power trade using different peak times among neighboring countries to minimize the need for building new generation capacity in each country; developing renewable energy sources; promoting clean energy and technology transfer, and regional benchmarking of clean energy practices and performance.
  - Expand the role of regional cooperation in promoting good policies and practices, sharing information and knowledge on issues such as disaster management, and promoting and undertaking climate-related research and development in the region, such as in developing regional climate scenarios and models to monitor and evaluate the impact of climate change.

China in launching pilot domestic ETS, and of India in mandating specific energy consumption decreases in large energy-consuming industries through a system of trading energy savings certificates among companies, could be helpful in this regard. However, several functional prerequisites including institutions and governance systems must be met before introducing a regional ETS.

Many climate change issues can be better addressed through regional cooperation.

Because most countries in the region experience similar climate hazards, regional strategies are likely to be more cost-effective than national and subnational actions in dealing with many transboundary issues, including integrated river basin and water resources management, forest fires, extreme weather events, threatened and shared coastal and marine ecosystems, climate change-induced migration and refugees, as well as regional outbreaks of heat-related disease, such as dengue, malaria, and cholera.

Regional cooperation could effectively address some climate change mitigation challenges, for example, by promoting power trade using different peak times among neighboring countries to minimize the need for building new generation capacity in each country; developing renewable energy sources; promoting clean energy and technology transfer, and regional benchmarking of clean energy practices and performance.

Regional cooperation also has an important role to play in promoting good policies and practices, sharing information and knowledge on issues such as disaster management, and promoting and undertaking climate-related research and development in the region. Regional cooperation is important in developing regional climate scenarios and models to monitor and evaluate the impact of climate change.

(v) Strengthening Government Policy Coordination

Given that climate change is an issue that cuts across all parts and levels of the government, there is a need for strong inter-governmental agency policy coordination. Addressing climate change requires leadership at the highest level of government.

Climate change is an issue involving not only the ministry of environment and related offices, but also the economic ministry, the finance ministry, and so on. Strong inter-ministerial coordination and planning are critical for the effective implementation of adaptation and mitigation policy. For example, if the environment ministry plans to raise the tax on petrol as part of the overall climate change strategy, this proposal should have full government backing and not be blocked by a ministry which, for example, is concerned over the objections of automobile producers. In the case of adaptation, there is a strong case for linking it with disaster risk management. There is also a need for putting in place or enhancing central government-local authority coordination, planning, and funding mechanisms to encourage local and autonomous adaptation actions, and to strengthen local capacity in planning and implementing adaptation initiatives. For effective coordination, there is a strong case for the government agency responsible for formulating and implementing the development plan and strategy take the lead (Box 10.4).

Box 10.4. Strengthening Government Policy Coordination

- Strengthen inter-government agency planning and policy coordination for the effective implementation of adaptation and mitigation policy, involving not only environment ministries but also economic and finance ministries.
- Put in place or enhance central government-local authority coordination, planning, and funding mechanisms to encourage local and autonomous adaptation actions, and to strengthen local capacity in planning and implementing adaptation initiatives.
- Improve coordination by having the government agency responsible for formulating and implementing the development plan and strategy take the lead.
- Build in fiscal stimulus packages "green investment" programs that combine adaptation and mitigation measures with current efforts to shore up the economy, create jobs, and reduce poverty

(vi) Undertaking more research on climate change-related issues

More research is required to better understand climate change challenges and cost effective solutions at the local levels and to fill knowledge gaps.

Despite the emergence of more and more regional and country-specific studies on climate change in Southeast Asia in recent years, knowledge gaps remain huge. There is an urgent need for undertaking more research in Southeast Asia to better understand:

- climate change and its impact, risks and vulnerability, adaptation needs, and mitigation potential at local levels;

- cost-effective technical and non-technical adaptation solutions in key climate-sensitive sectors including water resources, agriculture production, forestry, coastal and marine resources, such as optimal cultivation and cropping patterns, heat-resistant crop variety, sound practices in forestry management, early warning systems for extreme weather events;

- sound adaptation practices and strategies dealing with issues beyond the natural systems, such as migration, social protection mechanisms, livelihoods of small-scale farmers and fishermen, and governance of adaptation at all levels;

- cost-effective mitigation measures, in particular those "win-win" options, and policy, institutional, behavioral, and technological constraints to their adoption.

Southeast Asia also needs to develop regional research and development networks for climate change and strengthen regional climatic research capacity. Regional bodies such as the Association of Southeast Asian Nations could enhance collaboration with international agencies such as the International Energy Agency to enable better information sharing on low-carbon technologies. Technical cooperation and information sharing among neighboring countries in the region should be encouraged. Measures that promote the use of renewable energy sources could also be undertaken in the framework of regional cooperation, such as capacity building programs and benchmarking of clean energy practices.

(vii) Turning the economic crisis into an opportunity

The world is experiencing its worst economic turbulence since the Great Depression of the 1930s on the back of multiple crises—fuel, food, and financial—in 2008. The impacts of the crises are still unfolding. The global economy has already slid into recession. Developing Asian countries face weakening external demand, lower flows of remittances, falling investment, and rising unemployment, with adverse consequences for the region's poverty eradication prospects. Southeast Asian countries are not immune to the global economic turbulence. The Asian Development Bank recently predicted that Southeast Asian GDP growth is likely to fall from 4.3% in 2008 to 0.7% in 2009 (ADB 2009). This could result in tens of millions of people, who would otherwise be lifted out of poverty, being trapped, and would make the achievement of the MDGs more challenging.

The economic downturn could make the task of combating climate change more difficult. Government development priorities could be diverted to tackling short-term macroeconomic stabilization problems and away from addressing longer term climate change and other environmental issues. Policies and public resources to cope with the economic recession may be considered more urgent, with climate change initiatives postponed. With credit tightening, private investment in adaptation and mitigation may not be forthcoming.

This does not have to be the case. Recognizing the urgency of tackling both the global economic crisis and the planetary climate crisis, the UN Environment Programme (UNEP) has proposed a "Global Green New Deal". The Deal calls for developed countries to use "green" investment measures (improving energy efficiency, expanding clean energy options, and developing sustainable transport) equivalent to 1% of GDP in the next 2 years, as a fiscal stimulus. The Deal also calls for developing countries to invest in clean water and sanitation for the poor and to develop well-targeted safety net programs. The Deal is already being backed by many governments.

A number of countries, developed and developing, have included specific "green measures" in their proposed or announced fiscal stimulus packages. Leaders of the G20 at the 2009 London Summit agreed to make the best possible use of investment funded by fiscal stimulus programs toward the goal of building a resilient, sustainable, and green recovery, and to make the transition toward clean, innovative, resource-efficient, low-carbon technologies and infrastructure. Green development plans are already on the agenda in many countries in the region, such as the People's Republic of China, Japan, and Republic of Korea.

In Southeast Asia, fiscal stimulus is also being used by many countries, including Thailand, Philippines, Indonesia, and Singapore, to support domestic demand through tax cuts, investment in infrastructure, and increasing spending on social programs. There may be scope for building into such stimulus packages "green investment" programs that combine adaptation and mitigation measures with efforts to shore up the economy, create jobs, and reduce poverty. The present crisis offers an opportunity to start a transition toward a climate-resilient and low-carbon economy in Southeast Asia.

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