SOUTHEAST ASIA AND THE ECONOMICS OF GLOBAL CLIMATE STABILIZATION

ASIAN DEVELOPMENT BANK

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Abbreviations

µg/m^3	-	micrograms per cubic meter
AR5	-	Fifth Assessment Report
AEZ	-	agroecological zone
ADB	-	Asian Development Bank
AME	-	Asian Modeling Exercise
BAU	-	business as usual
C&C	–	contraction and convergence
CCS	-	carbon capture and storage
CES	-	constant elasticity of substitution
CGE	-	Computable General Equilibrium
CH_4	-	methane
CO_2	-	carbon dioxide
CO_2eq	-	carbon dioxide equivalent
CoP	-	Conference of Parties
DA5	-	Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam
ESCO	-	energy service company
FAO	-	Food and Agriculture Organization of the United Nations
GDP	-	gross domestic product
GHG	-	greenhouse gas
IIASA	-	International Institute for Applied Systems Analysis
ICES	-	Intertemporal Computable Equilibrium System
IEA	-	International Energy Agency
INDCs	-	intended nationally determined contributions
IGCC	-	integrated gasification combined cycle
IPCC	-	Intergovernmental Panel on Climate Change
LIMITS	-	Low climate impact scenarios and the implications of required tight emission control strategies
$MtCO_2eq$	-	million tons of carbon dioxide equivalent
MW	-	megawatt
N_2O/NOx	-	nitrous oxide
PAGE	-	Policy Analysis of the Greenhouse Effect
ppm	-	parts per million
PRC	-	People's Republic of China

R&D	-	research and development
RCP	-	representative concentration pathway
REDD	-	reducing emissions from deforestation and forest degradation
SO_2	-	sulfur dioxide
tCO_2eq	-	tons of carbon dioxide equivalent
UNFCCC	-	United Nations Framework Convention on Climate Change
WITCH	-	World Induced Technical Change Hybrid

Foreword

Southeast Asia is one of the most vulnerable regions of the world to climate change. In the absence of climate action, the region will be increasingly exposed to hotter temperatures, more destructive storms, greater flooding in some areas, and more droughts in others. Livelihoods and food security will suffer, especially for the poorest populations, if the challenge of rising greenhouse gas (GHG) emissions is not tackled.

Southeast Asia is also becoming a larger contributor to global GHG emissions, with the fastest growth in carbon dioxide emissions in the world between 1990 and 2010. Deforestation and land degradation have been driving most of the emissions to date. At the same time, low improvements in energy intensity and increasing reliance on fossil fuels are causing energy emissions to escalate. Given the region's vulnerability to climate change, curtailing global emissions growth should be a priority consideration, to which the region can make an important contribution.

Moving away from the region's current carbon-intensive development trajectory requires strong action. This study offers insights on what this might entail and how it might be achieved. It focuses on the five countries—Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam—that make up more than 90% of Southeast Asia's emissions. The objective is to analyze how different global arrangements to limit global warming will affect the region's energy, land use, and economic systems. Using two different economic models customized for the region, the study estimates the costs of climate inaction, the effects and costs of action, and benefits from mitigation actions and avoided climate change.

The analysis affirms that a global climate arrangement that keeps mean warming below 2°C—the stated goal of the 2015 Paris Agreement—is in the economic interest of the region. Although the policy costs for such stabilization during initial decades are not trivial, net benefits are found to far exceed net costs. The resource requirements are also not insurmountable, as costs are a smaller share of GDP than what the region has spent in recent years on fossil fuel subsidies. Moreover, the study finds that policy costs to achieve stabilization sharply increase if actions to reduce emissions are delayed.

The transformations needed to reap the benefits from mitigation are profound, but feasible. Avoiding emissions from deforestation and degradation is the most cost-effective way for the region to reduce emissions. If deforestation is not controlled, estimated policy costs would more than double for Indonesia, making ambitious mitigation economically unattainable.

For energy, the 2°C mitigation scenario requires improvements in energy efficiency that are doubled from business as usual. The results also imply that by 2050, most of the region's energy must be generated from low-carbon energy sources, and much must come from new energy technologies. These tremendous transformations require early preparation, supporting investments, innovation, and international cooperation.

The Asian Development Bank (ADB) is supporting efforts to make such transformations happen through its portfolio in the region. It has projects and technical assistance to address drivers of deforestation, expand clean power production, and fund energy efficient electricity and transport infrastructure. ADB also supports development and piloting of advanced low-carbon technologies, such as carbon capture and storage.

More broadly, ADB has embodied climate change as a core area of operations and assistance in its long-term corporate strategy. ADB supports its developing member countries with financing and knowledge both for coping with climate change and for ensuring that future emissions are limited. Across its developing member countries, ADB is funding solutions for resilient, green growth as core to its sustainable development agenda. In 2015, ADB announced its commitment to double annual climate financing to $6 billion by 2020.

The 21st Conference of Parties to the United Nations Framework Convention on Climate Change recently approved the seminal Paris Agreement to limit climate change, drawing on nationally determined emissions reduction contributions. The Agreement puts in place a process by which national contributions will be ratcheted up over time, so as to achieve a shared goal of limiting the mean global temperature increase to below 2°C. As a result, the onus remains on countries to find pathways toward low-carbon development and emissions consistent with climate stabilization. It is hoped that the findings of this report will inform efforts by countries in Southeast Asia to respond to this opportunity and realize their potential to curb GHG emissions. ADB stands ready to assist its developing member countries to translate those pathways into action.

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Executive Summary

From 1990 to 2010, carbon dioxide (CO_2) emissions in Southeast Asia have grown more rapidly than in any other region of the world. This report analyzes the potential role the region can play in climate change mitigation, focusing on the five countries of Southeast Asia that collectively account for 90% of regional greenhouse gas (GHG) emissions—Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam.

The study examines potential regimes for regulating global GHG emissions through 2050. These include (i) business as usual (BAU); (ii) fragmented national climate policies; (iii) a global climate stabilization agreement that is likely to keep warming below 3°C, by limiting GHG concentrations to 650 parts per million (ppm) CO_2 equivalent by the end of the century (650 ppm scenario); and (iv) a more ambitious target that is likely to avoid warming of more than 2°C, by limiting GHG concentrations to 500 ppm CO_2 equivalent (500 ppm scenario). Reducing emissions from deforestation and forest degradation (REDD) was included and excluded from the scenarios.

The study applies two global dynamic economy–energy–environment models: the World Induced Technical Change Hybrid (WITCH) model, which focuses on detailed representation of energy sector innovation, and the Intertemporal Computable Equilibrium System (ICES), which focuses on more disaggregated depiction of economic sectors. Within the scenarios, the cost of climate change inaction, changes that achieve mitigation, costs of climate action, co-benefits of mitigation responses, and benefits of avoided climate change are assessed.

New analysis suggests that the impacts of climate change in Southeast Asia may be larger than previously estimated

Southeast Asia is likely to sustain larger economic losses from climate change than most other areas in the world. Moreover, those losses—the collective effect of impacts on agriculture, tourism, energy demand, labor productivity, catastrophic risks, health, and ecosystems—may be larger than previously estimated. When these loss estimates are considered simultaneously in the modeling, gross domestic product (GDP) is found to be reduced by 11% in 2100 under the BAU emissions scenario of this study, which is 60% higher than the earlier assessment of the Asian Development Bank (ADB).

Southeast Asia is a growing source of greenhouse gas emissions, and rapid emissions growth will continue without mitigation action

The region has experienced rapid economic growth in recent years, and regional GHG emissions have rapidly increased, at nearly 5% per year over the last 2 decades. Deforestation and land use account for a majority of emissions. Energy efficiency in most of Southeast Asia is improving more slowly than in other areas of developing Asia or the world as a whole, while coal and oil have been rapidly rising as sources of primary energy.

Southeast Asia's per capita emissions are currently near the world average. Without explicit polices aimed at reducing future emissions, the region's GHG emissions are estimated to be at least 60% higher in 2050 than the actual value in 2010. Energy sector emissions are found to be 300% higher.

Emissions growth would need to fall substantially under a "contraction and convergence" framework

For purposes of transparency and simplicity, the modeled scenarios apply an equity-based emissions distribution framework known as "contraction and convergence." This framework has national shares of global emissions transition from BAU in 2020 to an equal per capita basis by 2050. The policy scenario to achieve 500 ppm stabilization under this framework would require a reduction in regional emissions of more than 60% from BAU—to a value 30% below 2010 emissions by 2050. Even the 650 ppm scenario requires that 2050 emissions would need to be slightly below 2010 levels.

Climate stabilization has substantial GDP costs, but effects on welfare are limited

Policy costs of emissions mitigation are found to be 2.5%–3.5% of regional GDP over the 2010–2050 period for the 500 ppm scenario, and are about 1% of GDP for the 650 ppm scenario (if deforestation is effectively reduced). However, effects on welfare (equivalent variation) are found to be less than half as large for the 500 ppm scenario, without counting co-benefits or benefits of avoided climate change. Under the 650 ppm scenario, welfare rises.

Co-benefits to climate stabilization offset many of its costs

Changes to energy and land use under climate stabilization lead to large quantified co-benefits from improved health, reduced transport congestion and reduced vehicular accident costs. By 2050, these reach nearly 3% of regional GDP under the 500 ppm scenario. Over the 2010–2050 period, co-benefits offset 40% to 50% of 500 ppm scenario policy costs in GDP terms and nearly all policy costs in terms of welfare.

Benefits from avoided climate damage and co-benefits strongly outweigh decarbonization costs

When avoided losses from climate change are added to co-benefits, the net benefits from climate stabilization for Southeast Asia are found to range from 5 to 11 times net mitigation costs from 2010 to 2100 using a 5% discount rate. Co-benefits are important initially, while reduced damage from climate change becomes more important over the longer term.

Climate goals to date reflect mitigation levels that are economically suboptimal

Countries across the globe, including those in the region, have submitted their Intended Nationally Determined Contributions (INDCs) on GHG mitigation and adaptation under the United Nations Framework Convention on Climate Change. At a global level, the INDCs submitted are likely to lead to greater warming than the 650 ppm scenario of this study. Southeast Asia is no exception to this trend. While the level of ambition varies among the countries, collectively, the unconditional INDCs (not premised on international assistance) from the region result in emission levels that are only slightly below what models in this study find as BAU. Conditional INDCs (premised on international assistance) from the region are found to reflect similar emissions levels to the 650 ppm scenario. A more ambitious level of mitigation is found to be economically beneficial for Southeast Asia.

Climate stabilization will cost much more if implementing a stringent global climate agreement is delayed

Achieving stabilization targets cost effectively requires early action. Emission reduction initiated early can avoid potential spikes in decarbonization costs later. For example, the WITCH model shows that a 10-year delay in implementation of the 500 ppm scenario could increase 2050 policy costs by 60%, which is a greater increase than for the world as a whole.

A global market for greenhouse gas emissions could benefit Southeast Asia

A global carbon market could benefit countries in the region, as Southeast Asia is a net exporter of emissions allowances under the 500 ppm and 650 ppm scenarios. In the absence of trade, the net present value of 2010–2050 policy costs under the 500 ppm scenario rises by 32% to 53% above the main scenarios with a global carbon market in place.

Emission reductions are driven by land use, energy efficiency, and low-carbon energy sources

Mitigation is achieved by reducing land-use emissions, increasing the efficiency of energy usage, and replacing carbon-intensive fuels with cleaner alternatives. About half of cumulative emissions abatement through the early-2030s arises from REDD/land use, making it the leading source through the medium term. The largest single long-term source of cumulative emission reductions over 2010–2050 is energy-efficiency gains, while low-carbon energy (such as from biomass and coal with carbon capture and storage) is most important in the longer-term portion of the analysis when present in the models.

Avoided deforestation is critical to reduce decarbonization costs in the short to medium term

Avoided deforestation is the major near-term low-cost abatement opportunity for Indonesia and Malaysia, where deforestation accounts for a large share of emissions. Inclusion of averted deforestation in carbon markets could benefit the rest of the region by lowering carbon prices. The GDP costs of mitigation are 50% higher for Indonesia and 20% higher for the rest of Southeast Asia if avoided deforestation is not available for mitigation in various scenarios.

Low-carbon energy technologies are critical to reduce decarbonization costs in the long term

The reduction in long-term costs of moving to a low-carbon economy is contingent on the effects of technological change and the availability of advanced low-carbon energy technologies. Under a 500 ppm stabilization scenario, low-carbon energy technologies have the potential to reduce 2050 GDP costs of emission reductions by more than 50%. Carbon capture and storage emerges as the most important technology for emission reduction.

Realizing the potential of advanced low-carbon energy sources to contain decarbonization costs requires up-front investment in research, with investment needs found to reach over $2 billion annually in Southeast Asia by the early 2020s under the 500 ppm scenario. In all scenarios other than BAU, research investment scales up over time, but more ambitious mitigation leads to investment that begins earlier.

Early action on advanced energy technologies is needed to enable their mitigation potential

Carbon capture and storage, as well as advanced second- and third-generation biofuels have the potential to be deployed widely and help reduce the costs of a low-carbon energy transition, according to the modeling. Advanced second-generation biofuels are already being commercialized and are becoming cost-competitive with crude oil. However, substantial piloting and an enabling policy environment are needed to support deployment of both technologies.

Further energy efficiency improvements are essential for cost-effective emission reduction

Energy efficiency improvement through adoption of more efficient technologies and changes in behavior is the biggest single source of long-term emission reduction in the stabilization scenarios. Only after the 2030s do advanced energy generation technologies make a larger potential contribution to abatement. The rate of efficiency improvement needed in the scenarios is much higher than is targeted in current energy plans in the region.

Green infrastructure investments can facilitate low-carbon transitions

Achieving dramatic improvements in energy efficiency and substitution of cleaner energy sources for fossil fuels requires investment in green infrastructure. This may include new zero or low-carbon power generation facilities, smarter power grids that can match both centralized and distributed supply and demand sources, energy-efficient buildings, public transport facilities that enhance mobility and safety while reducing congestion, and charging and refueling networks for electric and alternative fuel vehicles. The study finds that by 2050, an additional $30 billion will need to be invested annually in Southeast Asia's power generation alone under a 500 ppm scenario, but that this increase is offset by savings in other energy investments.

Climate stabilization can cost less than what the region has spent on energy subsidies

In 2010, governments in the region spent more than 3% of GDP on fossil fuel subsidies, which is much higher than the estimated costs of climate stabilization under the 500 ppm scenario after co-benefits are considered. Reducing these subsidies in a gradual and targeted manner—as Indonesia has done in early 2015—can free the resources needed to finance a low-carbon transition, while setting the right price signals for low-carbon development.

International assistance can help to achieve global climate stabilization goals

The mitigation potential identified in the scenarios can be most efficiently realized if appropriate preparatory actions are undertaken. Reducing deforestation depends upon enhancement of forestry institutions, while advanced energy technologies depend upon research cooperation to foster adaptation to circumstances in the region. Enabling infrastructure has a critical role to play to ensure energy efficiency and clean energy supplies. All countries in the region sought international assistance in their INDCs in the form of technological support, finance, and capacity building. Targeted assistance to facilitate transitions to low-carbon economies for the region is important, given its potential for growth of GHG emissions and the low-cost opportunities for mitigation that the region provides.

1

Introduction

Key messages

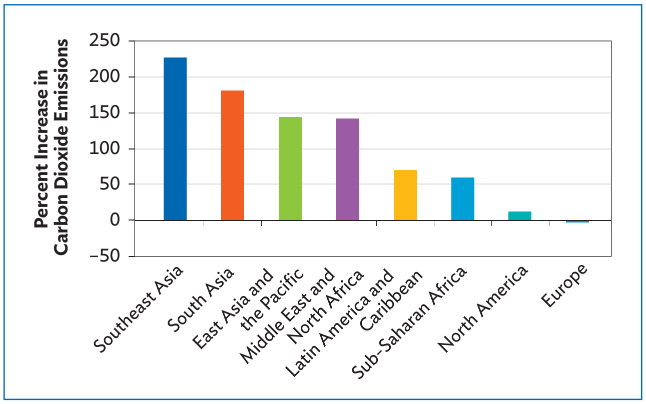
This chapter reinforces why Southeast Asia should care about climate change mitigation.

- Between 1990 and 2010, Southeast Asia had the most rapid rate of increase in carbon dioxide emissions among major world regions. Although its historical share of global greenhouse gas emissions is small, the region is on a trajectory that will make it a much larger emitter in the future.
- Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam (termed the DA5) collectively accounted for 90% of greenhouse gas emissions in 2010 in Southeast Asia, and are hence the focus of this report.
- The overall objective of this study is to examine the potential role that selected countries of Southeast Asia could play in global arrangements to achieve emissions consistent with international global warming scenarios. The modeled arrangements focus on what can be done to reduce emissions under economically efficient circumstances.
- Climate change is already evident in Southeast Asia, as evidenced by mean temperature increases of between 0.14 and 0.20 degrees centigrade per decade since 1960. Without climate action, impacts will be much larger in the future.
- Climate change poses substantial physical risks from increased river flooding, coastal inundation and sea level rise, increased water stress, and increased frequency of intense cyclones and storms.
- Sectoral effects of unmitigated climate change include reduced agricultural productivity, losses of labor productivity, reduced human health, increased energy and other resource demand, collapse of coastal ecosystems, and loss of terrestrial forest cover and biodiversity. Collectively, these effects lead to substantial economy-wide consequences.
- To avoid these long-term risks, countries in the region should help to lead the way in global climate action by transitioning toward low-carbon development.

1.1 Southeast Asia Matters to Climate Change

Southeast Asia is one of the most vulnerable regions of the world to the impacts of a changing climate. Millions of its inhabitants are still trapped in extreme poverty and are employed in climate-sensitive sectors. *The Economics of Climate Change in Southeast Asia: A Regional Review* (ADB 2009) estimated that, if left unaddressed, climate change would cost the region about 6.7% of combined annual gross domestic product (GDP) by 2100. Adaptation is necessary to manage the unavoidable impact of climate change, while mitigation of greenhouse gases (GHG) is crucial to avoid catastrophic long-term impacts.

Figure 1: Increases in Total Carbon Dioxide Emissions in World Regions between 1990 and 2010



Note: Includes fossil fuels emissions only.
Source: World Bank. World Development Indicators. http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators (accessed October 2015).

Southeast Asia is also following a trajectory that could make it a major contributor to global warming in the future. In recent decades, the region's growth in emissions of carbon dioxide (CO_2) has been more rapid than in any other area of the world (Figure 1). Moreover, the region has an array of policies that encourage high levels of emissions and technical inefficiency, such as extensive fossil fuel subsidies. Coupled with some of the world's most rapidly growing economies, the region is on track for large increases in emissions over the coming decades. Such a rapid rise is incompatible with the established international scientific consensus on the degree of global warming that can be accepted without leading to large catastrophic risks.

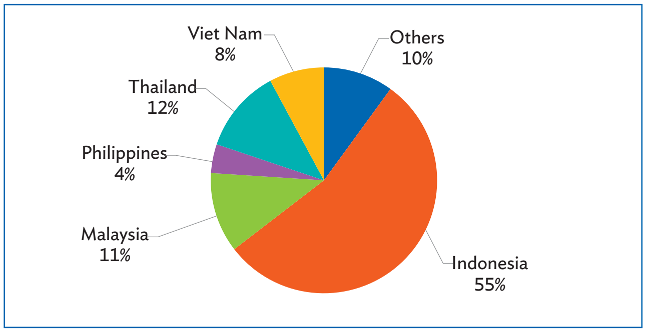
To avoid the potential risk of 4 degrees centigrade (°C) to 5°C mean global warming by 2100 at lowest cost, action needs to be taken now to reduce emissions, and this action needs to include all areas of the world. Southeast Asia, with its rapidly increasing emissions and massive potential for those emissions to grow, is no exception. To avoid long-term risks to their own economies, countries in the region should help to lead the way in global climate positioning by proposing stringent emission reduction goals. Moreover, transitions toward low-carbon economic systems provide a foundation to a balanced growth path that is more resource efficient, less carbon intensive, energy- and food-secure, and environmentally sustainable, with attendant co-benefits for ecosystem resilience and human health.

Fortunately, an array of options exists to help the countries of Southeast Asia decarbonize their economies. This study offers insights on these potentials, drawing on tools developed for the benefit of the region. It appraises what might occur in four overall scenarios: if emissions growth is unabated, if countries continue with fragmented nationally determined commitments, if a global climate agreement is formulated at moderate ambition, and if a global climate agreement is ambitious. This is accomplished through the application of two economy–energy–environment models that represent entire economies in the region, including energy and land use systems. The study illustrates what long-term investments in knowledge and institutional infrastructure can contribute to reducing the economic costs of these transitions. It also assesses a subset of the benefits that can be derived from mitigation in terms of reduced air pollution, traffic congestion, traffic accidents, and reduced damage from climate change.

1.2 Purpose, Structure, and Audience for this Report

The analyses focus on five countries of Southeast Asia that collectively account for 90% of regional emissions in recent years—Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam (Figure 2). These five countries in developing Asia are collectively termed the DA5 in this study.

Figure 2: Greenhouse Gas Emissions in Southeast Asia per Country, 2010
(in carbon dioxide equivalent)



Sources: International Energy Agency. CO_2 emissions statistics. http://www.iea. org/statistics/topics/co2emissions/ (accessed 5 December 2014); Food and Agriculture Organization of the United Nations. FAOSTAT. http://faostat.fao.org (accessed 1 November 2014).

The overall objective of this study is to examine the potential role that selected countries of Southeast Asia could play in hypothetical global arrangements to achieve emissions consistent with international global warming scenarios. By examining how the region responds to such arrangements, the study helps to reveal the land use and energy system transformations induced by ambitious climate policy, as well as the economic effects of such transformations, inclusive of both their costs and benefits. To do so, the study takes a top-down modeling approach, subject to conditioning assumptions. Primary among these is that the study assumes under its more ambitious scenarios that climate action will be achieved through a harmonized global carbon market. This is included in the global climate agreement approved in Paris in December 2015, but the precise nature and role of the market are not yet defined. In that context, this study adds value by illustrating what is possible were the global climate agreement to take a simple and economically efficient approach that allows mitigation to occur where it can be achieved at lowest cost. The intention of such an approach is to focus analysis on the larger question of what can be done to reduce emissions, rather than the contentious political debate on which country should act first.

The primary intended audiences of this study are experts and policy makers involved in shaping the positions of countries in the region in the context of a global climate agreement. It is intended that the study can help to illustrate what the countries have at stake in the evolution of a global agreement, and how ambitious contributions to mitigation may be in the self-interest of the region. In so doing, the modeling also helps to identify where and how aggressive mitigation can be achieved via cost minimizing changes in the region identified by global integrated economy–energy–environment models. This provides a vision into how the region might evolve if a low-carbon growth trajectory is prioritized.

ADB has previously published some analysis of mitigation options in Southeast Asia (ADB 2009). This study is an advancement over the earlier publication, as it enriches quantitative exploration of recommendations previously made. This study updates estimates of costs of inaction, quantifies the long-term costs of climate action, estimates the co-benefits of climate action, and adds cost–benefit analysis of mitigation. In so doing, it considers global interactions, carbon trade effects, dynamics of induced innovation, interactions between land use and energy abatement options, and many other aspects that are all not explicitly quantified in the 2009 report to give a more complete analysis of the potential contributions and responses of Southeast Asia to climate stabilization.

1.3 Climate Change Should Matter to Southeast Asia

1.3.1 Global warming scenarios suggest a substantially hotter planet

The Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) has concluded that evidence of anthropogenic climate change is "unequivocal" and that "climate change will amplify existing risks and create new risks for natural and human systems." The mean temperature of the earth has already warmed approximately 0.85°C from 1880 to 2012. The oceans are warming, polar ice sheets and glaciers are melting, and mean sea level has risen by 20 centimeters. Moreover, this warming is predicted to accelerate.

For the future, the AR5 depicts warming under four different representative concentration pathway (RCP) scenarios, each of which is named after expected radiative forcing values (in watts per square meter) by 2100. Each RCP roughly corresponds to a stabilized peak CO_2 concentration and a mean temperature rise, as shown in Table 1.

All RCPs, even those that represent drastic cuts in GHG emissions, reflect continued warming, and all but one indicate mean warming of at least several times the warming experienced to date. All but RCP2.6 reflect temperatures that continue to rise beyond 2100, such that true stabilization of climate change does not occur within several centuries. Although these scenarios are hypothetical, pathways to date are consistent with RCP6.0 or higher. This implies at least 3°C of mean warming by 2100, with a rapid rate of warming continuing thereafter.

1.3.2 Southeast Asia will be strongly affected by continued climate change

According to the AR5, warming trends have been observed across many parts of Southeast Asia, with mean temperatures increasing at a rate of 0.14°C–0.20°C per decade since the 1960s, bringing about more hot days and warm nights, as well as less cooler weather. Precipitation trends are also changing, although trends show high geographic and seasonal variability. Annual total wet-day rainfall increased by 22 millimeters per decade while rainfall on extreme-rain days increased by 10 millimeters per decade. Between 1955 and 2005, the ratio of wet-dry season rainfall in the region showed a general increase. Relative sea level increase in the Western Pacific Ocean was three times greater than the global mean during 1993–2012.

Table 1: Representative Concentration Pathway, Radiative Forcing, Peak Greenhouse Gas Concentrations, and Median Temperature Increase over Preindustrial Levels and Similar Scenarios

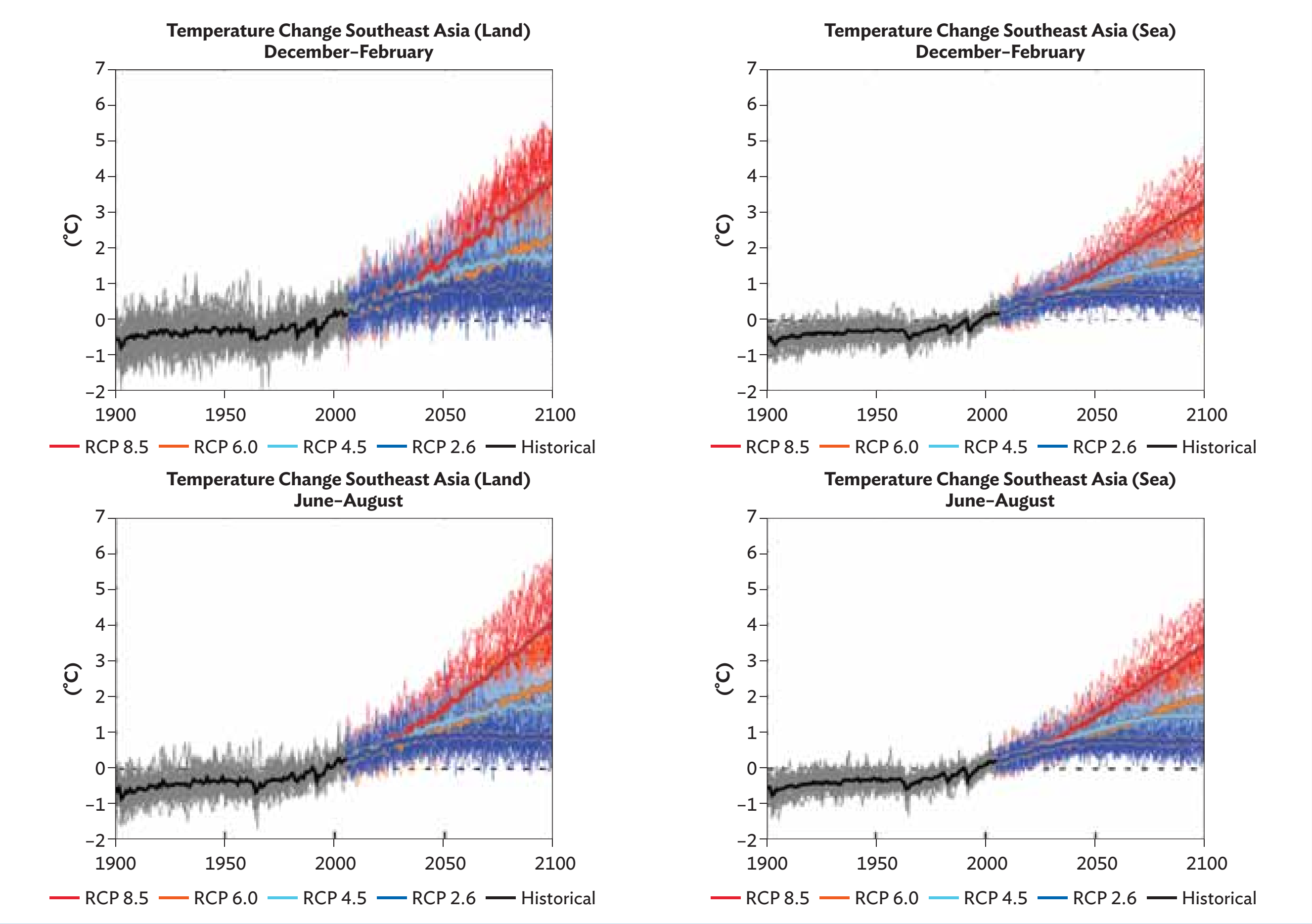
Name	Radiative Forcing in 2100 (watts/m²)	2100 Carbon Dioxide Equivalent (ppm)	Approximate 2100 Mean Temperature Increase (°C)	Most Similar SRES Scenario
RCP2.6	2.6	490	1.5	None
RCP4.5	4.5	650	2.4	B1
RCP6.0	6.0	850	3.0	B2
RCP8.5	8.5	1,370	4.9	A1F1

m2 = square meter, ppm = parts per million, RCP = representative concentration pathway, SRES = Special Report on Emission Scenario.
Notes: The B1 scenarios are of a world more integrated, and more ecologically friendly characterized by rapid economic growth, but with rapid changes toward a service and information economy, high rate of population growth and then declining, more energy efficiency, and with emphasis on global solutions to economic, social, and environmental stability. The B2 storyline depicts a world more divided, but more ecologically friendly, characterized by continuously increasing population, but with slower growth, on local rather than global solutions to economic, social, and environmental stability, intermediate levels of economic development, and less rapid and more fragmented technological change. A1FI is characterized by rapid economic growth, increasing then declining trend of population growth, and a convergent world with emphasis on fossil fuels (fossil intensive).
Source: Rogelj et al. (2012).

Warming will persist in Southeast Asia but with substantial subregional variations. According to the AR5, the median increase in land temperature by 2100 relative to the late 20th century will range from approximately 1.0°C in RCP2.6 to 3.7°C in RCP8.5. Oceanic warming is expected to be lower in the east than in the west of the tropical Indian Ocean and similar across seasons (Figure 3). Although the physical direct effects of climate change may appear to be gradual for the region, their long-term economic implications can be severe.

In the IPCC AR5 (Hijioka et al. 2014), the major climate impacts and risks identified for the Asian region were to include increased (i) risk of river flooding and sea flooding; (ii) water shortages in already arid zones; (iii) increased risk of river flooding and sea flooding leading to damages to infrastructure, livelihoods, and settlements; (iv) increased flood, storm, and inundation-related risks; (iv) crop failure and heat-related mortality; (v) risk of water- and vector-borne diseases and heat-related mortality; (vi) prospects of heat stress affecting labor; (vii) vulnerabilities of infrastructure and resources; (viii) coral reef decline; and (ix) ecosystem extinction. These all are relevant risks in Southeast Asia.

Figure 3: Historical and Expected Temperature Changes in Southeast Asia under Different Scenarios



RCP = representative concentration pathway.
Note: Left panels correspond to temperature changes over land; right panels over sea; top panels in December–February; and bottom panels in June–August.
Source: IPCC (2014).

Increased risk of river flooding, coastal inundation, and sea level rise

By 2100, sea level is expected to rise by 70 centimeters in RCP8.5, which puts many important areas of Southeast Asia at risk to both loss of land and to salinity intrusion. Many productive activities are found along the coastal zones and major floodplain areas in Southeast Asia, and about 436 million people live within 100 kilometers of the region's coasts (UNEP 2015).The Dynamic Interactive and Vulnerability Assessment model employed within the Climate Framework for Uncertainty, Negotiation and Distribution (FUND2.9) model identifies capital and land stock at risk to the effects of sea level rise, and finds up to nearly 1% of land and capital stock likely to be lost by 2050 (Anthoff et al. 2010, Anthoff et al. 2009). Much of this is likely to be in key low-lying coastal cities, such as Bangkok, Jakarta, Manila, and Ho Chi Minh. In addition, salinity intrusion is expected to cause the loss of hundreds of thousands of hectares of productive paddy and other agricultural land.

Increased water stress

As Southeast Asia develops, there will be increasing competition for water resources for different uses. Climate change will exacerbate this. According to ADB (2009), 185 million people in Southeast Asia are likely to experience water stress by 2050. The annual flow of the Red River is projected to decline by 13%–19%, while the Mekong River will decline by 16%–24%, affecting 60 million people. More broadly, increased evaporation and evapotranspiration will reduce water supplies for agriculture, drinking water, and other uses (Cuong 2008).

Increased risk from intense cyclones and storms

While climate change is expected to lead to a decline in total cyclone landfalls in the Southeast Asian region, cyclone intensity is projected to increase, with greater frequency of the most destructive events. Murakami et al. (2012) find an increase in category 5 cyclone frequency of up to 17% under warming similar to the late 21st century under RCP8.5.

Although precipitation is expected to rise by a relatively minor 8% in RCP8.5 for Southeast Asia by 2100, rainfall intensity is expected to increase, with more concentrated periods of rainfall. Extreme precipitation is projected to rise near the centers of tropical cyclone damage in the sea south of the PRC, east of Viet Nam, and west of the Philippines, Gulf of Thailand, and Andaman Sea.

Agricultural production and productivity declines

Despite the region's fast-paced structural transformation, in the DA5 countries, about 190 million people remain employed in the agriculture sector (ADB 2014a). Agriculture is conditioned by temperature and rainfall, and thus is vulnerable to changes in climatic conditions. Increases in peak temperature can lead to heat stress and crop sterility, while increases in nighttime temperatures may reduce yield. Changes in rainfall lead to water deficit stress, flooding losses, and changes to seasonal duration that often cause production declines.

Nearly 30% of the world's rice supply is from Southeast Asia, where rice remains the most important staple food for many households, particularly the poor. Declines in rice yield potential have already been observed as a result of warming nighttime temperatures in the Philippines under otherwise controlled conditions (Peng et al. 2004).

Nelson et al. (2010) applied the Decision Support System for Agrotechnology Transfer crop growth model and find that Southeast Asia's rice production is expected to suffer a decline of up to 5% between 2010 and 2050 (under approximately an RCP6.0 scenario). Production of rice along the Mekong River Delta in Viet Nam is expected to be severely impacted by climate change, particularly during selected seasons when production may decline by over 40% (START 2006).

Extreme weather events are expected to compound these losses (IPCC 2012). Flooding and sea level rise pose threats to the region's deltaic rice production areas such as the Mekong River Delta. Dasgupta et.al (2009) projected that 7% of Viet Nam's agricultural land may be at risk of submersion due to a 1-meter sea level rise.

Increased risk of heat-related mortality and water- and vector-borne diseases

With rising temperature, climate change is expected to lead to increased mortality from cardiovascular and respiratory diseases brought about by thermal stress and proliferation of water- and vector-borne diseases. According to ADB's (2009) results for Indonesia, the Philippines, Thailand, and Viet Nam, deaths due to heat-related cardiovascular and respiratory diseases will increase by 3% and 14%, respectively, in 2050; and will rise by 10% and 25%, respectively, by the end of the 21st century.

Losses of labor productivity

Human labor is only possible without medical risk up to a certain humidity-adjusted temperature limit, known as a wet bulb globe temperature (WBGT), with labor intensity limited when the WBGT exceeds 26°C. Much of Southeast Asia has portions of the year that already exceed this limit, and these portions will grow under climate change, such that labor in physically demanding industries will need to mechanize, investment in cooling will need to rise, or economic output will be sacrificed. Kjellstrom et al. (2015) estimate that the Philippines will lose 6% of labor days due to climate change effects on WBGTs by the mid-2050s, and Viet Nam will lose 5%.

Higher resource demands

Coastal infrastructure will be placed under increasing damage from sea level rise, storm surges, and extreme weather events, requiring much more repair, reconstruction, and increased reinforcement. A hotter climate also means increased energy needed for cooling. Electricity demand by 2050 in DA5 countries is expected to increase by 12% on average against a no-climate-change baseline, mainly driven by cooling needs (Bosello et al. 2012).

Coral reef extinction and coastal ecosystem collapse

About 40% of the world's coral reefs are found in Asia, with Southeast Asia regarded as having the world's most diverse reef communities in the "coral triangle," as well as extensive seagrass beds supporting most of the world's seagrass species (Spalding et al. 2001). Coral bleaching has been observed in the coasts of Bali, Java, and Lombok in Indonesia, where about 90%–95% of corals within 25 meters of the surface have been bleached (Burke et al. 2002). Amadore (2005) and Arceo et al. (2001) have reported massive coral bleaching in Philippine reefs during the severe 1997–1998 El Niño. Under 4°C of warming, as is predicted under RCP8.5 within the 21st century, virtually all coral within Southeast Asia will be extinct, along with the marine systems that it supports.

Loss of terrestrial forests and biodiversity

Tree species have long life cycles and often have limited ability to migrate quickly in response to changes in environmental suitability, which makes them vulnerable to changes in rainfall and temperature that condition forest distribution. As a result, they will have limited ability to adapt to changes in drought, flooding, diseases, insects, and other parasites (FAO 2010). Exotic species invasions will be facilitated by climatic conditions that increase exotic competitiveness with native species. The timing and frequency of plant flowering and seeding events may also be altered, such that reproduction is impeded, while forest fire risk may rise where dry seasons become more protracted. Tropic humid forests are at particular risk, as they depend largely on precise rainfall ranges. Zelazowski et al. (2011) find that insular Southeast Asia is at risk of losing up to 30% of tropical forest area under warming similar to RCP8.5. When endemic flora is lost, the fauna that depends upon it is at risk of extinction as well. Loss of natural forests will also eliminate supplies of energy, food, timber, and fiber, along with crucial ecosystem services.

1.3.3 Climate inaction poses economy-wide risks

There are many complexities to move beyond assessment of individual sector impacts and quantify the economy-wide implications of climate change. Over 20 years of multidisciplinary integrated assessment research has harnessed the combined efforts of the climate, environmental, and economic disciplines to tackle this challenge (e.g., IPCC 1996, 2001, 2007, 2014; Stern et al. 2006; Tol 2008 and 2009).

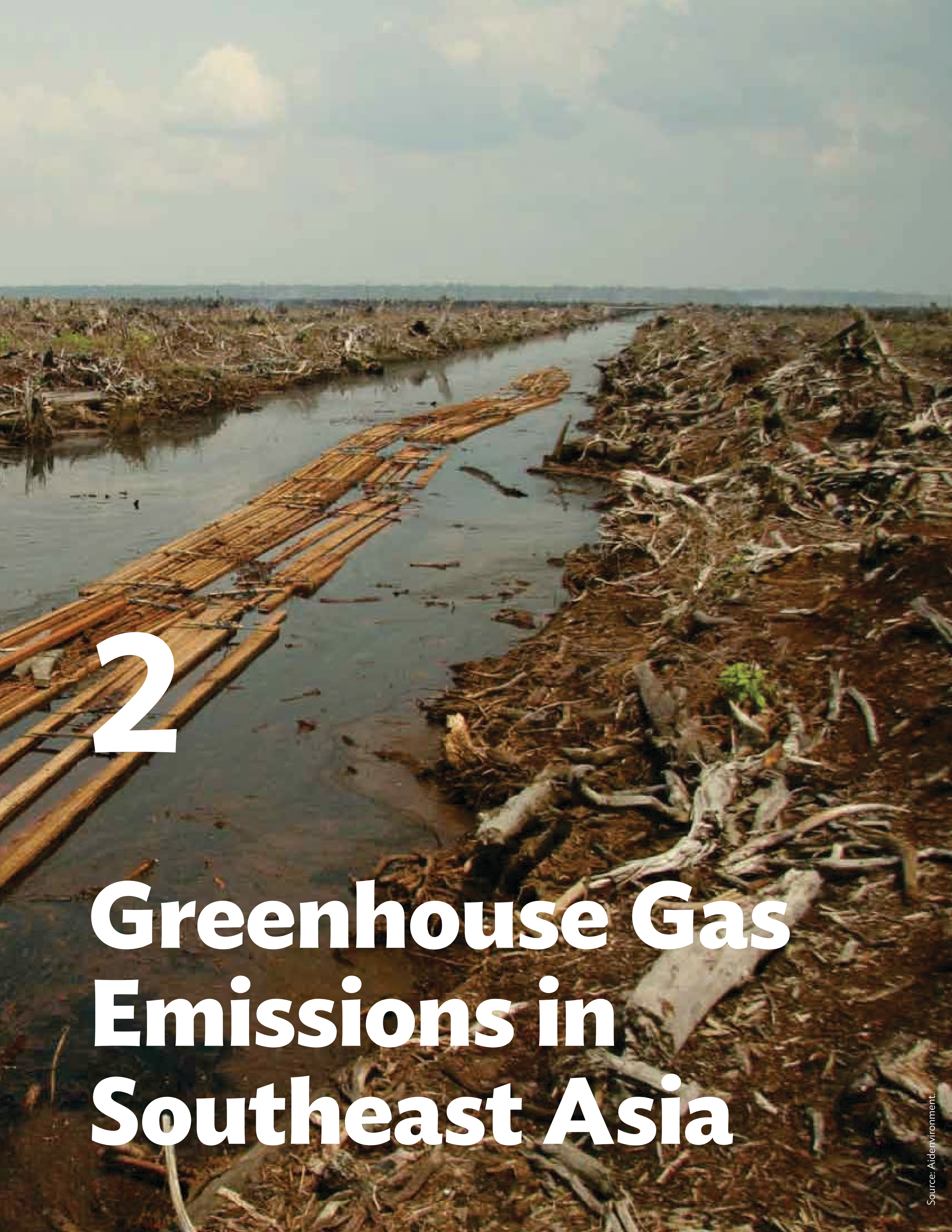
This literature indicates that the region is expected to suffer GDP losses ranging from 1.7% arising from 1.0°C of mean global warming (Tol 2002) to losses of 12.5% from 4.8°C of warming (Roson and van der Mensbrugghe 2010). This compares with an average world gain of 2.3% of GDP from 1.0°C of mean global warming and an average world loss of 4.6% of GDP from 4.8°C of warming, such that Southeast Asia is much more vulnerable than much of the globe.

ADB (2009) offers the only country-specific estimates of the economy-wide effects of climate change in Southeast Asia, using the Policy Analysis of the Greenhouse Effect (PAGE) integrated assessment model to estimate GDP losses in Indonesia, the Philippines, Thailand, and Viet Nam under the A2 IPCC scenario (similar to RCP8.5). Considering only "market impacts" (on agricultural production and inundation of coastal zones), the study estimated that the region can suffer a mean annual loss of 2.2% of GDP by 2100. The mean cost for the four assessed countries is estimated to reach 5.7% of GDP if nonmarket impacts related to health and ecosystems are included, and 6.7% of GDP if catastrophic risks are also taken into account.

Clearly, the Southeast Asian region has much at stake in how climate change is addressed. This leads to the ancillary question of what avoiding this damage entails for the region's economies.

2

Greenhouse Gas Emissions in Southeast Asia



Source: Aidenvironment.

Key messages

This chapter presents background information on regional circumstances of the study's focal countries: Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam (DA5).

- The DA5 is changing rapidly, with fast economic growth and poverty reduction, underpinned by structural transformation from agricultural to service and industry-based economies.
- Regional greenhouse gas (GHG) emissions have been rapidly rising at nearly 5% per year over recent decades.
- Deforestation and land use account for a majority of recent emissions from the DA5, although most of these emissions come from Indonesia.
- Indonesia and Malaysia were experiencing substantial deforestation in recent decades, whereas forest cover is stable or increasing in the other countries.
- Deforestation has been occurring more rapidly in peat swamp forests than in forests on mineral soils. This has profound emissions implications, as deforestation leads to large GHG emissions via peat oxidation and peat fires. On a national basis in Indonesia and Malaysia, peat soils contain 500% of the carbon stored in above-ground forest biomass.
- Energy intensity in most of the DA5 is improving more slowly than in other areas of developing Asia or the world as a whole.
- Coal and oil have been rapidly rising as sources of primary energy in the DA5, and industry and transport are the main drivers of increased energy demand.
- As the 2015 global climate agreement is expected to eventually lead to both low-carbon development and even more ambitious national mitigation commitments, it is important to understand the implications of climate stabilization policies for the region.
- Economy–energy–environment models offer the potential to help provide insights on the effects of low-carbon development strategies. Bottom-up models provide insights on specific technical options within sectors, whereas top-down models provide insights on economy-wide responses to policy instruments governing market behavior. Hybrid models blend the two.
- There have been few previous studies on the economy-wide effects of GHG mitigation for Southeast Asia and/or DA5 countries. Most earlier studies are neither in the context of a global stabilization target, nor do they reflect how the countries would interact with a global carbon market. Previous studies have also omitted or underestimated land-use emissions, particularly from peatlands, and none has attempted to fully capture the dynamics of costs, co-benefits, and benefits from reduced climate change.

2.1 Regional Circumstances

2.1.1 The region is changing rapidly

During the 25 years up to 2014, GDP in the DA5 countries grew at an average of 4%–7%, as a result of a rapid structural transformation (Table 2). As part of this process, value added from services and industry grew at nearly twice the rate of agriculture, with an attendant doubling of the urban population, which was pulled into these sectors. As a result, living standards changed dramatically, with poverty rates falling drastically across the region. This change in living standards, in urbanization rates, and in the movement toward economies driven by industry and services has caused GHG emissions from the region to rise rapidly. Such a transformation has also been underpinned by exploitation of natural resources in the region.

Emissions growth in the region has been almost as fast as economic growth, with nearly 5% annual increases over the 1990–2010 period (Table 3). The fastest areas of relative emissions growth have been electricity, manufacturing, and transportation, which are sectors associated with the region's structural transformation away from agriculture. However,

Table 2: Basic Characteristics of the DA5 Countries

Indicator	Indonesia	Malaysia	Philippines	Thailand	Viet Nam	Growth, 1990–2014 (average annual %)
Surface area ('000 sq km)	1,905	331	300	513	331	
Population 2014 (million)	252.8	30.2	100.1	67.2	90.7	1.5
Population growth, 1990–2014 (annual average, %)	1.5	2.1	2.0	0.7	1.3	
Urban population growth, 1990–2014 (annual average, %)	3.8	3.8	1.6	2.9	3.4	
Urban population, 2014 (%)	53.0	74.0	44.5	49.2	33.0	
Headcount poverty rate ($2/day PPP, %)	46.3	1.8	41.3	3.5	16.8	
Decline in $2/day PPP headcount poverty rate, 1990–2010 (%)	45.3	82.8	24.8	90.6	74.2	
GDP per capita, 2005 ($)	1,866	7,304	1,649	3,451	1,078	3.4
Total GDP, 2005 ($ billion)	471.7	220.5	165.1	232.0	97.8	4.9
Agriculture (% 2014 GDP)	11.3	6.9	9.5	9.5	15.3	2.7
Industry (% 2014 GDP)	42.3	36.4	34.4	42.4	39.0	4.9
Services (% 2014 GDP)	46.4	56.7	56.0	48.2	45.6	5.5
GDP growth 1990–2014 (annual average, %)	4.9	5.8	4.2	4.1	6.9	

GDP = gross domestic product, PPP = purchasing power parity, sq km = square kilometer.
Note: Land use includes agriculture, forestry, land-use change, and other related emissions.
Source: World Bank. World Development Indicators. http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators (accessed October 2015).

Table 3: Greenhouse Gas Emission Profiles of the DA5 Countries

2010 Emissions	Indonesia	Malaysia	Philippines	Thailand	Viet Nam	Total	Share (%)	Annual Growth, 1990–2010 (%)
Land use ($MtCO_2eq$)	1,374.80	163.70	48.69	71.06	47.68	1,705.94	55.0	4.4
All transportation ($MtCO_2eq$)	1,08.27	49.74	27.02	70.93	33.26	289.22	9.3	5.2
Electricity/heat ($MtCO_2$)	150.16	105.25	34.33	97.30	42.37	429.41	13.9	6.9
Manufacturing/construction ($MtCO_2$)	105.72	30.59	12.31	65.46	44.51	258.59	8.3	5.4
Other fuel combustion ($MtCO_2eq$)	65.57	11.29	10.83	25.83	23.04	136.56	4.4	3.1
Fugitive emissions ($MtCO_2eq$)	47.85	21.32	1.03	8.13	12.55	90.88	2.9	1.8
Others ($MtCO_2eq$)	78.24	50.69	21.33	32.64	37.44	220.34	7.1	3.7
Total GHG emissions ($MtCO_2eq$)	1,928.02	425.32	152.02	355.77	237.82	3,098.95		
Per capita GHG emissions (tCO_2eq)	8.01	15.04	1.63	5.36	2.74	6.01		
Annual total GHG emissions growth 1990–2010 (%)	3.2	NA - neg 1990 emissions	2.0	3.7	4.8	4.6		

GHG = greenhouse gas, $MtCO_2eq$ = million tons of carbon dioxide equivalent, NA = not applicable, neg =negative.
Note: Land use includes agriculture, forestry, land-use change, and other related emissions.
Source: World Resources Institute. Climate Data Explorer.http://cait.wri.org (accessed 15 September 2015).

the largest share of emissions is driven by land use, which accounts for 55% of 2010 emissions, and which is growing at the fastest rate in tons of carbon dioxide equivalent (tCO_2eq) emissions. Most of these emissions originate from deforestation and subsequent land degradation in Indonesia, which account for more than 70% of Indonesia's emissions. Outside of Indonesia, land use accounts for a minority of emissions, with energy use driving a majority of emissions in the Philippines, Thailand, and Viet Nam.

2.1.2 Deforestation in selected countries is driving most regional emissions to date

The countries with the largest shares of land cover under forest, Indonesia and Malaysia, are those experiencing substantial deforestation, with considerable GHG emissions as a consequence. Indonesia has lost considerable forest area over 1990–2011, both as a percentage of land area and as absolute area, given the large size of the country (Table 4). Much of this land has shifted into agriculture, although some has also remained uncultivated after clearance. Malaysia has also experienced substantial deforestation, while forest cover is stable in Thailand and rising in the Philippines and Viet Nam. Increases in forest area are driven largely by plantation establishment in Viet Nam, and plantation area growth is offsetting relatively minor natural forest loss in Thailand.

The emissions implications of deforestation are particularly large in Indonesia, because of the high biomass of widespread lowland dipterocarp forests, as well as the prevalence of peat swamp forests. Approximately 61% of Indonesia's peatland is forested, and peat swamp forest accounts for about 14% of forest area (Hooijer et al. 2010). Peat swamp forests contain thousands of tons of carbon in their soils per hectare, and the carbon stored in peat soils is about five times greater than in above ground biomass (Table 5). When peat swamp forests are cleared, the peat is drained, and is often burned. Drainage causes a process of oxidation and CO_2 release that continues for decades, while fire events can have enormous emissions. Page et al. (2002) estimate that between 3.0 gigatons and 9.4 gigatons of carbon dioxide equivalent (CO_2eq) emissions were released by extensive fires in Indonesia's peatlands in 1997, which is equivalent to 13%–40% of mean global emissions from fossil fuels.

Deforestation in peatlands is particularly pronounced, with the relative rate of clearance above that of forests more generally. In the main peat swamp forests of Sumatra, deforestation in 1990–2010 has been about 5% annually, and in Kalimantan it is 3%, compared with about 1% annually for all forests in Indonesia and less in Malaysia (Miettinen et al. 2012) (Table 6). At the current rate of clearance, all peat swamp forests in Indonesia and Malaysia will be lost by 2030.

Table 4: Land-Use Profiles of the DA5 Countries

Countries	Total Land Area (sq km)	Years	Land Use as % of Total Land Area			Coastline (km)
			Agriculture	Forest	Others	
Indonesia	1,811,570	1990	24.9	65.0	10.1	54,716
		2011	30.1	52.0	17.9	
Malaysia	328,550	1990	22.0	68.0	10.0	4,675
		2011	24.0	62.0	14.0	
Philippines	298,170	1990	37.4	22.0	40.6	36,289
		2011	40.6	26.0	33.4	
Thailand	510,890	1990	41.9	38.0	20.1	3,219
		2011	38.8	37.0	24.2	
Viet Nam	310,070	1990	20.7	29.0	50.3	3,444
		2011	35.0	45.0	20.0	

km = kilometer, sq km = square kilometer.
Note: Due to differences in forest definitions, forest areas estimated by the Food and Agriculture Organization (FAO) may differ from national estimates.
Sources: World Development Indicators. http://databank.worldbank.org/data/reports.aspx?source=2&Topic=1 (accessed July 2015); Food and Agriculture Organization of the United Nations.FAOSTAT.http://faostat3.fao.org/home/E (accessed July 2015); Maps of the World. http://www.mapsofworld.com/asia/thematic/coastal-countries.html (accessed July 2015).

Table 5: Forest Characteristics in the DA5 Countries

Indicators	Indonesia	Malaysia	Philippines	Thailand	Viet Nam
Total forest area ('000 ha)					
1990	118,545	22,376	6,555	14,005	9,363
2010	94,432	22,124	6,840	16,249	14,128
Forest plantation area ('000 ha)					
1990	2,209	1,956	301	2,668	967
2010	4,803	1,623	45	3,986	3,823
Carbon stock of above ground biomass (million tons)					
2010	10,413	2,047	479	693	773
Area of peatland ('000 ha)					
	20,695	2,589	645	638	533
Peatland with forest cover (%)					
2000	61%	54%	...	...	...
Carbon stock in peat soils (million tons)					
	57,367	9,134	172	32	13
Compounded Annual Growth Rates (%)					
Total forest area					
1990–2010	(1.13)	(0.06)	0.21	0.75	2.08
Forest plantation area ('000 ha)					
2005–2010	3.96	(0.93)	(9.06)	2.03	7.11

( ) = negative; ... = data not available at cutoff date; DA5 = Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam; ha = hectare.
Note: Due to differences in forest definitions, forest areas estimated by the Food and Agriculture Organization of the United Nations (FAO) may differ from national estimates.
Source: FAO Global Forest Resources Assessments (FRA) 2015 database. http://www.fao.org/forest-resources-assessment/en/ (accessed 30 October 2015); FAO Global Forest Resources Assessments 2005 database for Indonesian 1990 plantation area. http://www.fao.org/forestry/fra/fra2005/en/ (accessed 30 October 2015). Page et al. (2010) for peat areas and stocks; and Hooijer et al. (2010) for peat forest cover.

Table 6: Changes in Peat Swamp Forest Area in Subregions of Indonesia and Malaysia

	Area (hectare)			Rate of Change (%)	
	1990	2000	2010	1990–2000	2000–2010
Peninsular Malaysia	379,700	280,800	229,900	(2.97)	(1.98)
Borneo/Kalimantan	4,926,100	3,636,900	2,746,500	(2.99)	(2.77)
Sumatra	4,921,600	3,078,500	1,806,900	(4.58)	(5.19)

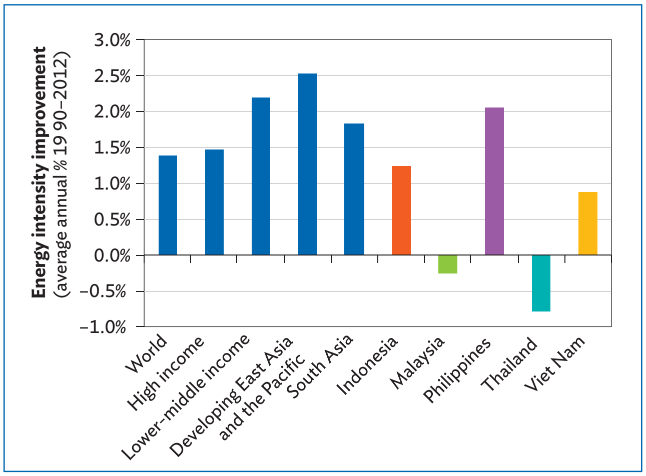
( ) = negative.
Source: Miettinen et al. (2012).

Deforestation in Indonesia, where deforestation emissions are greatest among the DA5, is driven by a number of factors. All "forest land" is owned by the state, but forest production, cultivation, and harvesting are undertaken by private sector licensees. Historically, the selective logging concession system has led to overharvesting and forest degradation, due to limited regulatory enforcement (Barr 1998). This has been accompanied by traditional swidden shifting agricultural cultivation, in which forest is burned, cultivated for a limited number of seasons, and subsequently abandoned for another site. Both shifting cultivation and overharvesting lead to forest that is considered "degraded," which can be allocated by the state for conversion to other land uses, such as large-scale plantations for oil palm, or short-rotation industrial tree crops. Often this "degraded forest" still has substantial timber, while royalties actually collected on timber cleared are below market values, such that it is economically attractive to obtain concessions for plantation development and extract the remaining timber, even if no plantation is ultimately established (Barr 2000). Remote sensing analysis correspondingly shows that 56%–90% of plantation area is being developed on forested land (Koh and Wilcove. 2008, Koh et al. 2011, Gibbs et al. 2010), while 62% of area deforested in Indonesia between 1990 and 2012 remained unproductively used following deforestation (Wijaya et al. 2015). This implies that deforestation-associated emissions can be curtailed at limited opportunity cost.

2.1.3 Development has been energy intensive

The DA5 countries have relied extensively on increasing use of energy to fuel their structural transformation, with GHG emissions rising rapidly as a result. Compared with the world average, averages in the developed world, or averages in developing Asia, the region (aside from the Philippines) has lagged in terms of shifting toward economic structures that use less energy for economic output (Figure 4). In fact, Malaysia and Thailand have worsened their "energy intensity," or energy use per dollar of GDP over this period, while Viet Nam and Indonesia lag behind other regions. This suggests that there are ample opportunities to shift toward a development path that is more energy efficient and climate friendly.

Figure 4: Average Annual Change in Energy Intensity, 1990–2012 (GDP/toe)



GDP = gross domestic product, toe = tons of oil equivalent.
Source: World Bank. World Development Indicators. http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators (accessed 30 October 2015).

2.1.4 Emissions from fossil fuels are rapidly rising

Fossil fuel use for energy supplies has risen very rapidly as a result of this continued reliance on expanded energy use to underpin economic growth, and has replaced other traditional energy sources, as may be expected under structural transformation. In 1990, biomass and waste constituted the largest source of primary energy for the DA5, but in 2012, crude oil was the largest energy source, followed by natural gas. Much of this has been driven by replacement of traditional fuelwood for energy. Although there has been expansion of renewable energy supplies, the most rapid relative increase in energy has come from coal, moving the region toward a carbon-intensive energy pathway (Table 7).

Table 7: Composition of Primary Energy Supplies

Indicators	Indonesia		Malaysia		Philippines		Thailand		Viet Nam	
	1990	2012	1990	2012	1990	2012	1990	2012	1990	2012
TPES (toe)	98,620	211,842	22,164	79,062	28,709	43,053	41,944	126,196	17,866	59,927
Energy resource share in TPES (ktoe)										
Coal	3,549	30,058	1,355	15,796	1,526	8,799	3,819	16,463	2,223	15,803
Crude oil	42,261	49,631	10,025	30,154	11,087	8,665	12,682	62,816	0	7,046
Oil products	(8,915)	25,787	1,325	(3,534)	(245)	4,907	5,281	(13,325)	2,711	9,305
Natural gas	15,814	34,996	6,799	32,403	0	3,157	4,993	35,187	3	8,081
Nuclear	0	0	0	0	0	0	0	0	0	0
Hydropower	491	1,101	343	779	521	882	428	753	462	4,541
Geothermal	1,934	16,192	0	4	4,699	8,818	1	55	0	7
Biofuel and waste	43,487	53,821	2,321	3,453	11,121	7,825	14,686	23,502	12,468	15,019
Electricity imports/exports	0	257	(5)	8	0	0	53	724	0	187

( ) = negative, ktoe = kiloton of oil equivalent, TPES=total primary energy supply.
Source: International Energy Agency. Country profile databases. http://www.iea.org/statistics/statisticssearch (accessed 10 December 2015).

At the same time, although rising rapidly, energy supply per capita still trails the world average in countries other than Malaysia and Thailand, with Indonesia, the Philippines, and Viet Nam all at less than half of the global average (Table 8). Electricity use follows similar patterns. Emissions from fossil fuels are rapidly rising as well, with Malaysia already with per capita levels above world averages. Clearly, following the development trajectory of the rest of the world suggests massive increases in energy production and use in the future, which is likely to be very carbon intensive if patterns to date in energy supplies continue.

Industry and transportation have been the major drivers of increased energy consumption, and indirectly, fossil fuel emissions, as may be expected under transformation of economies from an agrarian structure. In 1990, the largest share of energy was consumed by the residential sector in Indonesia, the Philippines, and Viet Nam (Table 9). By 2012, industry had a leading share in Thailand and Viet Nam, and transport had the leading share in Malaysia and the Philippines. Setting the right incentives for efficient and low emissions development in these sectors is important to GHG mitigation.

Table 8: Primary Energy Supply Indicators

Indicators	Indonesia		Malaysia		Philippines		Thailand		Viet Nam		World	
	1990	2012	1990	2012	1990	2012	1990	2012	1990	2012	1990	2012
Energy production (Mtoe)	168.52	440.25	48.82	88.80	17.22	25.17	26.58	75.45	18.28	69.02	8,805.76	13,349.83
TPES/Population (toe per capita)	0.55	0.86	1.22	2.78	0.46	0.45	0.74	1.89	0.27	0.68	1.66	1.89
TPES/GDP at PPP (toe/$1000, 2005)	0.14	0.11	0.13	0.14	0.13	0.08	0.13	0.15	0.20	0.15	0.22	0.16
Electricity use per capita (MWh/capita)	0.16	0.72	1.15	4.31	0.36	0.67	0.71	2.48	0.10	1.24	2.06	2.36
Energy CO_2 per capita (t CO_2/capita)	0.75	.97	2.70	6.55	0.61	0.83	1.43	3.58	0.26	1.43	3.91	4.47
Energy CO_2/GDP at PPP (kg CO_2 /$, 2005)	0.21	0.21	0.31	0.34	0.17	0.16	0.25	0.25	0.20	0.33	0.52	0.38

CO_2 = carbon dioxide, GDP = gross domestic product, kg = kilogram, Mtoe = million tons of oil equivalent, MWh = megawatt-hour, PPP = purchasing power parity, tCO_2 = tons of carbon dioxide, TPES = total primary energy supply.
Source: International Energy Agency. Country profile databases. http://www.iea.org/statistics/statisticssearch (accessed 10 December 2015).

Table 9: Final Energy Consumption

Indicators	Indonesia		Malaysia		Philippines		Thailand		Viet Nam	
	1990	2012	1990	2012	1990	2012	1990	2012	1990	2012
Total final consumption (Mtoe)	79,810	159,689	13,991	47,841	19,651	24,328	28,873	91,831	16,056	49,354
Industry (%)	22.7	23.4	39.8	28.9	23.7	26.5	30.0	31.6	28.3	37.7
Transport (%)	13.4	27.6	34.0	29.6	23.0	34.8	31.2	23.6	8.6	21.0
Residential (%)	52.1	37.0	14.6	9.3	46.4	24.9	26.1	12.9	59.3	31.2
Commercial and public service (%)	1.0	3.1	5.7	8.5	4.3	11.8	4.9	6.5	2.1	3.6
Agriculture/forestry/fishing (%)	1.2	1.6	0.0	2.1	1.5	1.3	6.3	4.2	1.6	1.3
Nonspecified (%)	0.3	0.2	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0
Nonenergy use (%)	9.2	7.1	6.0	21.6	1.2	0.7	1.5	21.1	0.2	5.2

Mtoe = million tons of oil equivalent.
Source: International Energy Agency. Country profile databases. http://www.iea.org/statistics/statisticssearch (accessed 10 August 2015).

2.2 Policy Context

2.2.1 A new global agreement aims to stabilize climate change

To tackle the long-term threats posed by climate change, an effective policy framework to mitigate emissions growth is essential. As the atmosphere is a global public good, an effective policy framework must include the world's major current and future emitters to be effective, and it must restrict global emissions to a level that is compatible with climate stabilization. To this end, the Paris Agreement adopted in December 2015 under the United Nations Framework Convention on Climate Change (UNFCCC) is vital, as the first global agreement that sets quantitative goals for GHG mitigation.

The main instruments for mitigation embodied in the Paris Agreement are nationally determined contributions, or goals set by countries individually regarding mitigation, usually by 2030. These goals were communicated prior to the 21st Conference of Parties (CoP) to the UNFCCC meeting in 2015 as "intended nationally determined contributions" (INDCs). As of early December 2015, more than 180 countries, including those in Southeast Asia, had submitted INDCs to the UNFCCC (Table 10).

Table 10: Intended Nationally Determined Contributions for 2030

Country	Unconditional Contribution (% greenhouse gas emission reduction)	Conditional Contribution (% greenhouse gas emission reduction)	Reference Period
Top 10 greenhouse gas emitters in 2011			
People's Republic of China	60%–65% per unit of GDP		2005
United States	26%–28%		2005
European Union	40%		1990
India		33%–35% per unit of GDP	2005
the Russian Federation		25%–35%	1990
Indonesia	29%	41%	BAU
Brazil	43%		2005
Japan	26%		2013
Canada	30%		2005
Mexico	22%	36%	BAU
Remainder of DA5			
Malaysia	35% per unit of GDP	45% per unit of GDP	2005
Philippines		70%	BAU
Thailand	20%	25%	BAU
Viet Nam	8%	25%	BAU

BAU = business as usual, GDP = gross domestic product.
Note: Conditional contributions refer to those under international support while unconditional contributions will be undertaken in even in the absence of such support.
Source: United Nations Framework Convention on Climate Change. UNFCCC Intended Nationally Determined Contributions. http://unfccc.int/focus/indc_portal/items/8766.php (accessed 1 December 2015).

CoP 21 in Paris during December 2015 was a seminal event, as it bound the INDCs together into a global climate agreement that provided for implementation, review, and updating of commitments every 5 years. The climate agreement also specifies a goal of "holding the increase in the global average temperature to well below 2°C above preindustrial levels." However, INDCs submitted are not sufficient to attain this goal, so a process is envisaged in the agreement by which national contributions will be ramped up toward the outlined level of stabilization through successive revisions. As specified in the Agreement, "each Party's successive nationally determined contribution will represent a progression beyond the Party's then current nationally determined contribution," such that mitigation goals become more ambitious.

The Paris Agreement is in many senses a beginning, rather than an end, to the process of developing an effective global GHG mitigation framework. By setting in place a mechanism by which mitigation contributions are to be revised upward over time, the Agreement creates a need for countries to continually evaluate mitigation potential and the expected effects thereof. At the same time, the means by which this will lead to the level of mitigation stated are not yet defined. Similarly, while the Agreement establishes "a mechanism to contribute to the mitigation of greenhouse gas emissions and support sustainable development" within which emission reductions funded by one country in another country can count toward mitigation in the former, future carbon markets are not delineated in detail.

Reducing Emissions from Deforestation and Forest Degradation (REDD) is an approach included in the Agreement that allows emission reductions from averted forest destruction to be counted toward emission reduction commitments, and to receive international support for such reductions. However, the performance of REDD demonstration activities has been mixed (Sills et al., 2014), which raises considerable uncertainty about the actual contribution that REDD will make.

Previously, the only international expression of GHG emissions goals for developing countries in Asia was through the 2009 UNFCCC Copenhagen Accord, which covers the period until 2020. The policy commitments of the DA5 countries for 2020 are to be implemented on the assumption that the Copenhagen Accord will come into force on an international basis, as stated during the 15th UNFCCC CoP held in 2009 in Copenhagen, Denmark. It exhorts the major world emitters to pledge voluntary climate-change policy commitments for the year 2020.[1] These pledges are generally expressed with reference to different baseline years or to the level of emissions in the absence of decarbonization actions (business as usual). Several countries or regions committed to two sets of goals: a more ambitious level known as "high Copenhagen pledge" and a less ambitious one known as "low Copenhagen pledge." Among the DA5, only Indonesia came up with a pledge whose commitment falls within the Copenhagen Accord—a 26% reduction in GHGs with respect to baseline emissions.

The rest of the DA5 have previously expressed climate change and energy policies toward decarbonization of their respective economic systems in different ways. In 2009, Malaysia expressed a voluntary commitment to reduce carbon intensity, or GHG emissions per unit of GDP by 40% by 2020. The Philippines defines its goal in the Philippines Energy Plan as a 10% savings in all sectors between 2009 and 2030. Similarly, Thailand has an energy intensity goal defined by its Energy Efficiency Development Plan of 25% reduction by 2030, compared with 2010. Viet Nam's 2012 Green Growth Strategy has a goal of reducing carbon intensity by 8%–10% by 2020 compared with 2010 levels; and reducing energy emission by 10% below business as usual by 2020. More stringently, Viet Nam aimed to reduce overall energy use by 5%–8% by 2015 versus 2006 in its National Energy Development Strategy.

2.2.2 Economy-energy–environment models can inform policy choices

The Paris Agreement is only the beginning of a process to achieve control of global warming, as contributions need to be increased for warming of more than 2.0°C to be averted. As a result, countries will need to consider how contributions can be effectively scaled up. This places a significant onus on each country to understand the implications of climate policy choices and identify resource needs associated with different levels of commitments. To do so, drivers of emissions growth and associated emissions trajectories should be characterized, technical options to reduce emissions growth should be identified, and analysis should be performed on those options to identify economic and emissions consequences. In so doing, choices on feasible levels of emission reduction commitments, options on timing of emission reductions, and the range of acceptable actions to achieve reduction will frame the choices to be considered.

When assessing the potential of mitigation options, it is important to reflect not only the costs that emission reduction will offer, but also the benefits that can be derived. These benefits flow not only from revenues from potential carbon markets, but also include co-benefits from reduced GHG-associated pollution, preservation of environmental resources, and reduction of other externalities from fossil fuel-intensive development. In addition, the economic benefits that derive from reduced climate change induced economic losses are an important element of understanding net economic effects from participation in a global climate stabilization arrangement.

Global economy–energy–environment models can help to answer these questions. They illustrate means by which policy instruments can incentivize changes in economic systems as part of a transition to low-carbon economies. The models illustrate how specific

[1] UNFCCC. Annex I. http://unfccc.int/meetings/copenhagen_dec_2009/items/5264.php; UNFCCC. Non-Annex I. http://unfccc.int/meetings/cop_15/copenhagen_accord/items/5265.php

Box 1: Reducing Emissions from Deforestation and Forest Degradation

Deforestation and land-use change are the largest sources of greenhouse gas (GHG) emissions in Southeast Asia. Substantial emissions from forest degradation and clearance represent both a challenge and an opportunity for decarbonization. If possibilities to reduce these emissions are ignored, mitigation in the fossil fuel sectors needs to be intensified to achieve emissions stabilization goals. Reduced deforestation is potentially the lowest opportunity-cost approach to reduce emissions in many countries.

Reducing Emissions from Deforestation and Forest Degradation (REDD) is an approach that allows emission reductions from averted forest destruction to be counted toward emission reduction commitments. REDD was recognized at the 13th session of the Conference of Parties (CoP-13) to the United Nations Framework Convention on Climate Change as a framework through which developing countries could be rewarded financially for emission reductions from reduced deforestation. The framework was expanded in the following year to include conservation and enhancement of forest carbon stocks and sustainable management of forests and this was reflected in the acronym REDD+, which was formalized at CoP-16 in 2010.

CoP-16 also resulted in agreement on a phased approach to implementing REDD+, by (i) developing national strategies, plans, policies, and capacity; (ii) implementing results-based demonstration activities; and (iii) evolving into results-based actions fully measured, reported, and verified. CoP-17 agreed that financing could come from public, private, bilateral, and multilateral sources. During CoP-19 (2013), the Warsaw Framework for REDD+ was adopted, on (i) a work program on results-based finance to progress to full implementation of REDD+ activities; (ii) modalities for measuring, reporting, and verification systems; (iii) guidelines for technical assessment of forest reference emission levels; (iv) safeguard information systems; (v) establishing REDD+ focal agencies; and (vi) addressing the drivers of deforestation and forest degradation. At the United Nations Climate Change Conference in 2015, final decisions were taken on reporting of safeguard compliance, joint mitigation and adaptation as an alternative to results-based payments and reporting on noncarbon benefits. The Paris Agreement, in turn includes these points as it encourages REDD+ for reducing emissions.

Although conceptually simple, REDD implementation is riddled with many complexities. REDD is envisaged to have performance-based payment, so that financing is only provided after emission reductions have occurred. However, determination of REDD-attributable emission reductions is challenging. Reduction from a "reference level" projection is the basis of attribution, but "reference level" determination has not yet occurred for many countries, and different projections may lead to different "reference levels." The definition of forests differs among countries, so that forest loss is not consistently defined. Benefit-sharing mechanisms between those who already have good stewardship of forests, such as indigenous local communities, and those entities responsible for forest destruction, are yet to be fully developed.

No agreement yet exists on financing of REDD and envisaged size of market-based mechanisms. While it is generally accepted that REDD will be partially financed through sovereign financial contributions from developed countries into multilateral funds that can be accessed by developing countries, inclusion of REDD in international emissions offset markets remains more controversial, partially due to fears that REDD credits could depress international carbon prices.

More fundamentally, REDD rests on the assumption that the provision of additional formal financial flows to government entities can change incentives that are often driven by informal incentives and the interests of politically connected actors. At present, forestry sector policies often forgo opportunities to collect greater revenues from public forest resources, as much timber is offered to concessionaires at below market prices. It is not clear if governments will respond to financing opportunities for averted deforestation, as REDD proponents envisage, when governments already ignore substantial opportunities to increase revenue generation from the forestry sector. To do so will require substantial institutional reform in many countries.

Sources: Center for International Forestry Research. Global Comparative Study on REDD+. http://www.forestsclimatechange.org/forests-climate-change-mitigation/unfccc-redd-negotiations-noncarbon-benefits-still-table/; The REDD Desk. http://theredddesk.org/; UN-REDD Programme. http://www.un-redd.org/AboutUN-REDDProgramme/tabid/102613/Default.aspx

sectors respond and how low-emission resources and practices can substitute for emission-intensive ones. Such models also illustrate the economic costs of decarbonization policies, what options can help to reduce those costs, and where costs accrue in the economic system to different populations.

Global applications of such models can help to enrich this analysis by illustrating the interactions between country actions under a global climate policy options. The Paris Agreement includes potential arrangements for a global carbon market and trade in carbon emissions quotas, and as mitigation commitments are scaled up over time, such arrangements may become more attractive. Carbon trade has the potential to improve the efficiency and cost effectiveness of emission reduction and alter the distribution of costs and benefits among countries, as the trade in emissions quotas can generate new revenue sources for exporting countries.

2.2.3 Different modeling approaches provide different insights

The long-term economic potential to reduce emissions can be modeled using a number of approaches, each of which contributes differently to understanding the consequences of climate policies. Generally, energy–economy models are either "top-down" or "bottom-up." Top-down models often draw on computable general equilibrium (CGE) modeling to assess the implications of policy measures to induce decarbonization. In these models, the means by which emissions are reduced are largely outputs of the model, rather than inputs. Decarbonization is achieved in these models through inducement of abatement, substitution of fuels, substitution of technologies, and macroeconomic adjustment. The effects that are measured are in terms of broader economic welfare, rather than financial abatement costs. When applied globally, trade can be incorporated as an effect, as can interactions between prices and consumption, which can condition long-term responses to decarbonization policies. When applied dynamically, such that the model uses estimates for each year as inputs into modeling of effects in the following year, long-term interaction and compounding of effects can be reflected. The trade-off is that CGE models usually do not represent possibilities for technological substitution at a high level of detail, and thus may miss key decarbonization potentials. This causes the cost of emission reduction to be potentially overestimated.

Bottom-up models focus on key possibilities to reduce emissions through replacement of technologies. These models give a clear picture of marginal abatement costs to reduce emissions, based on financial opportunity costs and transparent technological parameters. They also identify concrete potential project interventions applicable at low potential cost to reduce emissions, often while substantially enhancing efficiency. However, these models do not necessarily capture the broader costs of policy instruments required to induce technological replacement. Technological substitution is taken as exogenously directed by a central planner. As a result, costs tend to be underrepresented in the full welfare effects of policies required to induce such technological substitution, as financial opportunity costs constitute only a portion of full social costs.

Hybrid models are combinations of the two modeling approaches, with detailed representation of technical possibilities within key emitting sectors, combined with economy-wide models. Generally, in these models, the higher the detail of emitting sector disaggregation, the lower the detail usually included on the economic system.

No single modeling approach is broadly superior for the quantification of economic implications of emission reduction, as each brings advantages and limitations. For this reason, a combination of modeling approaches is useful to investigate different facets of decarbonization potentials and costs and identify appropriate emission reduction policies.

2.3 Knowledge of Mitigation Economics to Date

2.3.1 Despite previous studies, knowledge gaps remain for Southeast Asia

Many studies have been conducted on how energy economic systems respond to global climate policies, so as to understand how a low-carbon transition can be best fostered and with what consequences.

The IPCC's AR5 identified 1,184 emissions scenarios from 31 global economy-climate models. While the central tendency in the results is to generally find that global emissions stabilization can be achieved at low economic cost, with a mean of just over 2% GDP reduction to attain global climate stabilization consistent with a 2.0°C limit to mean global warming, there is large variability in results.

Only about 10% of scenarios identified by the IPCC AR5 report provide estimates for Asia, while only a fraction of those studies provide estimates specific for Southeast Asia or its individual countries. Those studies that do report Southeast Asian estimates often lack clear indications of the potential costs entailed by emission reduction policies. Key studies reporting how global climate stabilization affects Asia include the following:

- The Stanford Energy Modeling Forum 27 modeling intercomparison exercise (Kriegler et al. 2014) provides results for major Asian economies (e.g., the People's Republic of China [PRC], India, and Japan) and the Asian region. This combination of bottom-up and top-down models projected that GDP losses in Asia by 2050 range from almost 0% to 27% for stabilization scenarios of that are likely to avoid more than 2.0°C of peak warming.

- The Asian Modeling Exercise (AME) of Calvin et al. (2012a) brings together a considerable number of bottom-up and top-down models of Asian countries and conducts a comparison of baseline, emissions target, and carbon tax scenarios. According to Akashi et al. (2012), the 2010–2050 cumulative cost for Asia under a less than 2.0°C stabilization scenario is approximately a 1.7% loss of GDP discounted at 5%. Another key AME study, Saveyn et al. (2012), reported the cost implied by temperature stabilization at less than 2.0°C by the end of the century for the PRC, India, and Japan, using a hybrid approach (a CGE model in which the functioning of the energy sector is calibrated on bottom-up energy models). The world GDP loss in 2050 is 3.2%, with India and the PRC demonstrating much higher losses—8.1% and 6.3%, respectively. The study found that by 2050, 77% of total world energy generation would be produced by zero carbon technologies in the stabilization scenario.

- AME results for the Asian region confirm that there is large uncertainty on the GDP costs to stabilize warming: for a less than 3.0°C stabilization scenario, they are 0% to 7.5% in 2050, while for less than 2.0°C, they range from 0% to 7.9% in 2050. Six AME models also report results for Indonesia, which are higher than for Asia in general. For less than 3.0°C stabilization, GDP costs are 0%–6.3% in 2050 and for less than 2.0°C stabilization, they are 0%–26.8% in 2050.

- Another important model comparison exercise conducted for Southeast Asia is the Low Climate Impact Scenarios and the Implications of Required Tight Emission Control Strategies project (Kriegler et al. 2013, Tavoni et al. 2013, LIMITS). This project analyzed a set of climate policies based on different levels of ambition in terms of climate change. Findings show that substantial emission reductions can be achieved at relatively low cost for Southeast Asia, with a median loss of 1% of GDP in 2030 and 2.5% in 2050 under a scenario that limits warming to below 2.0°C.

- The response of Asian economies to climate change impacts and policy was investigated using the global CGE model ENVISAGE, updated with a simple climate module that converts levels of emissions into temperature changes (van der Mensbrugghe 2010). The study presented results of gradually imposing five different carbon taxes over 2004–2050, which peak at $14–$109 per ton of CO_2, for six Southeast Asian countries (DA5 + Cambodia). As a whole, Southeast Asia would bear the largest policy costs with an average income loss of 8.9% at $109 per ton of CO_2 unitary tax. The losses were 11.5% in Viet Nam, 8.1% in Malaysia, 5.8% in Indonesia, 3.5% in Thailand, and 1.1% in the Philippines. These costs do not reflect global stabilization targets per se and no emissions trade was included in the model.

- CGE analysis of different mitigation policy scenarios for Thailand found that 30% and 50% mitigation effort would reduce the annual average 2005–2050 GDP by nearly 0% and 4%, respectively, under a no-emission trading scenario, while emissions trade plus carbon capture and storage (CCS) would have positive effects on GDP (Thepkhun et al. 2013).

- The International Energy Agency's (2013c) Southeast Asia Energy Outlook modeled two scenarios of the evolution of energy and emissions in Southeast Asia through 2035. It contrasted a "new policies scenario" consisting of the implementation of announced energy policies with an "efficient ASEAN scenario" consisting of key policy measures to promote energy efficiency in the buildings, industry, transport, and power sector using a partial equilibrium bottom-up model linked to a global CGE model. The analysis finds that nearly 19% of emissions can be abated by energy efficiency measures by 2035, while increasing annual GDP by nearly 2%.

- ADB (2009) provides some estimates of the potential of energy sector mitigation options for four of the five countries covered by this study (with the exception of Malaysia), based on the bottom-up DNE21+ model. While the study illustrated the abatement possible by increased use of gas, nuclear, solar, biomass, and hybrid electric vehicles through 2050, it did not focus on long-term economic implications of abatement. Bottom-up estimates of 2020 marginal abatement costs were assembled for a 30% emission reduction, which correspond to 0.9% of GDP. However, these figures do not reflect the broader economic costs of policies to incentivize low-carbon development.

What is not yet known

All of these studies have critical limitations that mean that results for Southeast Asia have critical omissions or do not represent real world policy choices. These limitations help to drive the focus of the present analysis, so that it adds value to prior understanding.

First, most studies that offer findings for specific Southeast Asian countries do not do so in the context of a global stabilization scenario. Rather, they explore cases of unitary carbon taxes or imposed emission reduction levels. Thus, they do not reveal the effects of likely emission reductions to be undertaken in the context of global cooperation, including how the countries would interact with a global carbon market. Nor do they model explicitly a transition from national policies to an international climate regime, as is occurring under the Paris Agreement.

Second, the studies that offer results for Indonesia or a Southeast Asian aggregate in the context of global climate stabilization scenarios have omitted or underestimated land-use emissions. This is especially important in Indonesia, where land-use emissions from deforestation and peat oxidation make up the majority of emissions; and where previous studies have underestimated those baseline emissions by 100%–1,000%. In the absence of accurate baseline emissions, policy implications of emission reductions cannot be reliably identified, nor can appropriate abatement opportunities be included.

Third, none of these studies has attempted to fully capture the dynamics of costs and co-benefits. Co-benefits from reduced pollution, preserved ecosystems and other effects of mitigation measures can be very large and offset net costs. Nor are the direct benefits of reduced climate change impacts normally included. This has given a partial estimate of costs that is of little help in determining what levels of abatement are in the interest of countries in the region.

3

Methodology

Key messages

This chapter presents the study objectives, scenarios, and modeling framework.

- The objectives of this study are to (i) ascertain what the longer-term economic effects are on the DA5 for different levels of global climate ambition (including the benefits of mitigation or climate action); (ii) examine where decarbonization costs occur in the economic systems of the countries; and (iii) determine how those costs can be best contained while meeting global climate goals.
- The study models an array of global climate stabilization scenarios: business as usual (baseline); fragmentation (current climate goals), stabilization of the climate at 650 parts per million (ppm) carbon dioxide equivalent concentration, and stabilization of the climate at 500 ppm stabilization.
- Avoided deforestation is included and excluded from stabilization scenarios as a way to reduce emissions via reducing emissions from deforestation and forest degradation.
- Prior to 2020, all stabilization scenarios reflect domestic climate and energy goals, with a global carbon market implemented from 2020 to 2050. National emissions allowances follow a "contraction and convergence" framework from historical levels to equal per capita levels by 2050. Abatement is triggered by prices in the global carbon market.
- Two global economy–energy–environment models are applied for the analysis. The Intertemporal Computable Equilibrium System (ICES) is a recursive dynamic global computable general equilibrium model, while the World Induced Technical Change Hybrid model (WITCH) is a Ramsey optimal growth model with a detailed bottom-up depiction of the energy sector and innovation dynamics. The two global models have been jointly applied to reinforce each other.
- The models have different capabilities, strengths, and weaknesses:
    - ICES captures more country detail and includes more relationships among markets; and
    - WITCH captures induced technical improvement through research and learning by doing, as well as advanced energy technologies.
- Both models are "soft linked" to the International Institute for Applied Systems Analysis land-use model cluster to represent land use interactions, and have been modified to incorporate emissions from peat degradation and peat rehabilitation as an abatement option.
- Results are augmented by supplemental analysis of co-benefits from reduced air pollution, transport congestion, and avoided transport accidents.
- The modeling is subject to important limitations, including omission of market distortions and inefficiencies; transaction costs; institutional, social, or cultural constraints; and nonmarket responses to climate policies. Neither model represents abatement options beyond the energy and deforestation sectors, and co-benefit coverage is partial.

3.1 Study Objectives

The objectives of the present study are the following:

(i) ascertain what the longer-term economic effects may be on the DA5 for different levels of global climate ambition (including the benefits of mitigation or climate action);
(ii) examine where decarbonization costs occur in the economic systems of the countries; and
(iii) determine how those costs can be best contained while meeting global climate goals.

To understand better the implications for the DA5 of alternative global climate regime options, two global economy–energy–environment models have been developed and applied. As global models, they reflect international interactions in the implementation of the global agreement. The models include detailed energy sectors to allow for analysis of the potentials of new energy sources. They include REDD under different cost assumptions, to help understand the role that REDD can play in decarbonization strategies.

3.2 Scenario Matrix

3.2.1 Global scenario overview

The intention of the global scenarios modeled in this study is to represent alternative potential future directions for implementation of a global climate agreement and to identify their implications for Southeast Asia. The basic possibilities that are captured are as follows:

1. climate policies fail—business as usual (BAU; climate action is not prioritized by any government);

2. international climate agreement fails—fragmented national climate policies (FRAG; countries continue to pursue national climate actions at their current level of ambition);

3. international climate agreement implemented with moderate ambition (650; a global climate agreement comes into place in 2020 to reach a moderate target of 650 ppm CO_2e concentration); and

4. international climate agreement implemented with high ambition (500; a global climate agreement comes into place in 2020 to reach an ambitious target of 500 ppm CO_2e concentration)

As the recently approved global climate agreement is oriented towards the post-2020 period, the policy scenarios considered in this study have both a short-term and a long-term dimension. The first period focuses on policy objectives that the DA5 countries aim to pursue by 2020 as stated in their respective official national plans. The second period analyzes the implications of emission reduction strategies of various GHGs, to be deployed after 2020, assuming different degrees of stringency and levels of global coordination.

3.2.2 Scenario definition for 2010–2020

All scenarios other than BAU rely on interpretation of national goals for the period through 2020, and the fragmented scenario interprets these goals thereafter. Indonesia's Copenhagen pledge for this period is clear, with a 26% reduction of emissions relative to BAU. For the other countries, Table 11 describes the energy-efficiency and carbon-efficiency goals selected for this scenario as interpreted from national official documents (Hoa et al. 2010, IEA 2013a, Olz and Beerepoot 2010, Philippines Climate Change Commission 2010, Vinluan 2012). Other countries outside of the DA5 are modeled to follow their low Copenhagen pledges.

The country goals are expressed in different ways: (i) in terms of emission reduction with respect to BAU for Indonesia; (ii) in terms of emission intensity of GDP compared with a reference year for Malaysia; (iii) in terms of emission reduction and consequent energy-saving strategies for the

Table 11: Decarbonization Goals for 2020

Country	Goals Description	Interpretation (relative to 2010)
Indonesia	26% reduction of emissions relative to BAU by 2020	23.4% CO_2eq emissions decrease
Malaysia	Up to 40% CO_2eq emission reduction per unit of GDP relative to 2005	19.8% CO_2eq emissions increase
Philippines	10% energy savings from all sectors, 2009–2030	5.7% CO_2eq emissions decrease
Thailand	8% reduction of energy intensity by 2015 and 25% by 2030 compared with 2005	18.0% CO_2eq emissions increase
Viet Nam	Total energy savings of 3%–5% by 2010 compared with 2006 and by 5%–8% in 2012–2015 versus total energy demand forecast in Power Development Plan 7	15.0% CO_2eq emissions increase

BAU = business as usual, CO_2eq = carbon dioxide equivalent, GDP = gross domestic product.
Note: The "interpretation" is that of the authors, as a translation of goals into emissions levels. Most of the countries listed have no official emission reduction goals.
Sources: IEA (2010), Olz and Beerepoot (2010), Vinluan (2012), Hoa et al. (2010), Philippines Climate Change Commission (2010).

Philippines and Viet Nam; and (iv) in terms of reduction in energy intensity for Thailand. To make these different country goals comparable, they have been presented in Table 11 in terms of emission reduction with respect to 2010.

3.2.3 Scenario definition for 2020–2050

A baseline global BAU scenario is modeled, followed by three long-term global policy scenarios for the DA5 countries assessed. The first is a fragmented scenario, which has been provided for benchmark comparison. It extrapolates to the end of the century the "low pledge" stringency of the Copenhagen Accord with respect to further carbon intensity improvements, and assumes that countries and regions will act domestically without the possibility of emissions trade. In this setting, carbon prices are not equalized across regions, leading to efficiency losses in addition to not leading to the stabilization of the global climate.

The next two are long-term GHG concentration stabilization scenarios that aim by the end of the century to contain global concentrations of GHG gases plus aerosols at two levels: 500 ppm and 650 ppm CO_2eq. The more stringent 500 ppm CO_2e scenario leads to a mean global temperature increase that is likely to remain below 2.0°C with respect to preindustrial levels by the end of the century, and the 650 ppm CO_2e leads to a mean global temperature increase that is likely to remain below 3.0°C. The climate stabilization scenario at 500 ppm is assumed to follow the high Copenhagen pledges in 2020, while the climate stabilization scenario at 650 ppm is assumed to follow the low Copenhagen pledges.

The GHG concentration stabilization goals are implemented assuming full global cooperation in the form of an international quota system supported by global trading of permits. Regional and country allowances are determined according to "contraction and convergence" criteria under which allowances are initially calculated considering each country's share of total GHG emissions in 2020 (including land use and peatland), which then linearly converges to equal per capita allocation by 2050.

"Contraction and convergence" was proposed originally in 1989 by the Global Commons Institute, and has since attracted widespread support (Meyer 2000). It has been extensively used by the IPCC since the early 1990s, and has received statements of support from a wide array of leading officials in global climate policy, ranging from IPCC Chairman Rajenda Pachauri, to former Indonesian Minister of Environment Emil Salim, to UN Secretary Ban Ki Moon, and Sir Nicholas Stern of the Government of the United Kingdom. It is an equitable basis for emissions allowance allocation, which is far more transparent than most other possibilities favorable to developing countries (Box 2).

Box 2: Allocation Frameworks for Greenhouse Gas Emissions and Mitigation

Mitigation is both a technical issue and a distributional issue, as national emissions pathways need to be determined within the context of global greenhouse gas concentrations. An array of different frameworks has been proposed for determining the emission and/or emission reduction endowment for different countries at different points in time. These frameworks have been based on both "allocation of emissions rights" and "allocation of abatement effort." The former allocates the emissions to which countries are entitled over time, while the latter allocates directly the emission reduction among countries. Most allocation frameworks are based on "emissions rights."

Leading emissions rights based frameworks include the following:

- ***Grandfathering***, or the allocation of rights based on historical national emissions: This is based on the principle that prior resource use establishes a right to future resource use, but is distributionally regressive (Rose et al. 1998).
- ***Allocation of rights based on national gross domestic product (GDP).*** This framework assigns emissions allowances based on GDP for countries above a minimum threshold of per capita GDP, with extra allocation for countries with per capita GDPs below the global average (Vattenfall 2006).
- ***Equal per capita emissions*** or national allocation based on national population: This approach is distributionally progressive, but poses large adjustment costs to current emitters (Baer et al. 2000).
- ***Contraction and convergence*** (C&C): Emissions progress from historical levels to equal per capita allowances by a set date, often 2050 (Meyer 2000).
- ***C&C considering historical responsibility***: This follows a C&C allocation trajectory, but reduces future emissions to compensate for historical emissions in excess of equal per capita allowances.
- ***Common, but differentiated convergence***: The C&C framework is modified to delay the convergence time frame and add additional allowances for developing countries (Höhne et al. 2006).
- ***Triptych***: This allocation is based on an aggregation of sectoral allowances within countries. Household, fossil fuels, agriculture, and waste sectors follow a C&C approach, while industry and power sectors are based on production growth and potential efficiency gains (Blok et al. 1997).

Leading abatement allocation frameworks include:

- ***Greenhouse development rights***: Global mitigation effort is allocated on the basis of historical responsibility and per capita income (Baer et al. 2008).
- ***Ability to pay***: Mitigation effort is allocated as a function of welfare for countries above a per capita threshold (Jacoby et al. 1998).

Of these approaches, contraction and convergence has the advantage of simplicity and transparency, while blending equity and efficiency and/or adjustment considerations. It also has the widest support base , which has included statements from developed countries, such as France, Germany, Japan, and the United Kingdom, as well as developing countries such as Indonesia and the Philippines.

Source: ADB Study Team.

3.2.4 Scenario variants on REDD

In the climate stabilization scenarios, emission reductions from avoided deforestation produce credits that can be traded in the carbon market, provided that a country or region emits less than its allocated target. In the fragmented scenario, countries can use emissions from avoided deforestation to comply with their domestic targets, but cannot trade them.

As the role of REDD in future carbon markets is still not decided (Box 1), and the performance of REDD is not well understood, different assumptions on the feasibility of REDD[2] activities are introduced. This is particularly important for Indonesia and Malaysia (the two DA5 countries assumed to directly undertake REDD within this study) as well as more generally relevant to global climate policy in the context of the potential supply of REDD reduction from Latin American countries. In the "full" or "efficient" REDD case, emission reduction from deforestation and degradation is possible at

[2] As the modeling approaches employed cannot incorporate enhancement of carbon stocks, REDD, rather than REDD+ is used for accuracy in describing the scenario variants.

Table 12: Definitions of the Policy Scenarios in the Present Study

ICES–WITCH joint Scenario Matrix	BAU	Fragmented	Moderate Ambition International Climate Agreement	High Ambition International Climate Agreement
		Low Copenhagen pledges in 2020, extrapolation thereafter	Low Copenhagen pledges in 2020 and long-term GHG concentration at 650 ppm CO_2eq	High Copenhagen pledges in 2020 and long-term GHG concentration at 500 ppm CO_2eq
Full REDD potential	1 (BAU)	2 (Fragmented)	3 (650 Full REDD)	6 (500 Full REDD)
Higher REDD cost			4 (650 Low REDD)	7 (500 Low REDD)
No REDD			5 (650 No REDD)	8 (500 No REDD)

BAU = business as usual, CO_2eq = carbon dioxide equivalent, GHG = greenhouse gas, ICES = Intertemporal Computable Equilibrium System, ppm = parts per million, REDD = reducing emissions from deforestation and forest degradation, WITCH = World Induced Technical Change Hybrid.
Source: ADB Study Team.

the opportunity cost incurred. In the "low REDD" case, the cost of implementing REDD activities is assumed to increase by 150% with respect to opportunity costs alone. This increase takes into account additional possible transaction costs, potential project failures, and leakage that could result from overoptimistic reference levels or from REDD activities that simply displace deforestation, or a substitution effect. In the "no REDD" case, REDD is excluded altogether. Table 12 summarizes the eight policy scenarios considered.

3.3 Overview of the Low-Carbon Modeling Framework

The modeling framework of this study was developed based on consultations with the national planning and environment agencies, research and climate change institutes, and other relevant stakeholders in the DA5 countries (Box 3). This study uses two global modeling tools to analyze decarbonization policies in the five countries of Southeast Asia: the Intertemporal Computable Equilibrium System (ICES) model, and the World Induced Technical Change Hybrid (WITCH) model. The two models are complementary. Their joint use in a coordinated scenario analysis allows the study to capture distinct aspects of low-carbon development paths in the focal countries in a manner consistent with national input (Box 3).

ICES is a CGE model. It represents markets within sectors, sectors within countries, and countries in the global economy. The overall role of the model is to understand how changes to policies and prices cause the economic system to adjust, substitute, and respond. To do so, the model is rooted in the current structure of the economy, including representing current energy technologies.

WITCH, in contrast, brings in additional dynamics, while losing some CGE capabilities. In terms of the economy, WITCH is a Ramsey type growth model, without different production sectors, and with country aggregates only represented. However, what WITCH adds is a much richer "bottom-up" type of energy tree with advanced technologies reflected. Not only are the technologies themselves included, but the research and development and spillover processes that lead to their diffusion and application are modeled as well.

The intention with the joint use of the two models is that each brings in elements that the other lacks. ICES adds detail on the economic system, whereas WITCH adds detail on the energy innovation system. ICES provides more realistic short-term results, whereas WITCH may be more plausible over longer time frames. In many respects, WITCH provides insights similar to a bottom-up model, whereas ICES is more top-down. Neither model can be considered superior, as both add richness to understanding the possible low-carbon policy outcomes.

Box 3: Stakeholder Input into the Low-Carbon Modeling Framework

The modeling framework and parameterization applied within this study were developed in consultation with various national stakeholders and key planning agencies in the DA5. Project focal agencies provide regular guidance and input into representation of their respective countries in the model. Box Table 3.1 summarizes the regional and national consultation meetings and workshops conducted to obtain input the models used and baseline and low-carbon policy scenarios developed

- Indonesia: Ministry of National Planning (BAPPENAS)
- Malaysia: Environment Section of the Economic and Planning Unit
- Philippines: National Economic and Development Authority (NEDA), Department of Energy (DOE), and Department of Environment and Natural Resources (DENR)
- Thailand: Thailand Greenhouse Gas Management Organization (TGO)
- Viet Nam: Ministry of Planning and Investment (MPI) and Central Institute for Economic Management (CIEM)

Box Table 3.1: Consultation Process Used to Guide the Low-Carbon Modeling Approach for this Study

Name	Number of Participants and Partners	Date and Place
A. Regional Meetings		
1st Regional Consultation Meeting	43 participants from ministries of economic planning and environment in Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam, national research agencies and development partners	27–28 January 2011, Kuala Lumpur, Malaysia
2nd Regional Consultation Meeting	67 participants from ministries of economic planning, environment, and climate change agencies in Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam, international experts, development partners	9 March 2012, Bangkok, Thailand
3rd Regional Consultation Meeting	36 government representatives from Cambodia, Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam, international experts, development partners	18 October 2012, Bangkok, Thailand
Final Regional Consultation	30 participants from ministries of economic planning and environment in Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam, international experts	4–5 November 2014, Manila, Philippines
B. National Workshops		
Viet Nam	85 participants from national ministries, organizations, and institutes; Conducted in partnership with the MPI and CIEM	16–17 July 2012, Hanoi, Viet Nam
Thailand	70 participants from national ministries, organizations, and institutions; conducted in partnership with the TGO	19–20 July 2012, Bangkok
Philippines	60 participants from national government agencies and institutions; conducted in partnership with DOE	23–24 July 2012, ADB, Manila
Malaysia	27 participants from 16 national agencies; conducted in partnership with EPU	8–9 October 2012, Putrajaya, Malaysia
Indonesia	29 participants from 18 national agencies; conducted in partnership with BAPPENAS	11–12 October 2012, Jakarta ,Indonesia

Source: ADB Study Team.

3.4 The Intertemporal Computable Equilibrium System Model

3.4.1 Basic structure

ICES is a CGE model that is recursive-dynamic. This means that it uses findings from each year as the basis of modeling the next year. In particular, savings in the model in each year leads to investment in the next year, which is allocated to capital stock in sectors of each country, which build over time. As in all CGE models, ICES principally relies on an assumption of perfect competition in markets.

Industries are modeled through representative firms, which minimize costs while taking prices as given. In turn, output prices are given by average production costs. Production functions are specified via a series of nested constant elasticity of substitution (CES) functions, in which domestic and foreign inputs are imperfect substitutes. Capital and labor are perfectly mobile domestically, but immobile internationally. Land and natural resources are industry specific.

A representative consumer in each region receives income, defined as the service value of national primary factors (natural resources, land, labor, and capital). The income is used to finance three classes of expenditure: aggregate household consumption, public consumption, and savings. The expenditure shares are fixed, as the top-level utility function is standard Cobb-Douglas. Public consumption is split into a series of alternative consumption items, also according to a Cobb-Douglas specification. Private consumption is analogously split in a series of composite groups with imperfect substitution possibilities across domestic and imported commodities. The functional specification used is the constant difference in elasticities.

Investment is internationally mobile: savings from all regions are pooled and then investment is allocated to achieve equality of expected rates of return to capital.

Table 13: Regional and Sector Detail of the Intertemporal Computable Equilibrium System Model

Countries and Regions		
Developed	**Developing**	**DA5**
United States (US)	Economies in transition (TE)	Indonesia
WEURO (15 European Union Member States)	Middle East and North Africa (MENA)	Malaysia
EEURO (12 European Union Member States)	Sub-Saharan Africa (SSA)	Philippines
KOSAU (Republic of Korea, South Africa, Australia)	South Asia (SASIA)	Thailand
CAJANZ (Canada, Japan, Australia, New Zealand)	India	Viet Nam
	People's Republic of China (PRC)	
	East Asia (EASIA)	
	Latin America (LACA)	
Sectors		
Agriculture or Land Use	**Energy**	**Others**
Rice	Coal	Heavy industry
Other crops	Crude oil	Light industry
Vegetables and fruits	Natural gas	Services
Livestock	Petroleum products	
Timber	Nuclear	
Biofuels	Hydro	
	Solar	
	Wind	
	Other electricity	

Note: Other electricity is electricity produced using fossil fuel sources (i.e., coal, oil, or gas).
Source: ADB Study Team.

As a result, savings and investments are equalized at the world, but not at the regional, level.

The final geographic and sectoral details are reported in Table 13. The regional specification singles out Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam to allow analysis of the economic implications of medium- and long-term decarbonization policies in each of these countries. The production tree emphasizes energy-producing and land-using sectors, given that they are the major emissions sources.

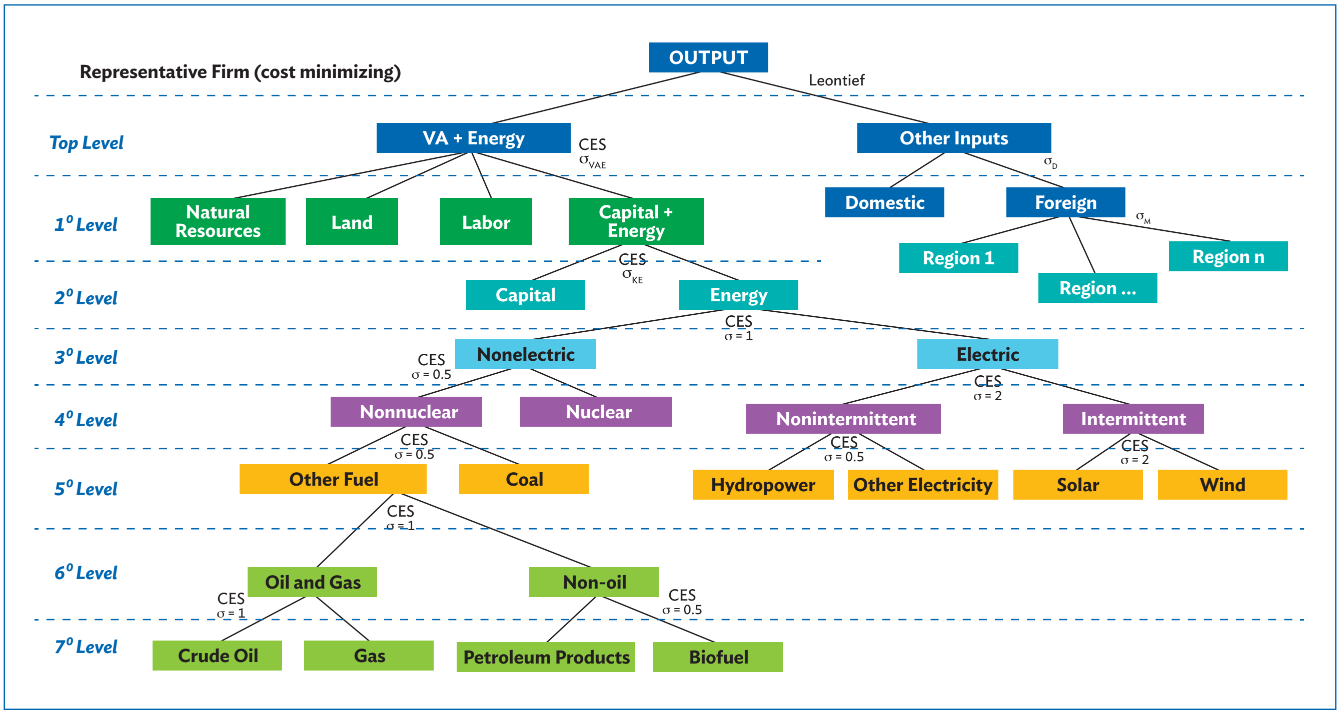
All sectors use primary factors, such as labor and capital-energy, as well as intermediate inputs. In some sectors (fossil fuel extraction and fishery), primary factors include natural resources (e.g., fossil fuels or fish) and land. The nested production structure (Figure 5) is the same for all sectors, while diversity in production processes is captured through sector-specific productivity and substitution elasticity parameters.

Renewable energy sources (hydropower, solar, wind) are stand-alone sectors providing electricity. Biofuels are transformation sectors processing the output of the agricultural "other crops" sector and selling output (biofuels) to the "services" sector that includes retail sale of automotive fuels. Nuclear energy is an alternative option for base-load energy along with coal, but with lower substitution than between coal and other fossil fuels (oil, gas), so that it is represented in a nest above coal. Technological progress, governing both productivity of factors and their substitutability, is exogenous. Energy efficiency is represented by an autonomous energy-efficiency improvement function.

3.4.2 Land-use emissions

ICES employs an agroecological zone (AEZ) approach for land use allocation. Crop switching is only possible between those crops that exist in each AEZ. The AEZ

Figure 5: Nested Production Function of the Intertemporal Computable Equilibrium System Model



CES = constant elesticity of substitution, VA = value added.
Source: ADB Study Team.

database (Avetisyan et al. 2011) identifies crop, forest extent, and production for each region by AEZ. The original data contain detailed information for 175 crops aggregated into the 8 Global Trade Analysis Project crop classification.

Avoided deforestation is a direct abatement option in ICES. Country-specific equations link different carbon prices to different REDD abatement levels. The parameterization of these equations derives from the International Institute for Applied Systems Analysis (IIASA) model cluster (Gusti et al. 2008). Country abatement has been estimated by downscaling Southeast Asia's estimates proportionally to the national shares of emission from deforestation in the regional total. Effects of REDD on agricultural land availability were estimated by the IIASA cluster model with estimates of the Food and Agriculture Organization of the United Nations (FAO 2006 and 2001) on the amount of land entering large-scale agriculture after deforestation. Under REDD, forest land-using sectors (agriculture and timber) are compensated through a subsidy equal to the value of the avoided emissions from REDD.

Peat emissions in Indonesia are considered as part of total emissions, drawing on parameters on peatland deforestation and emissions reported in Busch et al. (2012), with peat emissions taking place over 25 years before carbon is depleted. Averted deforestation leads to averted peat emissions on the share of deforestation that has historically occurred in peatlands. Emissions abatement via peatland restoration and rehabilitation, fire prevention, and water management were reflected through an aggregated marginal abatement cost curve based on DNPI (2010).

3.4.3 The multigas carbon market

ICES incorporates a global carbon market involving all GHGs, not only CO_2. This includes sector emissions from CO_2, (including emissions from deforestation), methane (CH_4), nitrous oxide (N_2O), perfluorinated compounds, hydrofluorocarbons, and sulfur hexafluoride derived from Rose et al. (2010).

ICES uses a global permitting system to represent the global carbon market. Under this system, a global carbon budget is established, and ICES solves for a global carbon tax that achieves emission reduction consistent with the global carbon budget. The global tax translates into different levels of abatement in different countries. For each country, the level of abatement achieved relative to a carbon allowance for the country determines whether there is an abatement deficit, in which case permits need to be purchased from other countries that abate more than is necessary; or there is surplus abatement, in which case permits can be sold. Revenues from the carbon market are remitted to the budget constraint of households in ICES. A similar carbon market framework is also employed in WITCH.

3.5 The World Induced Technical Change Hybrid Model

3.5.1 Basic structure

WITCH (Bosetti et al., 2007, Bosetti et al., 2009) is an optimal growth model of the world economy, disaggregated into 14 macro regions (Table 14), grouping countries with similar economic, geographic, resource, and energy characteristics. Regions interact through the presence of economic and environmental global externalities. For each region, the model maximizes intertemporal social welfare simultaneously with other regions as an open-loop Nash equilibrium. Through the optimization process, regions choose optimal dynamic paths, including investments in different capital stocks, research, energy technologies, and consumption of fossil fuels.

The optimal path of consumption is determined by optimizing the intertemporal social welfare function, which is defined as the log utility of per capita consumption, weighted by regional population. The social discount rate declines from 3% to 2% at the end of the century.

Table 14: Regions Represented in the World Induced Technical Change Hybrid Model

Developed	Developing and Middle-Income	Focal Countries
Canada, Japan, New Zealand	People's Republic of China	Indonesia
Republic of Korea, South Africa, Australia	Indian Subcontinent	Southeast Asia
Western Europe	Latin America and Caribbean	
United States	Middle East and North Africa	
	Eastern Europe	
	Other South Asia	
	Sub-Saharan Africa	
	Transition Economies	

Source: ADB Study Team.

As is typical of intertemporal optimal growth models, production in the economy is aggregated. Each region produces one commodity that can be used for consumption or investments. The final good (Y) is produced using capital, labor, and energy services. Capital and labor are aggregated using a Cobb-Douglas production function. This nest is then aggregated with energy services in a CES production function.

WITCH is termed a hard-link hybrid model because the energy sector is fully integrated with the rest of the economy, so that investments and the quantity of resources for energy generation are chosen optimally, together with the other macroeconomic variables of the model. The model is a hybrid because the energy sector features bottom-up characteristics, in which a broad range of different fuels and technologies are used in the generation of energy. Substitution across sectors is regulated via nested CES functions calibrated on 2005 values and previous econometric studies.

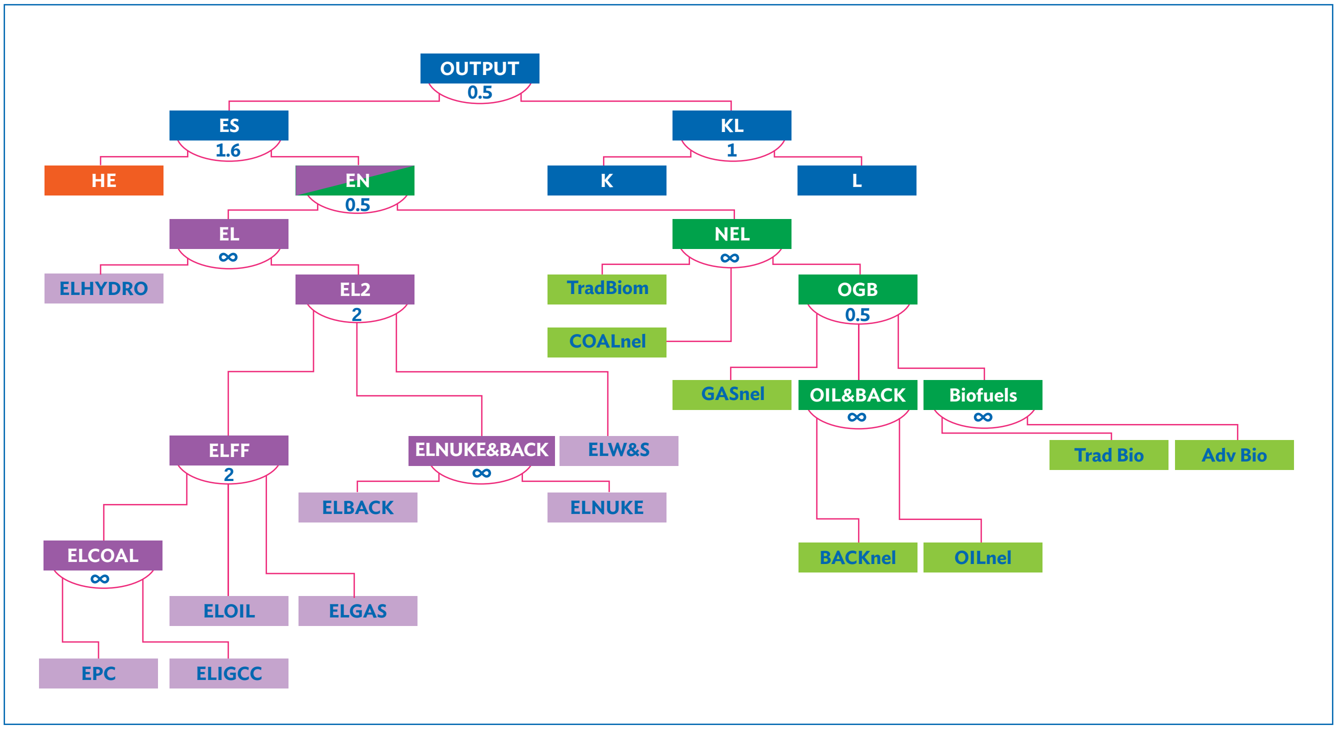
The energy sector endogenously accounts for technological change based on learning by doing and learning by researching. Overall, the economy of each region consists of one final good, which can be used for consumption or investments; one electric sector, representing a wide range of power generation options; and a nonelectric energy sector, aggregating the demand from transportation, industry, and residential services (Figure 6).

Energy services, in turn, are given by a combination of the physical energy input and a stock of energy efficiency knowledge. This modeling of energy services allows for endogenous improvements in energy efficiency. Energy efficiency increases with investments in energy research and development (R&D), which build the stock of knowledge, which can then replace actual energy in the production of energy services.

Both innovation and diffusion processes are modeled. WITCH distinguishes between R&D investments for enhancing energy efficiency and investments in making innovative low-carbon technologies more competitive. R&D processes are subject to technological progress and technological spillovers. International technological spillovers of knowledge are accounted for to mimic the flow of ideas and knowledge across countries. Experience processes via learning by doing are accounted for in the development of niche technologies, such as renewable energy (wind and solar) and backstops.

Electricity is generated from a series of traditional fossil fuel-based technologies and carbon-free options. Fossil fuel-based technologies include natural gas combined cycle, fuel oil, and pulverized coal power plants. Coal-based electricity can also be generated using integrated gasification combined cycle (IGCC) production with CCS. Low-carbon technologies are hydroelectric and nuclear power and renewable sources, such as wind turbines and photovoltaic panels (wind and solar).

Figure 6: The World Induced Technical Change Hybrid Optimal Growth Model of the World Economy Structure



Abbreviation	Name	Abbreviation	Name
KL	Capital-labor aggregate	ELNUKE&BACK	Electricity generated with nuclear and backstop
K	Capital invested in the production of the final good	ELBACK	Electricity generated with backstop
L	Labor	ELNUKE	Electricity generated with nuclear
ES	Energy services	ELW&S	Wind turbines and photovoltaic panels
HE	Energy R&D capital	NEL	Nonelectric energy
EN	Energy	TradBiom	Traditional biomass
EL	Electric energy	COALnel	Coal for nonelectric energy
ELYHYDRO	Electricity generated with hydroelectric	OGB	Oil, backstop, gas, and biofuel
EL2	Electricity generation	GASnel	Gas for nonelectric energy
ELFF	Fossil fuel electricity	OIL&BACK	Oil and backstop for nonelectric energy
ELCOAL	Electricity generated with coal	BACKnel	Backstop for nonelectric energy
EPC	Electricity generated with pulverized coal	OILnel	Oil for nonelectric energy
ELIGCC	Electricity generated with IGCC coal plus CCS	Biofuels	Traditional and advanced biofuels
ELOIL	Electricity generated with oil	Trad Bio	Traditional biofuels
ELGAS	Electricity generated with gas	Adv Bio	Advanced biofuels

Source: ADB Study Team.

Many technology features are represented for each: yearly utilization factors, fuel efficiencies, investment, and operation and maintenance costs. For CCS, supply costs of injection and sequestration reflect site availability at the regional level, as well as energy penalty, capture, and leakage rates. IGCC CCS competes with traditional coal and replaces it under a sufficient carbon price. For nuclear power, waste management costs are also modeled. Hydroelectric power evolves to reflect limited site availability.

Energy consumption in the nonelectric sector is based on traditional fuels (traditional biomass, oil, gas, and coal) and biofuels. In order to account for food security concerns, overall penetration of biofuels is assumed to remain modest over the century. The consumption of oil can be substituted with a carbon-free backstop technology, which may be next-generation biofuels or carbon-free hydrogen. As a consequence, the backstop technology is mostly thought of as an abatement option for the transport sector.

Energy prices depend on the extraction of fossil fuels, which in turn is affected by consumption patterns of all regions in the world. The cost of electricity generation is endogenous and combines capital costs, operation and maintenance expenditures, and fuel expenditures. The prices of fossil fuels and exhaustible resources (oil, gas, coal, and uranium) are also endogenously determined by the marginal cost of extraction, which in turn depends on current and cumulative extraction, plus a regional mark up to mimic different regional costs.

The use of fossil fuels generates CO_2 emissions, which are computed by applying stoichiometric coefficients to energy use. Beyond CO_2, WITCH features all the main Kyoto gases, including CH_4, N_2O, and short- and long-lived fluorinated gases. These are modeled through marginal abatement cost curves for each gas, which are region specific and are derived for the base year (2005) from the assessment of the United States Environmental Protection Agency. Technical change allows these curves to shift over time.

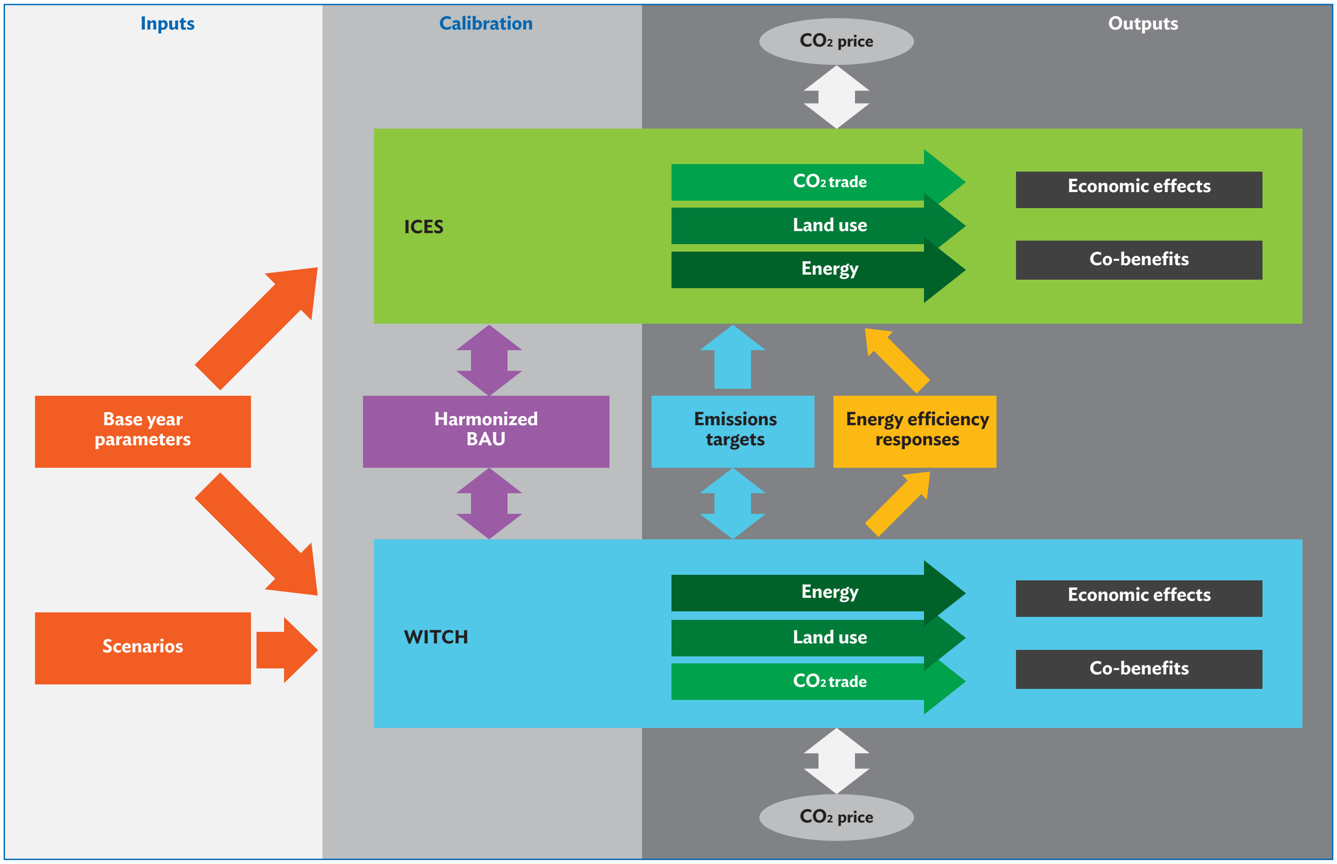
3.5.2 Land-use emissions

To represent the mitigation opportunities in the land-use and forestry sectors, WITCH has been coupled to a detailed agricultural and land-use model (GLOBIOM, developed at IIASA), which provides key information regarding the supply cost functions of biomass and marginal abatement costs in the two sectors. This is the same model to which ICES is linked. Emissions and abatement from peatlands are also incorporated in the same manner as in ICES.

3.6 Integration of World Induced Technical Change Hybrid and Intertemporal Computable Equilibrium System Models

The intention with the joint use of the two models is that fundamental features of WITCH can address ICES modeling limitations, while ICES can also contribute to WITCH. ICES adds detail on the economic system, whereas WITCH adds detail on the energy innovation system. As a unique aspect of this analysis, the models are run jointly and in a harmonized and mutually reinforcing way. Both models are used to run all scenarios, and WITCH has been calibrated to reflect a reduced form of the more detailed economic system first depicted in ICES. WITCH is intertemporally optimized, so that WITCH determines the optimal emission reduction path to accomplish each GHG stabilization target for both models, and also identifies an emissions BAU that reflects technological progress. As WITCH can model how technologies improve in response to climate policies, it identifies energy efficiency responses to climate policies for use in ICES. Each model then resolves its own energy substitution, carbon price, and economic responses (Figure 7).

Figure 7: Integrated Modeling Framework



BAU = business as usual, CO_2 = carbon dioxide, ICES = Intertemporal Computable Equilibrium System, WITCH = World Induced Technical Change Hybrid.
Source: ADB Study Team.

3.7 Harmonized Assumptions for Business-as-Usual Scenario

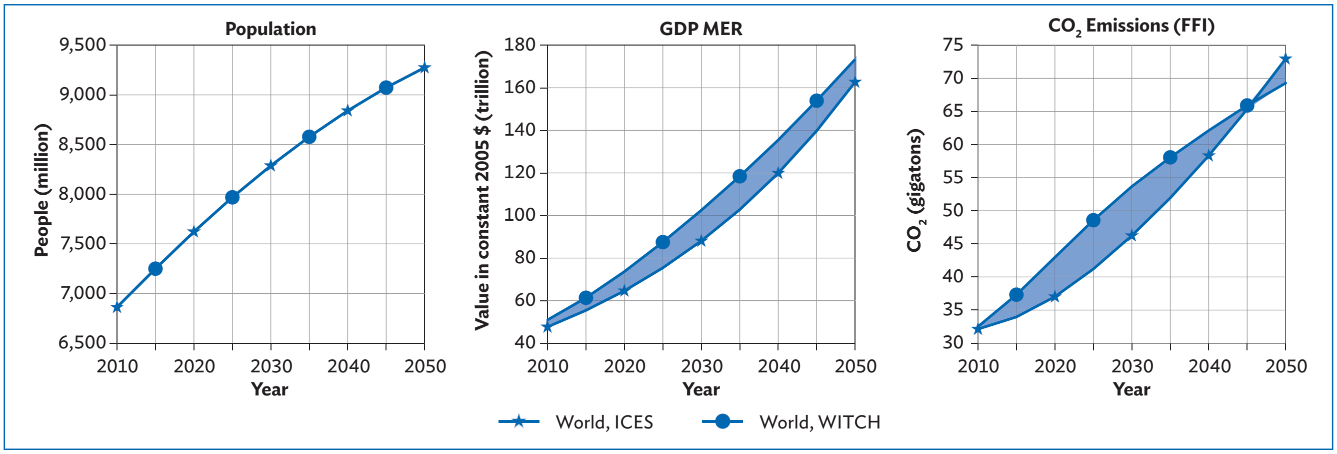
The BAU scenario was calibrated to (i) replicate the base year characteristics of the DA5, (ii) replicate credible projections of the main socioeconomic drivers in these countries, and (iii) harmonize assumptions across the ICES and WITCH models to facilitate comparative analysis.

For the non-DA5 economies, this calibration procedure is based on a "medium population—medium economic growth—fast convergence between regions" scenario that was constructed following the methodology developed in the Ampere project (Kriegler et al. 2014). Population reflects the medium-population scenario of the United Nations 2010 Medium Term Projection (UNDESA 2011). In the case of the DA5 countries, growth rates for GDP and macrosectoral composition of value added for the ICES model have been derived from Asian Development Bank (ADB) estimates (ADB 2011b) and validated through personal communication with local experts. In both ICES and WITCH, these GDP trends are replicated through modifications of total, factor-specific, or sector-specific productivity parameters.

Emissions of GHGs as output of the models are driven by the entire set of behavioral parameters governing supply and demand. ICES is different from WITCH both in the energy nest and in terms of trade representation, which means that emissions can be closely, but not fully, synchronized. As a result, ICES and WITCH are harmonized fully in terms of population and GDP and partially in terms of emissions (Figure 8). In the BAU, both models project a world population reaching roughly 9.3 billion, and a GDP of $170 trillion by 2050.[3] Emissions from fossil fuel-intensive industries (i.e., excluding land-use emissions) are roughly comparable, steadily increasing, and expected to reach between 67 gigatons and 73 gigatons of CO_2 equivalent by mid-century.

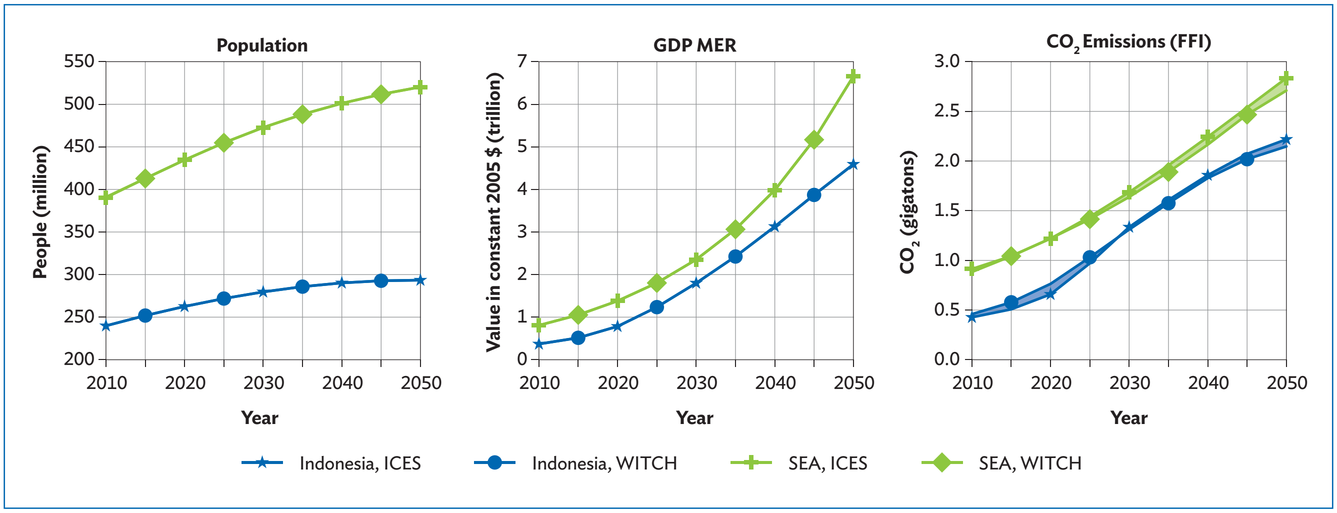
ICES and WITCH are also well harmonized regarding growth trends for population and GDP of Indonesia and the rest of Southeast Asia (Figure 9). Indonesia's population increases from 0.24 billion in 2010 to 0.29 billion in 2050; and in the rest of Southeast Asia, from 0.39 billion to 0.52 billion. Both areas show strong GDP growth, with Indonesia's reaching roughly $5 trillion and Southeast Asia's reaching

Figure 8: World Business-as-Usual Population, Gross Domestic Product, and Carbon Dioxide Emissions



CO_2 = carbon dioxide, GDP = gross domestic product, FFI = fossil fuel industrial, ICES = Intertemporal Computable Equilibrium System, MER = market exchange rate, WITCH = World Induced Technical Change Hybrid.
Note: Excludes land use, land-use change, and forestry.
Source: ADB Study Team.

Figure 9: Indonesia and Southeast Asia Business-as-Usual Population, Gross Domestic Product, and Carbon Dioxide Emissions



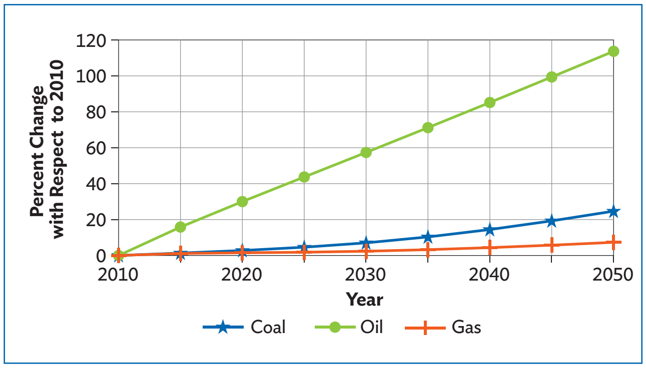
CO_2 = carbon dioxide, GDP = gross domestic product, FFI = fossil fuel industrial, GDP = gross domestic product, ICES = Intertemporal Computable Equilibrium System, MER = market exchange rate, SEA = Southeast Asia, WITCH = World Induced Technical Change Hybrid.
Source: ADB Study Team.

3 Statistics presented in this section are for Southeast Asia, as defined in WITCH, which includes countries additional to the DA5, such as Cambodia, the Lao People's Democratic Republic, Myanmar, Papua New Guinea, and the Pacific islands.

$7 trillion in 2050. CO_2 emissions (excluding those from land use) are also similar in growth across the two models.

BAU world trends for fossil fuel prices are reported in Figure 10, as derived from simulations conducted with the WITCH model and developed in the context of the European Union Ampere project (Kriegler et al. 2014). These forecasts have also been harmonized across ICES and WITCH.

Figure 10: Business-as-Usual World Prices of Fossil Fuels



Sources: Kriegler et al. (2014).

3.8 Quantification of Co-Benefits of Climate Action

3.8.1 Approach to co-benefit quantification

ICES and WITCH represent the costs of climate stabilization policies, but do not represent nonclimate benefits associated with abatement actions. Supplemental analysis of WITCH and ICES results was performed to include several sets of co-benefits of responses to climate policies. These co-benefits represent additional beneficial effects that are neither captured in the overall modeling of policy responses nor which are part of the benefits derived from reduced climate damage. Abatement actions have many different types of co-benefits, included ecosystem services, spillover effects to economic efficiency, reduced economic volatility from fossil fuel price fluctuations, effects on health, benefits from reduced vehicular traffic, and more. Of these, health and traffic benefits can be quantified most easily using energy mix and deforestation reduction results from ICES and WITCH, and were the focus of this analysis.

Within health benefits, included effects include reduced life years lost from fine particulate matter (2.5 micrograms (µg), PM2.5), sulfur dioxide emissions (SO_2), and nitrous oxides (NO_x) from the energy and transport sectors and reduced life years lost from reduced forest fire emissions of PM2.5. Other quantified transport benefits include reduced congestion from private transportation and reduced vehicular accident externalities.

3.8.2 Quantification of reductions in population exposure to pollution

For each fossil fuel energy source, pollutant emissions are calculated on the basis of emissions factors per unit of energy generated. For conventional coal and gas used in power generation and gasoline and diesel used in transport, country-specific emissions factors developed by IIASA are applied (from the GAINS model, see Nguyen et al. 2011), which reflect the current mix of control technologies, with improvement over time considered for coal. In the case of advanced energy technologies, including CCS and biomass, regional emissions factors from WITCH are applied. The net difference in emissions of each pollutant in energy and transport is calculated between the BAU and low-carbon scenario for each year and country.

Emissions changes are subsequently translated into ambient pollutant concentrations to which populations are exposed. To do so, intake fractions (representing the proportion of emissions that people inhale during breathing) identified by Parry et al. (2014) are applied for transport and power plant emissions of each pollutant in each country. Emissions are multiplied by the intake fraction and divided by the volume of air that exposed people breathe to approximate changes in ambient concentration exposure (micrograms per cubic meter) among national populations.

In the case of emissions from forest fires, the analysis draws on remote sensing based estimates produced by Reddington et al. (2014) for 2004–2009 average population-weighted PM2.5 increases in Indonesia attributable to forest fires in Indonesia; increases in Malaysia attributable to forest fires in Indonesia; and increases in Malaysia attributable to fires in Malaysia. PM2.5 loading is assumed to covary with deforestation in each source country over time, as fires are often associated with land clearing.

3.8.3 Quantification of mortality responses to pollution reduction

To translate changes in ambient concentrations into mortality consequences, concentration response equations have been created in reduced form. These equations are based on relating existing levels of life years lost from pollutant loads to existing pollution levels. National estimates of years of life lost attributable to PM2.5 concentrations in 2010 have been generated under the Global Burden of Disease study (Lim et al. 2012). These estimates are used to derive mortality concentration response functions from a linear response to PM2.5 concentrations above 5 micrograms per cubic meter (µg/m^3) in populations exposed to greater than 5 µg/m^3 average concentrations. In so doing, it is assumed that average PM2.5 concentrations of less than half the WHO (2006) recommended annual average exposure limit of 10 µg/m^3 have negligible health effects. This is consistent with the WHO's observation that background "natural" ambient PM2.5 concentrations have been observed to range 3–5 µg/m^3, at which level adverse health consequences have not been documented.

To estimate current exposure levels and populations exposed to average concentrations above the 5 µg/m^3 threshold, Brauer et al. (2012) spatial remote sensing derived estimates of all source PM2.5 have been translated into population-weighted average ambient PM2.5 concentrations for the population in areas with more than 5 µg/m^3 average concentration. Life years lost from Lim et al. (2012) are divided by the population-weighted average ambient concentration in excess of 5 µg/m^3 (for populations facing greater than 5 µg/m^3 average annual concentrations) to calculate a linear slope to the concentration response function. Changes in years of life lost are estimated as the product of the concentration response parameter and changes in ambient concentration exposure from changes to fossil fuel combustion and forest fires. Health effects of reduced energy and transport SO_2 and NO_x emissions are calculated based on a concentration-response parameter approximated based on the relationship between PM2.5 and SO_2 and NO_x concentration-response coefficients applied in Cropper et al. (2012).

3.8.4 Valuation of averted mortality

Averted years of life lost are modified to reflect annual changes in national population over the analytical period. The years of life lost are valued based on a value of statistical life years (VSLY), approximated based on the relationship between the VSLY applied by the United States Environmental Protection Agency in analysis of benefits of reductions in air pollution ($162,000 in 1999 dollars [EPA 2002]) and nominal annual per capita GDP in the United States in the reference year ($34,600). The ratio of VSLY to per capita GDP is multiplied by the annual per capita GDP (in 2005 $) in each country and year to value savings of life years.

3.8.5 Transport congestion reduction

Reduced fossil fuel use in transportation implies reduced use of private vehicles and modal shifts to more efficient public means of transit. This reduced vehicular traffic leads to reduced congestion and faster travel speeds, which reduce travel times and save opportunity costs for labor and leisure uses of time. These effects are valued, drawing on the work of Parry et al. (2014), which established relationships between fuel use, congestion, travel times, and time values for 100 countries. The value of time saved, quantified in 2010 terms based on the reduction in gasoline and diesel combusted, is adjusted for changes in per capita GDP over the period. Transport gasoline and diesel combustion reductions are approximated from reductions in energy from oil, based on the 2010 proportions of transport gasoline and diesel to total oil consumption reported in IEA Country Statistics.

3.8.6 Transport accident reduction

Parry et al. (2014) value external accident risks posed to other vehicles and pedestrians in terms of fatalities, as well as in terms of property damage and other injuries by country. Road damage from additional truck traffic is also approximated based on road maintenance expenditures. Both effects are related to fuel consumption as a unit externality. These external costs are applied to changes in transport gasoline and diesel consumption approximated from ICES and WITCH.

3.9 Limitations of Analysis

No single modeling approach can capture all aspects of how low-carbon development can be achieved. Rather, different analytical tools are needed to capture different aspects and answer different questions.

While ICES can capture how policy shocks spread over economic systems, it also has important limitations that need to be taken into account (Table 15). The model is calibrated to 1 specific year, which means that its explanatory power rapidly declines as the structural features of the macroeconomic context change. Most importantly, it adopts a top-down representation of the energy system—a limited number of “aggregated” primary energy generation technologies (coal, oil, gas, wind, solar, hydro, and nuclear) are considered, while some important renewable energy sources for the DA5 are omitted, such as geothermal power. The omission of geothermal power will bias costs somewhat upward, although geothermal is a relatively high-cost renewable power source, such that results may not be strongly affected. Perhaps more importantly, technological progress is also exogenous to the model. The higher energy prices usually associated with decarbonization policies can neither stimulate new carbon-free technologies, nor increase the productivity of existing low-carbon technologies. These limitations result in a tendency of ICES to highlight high abatement costs, especially in the long term.

Bottom-up description of the energy sector and endogenous technical progress allow WITCH to depict more energy sector mitigation responses, but WITCH offers coarser country and sector detail. Consequently, it can neither detail policy impacts on each of the DA5 countries nor capture demand-and-supply effects outside the energy sectors. It also omits international trade and endogenous price formation. As a result, important channels for international policy spillovers are not captured, causing underestimation of policy costs. Perhaps most importantly, WITCH reflects energy sector technologies with uncertain development potential, as it is far from certain whether and when CCS and

Table 15: Comparative Advantages of Intertemporal Computable Equilibrium System and World Induced Technical Change Hybrid Models

	Intertemporal Computable Equilibrium System	World Induced Technical Change Hybrid
Strengths	Represents countries, sectors Reflects substitution effects, trade interactions, rebound effects	Endogenous technological progress Reflects research, learning by doing Reflects strategic country group interactions Includes advanced energy technologies
Weaknesses	Technical change is exogenous Tied to 2010 economic structure Limited energy portfolio, with no advanced energy technologies	Does not represent individual countries Does not represent economic sectors Does not represent nonenergy substitution or rebound effects Trade other than in energy omitted
Appropriate use	Short term to midterm (e.g., up to 25 years)	Longer term (25–100 years)
Policy cost bias	Upward	Downward

Source: ADB Study Team.

advanced biofuels can be developed at scale. It also assumes high levels of continued technological progress in other sectors, such that resources can be freed for low-carbon energy generation. If these optimistic assumptions regarding future technological improvement do not hold, WITCH will underestimate decarbonization costs.

Both models share other fundamental limitations. Neither explicitly models market distortions and inefficiencies, which are common in the energy sector. As a result, they miss opportunities to avert emissions at negative cost through removal of perverse policy incentives or barriers to efficiency. The models are ill suited to represent frictions or transaction costs induced by institutional, social, or cultural constraints to adoption of low-carbon technologies. This can lead to underestimation of both climate change and policy costs. For example, such costs have important implications in the assessment of abatement opportunities from reduction of emissions from REDD, where institutional factors play a major role. Neither model represents abatement options beyond the energy and avoided deforestation sectors. Both models also only represent market responses to carbon price signals. Nonmarket responses, such as government investment in public goods infrastructure or conditioning policies are generally absent, even though such investment can help to facilitate low-carbon development. As a result, significant opportunities for abatement may be missed, causing costs of emission reduction to be overestimated.

In addition, although certain co-benefits are approximated, many important co-benefits associated with low-carbon development options still are not included. Reducing dependence on fossil fuels can help to stabilize domestic energy supplies and prices by helping to improve planning, resource allocation, and industry efficiency. Averted deforestation leads to preservation of biodiversity, watershed services, and other ecological functions. Modal shifts in transportation may increase exercise and human health outcomes. Reduced NOx and SO_2 emissions may benefit agricultural yields. All of these effects are omitted. In addition, those co-benefits that are included are modeled in a simplistic fashion, when many uncertainties characterize many cause–effect parameters employed. As a result, these numbers should be considered as indicative, rather than precise.

In summary, the results provided by these two models need to be considered more as illustrative than as predictive. They offer insights of what could happen and should be done if all the simplifying assumptions of the models hold, but they do not predict what will happen in the future. Accordingly, the results need to be interpreted as indications of the order of magnitude and of the direction of changes rather than exact figures.

4

Results

Key messages

This chapter presents the findings from the Intertemporal Computable Equilibrium System (ICES) and the World Induced Technical Change Hybrid (WITCH) models applied to four scenarios: (i) business as usual (BAU), where climate policies fail and climate action is not taken; (ii) fragmented (FRAG), where countries pursue national climate actions at their current level of ambition; (iii) a moderate long-term GHG concentration scenario of 650 parts per million (ppm) carbon dioxide equivalent (CO_2eq) (650) stabilization via a global climate agreement after 2020; and (iv) an ambitious stabilization scenario of 500 ppm CO_2eq (500) via a global climate agreement after 2020.

- Rapid economic growth under BAU leads to a fossil-fuel-dependent, carbon-intensive future, with 2050 greenhouse gas emissions that are 60% higher than in 2010 and fossil fuel emissions that are 300% higher.
- BAU emissions trajectories are similar to those of the Intergovernmental Panel on Climate Change (IPCC) representative concentration pathway (RCP) RCP8.5. Under those emissions, the overall Southeast Asian region can expect to have damages and losses of more than 11% of gross domestic product (GDP) by 2100, according to new modeling results from this study.
- Climate stabilization requires drastic changes in emissions trajectories, according to a contraction and convergence framework. The 500 ppm scenario leads to 30% lower emissions in 2050 than in 2010 for the Southeast Asian region, while 650 ppm stabilization requires no emissions growth. The fragmented scenario reduces regional emissions by 15% relative to BAU in 2050. In all scenarios, more emission reduction is required in Indonesia than the rest of the region.
- The presence of a global carbon market benefits the DA5 countries. The net present value of 2010 to 2050 policy costs in the absence of such a market are 32% to 53% higher if such a market is absent than if it is present.
- When reducing emissions from deforestation and forest degradation (REDD) is present as an abatement option in global stabilization scenarios, it accounts for a majority of emission reduction through 2030 to 2040 in both the WITCH and ICES models. Most of this occurs in Indonesia.
- The greatest source of emission reduction over the full 2010–2050 period in the stabilization scenarios is energy efficiency improvement in both the WITCH and ICES models.
- Carbon capture and storage (CCS) adoption is the largest source of abatement from changes to energy generation in WITCH, where it is included. Advanced biofuel is the second largest source of abatement. Adoption of clean energy under 500 ppm stabilization leads to $30 billion additional annual power sector investment by 2050.
- Contraction in the use of non-CCS coal is the most pronounced energy sector response to climate stabilization policies. Gas also contracts.
- With REDD in place, WITCH finds total 2010–2050 discounted costs of 2%–3% of GDP for the 500 ppm scenario, while the costs are approximately 4% of GDP under ICES. The 650 ppm scenario costs about 1% of GDP under both models. Effects on welfare are smaller than effects on GDP.
- REDD can allow Indonesia’s policy costs over the entire analytical period to be reduced by more than 50%, according to ICES and WITCH for both levels of stringency. In the rest of Southeast Asia, REDD allows policy costs to be reduced by 20% or more.
- A 10-year delay in the initiation of a global climate agreement increases 2050 policy costs by 60%.

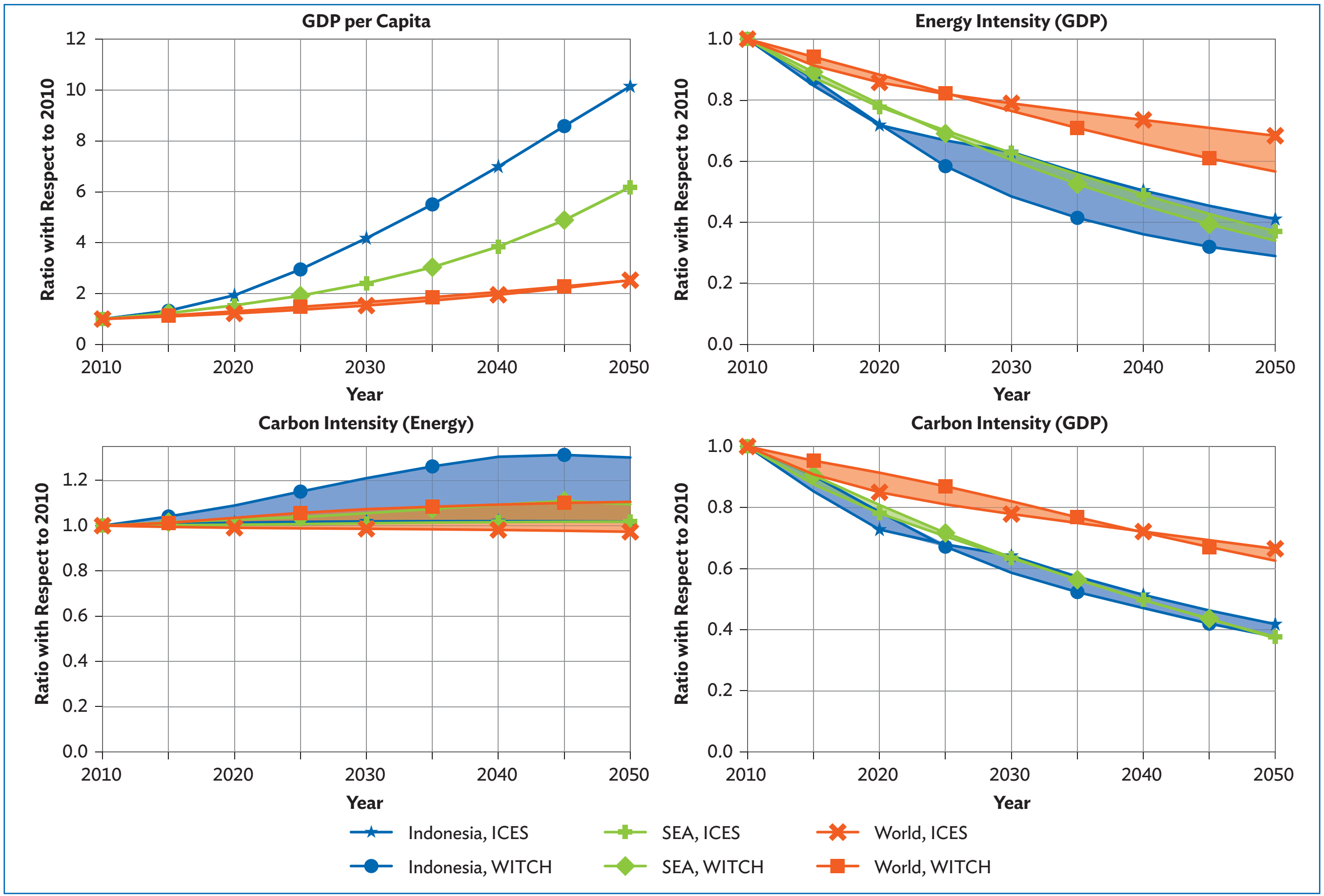
- Co-benefits from reduced air pollution, traffic congestion, and vehicular accidents offset 40%–50% of the policy costs of the climate stabilization scenarios in GDP terms.
- When co-benefits and benefits from reduced climate change damage are considered, benefits may exceed costs for 500 ppm stabilization as early as the 2040s for the region.
- In the context of continued economic growth, the regional net benefits from Southeast Asia's climate stabilization are found to range from 5.3 to 11.3 times net costs during the 21st century (under a 5% discount rate).

4.1 Business as Usual

4.1.1 Rapid growth leads to a carbon-intensive future

Economic growth is modeled as rapid in Southeast Asia, and as proceeding much more quickly than for the globe as a whole. Such quick economic growth creates substantial demand for energy from fossil fuels and for land, causing rapid emissions growth. However, that growth is still not as fast as that of the economy. Thus, both WITCH and ICES models project a constant decline in both the energy intensity and carbon intensity of GDP, which is faster in the region than in the rest of the world (Figure 11). This decline is more pronounced in WITCH than in ICES, with ranges of 60%–70% in the region.

Figure 11: Per Capita Gross Domestic Product, Energy Intensity, and Carbon Intensity under Business-as-Usual Scenario in Indonesia, Southeast Asia, and the World



GDP = gross domestic product, ICES = Intertemporal Computable Equilibrium System, SEA = Southeast Asia, WITCH = World Induced Technical Change Hybrid.
Source: ADB Study Team.

Even if carbon intensity is declining, there is a fossil-fuel-based future until 2050 for the two regions, with increasing use of coal, oil, and gas, and only a negligible role played by renewable energy (Figures 12–13). Negligible differences across the two models can be noticed in non-CO_2 emissions, mainly fluorinated gases, especially in Southeast Asia (Figure 15).

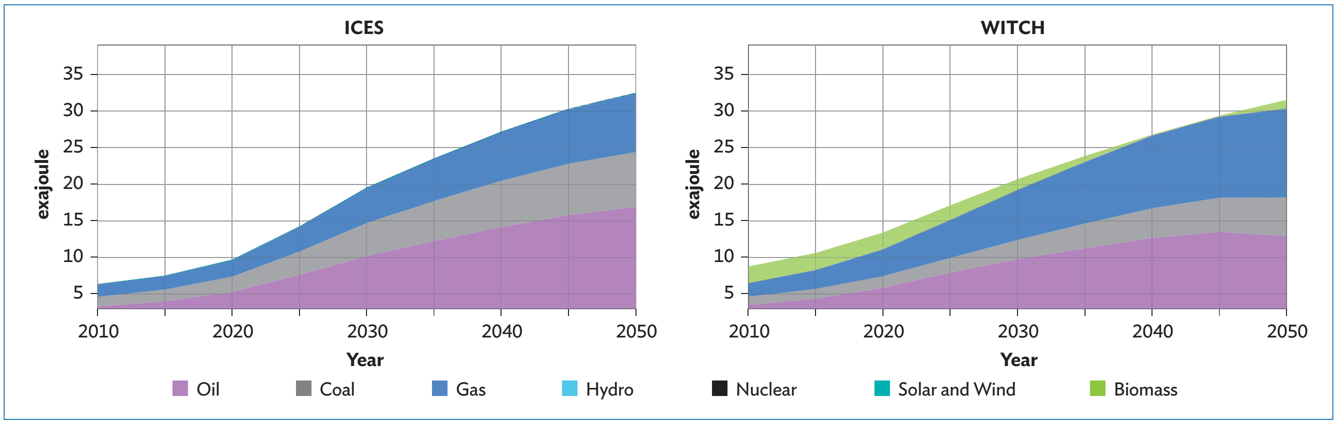
The BAU trends for land-use emissions (peatland and nonpeatland) are declining because of declining deforestation estimated by the IIASA model cluster (Figure 14, see also Gusti et al. 2008). This is compounded by depletion of carbon stocks in degraded peatlands, such that peat emissions cease (Hooijer et al. 2010).

4.1.2 Structural transformation drives emissions growth

ICES provides a more detailed picture of BAU. In accordance with national targets, the overall region is expected to experience rapid growth in GDP, with Indonesia expanding most rapidly through 2030, followed by Viet Nam (Figure 16). After 2030, Viet Nam's growth outpaces that of Indonesia. As a result, Indonesia and Viet Nam occupy an increasing share of the regional economy through 2050.

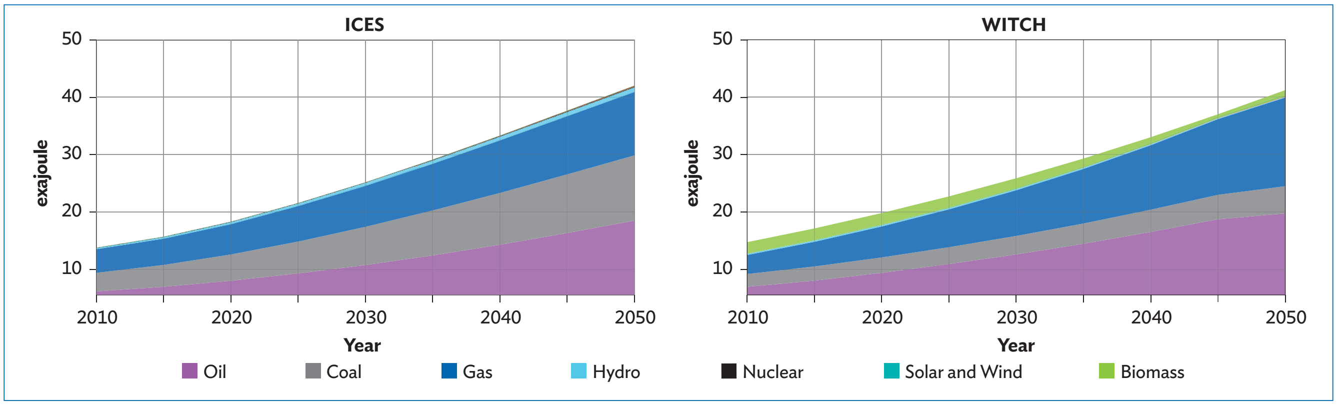
All sectors experience growth in value added, but the growth in heavy industry and services outpaces other sectors in Indonesia (Figure 17). The rest of

Figure 12: Indonesia—Primary Energy Consumption under Business-as-Usual Scenario



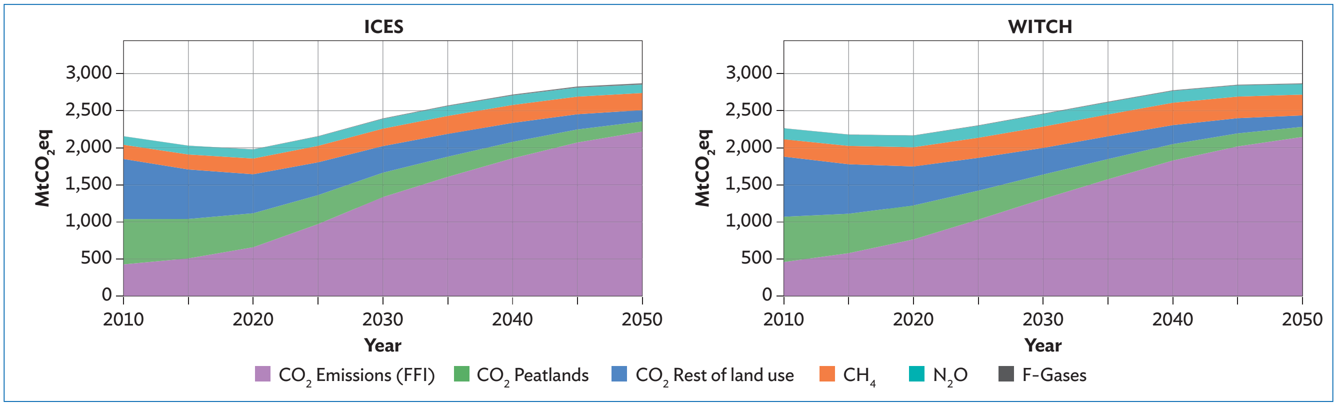
ICES = Intertemporal Computable Equilibrium System, WITCH = World Induced Technical Change Hybrid.
Note: 1 exajoule = 277,777,778 megawatt-hours.
Source: ADB Study Team.

Figure 13: Southeast Asia—Primary Energy Consumption under Business-as-Usual Scenario



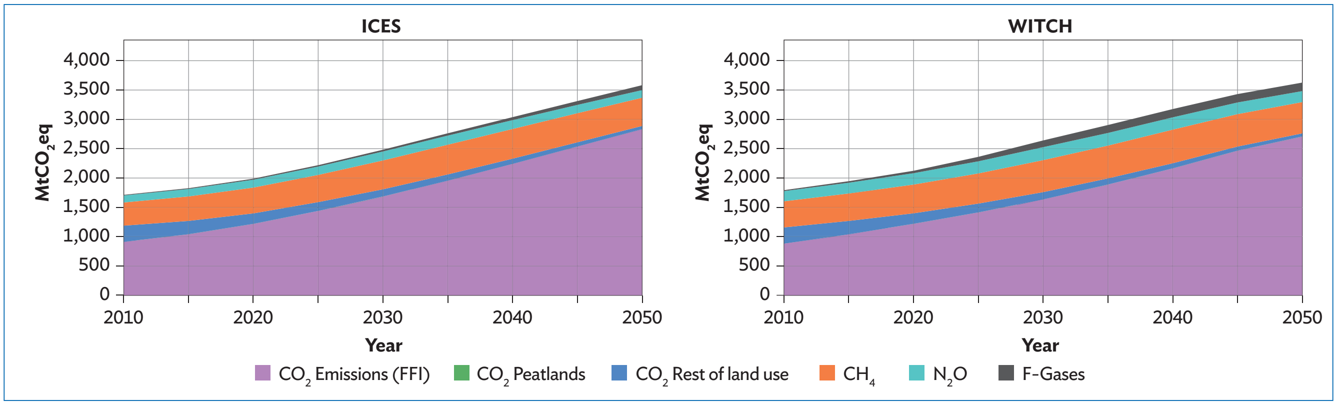
ICES = Intertemporal Computable Equilibrium System, WITCH = World Induced Technical Change Hybrid.
Note: 1 exajoule = 277,777,778 megawatt-hours. Rest of Southeast Asia includes Southeast Asian countries other than the DA5 (Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam).
Source: ADB Study Team.

Figure 14: Indonesia—Greenhouse Gas Emissions by Gas under Business-as-Usual Scenario



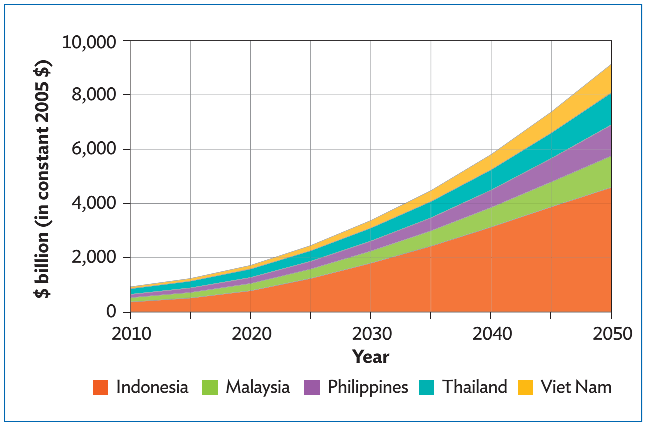
CH_4 = methane, CO_2 = carbon dioxide, FFI = fossil fuel industrial, F-gases = fluorinated gases, ICES = Intertemporal Computable Equilibrium System, $MtCO_2eq$ = million tons of carbon dioxide equivalent, N_2O = nitrous oxide, WITCH = World Induced Technical Change Hybrid.
Source: ADB Study Team.

Figure 15: Southeast Asia—Greenhouse Gas Emissions by Gas under Business-as-Usual Scenario



CH_4 = methane, CO_2 = carbon dioxide, FFI = fossil fuel industrial, F-gases = fluorinated gases, ICES = Intertemporal Computable Equilibrium System, $MtCO_2eq$ = million tons of carbon dioxide equivalent, N_2O = nitrous oxide, WITCH = World Induced Technical Change Hybrid.
Note: Rest of Southeast Asia includes Southeast Asian countries other than the DA5 (Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam).
Source: ADB Study Team.

Figure 16: Growth in Gross Domestic Product under the Business-as-Usual Scenario



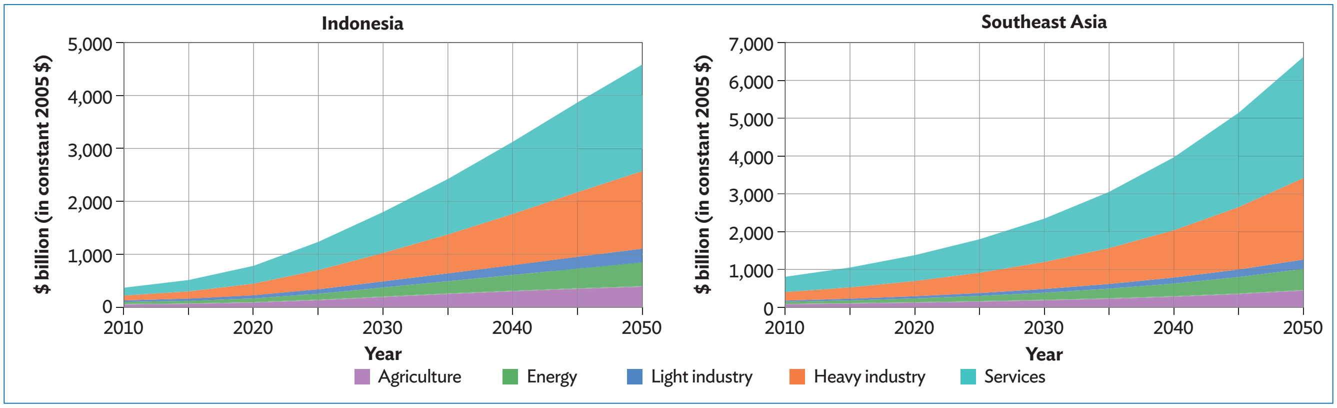
Source: ADB Study Team.

Southeast Asia has similar patterns, although energy has even faster relative growth.

In 2010, Indonesia accounted for approximately two-thirds of regional emissions. As a result of declining deforestation rates, this emissions rate does not grow as rapidly as those of other countries in the region, and Indonesia's share of regional emissions falls (Figure 18). Viet Nam has the most rapid emissions growth, whereas the other countries grow at similar rates.

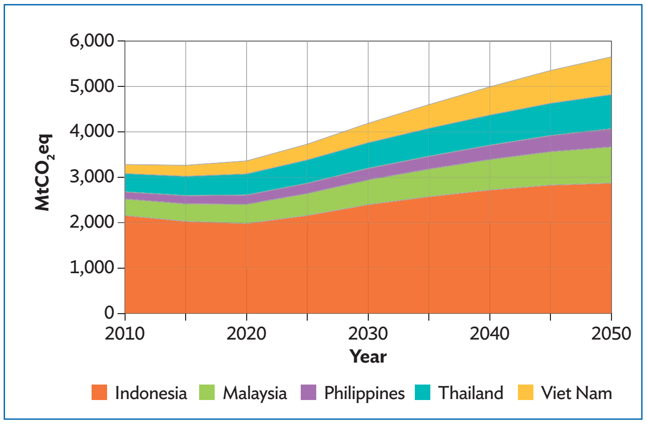
The effect of land-use emissions (all lumped here under "agriculture") is evident in Indonesia's emissions profile, where this accounts for nearly

Figure 17: Economic Growth by Sector in Indonesia and the Rest of Southeast Asia under the Business-as Usual-Scenario



Note: Rest of Southeast Asia includes Southeast Asian countries other than the DA5 (Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam).
Source: ADB Study Team.

Figure 18: Greenhouse Gas Emissions by Country under the Business-as-Usual Scenario

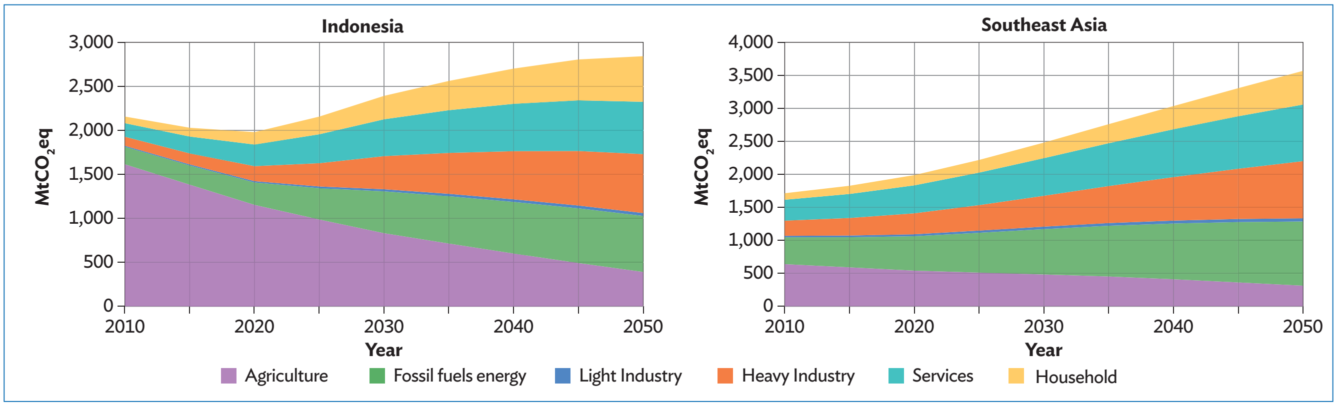


$MtCO_2eq$ = million tons of carbon dioxide equivalent.
Source: ADB Study Team.

three-quarters of 2010 emissions. Falling emissions from deforestation offsets other emissions growth until the late 2020s, when growing emissions from energy, industry, services, and households cause emissions to grow (Figure 19). The same pattern is evident to a lesser degree in the rest of Southeast Asia, where land-use emissions also decline to some degree, while energy, industrial, services, and household emissions rise rapidly.

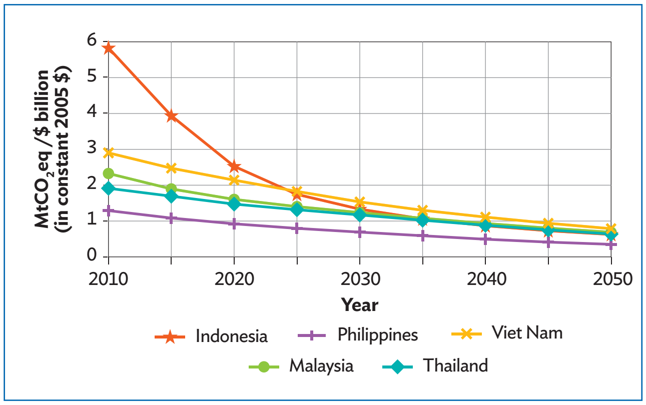
At the same time, GHG emissions intensity of economic activity is falling in all countries (Figure 20). The decline is most pronounced in Indonesia, as a result of declining land-use emissions, while economic growth is rapid. It is least pronounced

Figure 19: Sectoral Composition of Greenhouse Gas Emissions for Indonesia and the Rest of Southeast Asia under the Business-as-Usual Scenario



$MtCO_2eq$ = million tons of carbon dioxide equivalent.
Note: Rest of Southeast Asia includes Southeast Asian countries other than the DA5 (Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam)
Source: ADB Study Team.

Figure 20: Carbon Intensity of Gross Domestic Product under Business-as-Usual Scenario



$MtCO_2eq$ = million tons of carbon dioxide equivalent.
Source: ADB Study Team.

in the Philippines, where initial carbon intensity is already lowest.

4.2 Business-as-Usual Implies Substantial Climate Change Damage

The BAU emissions trends imply changes to GHG concentrations similar to RCP8.5, with attendant risks to the region. It is important to understand what the economic effects of inaction are likely to be, so as to be able to assess appropriate levels of action.

4.2.1 A computable general equilibrium approach offers new insights on climate change impacts

Although there are existing estimates of climate change impacts, previous literature on the impacts of climate change within Southeast Asia has not applied a CGE framework. Application of ICES adds value, because, unlike PAGE (used in ADB 2009) and other damage function approaches employed in integrated assessment models, ICES includes both interaction effects with the rest of the world as well as among sectors and markets within individual countries. Moreover, in the ICES model, the final economic implications of climate change are measured as changes in country GDP, relative to BAU, rather than damage costs. This allows the quantification of the effect of climate change on the ability of the economic system to produce goods and services in a manner that can be compared with the cost of climate action.

(i) *Recent studies on sea level rise, increased energy use, reduced tourism, and agricultural production losses are used as the bases of "market shocks"*

The approach taken is to use post-2009 literature to identify sector effects, which are applied as shocks in ICES to estimate "market impacts." These impacts include sea level rise, changes in energy-demand patterns, changes in crop yields, and changes in tourism flows. For the non-DA5 regions, all the impacts derive from a previous ICES climate change impact assessment reported in Bosello et al. (2012). For consistency with the referenced literature, initial impact estimates are based on the A1B IPCC Special Report on Emission Scenario, which projects for 2100 a median temperature increase of 3.5°C from preindustrial levels and falls between RCP6.0 and RCP8.5. The climate change impacts identified are translated into economic shocks against a no climate change reference scenario, as per Table 16.

For the DA5, climate shocks to energy demand and tourism use regional estimates from Bosello et al (2012) in combination with FUND2.9 from Tol (2009) to rescale the estimates nationally. Land loss from sea level rise is also taken from the FUND2.9 model (Anthoff et al. 2010). Changes in crop yields are derived from Nelson et al. (2010), using rice results to represent rice and weighted averages of other crop yield changes, according to crop physiological characteristics (not considering the possibility of a CO_2 fertilization effect).

When applied in ICES, changes in crop yields and in energy demand patterns produce macroeconomic consequences that are dampened by substitution within markets. Global interactions and substitution effects lead to some country-specific results that are slightly counterintuitive. For example, climate change leads to substitution of services for other types of goods, and this increased service demand benefits Viet Nam, even though the tourism subsector contracts. Similarly, for agriculture, larger relative production contraction in South Asia leads to output price increases that more than compensate Philippine agriculture for smaller production losses.

(ii) *Market losses are much higher than the world average*

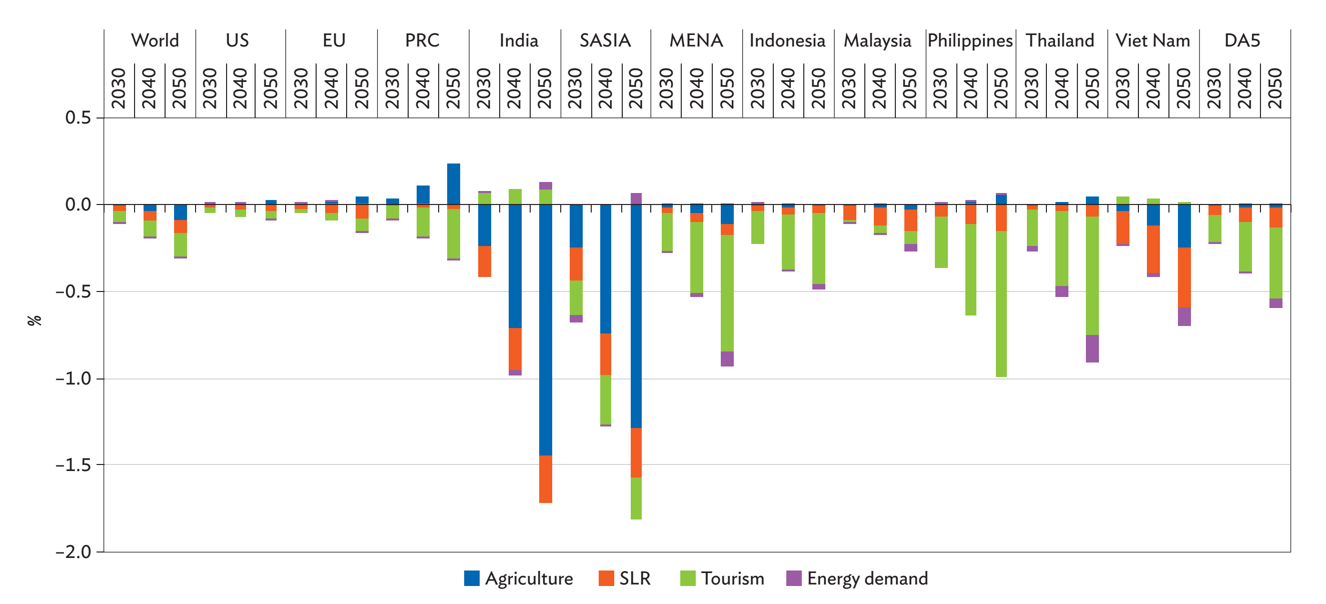
Figure 21 shows the climate change "market impact" on GDP of the DA5 in 2030, 2040, and 2050, indicating the relative importance of the different impacts considered. In 2050, climate change could cause a GDP loss of 0.6% in the DA5 aggregate, which is much higher than the global average and that experienced in more developed regions, such

Table 16: Climate Change Impacts in 2050, Change versus Business as Usual

	Energy Demand (% change)	Tourism (% change)	Tourism ($ billion)	Sea Level Rise (% change)	Agriculture (land productivity) (% change)		
Country	Electricity	Arrivals	Expenditure	Land + capital stock	Rice	Other Crops	Vegetable and fruits
Indonesia	11.49	(7.78)	(17.77)	(0.06)	(0.92)	0.08	1.50
Malaysia	12.21	(12.15)	(2.68)	(0.38)	2.68	(10.05)	(10.09)
Philippines	10.77	(12.23)	(7.61)	(0.20)	(2.71)	(0.94)	1.34
Thailand	13.62	(11.46)	(6.97)	(0.04)	(4.76)	0.54	(2.58)
Viet Nam	13.45	(11.77)	(4.51)	(0.73)	(5.24)	(5.17)	(5.24)

( ) = negative.
Source: ADB Study Team.

Figure 21: Gross Domestic Product Cost of Climate Change in the DA5 Countries and Major World Regions in 2030–2050 under the Special Report on Emission Scenario A1B



DA5 = Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam; EU = European Union; MENA = Middle East and North Africa; PRC = People's Republic of China; SASIA = South Asia; SLR = sea level rise; US = United States.
Source: ADB Study Team.

as the European Union and the United States.[4] The lowest losses are in Malaysia, while the highest are in the Philippines, with a GDP contraction of roughly 1% in 2050. In general, economic losses determined by changes in tourism flows tend to dominate other impacts and are of particular relevance in the Philippines and Thailand. This is due to the relatively high contribution of the sector to GDP. Land and capital losses induced by sea level rise follow, but this omits costs of lost infrastructure, forced migration, and displacement. At the same time, the DA5 demonstrate considerable differentiation in terms of vulnerabilities. For instance, sea level rise and decreases in crop yields are the most important drivers of economic losses in Viet Nam, while tourism is dominant in other countries and increased energy consumption needs are important in Thailand.

4.2.2 Additional nonmarket impacts add substantially to costs of inaction

Many nonmarket impacts are omitted from this analysis, such as increases in the risk of potentially catastrophic events, effects on labor productivity, and impacts on health and ecosystem services. Given that these effects are of a nonmarket nature, they are assessed outside of ICES to give a more complete analysis of the costs of inaction.

(i) *Increased catastrophic risk*

To include catastrophic risks, this study draws on Nordhaus (2007), which assesses catastrophic impacts in different world regions by weighting the scale of potential catastrophic outcomes with the probability of their occurrence for different levels of temperature increase. According to Nordhaus (2007), the A1B scenario leads to catastrophic losses equivalent to 0.86% of Southeast Asia's GDP in 2050.

(ii) *Lost labor productivity*

Under warming temperatures in the region, the number of hours during which temperatures exceed thresholds limiting physical labor will rise, causing labor either to need to be additionally cooled and/or altered in timing; or where this is not possible, for labor to be reduced, with potential effects on economic output. Kjellstrom et al. (2009) have provided estimates of labor lost by work intensity classes under 2050 climate projections for Southeast Asia. These labor losses have been applied to the DA5 based on the work intensity of labor in different sectors. The sectoral labor losses were reduced by 50% in industry and by 30% in services to account for cooling and timing substitution possibilities and were subsequently multiplied by employment elasticities of each sector to value added from Kapsos (2006) to approximate effects on 2050 GDP. This approach suggests an additional loss of 0.3% of GDP in Indonesia, 0.8% in Malaysia, 0.6% in the Philippines, 0.6% in Thailand and 0.5% in Viet Nam.

(iii) *Health and ecosystem losses*

Health and ecosystem losses are another set of nonmarket costs omitted from the above analysis. To reflect these, the analysis draws on ADB (2009), which reports nonmarket losses of 3.5% of GDP for the Southeast Asian region by 2100, and approximately 0.7% in 2050.

4.2.3 Integrated modeling of RCP8.5 through year 2100 shows large damage

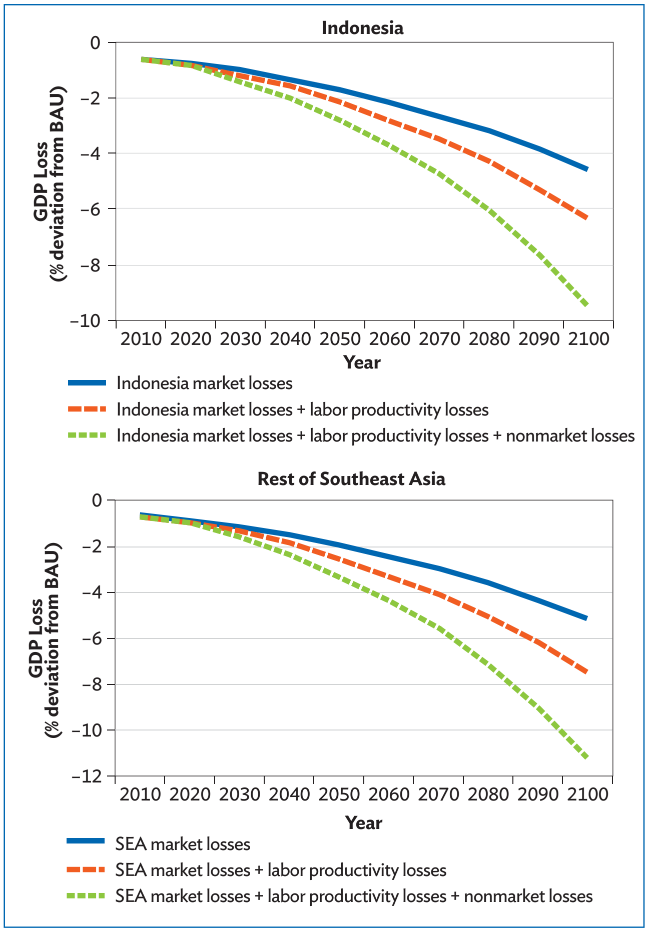
The ICES model can be applied only through 2050 and cannot directly estimate potential climate change losses beyond that time. However, reduced-form, climate-change damage impact functions relating losses to temperature increases can extend the analysis to longer periods. To explore longer-term impacts, this analysis reparameterized the reduced-form damage function estimated in Bosello and Parrado (2014) for Southeast Asia using the economic damage estimated through 2050.

With the reduced form damage function derived, it is possible to shift from the A1B emissions scenario to scenarios that are more consistent with the

[4] This value is also notably larger than that reported by the PAGE model in ADB (2009) for market impact (roughly 0.25% of GDP in 2050).

BAU emissions trajectory of ICES and WITCH. To do so, the analysis refers to RCP8.5, which has a similar emissions trajectory to the BAU scenario of this study. Application of the damage function to RCP8.5 finds much higher costs of inaction than ADB (2009) (Figure 22). Total costs to Indonesia are found to be nearly 10% of GDP by 2100, while the rest of Southeast Asia would face 11% GDP loss. By 2050, 3% of GDP could already be lost across the region. These results illustrate that future economies in the region will be heavily influenced by whether GHG emissions are stabilized under a global climate agreement.

Figure 22: Climate Change Impacts in Indonesia and the Rest of Southeast Asia under RCP8.5



BAU = business as usual, GDP = gross domestic product, RCP = representative concentration pathway, SEA = Southeast Asia.
Source: ADB Study Team.

4.3 Emissions Mitigation Scenarios

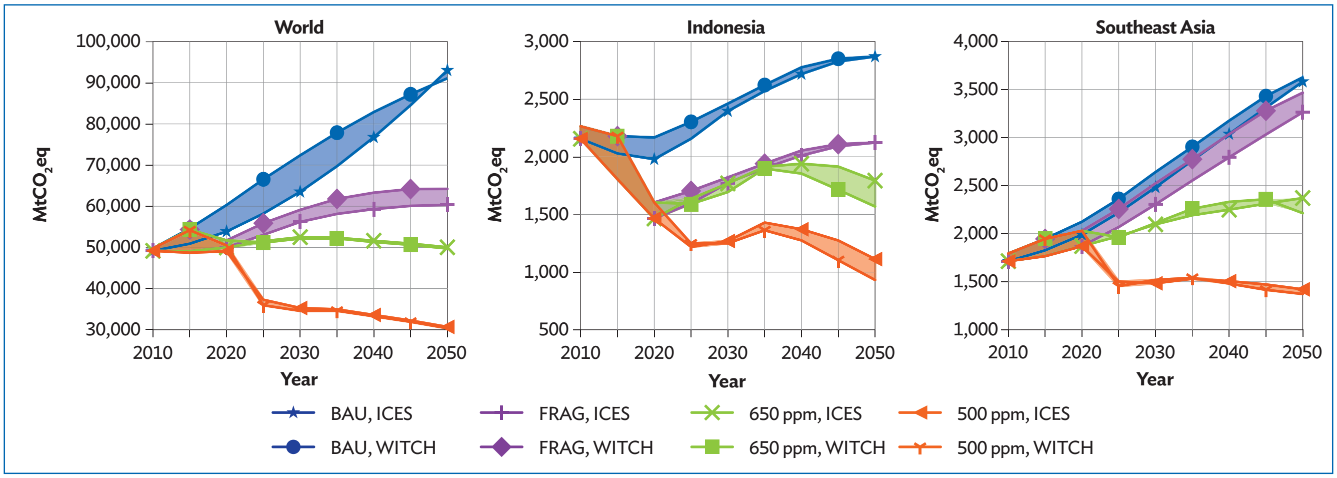
This section discusses the main results of the analysis of the different climate change mitigation policies. It provides a detailed comparison of ICES and WITCH model results at the regional level. Disaggregated national results available only from ICES are discussed in subsequent sections. The scenarios analyzed in this section were described in detail in Chapter 3.

4.3.1 Substantial mitigation is needed for climate stabilization

Greenhouse gas emissions in the BAU scenario are expected to rapidly rise through 2050 (Figure 23). Containing global warming in the modeled scenarios requires strong action both globally and within the region. As shown in Figure 23, the 650 ppm scenario depicts a global stabilization of emissions at 2010 levels, while the 500 ppm case represents a more pronounced emission reduction to 40% less than 2010 global levels by 2050.

For Indonesia, all scenarios illustrate a 26% emissions drop by 2020, in accordance with its Copenhagen pledge. From that point forward, the 650 scenario shows a relatively constant emissions rate, while 500 finds an additional 30% decline in emissions. Indonesia's fragmented scenario is similar to 650 through 2040, while after, there is some divergence. For the rest of Southeast Asia, the fragmented scenario turns out to be similar to BAU and the 650 scenario finds continued emissions growth by 50% between 2010 and 2050. In contrast, 500 ppm stabilization leads to a 25% emissions decline.

Figure 23: Greenhouse Gas Emissions Pathways for the World, Indonesia, and the Rest of Southeast Asia

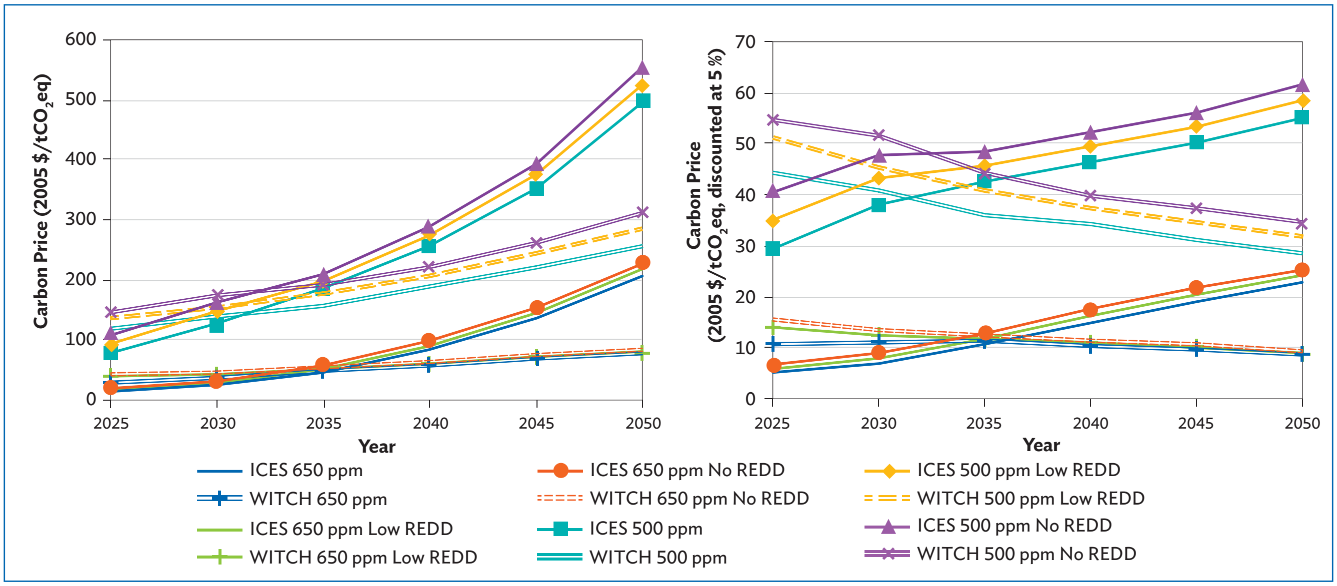


BAU = business as usual, FRAG = fragmented (policy), ICES = Intertemporal Computable Equilibrium System, $MtCO_2eq$ = million tons of carbon dioxide equivalent, ppm = parts per million, WITCH = World Induced Technical Change Hybrid.
Source: ADB Study Team.

4.3.2 Moderate carbon prices are needed to trigger abatement

Emission reduction presented above are triggered by sufficient prices in the global carbon market. Figure 24 shows the evolution over time of the international carbon price for the 650 ppm and 500 ppm scenarios. The models show a high level of agreement over carbon prices in the medium term and indicate substantial differences across policy scenarios. The 650 ppm stabilization scenario results in global prices that are about one-third of those in the 500 scenario. In the

Figure 24: International Carbon Prices Modeled without Discounting and Discounted at 5%



ICES = Intertemporal Computable Equilibrium System, ppm = parts per million, tCO_2eq = ton carbon dioxide equivalent, WITCH = World Induced Technical Change Hybrid. No REDD = no reducing emissions from deforestation and forest degradation.
Source: ADB Study Team.

former, prices remain below \$50–\$80/ton of CO_2 equivalent (tCO_2eq) until the late 2030s, whereas in the latter, prices will already exceed \$100/tCO_2e by the mid-2020s. While these values may appear to be high in absolute terms, they actually are increasing more slowly than economic growth in many cases. If a 5% discount rate is applied, which is less than the DA5 GDP growth rate over the period, carbon prices under WITCH are actually falling, and carbon prices under ICES experience only moderate growth. The exclusion or inclusion of REDD affects the price level for a given scenario, but it has little effect on the trajectory of carbon price development.

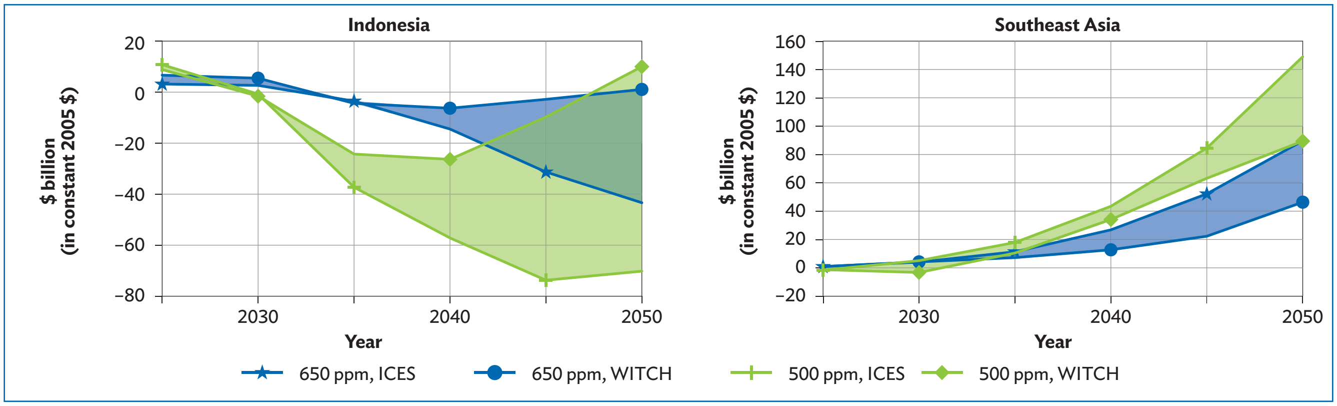
4.3.3 Southeast Asia benefits from a global carbon market

These prices form the mechanism that triggers a global abatement response to achieve the defined emissions cap. Within each country, the abatement triggered is conditioned by carbon trade. Figure 25 shows the trading of CO_2 permits that results from the "contraction and convergence" permit allocation applied in this study. The rest of Southeast Asia is found to face lower costs to meet climate targets than the rest of the world, and thus exports emissions permits across all scenarios, with more exports under the more stringent 500 ppm scenario.

However, Indonesia's carbon trade is more variable and dependent on the role of land use. With REDD, it is initially an exporter of emissions permits, and has modest imports after 2030 (Figure 25). In the absence of REDD, however, it is a major importer for the entire period, as sufficient abatement cannot be achieved domestically to stay within emissions allowances (Figure 26).

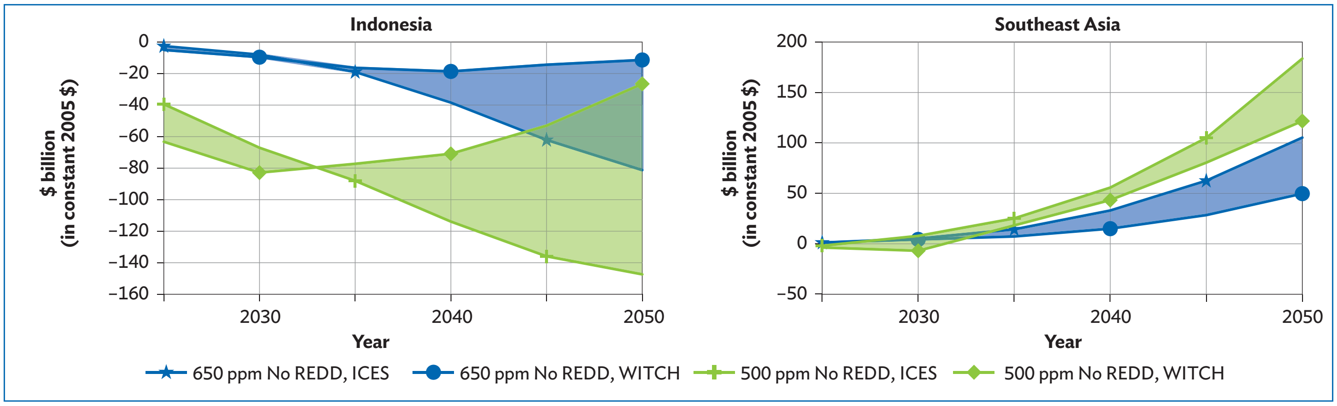
The global carbon market allows emission reductions to be achieved for the DA5 at lower costs than were each country to abate independently, as abatement can occur where it is most efficient. As a sensitivity test, the ICES model was run under the 500 ppm full REDD scenario without global carbon trade. This finds that the net present value of 2010 to 2050 policy costs for emission reduction in the DA5 rise by 32%–53% if trade is absent, and a 13% higher average discounted carbon price is required for the countries to comply with their emissions allowances than is the case when global emissions trade occurs (Figure 27).

Figure 25: Carbon Trade for Indonesia and the Rest of Southeast Asia with REDD Scenario



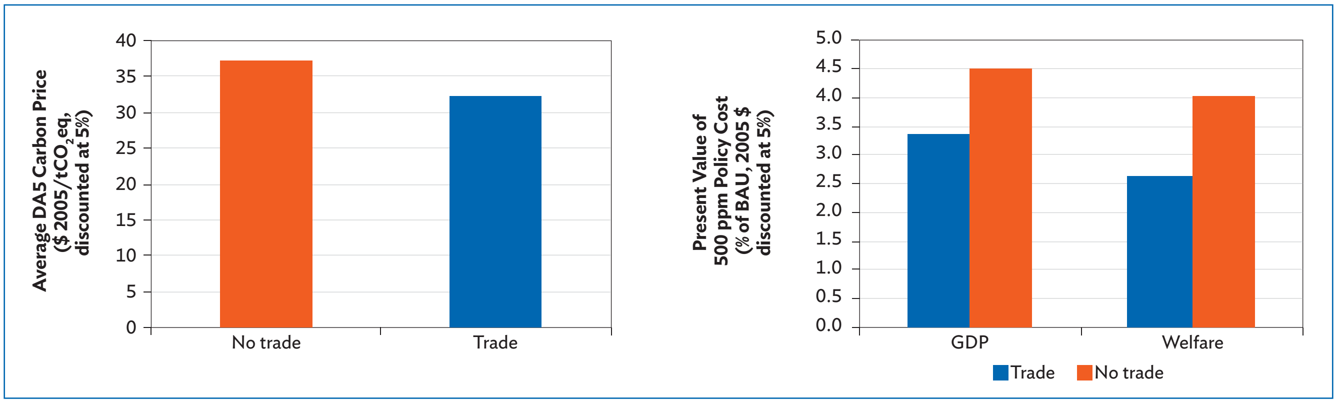
ICES = Intertemporal Computable Equilibrium System, ppm = parts per million, WITCH = World Induced Technical Change Hybrid.
Source: ADB Study Team.

Figure 26: Carbon Export Projections for Indonesia and the Rest of Southeast Asia, No REDD Scenario



ICES = Intertemporal Computable Equilibrium System, ppm = parts per million, REDD = reducing emissions from deforestation and forest degradation, WITCH = World Induced Technical Change Hybrid.
Source: ADB Study Team.

Figure 27: Average 500 ppm 2010–2050 Discounted Carbon Price and Discounted Policy Costs with and without Global Carbon Trade



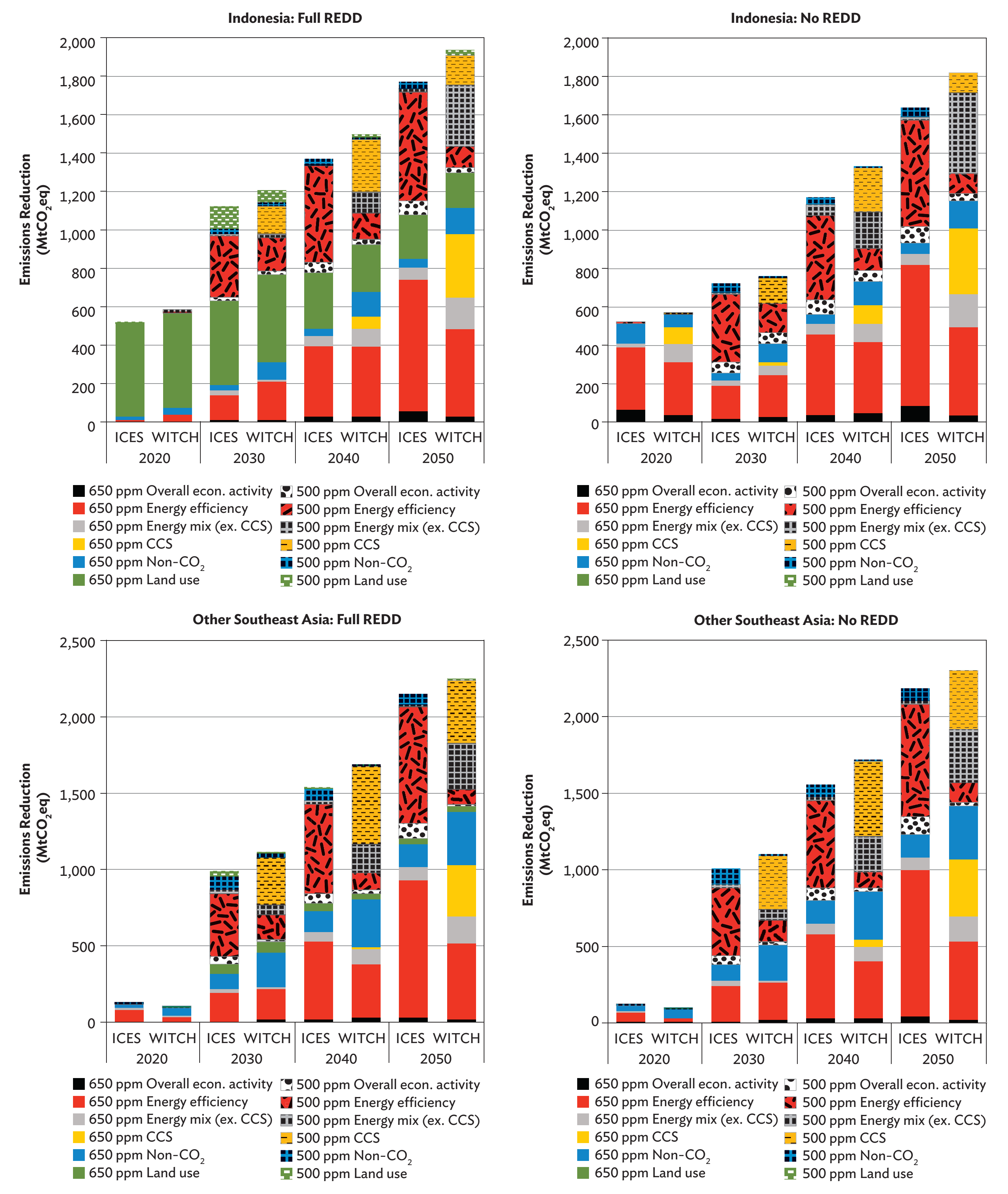
BAU = business as usual; CO_2eq = carbon dioxide equivalent; DA5 = Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam; GDP = gross domestic product; ppm = parts per million.
Note: Results from Intertemporal Computable Equilibrium System model. Scenario includes reducing emissions from deforestation and forest degradation.
Source: ADB Study Team.

4.3.4 Energy efficiency, low-carbon energy, and land-use drive abatement responses to carbon prices

These emission reductions are achieved via three main effects triggered by carbon markets: (i) increasing the efficiency of energy usage, (ii) replacing carbon-intensive fuels with cleaner alternatives, and (iii) reducing land-use emissions. Figure 28 reports sources of reductions under the stabilization scenarios.

Prior to 2040, when REDD is included in the scenarios, it accounts for more than half of abatement in Indonesia under both global stabilization scenarios, and accounts for about 10%–15% abatement for the rest of Southeast Asia by 2030. About half of emissions abatement aggregated across both regions through the mid-2030s arises from REDD. In Indonesia, the presence of REDD also increases abatement substantially, particularly in the period around 2030 and the 650 ppm scenario, where abatement is doubled. REDD makes a greater contribution to emission reduction than renewable energy in Indonesia for the entire period and in the rest of Southeast Asia prior to 2040.

Figure 28: Emission Reduction by Source under Stabilization Scenarios



CCS = carbon capture and storage, CO_2 = carbon dioxide, econ. = economic, ICES = Intertemporal Computable Equilibrium System, $MtCO_2eq$ = million tons of carbon dioxide equivalent, ppm = parts per million, REDD = reducing emissions from deforestation and forest degradation, WITCH = World Induced Technical Change Hybrid.
Note: Non-CO_2 refers to emission reduction from methane and other Kyoto gases, which are emitted largely from agriculture.
Source: ADB Study Team.

The largest single source of cumulative emission reductions over 2010–2050 is energy efficiency gains, under all scenarios and models when emissions are aggregated across Indonesia and the rest of Southeast Asia. This is particularly pronounced in the rest of Southeast Asia and under ICES, where it is the main mechanism for the energy sector to reduce emissions. In ICES, energy efficiency is the source of a rising share of emission reduction over the period, whereas in WITCH, its share is generally stable or declining in all cases other than Indonesia in the presence of REDD.

Emission reductions attributable to fundamental changes in energy production technologies only become dominant in 2050 under 650 ppm stabilization modeled in WITCH. Over the longer term, more advanced "backstop" technologies that are not yet economically viable and with uncertain development potential come into play. One such advanced "backstop" technology is carbon capture and storage (CCS), in which emitted GHGs are dissolved in a solvent and transported for underground storage. Another is advanced biofuel, which permits the use of agricultural residues, or microbes for fuel with zero net emissions.

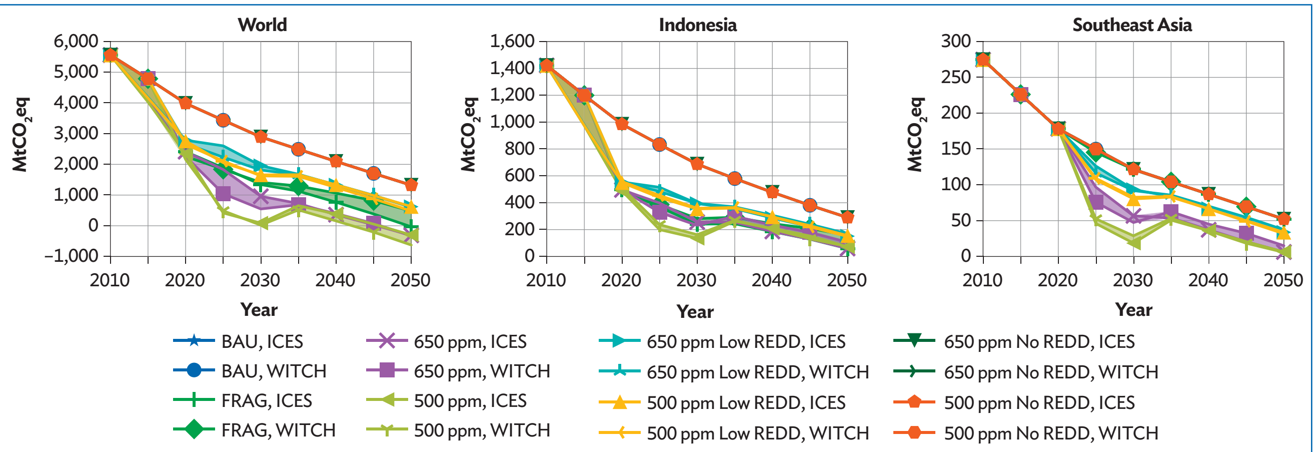
Under 500 ppm stabilization, emission reductions from these technologies occur more quickly. The combination of CCS and substitution of renewable sources (termed "energy mix" here) for fossil fuel energy becomes dominant in Indonesia after 2040 and in the rest of Southeast Asia after 2030 both under WITCH. ICES finds similar energy sector shares of emission reductions to WITCH, but generally relies on increased energy efficiency to substitute for the role of CCS and more renewable sources.

Renewable energy contributes less to emission reduction than does CCS when present in the models. In the rest of Southeast Asia, renewables also contribute less than non-CO_2 reductions, which principally take place in agriculture, in all periods under 650 ppm stabilization and prior to 2050 in the 500 ppm stabilization. Renewable energy begins to play as great a role as CCS when present in Indonesia only in 2050 under the 500 ppm stabilization scenario.

4.3.5 Land-use emissions drop strongly under all stabilization scenarios

Figure 29 provides an overview of net land-use emissions for the world, for Indonesia, and for the rest of Southeast Asia. Reducing emissions from land use via REDD is critical to emissions abatement, especially in through 2030. Global land-use emissions fall to nearly zero by 2030 in the 500 ppm scenario, and are significantly mitigated in the other scenarios. A similar pattern is found for Indonesia and the rest of Southeast Asia, although the pattern is more

Figure 29: Net Land-Use Emissions Projections for the World, Indonesia, and the Rest of Southeast Asia



BAU = business as usual, FRAG = fragmented (policy), ICES = Intertemporal Computable Equilibrium System, $MtCO_2$ = million tons of carbon dioxide, ppm = parts per million, REDD = reducing emissions from deforestation and forest degradation, WITCH = World Induced Technical Change Hybrid.
Source: ADB Study Team.

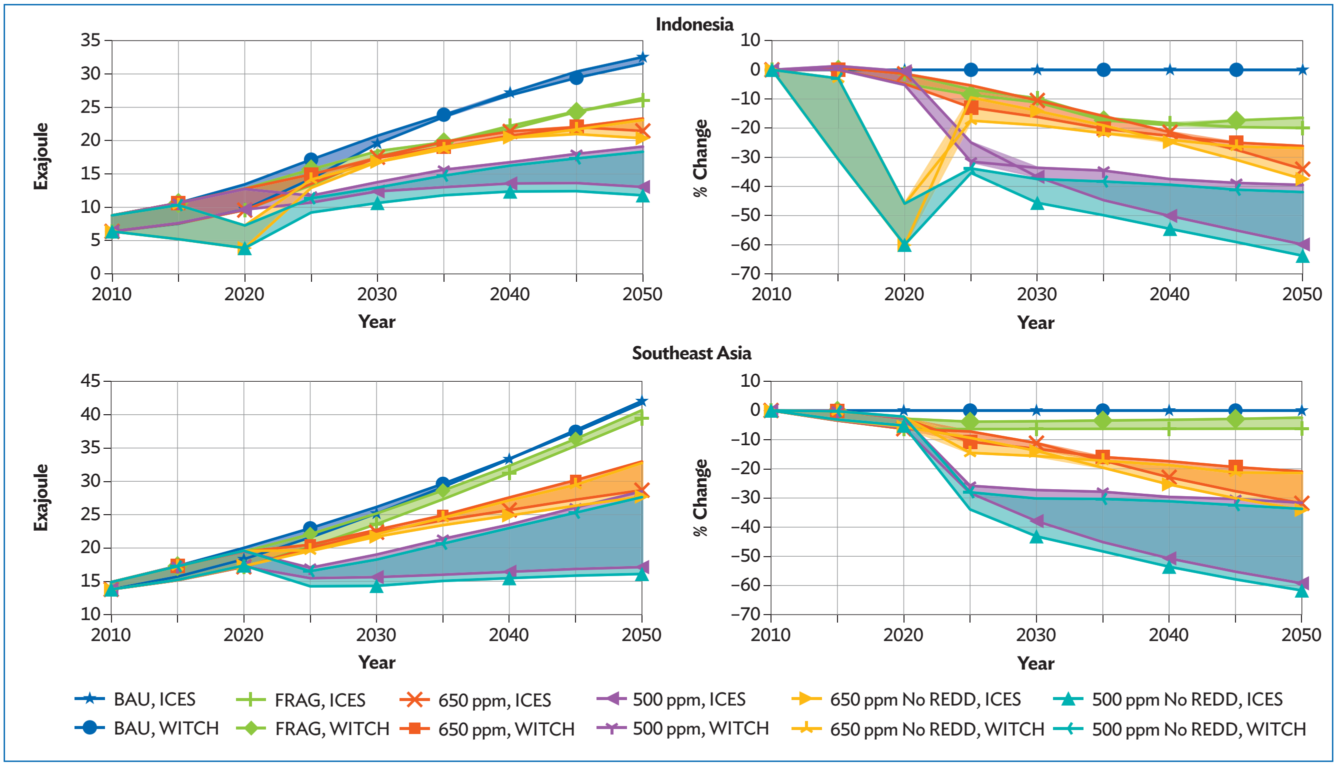
pronounced in Indonesia. For Indonesia, land-use emissions by 2020 are halved with respect to BAU as a result of its Copenhagen pledge. The quantity of Indonesia's emission reductions from REDD is relatively insensitive to a higher costing for REDD (termed "Low REDD" in the figure). For Indonesia and the rest of Southeast Asia, land-use emissions are expected to fall below 200 $MtCO_2$ and 50 $MtCO_2$ in 2030, respectively, and close to zero by mid-century.

4.3.6 Energy sector transformation drives long-term abatement

Achieving the transformations depicted in previous sections will require commensurate changes in the way energy is consumed and produced. As highlighted in Figure 30, energy consumption grows at a much smaller rate under climate stabilization scenarios than under the BAU scenario. The fragmented scenario also results in a decrease of 20% of Indonesian energy consumption by 2050. However, the weaker commitments of the rest of Southeast Asia make this scenario much closer to the BAU. The more stringent 500 ppm scenario requires considerable energy savings for both regions, especially in the ICES model.

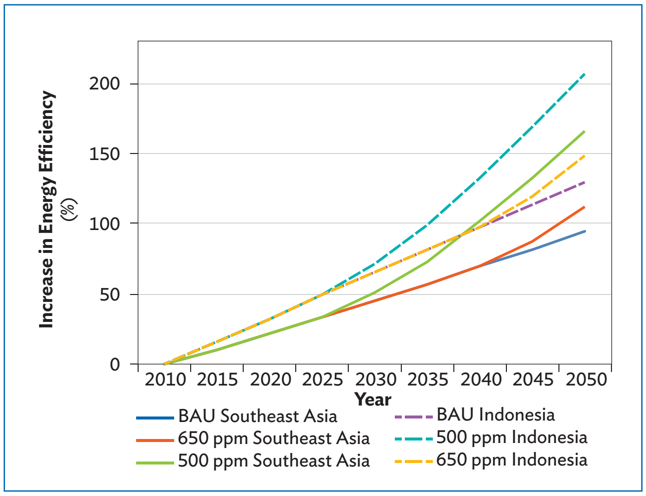
Much of this reduction in energy use is driven by energy efficiency, both as a directly induced response to climate policies, as well as an indirect response through induced technological improvement. Under BAU, energy efficiency improves at 1%–2% annually. Climate stabilization policies accelerate this improvement to 2%–3% annually (Figure 31).

Figure 30: Primary Energy Consumption



BAU = business as usual, FRAG = fragmented policy, ICES = Intertemporal Computable Equilibrium System, ppm = parts per million, REDD = reducing emissions from deforestation and forest degradation, WITCH = World Induced Technical Change Hybrid.
Note: 1 exajoule = 277,777,778 megawatt-hours. All percent changes are with respect to BAU.
Source: ADB Study Team.

Figure 31: Energy Efficiency Improvement under Full REDD Scenarios



BAU = business as usual, ppm = parts per million, REDD = reducing emissions from deforestation and forest degradation.
Source: ADB Study Team.

Figure 32 portrays the evolution of the primary energy mix across scenarios and models. The figure illustrates a gradual transition toward cleaner forms of energy, particularly under the more stringent scenarios. In the 500 ppm scenario, Indonesia's traditional coal use is reduced by at least 65% from 2020 to 2035 and nearly disappears by 2050. Gas also declines under the 650 and 500 ppm stabilization scenarios relative to BAU. In contrast, the share of oil remains substantial, especially in ICES, but declines in absolute values, given that overall energy use falls. Similar trends are found for the rest of Southeast Asia, although hydropower is more important in the stabilization scenarios.

In all WITCH scenarios, traditional biomass is phased out in both Indonesia and the rest of Southeast Asia. In BAU, it is replaced mainly by fossil fuels, but in the stabilization scenarios, fossil fuels are replaced by other cleaner sources, including modern biofuels, as well as non-biomass renewables, such as solar, wind, and hydropower. A portion of the fossil fuels is also expected to transition to CCS, and this transition is much stronger under the 500 ppm scenario than under 650 ppm, where CCS has later adoption. Under climate stabilization, CCS is adopted in the rest of Southeast Asia more rapidly than in the world primary energy mix, whereas in Indonesia, bioenergy expands more rapidly.

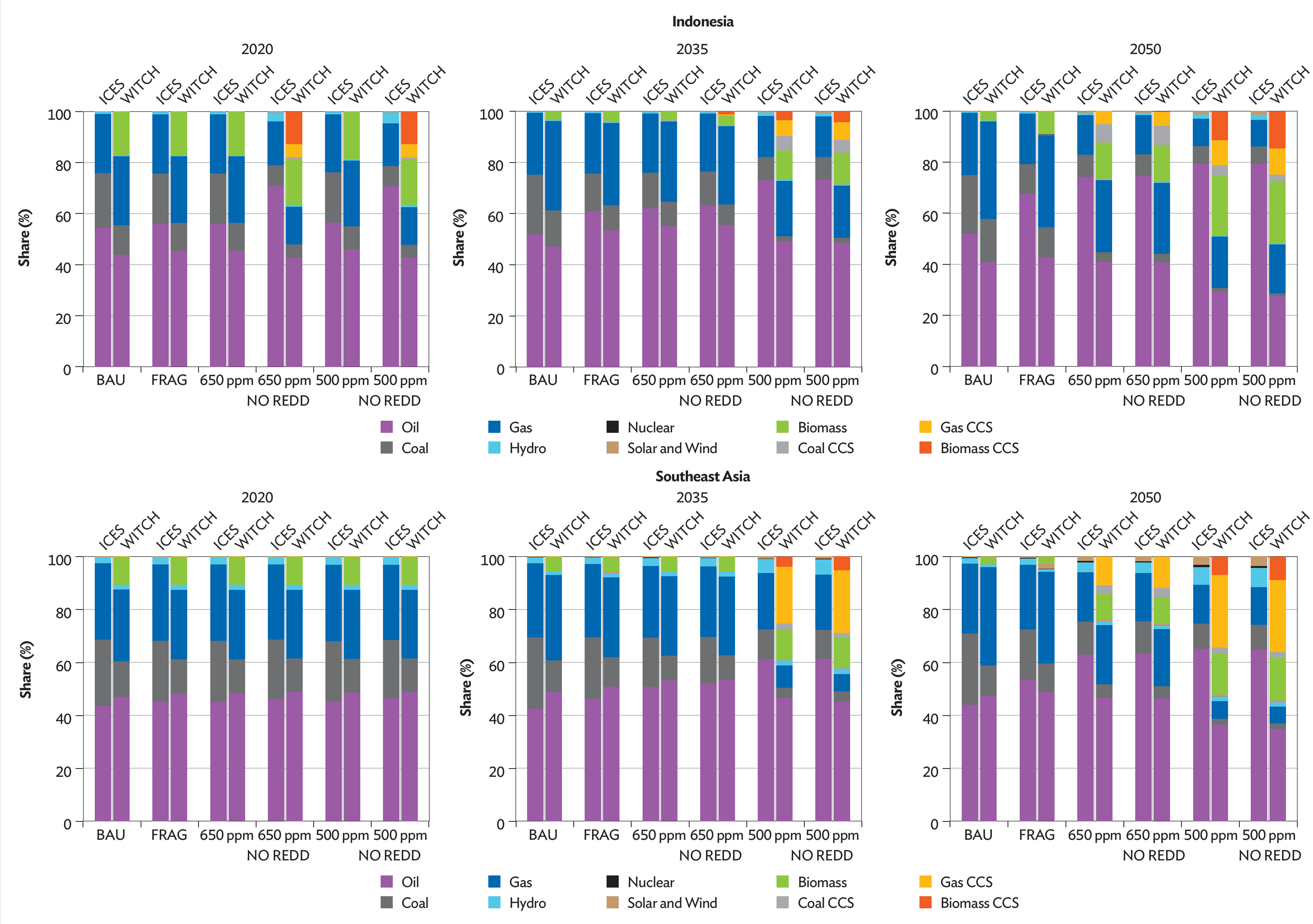
4.3.7 Advanced energy technologies require research investment

Advanced technologies in WITCH require extensive research to become commercially available. Climate policies make technological improvements to reduce emissions economically attractive, and thereby induce innovation. In WITCH, this mechanism is modeled for two key decarbonization options: low-carbon fuel in the transportation sector (advanced biofuels) and CCS.

Figure 33 shows the evolution of investments in clean energy research and development (R&D) for the world, as well as for Indonesia and the rest of Southeast Asia. Globally, R&D investments scale up very rapidly, especially for low-carbon fuels, given the difficulty in decarbonizing the transportation sector. A failure to do so early enough may lock in the energy system to more costly decarbonization pathways, especially when steeper emission reduction rates are required. Investments in energy efficiency would need to scale up over time more gradually than advanced biofuels, reflecting the difference between the marginal technological improvements of the former and the breakthrough innovation feature of the latter.

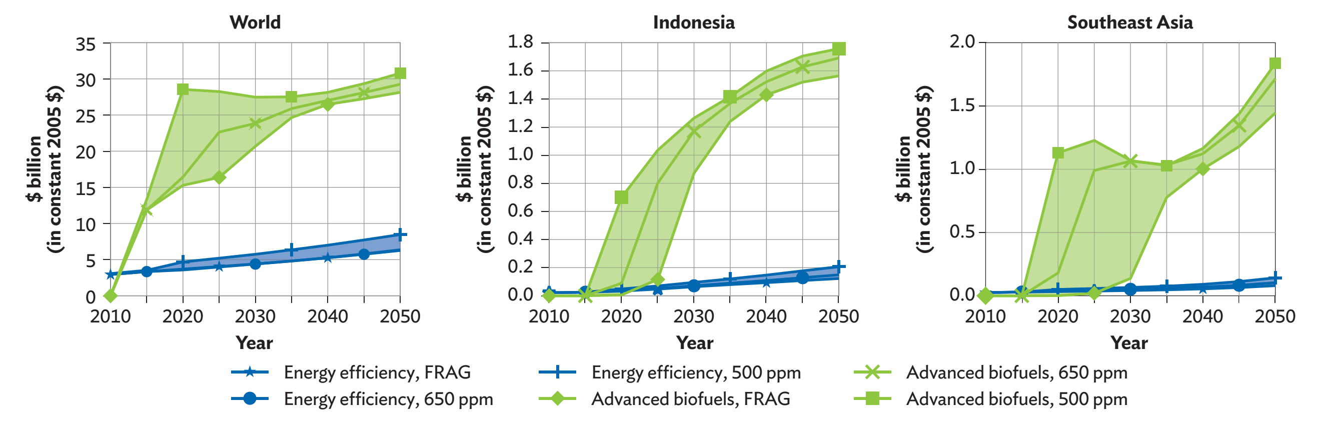
WITCH indicates that both Indonesia and the rest of Southeast Asia need their own R&D investments to make use of global technological advances. Although these would be a fraction of global investments, they are crucial in equipping the rest of Southeast Asia with the knowledge necessary to absorb advances in technology from the rest of the world. The different climate stabilization scenarios influence more the timing than the scale of R&D investment. The 500 ppm scenario leads R&D investment to be advanced by 10–15 years compared with the fragmented scenario. Even though this is a significant change from the status quo, such R&D figures remain below 0.05% of GDP through 2050.

Figure 32: Energy Mix Projections under Climate Stabilization Scenarios



BAU = business as usual, CCS = carbon capture and storage, FRAG = fragmented (policy), ICES = Intertemporal Computable Equilibrium System, ppm = parts per million, REDD = reducing emissions from deforestation and forest degradation, WITCH = World Induced Technical Change Hybrid.
Source: ADB Study Team.

Figure 33: Research and Development Investments Using the World Induced Technical Change Hybrid Model for the World, Indonesia, and the Rest of Southeast Asia



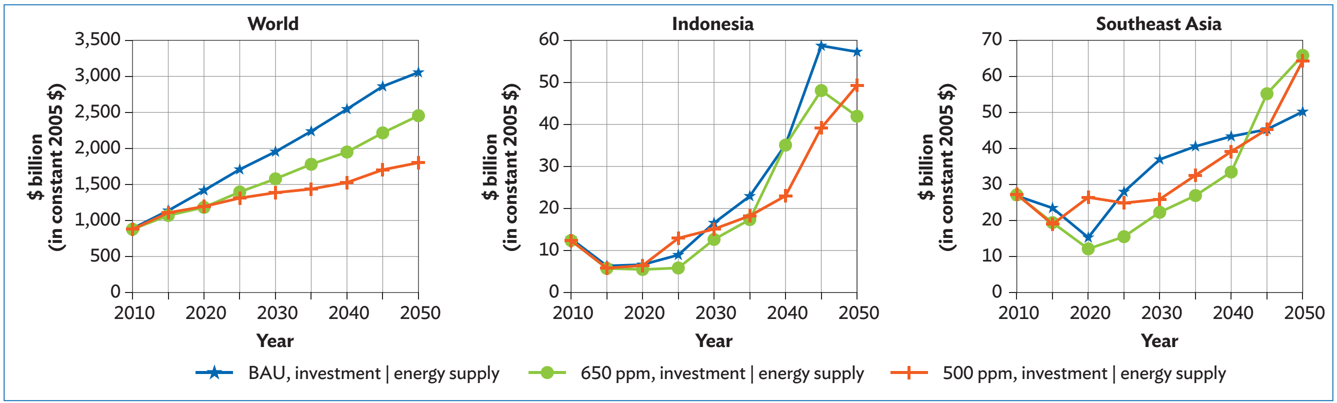
FRAG = fragmented (policy), ppm = parts per million.
Source: ADB Study Team.

4.3.8 Investment in low-carbon power matches divestment in fossil fuels

Figure 34 shows WITCH results in terms of total investments in the energy sector. These include both investments in energy extraction, as well as investments in electricity generation technologies. Across scenarios, energy supply investments increase over time, with annual needs on the order of $35 billion–$52 billion by 2030, and $107 billion–$115 billion by 2050, in both Indonesia and the rest of Southeast Asia.

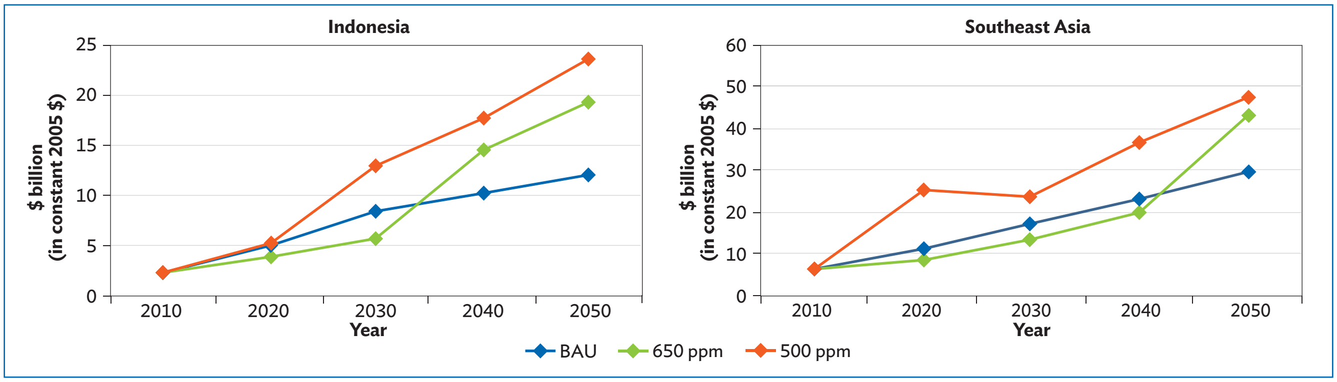
The similarity of the overall pattern across scenarios is driven by opposing forces, which have a net balancing effect. Climate policies significantly reduce the investments in extraction of fossil fuels, such as oil, gas, and coal, which are about half of the total energy sector investments. On the other hand, power generation investments increase, given the higher investment costs of low-carbon technologies, such as renewables and CCS. Figure 35 shows that by 2050, Indonesia would need to invest $12 billion extra annually in power generation, while the rest of Southeast Asia needs an additional $18 billion annually under the 500 ppm scenario, compared with BAU. These investment trends are robust across the different assumptions about availability of REDD.

Figure 34: Investments in Total Energy Supply across Scenarios and Regions Using the World Induced Technical Change Hybrid Model, Indonesia, and the Rest of Southeast Asia



BAU = business as usual, ppm = parts per million.
Source: ADB Study Team.

Figure 35: Investments in Power Generation across Full REDD Scenarios and Regions from the World Induced Technical Change Hybrid Model



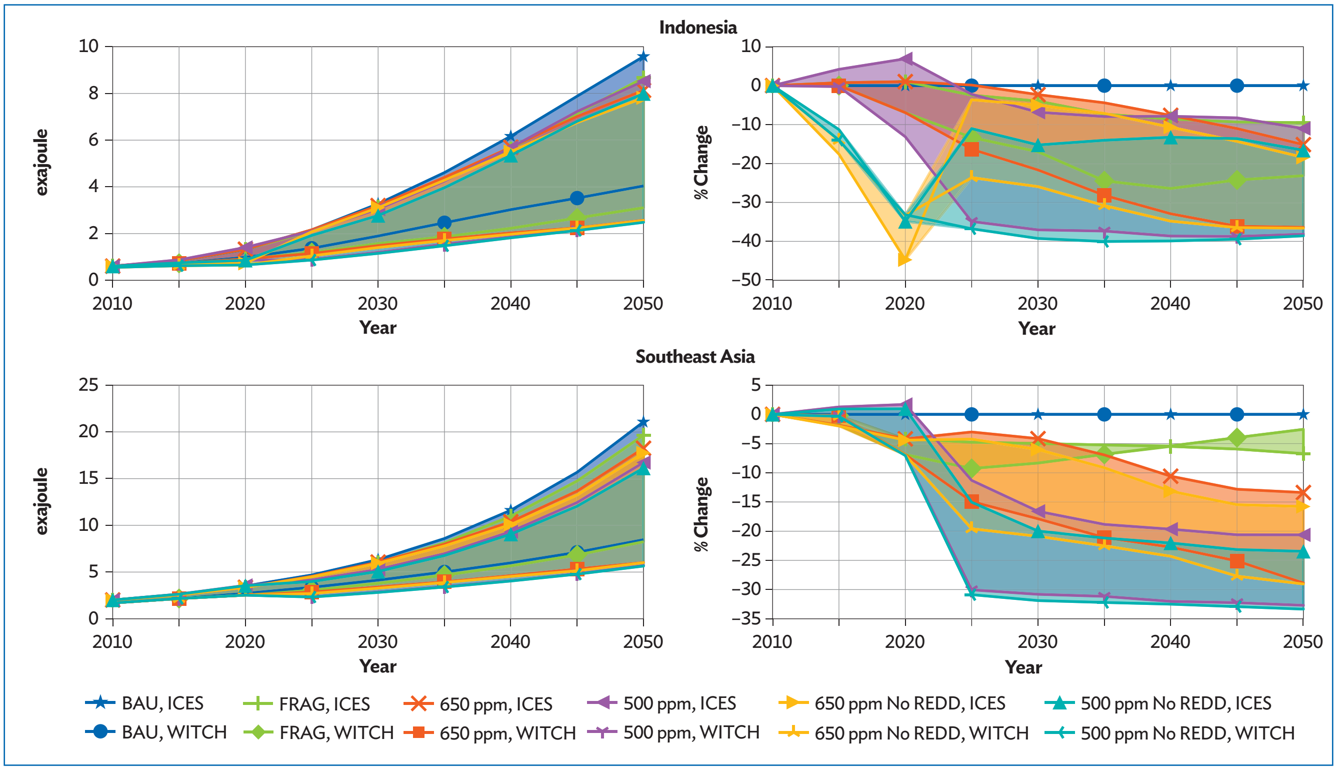
BAU = business as usual, ppm = parts per million, REDD = reducing emissions from deforestation and forest degradation.
Source: ADB Study Team.

4.3.9 The electricity sector has large changes due to climate policies

Both models find reduced growth in electricity consumption under climate stabilization scenarios (Figure 36), although this reduction is less than is the case for primary energy. The reduction is much more pronounced in WITCH than in ICES, due to differences in representation of the sectors and induced efficiency responses.

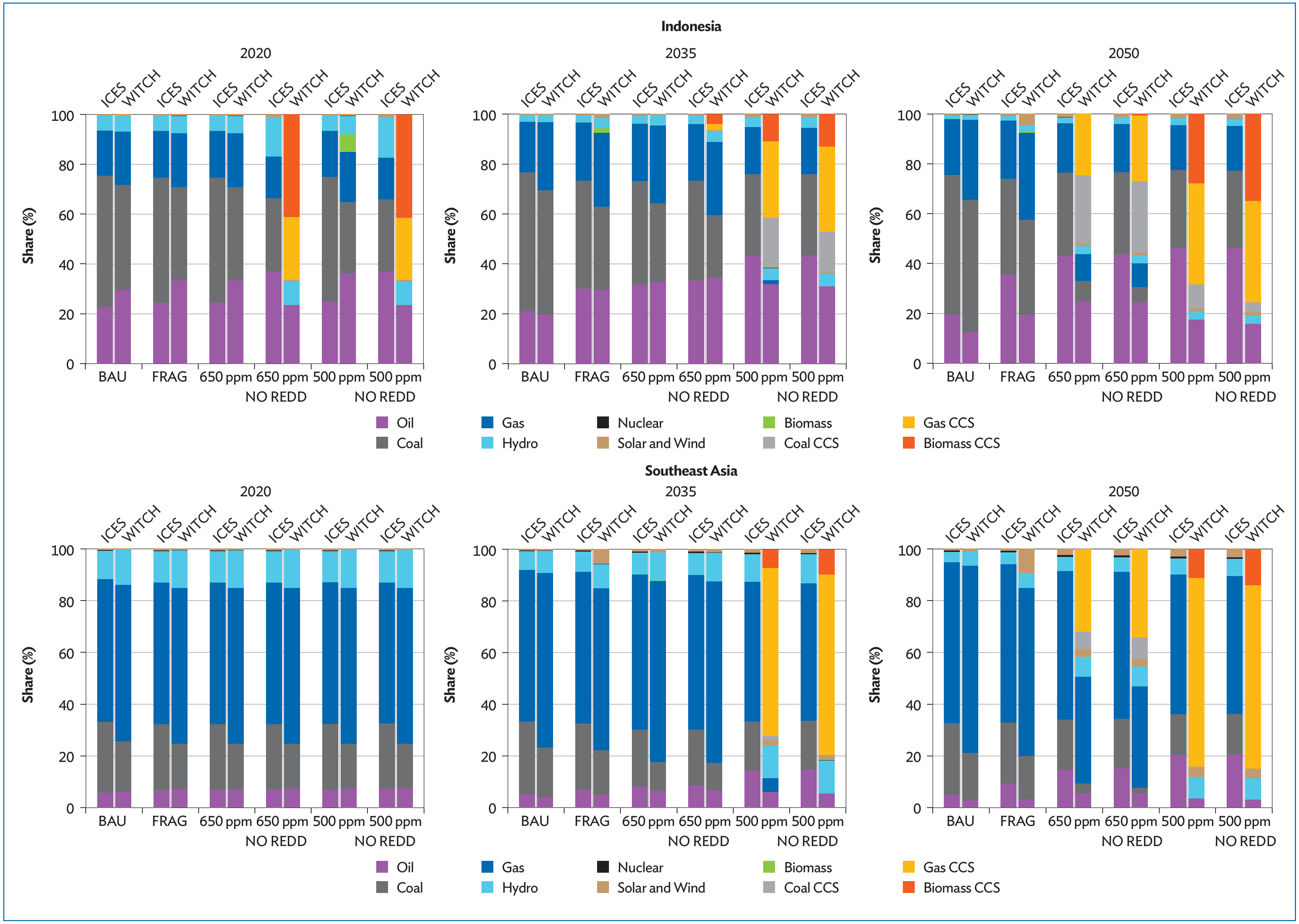
WITCH finds that the electricity mix evolves from 80% to 90% sourced in 2010 from fossil fuels without CCS, to 50%–70% of electricity from gas and coal

Figure 36: Electricity Consumption Response to Climate Stabilization Scenarios



BAU = business as usual, FRAG = fragmented policy, ICES = Intertemporal Computable Equilibrium System, ppm = parts per million, REDD = reducing emissions from deforestation and forest degradation, WITCH = World Induced Technical Change Hybrid.
Note: All percent changes are with respect to BAU.
Source: ADB Study Team.

Figure 37: Electricity Mix Projections under Climate Stabilization Scenarios



BAU = business as usual, CCS = carbon capture and storage, FRAG = fragmented (policy), ICES = Intertemporal Computable Equilibrium System, ppm = parts per million, REDD = reducing emissions from deforestation and forest degradation, WITCH = World Induced Technical Change Hybrid.
Source: ADB Study Team.

combined with CCS in 2050 in the 500 ppm scenario (Figure 37). Natural gas with CCS potentially plays an important role in transitioning away from coal, which would become less than 10% of the electricity mix in 2050 under the 500 ppm case. The use of CCS for power generation from modern biomass is included in the 500 ppm scenario, reaching 29% and 11% of electricity in Indonesia and Southeast Asia, respectively, by 2050.

4.3.10 Policy costs depend on REDD and advanced energy technologies

Figure 38 presents the effects of the climate policy scenarios on GDP. As can be seen in the contrast between scenarios with and without REDD, policy costs through 2035 greatly depend on avoided forest destruction, especially in Indonesia. In the presence of REDD, 500 ppm stabilization leads to negligible effects on GDP in WITCH through 2030, even if REDD is high cost, whereas the absence of REDD causes GDP to experience relatively large drops to comply with emissions targets. This is particularly true through 2020, as the country tries to fulfill its Copenhagen pledge through energy sector measures alone. The rest of Southeast Asia is also somewhat sensitive to REDD through its effect on carbon permit prices, although the effect is smaller.

Globally, due to the inefficiency of a fragmented policy regime, the fragmented policy generates midterm GDP losses similar to the 650 ppm case, despite achieving lower emission reductions. For Indonesia and the rest of Southeast Asia, both policies yield relatively small losses of value added. The more aggressive 500 ppm stabilization policy causes greater GDP cost, but there is more disagreement among the models. In particular, there is a high divergence in costs after 2035, with ICES presenting larger GDP losses. This is due to the detailed and endogenous modeling of technological change in WITCH and richer description of the energy sector. As energy demand increases over time in the models, WITCH's extra flexibility allows costs to be much better contained, compared with ICES.

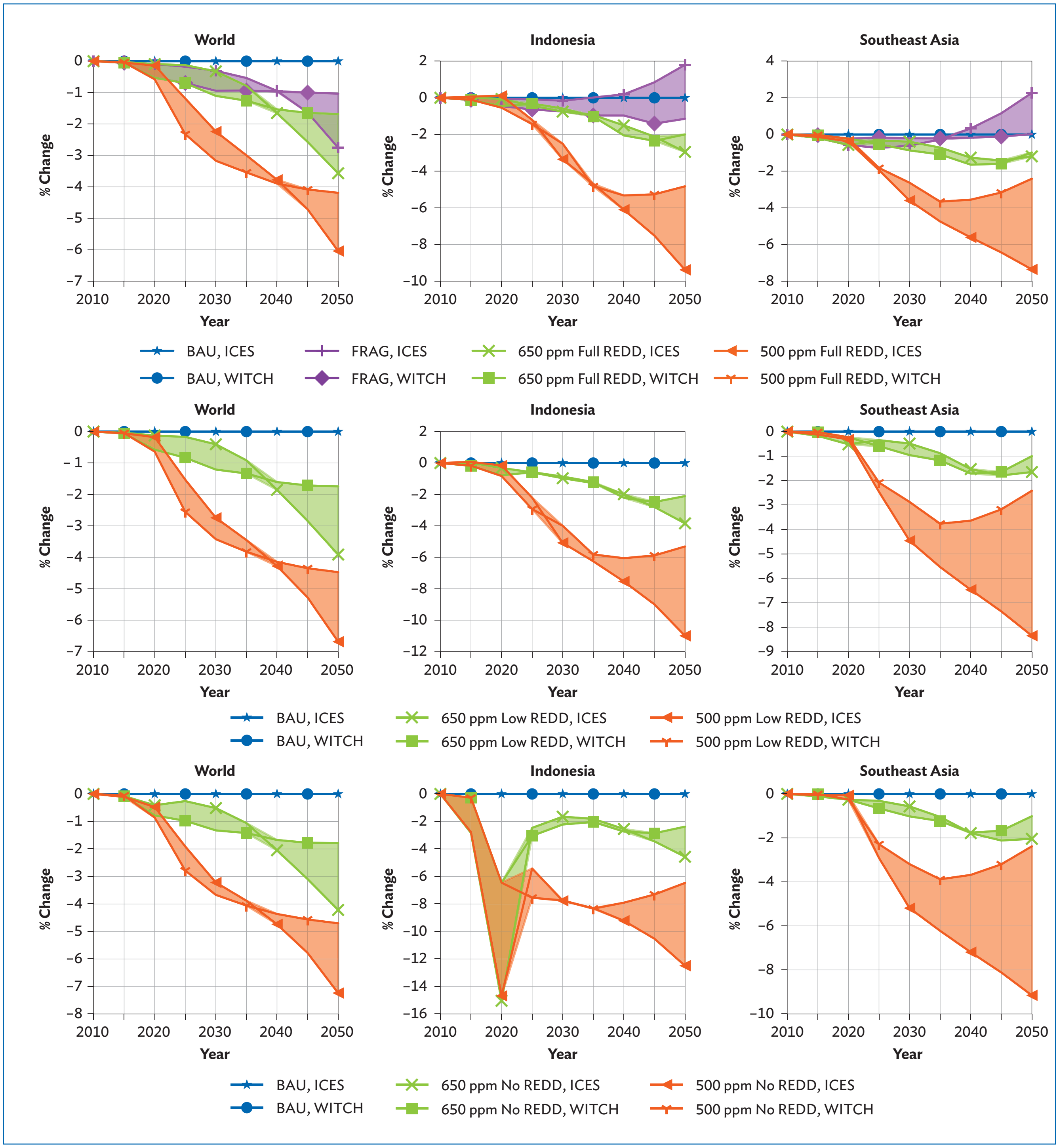
Figure 39 illustrates the cumulative discounted (at 5%) effects on GDP of the policy scenarios. The presence of efficient REDD can allow Indonesia's policy costs over the entire analytical period to be reduced by more than 50%, according to ICES and WITCH results for both levels of stringency. In the rest of Southeast Asia, REDD allows policy costs to be reduced by 20% or more.

With REDD in place, WITCH finds total costs of 2%–3% of GDP for the period, while the cumulative costs are approximately 4% of GDP under ICES. The 650 ppm stabilization costs about 1% of GDP under WITCH, as well as ICES. Both Indonesia and the rest of Southeast Asia have lower costs under the fragmented scenario. Even when REDD is an option, Indonesia demonstrates higher abatement costs than the rest of Southeast Asia according to both models. These policy costs are generally consistent with what previous literature has found (Box 4).

4.3.11 Welfare is less affected by climate policy than is gross domestic product

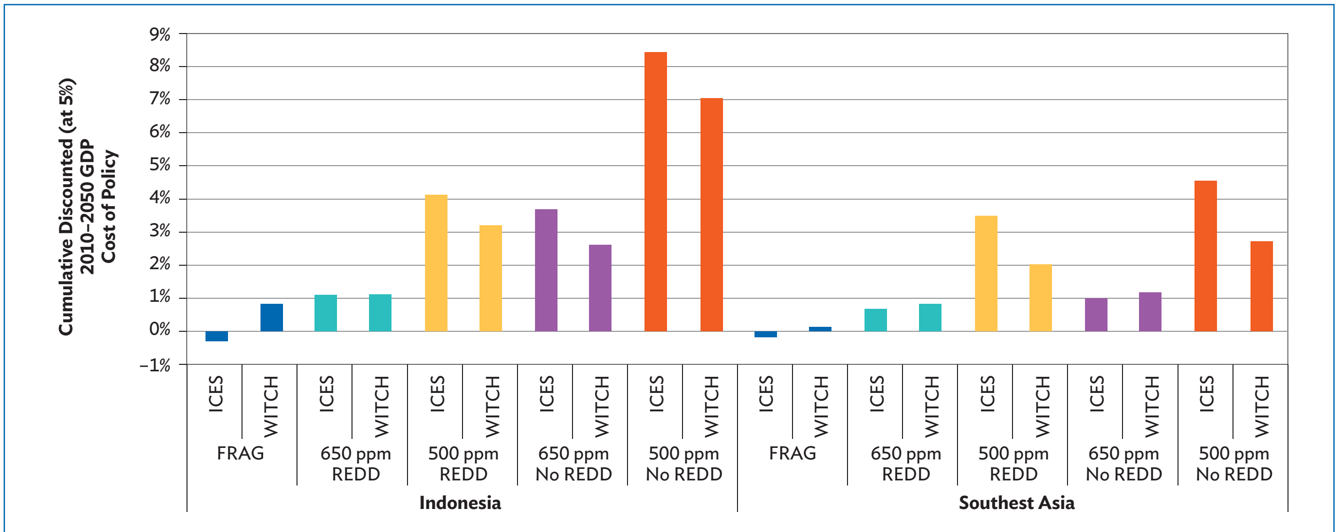
GDP is a measure of economic activity, in terms of value addition. However, that value addition may not be strongly correlated with welfare and living standards. Equivalent variation more directly captures welfare effects of price changes and structural adjustment, in that it equates changes in consumption to the effects on income that lead to the same outcome. Here the agreement across models is stronger and the costs are lower (Figure 40). Both models indicate that in the medium term, climate policies would not yield significant reductions in welfare and could even yield positive gains in some cases. This occurs in Indonesia according to ICES results, where the 500 ppm scenario, which has the highest GDP costs, also shows welfare gains until 2027, as a result of carbon offset sales. At the same time, welfare is more affected by the presence of REDD than is GDP, with losses vastly increased when REDD is absent.

Figure 38: GDP Effects (Excluding Benefits and Co-Benefits) of Global Climate Policy Scenarios for the World, Indonesia, and the Rest of Southeast Asia



BAU = business as usual, FRAG = fragmented (policy), GDP = gross domestic product, ICES = Intertemporal Computable Equilibrium System, ppm = parts per million, REDD = reducing emissions from deforestation and forest degradation, WITCH = World Induced Technical Change Hybrid.
Source: ADB Study Team.

Figure 39: Cumulative GDP Losses (Excluding Benefits and Co-Benefits) for Indonesia and the Rest of Southeast Asia, 2010–2050



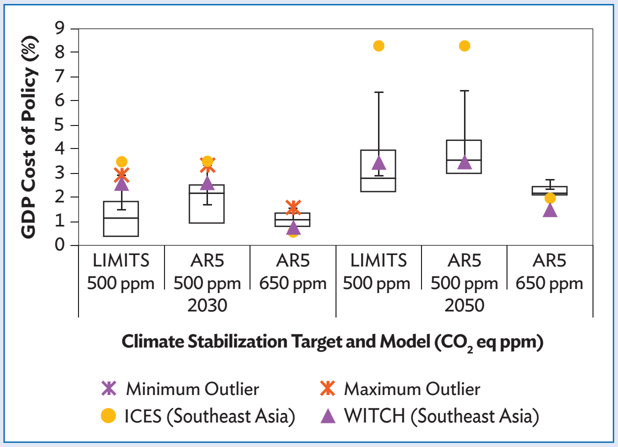
FRAG = fragmented (policy), GDP = gross domestic product, ICES = Intertemporal Computable Equilibrium System, ppm = parts per million, REDD = reducing emissions from deforestation and forest degradation, WITCH = World Induced Technical Change Hybrid.
Note: GDP discounted at 5%.
Source: ADB Study Team.

Box 4: Comparison of Results with Leading Model–Intercomparison Exercises

Globally, different modeling exercises surveyed by the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5) find that the cost in 2050 of achieving GHG stabilization at 580–650 parts per million (ppm) carbon dioxide equivalent (CO_2eq) ranges from nearly zero to 3.7% of GDP. Achieving GHG stabilization at 480–580 ppm CO_2eq is estimated to range from a loss of less than 1% to 10% of world GDP. The global costs estimated by the Intertemporal Computable Equilibrium System (ICES) for stabilization at 650 ppm amount to 3.5% of world GDP, and those to stabilize at 500 ppm are 6%. The World Induced Technical Change Hybrid (WITCH) generates considerably lower cost estimates—1% GDP to stabilize at 650 ppm and 4.2% to stabilize at 500 ppm. Both models thus fall within the ranges of the Intergovernmental Panel on Climate Change (IPCC) identified estimates, with ICES in the upper bound and WITCH in the middle-lower bound. In general, the higher cost estimates come from models like ICES with exogenous technical change and top-down representation of the energy sector. Models with endogenous technical change and a wide portfolio of energy generation options produce lower-bound estimates similar to those of WITCH.

Within the AR5 scenario database, estimates for Asia can be isolated and compared with the present study, although the DA5—Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam—is obviously only a small subset of Asia. The database includes 122 estimates of costs under similar global scenarios to this study. The multimodel Low climate IMpact scenarios and the Implications of required Tight emission control Strategies (LIMITS) of Kriegler et al. (2013) and Tavoni et al. (2013) model intercomparison exercise report 26 comparable estimates for "other Asia," which is principally Southeast Asia. Box Figure 4.1 compares various GDP policy cost estimates of the AR5

Box Figure 4.1: Comparison of 2050 GDP Policy Cost Estimates under Global Climate Stabilization Scenarios



AR5 = Fifth Assessment Report, CO_2eq = carbon dioxide equivalent, GDP = gross domestic product, ICES = Intertemporal Computable Equilibrium System, LIMITS = Low climate IMpact scenarios and the Implications of required Tight emission control Strategies, ppm = parts per million, WITCH = World Induced Technical Change Hybrid.
Note: Excludes co-benefits and benefits of avoided climate change.
Sources: International Institute for Applied Systems Analysis. AR5 Scenario Database. https://tntcat.iiasa.ac.at/AR5DB/dsd?Action=htmlpage&page=about (accessed 10 June 2015).

continued

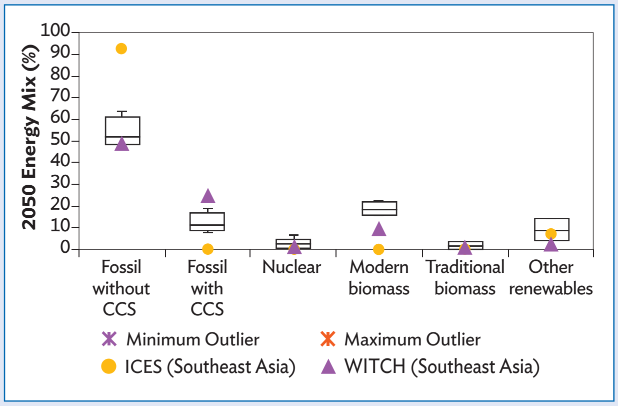
Box 4 continued

database for Asia, LIMITS, and those that have been generated by this study through ICES and WITCH for 2030 and 2050. In this figure, boxes represent the distributions of estimates around median values, drawing on all studies and scenarios oriented toward particular global emission stabilization scenarios. ICES 500 ppm estimates appear at the upper end of the literature for both 2030 and 2050. However, under the less stringent 650 ppm scenario, ICES GDP policy costs fall below previous estimates.

WITCH generates economic cost estimates that fall within the range of most 2050 estimates produced in previous studies for Asia. Under a 500 ppm climate stabilization scenario, WITCH's estimate of economic cost is within the range of previous estimates for 2050, while for a 650 ppm scenario, WITCH is below the range of previous values. For 2030, WITCH is at the bottom end of 650 results, but is at the upper end for 500 ppm.

Box Figure 4.2 compares the energy mix in 2050 from the LIMITS exercise with the results of this study. WITCH draws more carbon capture and storage (CCS) into the energy mix, but relies less than LIMITS on other renewables. In contrast, ICES draws on other renewables to a greater degree, similar to the LIMITS median value. Yet, other renewables still only account for 10% of primary energy and have limited potential to help achieve emission reductions. ICES also lacks representation of CCS and biomass, so energy remains much more concentrated in traditional fossil fuels.

Box Figure 4.2: Comparison of LIMITS Results on Energy Mix under Global Climate Stabilization Scenarios



BAU = business as usual, CCS = carbon capture and storage, ICES = Intertemporal Computable Equilibrium System, WITCH = World Induced Technical Change Hybrid.
Note: All energy mix estimates are for a 500 parts per million carbon dioxide equivalent (ppm CO_2eq)
Sources: International Institute for Applied Systems Analysis. AR5 Scenario Database. https://tntcat.iiasa.ac.at/AR5DB/dsd?Action=htmlpage&page=about (accessed 10 June 2015).

The recently completed Asian Modeling Exercise (AME) by Calvin et al. (2012b) includes estimates of the effects of decarbonization policies for Indonesia using the AIM–CGE and the PHOENIX CGE model. For a scenario similar to 500 ppm stabilization, the AIM–CGE reports 27% GDP loss in 2050, while 650 ppm stabilization leads to more than 6% GDP loss in 2050. Both values are far higher than ICES or WITCH. PHOENIX reports 2.4% GDP loss for 650 ppm stabilization in 2050, which is between ICES and WITCH.

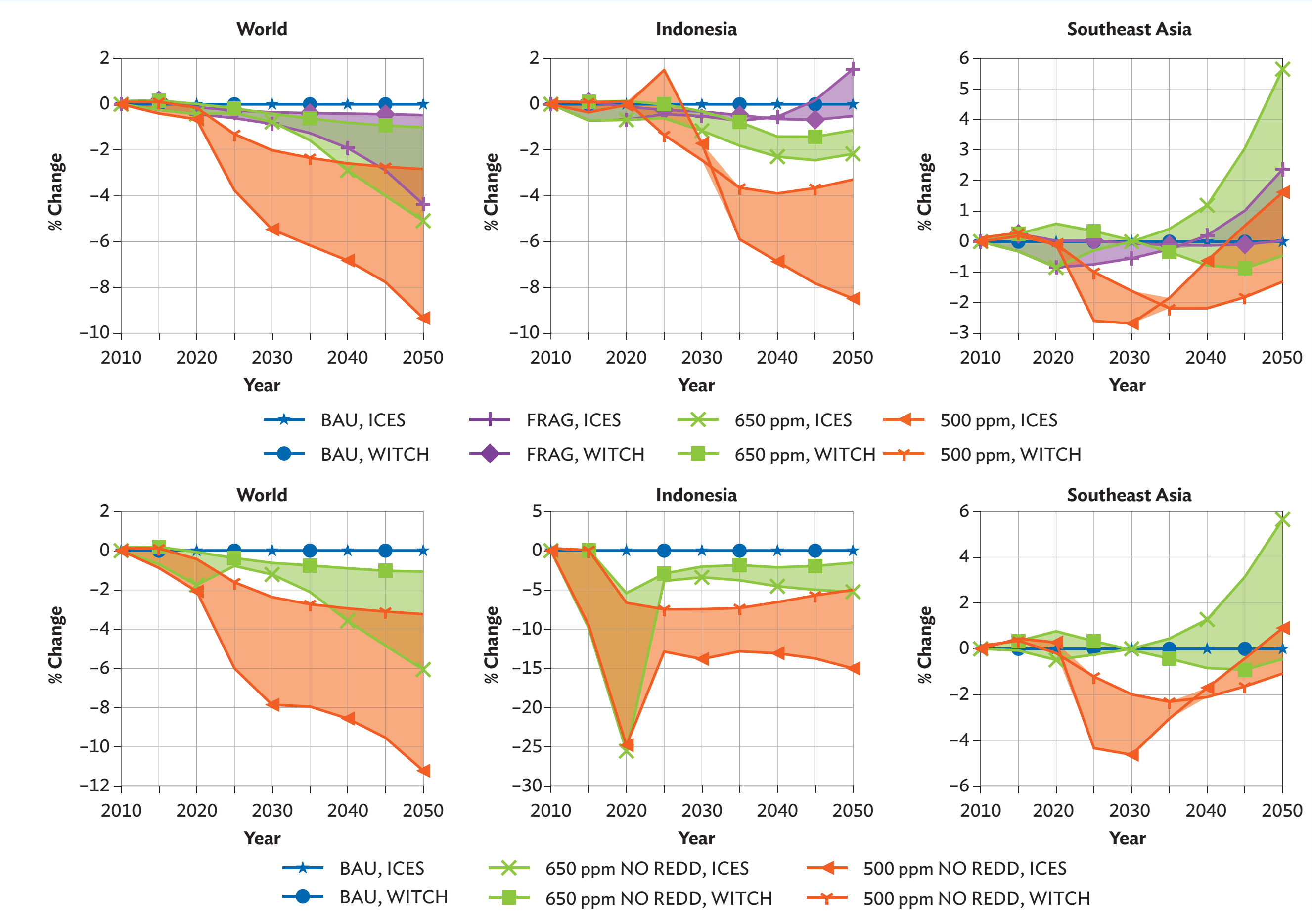
A clear pattern in these results shows that economic modeling that finds relatively low costs to ambitious emission reductions depends on the assumption that CCS and advanced biofuels will be viable at large scale. If these assumptions turn out to be false, the ICES results are more likely to be accurate, because drastic reductions in energy use compared with the BAU will be required, with consequences for the broader economy.

Source: ADB Study Team.

4.3.12 Delayed mitigation leads to higher policy costs

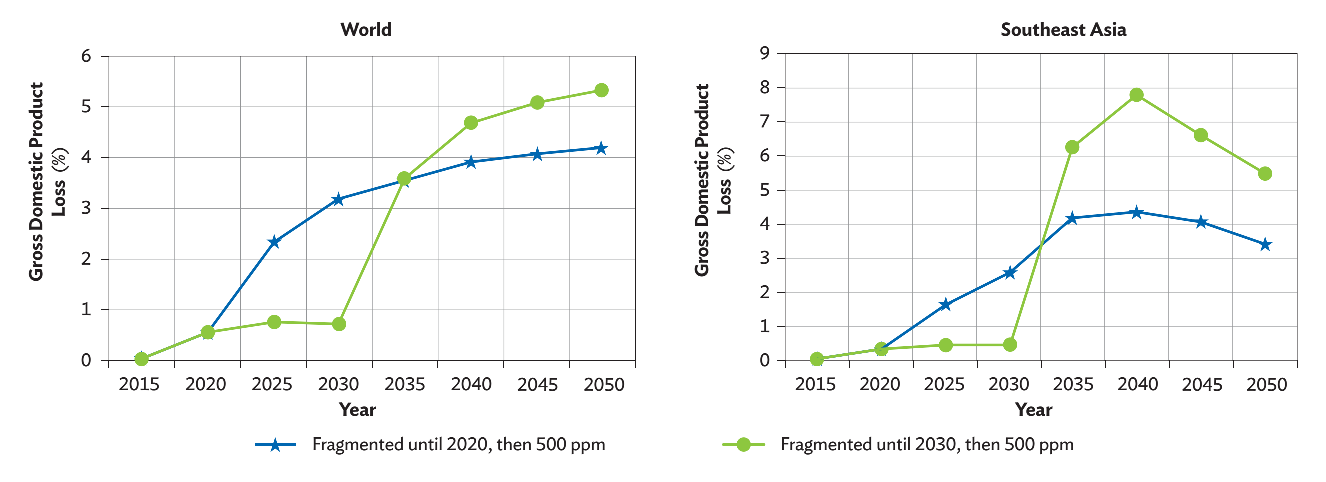
Achieving stabilization pathways efficiently requires early action, even though the response of the climate system lags behind emission reduction. Emission reduction initiated early can allow insurmountable decarbonization cost spikes to be avoided. To test the degree of this response, WITCH was run with a 10-year delay to the onset of a 500 ppm stabilization scenario. This finds that the decade delay leads to Southeast Asian GDP losses in 2050 that are 60% higher than under the main modeled scenarios (Figure 41).

Figure 40: Welfare (Equivalent Variation) Effects (Excluding Benefits and Co-Benefits) in Indonesia and the Rest of Southeast Asia



BAU = business as usual, FRAG = fragmented (policy), ICES = Intertemporal Computable Equilibrium System, REDD = reducing emissions from deforestation and forest degradation, WITCH = World Induced Technical Change Hybrid.
Source: ADB Study Team.

Figure 41: Policy Costs of Early and Delayed Action in the World and Southeast Asia (including Indonesia)



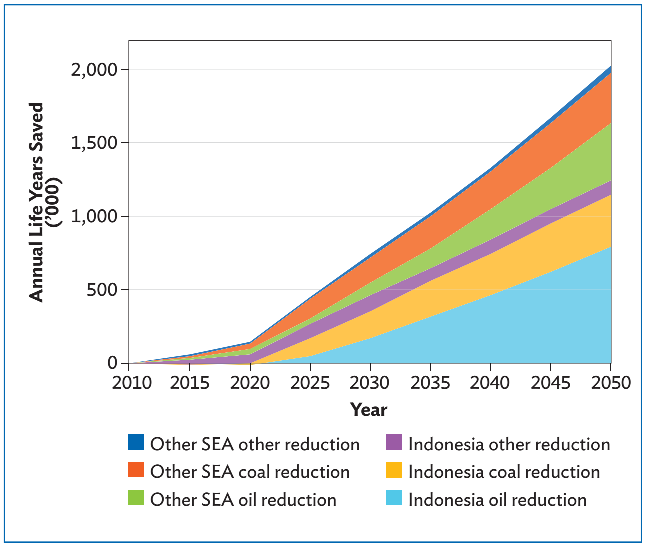
ppm = parts per million.
Note: Excludes co-benefits and benefits of avoided climate change.
Source: ADB Study Team.

4.3.13 Co-benefits are substantial

Reductions in combustion of fossil fuels and reduced forest fires lead to much better air quality and lower mortality associated with pollution. Approximately 33 million life years are found to be cumulatively saved by emission reduction achieved through 2050 under 500 ppm stabilization with ICES, of which a majority are associated with reduced use of oil in transportation, followed by reduced use of coal (Figure 42). In addition, reduced use of oil in transport is associated with fewer private vehicles, with less congestion and fewer accidents.

Co-benefits generated based on WITCH and ICES results are broadly similar. Figure 43 presents valuation of patterns of co-benefits, including valuation of reduced mortality and private transportation externalities under WITCH and ICES stabilization scenarios with REDD. Co-benefits increase as the level of ambition increases for climate stabilization, and reach 3.4% of GDP under 500 ppm stabilization from both ICES and WITCH results in Indonesia. In the rest of Southeast Asia, co-benefits are slightly smaller, and reach 1.9% to 2.5% of GDP. Under 650 ppm stabilization, ICES finds co-benefits that only reach around 1% of GDP, whereas WITCH finds co-benefits that are about twice as high.

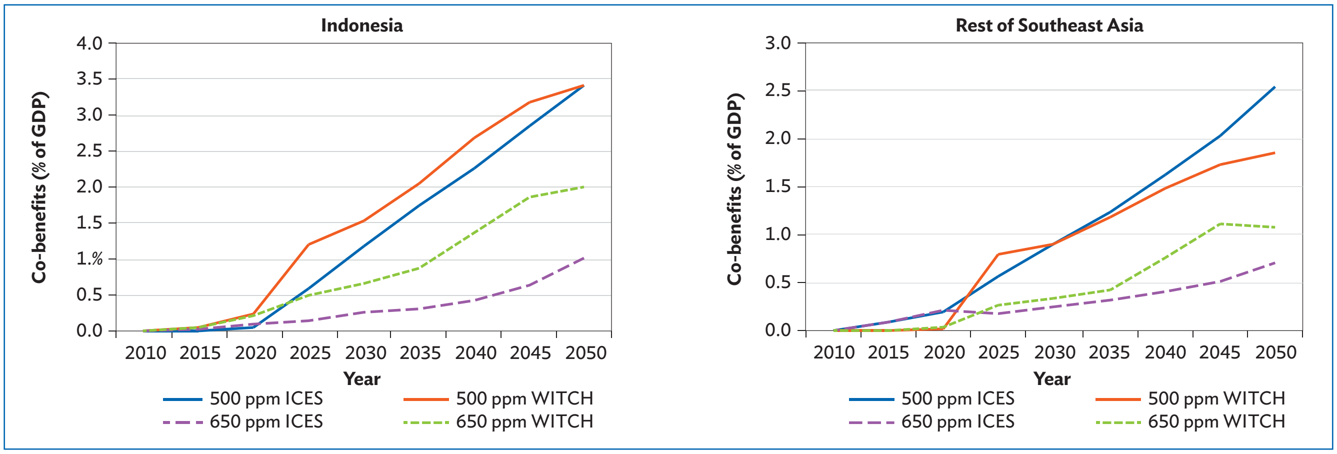
Figure 42: Annual Averted Mortality Based on ICES 500 ppm Full REDD Changes in Energy Consumption and Deforestation



ICES = Intertemporal Computable Equilibrium System, REDD = reducing emissions from deforestation and forest degradation, ppm = parts per million, SEA = Southeast Asia.
Source: ADB Study Team.

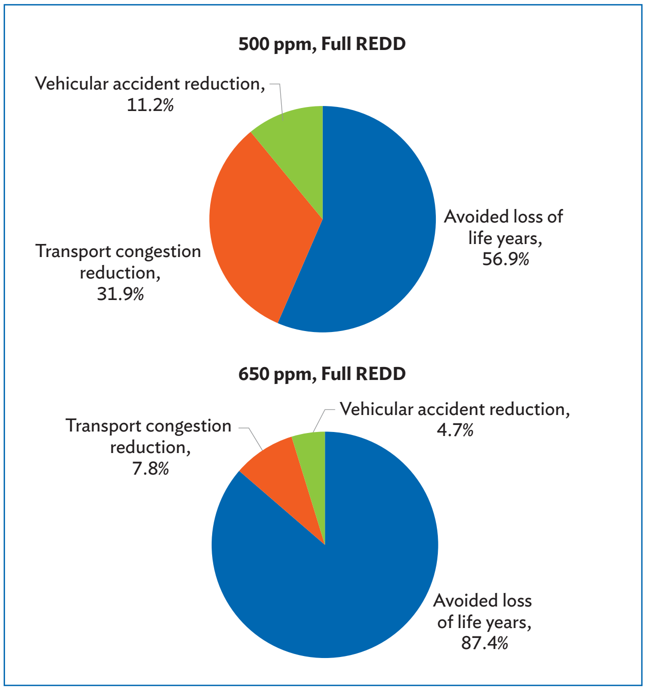
Figure 44 presents a breakdown of co-benefits by type under 500 ppm and 650 ppm stabilization with efficient REDD. The largest single component of co-benefits is in terms of health, primarily as a result of reduced fuel use in transportation, followed by combustion of conventional coal, reduced

Figure 43: Co-Benefits of Climate Stabilization under Different Scenarios



GDP = gross domestic product, ICES = Intertemporal Computable Equilibrium System, ppm = parts per million, WITCH = World Induced Technical Change Hybrid.
Source: ADB Study Team.

Figure 44: Net Present Values of Co-Benefits Generated under Climate Stabilization Scenarios in ICES



ICES = Intertemporal Computable Equilibrium System, ppm = parts per million, REDD = reducing emissions from deforestation and forest degradation, WITCH = World Induced Technical Change Hybrid
Note: Shares of total values discounted at 5%.
Source: ADB Study Team.

forest fires, and reduced gas combustion. Transport congestion is the second largest source of benefits, followed by reduced vehicular accidents. Under 650 ppm stabilization, oil use in transport is less curtailed, so that health benefits from reduction in the use of other fossil fuel energy sources dominate benefits more strongly.

4.3.14 Initial abatement costs lead to much greater long-term benefits

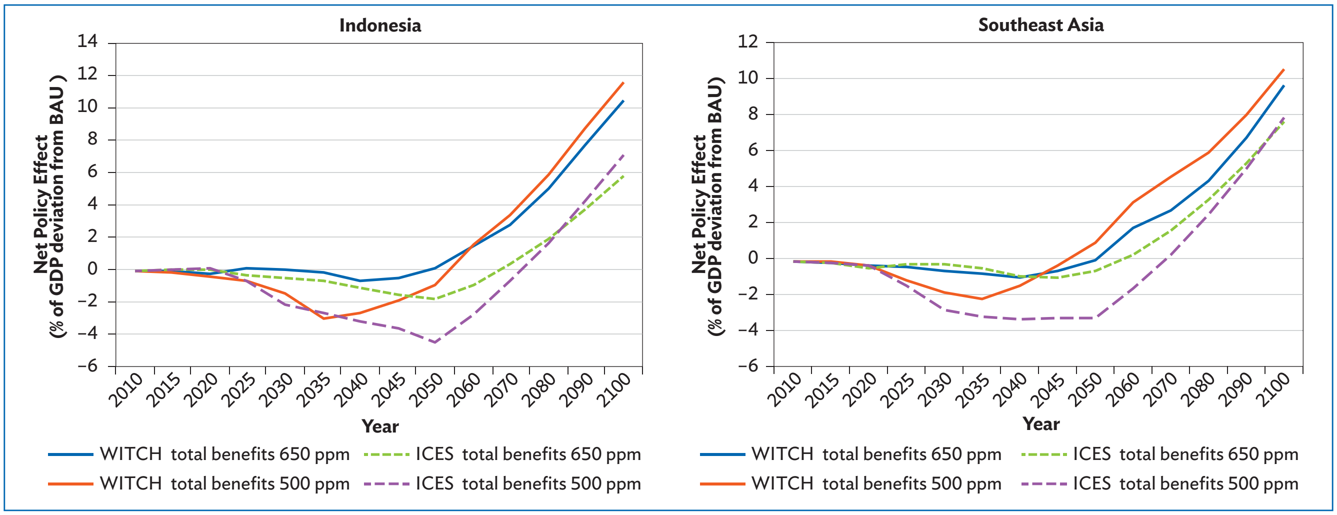
Results on the cost of inaction illustrate that the economic consequences of unabated climate change can be large over the long term. According to this study, which considered only a subset of possible impacts (sea level rise, agriculture, energy demand, and tourism), using methods that tend to underestimate costs due to assumptions of frictionless economic adjustments, the GDP loss by the end of the century for the five Southeast Asian countries considered is estimated as 4.9%. Estimates of lost labor productivity, health, ecosystem damage, and catastrophic events raise this to 11% of GDP. To derive the benefits associated with climate change stabilization at 650 ppm and 500 ppm GHG concentrations, the damage that is still experienced in correspondence with the warming that remains after mitigation is netted out. Co-benefits are added based on time series extrapolations from calculations performed for 2010 through 2050.

The decarbonization costs up to 2100 are those directly computed by the model in the case of WITCH. In the case of the ICES model, it is assumed that decarbonization costs remain constant at the 2050 level in the years between 2050 and 2100. This assumption, which may seem optimistic, is, in fact, rather conservative. On the one hand, the emissions quota allocation rules progressively favor countries with high population growth. On the other hand, it is reasonable to assume that in the second half of the century, new low-carbon energy generation technologies spurred by high carbon prices will enter the market, allowing decarbonization at declining costs.

When net costs and avoided climate change damage are considered in the presence of REDD, the net effect of climate stabilization on GDP returns to zero by the 2040s under both scenarios in WITCH and by the 2060s in ICES. Net costs of 500 ppm stabilization peak at less than 3% in WITCH and 4% in ICES in Indonesia and at 2% in WITCH and 3% in ICES for Southeast Asia (Figure 45). Before those dates, the inertia of the climate system is such that temperature increase and the associated damages would remain very similar to the no-policy BAU even in the presence of active mitigation policies.

What may be masked in the above comparison is that GDP is growing over time. This means that a given percentage GDP cost in the beginning of the period is much smaller than a percentage effect in the end of the period in absolute terms. Figure 46 illustrates for the DA5 how policy costs and benefits appear in levels, under the assumption

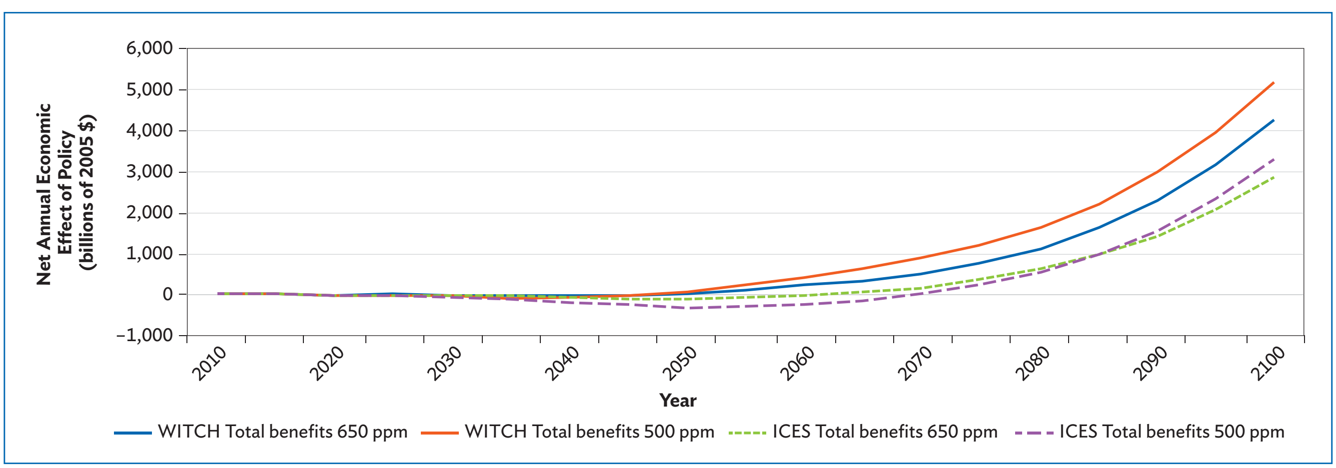
Figure 45: Comparing GDP Costs and Benefits of Decarbonization Policies in Indonesia and the Rest of Southeast Asia with REDD (% change of GDP over business as usual)



BAU = business as usual, GDP = gross domestic product, ICES = Intertemporal Computable Equilibrium System, ppm = parts per million, WITCH = World Induced Technical Change Hybrid.
Source: ADB Study Team.

of 3% GDP growth from 2050 through 2100 (a lower value than is reflected for the 2010–2050 period for any DA5 country). Here, it is striking how benefits exceed costs. Taking a net present value of costs and benefits presented in Figure 46 finds that, under a 5% discount rate, 650 ppm stabilization has net benefits that are 11.3 times net costs, and 500 ppm stabilization has net benefits that are 5.3 times net costs, according to WITCH, which is a more plausible model over long time periods. If the analytical period proceeded beyond 2100, the ratio of benefits to costs for 500 ppm stabilization would grow relative to 650 ppm stabilization, due to faster growth in benefits in later years. Clearly, climate stabilization is a high payoff investment over the longer term.

Figure 46: Comparing GDP Costs and Benefits of Decarbonization Policies in the DA5 ($ change of GDP over BAU)



BAU = business as usual; DA5 = Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam; GDP = gross domestic product; ICES = Intertemporal Computable Equilibrium System; ppm = parts per million; WITCH = World Induced Technical Change Hybrid.
Source: ADB Study Team.

4.4 National Comparison Using the ICES Model

There are important commonalities, as well as substantial differences in these country responses to climate stabilization policies, as is revealed by ICES results for particular countries. This section describes and compares key elements of how the five countries individually respond to climate policies.

4.4.1 All countries in the region have substantial abatement potential

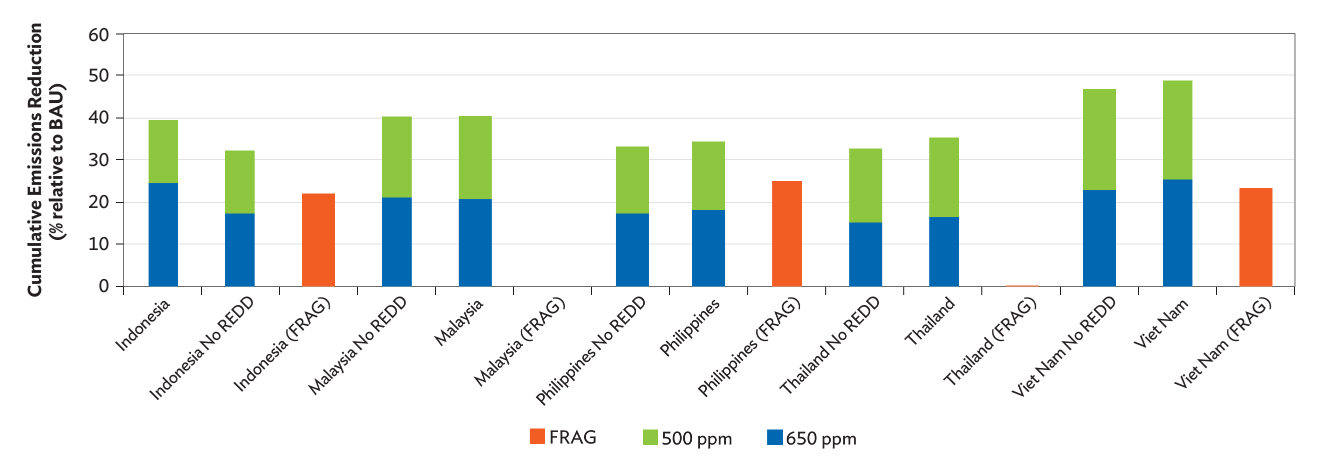
Figure 47 shows that all DA5 countries make substantial cumulative emission reduction under both 650 ppm and 500 ppm scenarios during 2010–2050. The level of overall reduction is sensitive to REDD only in Indonesia. The majority of cumulative emission reduction (55%–68%) under 500 ppm stabilization occurs even under the less stringent 650 ppm target across all the countries.

The relatively uniform high levels of potential emission reduction contrast with fragmented pursuit of national climate-related goals. Existing national goals in Indonesia and Viet Nam lead to cumulative emission reductions over the 2010–2050 period that are similar to the 650 pppm scenario, while the Philippines' goals lead to greater reductions. The Malaysian and Thai policy goals based on carbon intensity are similar to BAU levels of improvement.

4.4.2 Selected countries have carbon emissions permit export potential

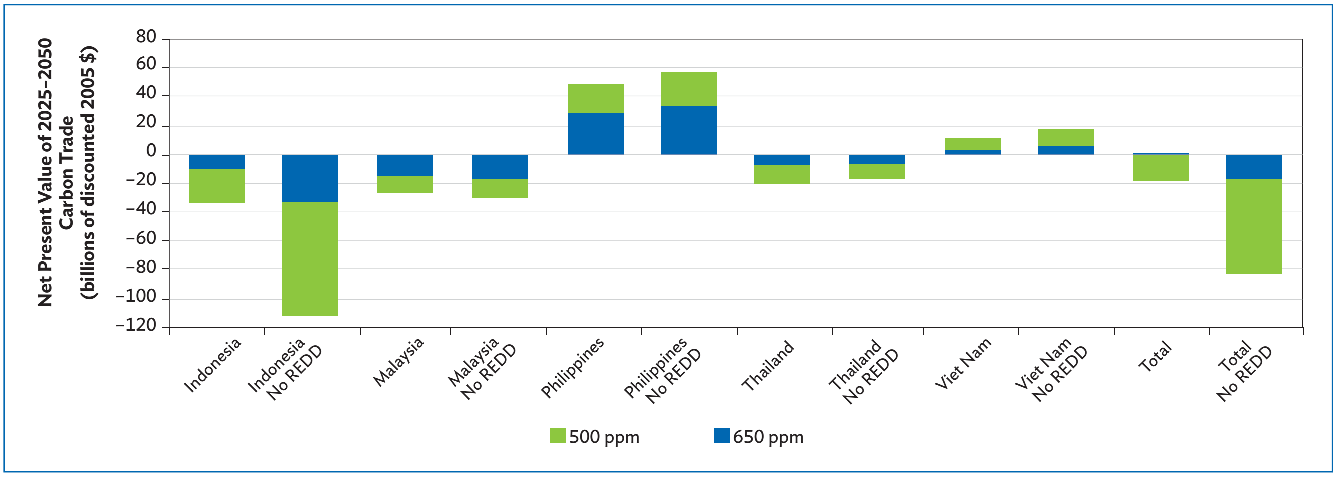
Indonesia has minimal carbon permit purchases when REDD is present and Southeast Asia is net permit exporter (Figure 48). In the absence of REDD, however, Indonesia has large purchases of permits, rendering the region an overall importer. Although the Philippines has the highest unit GDP cost for emission reduction, it has the highest export value relative to GDP, because its BAU emissions growth is lower than that of the other countries, such that it has excess permits to sell.

Figure 47: Cumulative Percentage of Greenhouse Gas Emission Reduction Using the ICES Model, 2010–2050



BAU = business as usual, FRAG = fragmented (policy), ICES = Intertemporal Computable Equilibrium System, ppm = parts per million, REDD = reducing emissions from deforestation and forest degradation.
Source: ADB Study Team.

Figure 48: Cumulative Net Present Values of Carbon Permit Exports Using the ICES Model, 2010–2050

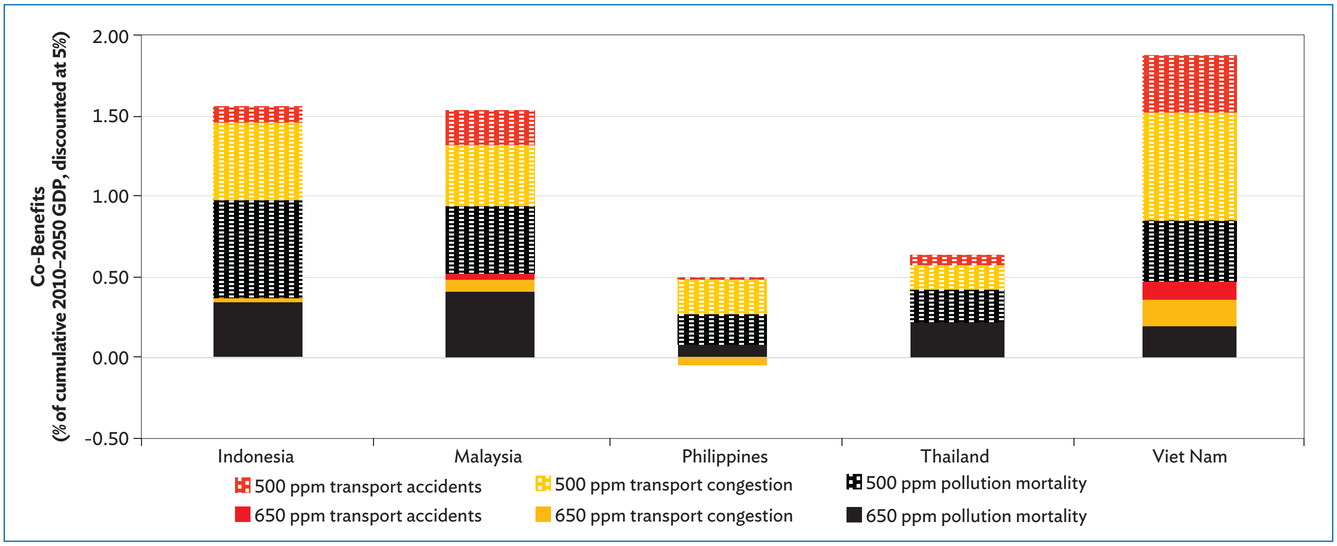


ICES = Intertemporal Computable Equilibrium System, ppm = parts per million, REDD = reducing emissions from deforestation and forest degradation.
Source: ADB Study Team.

4.4.3 Co-benefits are largely dependent on transport sector characteristics

The discounted (at 5%) net present value of co-benefits ranges from 0.5% to 1.9% of 2010–2050 GDP, with the lowest co-benefit values found in Thailand and the Philippines (Figure 49). Thailand has lower co-benefits due to lower emissions factors for transport, as well as less transport oil reduction, while the Philippines requires the least abatement as a result of the lowest BAU emissions. Averted pollution mortality is the largest source of benefits in all countries, except Viet Nam, where congestion reduction in transport is the main co-benefit category.

Figure 49: Co-Benefits as a Percentage of Cumulative GDP, Discounted at 5%



GDP = gross domestic product, ppm = parts per million.
Note: Scenarios with reducing emissions from deforestation and forest degradation (REDD).
Source: ADB Study Team.

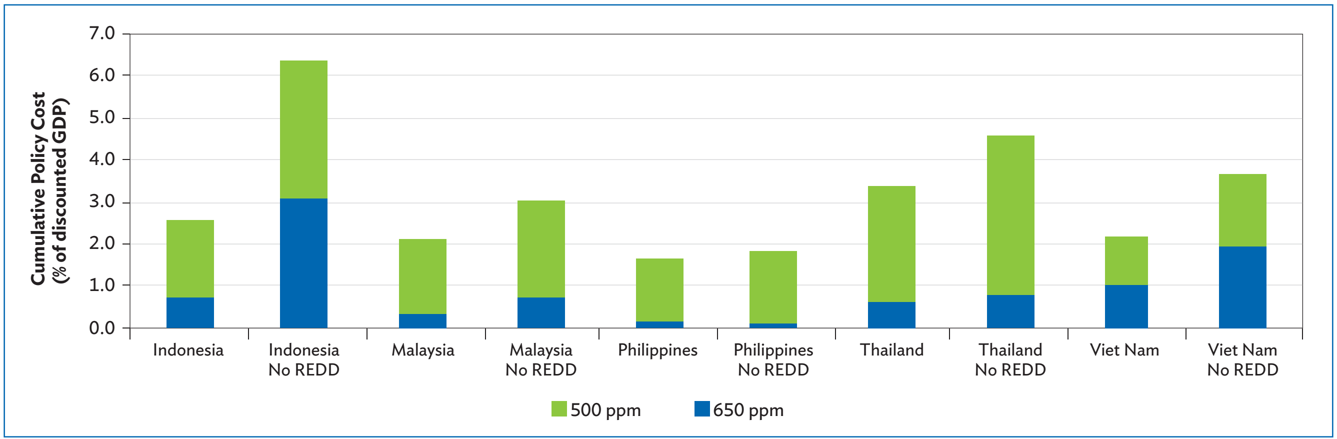
4.4.4 Policy costs vary substantially among countries

Cumulative GDP costs are highest in Thailand in the presence of REDD, and are highest in Indonesia in the absence of REDD (Figure 50). In Indonesia, REDD allows GDP costs to be halved over the 2010–2050 period. However, in all countries, REDD helps to lower cumulative GDP costs of climate stabilization. Costs rise several times over to achieve a smaller additional reduction in emissions under the 500 ppm target, compared with 650 ppm, due to declining marginal effectiveness of investment in abatement action.

4.4.5 Unit costs of emission reductions are small to moderate

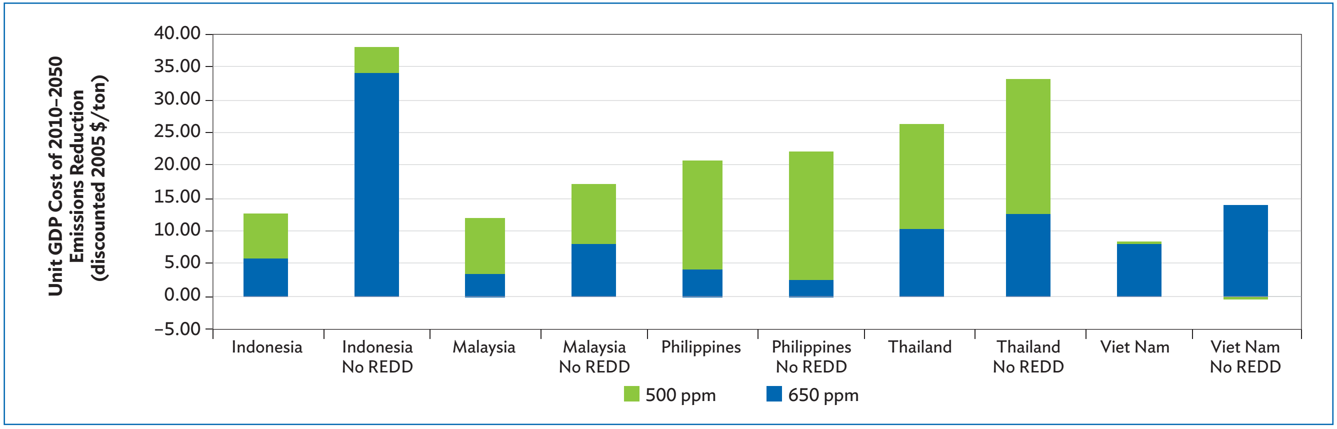
The net discounted unit net present value cost to GDP per ton of CO_2eq emission reduction among the DA5 is \$2–\$34 under 650 ppm stabilization and \$8–\$38 under 500 ppm stabilization. The difference illustrates increases in marginal abatement costs as abatement effort increases (Figure 51). The costs are lowest in Indonesia and Viet Nam in the presence of REDD and highest in Indonesia in the absence of REDD. In Indonesia, unit costs more than quadruple without REDD under the 650 ppm and more than

Figure 50: GDP Loss (Relative to Business as Usual) under Global Stabilization Scenarios with and without REDD, 2010–2050



BAU = business as usual, GDP = gross domestic product, ICES = Intertemporal Computable Equilibrium System, ppm = parts per million, REDD = reducing emissions from deforestation and forest degradation.
Note: Includes co-benefits and excludes benefits of avoided climate change.
Source: ADB Study Team.

Figure 51: Cumulative GDP Loss of Emission Reductions (per ton of CO_2eq), 2010–2050



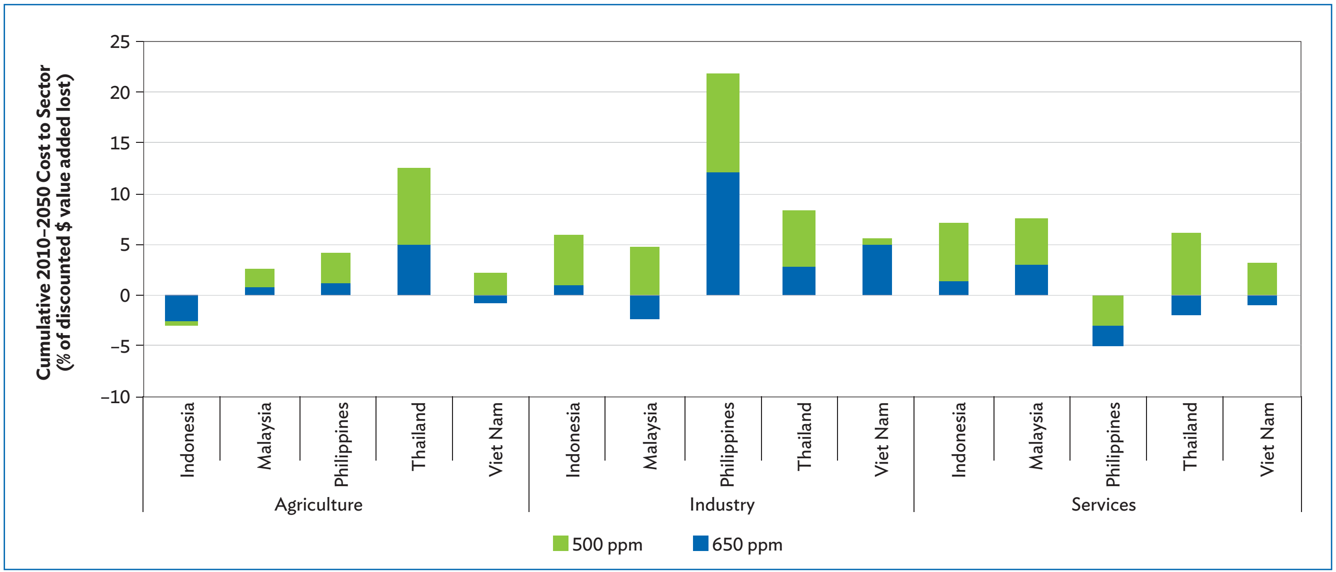
CO_2eq = carbon dioxide equivalent, GDP = gross domestic product, ICES = Intertemporal Computable Equilibrium System, ppm = parts per million, REDD = reducing emissions from deforestation and forest degradation.
Note: Discounted at 5% annually. Estimates include co-benefits but exclude benefits of avoided climate change.
Source: ADB Study Team.

double under the 500 ppm scenario. Given that Indonesia is by far the largest emitter in the region, this highlights the importance of reducing deforestation for climate stabilization at acceptable cost, even if the stabilization target is not highly stringent.

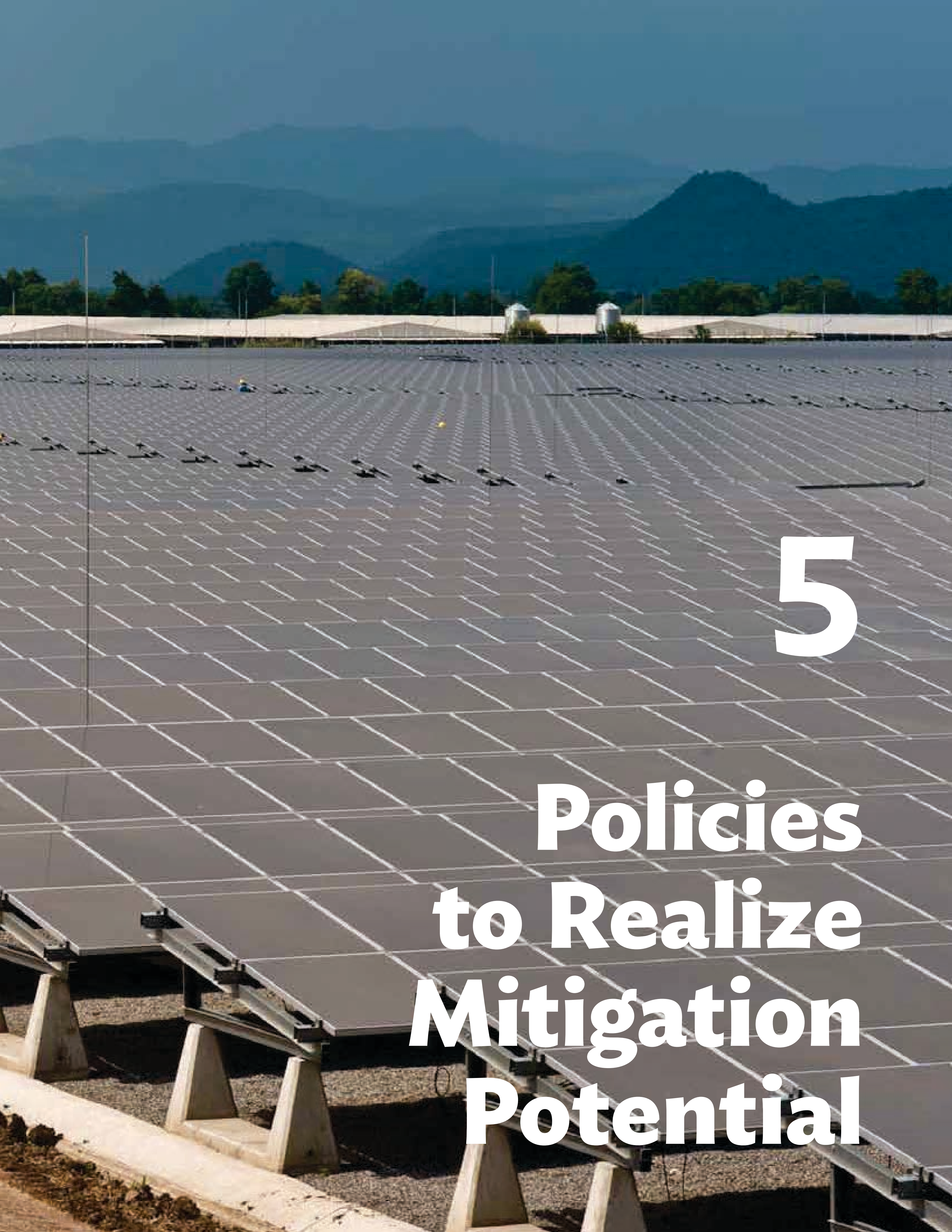
4.4.6 Effects by sector vary among the countries

Low-carbon policies primarily affect different sectors of each of the countries (Figure 52). ICES finds that the industry sector will be the most affected in the Philippines, whereas the agriculture sector has the greatest impact in Thailand and the services sector is the most affected in Malaysia. Agriculture in Indonesia is positively affected when REDD is present.

Figure 52: Sectoral GDP Lost (Relative to Business as Usual) under Global Climate Stabilization Scenarios in 2010–2050



BAU = business as usual, GDP = gross domestic product, ICES = Intertemporal Computable Equilibrium System, ppm = parts per million.
Note: Includes reducing emissions from deforestation and forest degradation (REDD). Excludes co-benefits and benefits of avoided climate change.
Source: ADB Study Team.



5

Policies to Realize Mitigation Potential

Key messages

This chapter presents analysis of policies and investments that can facilitate the low-carbon scenarios modeled.

- All countries in the region have important plans and goals related to mitigation of greenhouse gas emissions, including Intended Nationally Determined Contributions. At the same time, this report suggests that a higher level of mitigation ambition for the region may be economically beneficial.
- Investment in climate stabilization can have large potential payoff for the region. Preparation for such investments is necessary to access these benefits, and can be initiated immediately.
- Reducing deforestation is critical to abatement costs through at least the medium term. Countries in the region have taken important steps to prepare for reducing emissions from deforestation and forest degradation (REDD), and they have valuable forest cover targets. Beneficial policy reforms have also been undertaken.
- At the same time, more action is needed, particularly in Indonesia, to make natural forest clearance less economically attractive in concessions, to monitor and enforce existing regulations, and to resolve land-use conflicts.
- Energy efficiency is the largest overall source of abatement, according to this study, and this study indicates that energy efficiency improvement can be accelerated, compared with current government targets.
- Many important policy measures have been taken to encourage greater energy efficiency in Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam (DA5). At the same time, an array of instruments already deployed in other countries remains unutilized, and could help foster faster efficiency improvement.
- Fossil fuel subsidies in the DA5 have been substantial in recent years, and these subsidies encourage energy inefficiency and make low-carbon energy sources economically uncompetitive. Recent reforms by Indonesia illustrate that these subsidies can be reduced.
- Most DA5 countries have ambitious plans to scale up renewable energy, which the models confirm as appropriate if the rate of increase is maintained over the long term.
- The World Induced Technical Change Hybrid (WITCH) results indicate that carbon capture and storage (CCS) has important potential to lower long-term abatement costs. Although CCS for the power sector is only economically viable in the context of moderate carbon prices, demonstration activities for gas can be initiated to pilot CCS systems, and legal frameworks for CCS can be established soon.
- WITCH results also demonstrate the potential of advanced biofuels, particularly for the transport sector. Second-generation biofuel production is already being commercialized and is cost competitive with crude oil. Countries in the region can already begin action toward pilots and addressing supply chain constraints to the use of agricultural residues as feedstock.
- Achieving deep decarbonization will mean major changes to energy, transport, and urban infrastructure. This requires investment in new power generation, transmission, and distribution systems, green buildings, and more efficient transport systems.

5.1 Climate Change Mitigation is in the Interest of the Region

5.1.1 Countries in the region have made important commitments to address GHG emissions

Southeast Asia is one of the world's most vulnerable regions to the effects of increasing GHGs. This study finds that 11% of GDP may be lost due to climate change effects by 2100. Much of this damage will arise from historical emissions generated by industrialized countries. Although the region's historical contribution to climate change is limited, all countries in the region have undertaken some level of commitment to GHG emissions mitigation, which reflects important recognition of the need to move to a low-carbon development trajectory. These include policy goals, strategies, and action plans, as well as INDCs embedded in the Paris Agreement.

Indonesia's Copenhagen pledge set a goal of 26% GHG emission reduction from BAU by 2020 and 41% reduction with international support. To achieve this goal, Indonesia's National Action Plan on GHG Emission Reduction was formulated in 2011, with a focus on forestry and peatland, waste, agriculture, manufacturing and energy, and transportation (Table 17). Indonesia's INDC indicates that the unconditional reduction will extend to 29% by the year 2030, and that 41% emission reduction is possible with international support (Table 18).

In 2009, Malaysia announced a voluntary reduction of up to 40% in carbon emissions intensity of GDP by 2020 from 2005 levels (APEC 2014), conditional on technology transfer and finance from developed countries. Malaysia submitted an INDC, which indicates an unconditional 35% reduction in carbon emissions intensity between 2005 and 2030, and a 45% reduction conditional on international support.

The Philippines approved its Climate Change Act in 2009 and created the Climate Change Commission under the Office of the President. The Philippine government's approach has framed mitigation as a function of adaptation, and mitigation-related policies are reflected in sector plans, particularly for the energy, transport, and agriculture sectors. The Philippines submitted an INDC that indicates a 70% reduction in GHG emissions by 2030 if appropriate international support is provided.

Thailand developed a Strategic Plan on Climate Change in 2008, followed by a Climate Change Master Plan for 2014–2050. Development of a

Table 17: Indonesia's National Action Plan on Greenhouse Gas Emission Reduction

Sector	Emission Reduction Plan (ton CO_2)		Action Plan	Implementing Ministry
	26%	15%		
Forestry and peatland	0.672	0.367	Fire control, land and forest rehabilitation, illegal logging eradication, deforestation prevention.	Forestry and environment, public works, agriculture
Waste	0.048	0.030	Landfill/disposal site development, waste management, and integrated liquid waste management	Public works, environment
Agriculture	0.008	0.003	Introduction of low emission paddy variety, irrigation water efficiency, utilization of organic fertilizer	Agriculture, environment
Industry	0.001	0.004	Energy efficiency	Industry
Energy and transportation	0.038	0.018	Biofuel utilization, demand side management, energy efficiency, renewable energy development	Transportation, energy and mineral resources, public works
Total	**0.767**	**0.422**		

CO_2 = carbon dioxide.
Source: Murtiningtyas (2012).

new 5-year Strategic Plan on Climate Change is in progress. The Thailand Greenhouse Gas Management Organization was also established in 2007 through the Energy Industry Act (B.E. 2550). Thailand submitted an INDC that reflects 20% GHG emission reduction from BAU by 2030 unconditionally and 25% reduction with international support.

Viet Nam's National Climate Change Strategy was formulated in 2011, followed by a 2012 announcement by the Prime Minister that by 2020 the country would launch a national carbon emissions trading scheme, with a target to reduce GHG emissions (compared with 2005 levels) by 8% in the energy and transport sectors, 20% in the agriculture sector, 20% in land use, and 5% in waste management. Viet Nam's late 2015 INDC unconditionally offers an 8% GHG emission reduction by 2030, which can increase to 25% with international support.

5.1.2 More ambitious mitigation is economically justified

(i) *Benefits from more ambitious mitigation by the region are substantial*

The modeling applied in this analysis finds that current policies translate into varying levels of climate ambition (Table 18). Indonesia's Copenhagen commitment is ambitious and is consistent with the modeled 500 ppm scenario or even more stringent mitigation in the short term. Over the 2030 time frame, Indonesia has estimated BAU emission for its INDC that are higher than those in ICES or WITCH, which offsets this mitigation, such that only the conditional 41% emission reduction pledge is consistent with the 650 ppm scenario in terms of emissions in absolute levels.

The Philippines has pre-INDC goals that are more stringent than 650 ppm stabilization, according to ICES, and its INDC is likely to lead to a lower level of 2030 emissions than the 500 ppm scenario, which reflects high ambition. Thailand has pre-INDC goals that lead to improvements similar to BAU in ICES, but its unconditional INDC is more ambitious and leads to lower emissions than in the ICES 650 ppm scenario, provided that the INDC coverage is comprehensive.

Viet Nam's pre-INDC goals are modeled as similar to 650 ppm stabilization when considered as a relative reduction. However, its INDC shows a much higher level of BAU 2030 emissions than does ICES, so that even the conditional reduction when considered in levels is above that of ICES' BAU. Malaysia's pre INDC goals are similar to pathways of improvement under BAU and both Malaysia's conditional and unconditional INDCs reflect a lower rate of emission reduction than this previous goal.

Globally, the INDCs will lead to warming that is greater than the modeled 650 ppm scenario (Jeffrey et al. 2015), and Southeast Asia is little different from this larger trend. On a regional level, the INDCs conditioned on international support lead to emissions similar to the modeled 650 ppm scenario, while unconditional INDCs are only very slightly (2%) below the modeled BAU emissions for the region in 2030 in levels. This analysis suggests that more ambitious long-term goals may be in the economic interest of the region, even if historical responsibility or the development needs of the region are not taken into special account. As time passes, co-benefits and the benefits of avoided climate damage are found to grow faster than the policy costs of climate action, and greatly outweigh costs after the 2040s. To access these benefits, more ambition is needed.

(ii) *There are more benefits to mitigation than are quantified in this study*

The "costs" to achieve climate stabilization benefits should be considered in terms of the limitations of GDP as an economic measure. Effects on GDP reflect changes in economic activity. They do not represent effects on welfare, which show smaller policy costs. The GDP costs also do not reflect only the financial costs of specific low-carbon investments, which are far smaller than the values analyzed here. The ratios of benefits to costs for the specific capital and institutional investments needed for a low-carbon transition are thus much higher than the social ratios mentioned previously.

Table 18: Intended Nationally Determined Contributions Submitted to Underpin Negotiations on a Post-2020 Global Climate Agreement under the United Nations Framework Convention on Climate Change

Country	Intended Nationally Determined Contribution						2030 Emissions from ICES Model ($MtCO_2eq$)		
	2030 Unconditional Emission Reduction	2030 Conditional Emission Reduction	Coverage	2030 Business as Usual (BAU) Emissions ($MtCO_2eq$)	Implied Unconditional 2030 Goal ($MtCO_2eq$)	Implied Conditional 2030 Goal ($MtCO_2eq$)	BAU	650 ppm	500 ppm
Indonesia	29% from BAU	41% from BAU with international support, including technology development and transfer, capacity building, payment for performance mechanism and finance	Energy (including transport), industrial processes and product use, agriculture, land use, land-use change and forestry, waste	2,882	2,046	1,700	2,396	1,769	1,270
Malaysia	35% reduction in intensity (tCO_2e/GDP) from 2005	45% reduction in intensity from 2005 conditioned upon receipt of climate finance, technology transfer and capacity building	Energy, industrial processes, waste, agriculture, land use, land-use change and forestry	...	657[a]	556[a]	545	455	315
Philippines	...	70% from BAU, conditioned on the extent of financial resources, technology development and transfer and capacity building	Energy, transport, waste, forestry and industry sectors	...	...	...	255	221	172
Thailand	20% from BAU	25% from BAU, conditioned on enhanced access to technology development and transfer, financial resources and capacity building	Economy-wide (inclusion of land use, land-use change and forestry not yet decided)	550	440	413	566	502	388
Viet Nam	8% from BAU	25% from BAU with international support	Energy, agriculture, land use, land-use change and forestry, waste	787 (excluding industrial processes)	724	590	427	373	239

... = not applicable, ICES = Intertemporal Computable Equilibrium System, $MtCO_2eq$ = million tons of carbon dioxide equivalent, ppm = parts per million.
[a] indicates ADB calculation drawing on ICES results.
Note: Includes submissions as of 15 December 2015.
Source: United Nations Framework Convention on Climate Change. UNFCCC Intended Nationally Determined Contribution. http://unfccc.int/focus/indc_portal/items/8766.php (accessed 1 December 2015).

Results presented show that co-benefits from climate stabilization are substantial and offset an important and rising share of policy costs. However, these co-benefits are likely to be underestimates, as they focus on only a few effects that can be easily quantified with limited data. As noted earlier, a wide array of potential co-benefits associated with mitigation of GHG emissions has not been captured. These are likely to be substantial, as decarbonization typically takes place through the adoption of new technologies, fosters the development of new production activities, and preserves ecosystems that enhance opportunities to develop recreational services. All these can create important job opportunities in new "green sectors." Fossil fuel markets, especially for oil, are notably volatile, with large international price fluctuations that lead to significant domestic costs. Low-carbon energy sources tend to have less market volatility, which enables greater predictability and efficiency in consuming industries.

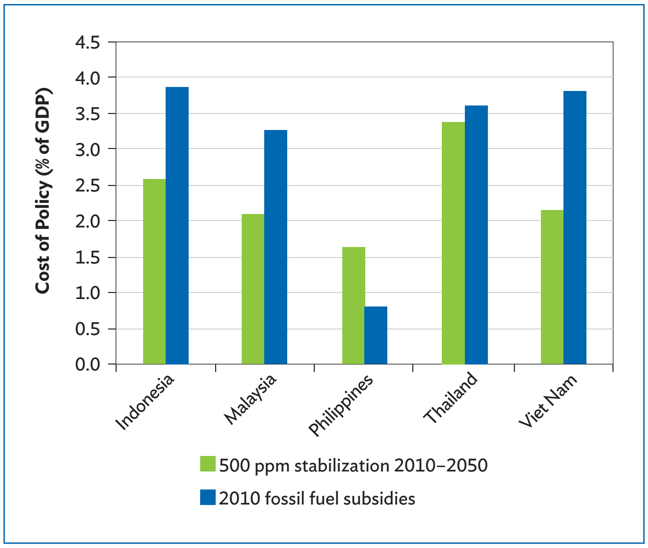
In addition to the health effects quantified, other environmental co-benefits from mitigating climate change derive from the improvement of freshwater, marine, agricultural, and forestry ecosystem quality and the reduction of biodiversity loss. All of this results from both reduction of damaging pollution, such as precursors to acid rain, as well as from REDD actions that preserve natural forests and other ecosystems. The consequences not only entail direct positive effects on health, (e.g., when the quality of drinking water resources improves), but also constitutes essential support to broader provisioning services for local communities, which rely on forested areas for traditional needs and ecosystem services, such as pollination for agriculture. In fact, the alternative of ubiquitous fossil fuel-dependent development and widespread conversion of forested areas to other land uses on a global scale may threaten the long-term ecological balance that sustains human civilization. Inclusion of these omitted effects would further reduce net policy costs, and make the social payback period for investment in a low-carbon economy shorter than identified here.

(iii) *Ambitious mitigation can cost less than recent energy policies*

Participation of countries in the region in an ambitious but "equitable" climate global stabilization regime is found in the present analysis to have only moderate costs. The models suggest that 650 ppm stabilization can be achieved with very little effect on economic systems. This level of mitigation, which corresponds to a nearly 40% emission reduction relative to BAU by 2050, has less than a 1% peak net effect on GDP and a positive effect on economic welfare. The finding of substantial mitigation opportunities at low cost confirms bottom-up assessments, which find ample opportunities for "win-win" abatement at negative or trivial opportunity cost (see Boxes 7 and 8 for examples). More ambitious 500 ppm stabilization has net costs of 2%–3% in the 2030s, but benefits greater than costs as early as 2 decades after a global climate agreement begins.

There is precedent in the region to spend a substantial percentage of GDP on policies for emitting sectors. All countries in the region have had some degree of subsidies on fossil fuels in recent years. Figure 53 illustrates how the proportion of GDP spent by governments in the region on fossil fuel subsidies in 2010 is higher than the net discounted cost of participation in the 500 ppm scenario from 2010 through 2050 from ICES (the model with higher policy costs). Such subsidies, by definition, represent deadweight welfare loss, as the subsidy is equivalent to the marginal difference between what the good costs to society and the value of the good to the consumer. Hence, they are economically inefficient.

Figure 53: Comparison of Discounted GDP Policy Costs (including co-benefits) for 2010–2050 under 500 ppm Stabilization with REDD from ICES with 2010 Fossil Fuel Subsidies



GDP = gross domestic product, ICES = Intertemporal Computable Equilibrium System, ppm = parts per million, REDD = reducing emissions from deforestation and forest degradation.
Note: Excludes benefits of avoided climate change.
Sources: IEA (2013b) and ADB Study Team.

This suggests that the level of resources required for a low-carbon transition can be mobilized if it is a political priority, and that fossil fuel subsidy reform could potentially serve as a source of resources to do so. Obviously, eliminating subsidies faces political economy challenges, due to costs imposed by macroeconomic adjustments. However, the similarity of the magnitude of these costs to existing subsidies does illustrate that similar or greater resources are already allocated toward measures deemed important by governments in the region.

5.1.3 Initiating international carbon markets soon can benefit the region

(i) *Carbon trade can lower mitigation costs*

To date, carbon markets have been fragmented, with the Clean Development Mechanism for developing countries separated from the Joint Implementation Mechanism for Annex I countries under the Kyoto Protocol, complemented by various domestic and regional emissions trading systems. Within this context, CO_2 prices have been falling, and have reached very low levels, as a result of low levels of mitigation ambition in recent policies for many developed countries, which have led to little demand for CO_2 permits.

The Paris Agreement has the potential to change this eventually, both by creating demand for carbon permits and by setting in place potential pathways towards international carbon markets. Article 6 of the agreement offers opportunities for "internationally transferred mitigation outcomes to achieve nationally determined contributions" allows for potential carbon trade. Likewise, the proposed "Framework of Various Approaches" is intended to patch together different mitigation mechanisms to this end. At the same time, most INDCs indicate no use of international offset mechanisms, which suggests that the global climate regime may continue to be fragmented under a post Kyoto Agreement without further efforts toward carbon market development.

Countries in the region have little to gain and much to lose from continued fragmentation of the global climate regime, according to this study. A consistently implemented global climate agreement is found to be more efficient and effective than uncoordinated national policies. Through 2035, 650 ppm global stabilization is cheaper for the DA5 (in terms of GDP and welfare) than fragmented extrapolation of current goals, yet it achieves more than 50% greater emission reduction. Presence of a global carbon market is found to reduce mitigation costs substantially under 500 ppm stabilization. This occurs because trade allows emission reduction to occur where it is cheapest to do so. In the context of trade, countries with higher abatement costs benefit from buying cheaper offsets elsewhere, while countries with low abatement costs benefit from the revenues from carbon permit sales. Although the greatest gains can come from a global trading system, initial efforts to link national trading schemes can offer many of the same types of benefits at a smaller scale.

(ii) *Faster global climate action benefits the region*

The results of modeling under this study indicate no meaningful economic gain from a delay in climate action, as the returns to investment in climate stabilization will only fall over time. A decade's delay in climate action is found to not only increase 2050 policy costs by 60% in WITCH, but also delays streams of co-benefits and reduced damage from climate change.

Global climate change negotiations to date have been characterized by consensus on a global stabilization level of ambition, but contributions from individual countries are not sufficient to achieve the agreed goal. These results suggest that it may be better for the welfare of the countries in the region to aim for rapid increases in ambition across all INDCs in successive negotiations, rather than focus on more differentiation in contributions that achieves mitigation more slowly.

5.2 Controlling Deforestation is Essential to Medium-Term Mitigation

5.2.1 If deforestation continues, mitigation becomes much more expensive

(i) *Reducing deforestation is the lowest cost major mitigation opportunity*

Achieving deep decarbonization depicted in global climate stabilization rests upon a fundamental alteration of patterns of land-use change to date. The largest determinant of short-term costs to emission reduction is REDD, according to the results of this study. This is especially true for Indonesia, where REDD contributes the majority of emission reductions until 2040. Reducing deforestation and forest degradation is the lowest-cost mitigation opportunity for the country, and is essential to address as the major emissions source through the medium term. The deforestation reduction has low opportunity cost, because land-demanding industries can be shifted to extensive areas that are already barren or degraded.

The importance of REDD is simple to explain. Indonesia and Malaysia have a large share of emissions from land-use change. If the countries need to reduce emissions severely, but can only do so through energy sector changes and purchases of carbon credits, reduction has a much higher cost than if reductions are achieved in all the major emitting sectors. If REDD were not to work well or to be available, Indonesia's energy intensity of GDP would need to be strongly reduced to align with a contraction and convergence framework, as all abatement effort is concentrated in the energy sector, which contributes a minor share of emissions. Such a strong contraction would come at large economic cost.

As revealed in the modeling, REDD does not just benefit Indonesia. Under a global carbon market, costs to other countries in the region are substantially reduced, as a result of lower carbon prices. In the medium term, the rest of Southeast Asia faces approximately 50% lower cost when REDD is in place than when it is not. Thus, REDD is beneficial to even those countries without a problem of forest destruction.

(ii) *Reducing deforestation may be even more important than these results indicate*

Over the long term, REDD has a smaller role only because the BAU scenario applies an economic model that determines that deforestation will decline over time in Malaysia and Indonesia long before all natural forest is eliminated. However, this is not a foregone conclusion, as the pattern of deforestation to date in these countries has not revealed a declining rate of clearance. If deforestation continued at a constant rate in the BAU scenario through 2050, it would continue to make a major difference to policy costs throughout the period. Thus, the optimism of the BAU models may actually underestimate the potential difference that REDD can make.

5.2.2 Progress is being made to address deforestation, but more is needed

(i) *Countries in the region are taking steps toward REDD+ preparedness and forest sector reforms*

There is growing awareness in the DA5 of the importance of land use to mitigation. The need to address emissions from deforestation has appeared more prominently in government climate policies, and is the main mitigation mechanism under Indonesia's mitigation Action Plan, along with peat rehabilitation.

Accordingly, all countries in the region have taken steps toward "REDD preparedness" (Table 19). Indonesia, the Philippines, and Viet Nam have all developed detailed REDD+ strategies or action plans, while Malaysia and Thailand have strategies under development. Dedicated REDD+ agencies have been established in Indonesia and Viet Nam (although the Indonesian agency has since been merged into the Ministry of Environment and Forestry). "Readiness" steps, such as forest mapping, definition of reference levels, and definition of monitoring and verification systems have been initiated for all countries, and pilots have been started in all but Malaysia.

Similarly, those countries with deforestation, Indonesia, Malaysia, and to a very small extent Thailand, all have established policy targets to reduce forest loss or maintain forest cover. Moreover, those countries with net afforestation have targets to increase forest cover.

Indonesia is the source of more than 80% of regional deforestation emissions in recent years, so policy measures for the country to reduce emissions merit special attention. The country's Climate Change Action Plan not only recognizes the importance of deforestation as the major emissions source, but targets it for 90% of abatement.

As accompanying measures to REDD, Indonesia has offered a number of forest sector reforms intended to reduce pressure on forests, which reflect greater recognition of drivers of deforestation. In 2011, Indonesia issued a moratorium on the approval of new plantation concessions for forest clearance in areas of primary forest and peatlands, although it still allowed clearance within existing concessions, concession renewals, and "national development" projects. This moratorium was extended in mid-2015 for another 2 years under the same terms. Data collection and sharing on concession issuance and approvals has also been improved, and "license information systems" have been introduced to make information more widely available. In 2014, a major change to forest administration was initiated via the establishment of local forest management units, which will perform onsite inspection of forest concessions for compliance with forestry regulations. A Constitutional Court ruling in 2013 recognized that customary forests should belong to local communities who have customarily resided in those forests, rather than the state.

This all represents substantial progress, but more is still needed to drastically reduce deforestation. The moratorium on concession allocation only affected 15% of potential deforestation emissions, and forest clearance may still occur at a lower frequency even in the absence of formal concessions. As a result Busch et al. (2015) found that the policies reduce deforestation emissions by only 2.5%–6.4% if implemented over a decade. For such a moratorium to have much greater effectiveness, it should apply to secondary forests, as well as existing concessions. Given that existing concessions generally exhibit larger areas of forest land cleared than plantation established, one possible reform is to restrict approval of further land clearing on concession areas

Table 19: Forest Targets and REDD+ Readiness Status of DA5 Countries

Countries	Forest Preservation Targets	Afforestation/ Rehabilitation Targets	REDD Strategy	MRV System Established	Establishment of Reference Emission Level	Safeguards Framework	Number of REDD Pilot Projectsd	Total Financing from Multilateral/ Bilateral Sources for REDD+ support (2010–2012)
Indonesia	10 million hectares reduced deforestation by 2025	Rehabilitation of forest 2009–2012: 16.7 Mha, 2012–2025: 36.3 Mha 2025–2050: All remaining	2012 National REDD+ Strategy; 2013 REDD+ Agency established		X	X	30	$527.88 million
Malaysia	Maintain 50% forest cover	National Landscape Department to plant 20 million trees between 1997 and 2020	REDD+ strategy under development				0	$13.47 million
Philippines		National Greening Program target: 1.5 billion trees covering 1.5 million hectares for a period of 6 years from 2011 to 2016	2010 National REDD+ Strategy			X	4	$21.02 million
Thailand	Expand forest reserves up to 40%		REDD+ strategy under development				1	$17.66 million
Viet Nam		Increase forest cover from 43% (2010) to 47% (2020)	2011 National REDD+ Office established; 2012 National REDD+ Action Programme	X	X	X	4	$26.32 million

DA5 = Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam; Mha = million hectares; MRV = monitoring, reporting, and verification, REDD = reducing emissions from deforestation and forest degradation; .

Sources: The REDD desk, a collaborative resource for REDD readiness. http://thereddesk.org/countries (accessed 30 October 2015); UN REDD Country programs (as cited in ADB 2010), and various country development plans.

for concessionaires that have not fully developed plantations in areas that they have previously cleared. Indonesia also has millions of hectares of degraded *Imperata cynlindrica* grasslands, which could be swapped with forested concession areas, so that plantation development does not occur at the expense of forests. This could be prioritized in peat forest areas, as they have concentrated emissions potential, and peat soils tend to be associated with lower plantation productivity than mineral soils.

5.2.3 Getting incentives right is critical to reducing deforestation

(i) *Timber royalty systems can be improved*

More generally, the ability of actors to obtain economic "rent" from forest clearance should be eliminated for large-scale deforestation to be reduced. Currently, much of this "rent" is derived from the fact that concessionaires often pay royalties and fees that are substantially lower than the market value of timber cleared from concessions, as a result of incomplete monitoring and low royalty rates (Wakker 2014). This rent can be eliminated by aligning the resource price paid with its market value. One means of achieving this alignment is through functioning land markets, which ensure that the price paid for forest land will inherently incorporate the market value of wood. An alternative second means of alignment is to ensure that royalty rates are market based, and that actual wood extraction is closely monitored and verified against royalties collected. The establishment of clear "license information systems," coupled with better information sharing on concession areas and local forest management unit establishment, as is currently being pursued by the Government of Indonesia, has valuable potential to help foster these improvements.

(ii) *Existing regulations can reduce emissions if enforced*

Many existing regulations in Indonesia actually have potential to strongly curtail deforestation associated emissions. For example, Presidential Decree Number 32/1990 forbids clearance of forest on peat more than 3 meters deep, and Ministerial Decree 10.1/2000 specifies that forest clearance for plantations should not be approved in forests with more than 5 cubic meters per hectare of standing timber over 10 centimeter in diameter, or more than 200 trees per hectare, which basically excludes all forest cover. A principal problem is that clearance permits have often been issued by local authorities regardless of compliance with these regulations, and that loss of important forest cover thereby becomes "legal" (EIA 2014, Barr et al. 2006). Better on-the-ground monitoring and enforcement of these existing regulations could do much to address deforestation.

(iii) *Reduction of land tenure conflicts can lead to better outcomes for forests*

Land tenure conflicts are a large driver of deforestation, fires, and emissions. In Indonesia, nearly all "forest land" is owned by the state, and much of that land has long had local populations who also feel that the land belongs to them. When concessions are allocated to companies for forest extraction, local communities may try to clear valuable timber quickly to claim the value of what they perceive as their assets before they are taken by concession holders (Barber 2002). This creates pressure for quick clearance. Similarly, concession holders may feel pressure to clear forest quickly before local claims of ownership or compensation emerge. Both sides may use fire events to suppress evidence of their actions, so that unclear tenure contributes to forest fires. Greater recognition of local tenure rights, as is stipulated by the Constitutional Court ruling, may help to reduce these conflicts and associated forest loss.

5.2.4 Institutions need reform for REDD to be effective

(i) *Substantial funds are already available to change forest cover outcomes*

Making REDD work still requires up-front investments in institutions, awareness, and broadly accepted regulations. Administrative capacity and incentives in ministries of forestry will need additional attention and reforms. Addressing these issues is not merely a matter of attracting finance. Although royalty reform to disincentivize deforestation has been a conditionality of large-scale ($43 billion) lending to Indonesia during the Asian financial crisis, disparities remain between wood values and royalties collected (Gautam et al. 2000). In 2009, the Government of Norway offered $1 billion of funding for REDD in Indonesia. Despite some promising measures that resulted, such as restrictions on new concession allocation, progress has been limited, and the vast majority of the funding remains undisbursed. Long before REDD, Indonesia domestically collected nearly $6 billion for reforestation from wood royalties, but actual progress on forest regeneration remains limited (Barr et al. 2010).

(ii) *Investment in institutional capacity is essential*

Avoiding large-scale deforestation requires major shifts in how forests are perceived, regulated, and governed. Current Indonesian arrangements result in large economic losses to the public under low current royalty recoveries. Over the 2003 to 2014 period, the Indonesian state lost timber assets with estimated values of $61 billion to $81 billion, which were harvested but unreported to revenue collecting authorities (Corruption Eradication Commission 2015). Accordingly, 77% to 81% of national timber production has been estimated as unreported. Indonesia's Corruption Eradication Commission found in a 2012 survey that the Ministry of Forestry was perceived to have lower integrity than most other government agencies (Corruption Eradication Commission 2013). More broadly, decentralization of forest management has resulted in many problems of coordination in regulatory approvals among various government units, and has limited accountability for enforcement (Barr et al. 2006). Investment in new institutional arrangements is needed to ensure that perverse incentives are eliminated, regulations are clear and monitored, and violations are prosecuted.

Implementing REDD requires investment to foster procedures and standards that reflect consensus, fairness, and accountability. Effective local baseline deforestation trajectories and drivers need to be identified, so that reductions in deforestation can be assessed in a manner that meets market reporting and verification requirements. Benefit-sharing arrangements will necessarily need to have an appropriate balance of rewards to those who have preserved forests and incentives to change the behavior of those likely to destroy them. Much effort is still needed to identify a mix of measures to ensure that REDD is truly effective, efficient, and equitable. For climate stabilization to occur at acceptable cost in the medium term, steps toward comprehensive REDD preparedness need to take on greater priority and urgency. At the same time, although REDD is important to abatement costs in the short to medium term, it is by no means a sufficient measure for long-term low-carbon growth.

5.3 Long-Term Mitigation Depends on Energy System Transformation

5.3.1 Rapid improvement in energy efficiency is essential

(i) *Energy efficiency is the largest long-term mitigation opportunity*

Achieving deep decarbonization depicted in global climate stabilization scenarios depends on a fundamental structural transformation of energy systems. Both models depict vigorous energy intensity declines starting early in 2020, the year when these policies are expected to be adopted. Efficiency improvement is the biggest single source of long-term emission reduction in the stabilization scenarios.

There are many opportunities to increase the efficiency of electricity generation, transmission, distribution, and consumption, as well as to improve transport fuel–use efficiency (see Box 5 for examples). Despite rapid economic growth, Southeast Asia has faced some of the slowest improvements in energy intensity in the world. The energy intensity of industrial production actually declined in the region between 1980 and 2011,

Box 5: Bottom-Up Modeling of the Financial Costs of Emissions Abatement from Fossil Fuels in Viet Nam

To explore the potential of efficiency improvement to reduce greenhouse gas emissions, the Asian Development Bank, the World Bank, and national partners led by the Ministry of Planning and Investment developed a bottom-up model for Viet Nam using the Energy Forecasting Framework and Emissions Consensus tool to analyze the mitigation potential of 64 specific possible technology measures in four key sectors: power generation, household electricity consumption, industry, and transport. Over the modeling period (2010–2050) these future measures are found to have the potential to mitigate 4,500 million tons of carbon dioxide equivalent ($MtCO_2eq$), with an average financial opportunity cost of –\$0.67/ton of carbon dioxide equivalent (tCO_2eq). This is modeled to permit emissions from these sectors to peak at 600 $MtCO_2eq$ per year after 2035, compared with 1200 in the baseline.

Power sector: Twelve low-carbon measures were evaluated, which contribute 64% of total modeled mitigation potential over 2010–2050. Increasing generation from biomass, solar, and to a lesser extent, onshore wind and micro-hydro can potentially mitigate 348 $MtCO_2eq$ annually by 2050. Over the 2010–2050 time frame, these measures generate a total mitigation of 2,962 $MtCO_2eq$ at a weighted average marginal abatement saving (negative cost) of \$1.06 per ton of CO_2eq.

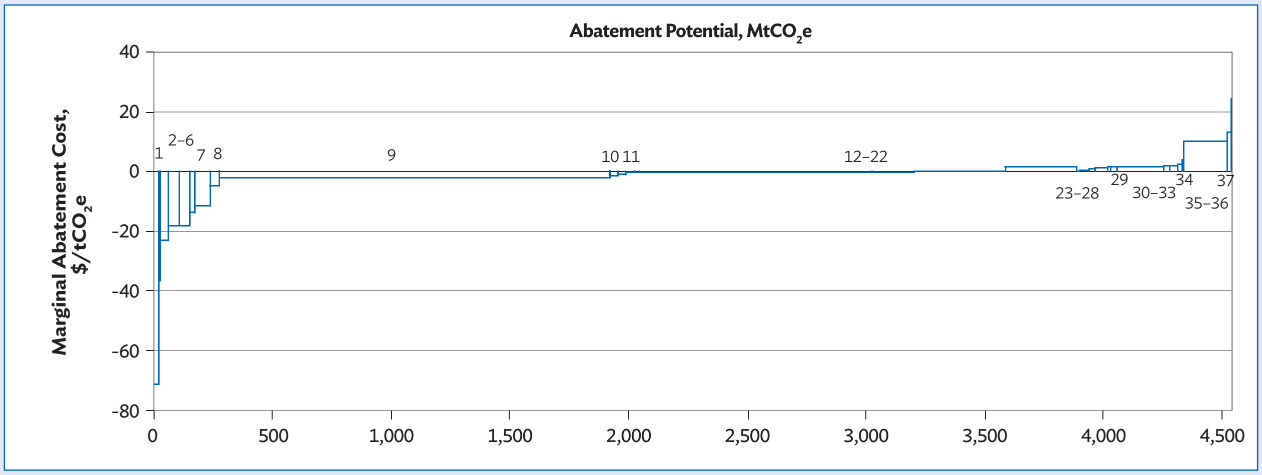
Household: Over 405 $MtCO_2eq$ of cumulative (2010–2050) mitigation can be potentially achieved through improvements in household appliance efficiency and building standards. Improved efficiency of building cooling is the most important potential area of intervention to achieve this mitigation.

Industry: Energy efficiency measures for the five highest energy-consuming industries (iron and steel, cement, fertilizer, refining, and pulp and paper) have the potential to mitigate a cumulative (2010–2050) 626 $MtCO_2eq$ at an overall average mitigation cost of \$1.88/tCO_2eq. Of this, almost 71% of abatement comes from power generation from waste heat recovered in large integrated iron and steel and cement plants.

Transport: This sector accounts for 36% of the cumulative (2010–2050) modeled mitigation, with emission reduction of 645 $MtCO_2eq$. Eleven interventions were assessed, of which improving vehicle technology, biofuel use, and bus transport improvements are modeled to mitigated 550 $MtCO_2eq$.

It should be noted that these abatement costs are in financial terms, and generally include only facility and opportunity costs. The broader economic costs of policies necessary to incentivize these technical changes are omitted, such that the costs cannot be directly compared with the findings of top-down models, such as ICES and WITCH. Nevertheless, these study results indicate that there is ample opportunity to achieve energy efficiency and system improvements at relatively low cost if an appropriate policy environment exists.

Box Figure 5.1: Overall Marginal Abatement Cost Curve of Power, Industry, and Transport Sectors



$MtCO_2eq$ = million tons of carbon dioxide equivalent, tCO_2e = ton of carbon dioxide equivalent.
Source: ADB Study Team.

continued

Box 5 continued

Box Table 5.1: Overall Marginal Abatement Cost Curve of Power, Industry, and Transport Sectors

	Sector	Scenario	Mitigation Potential ($MtCO_2eq$)	Marginal Abatement Cost ($/$tCO_2eq$)
1	T	Fuel switching to CNG for buses	20	(71)
2	T	Other improvements	8	(36)
3	H	Refrigerator	31	(23)
4	H	Other household appliances	45	(18)
5	H	Air conditioning	49	(18)
6	T	Freight modal shift from road to coastal	16	(14)
7	H	Lighting	68	(11)
8	P	Hydro	37	(5)
9	P	Biomass	1,648	(2)
10	Steel ISP	Natural gas injection in blast furnace	33	(1)
11	Steel ISP	Pulverized coal injection (PCI) in blast furnace	32	(1)
12	T	Increase freight modal shift from road to rail	41	0
13	T	Inland waterways improvement	16	0
14	P	Solar	978	0
15	T	Increase sales of electric two-wheelers	180	0
16	T	Technology improvement in private vehicles toward EU efficiency standards	200	0
17	T	Increasing the use of biofuel	96	0
18	Fertilizer	Installation of variable speed drives for cooling tower fans of ammonia and power plant	18	0
19	Cement	Combustion system improvements	73	0
20	P	Wind	299	2
21	Pulp and Paper	Waste heat recovery from paper drying	15	0
22	Steel ISP	Sinter plant heat recovery	25	0
23	Fertilizer	Other improvements	8	1
24	Steel SSP	Other improvements	26	1
25	Steel ISP	Other improvements	4	1
26	Steel ISP	Blast furnace and coke oven cogeneration	49	1
27	Pulp and Paper	Other improvements	13	2
28	Pulp and Paper	Increased use of recycled pulp	25	2
29	Steel ISP	Thin Slab Casting (TSC) and Strip Casting (SC)	198	2
30	Steel ISP	Hot charging in rolling mills	24	2
31	Steel ISP	BOF gas sensible heat recovery	33	2
32	Steel ISP	Installation of the top pressure recovery turbine	22	2
33	Refinery	Other improvements	4	4
34	H	Low E windows or shades + HE ceiling fan	186	10
35	H	Water heater	24	13
36	Cement	Other improvements	22	25
37	T	Passenger modal shift from 2W and cars to buses	68	26
		Total	**4,638**	**(0.68)**

( ) = negative, CNG = compressed natural gas, ISP = integrated steel plant, $MtCO_2eq$ = million tons of carbon dioxide equivalent, tCO_2e = ton of carbon dioxide equivalent.
A = Agriculture, H = Household, I = Industry, N=Nonresidential, P = Power,T = Transport.
Source: ADB Study Team.

in stark contrast to the global average and patterns in other parts of developing Asia (IEA 2013c). This reinforces the finding that there is substantial scope to increase energy efficiency and thereby achieve significant GHG emissions mitigation.

5.3.2 Energy efficiency improvement can be accelerated, compared with current targets

(i) *Countries in the region have important energy efficiency programs*

Each country in the region recognizes the importance of energy efficiency through policies and relevant targets.

- Indonesia's "Energy Vision 25/25" stipulates that 18% of primary energy should be conserved between 2011 and 2025, to be achieved as per the 2010 revision of the National Energy Conservation Master Plan.
- Malaysia's 2014 draft Energy Efficiency Action Plan targets a 6% improvement in energy efficiency over 10 years.
- The Philippine Energy Efficiency and Conservation Program set out a general target of 10% energy savings by 2030 on total annual energy demand for all sectors.
- Thailand's Energy Efficiency Development Plan, approved in 2011, defines energy conservation targets as to (i) reduce energy intensity (energy use per unit of GDP) by 25% in 2030, compared with 2005 levels; and (ii) reduce overall energy consumption by 20% relative to BAU levels in 2030.
- Viet Nam's Energy Efficiency and Conservation Programme, 2011 and National Target Programme for Energy Efficiency and Conservation, 2012 target saving 5%–8% of total national energy consumption during 2012–2015.

(ii) *A greater array of policy instruments can be applied to foster efficiency gains*

At the same time, the energy efficiency targets set for DA5 countries in energy or power sector plans are at or below BAU levels of improvement identified in WITCH and nationally interpolated for ICES (Table 20). This suggests that global climate stabilization will require much more aggressive efforts to improve energy efficiency than is currently the case.

Table 20: Annual Energy Efficiency Improvements under Current Government Plans and ICES (%)

Countries	Government Target	BAU	650 ppm	500 ppm
Indonesia	1.38	1.85	2.13	2.83
Malaysia	0.59	1.17	1.44	2.14
Philippines	0.92	1.55	1.71	2.14
Thailand	0.96	1.17	1.43	2.11
Viet Nam	1.60	1.85	2.31	3.40

BAU = business as usual, ICES = Intertemporal Computable Equilibrium System, ppm = parts per million.
Source: ADB Study Team.

A variety of policy instruments can be used to foster faster energy efficiency improvement. These include minimum efficiency performance standards, efficiency labeling, codes that require energy efficiency in buildings, fuel economy standards for transportation, industrial energy management, and support to energy service companies (ESCOs) that advise on efficiency enhancement. Countries in the region have made use of some of these instruments (Table 21). All DA5 countries require management or auditing of industrial energy efficiency, and all provide some degree of support to ESCOs. Similarly, all have some forms of energy efficiency labeling for some energy-consuming appliances and voluntary standards for building efficiency.

At the same time, many policy tools are not fully utilized. Support to ESCOs could be expanded in most countries in the region. Industrial energy efficiency could be enhanced through a greater array of energy performance standards for energy-consuming equipment such as electric motors. Fuel efficiency standards could be introduced for vehicles. Mandatory building codes for energy

Table 21: Energy Efficiency Policies in the DA5 Countries

Countries	Cross-Sector: National Strategy	Cross-Sector: ESCO	Industry: Energy Management	Transport: Fuel-Economy Standard	Buildings: Building Code	Buildings: MEPS and Labeling
Indonesia	National Energy Conservation Master Plan	Partnership Program on Energy Conservation	Mandatory energy management (>6000 toe/y)	Fuel-economy standard under consideration	Voluntary codes (building envelope, air conditioning, lighting, energy auditing)	Mandatory labeling (CFLs)
Malaysia	The National Energy Efficiency Action Plan under consideration	Investment tax allowance; import duty and sales tax exemption	Mandatory energy management (>3 million kWh per 6 months)	Tax measures to promote hybrid cars	Voluntary codes (energy efficiency, renewable energy)	Mandatory MEPS (refrigerators, lighting, air conditioners, fans television sets)
Philippines	The National Energy Efficiency and Conservation Program	ESCO certificate of accreditation	Energy audit service	None	Voluntary codes (energy-conserving design)	Mandatory MEPS (air conditioners, CFLs, linear fluorescent lamps); mandatory labeling (eight products: refrigerators, air conditioners, CFLs, etc.)
Thailand	20-Year Energy Efficiency Development Plan 2011–2030	Tax exemption (maximum 8 years); ESCO fund; low-interest loans; promotion activities	Mandatory energy management (<1,000 KW or 20 TJ/y).	Fuel-economy standard under consideration Tax measures to promote energy-efficient vehicles (5 l/100 km)	Mandatory codes (building envelope, lighting, air conditioning); voluntary labeling	Mandatory MEPS (refrigerators, air conditioners); voluntary labeling (23 products: refrigerators, air conditioners, rice cookers, etc.)
Viet Nam	The National Target Program on Energy Efficiency and Conservation	Market development project	Mandatory energy management (over 1,000 toe/y) Mandatory MEPS for electric motors from July 2013	Mandatory fuel-economy labeling (applied only for vehicles under 7-seater category) from January 2015	Voluntary codes (building envelope, lighting, air conditioning, ventilation)	Mandatory MEPS from January 2015; mandatory labeling from July 2013 (eight products: air conditioners, fans, rice cookers, etc.)

CFL = compact fluorescent lighting, ESCO = energy service company, km = kilometer, KW = kilowatt, kWh = kilowatt-hour, MEPS = Minimium Energy Performance Standards, TJ = terajoule, toe/y = tons of oil equivalent per year
Source: IEA (2013c).

efficiency could be introduced in most countries. Minimum energy performance standards for key appliances could be introduced or expanded from narrow ranges of goods in most countries. All of these measures could help promote much faster progress in energy efficiency improvement.

5.3.3 Fossil fuel pricing reform can stimulate energy efficiency improvement

(i) *Fossil fuel subsidies are a negative carbon tax*

Efficiency improvement is the biggest single source of long-term emission reduction in the models applied in this study, and all efficiency improvement is induced as a response to carbon price signals applied to fossil fuels. According to economic theory, there is no difference in the behavioral response expected from the removal of a subsidy (a negative tax) and the imposition of a tax. Thus, the efficiency improvement demonstrated is analogous to what may be expected if similar levels of fossil fuel subsidies were eliminated. This suggests that subsidy reform may have important potential to help shift the DA5 toward an efficient and low-carbon development pathway.

(ii) *Fossil fuel subsidies have been substantial in the region*

Fossil fuel subsidies encourage inefficient use of energy, disincentivize use of low-carbon energy sources, and consume significant public resources. At the same time, fossil fuel subsidies have been widespread in the DA5, and were growing rapidly during 2007–2011 (Table 22). Oil, principally for transportation, is the principal subsidized fossil fuel in Indonesia, Malaysia, and the Philippines, while electricity receives substantial subsidies in Indonesia, Malaysia, Thailand, and Viet Nam. Indonesia has made major progress by reducing oil subsidies by approximately 90% in early 2014, after the period covered by international databases.

Table 22: Fossil Fuel Subsidies in the DA5
(billions of nominal $)

Country		2007	2008	2009	2010	2011
Indonesia	Oil	11.30	14.28	8.99	10.15	15.72
	Electricity	1.87	4.74	5.31	5.79	5.56
	Natural gas	0.00	0.00	0.00	0.00	0.00
	Coal	0.00	0.00	0.00	0.00	0.00
	Total	13.17	19.02	14.30	15.94	21.28
Malaysia	Oil	2.69	4.61	1.58	3.89	5.35
	Electricity	0.49	2.20	1.71	0.81	0.94
	Natural gas	1.42	2.97	1.68	0.97	0.89
	Coal	0.00	0.00	0.00	0.00	0.00
	Total	4.60	9.78	4.97	5.67	7.18
Philippines	Oil	0.16	0.12	0.03	1.10	1.46
	Electricity	0.00	0.00	0.00	0.00	0.00
	Natural gas	0.00	0.00	0.00	0.00	0.00
	Coal	0.00	0.00	0.00	0.00	0.00
	Total	0.16	0.12	0.03	1.10	1.46
Thailand	Oil	1.55	2.08	1.20	2.11	3.29
	Electricity	0.88	4.16	4.23	5.44	5.67
	Natural gas	0.22	0.58	0.24	0.48	0.48
	Coal	0.17	0.56	0.50	0.44	0.85
	Total	2.82	7.38	6.17	8.48	10.29
Viet Nam	Oil	0.32	1.09	0.00	0.00	1.02
	Electricity	1.68	2.25	2.10	2.69	2.92
	Natural gas	0.09	0.21	0.13	0.23	0.16
	Coal	0.01	0.01	0.01	0.01	0.02
	Total	2.10	3.57	2.23	2.93	4.12

DA5 = Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam.
Source: IEA (2013b).

(iii) *Removing fossil fuel subsidies incentivizes greater efficiency*

Removing fossil fuel subsidies increases the returns to investment in energy-efficient goods, services, and infrastructure, and makes energy inefficiency more costly. As found by IEA (2013a), the payback period to investments in efficient goods can be halved in countries, such as Indonesia, if subsidies are removed. It is no coincidence that the Philippines, which has the smallest energy subsidies, also has the most rapid improvement in energy intensity of the DA5. Fossil fuel subsidies also undercut the prices of renewable sources of energy, especially at early stages of commercialization, and thereby restrict demand. In turn, restricted demand for renewable energy deters investment in research, development, and deployment, further delaying processes that ultimately are necessary to make renewable energy widely adoptable. This locks countries into an inefficient and carbon-intensive development path.

Reform to these subsidies is politically contentious, as it leads to undesirable short-term macroeconomic effects as economies adjust, including increases in inflation that may harm the poor. Safety nets and other pro-poor measures may need to be strengthened as reform is implemented to facilitate acceptance and ensure equitable outcomes for vulnerable populations with limited purchasing power. However, as Indonesia's recent progress shows, reform is possible.

5.3.4 Ambitious plans to expand renewable energy by countries in the region are important

(i) *Transition to low-carbon energy is essential to long-term mitigation*

The results of this study indicate that 500 ppm scenario requires a dramatic shift to low-carbon energy sources. WITCH finds that by the 2030s, 80% of primary energy and nearly all power generation in the region would be from low-carbon energy. As power generation and energy systems are long-term investments, early preparation for such a shift can allow such a low-carbon energy transition to occur at lower cost.

(ii) *Countries in the region plan to rapidly expand renewable energy*

The model results indicate substantial changes in energy sector investments under global climate stabilization scenarios. Disinvestments in the extraction sector are found to be roughly equaled by additional investments in low-carbon sources, such as renewables. All countries in the region have ambitious targets to expand generation of renewable energy, which the results of this study generally confirm:

- According to Indonesia's National Energy Policy (2014), 23% of the national energy mix should be from renewable sources by 2025, with oil falling from 41% of the 2012 mix to 25%, coal rising from 29% to 30%, and natural gas falling from 24% to 22%. The main renewables targeted are geothermal in the power sector and biofuels for transport, with gradual scaling up of hydropower, solar, and new energy sources, such as liquefied coal.

- The Tenth Malaysia Development Plan, 2010–2015, outlined a gradual scaling-up of renewable energy. Targets include renewables as 5% of the power mix by 2015, 11% by 2020, and 17% by 2030. The identified renewable energy sources are solar photovoltaic, solid waste, mini-hydro, biogas, and biomass. The Renewable Energy Act established a system of feed-in tariffs for renewables by setting fixed tariff rates for electricity generated from solar, biomass, biogas, and hydro energy, guaranteed for a period of 16–21 years.

- For the Philippines, the National Renewable Energy Plan, 2012" with "Program targets a tripling of renewable energy installed capacity by 2030 from its 2010 level of 5,369 MW to 15,236 MW by 2030 (DOE 2011). More than half (54%) of the additional capacity is expected to come from hydropower; 24% from wind; 15% from geothermal; and the remainder from solar, biomass, and ocean power.

- In Thailand, the 2011 Renewable and Alternative Energy Development Plan, 2012–2021 introduced a new feed-in tariff scheme for renewable power and promotes the development of ethanol and biofuel production. Further amended in 2013, the plan aims to increase the share of renewable and alternative energy to 25% of installed capacity by 2021, of which half is from solar, wind, and hydropower and half is bioenergy.

- Viet Nam's Power Master Plan 7 specifies that 4.5% of power should be from renewables by 2020, and 6% by 2030. The Renewable Energy Development Plan intends to double the total capacity of hydroelectric power from the current 9,200 MW to 17,400 MW and increase the production of wind power to 1,000 MW in 2020 (0.7% of total electricity generation) and 6,200 MW in 2030 (2.4% of total generation). Biomass and cogeneration capacity is expected to reach 500 MW (0.6%) in 2020 and 2,000 MW (1.1%) in 2030. Under the 2007 National Energy Development Strategy, 8,000 MW nuclear capacity is expected by 2025, and a 15%–20% nuclear share of total energy consumption is projected by 2050. Coal-fired power generation is expected to account for over 50% of total capacity by 2030.

- At the level of the Association of Southeast Asian Nations (ASEAN), energy ministers approved in 2015 the ASEAN Plan of Action for Energy Cooperation for 2016–2025, which sets a target to increase the share of renewable energy in total primary energy supply to 23% by 2020 across the region.

A large share of renewable targets in Indonesia, Malaysia, and Thailand are also to be achieved outside the power sector. When the power sector alone is considered, targets range from 5% of generation to 52% of installed capacity (Table 23). The composition of targets is highly variable, with Malaysia and the Philippines aggressively focusing on solar, only the Philippines aggressively focusing on wind and hydropower, Thailand prioritizing bioenergy, and Indonesia highlighting geothermal. Although these targets reflect very large renewable capacity expansion, only the Philippines has a future target greater than the 23% global share of renewables in power generation as of 2014. This suggests that expansion of renewable energy shares might be continued far beyond these targets.

Table 23: Renewable Power Targets of DA5 Countries

Countries	Year	Approximate Power Development Targets (% energy share)						
		Renewable Share	Type of Share	Hydropower	Geothermal	Bioenergy	Wind	Solar
Indonesia	2025	23	Primary energy	1.2	7.8	0.0	0.1	0.1
Malaysia	2030	11	Power generation	2.5	0.0	4.1	0.0	4.4
Philippines	2030	52	Power capacity	25.4	7.1	3.3	11.3	4.7
Thailand	2021	25	Primary energy	2.3	0.0	6.7	0.4	0.7
Viet Nam	2020	5	Power generation	2.7	0.0	0.8	1.6	0.0

DA5 = Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam.
Note: Renewable share may be of all energy, whereas power development target refers to the power sector only.
Sources: IRENA (2014), IEA (2013a), REN21 (2014).

(iii) *Achieving renewable energy expansion targets is important to mitigation*

These renewables targets are important to climate stabilization. Indonesia's targeted 5% annual increase in renewable power is consistent with what WITCH and ICES find under 500 ppm stabilization. Indonesia has also targeted a dramatic drop in the oil share of energy, to an extent such that the 2020 target share is far less than what WITCH or ICES find under 500 ppm stabilization in 2050. Malaysia, the Philippines, and Thailand have renewable power targets for the energy sector that reflect rapid growth rates that are compatible with ICES modeling results for climate stabilization—if the growth rates are maintained through 2050. Malaysia and Thailand have a low modern renewable starting share, so their very ambitious targets on growth in the share of power generation from renewables are consistent with what ICES finds under 500 ppm stabilization. In the Philippines, the target growth of renewables under National Renewable Energy Program is actually greater than 500 ppm stabilization under ICES.

At the same time, decarbonization also implies some important changes to power generation targets, particularly regarding coal. Indonesia and Viet Nam's power development plans target an increase in energy from coal, which is greater than ICES or WITCH find even under BAU, and which need to dramatically drop for emissions stabilization. Similarly, the models suggest a faster rate of increase in renewables is needed for Viet Nam to be consistent with the stabilization scenarios.

All DA5 countries have established an array of supporting policies to facilitate renewable power expansion (Table 24). These include recent introduction of stable guaranteed feed-in tariffs for certain types of renewable power. Tax incentives have also been established in all countries on renewable generation facilities, such as grace periods and accelerated depreciation. Other instruments have been used more variably. Only the Philippines has net metering, which allows consumers to be paid for power sent back to the grid. Renewable performance standards, which require renewable power shares from all power providers have been employed in three of the five countries. Open and predefined standard producer purchase agreements are in place in most countries, but not all. Support for financing and equity also vary among the countries. The gaps that remain in support policies suggest that additional instruments can be applied, particularly to facilitate financing and reduce risks that may deter investment.

5.3.5 Advanced energy technologies should be a long-term priority

(i) *Advanced biofuels and possibly carbon capture and storage could be widely adopted by the 2030s*

WITCH shows massive adoption of low-carbon technologies that allow more energy consumption by the DA5. Under 500 ppm stabilization, fossil fuels with CCS, advanced biofuel, and bioelectricity represent more than 45% of the total primary energy

Table 24: Policies Employed in DA5 Countries to Support Expanded Renewable Power Generation

Renewable Power Support Policy	Indonesia	Malaysia	Philippines	Thailand	Viet Nam
Fixed feed-in tariff	🔵	🔵	🔵	🔵	🔵
Net metering			🔵		
Renewable performance standards		🔵	🔵	🔵	
Standard producer purchase agreement	🟡	🔵		🔵	🔵
Equity support	🔵		🔵	🔵	🟡
Debt financing			🔵	🔵	
Tax incentives	🔵	🔵	🔵	🔵	🔵

DA5 = Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam.
Notes: 🟡 is partially implemented, 🔵 is implemented.
Source: Adapted from ASEAN Centre for Energy (2013).

mix in Indonesia and 50% in the rest of Southeast Asia. Decarbonization patterns are even stronger in the electricity sector. According to the WITCH results, the 500 ppm scenario requires more than 80% of electricity generation from carbon-free sources in Indonesia and more than 90% in the rest of Southeast Asia by 2050. Inclusion of these technologies is the major reason why 2050 500 ppm policy costs in WITCH are half of those in ICES. This implies that action should be initiated quickly to facilitate deployment of advanced energy in the region for low-carbon development at low cost.

(ii) *If successfully developed, carbon capture and storage has the potential to help reduce mitigation costs substantially*

CCS is the key energy technology found to reduce the cost of long-term emissions mitigation, as found in this study and previously in the IPCC's AR5. Given that coal is the main basis of planned power developments in much of the region, CCS is a key strategy to reconcile this with a low-carbon emission pathway. However, CCS is an expensive and yet unproven (at scale) technology, which will need to develop significantly before becoming commercially viable (Box 6). CCS also requires extra energy, with attendant costs, so it would be deployed only in the presence of climate policies. Its viability also depends upon the longer-term ability of geological structures to contain carbon dioxide, as well as improved efficiency. As these are unknown, it is premature to conclude that CCS will indeed be widely deployable, even if it has large potential.

At the same time, ADB (2013a) has confirmed that CCS has the potential to be technically viable in Indonesia, the Philippines, Thailand, and Viet Nam, with sufficient saline aquifers present to store 54 gigatons of CO_2. Given current cost structures, total abatement costs (inclusive of efficiency losses, capture, transport, and storage) are nearly $100/ton. These carbon prices are modeled in the present analysis to be reached under a 500 ppm by the 2020s, triggering CCS deployment and technical improvement, which reduces costs to allow further adoption. ADB (2013a) finds that a 50% reduction in incremental capital costs for CCS in representative coal supercritical plants leads to a 26% reduction in abatement costs, while a 50% reduction in fuel costs leads to a 15% reduction in abatement costs. Both progress in reduction in incremental capital costs as well as incremental fuel costs (from better capture and storage efficiency) would be expected as a result of learning by doing and formal research if CCS were widely deployed.

No country in the region has established plans or targets pertaining to CCS for the energy sector. Initial piloting of CCS for gas extraction is being implemented in Indonesia. Wide-scale deployment of CCS will take substantial preparation and decades to develop, so it may be useful for countries in the region to take initial steps soon to initiate a low-carbon energy transition. ADB (2013a) proposes a sequenced approach over the period up to approximately year 2030. The initial stage would consist of small-scale pilots to capture several hundred tons of CO_2 per day for several years. As is currently occurring in Indonesia, these pilots can

Box 6: Carbon Capture and Storage: Potentials and Challenges

As revealed in the present analysis, there are insufficient substitutes for fossil fuels for a majority of energy needs to be fulfilled by nonfossil sources prior to 2050. However, carbon capture and storage (CCS) can potentially disassociate carbon dioxide (CO_2) emissions from fossil fuel combustion at scale. CCS deployment could be an interim measure to address CO_2 emissions from fossil fuel use in energy generation and industrial processes in developing countries, allowing time for other alternative low-carbon technologies to become more cost-effective and widely deployed. CCS can also be combined with biomass-based energy production to generate negative emissions. In the most stringent climate simulations for this study using the WITCH model, 18% of global primary energy is produced using CCS by 2050.

CCS methods can be applied to point emissions sources. They consist of capturing CO_2 from combustion processes, transporting to storage facilities, and storing the CO_2 permanently. CO_2 can be captured postcombustion, from flue gases; precombustion through a gassifier that creates syngas; or through oxy-fuel or chemical looping combustion. Transport of captured CO_2 is usually by pipeline. Storage and/or sequestration takes two principal forms—mineral carbonates after reactions with metals, or as a supercritical gas stored in underground geological formations.

Yet, CCS has uncertain technological potential and drawbacks. Currently available CCS methods create a substantial energy drain that increases fuel use per unit of generation, and, as a result, it increases emissions associated with fossil fuel extraction and transport. In addition, CCS is reliant on the ability of geological formations to hold CO_2 in perpetuity. Leakage from these formations is a major technological concern. Technological progress for CCS has been slower than anticipated in recent years, and a number of planned CCS facilities have been abandoned due to the costs involved.

According to International Energy Agency (IEA) estimates, the cost of a new, average-sized, coal-fired power plant that captures up to 90% of its CO_2 emissions will cost about $1 billion over 10 years. The estimated abatement cost for CCS falls in the range of $30–$118 per ton of CO_2 equivalent emissions for coal-fired power plant projects, as shown in Box Table 6.1.

Box Table 6.1: List of Cost Estimates for Early Carbon Capture and Storage Projects

Source	Estimates
IPCC (2005)	New pulverized coal; Cost avoided $30–70/t$CO_2$; Increase in electricity cost: 43%–91%
	New IGCC: Cost avoided $14–53 t$CO_2$; Increase in electricity cost 21%–78%
IEA (2008)	$40–$90/ tCO_2 abated
IEA (2010)	Pilot to large scale: Average $1 billion investment per project over the next 10 years
IEA (2011)	Postcombustion capture (OECD only) average $58 with range $40–$69/tCO_2 avoided
	Precombustion IGCC $43 with range $29–$62/tCO_2 avoided
	Oxycombustion average $52 and range $27–$72/tCO_2 avoided
Coal Utilization Research Council	$17.3 billion/year incremental cost for early adopter 45 GW (30-year plant life) over 20 years $4.5 billion/year incremental cost for pioneer
McKinsey (2009)	New project: $0.6–$1.0 billion additional cost per plant; $78–$118/tCO_2 abated

CO_2 = carbon dioxide, GW = gigawatt, IEA = International Energy Agency, IGCC = integrated gasification combined cycle, IPCC = Intergovernmental Panel on Climate Change, OECD = Organisation for Economic Co-operation and Development, tCO_2 = ton of carbon dioxide.
Notes: Current figures are focused on coal-fired power plants unless otherwise stated. CCS projects that include capture from industrial sources such as cement, iron and steel, ammonia, and natural gas processing offer lower capture costs because of the high purity of emitted CO_2.

Investment in CCS will not be attractive until carbon prices are higher than these abatement costs. However, with additional investment in CCS technologies, it is possible that coal coupled to CCS could provide cheaper energy than conventional coal plants provide at present.

In the meantime, development assistance has focused on building capacity for deployment. The IEA CCS Roadmap (IEA 2012) proposes 50 CCS projects in developing countries in the next 10 to 20 years. As well as reducing the developing world's greenhouse gas emissions, accelerating CCS demonstration efforts in countries outside the Organisation for Economic Co-operation and Development (OECD) can likely also improve technologies, increase efficiency, reduce uncertainty and risk, and initiate learning-by-doing at a lower cost than would be possible in OECD countries.

Sources: IPCC (2005), IEA (2012a) Almendra et al. (2011).

be targeted to the natural gas extraction sector, where CO_2 capture is less energy-intensive and CCS is less costly. This would be followed by a demonstration period with larger projects of several thousands of tons of CO_2 abated per day for 5–6 years, after which commercial deployment would be initiated.

CCS deployment requires a defined and supportive regulatory environment, which may take considerable time to develop, as it intersects many different concerns. For example, CO_2 needs to be clarified as to whether it is treated as a pollutant, requirements for environmental impact assessment should be defined for CCS operations, and regulatory approaches to CCS pipelines need to be clarified (ADB 2013a). Long-term subsurface storage rights need to be accessible and clearly defined, along with legal liabilities, and procedures to access foreign direct investment. Although CCS is clearly a long-term mitigation option that is only economically feasible for power generation under sufficient carbon prices, preparation for CCS deployment can be initiated now to facilitate faster potential adoption when price signals are appropriate.

(iii) *Advanced biofuels can enable transport sector decarbonization*

Modeling results from WITCH in this study show large adoption of biofuels as an energy source under climate stabilization scenarios. Biofuels uniquely hold the promise of allowing direct decarbonization of transport, which is traditionally a difficult sector for emissions abatement. If available at scale, biofuels could provide an important contribution toward emission reduction in the region.

Most of the countries in the region have set blending mandates to increase use of biofuels, particularly for the transport sector (Table 25). However, these biofuels are "first generation," and use food crops as feedstocks. Biodiesel in the region is principally derived from oil palm or coconut, while ethanol is derived from sugarcane, or cassava. Countries in the region have struggled to consistently supply sufficient quantities of biofuels to fulfill blending mandates (Dermawan et al. 2012).

Use of these food feedstocks competes with food security objectives and creates pressure for agricultural expansion and deforestation, exacerbating the largest source of emissions from the DA5. This is particularly so for oil palm, as domestic blending mandates increase palm oil prices and encourage new oil palm concession development, which is associated with deforestation in Indonesia and Malaysia. It is also uneconomic, as these feedstocks are relatively expensive.

However, what this study shows is that the true mitigation potential of bioenergy lies with advanced biofuels. Second generation biofuels, which use enzymes or thermochemical processes to convert cellulose to ethanol or diesel have much higher potential, as they utilize agricultural residues as feedstocks, which are cheaper, and do not compete with agricultural production. At the same time, enzymes able to convert cellulosic materials into biofuels require advanced technological know-how for appropriate deployment. The potential of second generation biofuels is beginning to be recognized in the DA5. Malaysia has a second generation biofuel strategy, which targets development of a $10 billion industry by 2020 that utilizes 20 million tons of biomass (AIM 2013). Similarly, Thailand's Alternative Energy Development Plan targets 7,900 kilotons of oil equivalent of second generation biodiesel annually by 2021.

Table 25: Biofuel Blending Mandates in the DA5 in Late 2014 (%)

	Indonesia	Malaysia	Philippines	Thailand	Viet Nam
Ethanol	3		10		5
Biodiesel	10	5	5	5	
Sectors covered	Transport, industry, and power	Transport	Transport	Transport	Transport

DA5 = Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam.
Source: Lane (2014).

Box 7: Advanced Biofuels

Biofuels offer the potential to replace fossil fuel-based one-way carbon flows into the atmosphere with a sustainable process of carbon cycling from fixation to combustion. There are three major categories of biofuels: traditional biomass, first generation, and advanced biofuels, each with different societal impacts.

Traditionally, biomass in the form of fuelwood has served as the principal source of primary energy, which remains important in developing countries. Under the WITCH model, biomass in Indonesia provides 25% of 2010 primary energy and 15% in Southeast Asia. When sourced sustainably, traditional biomass can be carbon-neutral. However, as economies develop, traditional biomass cannot keep pace with increasing energy demands, and rising opportunity costs for labor involved in collection cause other fuels to displace it. As a result, traditional biomass is falling as an energy source in all simulation scenarios.

First generation biofuels are generated from the sugars and oils in arable food crops. Sugars are generally fermented into alcohol fuels, whereas oils are converted into biodiesel through transesterification. This leads to biofuel as an additional source of demand for food crops, which can raise food prices and lead to regressive effects on poorer households. Increases in food crop prices also encourage agricultural expansion at the expense of natural ecosystems. When indirect emissions, including from land-use change, are included, GHG emissions from first generation biofuels may be higher than from fossil fuel use.

Advanced biofuels are less reliant on food crop feedstocks, and thus have fewer such problems. Second generation biofuels rely on lignocellulosic feedstocks (i.e., agricultural and forestry residues), where sugar is isolated from cellulose and converted to ethanol. In addition, lignin is produced as a byproduct, which also can be used as a fuel. Current processes use enzymes or heating for lignincellulosis, while gasification, pyrolysis (heated anaerobic decomposition), and biochemical techniques are under development.

Third generation biofuels refer to the potential use of algae, which can be genetically manipulated to directly synthesize an array of useful fuels from butanol to methane. Algae have the possibility to generate biofuel yields that are 20 times higher than the best potential second generation biofuels. However, they are highly intensive in the use of water and nutrients, so that the indirect emissions per unit of output exceed those of conventional fuels. Solving this constraint will require decades of research.

Fourth generation biofuels are based on fuel cultivation and extraction that does not require the destruction of biomass. These biofuels are instead synthesized and excreted by bio-engineered organisms. One example of this type of biofuel is microbial electrosynthesis, which uses solar power to generate electricity used as an energy source by microbes that generate fuel outputs that can be stored more easily than electricity. These biofuels are at an early development phase.

To date, only first generation biofuels have been widely commercialized. In Asia, in response to policy incentives triggered by high oil prices, production of biofuels grew five-fold, from just over 2 billion liters in 2004 to almost 12 billion liters in 2008. Second generation biofuel plants are currently being initiated, with the world's first plants opened in the People's Republic of China and Italy.

Although second generation biofuels can utilize residue feedstocks and third generation biofuels have high yields, some areas may still need to be cultivated with feedstock crops for biofuels to expand rapidly as energy supplies. For this to happen without infringing on ecologically sensitive areas, agricultural land productivity will need to rise rapidly in order to meet rising food demands with less land in the future. Thus, biofuel feasibility rests on research and development efforts both in biofuel technologies and agricultural production.

Source: USAID (2009).

Second generation biofuel production methods are now becoming commercially available at prices that are potentially competitive with crude oil, and the first commercial second generation biofuel plants have already begun operations in the People's Republic of China and in Italy. A 70%–80% decrease in enzyme costs has been achieved during 2008–2013 through research by an array of private sector companies, and similar production cost advancements have been achieved for thermo chemical methods (ATKearney 2014). Current agricultural residues generated in the DA5 have the potential to supply 18.1 million tons of oil equivalent bio-ethanol, and this is likely to grow along with production of these commodities (Table 26).

A key challenge is to establish appropriate feedstock supply chains. Agricultural residue feedstocks are currently distributed across vast areas, and are not systematically collected. Coordination among large numbers of actors, including producers, collectors, transporters, and processors within supply chains is needed. Innovations in logistics, preprocessing to enhance energy densities before transport, and distributed refining infrastructure will be needed for second generation biofuels to be feasible.

Biofuels are the only type of renewable energy that can be used as a direct energy source in the transport sector, but current vehicle technology in the DA5 is only appropriate to limited blending rates for ethanol, which is the principal liquid biofuel product. Expanded substitution of biofuels for crude oil will require changes to vehicular engine technology that are already commercially available in other markets.

To facilitate the transition to advanced biofuels, supportive policies and government investments are needed. Adaptive research is needed to refine processing technology and deploy it appropriately to the supply chain challenges of the region. Initial pilot projects under public sector support may be needed to demonstrate how supply chain constraints can be overcome and establish commercial viability for investors. Increased blending mandates for transport sector fuels and appropriate regulations on vehicular engine technology may be needed to assure investors of market demand. Subsidies on competing fossil fuels often need to be reduced to allow biofuels to be price competitive.

5.3.6 Research and absorptive capacity need greater investment

(i) *Substantial adaptive research is needed for adoption of advanced energy technologies*

Advanced energy technologies, such as CCS and advanced biofuels, require further research to make best use of their technical potential, and adapt them for widespread deployment in the DA5. This is represented in the WITCH results, which find that by 2050, this investment amounts to $3.7 billion in the region, equally distributed between Indonesia and the rest of Southeast Asia (approximately .03% of regional GDP). The size of R&D investment is found to be similar for both 650 and 500 scenarios,

Table 26: Second Generation Bioethanol Production Potential in the DA5, Based on Mid-2000s Agricultural Production Patterns

	Quantity (million tons)				Production Potential (million tons)	
Commodity Residues	Raw Quantity	Dry Weight	Cellulose	Hemi-Cellulose	Bio-Ethanol	Oil Equivalent
Oil palm fronds	94	56	35.1	13.6	13.4	8.6
Empty palm fruit bunch	36	23	12.7	6.6	5.2	3.3
Oil palm fibers	22	9	1.9	3.6	1.4	0.9
Oil palm shells	9	1	0.1	0.1	0.1	0.1
Oil palm trunks	22	17	6.9	5.7	3.3	2.1
Sugar cane bagasse	34	17	8.5	4.3	3.5	2.2
Paddy straw	34	4	1.3	0.8	0.6	0.4
Rice husks	19	2	0.6	0.4	0.3	0.2
Coconut husks	5	1	0.3	0.1	0.1	0.1
Wood residues	17	2	0.9	0.6	0.4	0.3
Total	**292**	**132**	**68.3**	**35.8**	**28.3**	**18.1**

DA5 = Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam.
Source: Goh and Lee (2011).

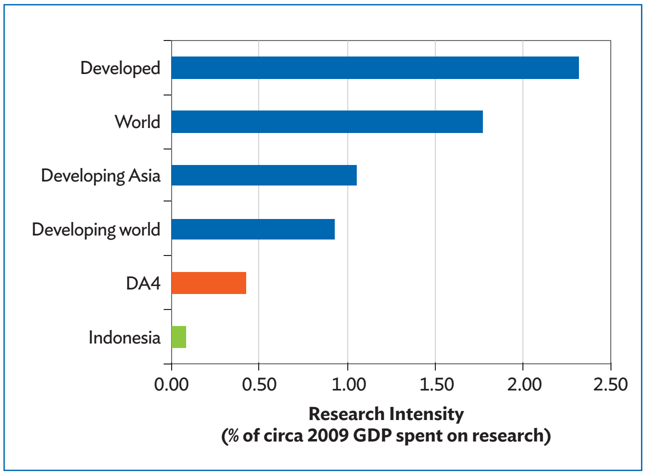
although the latter leads to investment earlier. Most of this research is invested toward advanced second and third generation biofuels, while more minor and gradual investment in R&D promotes energy efficiency improvements. This is about 10% of the global total energy research and is principally oriented toward adaptation and absorption of upstream innovations generated in advanced economies. At the same time, the share of research investment to GDP in the region is found to be higher than the world average.

(ii) *Investment in research needs to be increased to facilitate advanced energy deployment*

However, these needs for research investments contrast strongly with current investment patterns. At present, investment in research and development in the region is very limited in comparison with the rest of the world, while the rest of the world is still only investing a fraction of the research resources needed to attain a low-carbon development trajectory. Southeast Asia trails not only the developed world, but even the rest of the developing world and developing Asia in research and development expenditure across all sectors, not only energy (Figure 54). The region could facilitate faster adoption of advanced energy technologies by initiating adaptive research programs and scaling up research collaboration with providers of more upstream research in other regions. This is particularly so in Indonesia, where current research intensity is very low, but substantial economies of scale should exist, due to the large size of the country.

Underinvestment in research is associated with underinvestment in human capital and technical know-how for design, construction, operation and maintenance of advanced and low-carbon energy technologies. Development of this capacity can be facilitated through expanded cooperation with centers of excellence in both the public and private sectors of countries with greater research intensities, as well as through upscaling of research intensity in the region.

Figure 54: Shares of Gross Domestic Product Invested in Research and Development in World Regions



DA4 = Malaysia, the Philippines, Thailand, and Viet Nam; GDP = gross domestic product.
Source: UNESCO. UNESCO Institute for Statistics. http://data.uis.unesco.org/ (accessed 10 August 2015).

5.3.7 Energy and transport infrastructure investments can facilitate deep decarbonization

(i) *New power generation infrastructure will be needed*

The modeling results from this study imply large changes to energy and transport infrastructure. Under the low-carbon scenarios, coal power expansion is almost entirely replaced by low-carbon energy sources, whereas under BAU it grows considerably. According to WITCH, additional power generation investment needs for the 500 ppm scenario in Southeast Asia will be \$30 billion annually by 2050. Gas, often considered a potential solution to reduce carbon emissions from the power sector, also needs to fall considerably. In contrast, advanced energy technologies depicted in WITCH require entirely new power generation infrastructure, as well as infrastructure for CO_2 transport and storage, and agricultural evolution to produce advanced biofuels. Increased penetration of renewables in the energy mix also requires development of storage capacity, smart metering, and grid architectural improvements.

(ii) *Improved infrastructure for power transmission, distribution, and use enhances efficiency*

Energy efficiency improvement, which is the largest long-term source of mitigation in the modeled scenarios, requires substantial infrastructure investment. Buildings are substantial consumers of energy as economies develop and urbanize, and they often grow to consume more energy than either transportation or industry. Construction, so as to maximize energy efficiency for cooling and lighting is a key means to achieve better energy efficiency in this critical subsector. Technical transmission and distribution losses for electricity in the five focal countries are also often substantial, with Viet Nam and the Philippines having nearly twice the average percentage losses of the developed world, and Indonesia with losses nearly 50% higher than the developed world average. One key way to achieve efficiency gains for electricity is to reduce these technical losses through new transmission and distribution infrastructure.

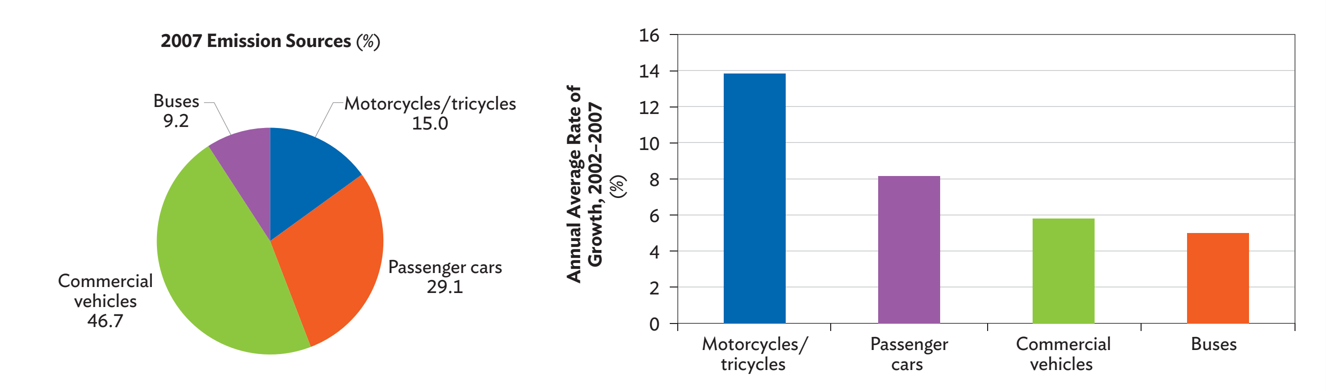
(iii) *An avoid–shift–improve approach to transport infrastructure can facilitate reduced emissions*

The models find that substantial mitigation will need to occur within the transportation sector. Oil consumption, which is principally for transport, is found to decrease by 40% under the 500 ppm stabilization scenario, compared with BAU. Improved transport efficiency is important to facilitate this reduction. Transport is also the sector found to generate the majority of co-benefits in the modeling, which suggests that it is an area that merits investment in "green growth" for multiple reasons.

Emissions from the transportation sector can be reduced according to the "avoid–shift–improve" approach. Such an approach benefits from the integrated implementation of hard infrastructure and soft policy measures that facilitate more efficient transportation behavior. Given that commercial vehicles represent a substantial share of emissions, increasing efficiency of freight is important within this framework, as well as for passengers (Figure 55). However, passenger vehicles are the fastest growing sources of transport emissions, so it needs priority to address future emissions growth.

"Avoiding transport" consists of using appropriate spatial planning and efficient transport infrastructure development to minimize distance traveled by individual vehicles. Appropriate urban development is essential to this element, along with "demand management," which includes measures to discourage private vehicle use in urban centers. These measures can include road or congestion pricing, parking fees, high occupancy vehicle requirements, and limitations to urban access.

Figure 55: Sources of Land Transport Emissions and their Annual Growth in the DA5



DA5 = Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam; GDP = gross domestic product,
Sources: Clean Air Asia. CitiesAct. http://citiesact.org/ (accessed September 2015); and BPPT and KLH (2009).

Box 8: Bottom-Up Modeling of the Financial Costs of Emissions Abatement from Fossil Fuels in the Philippines

The Asian Development Bank (ADB) commissioned a bottom-up modeling study in the Philippines using the Energy Forecasting Framework and Emissions Consensus Tool (EFFECT) to evaluate hypothetical low-carbon development options in the household electricity, power generation, and land transport sectors over the 2015 to 2050 period. The modeling was developed together with relevant national focal agencies and technical support from a National Technical Working Group, under the guidance of the National Economic Development Authority.

The modeling, which appraises the effects of future deployment of technologies, rather than specific projects or programs, suggests that the largest greenhouse gas (GHG) mitigation opportunity is in the power generation sector (Box Table 8.1, Box Figure 8.1). Implementing all mitigation options in the model leads to an estimated GHG emission reduction of 3,160 million tons of carbon dioxide equivalent ($MtCO_2eq$). If nuclear power is included, total GHG reduction rises to 4,110 $MtCO_2eq$, but other environmental costs and risks are increased.

Household Sector: The top five appliances identified in the model as contributing more than 70% of the total household electricity demand are as follows: (1) refrigerators, (2) air conditioners, (3) lighting units, (4) television s'sets, and (5) electric fans. By implementing minimum efficiency standards for these appliances, total cumulative demand is appraised as reduced by 164 terawatt hours from 2010–2050, which can mitigate 181 $MtCO_2eq$ GHG emissions.

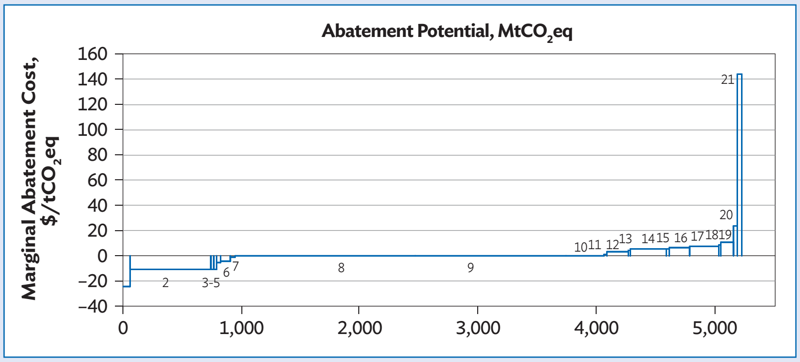
Transport: The road transport sector provides the pathway to reduce GHG emissions at the lowest cost per ton of CO_2eq emissions, according to the model. Doubling bus services to accommodate about 11% of passenger's per kilometer travel from private vehicles could avoid an estimated 63 $MtCO_2eq$, at –\$24/tCO_2eq. Vehicle

Box Table 8.1: Summary of Mitigation Potential and Costs for Assessed Low-Carbon Development Options

	Sector	Scenario	Mitigation Potential $MtCO_2eq$	Marginal Abatement Cost \$/$MtCO_2eq$
1	T	Promotion of buses	63.2	(24.40)
2	T	Compliance with EU emission requirement	681.2	(11.10)
3	T	Electric motorcycles	19.5	(10.90)
4	T	Hybrid buses	26.1	(10.80)
5	T	Electric tricycles	36.6	(5.60)
6	H	Refrigerators	79.9	(4.33)
7	H	Air conditioning unit	39.8	(1.05)
8	P	Use of nuclear plants	1,515.0	(0.50)
9	P	Development of hydro capacity	1,277.0	(0.42)
10	P	Development of geothermal capacity	320.0	0.21
11	H	Fans	20.7	1.52
12	P	Use of supercritical coal plants	182.0	3.17
13	H	Televisions	15.4	4.79
14	P	Use of natural gas plants	307.0	4.92
15	H	Lighting	26.4	5.36
16	T	Electric jeepneys	168.7	6.40
17	T	Biofuels blending	244.8	7.80
18	T	Motor vehicle inspection	20.3	8.10
19	P	Development of wind capacity	106.0	10.48
20	P	Development of solar capacity	34.0	23.97
21	T	Light rail infrastructure	34.7	144.30

( ) = negative, EU = European Union, H = Household, $MtCO_2eq$ = million tons of carbon dioxide equivalent, P = Power, T = Transport.
Source: ADB Study Team.

Box Figure 8.1: Philippines' Marginal Abatement Cost Curve, 2010–2050



$MtCO_2eq$ = million tons of carbon dioxide equivalent, tCO_2eq = tons of carbon dioxide equivalent.
Source: ADB Study Team.

continued

Box 8 continued

technology improvements, including mandating emissions standards for all passenger cars or commercial vehicles in the Philippines, are found in the model to have the largest avoided emission contribution of 681 $MtCO_2eq$, at a cost of –\$11/tCO_2. Electric tricycles, if widely adopted, can potentially avoid up to 37 $MtCO_2eq$ at an abatement cost of –\$6/tCO_2eq. Other low-carbon options in this sector with positive abatement costs include biofuel blending, with an estimated mitigation potential of about 245 $MtCO_2eq$ by 2050 at \$8/tCO_2eq. Electric jeepneys, if widely adopted, are modeled as having the potential to avoid 169 $MtCO_2eq$ at a mitigation cost of \$6/tCO_2. Light rail infrastructure is identified as the most expensive option at \$144/$MtCO_2eq$. If all low emissions strategies identified under the transport sector are implemented, the total emission reduction potential is found to be 1,003 $MtCO_2eq$, with an average mitigation cost of \$0.4/tCO_2eq.

Power Generation: The three low-carbon development options for the power sector with the highest estimated mitigation potential and lowest cost include hydropower, geothermal power, and nuclear. Expanded hydropower yields potential GHG mitigation of around 1,300 $MtCO_2eq$, approximately 24% of the emissions in the baseline scenario, with an abatement cost of –\$0.4/tCO_2eq. Development of solar and wind capacities has higher estimated abatement costs they have high intermittance. Solar generation is found to avoid GHG emissions of 34 $MtCO_2eq$, approximately 0.64% of the baseline GHG emissions, at an abatement cost of \$24/tCO_2eq. Wind is estimated to mitigate 105 $MtCO_2eq$, at an abatement cost of \$11/tCO_2eq. The simultaneous implementation of all options has the potential to reduce CO_2eq emissions by an estimated 3,067 $MtCO_2eq$ (55%) by 2050 with an abatement cost of \$0.70/tCO_2eq.

Source: ADB Study Team.

"Shifting transport" consists of increasing the use of public transport, which requires new busways, rail and light rail development, as well as cities that develop spatially so as to facilitate public transport use. This should be complemented by measures to facilitate nonmotorized transport use, such as pedestrian zones, walkways, and bicycle lanes. Shifting transport may be important for freight, as well as for passengers, as rail lines can move freight much more efficiently than trucks.

The largest urban areas in each of the DA5 have developed public transport systems and most are under expansion (Table 27). These are valuable measures, but more can still be done. Urbanization rates remain rapid, leading to growing populations in need of transit. At the same time, modern transit forms are only serving small shares of populations, even in the largest cities. These cities have far smaller average road lengths per capita than the developed Asian average of 2.0 meters. Similarly, most have smaller average freeway lengths than the developed Asian average of 0.02 meters. In the context of limited space for road expansion, expansion of public transport is necessary to avoid much more congestion and higher associated emissions.

"Improving transport" consists of enhanced technology for transport systems, including both infrastructure and vehicles. Enhanced traffic engineering and management systems can improve efficiency on road systems, while vehicle technology can enhance the efficiency of individual vehicles or enable substitution of low-carbon energy sources for fossil fuels. Over the longer term, substitution of electricity for oil is also key to low-carbon growth in the transport sector, which means much broader adoption of electric cars, with associated recharging infrastructure.

Indonesia, the Philippines, and Viet Nam have extensive and growing transportation congestion. This congestion reduces travel speed and fuel efficiency, increasing emissions substantially—even to levels above those of developed countries for urban commutes, according to certain estimates (Nationmaster 2015). As economies in the region develop, and private car ownership increases, this congestion and associated emissions will rapidly increase without appropriate action.

Table 27: Urban Transport Characteristics in the Largest Cities of the DA5

City	Countries	City pop ('ooo)	Metro pop ('ooo)	Road per Capita (m)	Freeway per Capita (m)	Bus Rapid Transit (km)	Bus Rapid Transit Riders ('ooo)/day	Urban Rail (km)	Rail Riders ('ooo)/day	Daily BRT and Rail Riders (% metro pop)
Bangkok	Thailand	8,213	14,565	0.6	0.013	15	15	87 current; 180 (planned 2019)	884	6.2
Ho Chi Minh	Viet Nam	6,189	7,389	0.3	0	25 (planned 2016)		107 (planned 2020)		0.0
Jakarta	Indonesia	15,519	27,957	0.7	0.007	207	370	235 current; 251 (planned 2018)	850	4.4
Kuala Lumpur	Malaysia	1,524	7,200	1.5	0.068	5		332	533	7.4
Manila	Philippines	11,654	24,123	0.5	0.004	28 (planned 2018)		94 current; 124 (planned)	2,800	11.6

DA5 = Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam; BRT = Bus Rapid Transit, km = kilometer, m = meter.
Note: Population statistics refer to 2010, ridership refers to 2013 to 2014, and infrastructure refers to 2014. Urban rail includes metro rail, light rail, and commuter rail.
Sources: UNHABITAT(2013).

Box 9: ADB's Clean Energy Investments in Southeast Asia

The Asian Development Bank (ADB) is aiming to provide $4 billion of annual finance to help developing Asian countries mitigate greenhouse gas emissions. This includes projects for improved efficiency in the energy, transport, and urban sectors and deployment of clean energy sources. In so doing, ADB leverages private finance through innovative funding instruments that alleviate barriers to investment, such as sovereign risk and promote large-scale, low-carbon technology transfer and deployment.

In the DA5, energy efficiency investments dominated ADB's clean energy portfolio, with major investment projects amounting to $1.1 billion, while key renewable energy investments countries amounted to over $600 million from 2011 to 2014 (Box 9 Table 9.1). These investments averted an estimated 61 million tCO_2eq of greenhouse gas (GHG) emissions. ADB's approach to low-carbon energy finance is illustrated with selected examples below.

Renewable power
ADB invests in both on-grid and off-grid renewable energy, using financing tools that leverage private sector investment. The Subyai Wind Power Project (Thailand) works through a special-purpose joint venture with private power producers as one means to help achieve a government target of 1.8 gigawatts (GW) of wind power capacity by 2021. In Indonesia, the Sarulla Geothermal Power Generation Project will construct, operate, and maintain three geothermal power generation units with a total capacity of about 320 megawatts (MW), developed and implemented under risk guarantees. On a smaller scale, the Provincial Solar Power Project (Thailand) involves construction of 40 MW of solar capacity, and the Renewable Energy Development and Network Expansion and Rehabilitation for Remote Communes Sector Project in Viet Nam develops mini-hydropower for households in remote, mountainous, and poor communes.

Development of smart, efficient power grids
Transmitting and distributing power from the grid offers substantial opportunity for efficiency improvements. The West Kalimantan Power Grid Strengthening Project (Indonesia) will ensure that as the power grid grows from 200 MW in 2012 to 600 MW in 2020, transmission and distribution losses are minimized, connected households are trained in energy efficiency and lighting is energy efficient. Similarly, the Hanoi and Ho Chi Minh City Power Grid Development Sector Project will improve efficiency and reliability of grid power infrastructure.

Energy efficient transport
Transportation is a rapidly growing source of fossil fuel consumption and emissions, which can be mitigated by more efficient vehicles and modal shifts. The Market Transformation through Introduction of Energy-Efficient Electric Vehicles Project (Philippines) aims to leverage the private sector to replace gasoline tricycles with e-trikes, so as to reduce greenhouse gas emissions, improve the work environment for tricycle drivers and reduce pollution effects on health. To facilitated shifts from private to public transport, the Ha Noi Metro Line Project (Viet Nam) will construct 12.5 kilometers of dual track rail through five districts, which will be accessible through integrated multimodal stations. This is complemented by the Sustainable Urban Transport for Ho Chi Minh City Mass Rapid Transit Line 2 Project (Viet Nam), which will develop a public transport system serving six districts in the city that integrates stations with other modes of public and private transport. Together, these four energy-efficient transport projects will help avert more than 4.0 million tCO_2eq of GHG emissions.

continued

Box 9 continued

Promoting advanced energy technology development and deployment

In Indonesia, ADB is providing technical assistance to establish one of the first Carbon Capture and Storage (CCS) pilots in South and Southeast Asia for the gas sector, and has helped to identify CCS potential in Southeast Asia. More broadly, ADB is in the process of establishing a Low-Carbon Technology Exchange, which will follow an assisted broker model for identifying partnerships between suppliers and consumers of low-carbon technologies. The Asia Climate Change and Clean Energy Venture Capital Initiative provides equity to venture capital funds that support innovation, transfer, and diffusion of climate change mitigation and adaptation technologies.

Support to improved policies for clean and efficient energy

ADB offers both technical assistance and resources to enable policy reforms for low carbon transitions. The Sustainable and Inclusive Energy Program (Indonesia), approved in 2015, supports a range of reforms that will improve transitions towards an efficient and lower carbon energy sector. These policy reforms include reduction of energy subsidies, enhanced performance of state owned electricity companies, improvements to energy markets, incentives and regulations to scale up renewable power, improved energy efficiency standards, and wider deployment of CCS.

Box Table 9.1: A Snapshot of Major ADB Clean Energy Investments Projects in the DA5 Countries, 2011–2014

Countries	Year (Board Approval)	Project Name	Predominant Technology/Intervention	Estimated Emission Reduction ('000 tCO_2eq/ project life)	Clean Energy Investment ($ million)
Indonesia	2011	Loan and Administration of TA for Indonesia Eximbank	Demand-side energy efficiency	920	30
Indonesia	2013	West Kalimantan Power Grid Strengthening Project	Transmission and distribution	16,000	101
Indonesia	2013	Sarulla Geothermal Power Generation Project	Geothermal (320 MW)	...	350
Indonesia	2014	Supreme Energy Rantau Dedap (Rantau Dedap Geothermal Development Project Phase 1)	Geothermal (240 MW)	...	50
Philippines	2012	Market Transformation through Introduction of Energy-Efficient Electric Vehicles	Sustainable transport (demand-side energy efficiency)	3,322	310
Thailand	2011	Gulf JP NS Company Limited (Nong Saeng Natural Gas Power Project)	Supply-side energy efficiency	...	39
Thailand	2012	Bangchak Solar Energy Company Limited (Provincial Solar Power Project)	Solar power (38 MW)	...	38
Thailand	2012	Ayudhaya Natural Gas Project	Natural gas	...	107
Thailand	2012	Theppana Wind Power Project	Wind energy (7.5 MW)	...	8
Thailand	2013	Central Thailand Solar Power Project	Solar power (57 MW)	...	87
Thailand	2014	Subyai Wind Power Project	Wind power (105 MW)	...	83
Viet Nam	2011	Hanoi Metro Line System-Line 3	Sustainable transport system (demand-side energy efficiency)	544	59
Viet Nam	2011	Viet Nam Water Supply Sector Investment Program PFR 1	Energy efficient water system pumps technology (variable frequency drive), energy-efficient air-conditioning system	945	32
Viet Nam	2011	O Mon 4 Combined Cycle Power Plant Project	CCGT power plant construction; supply-side energy efficiency	18,000	76
Viet Nam	2012	Ho Chi Minh City Urban Mass Rapid Transit Line 2 Investment Program - Tranche 2	Sustainable urban transport (demand-side energy efficiency)	...	100
Viet Nam	2012	Low-Carbon Agricultural Support Project	Construction of biogas plants	2,250	74
Viet Nam	2013	Energy Efficiency for Ho Chi Minh City Water Supply	Demand-side energy efficiency	90	2
Viet Nam	2014	Hanoi and Ho Chi Minh City Power Grid Development Sector Project	Supply-side energy efficiency	18,400	160
Viet Nam	2014	Renewable Energy Development and Network Expansion and Rehabilitation for Remote Communes Sector	Mini-hydro; transmission and distribution; Grid expansion and rehabilitation	60	3
Viet Nam	2014	Sustainable Urban Transport for Ho Chi Minh City Mass Rapid Transit Line 2	Sustainable transport system (demand-side energy efficiency)	81	29
Viet Nam	2014	Strengthening Sustainable Urban Transport for Hanoi Metro Line 3	Demand -side energy efficiency	168	26
TOTAL				**60,779**	**1,764**

... = data not available; CFL = compact flourescent lamp; CCGT= combined cycle gas turbine; CCS = carbon capture and storage; DA5 = Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam; MW = megawatt; PFR = periodic financing request; PV = photovoltaic; tCO_2eq = ton of carbon dioxide equivalent.
Source: ADB (2012), ADB (2013b), ADB (2014b), and ADB (2015).

6 Conclusions

Reducing greenhouse gas emissions is particularly relevant to Southeast Asia

Southeast Asia is particularly exposed to climatic changes and vulnerable to their adverse consequences, with expected economic losses that are much higher than the world average. This study confirms high losses for the region, as the regional damage from a limited range of climate change impacts is estimated as approximately 11% of GDP by 2100.

Climate change is thus a development challenge for the region, especially in the light of the large share of the Southeast Asian population still living in poverty and employed in climate-sensitive sectors. Addressing the risks posed by climate change requires substantial mitigation and adaptation action. At the same time, Southeast Asia is also fast becoming one of the world's important contributors to global warming, as it currently couples policies that encourage high levels of emissions and technical inefficiency with some of the world's most rapidly growing economies.

A more complete analysis offers new insights

In this context, it is critical to improve understanding of decarbonization dynamics, costs, and potential. Prior mitigation policy cost assessments provide little detail on effects for Southeast Asia, and often do not reflect potential global mitigation arrangements. Moreover, crucial characteristics, such as peat emissions for Indonesia, are often omitted or mischaracterized, and co-benefits have been excluded from prior efforts.

To go beyond previous studies, a recursive-dynamic CGE model is used to capture DA5 country and sectoral specificities and international trade effects, while a hard-linked economy-energy-environment dynamic optimization model is applied to represent long-term dynamics in technological improvement and abatement opportunities in the energy sector. Both models show that stabilizing global temperature at a level that is likely to remain below the 2.0°C goal set by the international community to limit catastrophic and potentially irreversible effects requires early action embedded in a global and coordinated effort.

Strong action is needed to move Southeast Asia away from its current carbon-intensive development trajectory

Southeast Asia has had the fastest relative growth in CO_2 emissions of major world regions between 1990 and 2010. In selected countries of the region, deforestation has led to large land-use emissions, while energy sector emissions have been rapidly rising. Energy intensity improvement has trailed most of the world, while fossil fuels are the source most of the energy associated with the region's rapid economic growth. This study finds that many of these trends will continue to cause rapid emissions growth without strong climate policies.

Climate stabilization implies large emission reductions

Avoiding more than 2°C of global warming requires not only strong global mitigation responses, but also implies substantial mitigation within the region, according to a "contraction and convergence" framework. For 500 ppm stabilization, Southeast Asia's emissions need to decline by 20%–25% compared to BAU in 2025 and by 60% by 2050, while 650 ppm stabilization leads to 2050 emissions that are below 2010 levels.

Emission reductions are driven by land use, energy efficiency, and low-carbon energy sources

Mitigation is triggered by reducing land-use emissions, increasing the efficiency of energy usage and replacing carbon-intensive fuels with cleaner alternatives. About half of emissions abatement through the mid 2030s arises from REDD, making it the leading source through the medium term. The largest single long-term source of cumulative emission reductions over 2010–2050 is energy efficiency gains, while low-carbon energy is most important in the longer-term portion of the analysis.

Reducing deforestation is essential to mitigation costs at least through the medium term

REDD is critical to medium-term mitigation costs, especially in Indonesia. Deforestation reductions can be made at low opportunity cost, as Indonesia has large areas of unproductive degraded grasslands, where land-demanding industries, such as plantation agriculture, could still be developed were natural forest clearance more limited. This could allow Indonesia to sustain negligible policy costs, while exporting hundreds of billions of dollars of carbon credits. In the medium term, this would lead to positive effects on consumption and living standards for Indonesia, as well as reduced policy costs for the region.

However, REDD also requires early investment in policies and institutions. The forestry sector in Southeast Asia currently has many governance constraints. Building institutions appropriate to REDD requires political will and substantial investment to foster procedures and standards that reflect consensus, fairness, and accountability. Much effort is still needed to identify a mix of measures to ensure that REDD is effective, efficient, and equitable.

Energy efficiency and energy substitution determine long-term mitigation costs

Decarbonization of the energy sector is found to derive from increased efficiency of energy use, replacement of carbon-intensive fuels with cleaner alternatives, and reduction in energy consumption. However, the relative importance of these three components depends largely on the availability of low-carbon technological options.

Advanced energy technologies are critical to long-term mitigation at acceptable cost

The development and availability of these advanced low-carbon energy technologies critically affect overall economic costs of climate stabilization. In the absence of advanced energy technologies, oil will become even more dominant as an energy source even under a global climate regime. Solar and wind energy will experience a strong increase in production, but their share in primary energy will remain low. The contraction in energy use needed to reduce emissions would most affect the energy-intensive sectors, followed by services and agriculture. However, if low-carbon technologies are developed and available, the 2050 GDP costs of decarbonization for the region could be reduced by 50%, with a peak in 2040, before declining.

Research investment is required for advanced energy availability

Realizing the potential of advanced low-carbon energy sources to contain decarbonization costs requires early investment in research, which scale up in the region to billions of dollars by the 2020s. Although this figure may appear to be large in absolute terms, it is only a small share of regional GDP, and has large payoff under global climate stabilization scenarios in terms of reduced policy costs

Ambitious mitigation is affordable

Emission reduction is a long-term investment in the viability of future ecological, economic, and social systems, with inherently front-loaded costs and back-loaded benefits. At the same time, the study finds that, even under the ICES model, which generates higher policy costs, and more stringent 500 ppm stabilization, the net present value of costs (after co-benefits are accounted) is only 3% of the net present value of GDP through 2050—a value lower than the 2010 proportion of GDP spent collectively on fossil fuel subsidies by countries in the region.

Mitigation leads to substantial co-benefits

The upside to the policy costs of climate stabilization is that substantial co-benefits are generated in the short to medium term, in terms of health, congestion, and transportation accidents. These are approximated to reach nearly 3% of GDP under

500 ppm stabilization for the region and 1% under 650 ppm stabilization. These stand in addition to substantial reduction of climate-induced losses after around 2050.

Ambitious mitigation is economically attractive

Benefits outweigh the costs of participation in a global stabilization agreement as early as the 2040s in GDP terms. This study shows that the costs of participation in a global stabilization agreement are likely to be a good investment for countries in the region, with indicative ratios of net benefits to net costs ranging from 5 to 11.

Delayed action only increases mitigation costs

Early action is required to keep costs of mitigation contained and exploit the potential for large ratios of benefits to costs from mitigation investments. Delayed action will mean a much more rapid rate of emission reduction and/or more damage from climate change, which are both costly. For example, a 10-year delay in implementation of the 500 ppm target in WITCH leads to 2050 Southeast Asian GDP losses that are 60% higher than with no delay.

Climate positioning to date reflects mitigation levels that are economically suboptimal

Although individual countries have varied levels of mitigation ambition reflected in their INDCs, collectively, unconditional INDCs from the region reflect emissions levels that are only slightly below what this study finds under BAU. Conditional INDCs from the region reflect similar emissions levels to the modeled 650 ppm scenario. Given that the 500 ppm scenario has a high ratio of benefits to costs, this study's results suggest that it would be economically beneficial for the region if a more ambitious level of mitigation were pursued.

Action toward low-carbon development can begin immediately

Supportive policies and investments are important to facilitate a low-carbon transition and access these benefits. Policy reforms are necessary to eliminate perverse incentives for deforestation, the largest current and near-term driver of GHG emissions. An expanded array of regulatory mechanisms and fossil fuel subsidy reform can help to ensure faster progress on energy efficiency, the largest long-term source of abatement identified by the modeling. Adaptive research and early piloting can help to facilitate adoption of CCS and advanced biofuels, which enable mitigation at low cost. Investment in appropriate infrastructure can help to support greater efficiency and moves toward lower carbon fuels in energy and transport systems.

International assistance can play a key role to support low-carbon transitions

All countries in the region have requested international support in their conditional INDCs, and this support can play an important role in facilitating mitigation outcomes. The region can benefit from technical cooperation to help enhance forestry institutions to better control deforestation, as well as to improve energy efficiency and develop and deploy locally appropriate advanced energy generation technologies. Low-carbon infrastructure often requires higher front loaded financing and improved design capacity, which international sources can help to contribute. Given the low cost opportunities that exist for future abatement, targeted support to the region has important potential to achieve substantial emission reduction.

Appendixes

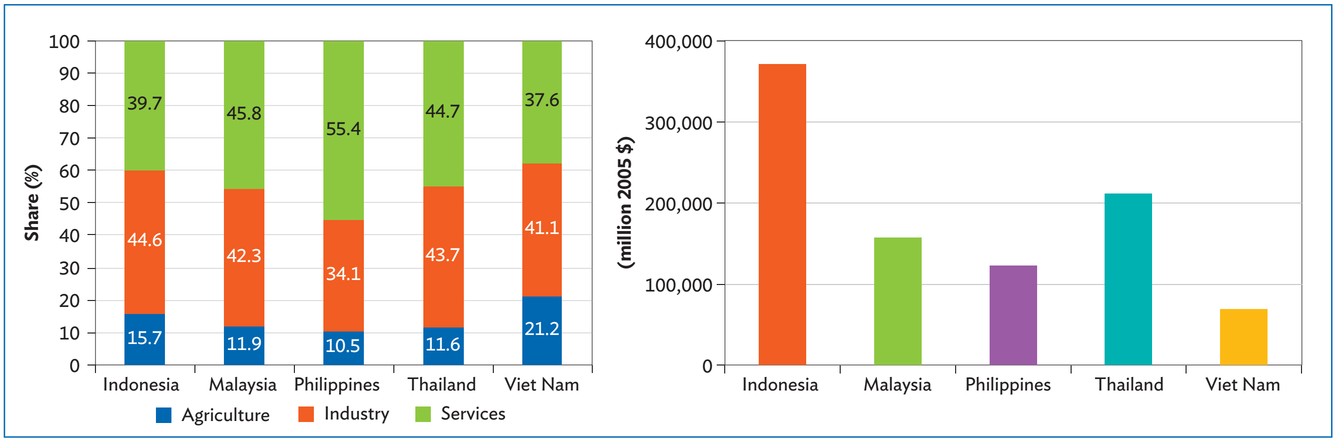
Appendix 1: Model Calibration

A. Intertemporal Computable Equilibrium System Calibration to Reflect Southeast Asian Countries

The original simulation and calibration year for the Intertemporal Computable Equilibrium System (ICES) model is 2004, using the GTAP7 database (Narayanan and Walmsley 2008). To update the model and ensure consistency with national statistics on the target countries, 2010 data have been embedded in the model database and structure, making 2010 the new reference year for the model simulations.

The procedure followed for the update is termed "pseudo-calibration" (Dixon and Rimmer 2002). It involves perturbing selected input variables that are the drivers of growth in the model so as to replicate observed key economic features that are determined by the model, such as gross domestic product (GDP), energy production and consumption, and emissions. Based on its structure and background assumptions, the model determines all the other economic variables. The ICES model perfectly replicates the 2010 GDP and replicates well the macrosectoral composition (Figure A1.1). The characterization of energy production and consumption and greenhouse gas (GHG) emissions is close to historical figures (Figure A1.2 and Figure A1.3).[1]

Figure A1.1: DA5 Gross Domestic Product Composition and Levels in 2010

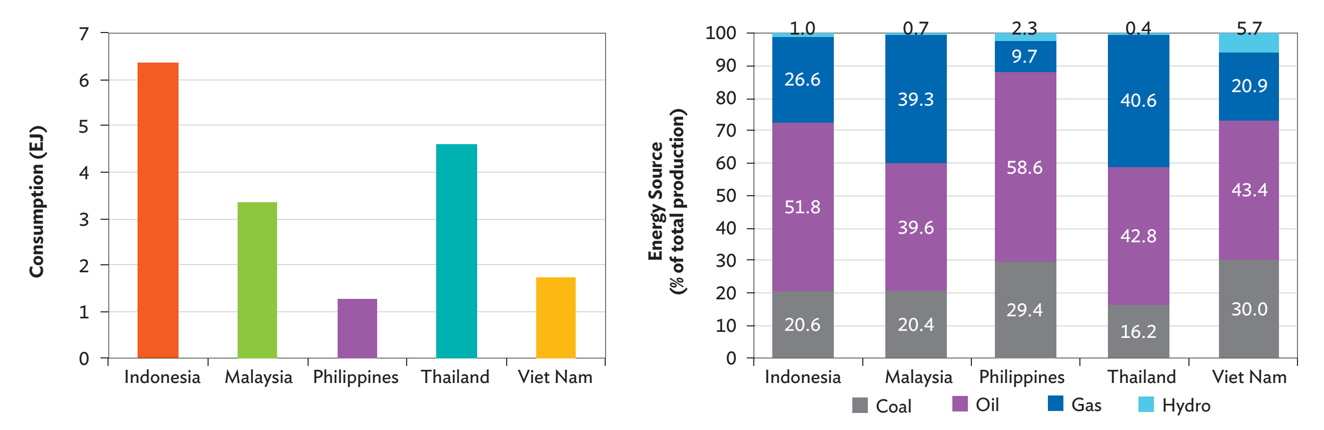


DA5 = Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam.
Note: Estimates were from 2012, the year in which the calibration exercise took place, and were integrated with information from local experts.
Sources: ADB (2011a) and World Bank (2012).

1 In the case of emissions, historical records referred mostly to 2008 for carbon dioxide (CO_2) or 2005 for methane and nitrous oxide. Accordingly, the data reported by ICES for 2010 are often estimates and not the true value.

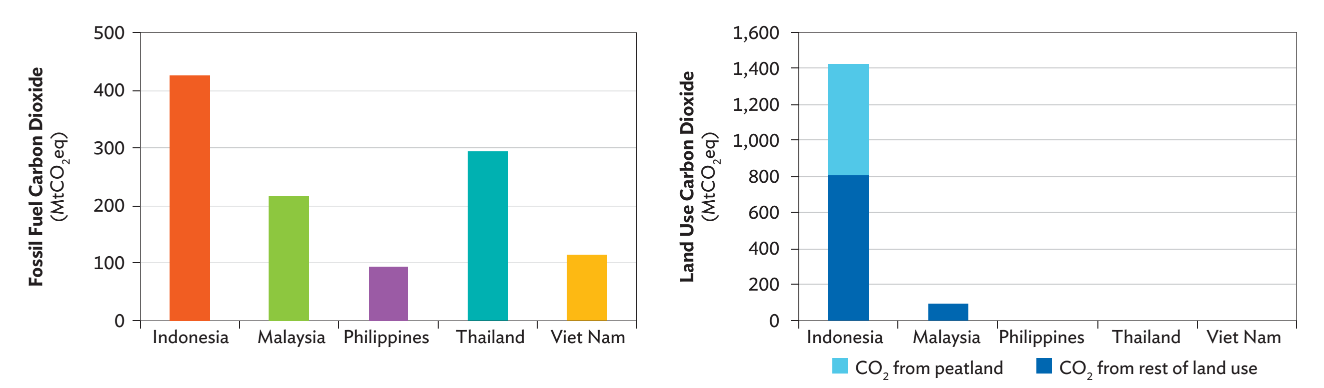
The figures for carbon dioxide (CO_2) emissions from land use have been harmonized with those of the World Induced Technical Change Hybrid (WITCH) model, but only full emissions details for Indonesia and Southeast Asia are included. To define the emissions for the remaining four countries, the total of East Asia was assigned a per country allocation proportional to the national shares reported in the Climate Analysis Indicators Tool (CAIT) Version 9.0. (WRI 2012). No positive land-use emissions were included for the Philippines, Thailand, and Viet Nam, which already display net afforestation, rather than deforestation, trends (Figure A1.3, right panel).

Figure A1.2: DA5 Primary Energy Consumption and Energy Source in 2010



DA5 = Indonesia; Malaysia; the Philippines; Thailand; and Viet Nam, EJ = exajoule.
Note: Estimates were from 2012, the year in which the calibration exercise took place, and were integrated with information from local experts.
Sources: ADB (2011a) and World Bank (2012).

Figure A1.3: Fossil Fuel Carbon Dioxide and Land-Use Carbon Dioxide Emissions, 2010



CO_2 = carbon dioxide; DA5 = Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam; $MtCO_2eq$ = million tons of carbon dioxide equivalent.
Note: Estimates were from 2012, the year in which the calibration exercise took place, and were integrated with information from local experts.
Sources: ADB (2011a) and World Bank (2012).

B. World Induced Technical Change Hybrid Calibration to Reflect Southeast Asian Countries

The model's relevance was improved by splitting Southeast Asia into two subregions: Indonesia and the rest of Southeast Asia. Its update to accommodate the regional disaggregation did not change the underlying structure of the previous version of the model code. However, base year calibration on all energy variables has been reperformed in order to include the two new regions, with a focus on electricity production from coal, oil, gas, nuclear, hydro, wind, solar, and other nonconventional sources, using International Energy Agency and national energy statistics. Investment costs and operation and maintenance costs were derived from the Enerdata database (Enerdata 2008) for traditional biomass, biofuels, coal, gas, and oil.

The model also includes woody biomass as a possible feedstock that can be mixed with coal in power plants (cofiring). The cost of the biomass feedstock is determined on the basis of regional supply cost curves obtained by the land use GLOBIOM (Havlik et al. 2011) model. A downscaling procedure has been adopted to estimate the supply cost curves for Indonesia and Southeast Asia using data on production of nonconiferous wood from the forestry database of the Food and Agriculture Organization.

Appendix 2: Supplemental National Findings from the ICES Model

This section presents country-specific results that exploit the higher sectoral detail offered by the ICES model. The business-as-usual (BAU) results presented should not be considered as ADB's official estimates, as they are calibrated to economic forecasts available at the time of model development in 2011, and BAU represents a hypothetical scenario in the absence of existing climate-related policies. In this section, the analysis of decarbonization policy effects is divided into (i) a 2020 assessment that investigates the implications of short-term goals for DA5 countries, and (ii) a long-term assessment that describes the consequences of long-term decarbonization paths. Note that the ICES model assumes both exogenous technical progress and a quite rigid structure for its energy generation system, with limited options for decarbonizing the economic system. For this reason, the estimated long-term policy costs yielded by the ICES model are biased upward over long time frames.

A. Indonesia

1. Business-as-Usual Results

With a 2010 GDP of around $0.35 trillion and a population close to 250 million, Indonesia is the largest economic system in the DA5. It is also the largest GHG emitter, as in 2010, emissions totaled nearly 2,000 million tons of carbon dioxide equivalent ($MtCO_2eq$) 1,400 million tons of which were from land-use processes and the remainder by industrial activity and agricultural production. The land-use emissions were largely driven by deforestation, which caused Indonesia to lose 5% of its forest cover in the last decade, largely as a result of plantation expansion. With rapid industrialization, industry sectors accounted for 47% of the country's GDP in 2010, followed by services at 37.6%. Agriculture remains important at 15.3% of total GDP.

Total actual primary energy consumption in 2010 consisted of 52% oil and gas, 15% coal, 25% from biomass, 8% geothermal, and 1% hydropower (IEA 2012b). In ICES, which excludes biomass and geothermal, energy consumption in Indonesia is based almost entirely on fossil fuels, particularly oil, which constitutes nearly 50% of 2010 primary energy demand. Indonesia in 2010 was the third-largest emitter in per capita terms among the DA5 without considering land-use emissions; and was fourth in terms of the energy and carbon intensities of GDP.

According to ADB (2011b), Indonesia is expected to demonstrate the highest average annual increase of GDP growth rates among the DA5 economies until 2030, and to sustain this ranking afterward at a lower growth rate (Table A2.1). Its GDP is modeled[2] to reach a peak of $4.5 trillion in 2050, which would be a 1,141% increase over the 2010 level (Figure A2.1, left). There are only slight changes identified in the composition of GDP during the period. The services sector and the heavy manufacturing sector grow in importance, while the share of the agriculture sector is found to decline to roughly half of the 2010 level by 2050 (Figure A2.1, right).

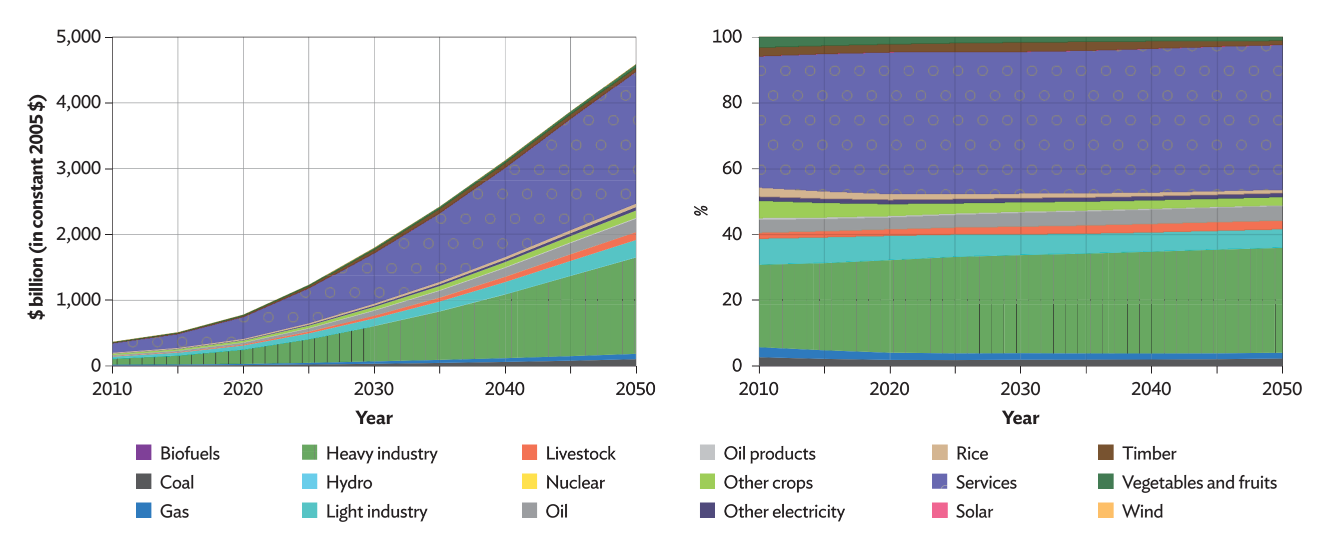
Table A2.1: Indonesia—Business-as-Usual Annualized Growth Rate and Population

	Annual GDP Growth (%)	
	ICES-Simulations	Projections
2011–2020	7.8	7.8
2021–2030	8.7	8.8
2031–2040	5.7	5.6
2041–2050	3.9	3.3

	Population (million)
2010	239.9
2020	262.6
2030	279.7
2040	290.2
2050	293.5

GDP = gross domestic product, ICES = Intertemporal Computable Equilibrium System.
Note: Projections refer to ADB (2011b) data, integrated with information from local experts.
Source: ADB Study Team.

Figure A2.1: Indonesia—Business-as-Usual Gross Domestic Product and Sectoral Composition

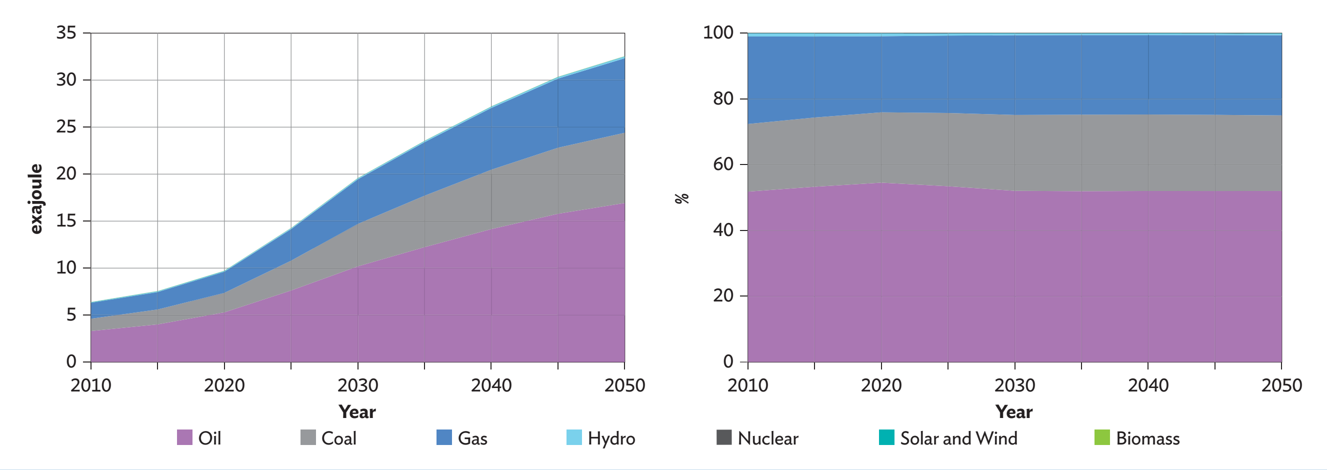


Source: ADB Study Team.

2 Note that these are not authoritative or official ADB projections. This is simply description of ICES' behavior, as calibrated to ADB (2011b).

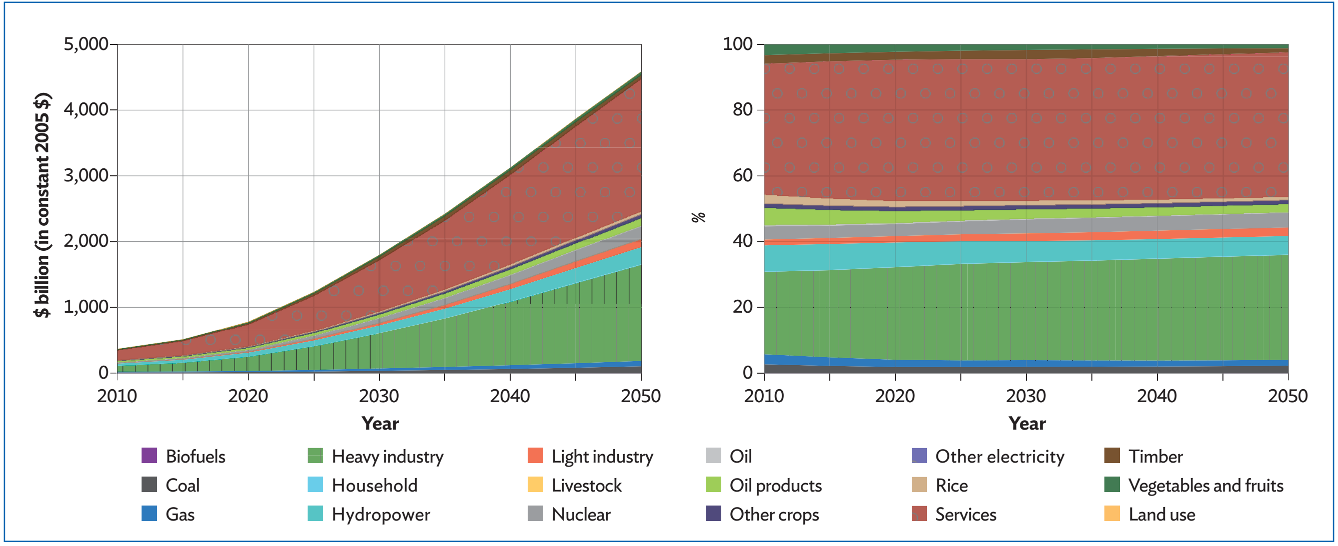
The energy consumption mix is found by ICES to remain fairly stable, with oil dominant at 50% of the total, followed by gas at roughly 30% and by coal at 20%. In the absence of climate-related policies, the role of renewable energy remains negligible, with minor shares from hydropower. To sustain Indonesia's rapid growth, energy consumption is found to increase from 5 exajoules in 2010 to 33 exajoules in 2050, largely from fossil fuels (Figure A2.2). The country's GHG emissions are found to follow the growth of industrial production and GDP, increasing from 2,200 $MtCO_2eq$ in 2010 to 2,800 $MtCO_2eq$ in 2050 (Figure A2.3). In particular, the fossil-fuel intensive sectors—heavy manufacturing, services including transportation, fossil-fired electricity generation, and household demand—increase to nearly 90% of the total from 34% of the total in 2010. Land-use emissions are found to shrink from 66% to around 10% of total emissions by 2050.

Figure A2.2: Indonesia—Business-as-Usual Primary Energy Consumption by Source and Share by Source



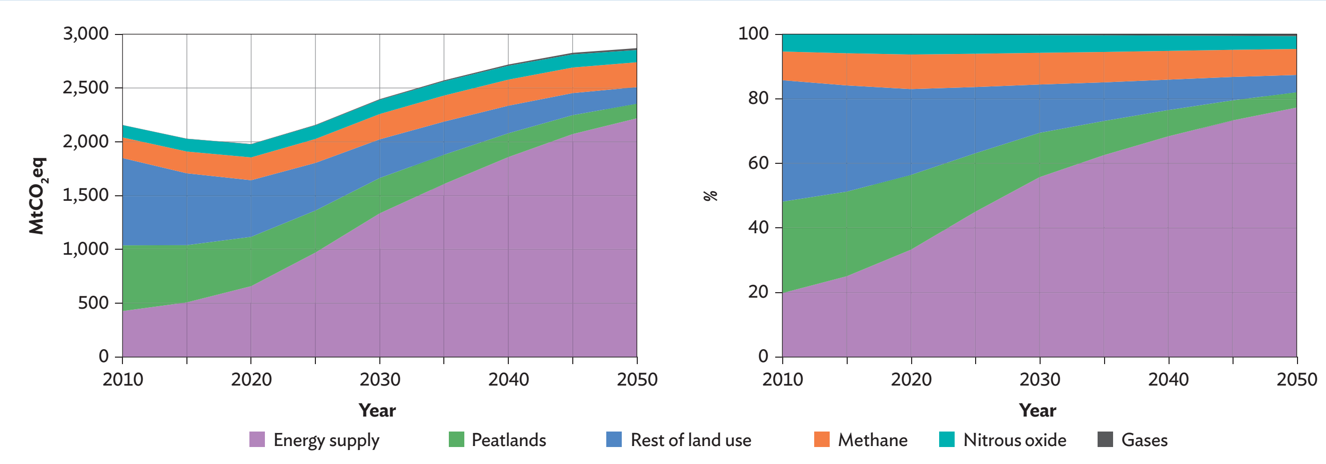
Note: exajoule = 277,777,778 megawatt-hours.
Source: ADB Study Team.

Figure A2.3: Indonesia—Business-as-Usual Greenhouse Gas Emissions by Source and Share by Source



Note: Other electricity is electricity produced using fossil fuel sources (e.g. coal, oil, or gas).
Source: ADB Study Team.

Figure A2.4: Indonesia—Business-as-Usual Emissions by Gas and Shares by Gas

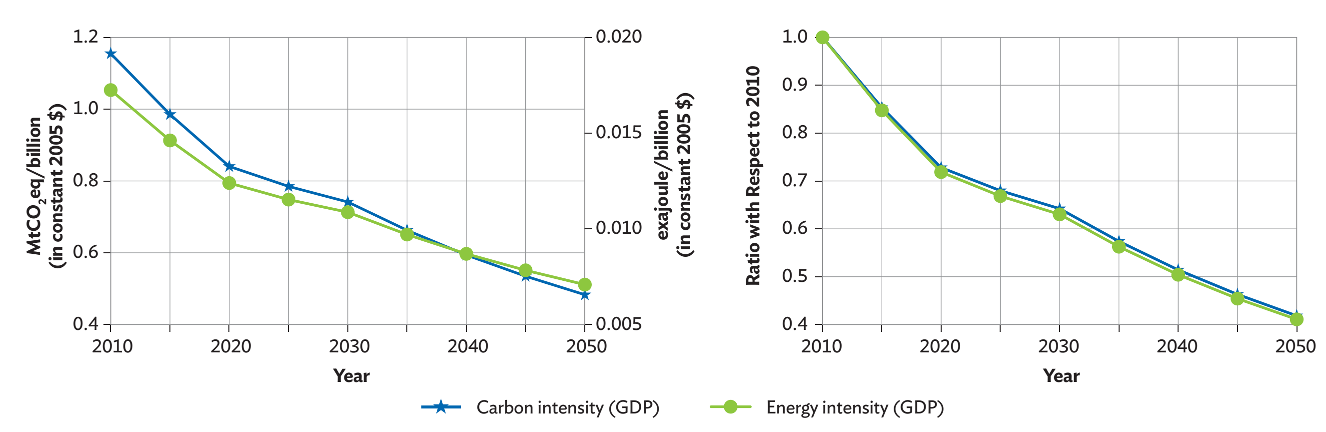


$MtCO_2eq$ = million tons of carbon dioxide equivalent.
Source: ADB Study Team.

Despite the sharp increase in energy use and emissions in Indonesia, both the energy intensity and the fossil fuel carbon intensity of its GDP are found to decline by roughly 60% within the period. This decline will be driven mainly by improvements in energy efficiency.

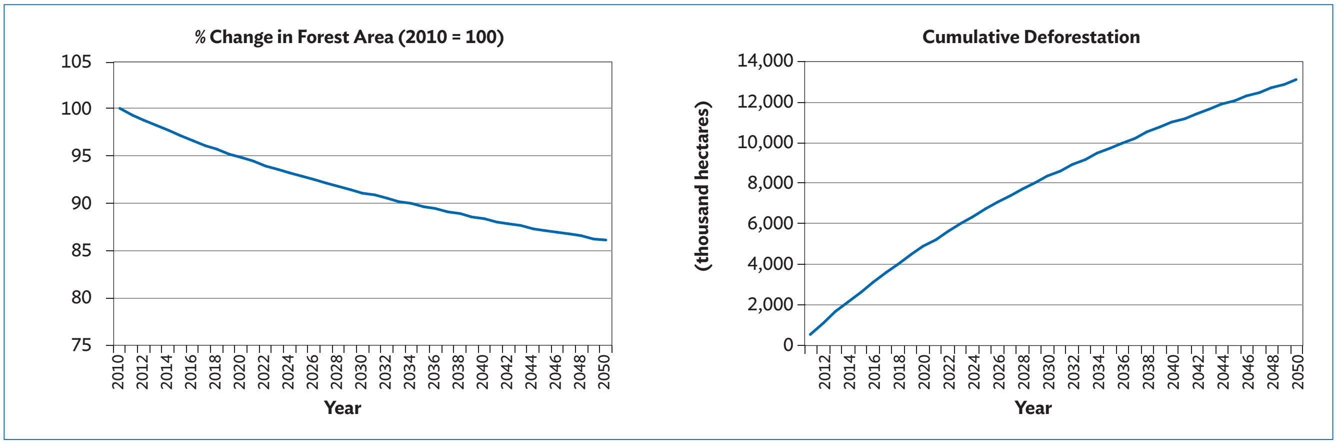
Figure A2.6 reports the BAU deforestation patterns for Indonesia based on ADB (2011a), Gusti et al. (2008), and Eliasch (2008). By midcentury, the country is expected to lose 15% of its 2011 forest cover, with the loss reaching almost 14 million cumulative deforested hectares in 2050.

Figure A2.5: Indonesia—Business-as-Usual Fossil Fuel Carbon and Energy Intensity Levels and Index (2010 = 1)



GDP = gross domestic product, $MtCO_2eq$ = million tons of carbon dioxide equivalent.
Note: Includes fossil fuel emissions only. 1 exajoule = 277,777,778 megawatt-hours.
Source: ADB Study Team.

Figure A2.6: Indonesia—Business-as-Usual Deforestation Pathways and Cumulative Deforestation



Source: ADB Study Team.

2. Indonesia's 2020 Emission Reduction Goals

The 2020 goal for Indonesia is a 26% reduction of GHG emissions with respect to BAU (Figure A2.7). For Indonesia, reducing emissions from deforestation and forest degradation (REDD) availability has a great influence in determining how those goals are achieved in terms of carbon intensity and energy intensity (Figure A2.8) as well as overall energy consumption levels (Figure A2.9). Under "perfectly efficient" full REDD, Indonesia could leave these energy consumption levels almost unchanged with respect to the BAU. This is because the required emission reduction for Indonesia can be attained almost entirely through REDD actions without strongly affecting the country's energy and/or industrial system.

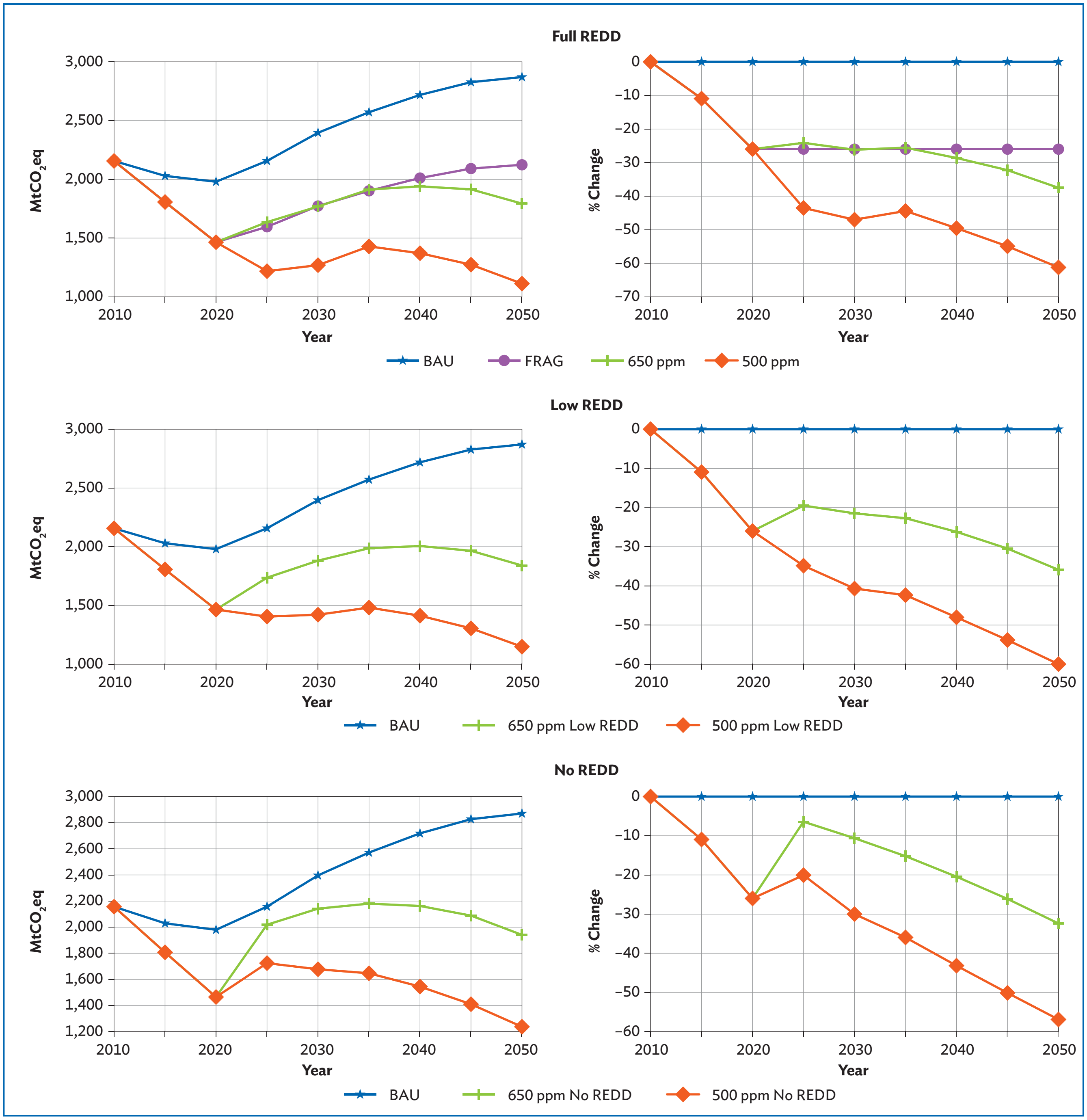
If REDD is not perfectly efficient, and faces higher costs for transactions and leakage payments (+150% with respect to BAU) or become totally unavailable, Indonesia's carbon intensity of GDP is reduced by 8% and 56%, and energy consumption by 7.5% and 60%, respectively. The energy consumption mix is affected as a result, with 2020 wind and solar production 30% higher than in the BAU. However, given that the BAU share of wind and solar energy generation in 2020 is very low, the contribution to total energy production remains minor. There remains rigidity in demand for oil and oil products, as a result of a lack of substitutes within the transportation sector. There is a large difference in abatement behavior between the high REDD cost case and the no-REDD case. This is partially due to the low-cost abatement option of peatland rewetting and rehabilitation, which remains possible even in the context of raised REDD costs, but not in a climate regime that excludes REDD.

3. Indonesia's Long-Term Stabilization Scenarios

(i) Emission reduction pathways

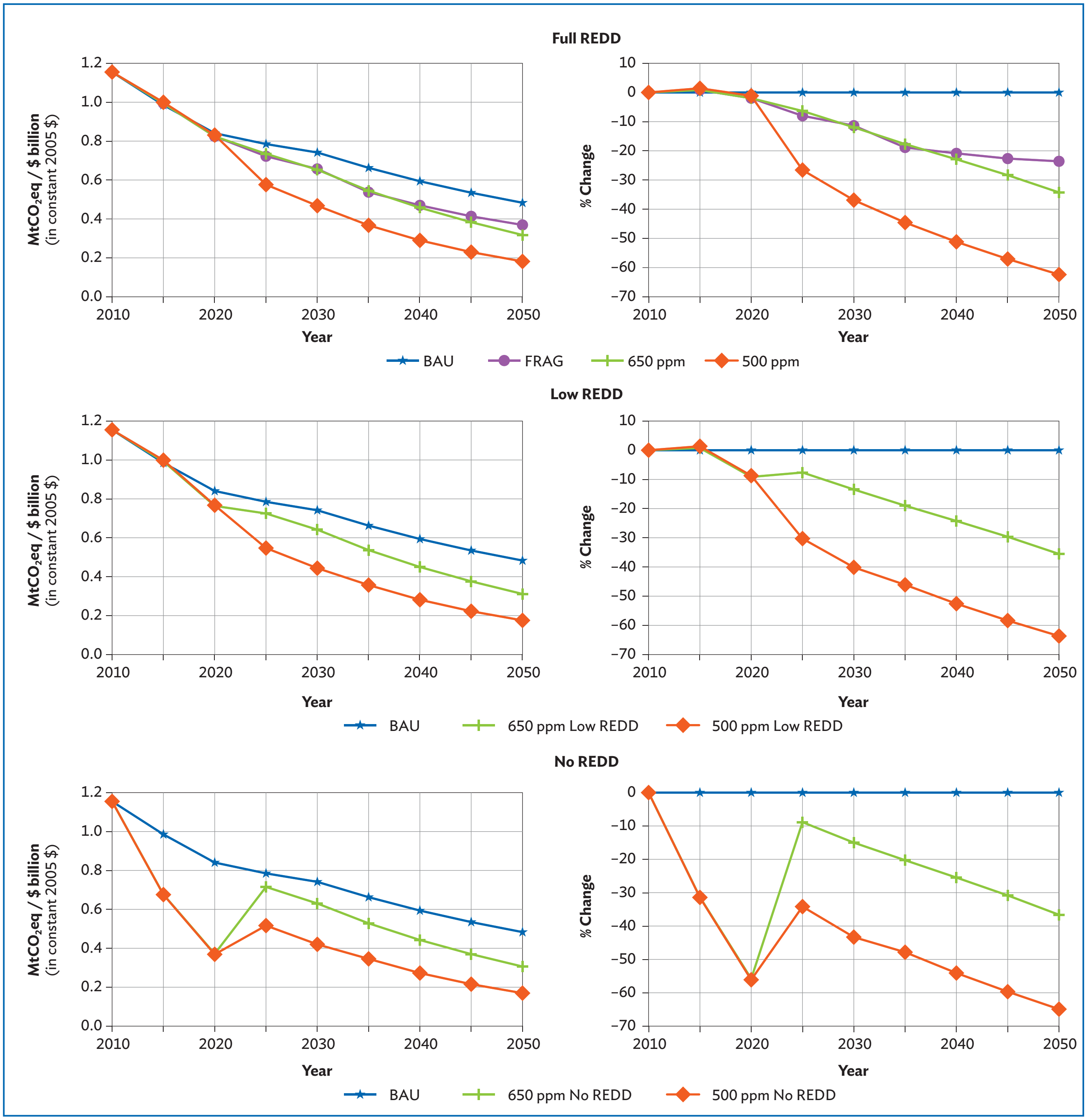
Figure A2.7 represents the stringency of the different stabilization targets for Indonesia, as a result of the intersection of global carbon prices and domestic abatement costs. The 500 parts per million (ppm) scenario leads to an emission reduction of 56%–61% by midcentury, depending on the use of REDD, while the 650 ppm scenario leads to an emission reduction of 32%–37%. The fragmented (FRAG) scenario is projected to attain the same percentage of emission reduction during 2020 through 2050. The possibility of selling REDD credits

Figure A2.7: Indonesia—Greenhouse Gas Emission Projections in Quantity and Percent Change from Business as Usual



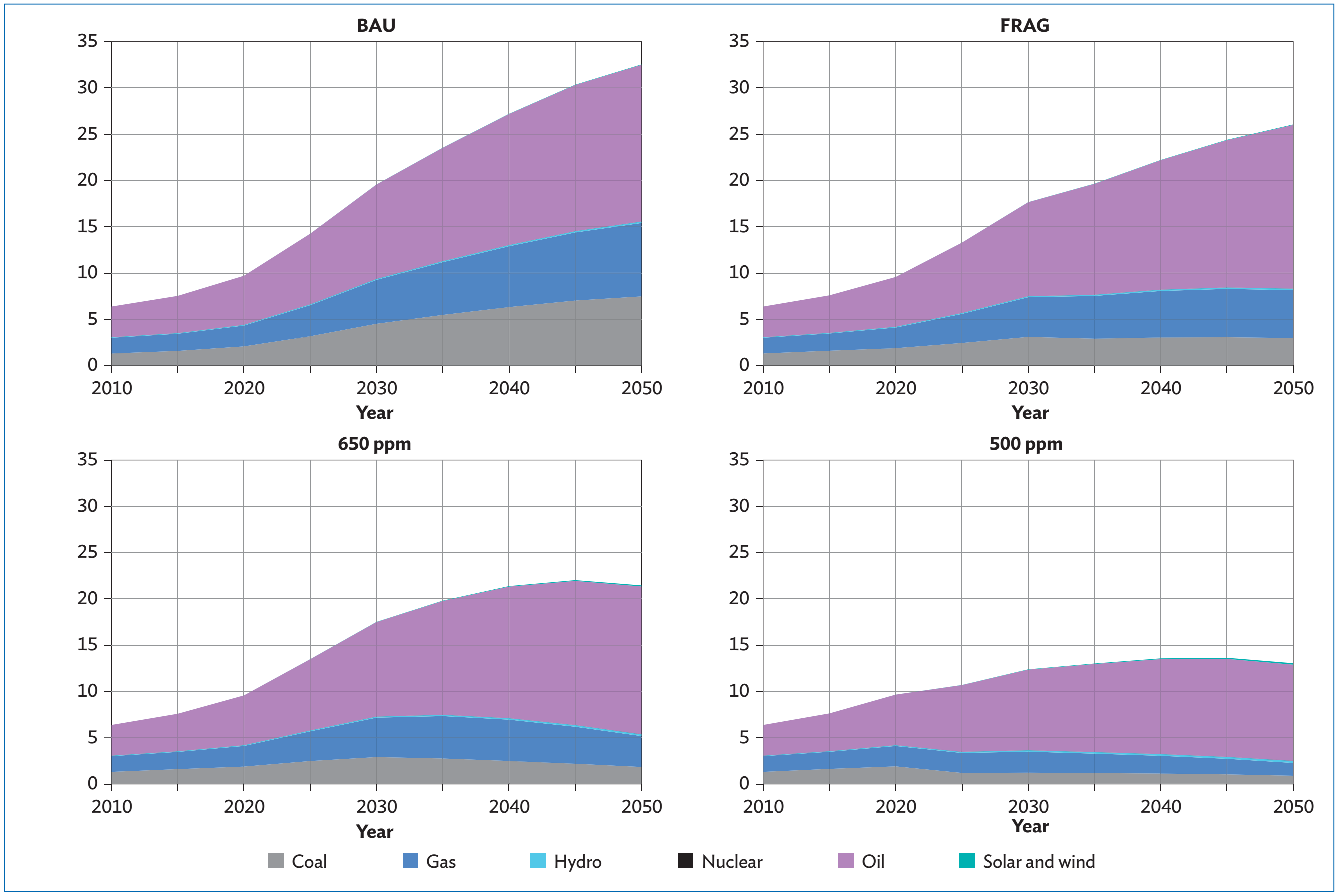
BAU = business as usual, FRAG = fragmented (policy), $MtCO_2eq$ = million tons of carbon dioxide equivalent, ppm = parts per million, REDD = reducing emissions from deforestation and forest degradation.
Note: All percent changes are with respect to BAU.
Source: ADB Study Team.

Figure A2.8: Indonesia—Carbon Intensity of Gross Domestic Product Changes from Business as Usual



BAU = business as usual, FRAG = fragmented (policy), $MtCO_2eq$ = million tons of carbon dioxide equivalent, ppm = parts per million, REDD = reducing emissions from deforestation and forest degradation.
Note: All percent changes are with respect to BAU.
Source: ADB Study Team.

Figure A2.9: Indonesia—Total Primary Energy Consumption (exajoule)



BAU = business as usual, FRAG = fragmented (policy), ppm = parts per million.
Source: ADB Study Team.

in the carbon market provides an incentive for Indonesia to reduce its emission more than in the no-REDD case. This pattern is more evident in the midterm than in the long term, given that the BAU land-use emission trends rise initially and then decline.

(ii) Mechanisms of emission reduction

Both the 500 ppm and 650 ppm decarbonization scenarios imply large carbon and energy intensity declines—roughly 60% and 35%, respectively, by 2050 compared to BAU (Figure A2.8). In the absence of REDD, a massive reduction in energy consumption implies stronger contractions in the use of all fossil energy sources.

The primary energy consumption mix reflects a continuation of the trend highlighted in 2020, as oil has few substitutes. By 2050, oil is expected to constitute almost 80% of energy consumption in the 500 scenario and 75% in the 650 scenario, while coal is reduced to 7%, with hydropower also having a 2% share (regardless of REDD assumptions: Figure A2.9). The lower stringency of the fragmented target induces less change in the energy mix, despite increases in the share of oil from the BAU 45% to 60% in 2050. In the no-REDD case, growth of wind and solar production is increased (Figure A2.10).

(iii) Economic contributions of carbon trade

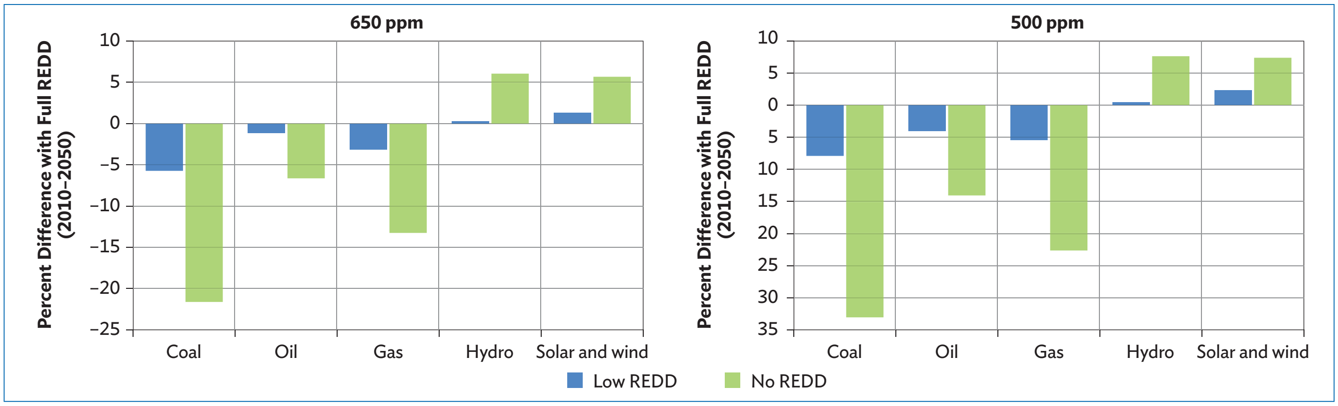
After 2020, prices in the global carbon market steadily increase following the increasing stringency imposed by the stabilization scenarios, reaching \$495/tCO_2eq and \$205/tCO_2eq in 2050 in the 500 ppm and 650 ppm stabilization scenarios, respectively. In 2050, the supply of REDD credits allows the global cost of carbon allowances to be lower at \$495/tCO_2eq against almost \$554/tCO_2eq in the no-REDD case.

Indonesia's position in the global carbon market is dependent on REDD (Figure A2.11). In the REDD case, the country remains a net seller in the 650 ppm stabilization scenario until 2034 and in the 500 stabilization scenario until 2029. Consistent with the carbon prices, revenues are higher in the 500 case. When REDD is not available, Indonesia is always a buyer of permits, with increasing volumes until 2045. Then its purchases tend to stabilize. This is the combined effect of the initial stringency of the historically rooted goal and the rise in allowance allocation as a result of the contraction and convergence framework.

(iv) Co-benefits

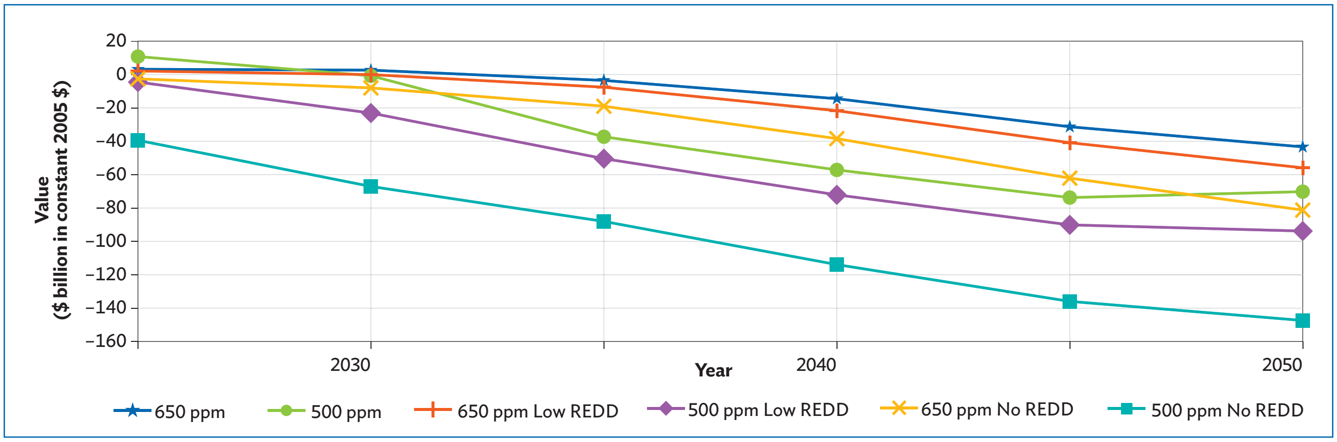
Co-benefits increase at an increasing rate over the analyzed period. Under 500 ppm stabilization with REDD, co-benefits reach \$160 billion annually by 2050. The largest share of co-benefits arises from reduced pollution-related mortality, followed by reduced transportation congestion. Less than a third of total co-benefits under 500 ppm stabilization are achieved under 650 ppm stabilization (Figure A2.12).

Figure A2.10: Total Primary Energy Consumption Change from REDD, 2010–2050



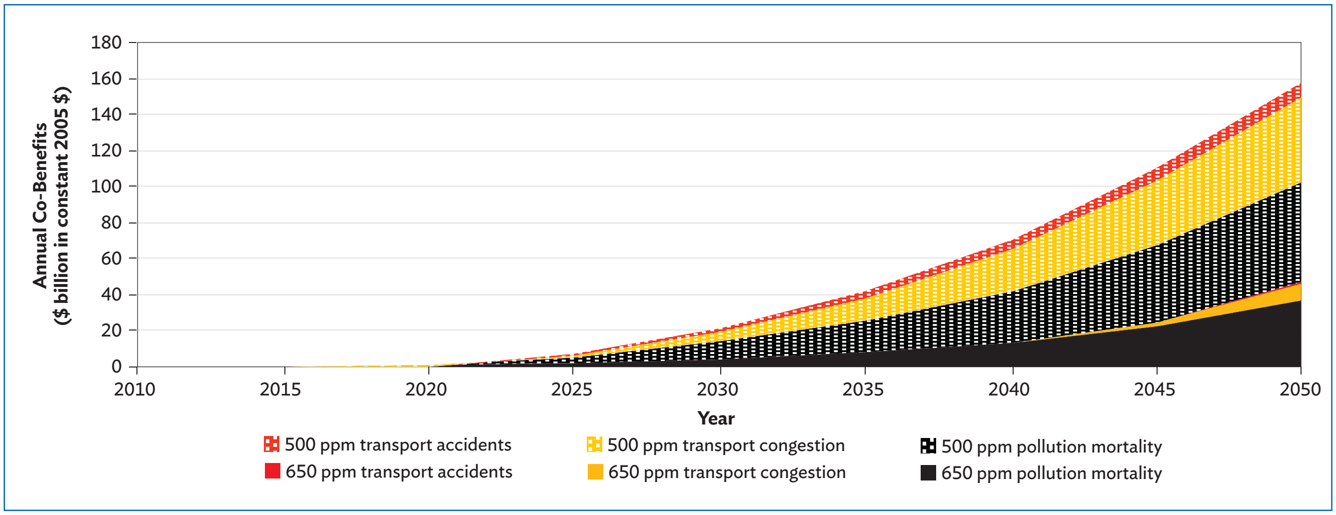
ppm = parts per million, REDD = reducing emissions from deforestation and forest degradation.
Source: ADB Study Team.

Figure A2.11: Indonesia—Projections of Carbon Permit Trade



ppm = parts per million, REDD = reducing emissions from deforestation and forest degradation.
Note: > 0 selling, < 0 buying.
Source: ADB Study Team.

Figure A2.12: Indonesia—Co-Benefits under Scenarios with Full REDD



ppm = parts per million, REDD = reducing emissions from deforestation and forest degradation.
Source: ADB Study Team.

B. Malaysia

1. Business-as-Usual Results

In 2010, Malaysia's GDP was around $0.15 trillion, slightly less than Thailand's and slightly more than that of the Philippines. However, with a population of 25 million (Table A2.2), it has the highest GDP per capita among the DA5. Malaysia's service sector was 46% of total value added in 2010, followed by industry at 43% and agriculture at 11%. The industrial sector is largely based on heavy industry, which accounts for 80% of industrial production.

In 2010, actual primary energy consumption for Malaysia consisted of 44% gas, 31% oil, 19% coal, and 4% biomass (IEA 2012b). In ICES, the energy sector, which accounts for one-third of industrial value added, relies mainly on natural gas (around 40%) and oil (around 38%) in 2010, while the remainder is mostly contributed by coal.

In 2010, Malaysia emitted about 400 $MtCO_2$ equivalent of GHGs, mostly from the production of electricity and transportation. The composition of emissions includes CO_2 (79%) and CH_4 (15%). Malaysia is the third-largest total emitter among the DA5 after Indonesia and Thailand, but has the highest level of emissions per capita. In both energy and carbon intensity, Malaysia comes third after Viet Nam and Thailand.

According to modeling assumptions[3] for 2010 to 2050 (Table A2.2), Malaysia's GDP will grow on average by 5% annually, reaching $1.1 trillion by 2050, or almost seven times that of 2010, spurred by the further development of market services. From an initial contribution of 43% to national value added in 2010, the industry sectors (including energy) are modeled to grow to more than 50% by 2050 (Figure A2.13). Although the agriculture sector is modeled to grow in levels, its overall contribution to the national value added is projected to shrink from 11% in 2010 to 6% in 2050.

Table A2.2: Malaysia—Business-as-Usual Annualized Growth Rate and Population

	Annual GDP Growth (%)	
	ICES-Simulations	Projections
2011–2020	5.4	5.5
2021–2030	5.2	4.8
2031–2040	5.0	4.8
2041–2050	4.9	4.8

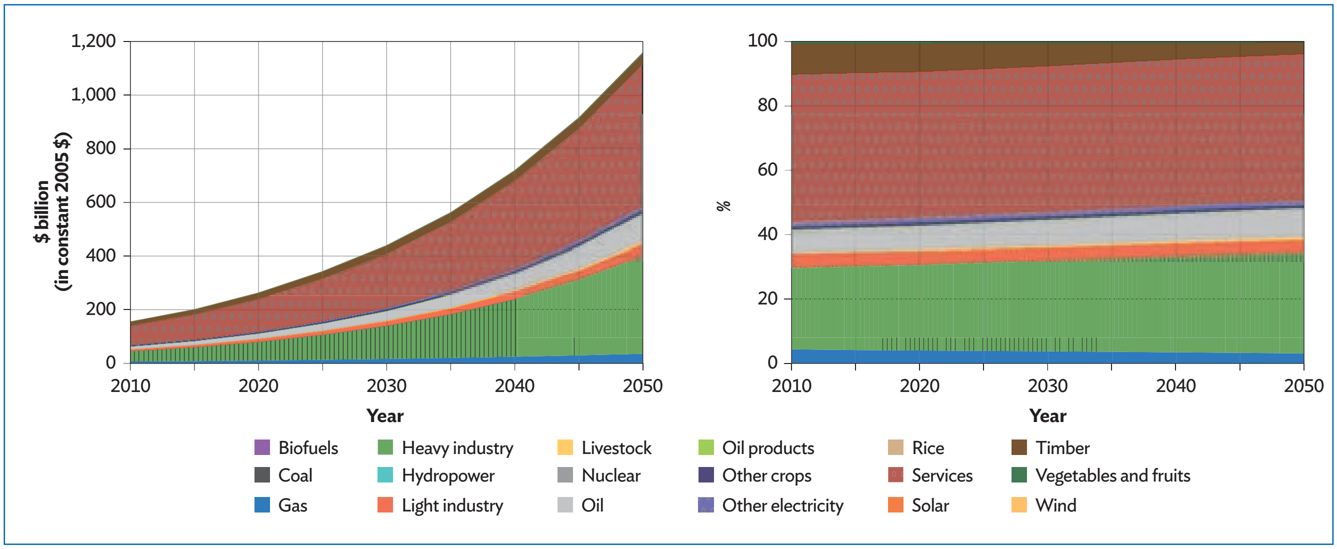
	Population (million)
2010	28.4
2020	33.0
2030	37.3
2040	40.8
2050	43.5

GDP = gross domestic product, ICES = Intertemporal Computable Equilibrium System.
Note: Projections refer to ADB (2011b) data integrated with information from local experts.
Source: ADB Study Team.

In the absence of climate-related policies, overall energy production is found to increase to 10.4 exajoules in 2050. It continues to rely primarily on fossil sources, with coal replacing some oil (Figure A2.14) Although hydroelectric energy is found to increase by more than ten times, its share of national energy production remains negligible. Despite a large increase from the 2010 levels, the share of solar generation in 2050 is found to become smaller.

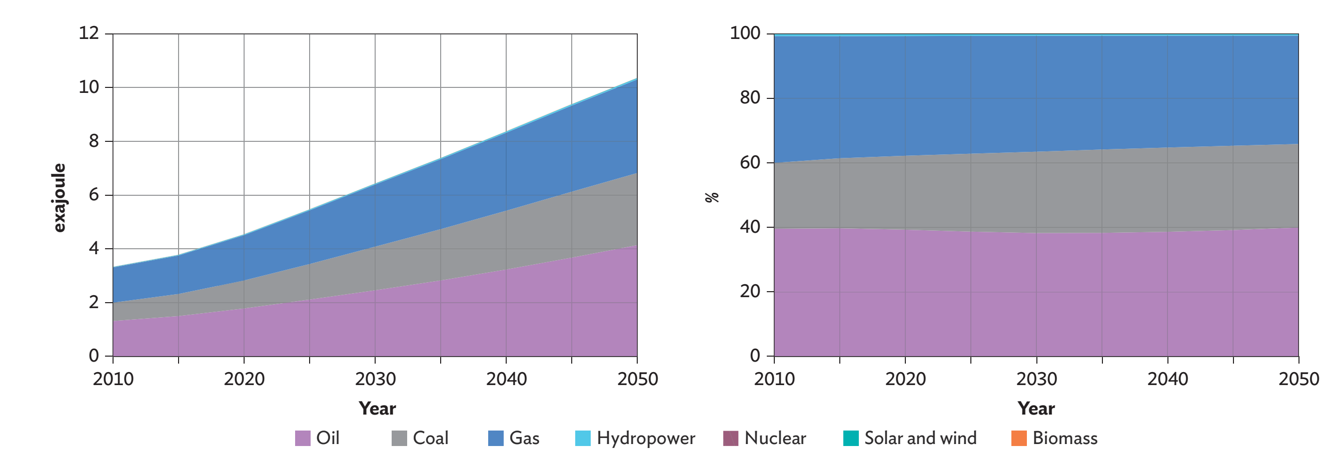
3 Note that these are not authoritative or official ADB projections. This is simply description of ICES' behavior, as calibrated to ADB (2011b).

Figure A2.13: Malaysia—Business-as-Usual Gross Domestic Product and Sectoral Composition



Source: ADB Study Team.

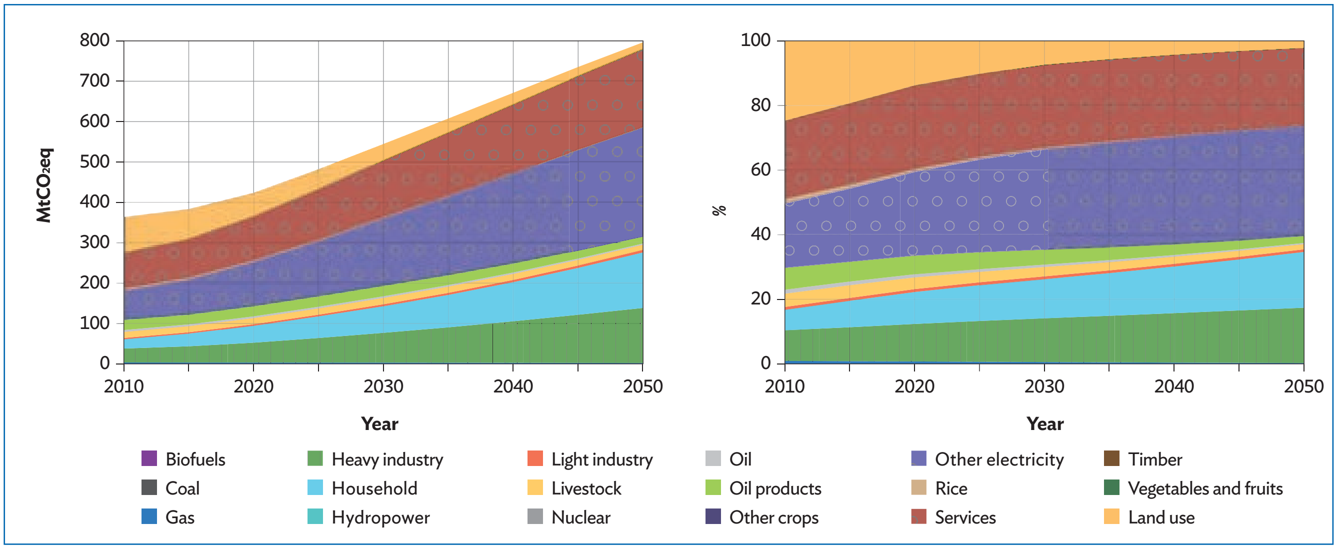
Figure A2.14: Malaysia—Business-as-Usual Primary Energy Consumption by Source and Share by Source



Note: 1 exajoule = 277,777,778 megawatt-hours.
Source: ADB Study Team.

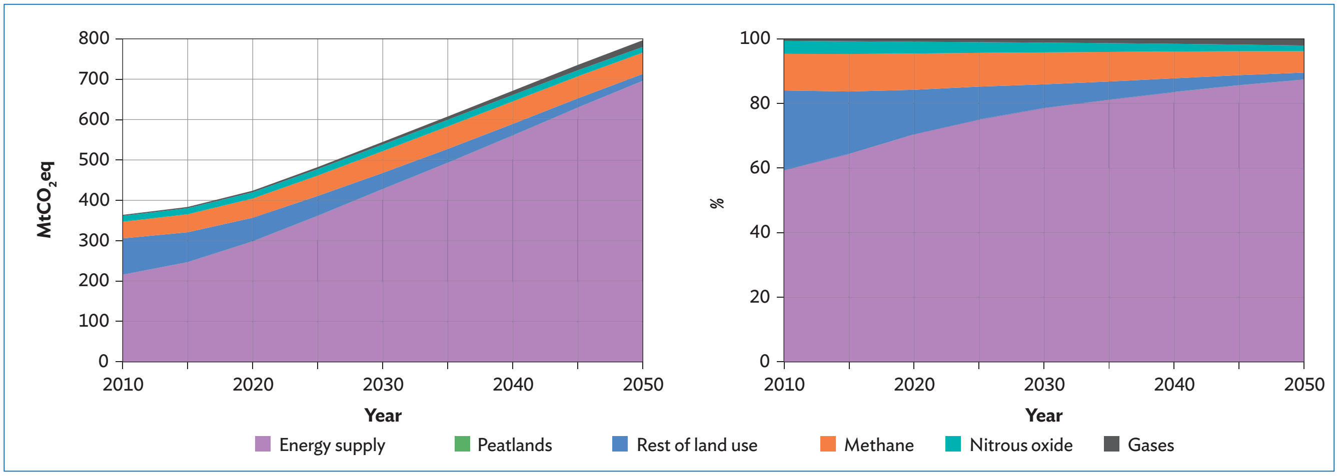
From 2010 to 2050, BAU GHG emissions are found to grow more than twofold, with the electricity sector accounting for almost half of national emissions (Figure A2.15). The model finds a slight increase in share of emissions linked to household consumption, and the share of emissions from land use shrinks to a very marginal level (Figure A2.16). Overall emissions increase but grow less in proportion to GDP, resulting in reductions in carbon intensity and energy intensity of 60% (Figure A2.17). Malaysia is also found to have lost almost a quarter of its 2010 forest area by 2050 (Figure A2.18).

Figure A2.15: Malaysia—Business-as-Usual Emissions by Source and Share by Source



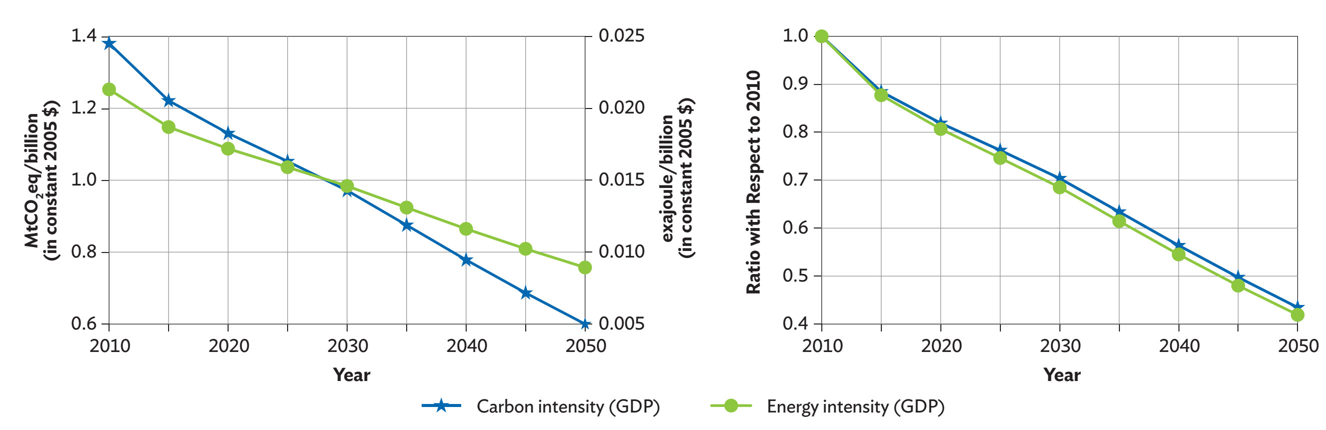
$MtCO_2eq$ = million tons of carbon dioxide equivalent.
Note: Other electricity is electricity produced using fossil fuel sources (e.g., coal, oil, or gas).
Source: ADB Study Team.

Figure A2.16: Malaysia—Business-as-Usual Emissions by Gas and Shares by Gas



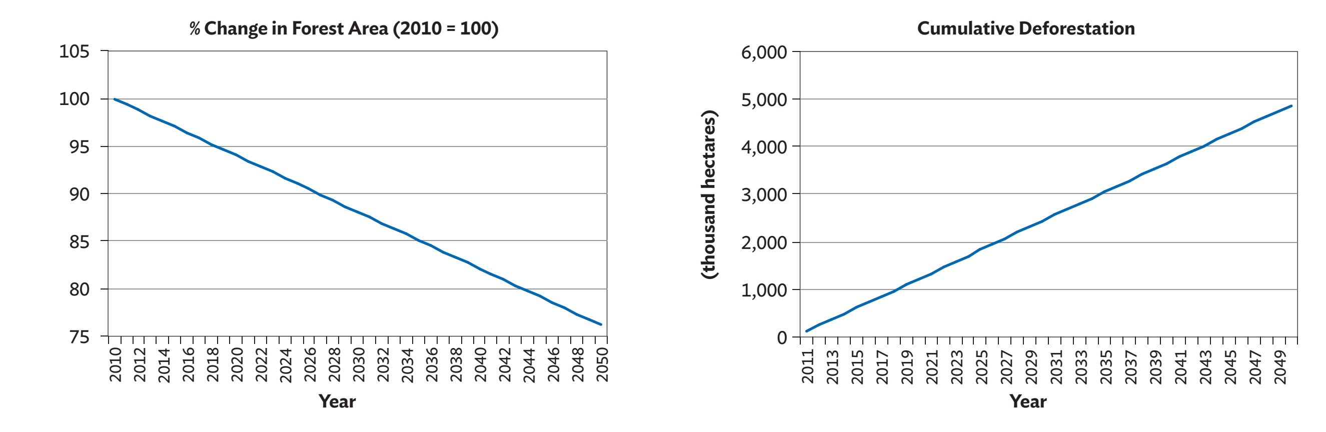
$MtCO_2eq$ = million tons of carbon dioxide equivalent.
Source: ADB Study Team.

Figure A2.17: Malaysia—Business-as-Usual Fossil Fuel Carbon and Energy Intensity Levels and Index (2010 = 1)



GDP = gross domestic product, $MtCO_2eq$ = million tons of carbon dioxide equivalent.
Note: Includes fossil fuel emissions only. 1 exajoule = 277,777,778 megawatt-hours.
Source: ADB Study Team.

Figure A2.18: Malaysia—Business-as-Usual Deforestation Pathways and Cumulative Deforestation



$MtCO_2eq$ = million tons of carbon dioxide equivalent.
Source: ADB Study Team.

2. Malaysia's 2020 Emission Reduction Goals

The 2020 goal for Malaysia is up to a 40% CO_2eq per unit of GDP from 2005 levels. Given that the BAU emissions growth path to 2020 leads to a similar level of decarbonization in ICES as the goal, the goal does not imply substantial emission reduction, compared with business as usual (see Chapter 5).

3. Malaysia's Long-Term Stabilization Scenarios

(i) Emission reduction pathways

Figure A2.19 shows the level of emission reduction achieved according to the intersection of Malaysia's abatement costs and global carbon prices. The 500 ppm scenario leads to an emission reduction of 70% in 2050 compared with BAU. The 650 ppm scenario leads to a reduction of 40%, while the fragmented scenario leads to almost no emission reduction compared with the BAU by midcentury. Malaysia's GDP carbon intensity and energy intensity closely follow the country's emission trends (Figure A2.20) resulting in the highest percentage reduction among the DA5 with respect to BAU. This is a direct consequence of the country's higher carbon intensity. In a global carbon market, which allows the possibility to allocate abatement where it is cheaper, higher intensity reductions often accrue in countries with the highest carbon intensity.

(ii) Mechanisms of emission reduction

To achieve the 70% emission reduction against BAU implied by the 500 ppm stabilization scenario in 2050, primary energy consumption in 2050 falls below 2010 levels. Although the 650 ppm stabilization scenario is less stringent, it still implies energy consumption 40% lower than BAU in 2050 (Figure A2.21). The mix in primary energy consumption shows a shift toward oil and oil products—which increase their share in energy from 40% in the 2050 BAU to 61% and 67% in the 650 ppm scenario and 500 ppm stabilization scenario, respectively. The contribution of natural gas and coal to energy consumption falls, while hydropower increases, but remains below 2.5%. In contrast, solar and wind production sharply increase, but their contribution to energy generation remains small (0.4%). In the absence of REDD, fossil fuel power use declines and renewable energy increases in the stabilization scenarios (Figure A2.22).

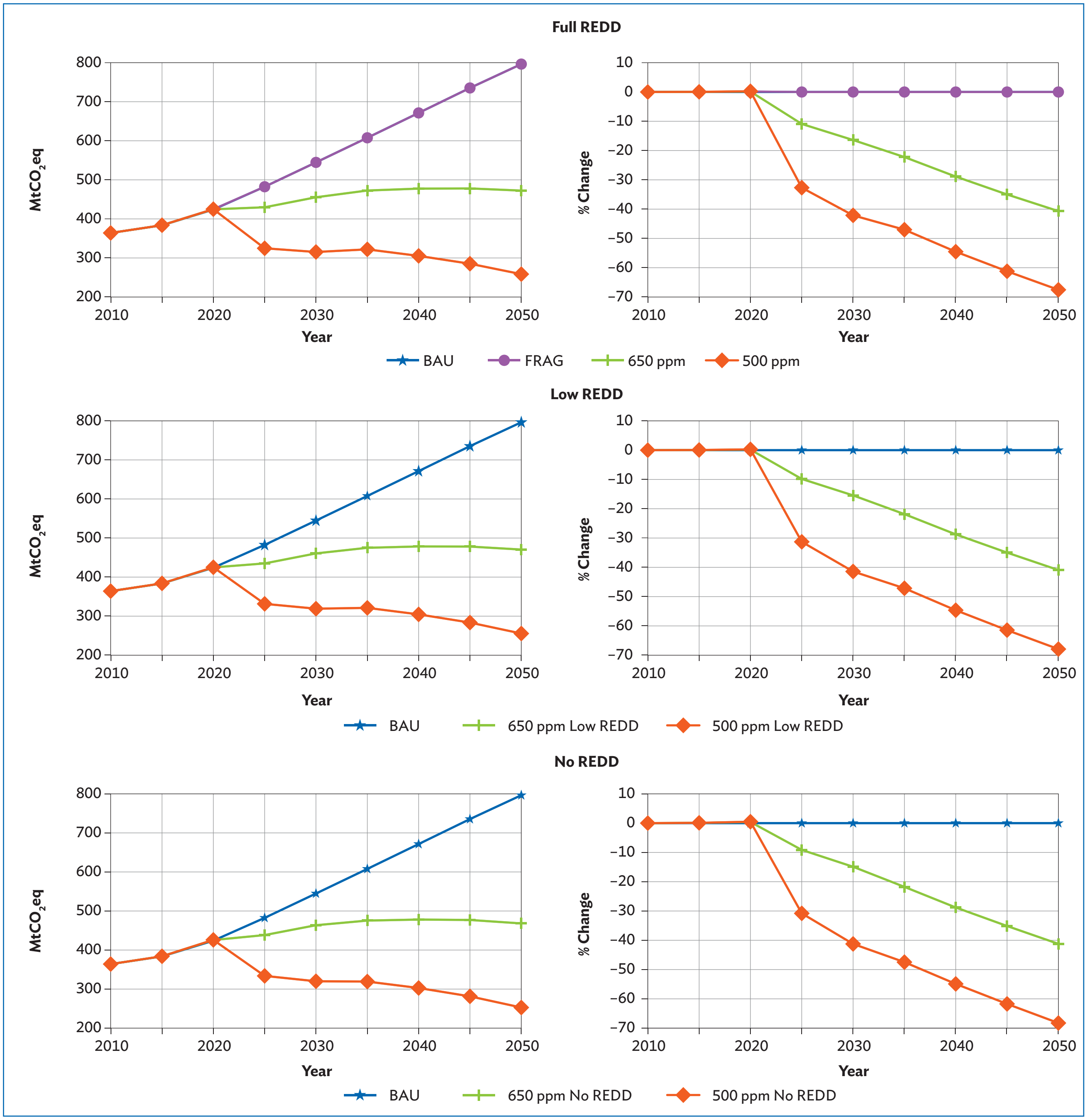
(iii) Economic contributions of carbon trade

In the carbon market, Malaysia is a net buyer of permits and behaves very similarly across the full REDD, the low REDD, and the no-REDD scenarios (Figure A2.23). Due to the increasing stringency of the target and the higher carbon prices, the country requires higher expenditure to import permits in the 500 than in the 650 stabilization scenarios.

(iv) Co-benefits

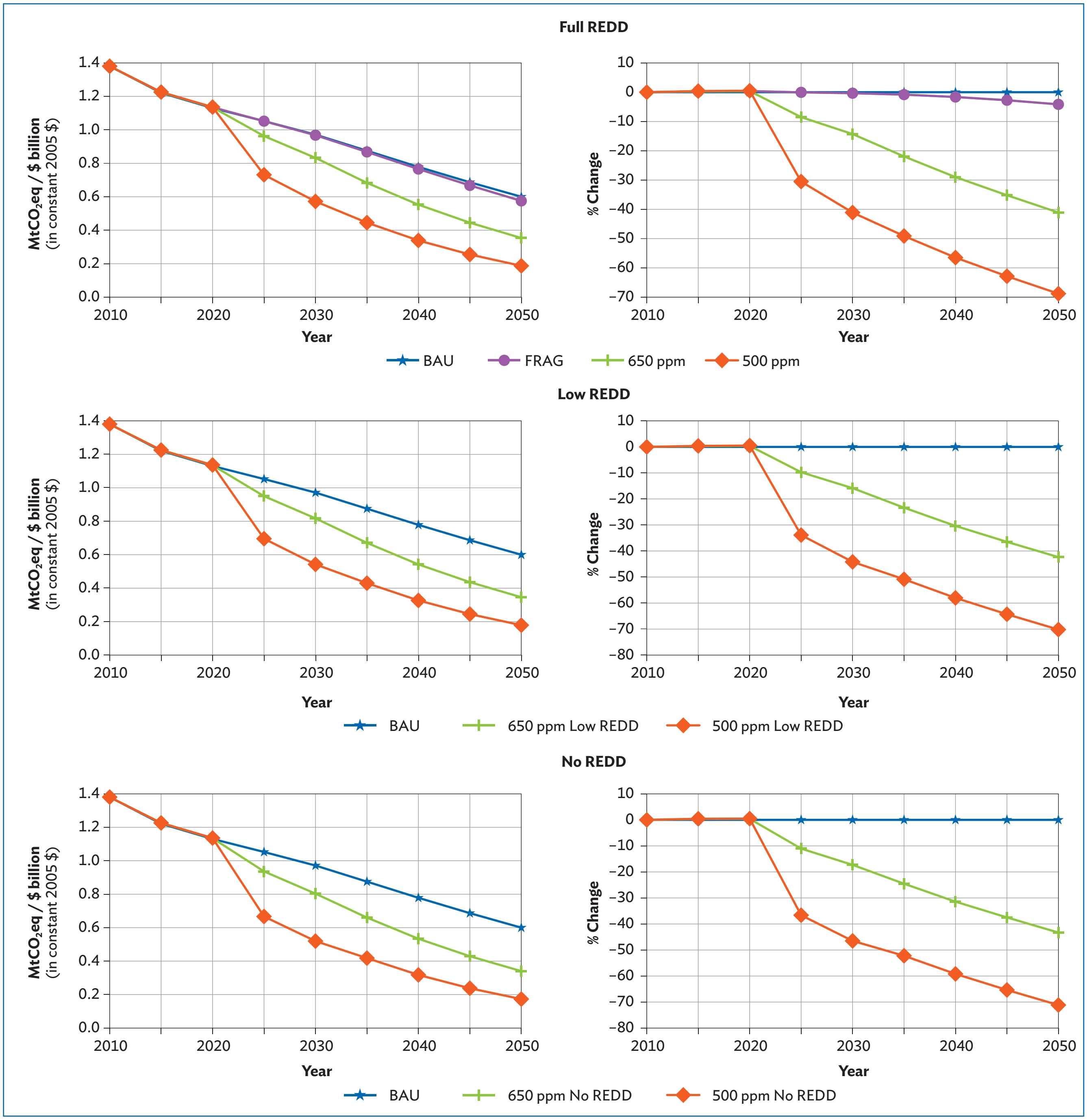
Co-benefits increase at an increasing rate over the analyzed period. Under 500 ppm stabilization with REDD, co-benefits reach $46 billion annually by 2050. The largest share of co-benefits arises from reduced pollution-related mortality, followed by reduced transportation congestion. Less than a third of total co-benefits under 500 ppm stabilization are achieved under 650 ppm stabilization (Figure A2.24).

Figure A2.19: Malaysia—Greenhouse Gas Emission Projections in Quantity and Percent Change over Business as Usual



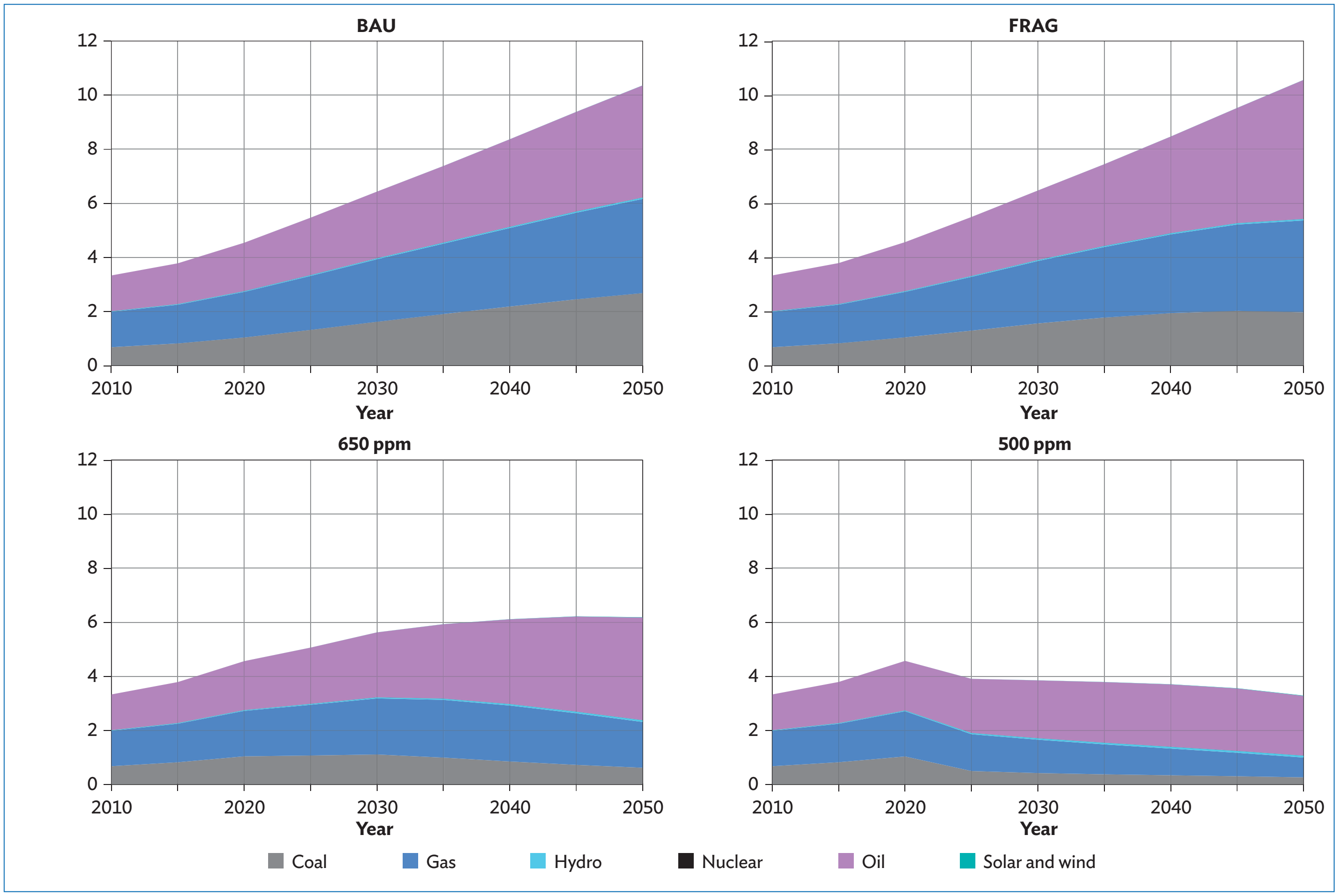
BAU = business as usual, FRAG = fragmented (policy), $MtCO_2eq$ = million tons of carbon dioxide equivalent, ppm = parts per million, REDD = reducing emissions from deforestation and forest degradation.
Note: All percent changes are with respect to BAU.
Source: ADB Study Team.

Figure A2.20: Malaysia—Carbon Intensity of Gross Domestic Product Changes from Business as Usual



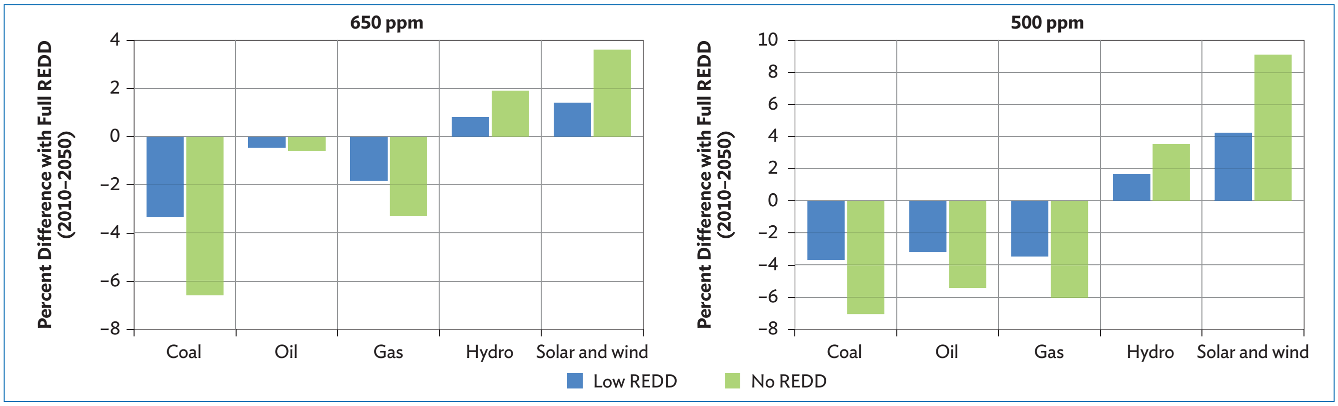
BAU = business as usual, FRAG = fragmented (policy), $MtCO_2eq$ = million tons of carbon dioxide equivalent, ppm = parts per million, REDD = reducing emissions from deforestation and forest degradation.
Note: All percent changes are with respect to BAU.
Source: ADB Study Team.

Figure A2.21: Malaysia—Total Primary Energy Consumption (exajoule)



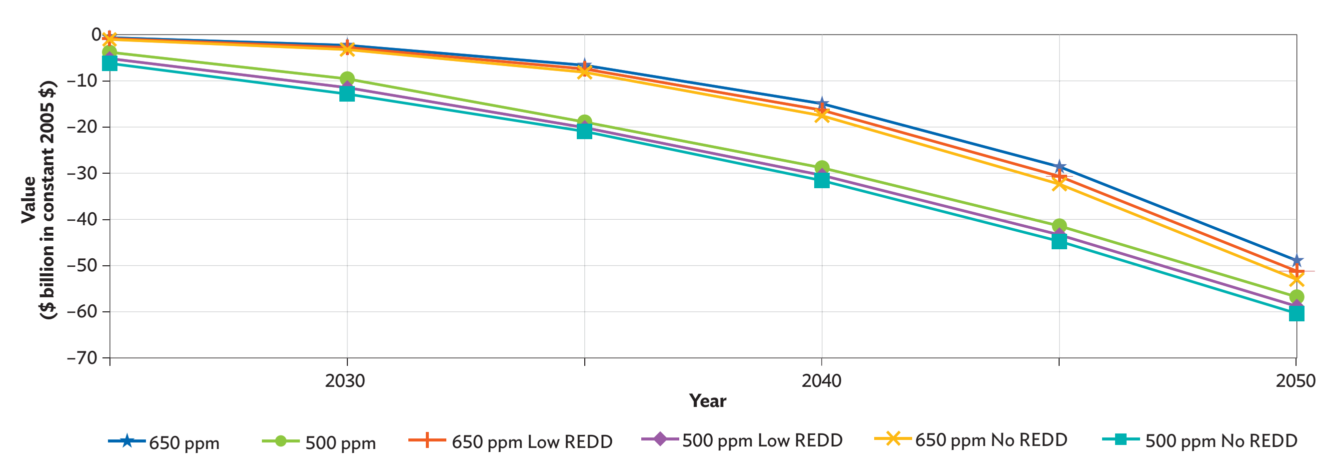
BAU = business as usual, FRAG = fragmented (policy), ppm = parts per million.
Source: ADB Study Team.

Figure A2.22: Malaysia—Total Primary Energy Consumption Change from REDD, 2010–2050



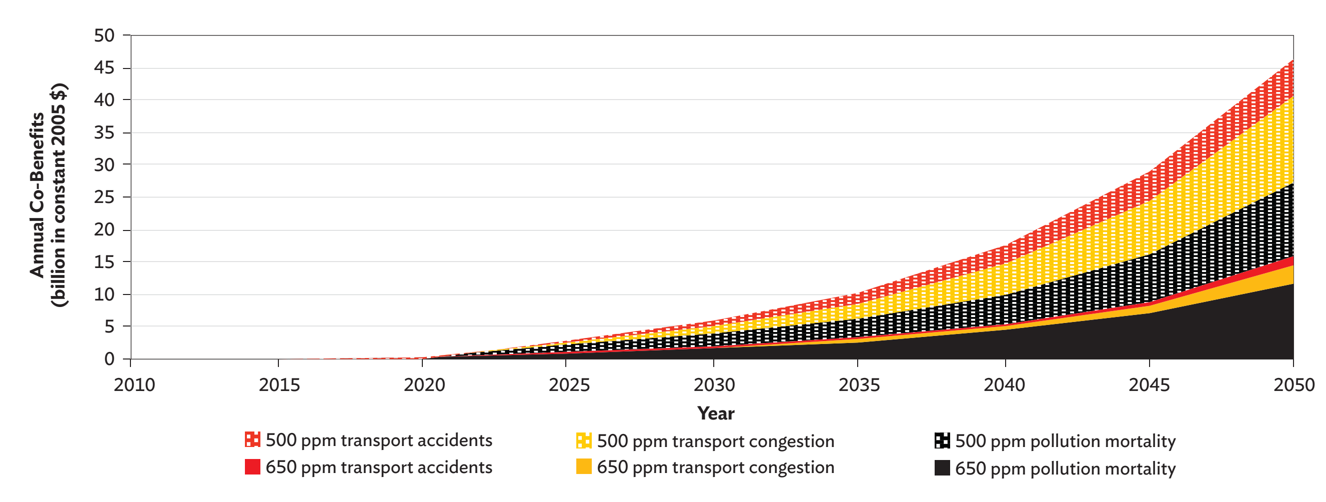
REDD = reducing emissions from deforestation and forest degradation.
Source: ADB Study Team.

Figure A2.23: Malaysia—Projections of Carbon Permit Trade



ppm = parts per million, REDD = reducing emissions from deforestation and forest degradation.
Note: > 0 selling, < 0 buying).
Source: ADB Study Team.

Figure A2.24. Malaysia—Co-Benefits under Scenarios with Full REDD



ppm = parts per million, REDD = reducing emissions from deforestation and forest degradation.
Note: > 0 selling, < 0 buying.
Source: ADB Study Team.

C. Philippines

1. Business-as-Usual Results

In 2010, with a population of 93.3 million, the Philippines was the second most heavily populated of the DA5 (Table A2.3). Its GDP ranked fourth at $0.118 trillion, and the level of its GHG emissions, at about 150 $MtCO_2eq$, was the lowest among the DA5. Of paramount importance in the country's economy was the services sector, which at 55% represents the highest share of value added among the DA5 countries. Industry and agriculture follow at 32% and 12%, respectively.

Table A2.3: Philippines—Business-as-Usual Annualized Growth Rate and Population

	Annual GDP Growth (%)	
	ICES-Simulations	Projections
2011–2020	6.2	6.0
2021–2030	5.2	5.5
2031–2040	5.7	5.5
2041–2050	6.0	5.5

	Population (million)
2010	93.3
2020	109.7
2030	126.3
2040	141.7
2050	154.9

GDP = gross domestic product, ICES = Intertemporal Computable Equilibrium System.
Note: Projections refer to ADB (2011b) data, integrated with information from local experts.
Source: ADB Study Team.

In 2010 according to IEA (2012b), primary energy was actually sourced primarily from oil (34%), geothermal (21%), coal (19%), biomass (17%), gas (8%), and hydropower (2%). In ICES, which excludes biomass and geothermal power, the country's primary energy consumption in 2010 was about 1.3 exajoule, sourced mainly from oil, followed by coal and gas, while renewable sources only had a marginal role, accounting for less than the 3% of energy consumption.

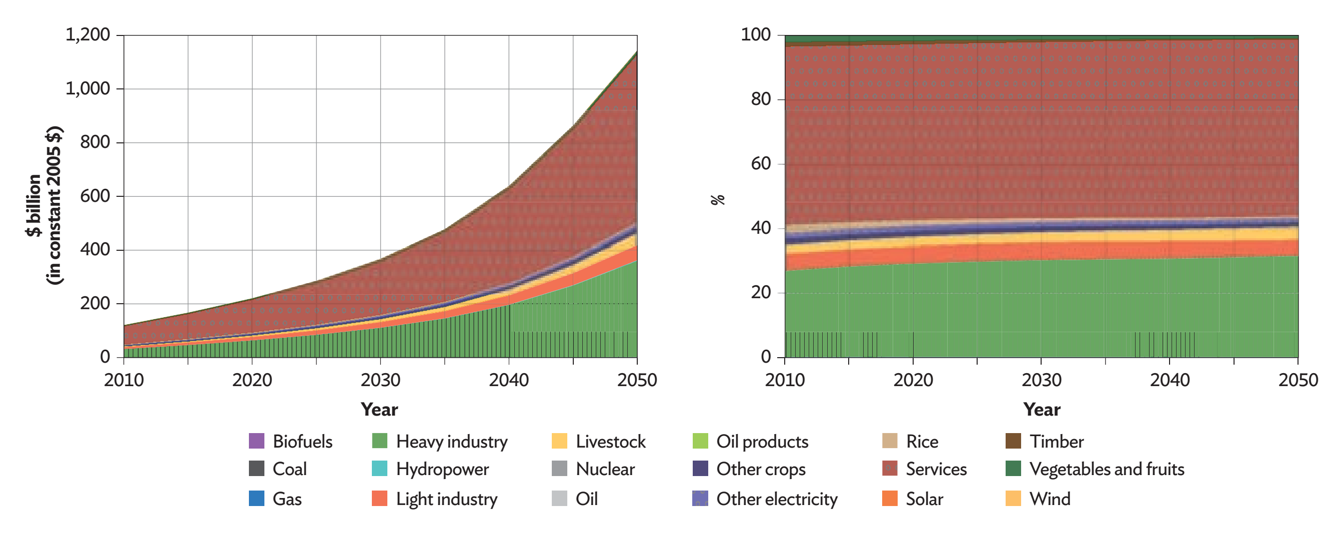
The main sources of GHG emissions are transportation, electricity generation, heavy industries, and rice and livestock production (Figure A2.27). The energy intensity and carbon intensity of the country's GDP are the lowest among the DA5.

For 2010–2050, the modeling assumptions[4] for the Philippines would make it the third fastest growing economy among the DA5. GDP is modeled to reach $1.1 trillion in 2050 (Figure A2.25), primarily supported by the growth of the service sector. Heavy industries slightly increase their share. The relative share of agriculture in GDP shrinks from 11% in 2010 to 7.7% in 2050. Given this development scenario, energy consumption is projected to increase more than threefold (Figure A2.26), peaking at 4.3 exajoule in 2050. In the absence of climate or renewable energy policies, the energy consumption mix is modeled as remaining dominated by fossil sources, which account for over 90% of the total, with hydropower expected to double by 2050.

Mirroring this development scenario, in the absence of climate-related policies, GHG emissions in the Philippines increase from just above 150 $MtCO_2eq$ in 2010 to 400 $MtCO_2eq$ in 2050 (Figure A2.27). Following the sectoral restructuring of the economy, there is an increase in share of emissions from transportation services, fossil-fuel-based electricity, heavy industry, and households. In contrast, the share of emissions by the agriculture sector is found to decline from around 28% to 6.4% (Figure A2.28). Improvements in energy efficiency and productivity growth are found to foster reduction in the carbon intensity and energy intensity of the country's GDP by roughly 60% between 2010 and 2050 (Figure A2.29).

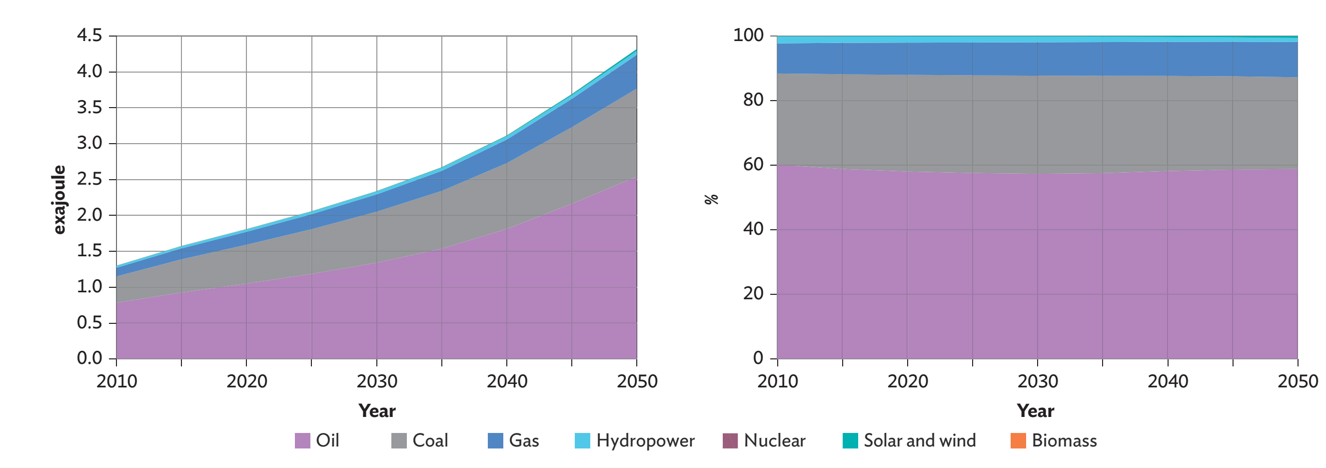
[4] Note that these are not authoritative or official ADB projections. This is simply description of ICES' behavior, as calibrated to ADB (2011b).

Figure A2.25: Philippines—Business-as-Usual Gross Domestic Product and Sectoral Composition



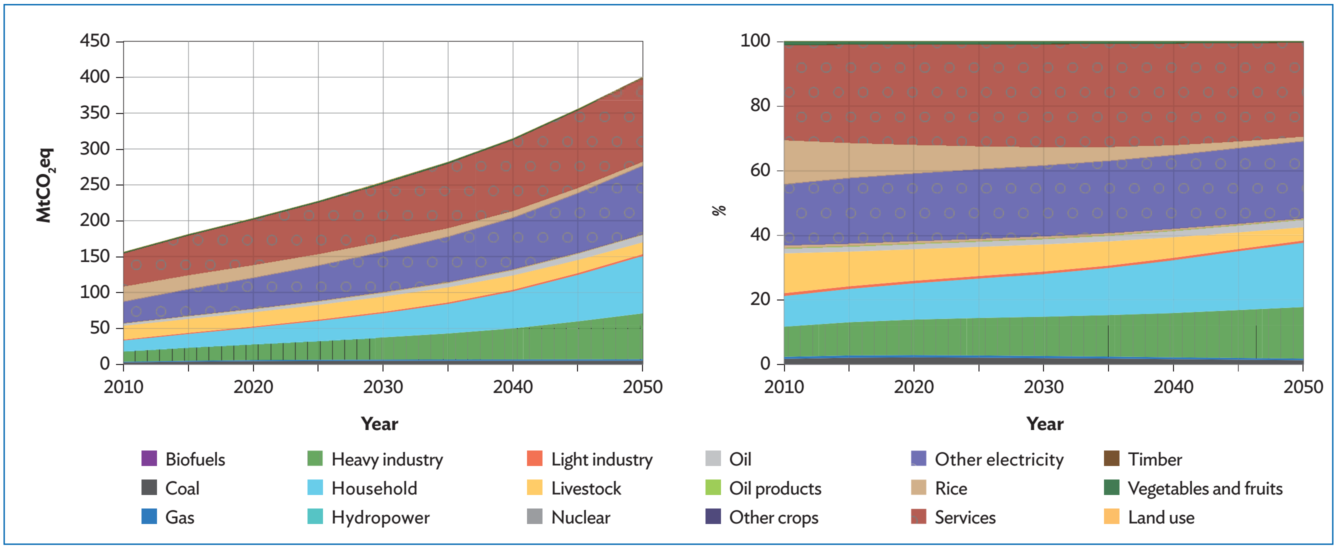
GDP = gross domestic product.
Source: ADB Study Team.

Figure A2.26: Philippines—Business-as-Usual Primary Energy Consumption by Source and Share by Source



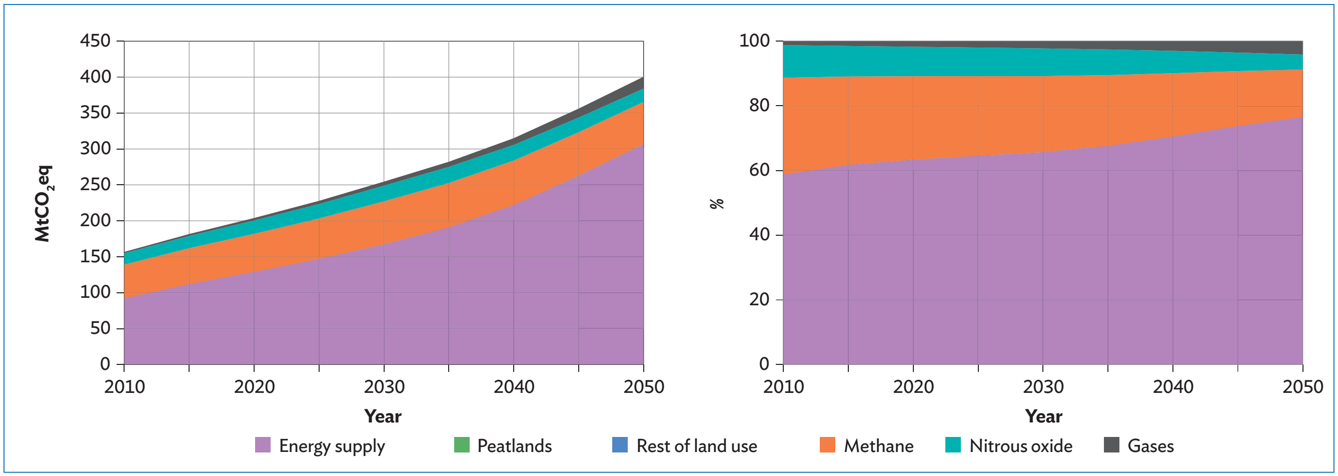
Note: 1 exajoule = 277,777,778 megawatt-hours.
Source: ADB Study Team.

Figure A2.27: Philippines—Business-as-Usual Greenhouse Gas Emissions by Source and Share by Source



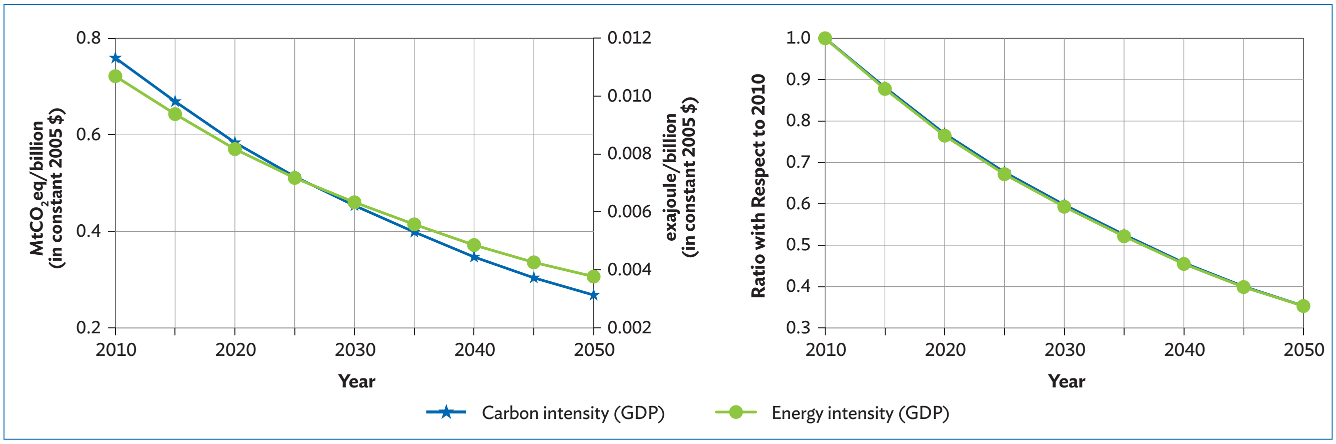
$MtCO_2eq$ = million tons of carbon dioxide equivalent.
Note: Other electricity is electricity produced using fossil fuel sources (e.g., coal, oil, or gas).
Source: ADB Study Team.

Figure A2.28: Philippines—Business-as-Usual Emissions by Gas and Shares by Gas



$MtCO_2eq$ = million tons of carbon dioxide equivalent.
Source: ADB Study Team.

Figure A2.29: Philippines—Business-as-Usual Fossil Fuel Carbon and Energy Intensity Levels and Index (2010 = 1)



GDP = gross domestic product, $MtCO_2eq$ = million tons of carbon dioxide equivalent.
Note: Includes fossil fuel emissions only. 1 exajoule = 277,777,778 megawatt-hours.
Source: ADB Study Team.

2. Philippines' 2020 Emission Reduction Goals

The interpreted goal (based on energy sector targets) for the Philippines is 5.7% reduction of CO_2 emissions in 2030 compared with 2010 levels. This amounts to an ambitious emission reduction of roughly 30% in 2020 compared with the BAU level (Figure A2.30), which is the most stringent among the DA5 countries' objectives for 2020. In the Philippines, BAU deforestation is not substantial, which results in carbon and energy intensity being the same across the full, higher-cost, and no-REDD cases. To meet the stated goal, carbon and energy intensity are expected to decline after 2010 and to achieve in 2020 levels that are 34% and 31% lower than BAU, respectively. Total energy consumption declines by 30% in 2020 compared with BAU (Figure A2.32). The energy consumption mix reflects a larger share of oil and a crowding out of coal. Gas and hydropower shares of energy consumption remain unaffected.

Renewable energy production from wind and solar doubles from the 2020 BAU. However, this remains small in absolute terms, as the BAU value is tiny. The hydropower sector slightly declines in production compared with BAU because of reduced power demand from energy-intensive sectors, although this decline is much smaller than for fossil fuels.

3. Philippines' Long-Term Stabilization Scenarios

(i) Emission reduction pathways

Figure A2.30 represents the stringency of the different stabilization targets for the Philippines. The 500 ppm scenario leads to an emission reduction of 50%, while the 650 ppm scenario leads to a reduction of 20%. The fragmented scenario turns out to be more stringent than the 650 ppm scenario, as the extrapolated domestic commitments are greater than those triggered by global carbon prices, even with the Philippines as a net seller of permits.

(ii) Mechanisms of emission reduction

Both the 500 ppm and 650 ppm decarbonization scenarios imply large carbon and energy intensity declines (Figure A2.31) of 55% and 43%, respectively by 2050, with little sensitivity to different assumptions about REDD. Similarly, energy consumption falls by 45% and 21% compared with BAU levels in 2050 in the 500 and 650 stabilizations, respectively (Figure A2.32). Oil is the dominant energy source in all scenarios. In the Philippines, this tendency is particularly extreme and in 2050, energy consumption is expected to be dominated by oil with a significant share of solar and wind (7.4%), a 3.4% share of hydropower and a negligible amount of coal. Gas is phased out. The fragmented scenario implies a 31% and 27% reduction in carbon and energy intensity, respectively, over BAU levels in 2050, and a 30% reduction in total energy consumption. In the absence of REDD, coal and gas energy use declines, and solar and hydropower are increased (Figure A2.33).

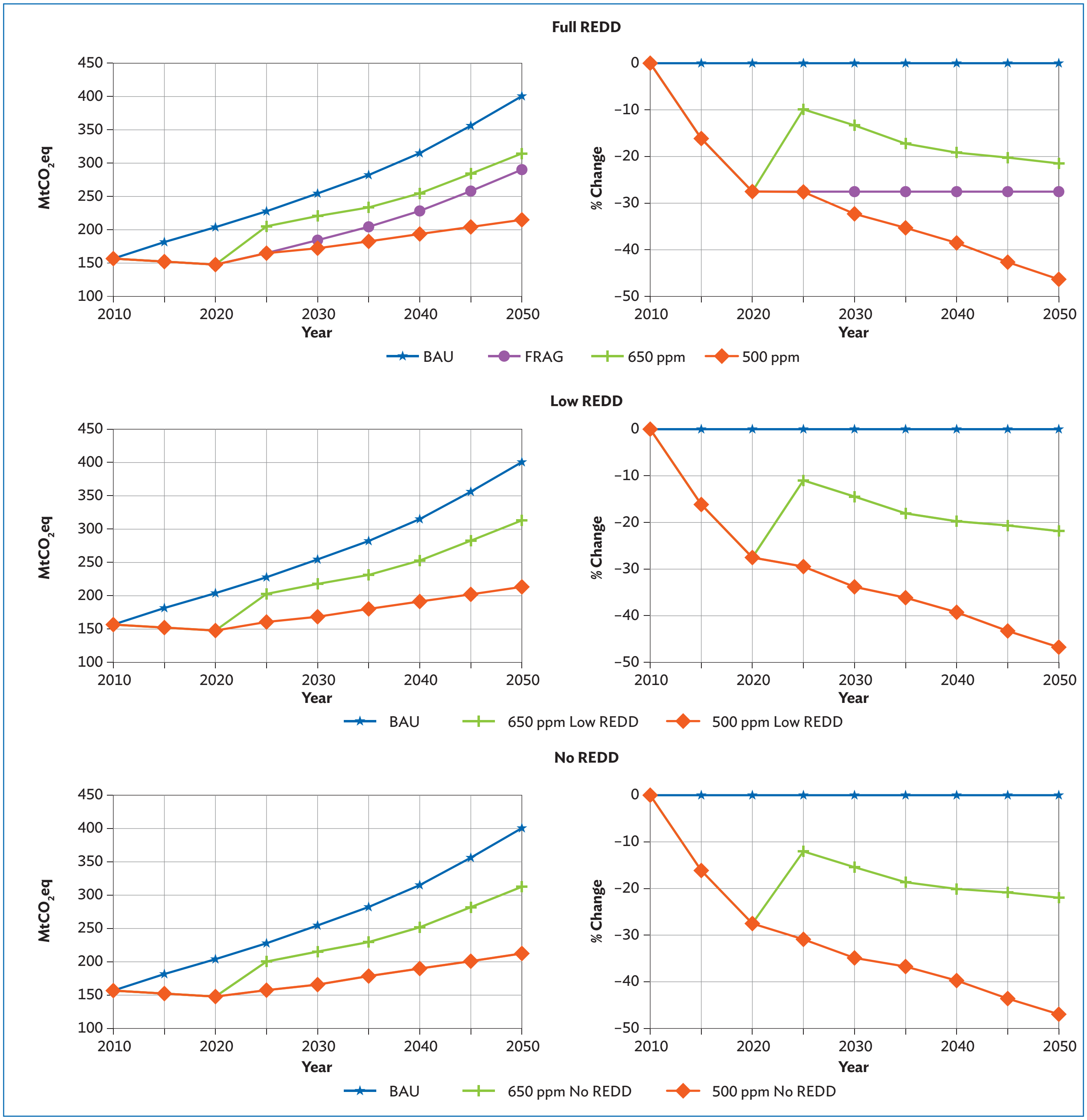
(iii) Economic contributions of carbon trade

With higher carbon prices in the 500 ppm than in the 650 ppm stabilization scenario, total revenues from exports of carbon permits are also higher in the former, with $140 billion in the full REDD case in 2050 (Figure A2.34). If REDD credits are not allowed to enter the global carbon market, increased carbon prices will raise carbon permit export values to $160 billion in 2050. Under 650 ppm stabilization, 2050 permit sales are approximately $110 billion.

(iv) Co-benefits

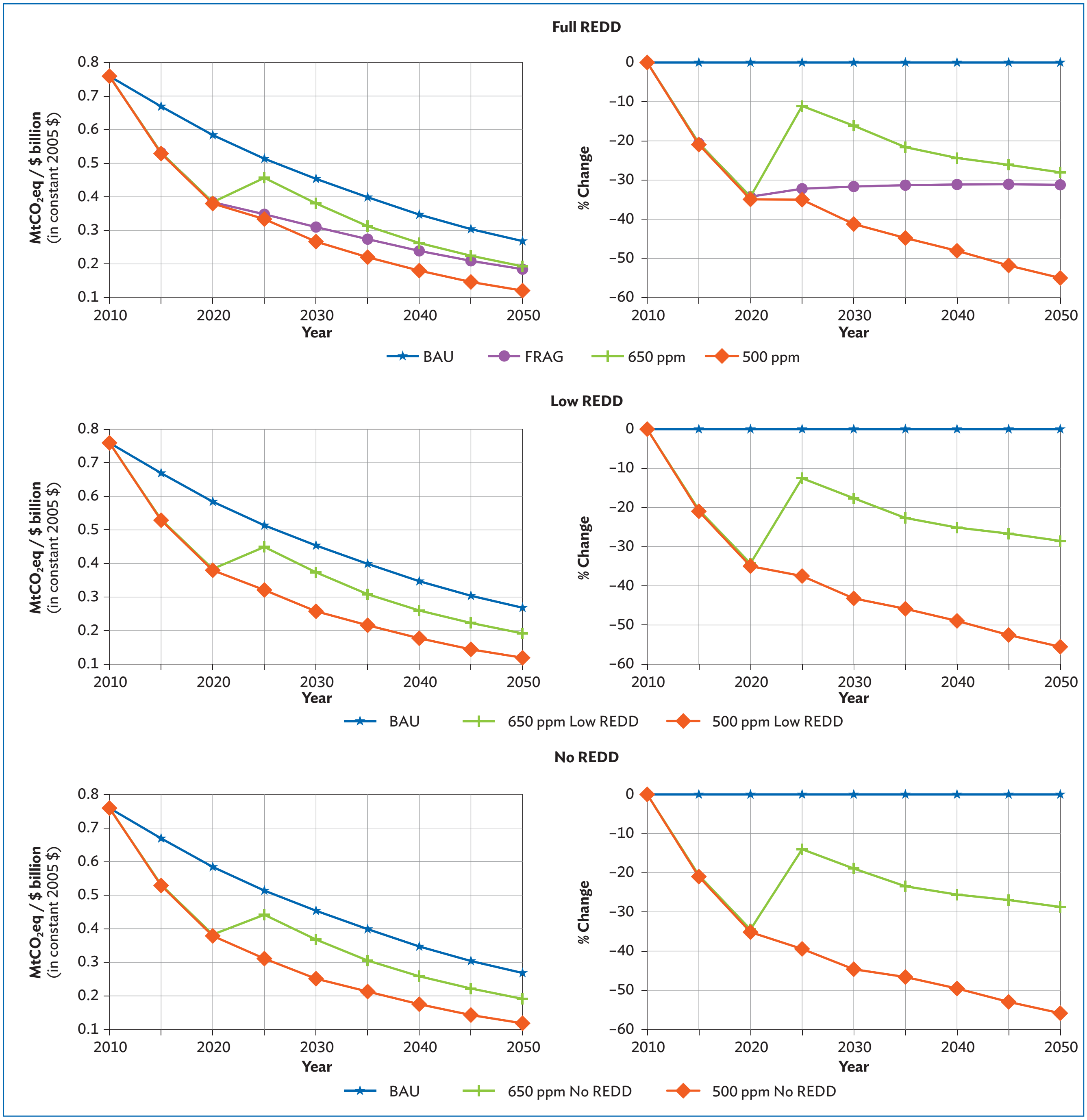
Co-benefits increase at an increasing rate over the analyzed period under 500 ppm stabilization with REDD, where co-benefits reach $10 billion annually by 2050. The largest share of co-benefits arises from reduced transportation congestion. Under 650 ppm stabilization, however, co-benefits are negative as revenues from the international carbon market lead to increased consumption and use of transportation (Figure A2.35).

Figure A2.30: Philippines—Greenhouse Gas Emission Projections in Quantity and Percent Change over Business as Usual



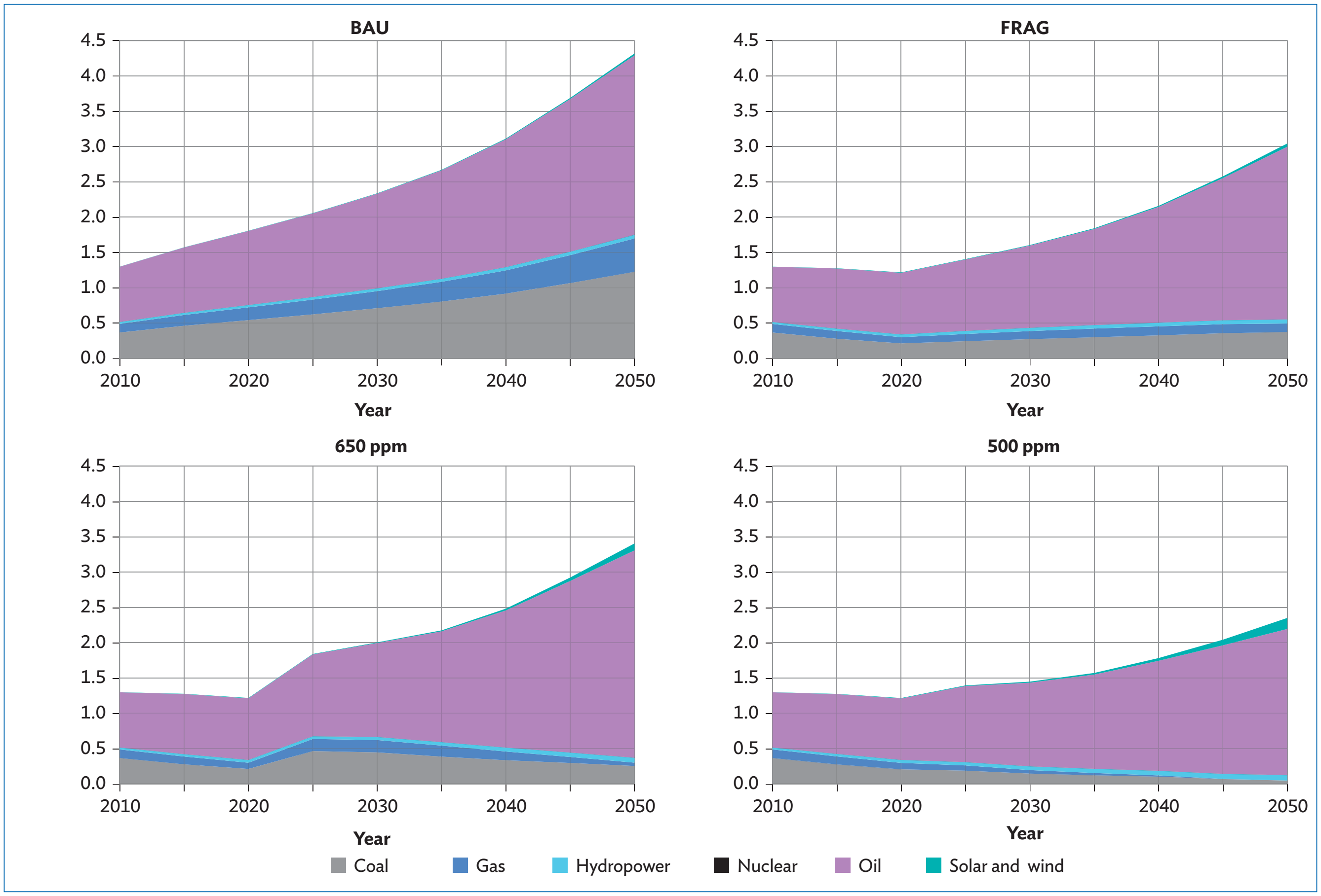
BAU = business as usual, FRAG = fragmented (policy), $MtCO_2eq$ = million tons of carbon dioxide equivalent, ppm = parts per million, REDD = reducing emissions from deforestation and forest degradation.
Note: All percent changes are with respect to BAU.
Source: ADB Study Team.

Figure A2.31: Philippines—Carbon Intensity of Gross Domestic Product Changes from Business as Usual



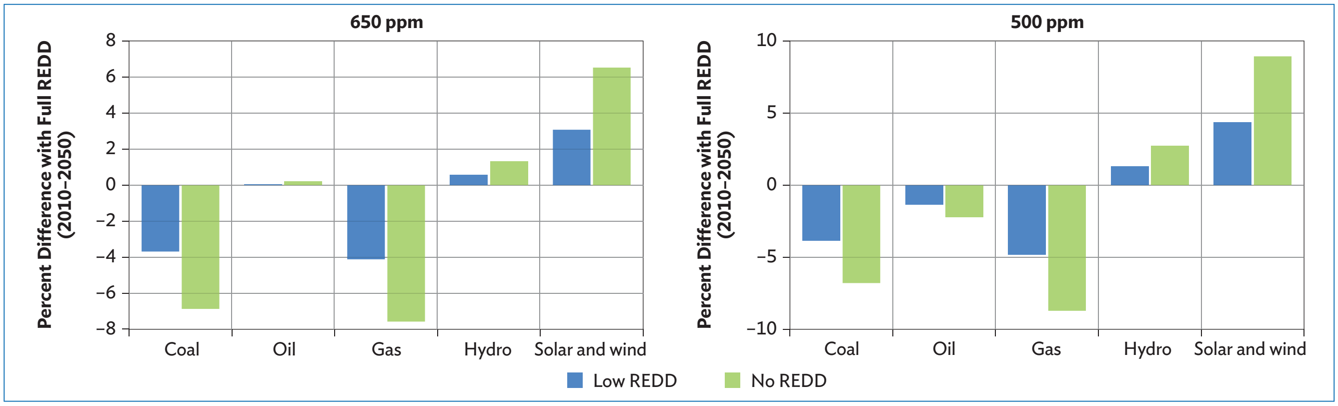
BAU = business as usual, $MtCO_2eq$ = million tons of carbon dioxide equivalent, ppm = parts per million, REDD = reducing emissions from deforestation and forest degradation.
Note: All percent changes are with respect to BAU.
Source: ADB Study Team.

Figure A2.32: Philippines—Total Primary Energy Consumption (exajoule)



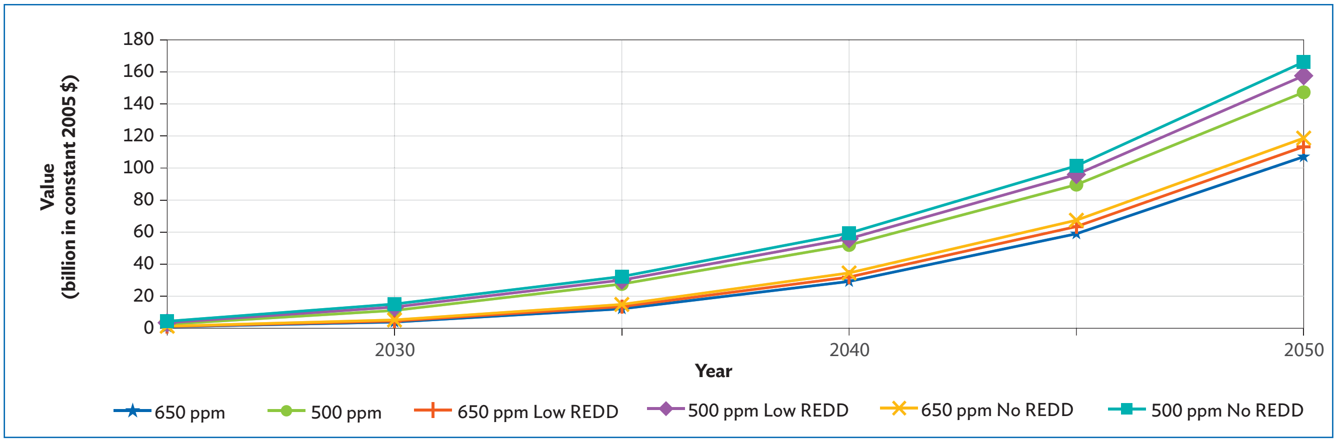
BAU = business as usual, FRAG = fragmented (policy), ppm = parts per million.
Source: ADB Study Team.

Figure A2.33: Philippines—Total Primary Energy Consumption Change from REDD, 2010–2050



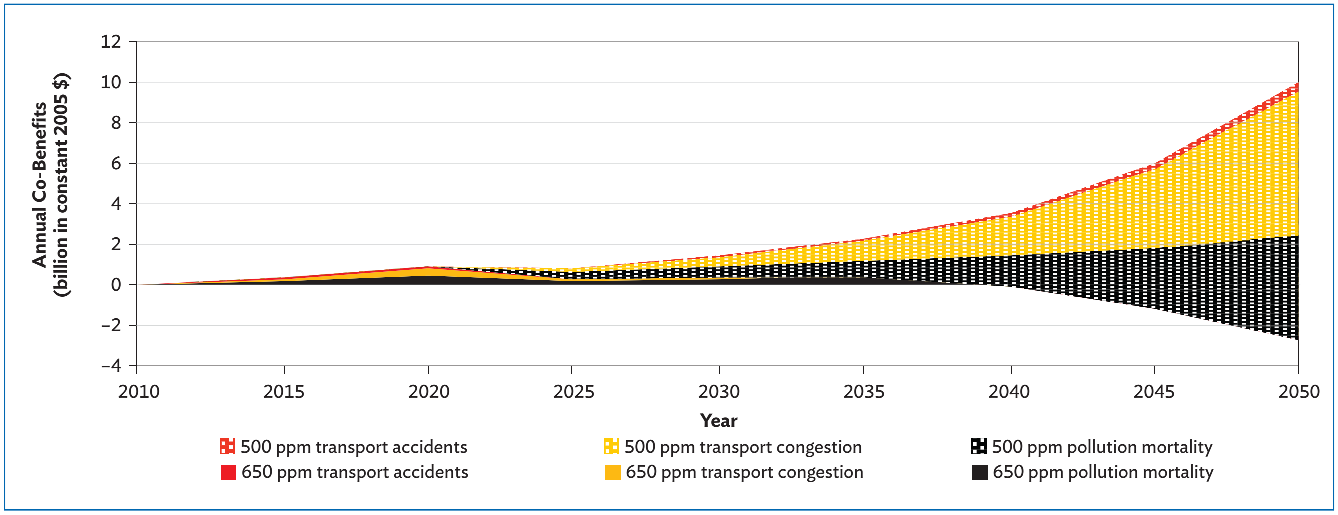
ppm = parts per million, REDD = reducing emissions from deforestation and forest degradation.
Source: ADB Study Team.

Figure A2.34: Philippines—Projections of Carbon Permit Trade



ppm = parts per million, REDD = reducing emissions from deforestation and forest degradation.
Note: > 0 selling, < 0 buying.
Source: ADB Study Team.

Figure A2.35: Philippines—Co-Benefits under Scenarios with Full REDD



ppm = parts per million, REDD = reducing emissions from deforestation and forest degradation.
Source: ADB Study Team.

D. Thailand

1. Business-as-Usual Results

In 2010, Thailand ranked second among the DA5 in terms of both GDP and GDP per capita. Its economic structure is dominated by industry and services, with almost equal contributions to total value added at 43% and 45%, respectively. Agriculture accounted for 12% of GDP (Figure A2.36). GHG emissions levels are similar to Malaysia, with a value of about 360 $MtCO_2eq$. The largest source of emissions is electricity generation from fossil sources, followed by transportation and industrial processes. The agriculture sector, primarily through rice cultivation, was also an important source of emissions.

In 2010, actual primary energy consumption was dominated by oil (34%), gas (32%), biomass (19%), and coal (14%) (IEA, 2012b). In ICES, which omits biomass, the national energy consumption mix was dominated by oil at 43% and gas at 39%, with coal making up the balance (Figure A2.37).

Thailand's GDP modeling, in accordance with assumptions[5] reflects uniform average yearly growth rates, ranging from 4.1% to 4.6% (Table A2.4). By 2050, national GDP is modeled to reach $1.2 trillion, a 6-fold increase from 2010 (Figure A2.36). Heavy industries are found to grow in relative importance in value added, compared with agriculture and services, with agriculture's share reduced from 12% in 2010 to 7.7% in 2050, and the latter's share from 45% to 38.4%. The model finds a primary energy consumption of almost 10 exajoules in 2050, which is more than twice the 2010 levels (Figure A2.37).

Table A2.4: Thailand—Business-as-Usual Annualized Growth Rate and Population

	Annual GDP Growth (%)	
	ICES-Simulations	Projections
2011–2020	4.1	4.2
2021–2030	4.4	4.2
2031–2040	4.5	4.3
2041–2050	4.6	4.2

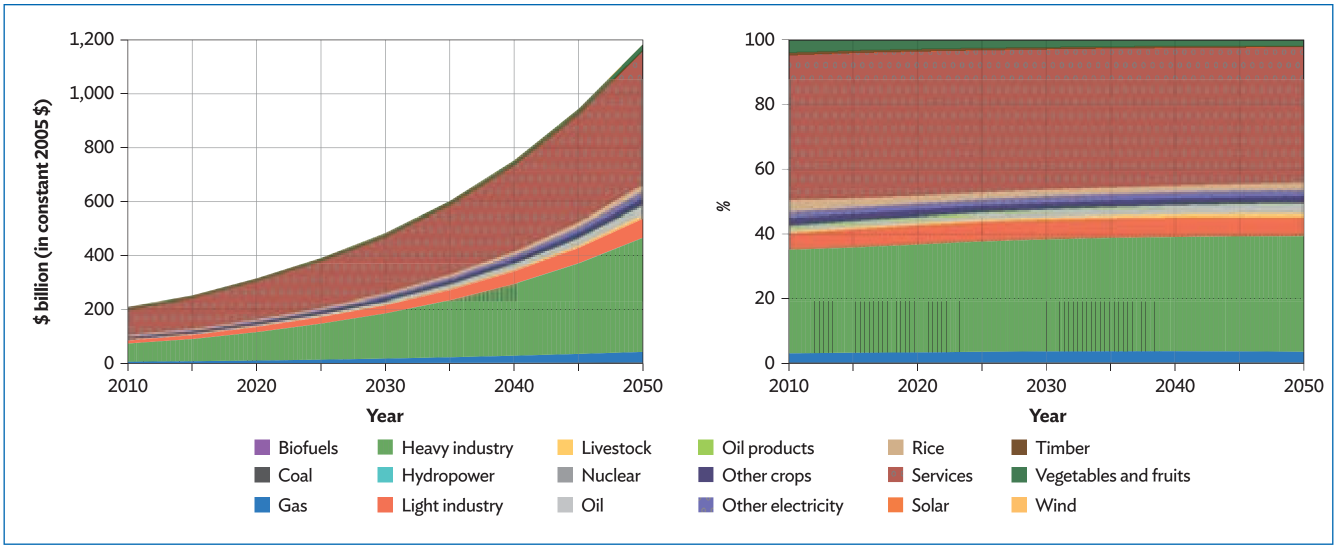
	Population (million)
2010	69.1
2020	72.1
2030	73.3
2040	73.0
2050	71.0

GDP = gross domestic product, ICES = Intertemporal Computable Equilibrium System.
Note: Projections refer to ADB (2011b) data, integrated with information from local experts.
Source: ADB Study Team.

In the absence of climate-related policies, all of Thailand's primary energy requirements are modeled to come from fossil sources, even if the share from natural gas increases after 2020. GHG emissions are found to have a twofold increase from 2010 to 2050 (Figure A2.38 and Figure A2.39). However, this is lower than the modeled relative increase in GDP. Both the fossil fuel carbon intensity and energy intensity of Thailand's GDP are found to decline by 60% through 2050 (Figure A2.40).

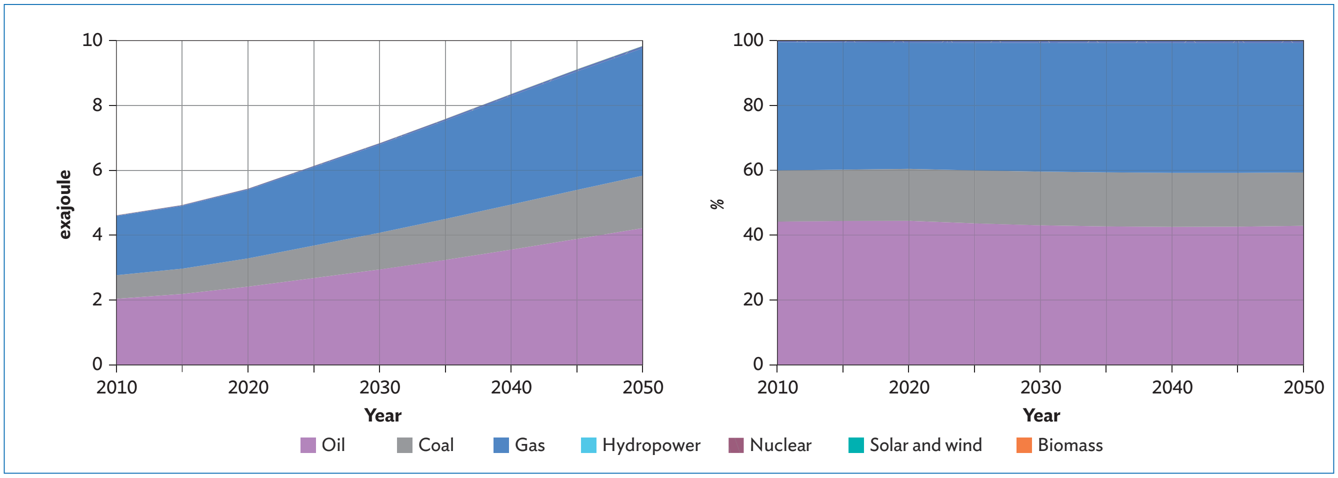
5 Note that these are not authoritative or official ADB projections. This is simply description of ICES' behavior, as calibrated to ADB (2011b).

Figure A2.36: Thailand—Business-as-Usual Gross Domestic Product and Sectoral Composition



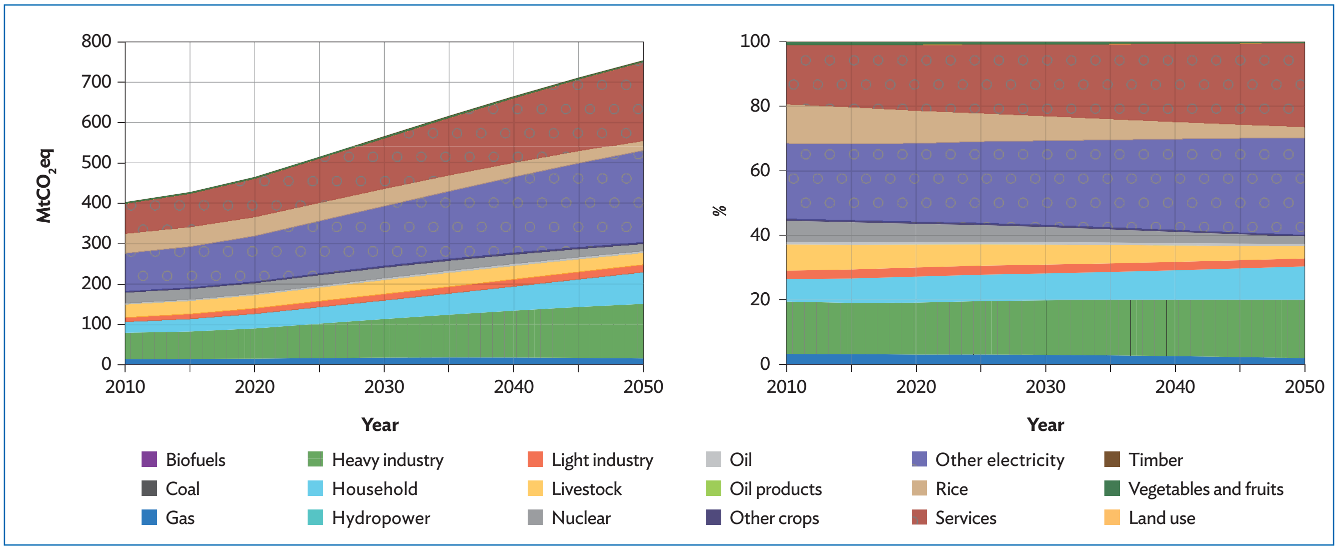
Source: ADB Study Team. .

Figure A2.37: Thailand— Business-as-Usual Primary Energy Consumption by Source and Share by Source



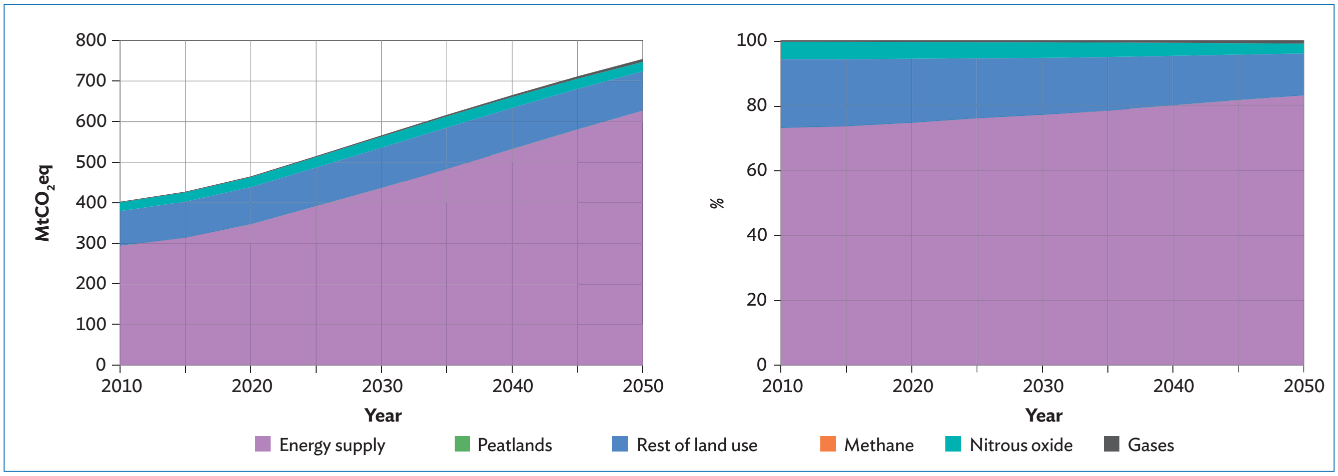
Note: 1 exajoule = 277,777,778 megawatt-hours.
Source: ADB Study Team. .

Figure A2.38: Thailand—Business-as-Usual Greenhouse Gas Emissions by Source and Share by Source



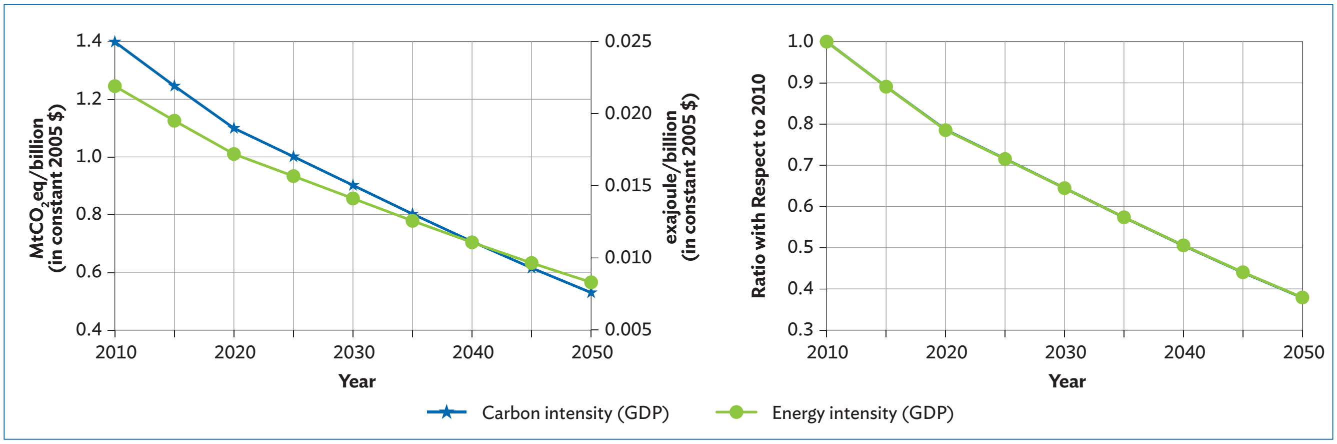
$MtCO_2eq$ = million tons of carbon dioxide equivalent.
Note: Other electricity is electricity produced using fossil fuel sources (e.g., coal, oil, or gas).
Source: ADB Study Team.

Figure A2.39: Thailand—Business-as-Usual Greenhouse Gas Emissions by Gas and Shares by Gas



$MtCO_2eq$ = million tons of carbon dioxide equivalent.
Source: ADB Study Team.

Figure A2.40: Thailand—Business-as-Usual Fossil Fuel Carbon and Energy Intensity Levels and Index (2010 = 1)



GDP = gross domestic product, GHG = greenhouse gas, $MtCO_2eq$ = million tons of carbon dioxide equivalent.
Note: Includes fossil fuel emissions only. 1 exajoule = 277,777,778 megawatt-hours.
Source: ADB Study Team.

2. Thailand's 2020 Emission Reduction Goals

Thailand's policy goal consists of a reduction in energy intensity of GDP from 2005 levels by 8% by 2015 and 25% by 2030. These goals are similar to how Thailand is already performing under BAU, according to ICES. Therefore, carbon and energy intensities do not diverge significantly from BAU levels and the energy mix is unchanged. This implies very little additional action to meet the policy goal set by the government.

3. Thailand's Long-Term Stabilization Scenarios

(i) Emission reduction pathways

Figure A2.41 shows the level of emission reduction achieved according to the intersection of Thailand's abatement costs and global carbon prices. The 500 ppm scenario leads to emission reduction of 60%–63%, depending on the presence of REDD credits in the carbon market by 2050. The 650 ppm scenario leads to emission reduction of 31%–33%. In the fragmented scenario, Thailand will continue to benefit from its nonstringent target with negative costs that reach 5% with respect to BAU in 2050.

However, both the 500 ppm and 650 ppm decarbonization scenarios imply large carbon and energy intensity declines (Figure A2.42) of roughly 60% and 30%, respectively, by 2050, with little sensitivity to different assumptions about REDD. This implies significant cuts in energy consumption of 60% and 30% compared with BAU levels in 2050 in the 500 and 650 stabilizations, respectively.

(ii) Mechanisms of emission reduction

In terms of primary energy, oil is the fossil fuel that is least sensitive to emissions policies. All energy sources decline in quantity (Figure A2.43) but the share of oil increases to constitute almost 70% of energy consumption in the 500 ppm scenario and 62% in the 650 ppm scenario. Coal is reduced to 5% and hydropower to 3.8% in the energy mix. The fragmented scenario is much less ambitious. The changes in 2050 compared with BAU levels include only a 3.5% reduction of carbon and energy intensity with no reduction in total energy consumption compared with BAU levels. In the climate stabilization scenarios, solar and wind energy increase but remain with very small shares of the mix. In contrast, hydropower consumption increases substantially by 170% in the 650 ppm stabilization and 200% in the 500 ppm stabilization. In the absence of REDD, coal and gas energy use declines (Figure A2.44).

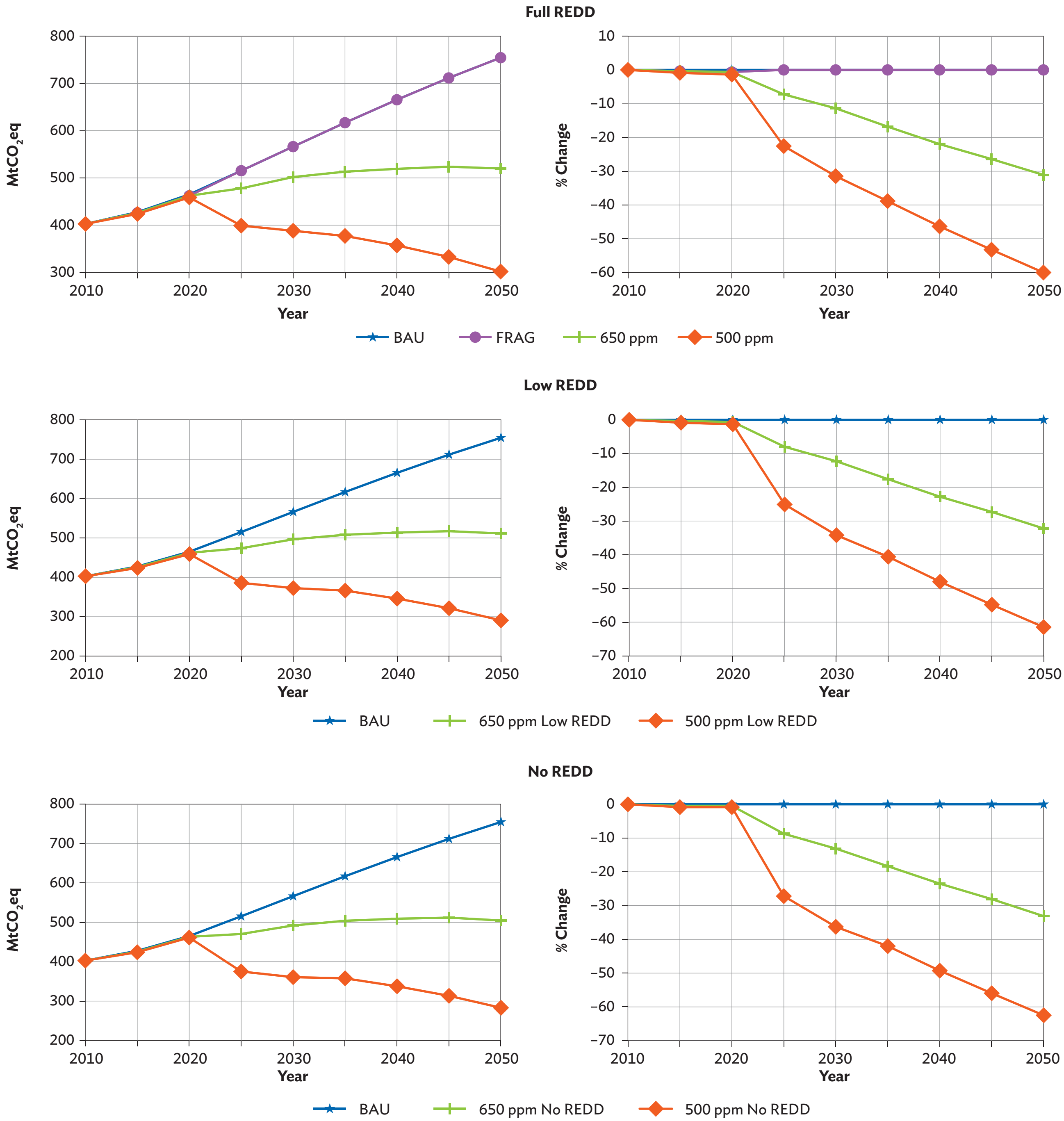
(iii) Economic contributions of carbon trade

Thailand remains a net buyer of permits throughout the period. The country would buy more than $28 billion of permits in 2050 under 650 ppm and $33 billion under 500 ppm by 2050. In quantity, this implies 138 and 67 MtCO_2eq in 650 ppm and 500 ppm, respectively (Figure A2.45).

(iv) Co-benefits

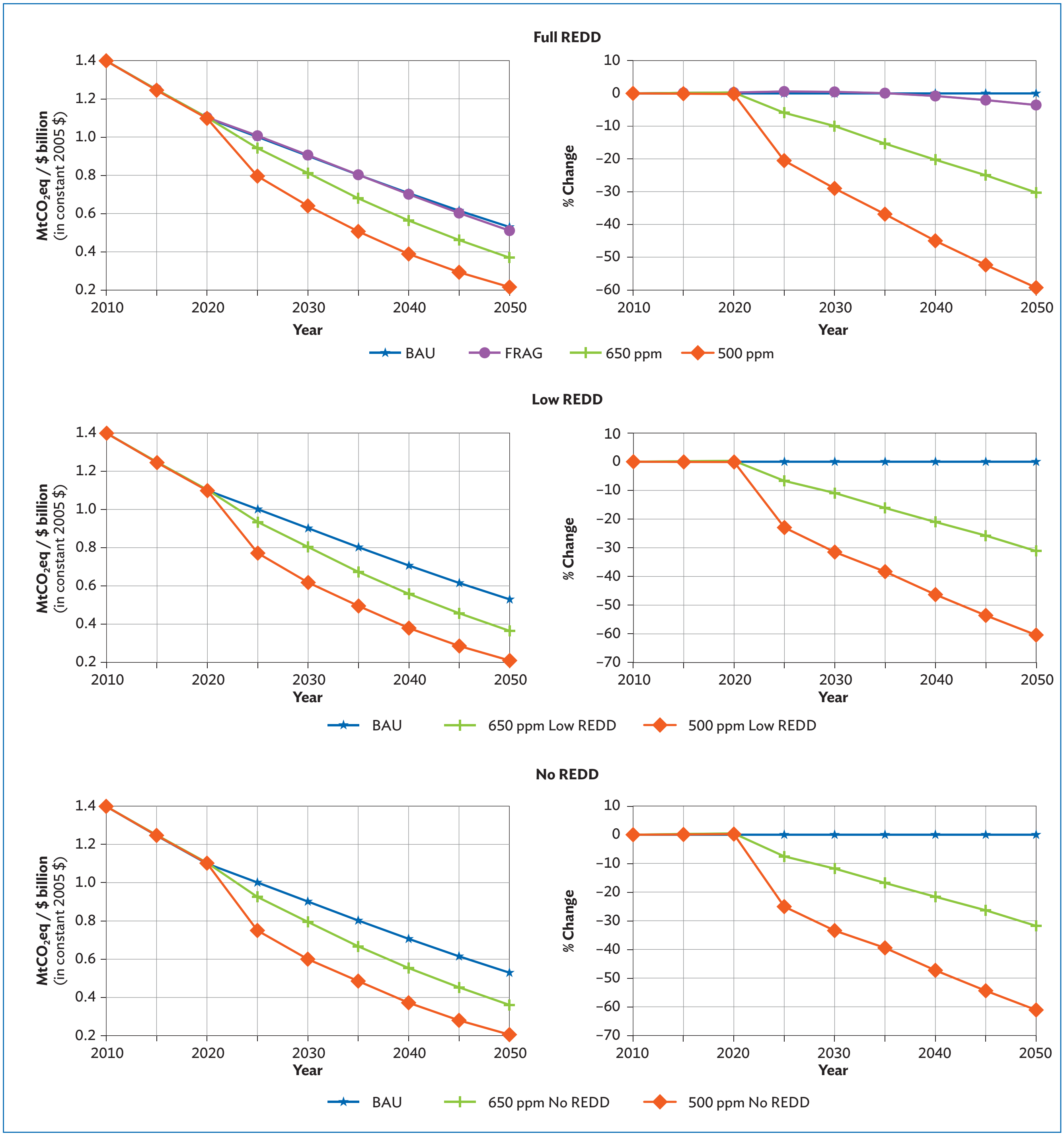
Co-benefits increase at an increasing rate over the analyzed period. Under 500 ppm stabilization with REDD, co-benefits reach $22 billion annually by 2050. The largest share of co-benefits arises from reduced pollution-related mortality, followed by reduced transportation congestion. Lest than a third of total co-benefits under 500 ppm stabilization are achieved under 650 ppm stabilization (Figure A2.46).

Figure A2.41: Thailand—Greenhouse Gas Emission Projections in Quantity and Percent Change over Business as Usual



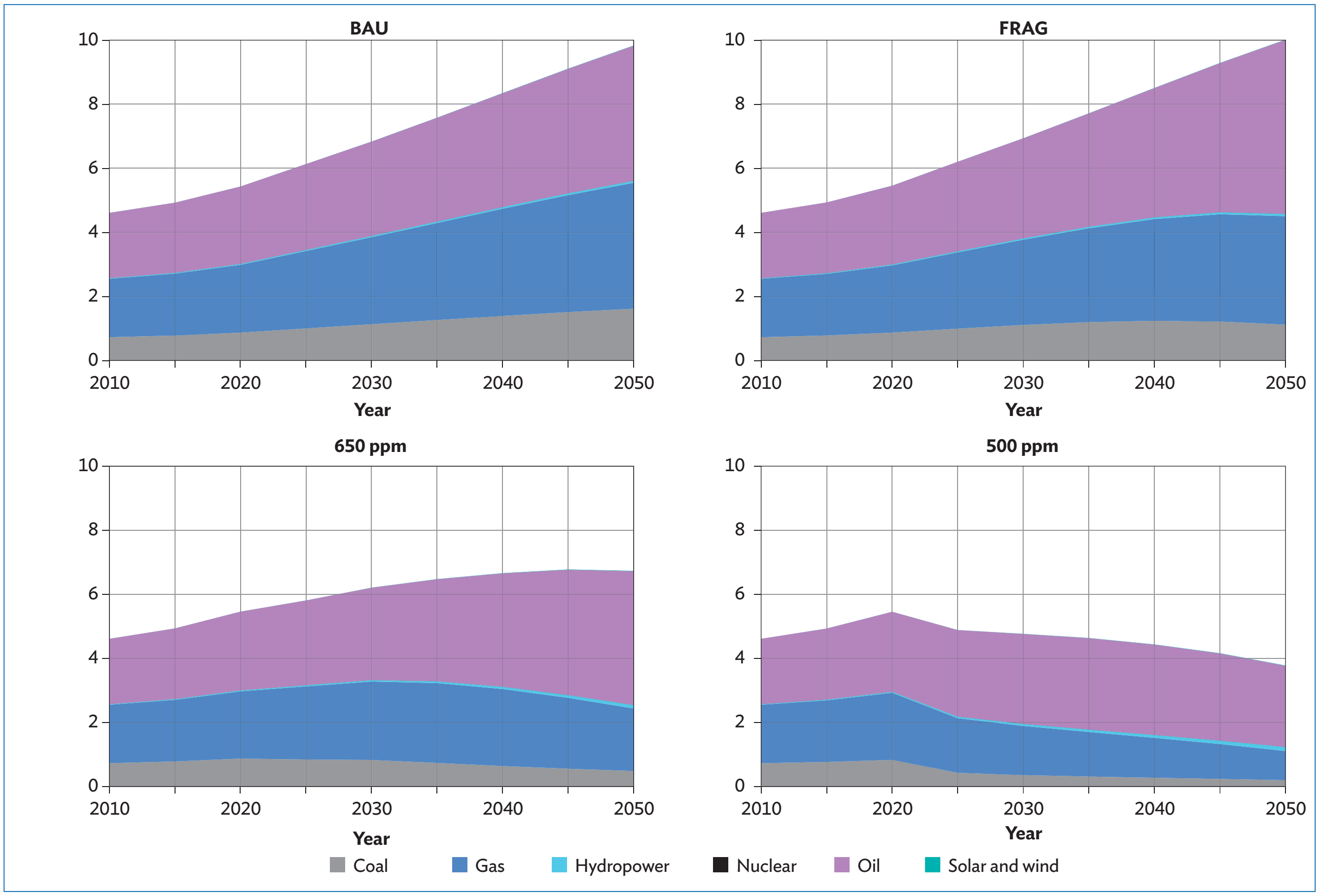
BAU = business as usual, FRAG = fragmented (policy), $MtCO_2eq$ = million tons of carbon dioxide equivalent, ppm = parts per million, REDD = reducing emissions from deforestation and forest degradation.
Note: All percent changes are with respect to BAU.
Source: ADB Study Team.

Figure A2.42: Thailand—Carbon Intensity of Gross Domestic Product Changes from Business as Usual



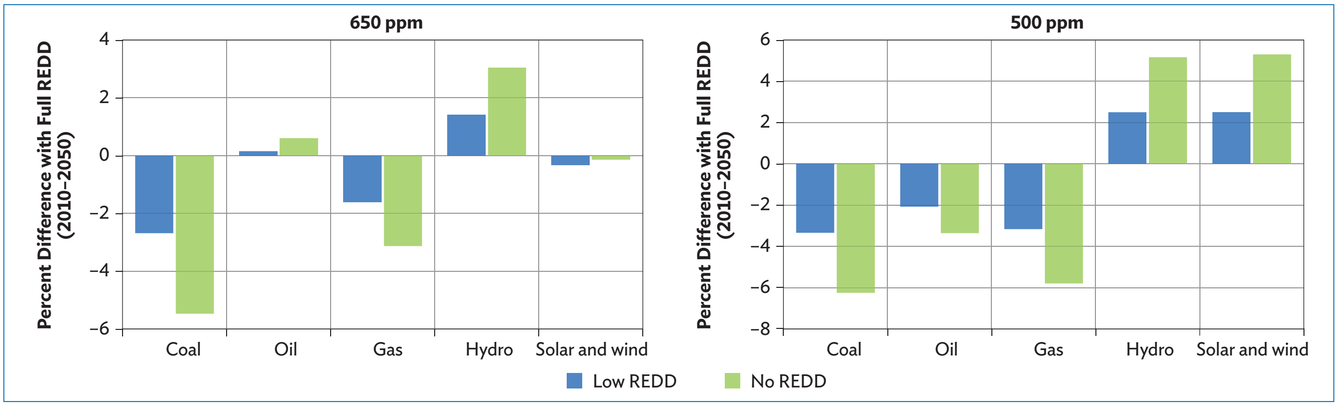
BAU = business as usual, $MtCO_2eq$ = million tons of carbon dioxide equivalent, REDD = reducing emissions from deforestation and forest degradation.
Note: All percent changes are with respect to BAU.
Source: ADB Study Team.

Figure A2.43: Thailand—Total Primary Energy Consumption (exajoule)



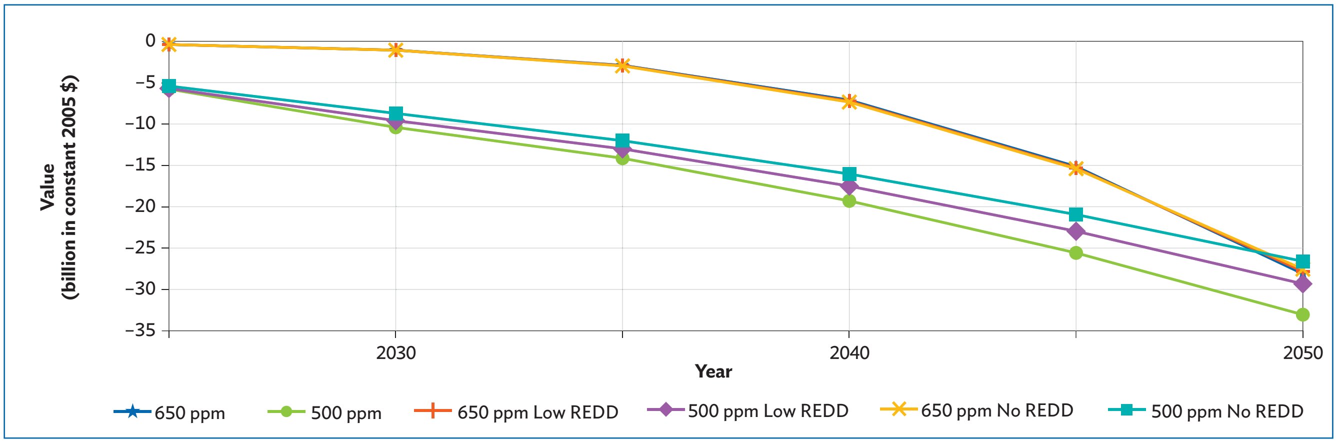
BAU = business as usual, FRAG = fragmented (policy), ppm = parts per million.
Source: ADB Study Team.

Figure A2.44: Thailand—Total Primary Energy Consumption Change from REDD, 2010–2050



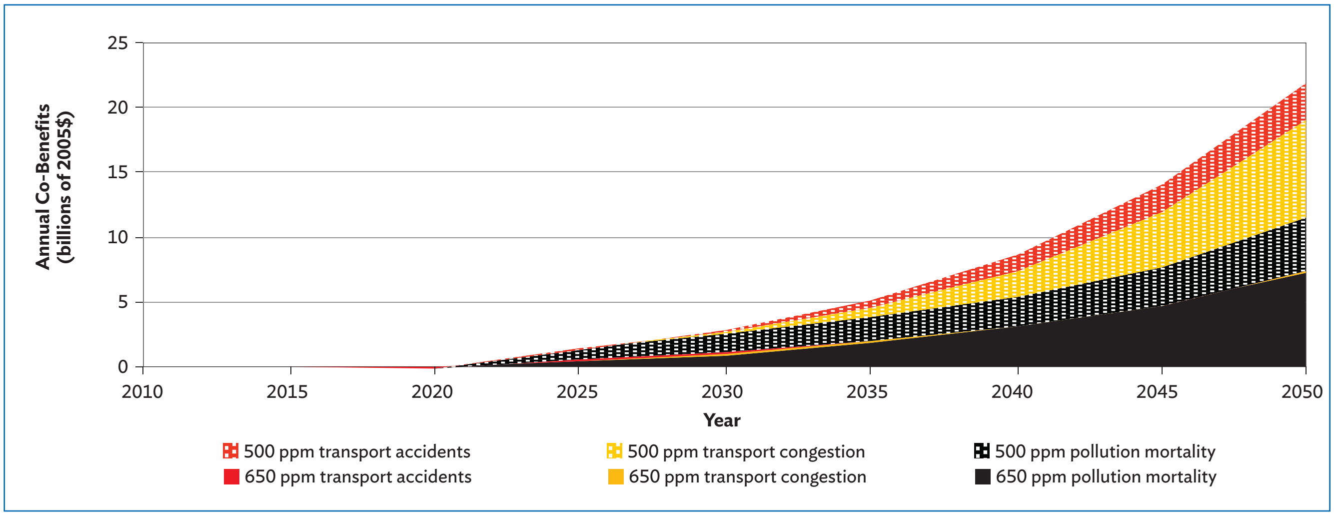
ppm = parts per million, REDD = reducing emissions from deforestation and forest degradation.
Source: ADB Study Team.

Figure A2.45: Thailand—Projections of Carbon Permit Trade



ppm = parts per million, REDD = reducing emissions from deforestation and forest degradation.
Note: > 0 selling, < 0 buying.
Source: ADB Study Team.

Figure A2.46. Thailand—Co-Benefits under Scenarios with Full REDD



ppm = parts per million, REDD = reducing emissions from deforestation and forest degradation.
Source: ADB Study Team.

E. Viet Nam

1. Business-as-Usual Results

In 2010, Viet Nam had a GDP of $70 billion (constant 2005 $),[6] which is the lowest among the DA5, and a population of 87 million, the third highest among them. Industry and services account for the bulk of total value added, while agriculture at 21% represents the highest agriculture share among the DA5.

IEA (2012b) reports that in 2010, actual primary energy consumption was dominated by oil (31%), coal (25%), biomass (25%), gas (14%), and hydropower (4%). In ICES, as biomass is not included, total energy consumption amounted to 1.7 exajoule, of which 95% was provided by fossil sources, principally oil, and the remaining 5% by hydropower (Figure A2.48).

The country's GHG emissions in 2010 were driven mainly by rice production, heavy industry, electricity generation from fossil sources, and transportation services (Figure A2.49). The carbon intensity and energy intensity of Viet Nam's GDP were the highest across the DA5, and its emissions per capita (excluding those from land use) placed Viet Nam fourth in the group. Total GHG emissions in 2010 were about 240 $MtCO_2eq$.

Viet Nam is modeled[7] to be the second fastest growing economy among the DA5 (Table A2.5). Its GDP in 2050 is modeled as reaching $1 trillion, or 14 times more than in 2010 (Figure A2.47). Economic growth is found to be driven mainly by the development of the service sector and industry sector. The agriculture sector is found to contribute a declining share of national value added, shrinking from 21% in 2010 to 10% in 2050.

As a fast-growing economy, Viet Nam is found to experience a sharp increase in energy consumption in the absence of climate-related policies (Figure A2.48). As with the rest of the DA5, Viet Nam's energy requirements are found to be mostly provided by fossil sources—oil, coal, and gas—although hydropower grows to 0.41 exajoule in 2050. Overall GHG emissions are found to increase by 311% during the period (Figure A2.49). Emissions from agriculture decline in relative importance until 2050, at which time they account for 6.8% of the total. Emission shares of transportation services, industrial processes, electricity generation, and household demand increase in the model (Figure A2.50). Even so, the emission growth rates in Viet Nam turn out to be lower than the growth in GDP, such that the energy intensity and fossil fuel carbon intensity of GDP both decline by 60% by 2050 (Figure A2.51).

Table A2.5: Viet Nam—Business-as-Usual Annualized Growth Rate and Population

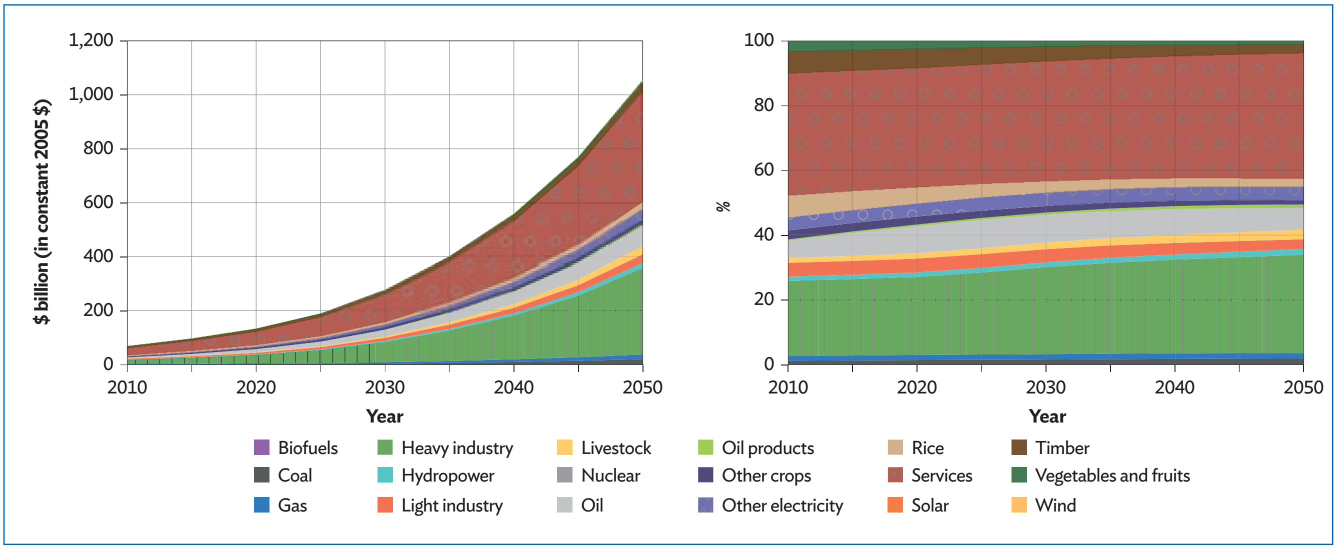
	Annual GDP Growth (%)	
	ICES-Simulations	Projections
2011–2020	6.8	6.7
2021–2030	7.6	7.7
2031–2040	7.2	7.1
2041–2050	6.5	6.6

	Population (million)
2010	87.8
2020	97.2
2030	104.2
2040	108.1
2050	110.0

GDP = gross domestic product, ICES = Intertemporal Computable Equilibrium System.
Note: Projections refer to ADB (2011b) data, integrated with information from local experts.
Source: ADB Study Team.

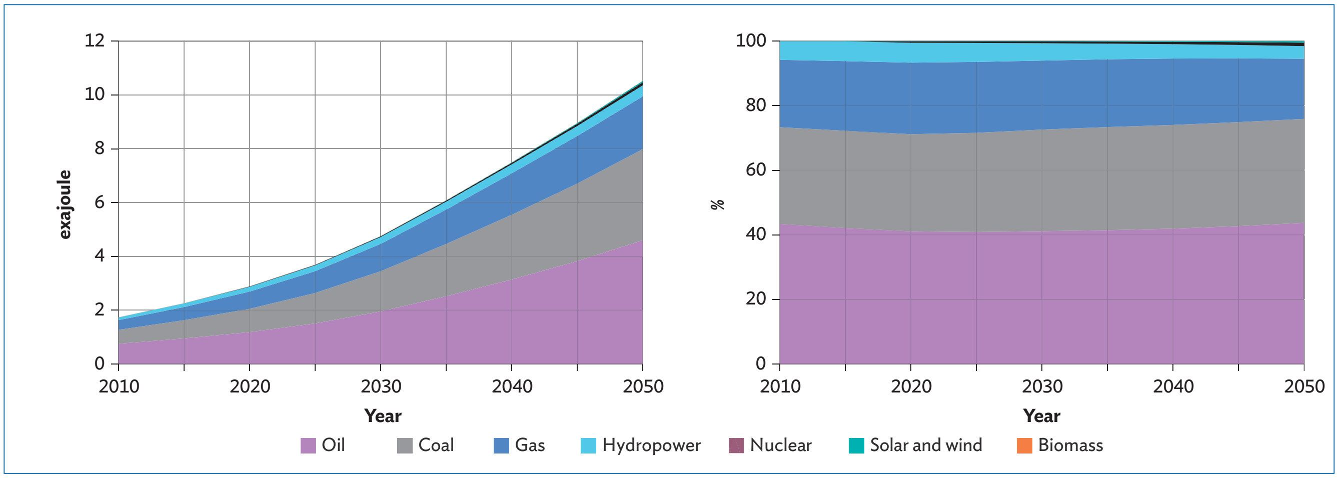
6 According to World Bank 2012 (May revision), this corresponded to $106 billion current 2010 $.
7 Note that these are not authoritative or official ADB projections. This is simply description of ICES' behavior, as calibrated to ADB (2011b).

Figure A2.47: Viet Nam—Business-as-Usual Gross Domestic Product and Sectoral Composition



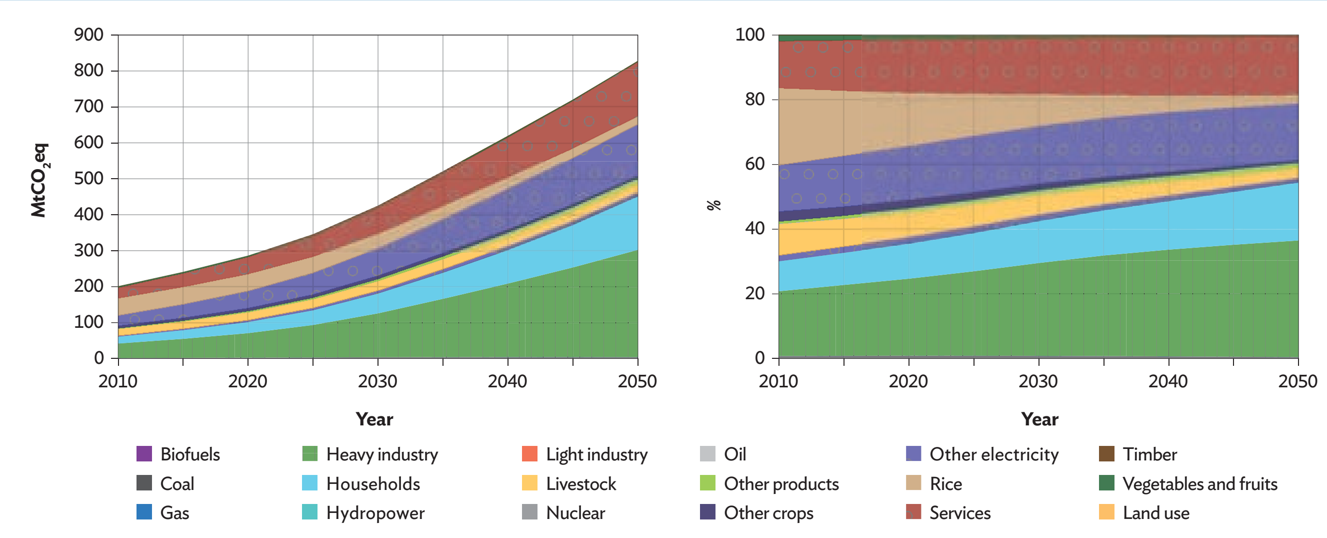
Source: ADB Study Team.

Figure A2.48: Viet Nam—Business-as-Usual Primary Energy Consumption by Source and Share by Source



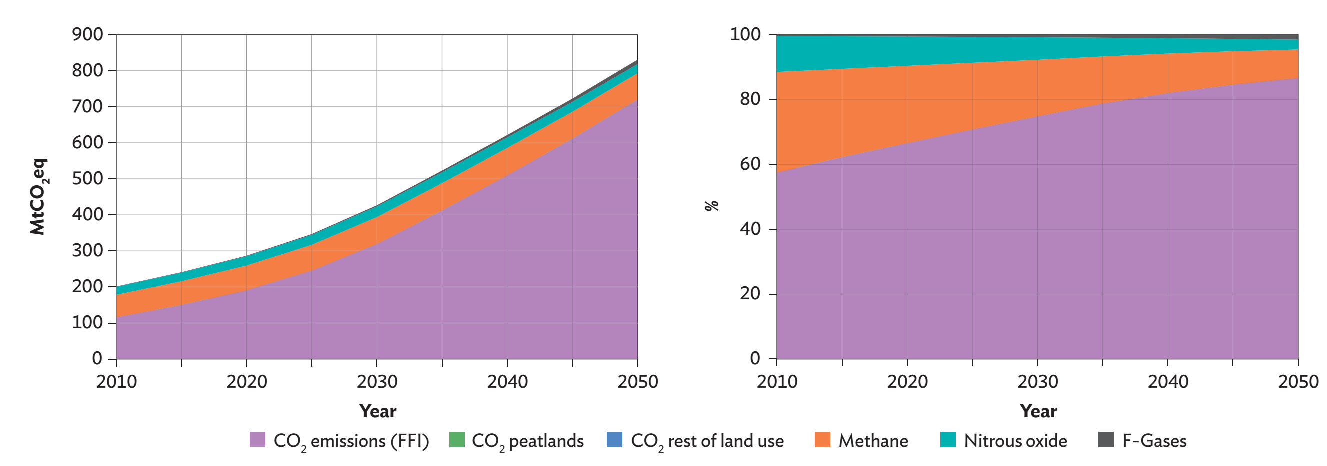
Note: 1 exajoule = 277,777,778 megawatt-hours.
Source: ADB Study Team.

Figure A2.49: Viet Nam—Business-as-Usual Greenhouse Gas Emissions by Source and Share by Source



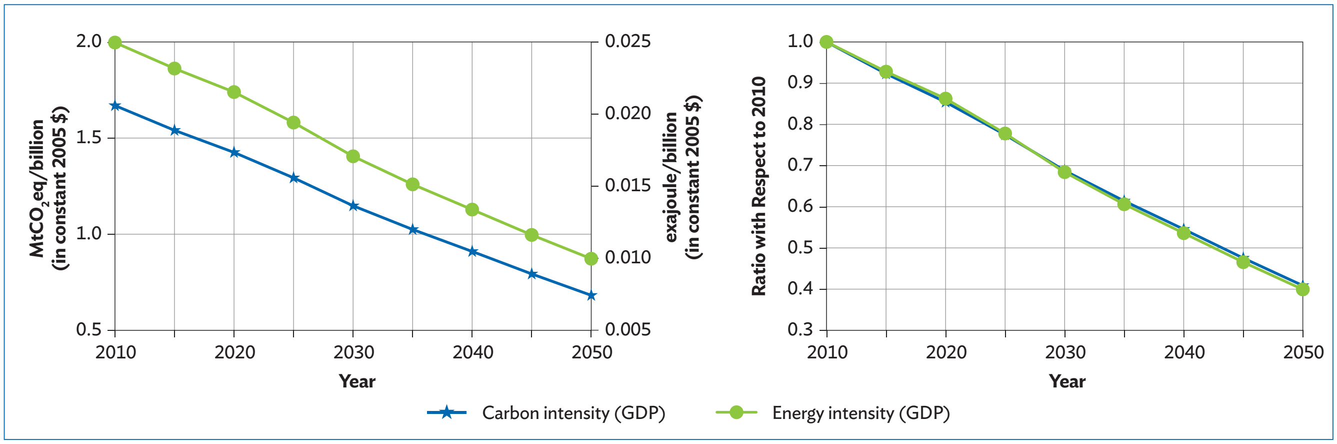
$MtCO_2eq$ = million tons of carbon dioxide equivalent.
Note: Other electricity is electricity produced using fossil fuel sources (i.e. coal, oil, or gas).
Source: ADB Study Team.

Figure A2.50: Viet Nam—Business-as-Usual Emissions by Gas and Shares by Gas



CO_2 = carbon dioxide, FFI = Flora and Fauna International, $MtCO_2eq$ = million tons of carbon dioxide equivalent.
Source: ADB Study Team.

Figure A2.51: Viet Nam—Business-as-Usual Fossil Fuel Carbon and Energy Intensity Levels and Index (2010 = 1)



GDP = gross domestic product, $MtCO_2eq$ = million tons of carbon dioxide equivalent.
Note: Includes fossil fuel emissions only. 1 exajoule = 277,777,778 megawatt-hours.
Source: ADB Study Team.

2. Viet Nam's 2020 Emission Reduction Goals

Viet Nam has planned several programs and policies to promote clean development and low-carbon growth. The 2012 National Green Growth Strategy (VGGS) aims to reduce energy emissions by 10% below BAU by 2020. Viet Nam also set a goal to reduce overall energy use by 5% to 8% by 2015, compared with 2006 in its National Energy Development Strategy.

To translate these national objectives into concrete policies, the analysis of Hoa et al. (2010) is followed. The interpreted level of ambition of the Viet Nam target, as presented in Figure A2.52, shows a reduction in emissions of 20% with respect to BAU in 2020. Primary energy consumption is reduced by 25%, with considerable contraction in coal use from 0.9 to 0.5 exajoules (a decline of 43%) (Figure A2.54).

3. Viet Nam's Long-Term Stabilization Scenarios

(i) Emission reduction pathways

Figure A2.52 shows the level of emission reduction achieved according to the intersection of Viet Nam's abatement costs and global carbon prices. By 2050, the 500 scenario leads to an emission reduction of 63%, while the 650 scenario leads to a 35% reduction. The fragmented scenario retains 2020 targets to 2050, keeping the reduction constant at 20% during the period. Both the 500 ppm and 650 ppm decarbonization scenarios imply large carbon and energy intensity declines (Figure A2.53), which are approximately 70% for the 500 ppm scenario and 40% for 650 ppm by 2050. These results are insensitive to different assumptions on REDD.

(ii) Mechanisms of emission reduction

Although all primary energy sources are reduced in quantity, the share of oil increases and is expected to constitute nearly 52% of energy consumption in the 500 ppm and 650 ppm scenarios by 2050 (Figure A2.54). The production of wind electricity increases by 65% in 2050 in the 500 full-REDD scenario compared with BAU. The fragmented scenario results in less restructuring of the energy mix in 2050, as coal declines from 32% to 17%, while oil increases from 41% to 52%. In the absence of REDD, coal and gas energy use declines, but effects on renewable energy are minor (Figure A2.55).

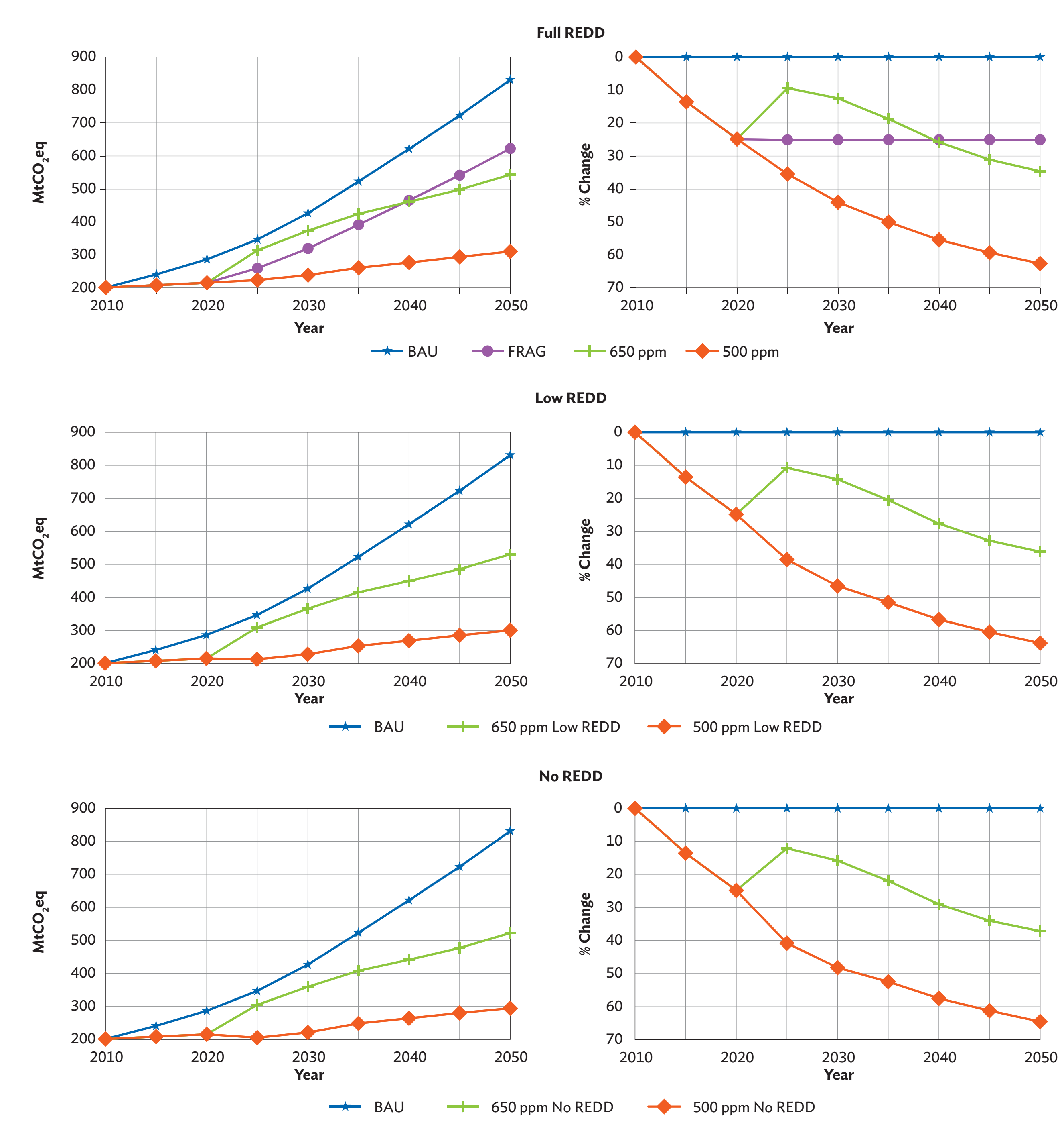
(iii) Economic contributions of carbon trade

Viet Nam is a net exporter of permits, initially with modest quantities, but then becoming an important seller (compared with the other DA5 countries). Traded values by 2050 range from $10 billion to $26 billion, implying 51 $MtCO_2eq$ and 53 $MtCO_2eq$ in 650 ppm full-REDD and 500 ppm no-REDD scenarios, respectively (Figure A2.56).

(iv) Co-benefits

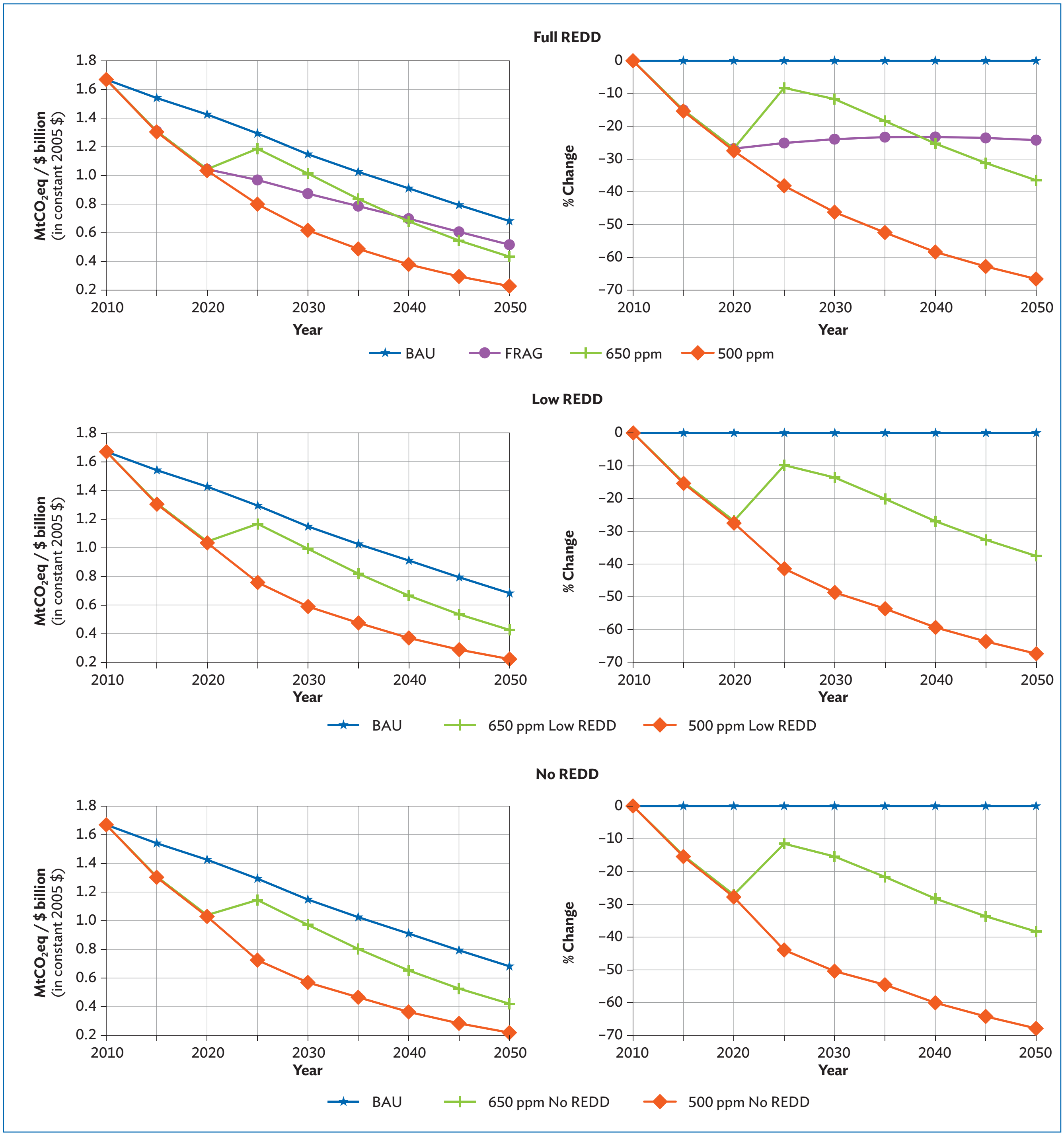
Co-benefits increase at an increasing rate over the analyzed period. Under 500 ppm stabilization with REDD, co-benefits reach $37 billion annually by 2050. The largest share of co-benefits arises from reduced transportation congestion. Less than a third of total co-benefits under 500 ppm stabilization are achieved under 650 ppm stabilization (Figure A2.57).

Figure A2.52: Viet Nam—Greenhouse Gas Emission Projections in Quantity and Percent Change over Business as Usual



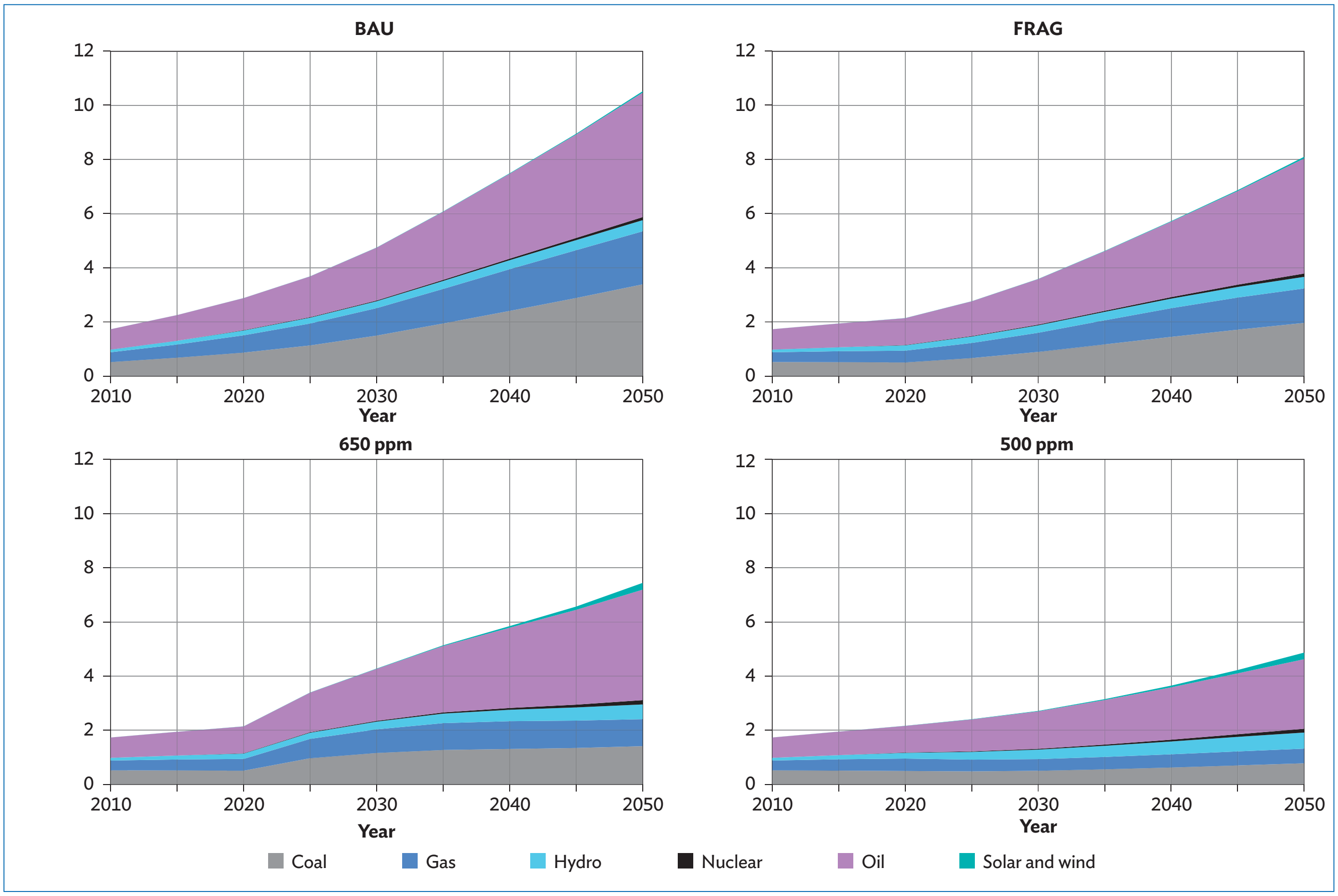
BAU = business as usual, FRAG = fragmented (policy), $MtCO_2eq$ = million tons of carbon dioxide equivalent, ppm = parts per million, REDD = reducing emissions from deforestation and forest degradation.
Note: All percent changes are with respect to BAU.
Source: ADB Study Team.

Figure A2.53: Viet Nam—Carbon Intensity Projections in Value and Change from Business as Usual



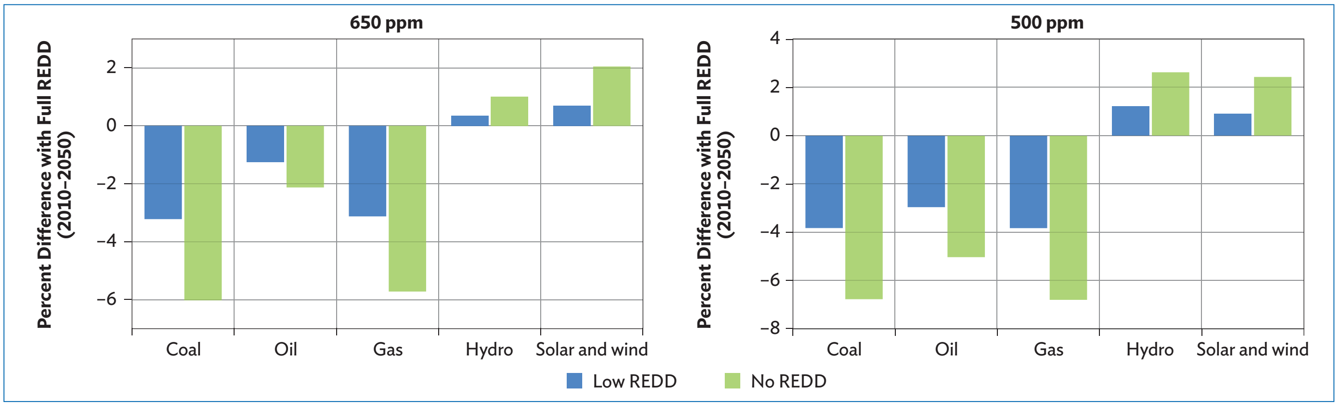
BAU = business as usual, FRAG = fragmented (policy), $MtCO_2eq$ = million tons of carbon dioxide equivalent, ppm = parts per million, REDD = reducing emissions from deforestation and forest degradation.
Note: All percent changes are with respect to BAU.
Source: ADB Study Team.

Figure A2.54: Viet Nam—Total Primary Energy Consumption (exajoule)



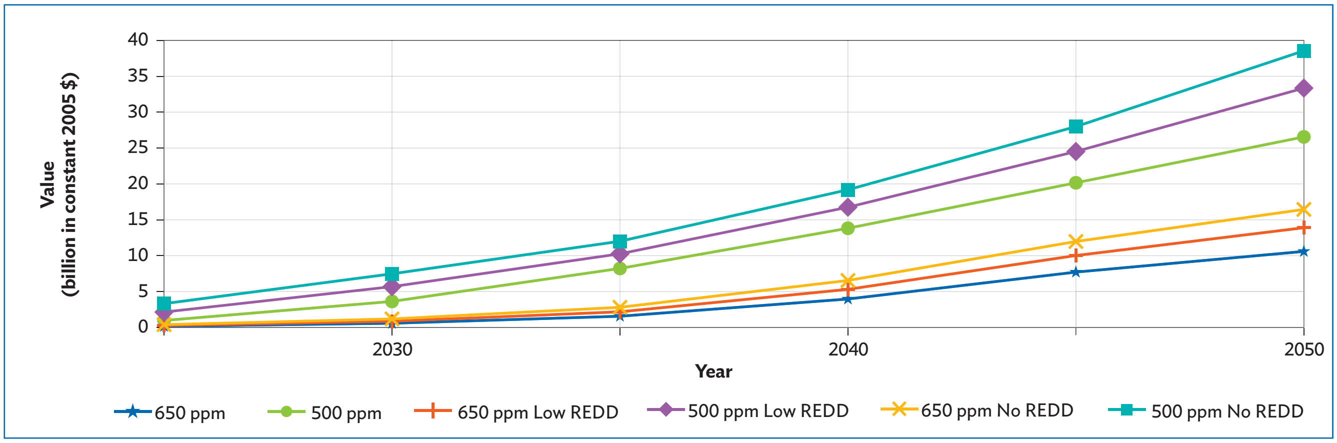
BAU = business as usual, FRAG = fragmented (policy), ppm = parts per million.
Source: ADB Study Team.

Figure A2.55: Viet Nam—Total Primary Energy Consumption Change from REDD, 2010–2050



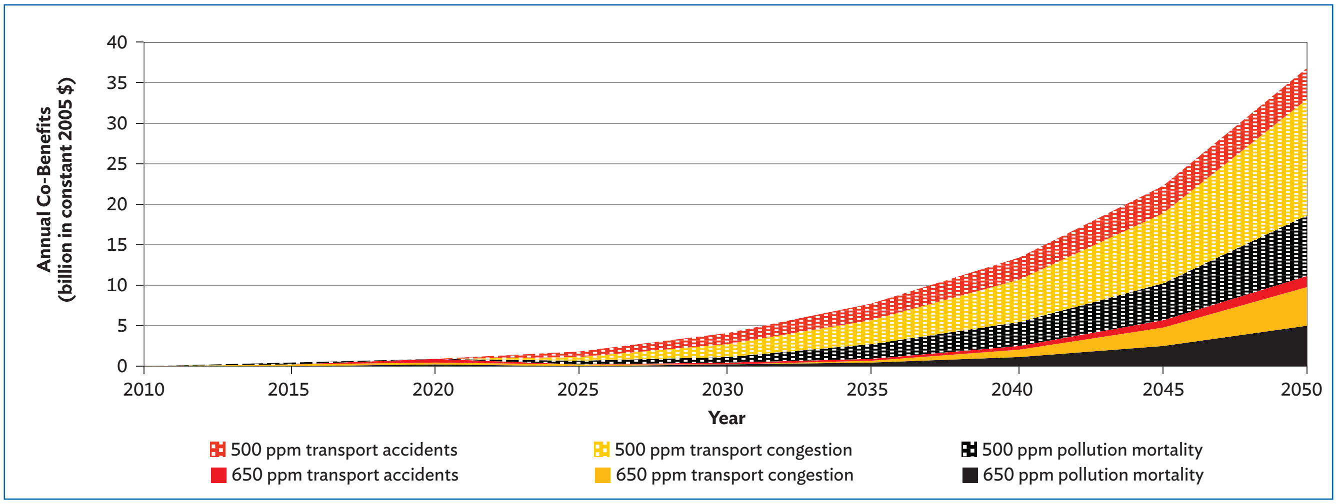
ppm = parts per million, REDD = reducing emissions from deforestation and forest degradation.
Source: ADB Study Team.

Figure A2.56: Viet Nam—Projections of Carbon Permit Trade



ppm = parts per million, REDD = reducing emissions from deforestation and forest degradation.
Source: ADB Study Team.

Figure A2.57: Viet Nam—Co-Benefits under Scenarios with Full REDD



ppm = parts per million, REDD = reducing emissions from deforestation and forest degradation.
Source: ADB Study Team.

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Southeast Asia and the Economics of Global Climate Stabilization

Climate change is a global concern of special relevance to Southeast Asia, a region that is both vulnerable to the effects of climate change and a rapidly increasing emitter of greenhouse gases (GHGs). This study focuses on five countries of Southeast Asia that collectively account for 90% of regional GHG emissions in recent years—Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam. It applies two global dynamic economy–energy–environment models under an array of scenarios that reflect potential regimes for regulating global GHG emissions through 2050. The modeling identifies the potential economic costs of climate inaction for the region, how the countries can most efficiently achieve GHG emission mitigation, and the consequences of mitigation, both in terms of benefits and costs. Drawing on the modeling results, the study analyzes climate-related policies and identifies how further action can be taken to ensure low-carbon growth.

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