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Summary

Southeast Asia is one of the most vulnerable regions of the world to the impacts of climate change. At the same time, the region is also following a trajectory that could make it a major contributor to greenhouse gas emissions in the future. Understanding the economic implications of policy options for low carbon growth is essential to formulate instruments that achieve the greatest emissions reductions at lowest cost. This study focuses on five developing countries of Southeast Asia that collectively account for 90% of regional emissions in recent years—Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam. The analyses are based on the CGE economy-energy-environment model ICES under an array of scenarios reflecting business as usual, fragmented climate policies, an approximately 2.4°C post 2020 global climate stabilization target, termed 650 parts per million (ppm) carbon dioxide (CO2) equivalent (eq), and an approximately 2°C global target (termed 500 ppm CO2 eq). Averted deforestation through reducing emissions from forest degradation and deforestation (REDD) is included in some scenarios. The study shows that global and coordinated action is found to be critical to the cost effectiveness of emissions stabilization policies. A 650ppm stabilization scenario (below 3°C in 2100) has a similar cost to the region to current fragmented targets, but achieves much higher levels of emissions reductions. However, only some of the countries have short-term emissions targets that are consistent with a stabilization scenario at 650ppm: these are Indonesia, Philippines and Viet Nam. None of the countries' mid-term targets are coherent with more ambitious stabilization scenario at 500ppm.

Keywords: Climate Change Mitigation, Asian Economies, Computable General Equilibrium Models

JEL Classification: Q54, Q58, C68

This work is an elaboration of part of the background material prepared for the Asian Development Bank report: "Southeast Asia and the Economics of Global Climate Stabilization" developed within the Asian Development Bank Technical Assistance project, "Strengthening Planning Capacity for Low-Carbon Growth in Developing Asia," co-financed by the Government of the United Kingdom and the Government of Japan whose financial supports are gratefully acknowledged. Authors wish also to thank for useful discussions and feedback Fabio Eboli, Giacomo Marangoni, Ramiro Parrado, John Rogers, Jindra Nuella G. Sampson, Massimo Tavoni. The study would not have been possible without support and feedback from stakeholders at various national ministries from Indonesia, Malaysia, Philippines, Thailand and Viet Nam. Any mistake in the present paper like any view expressed are of authors' sole responsibility.

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Francesco Bosello, Carlo Orecchia, David A. Raitzer

Abstract

Southeast Asia is one of the most vulnerable regions of the world to the impacts of climate change. At the same time, the region is also following a trajectory that could make it a major contributor to greenhouse gas emissions in the future.

Understanding the economic implications of policy options for low carbon growth is essential to formulate instruments that achieve the greatest emissions reductions at lowest cost. This study focuses on five developing countries of Southeast Asia that collectively account for 90% of regional emissions in recent years—Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam. The analyses are based on the CGE economy-energy-environment model ICES under an array of scenarios reflecting business as usual, fragmented climate policies, an approximately 2.4°C post 2020 global climate stabilization target, termed 650 parts per million (ppm) carbon dioxide (CO2) equivalent (eq), and an approximately 2°C global target (termed 500 ppm CO2 eq). Averted deforestation through reducing emissions from forest degradation and deforestation (REDD) is included in some scenarios.

The study shows that global and coordinated action is found to be critical to the cost effectiveness of emissions stabilization policies. A 650ppm stabilization scenario (below 3°C in 2100) has a similar cost to the region to current fragmented targets, but achieves much higher levels of emissions reductions. However, only some of the countries have short-term emissions targets that are consistent with a stabilization scenario at 650ppm: these are Indonesia, Philippines and Viet Nam. None of the countries' mid-term targets are coherent with more ambitious stabilization scenario at 500ppm.

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Summary

1. Introduction

Globally, there has been considerable attention to the emissions reduction potential of leading low-carbon technologies, as well as their economic implications. The IPCC's Fifth Assessment Report (AR5) identified 1184 emissions scenarios from 31 global economy-climate models. These models 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°C limit to mean global warming.

Much less is known about the implications of potential global limitation mechanisms for Southeast Asia, even though it is the fastest growing source of emissions in the world. Only approximately 10% of scenarios identified by the IPCC even report estimates for Asia as whole, which includes the People's Republic of China (PRC), the world's largest emitter, and only a fraction of those studies report estimates specifically 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.

A number of recent model intercomparison exercises provide partial indications of costs for Asia and Southeast Asia. The Stanford Energy Modeling Forum (EMF) 27 modeling comparison exercise (Kriegler et al. 2014) is well cited and provides results for major Asian economies (e.g., PRC, India, and Japan) and the Asian region. For Asia, GDP losses in 2050 show large variability among models, ranging from almost 0% to 27% and from 5.5% to 50% for stabilization scenarios of around 2°C of peak warming.

An important model comparison exercise with results for Southeast Asia is the "Low Climate Impact Scenarios and the Implications of Required Tight Emission Control Strategies" (Kriegler et al., 2013; Tavoni et al., 2013; LIMITS). The aim of the project was to analyze a set of climate policies with different level of ambition in terms of climate change. In assessing the feasibility of different climate policies, the comparison also indicates key energy technologies that might be relevant to transform current energy systems and help reach future climate targets. The analysis only covers major economies (PRC or India) or large regions (e.g., Southeast Asia). It found that substantial emissions reductions can be achieved at relatively low cost for Southeast Asia, with a median loss of 1% of GDP in 2030 and in 2050 under a scenario that limited warming to 2°C.

A recent Asia-focused multimodel project is the Asian Modeling Exercise (AME). It brings together a considerable number of integrated assessment models and regional models of Asian countries and conducts a comparison of baseline, emissions target, and carbon tax scenarios. AME analyses explore the contribution of different technologies to emissions mitigation (Akashi et al., 2012; Luderer and Pietzcker, 2012; Mi et al., 2012; Okagawa et al., 2012; Saveyn et al., 2012) and the co-benefits of emission reduction policies in Asia (Dowling and Russ, 2012; Shrestha and Shakya, 2012; van Ruijven and van Vuuren, 2012; van Vliet and Krey, 2012).

Overall, the AME provides limited information on the policy costs of climate mitigation policies. Indeed, among all 28 articles published from AME, only two (Akashi et al., 2012, and Saveyn et al., 2012) contain a clear costs assessment of temperature stabilization. According to the first study, the 2010–2050 cumulative cost for Asia, discounted at 5%, in a radiative forcing stabilization scenario at 2.6 watts per square meter (W/m2) would be about $6.16 trillion. The region would then bear roughly 45% of the world's total emission reduction costs and would sustain approximately a 1.7% loss of discounted GDP.

Saveyn et al. (2012) reported the cost implied by temperature stabilization at 2°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 information from the PRIMES and POLES bottom-up energy models. The world GDP loss in 2050 would be 3.2%, with India and the PRC demonstrating much higher losses—8.1%, 6.3% respectively—as well as much higher losses for countries with lower GDP. The study found that by mid century, 77% of total world energy generation would be produced by zero carbon technologies in the stabilization scenario.

Only a subset (i.e., 14 of 23) of the AME models performed stabilization scenarios at 2.5°C peak warming (expressed as 3.7 W/m2) or at 2°C peak warming (expressed as 2.6 W/m2). Results for the Asia region confirm that there is large uncertainty on the GDP costs to stabilize warming: for 2.5°C stabilization scenario, they are 0%–4.6% in 2030 and up to 0%–7.5% in 2050. In the case of 2°C, they range from 0% to 3.4% in 2030 and from 0% to 7.9% in 2050. Of the 23 models, six also report results for Indonesia. For 2.5°C stabilization, GDP costs are 0%–1.4% in 2030 and rise to 0%–6.3% in 2050, and for 2°C stabilization, they are 0%–1.6% in 2030 to 0%–26.8% in 2050. Overall, Asia would contribute between 30% and 60% of global emissions reduction.

Van Der Mensbrugghe (2010) explored the response of Asian economies to climate change impacts and policy using the global CGE model ENVISAGE, updated with a simple climate module that converts the stock levels of emissions into radiative forcing and thus into temperature changes. The study presented results for six Southeast Asian countries, namely Cambodia, Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam, for the imposition of five different carbon taxes gradually imposed over 2004–2050, which peak at $14–$109 per ton of CO2. As a whole, Southeast Asia would bear the largest policy costs with an average income loss of 8.9% at $109 per ton of CO2 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 is included in the model.

Thepkhun et al. (2013), applied a CGE model for Thailand to analyze emission reduction targets of 30% and 50% with respect to business as usual, coupled with several options that included CCS as well as emission trading. The study 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 CCS would have positive effects on GDP.

All of these studies have critical limitations that impede their ability to offer mitigation policy-relevant findings for Southeast Asia. First, those studies that offer findings for specific Southeast Asian countries do not do so in the context of a global stabilization target. Rather, they explore cases of unitary carbon taxes or imposed emissions reduction levels. Thus, they do not reveal the effects of likely emissions reductions to be undertaken in the context of a global climate agreement, including how the countries would interact with a global carbon market. 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 previous studies have underestimated those baseline emissions by 100%–1,000%. In the absence of accurate baseline emissions, policy implications of emissions reductions cannot be reliably identified. Third, there are limitations to the realism of stabilization scenarios applied to date, as no exercise has explicitly modeled a transition from national targets in a pre-climate agreement period, followed by a global stabilization regime implemented in the post-2020 timeframe targeted by current international negotiations.

The present study addresses these limitations by exploring the potential implications of actual possible policy outcomes from the UNFCCC process focusing on five countries, Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam (DA5 thereafter). The analyses are based on the economy-energy-environment model ICES, a dynamic recursive CGE model.

2. Reference scenario

2.1 Indonesia

With a GDP of around $0.35 trillion and a population close to 250 million, Indonesia is the largest economic system among the DA5 countries. It is also the largest GHG emitter; in 2010, the emissions totaled more than 2,000 million tons (Mt) of CO_2 equivalent, 1,400 Mt of which were contributed by land-use processes and the remainder by industrial activity and agricultural production. The land-use emissions were largely driven by deforestation activities that in the last 10 years had caused Indonesia to lose 5% of its forest cover in favor of agricultural activities, especially oil palm production. With rapid industrialization, the various industry sectors accounted for 47% of the country's GDP by 2010, followed by services at 37.6%. However, agriculture remains important with its share of 15.3% of total GDP.

According to ADB (2011), 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 afterwards although at a lower growth rate. Its GDP is projected to reach a peak of $4.5 trillion in 2050, which would be a 1,141% increase over the 2010 level. There will only be slight changes in the composition of its GDP generators during the period. The service sector and the heavy manufacturing sector will grow in importance as the main engines of growth, while the share of the agricultural sectors will decline to roughly half of their 2010 level, dropping to a low of 7.9% in 2050.

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. 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.

The country's GHG emissions will follow the growth of industrial production and GDP, increasing from the 2,200 $MtCO_2$ equivalent in 2010 to 2800 $MtCO_2$ equivalent in 2050. In particular, the fossil-fuel intensive sectors—heavy manufacturing, services including transportation, fossil-fired electricity generation, and household demand—will increase to nearly 90% of the total within that period from 34% of the total in 2010. The opposite will happen in the case of land-use emissions, the share of which is projected to shrink from 66% to 10% of total emissions within that period.

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

Figure 2 reports the baseline deforestation patterns for Indonesia based on ADB (2011), Gusti et al. (2008), and Eliasch et al. (2008). By mid-century, the country is expected to lose 15% of its 2011 forest cover, with the loss reaching almost 14 million cumulative deforested hectares in 2050.

Table 1: Indonesia's Annualized GDP Growth Rate, 2011–2050 (left) and Population (right)

	GDP (yearly growth rates)	
	ICES simulated	Projections
2011–2020	7.8%	7.8%
2021–30	8.7%	8.8%
2031–40	5.7%	5.6%
2041–50	3.9%	3.3%

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

Note: Projections refer to ADB (2011b) data, integrated with information from local experts
GDPP = gross domestic product.

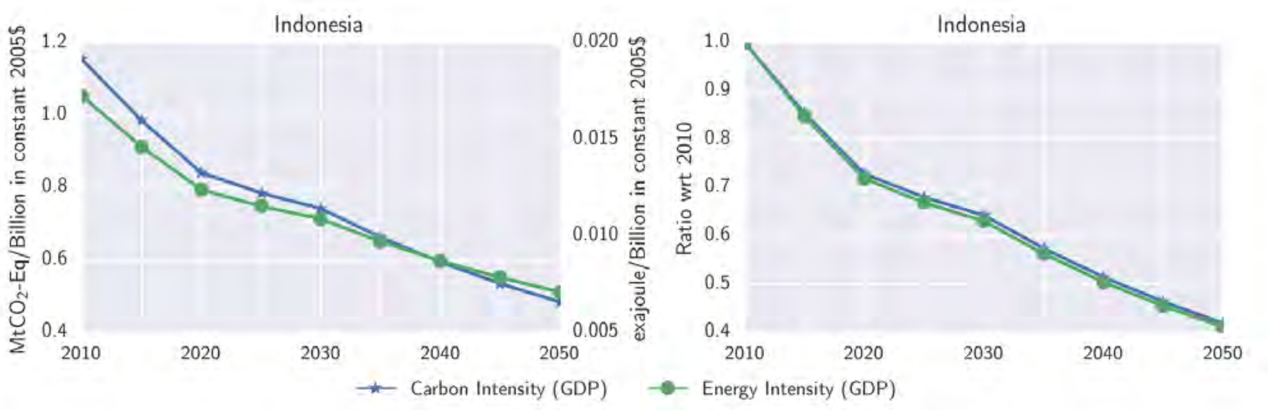


Figure 1: Indonesia's Baseline Carbon and Energy Intensity, Levels* (left) and Indexed, 2010=1 (right)

GDP = gross domestic product.

Note: Carbon intensity expressed in MtCO2eq/$ billion (left axis), energy Intensity expressed as EJ/$ billion (right axis)

a) Forest area (2010 = 100) b) Cumulative deforestation (thousand hectares)

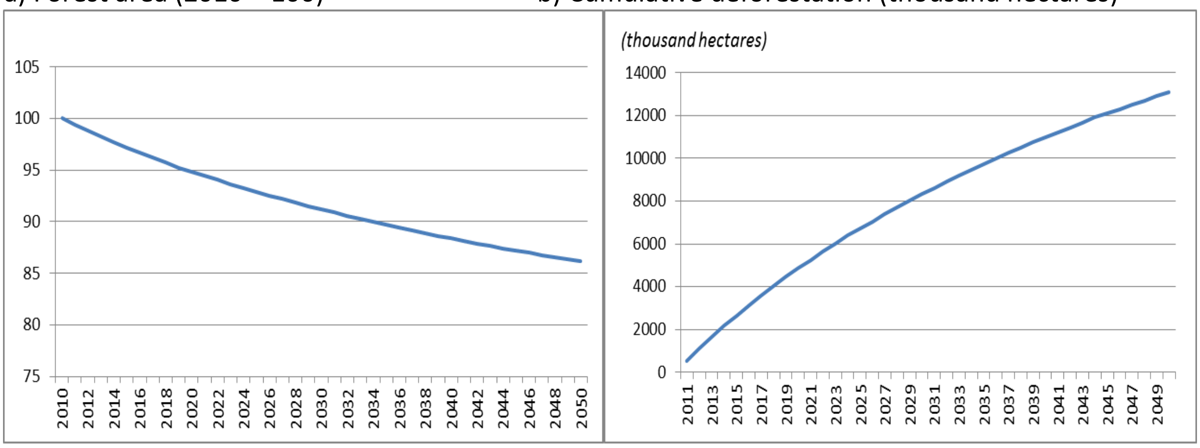


Figure 2: Indonesia's Baseline Deforestation Pathways

2.2 Malaysia

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 2), which is one quarter that of the Philippines and more than half of Thailand's, it has the highest GDP per capita among the DA5. Malaysia's service sector has supported one of the more dynamic economic systems in the region in the last 30 years, reaching a share of 46% of total value added in 2010, followed by industry at 43% and by agriculture at 11%. The industrial sector is largely based on heavy industry, which accounts for 4/5 of industrial production. The energy sector, which accounts for 1/3 of industrial value added, relies mainly on natural gas (around 60%) and oil (around 38%), with the remainder contributed by coal and a very tiny fraction by hydroelectric sources.

In 2010, Malaysia emitted almost 400 $MtCO_2$ equivalent of GHGs, mostly related to the production of electricity and to transportation. Main emissions include CO_2 (79%) and CH_4 (15%). Malaysia is only the third biggest emitter among the DA5 after Indonesia and Thailand, but has the highest level of emissions per capita (excluding land-use emissions). In both energy and carbon intensity, Malaysia comes third after Viet Nam and Thailand.

According to projections for 2010–2050 (Table 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 industrial sectors (including energy) are expected to grow to more than 50% by 2050. Although the agricultural sectors are expected to increase their production, their overall contribution to the national value added is projected to shrink from the 11% level in 2010 to only 6% in 2050.

The overall energy production is projected to increase to 10.4 EJ in 2050. It will continue to rely primarily on fossil sources, with coal replacing some of the oil requirements. Although hydroelectric energy is expected to increase by more than ten times, its share of national energy production will remain negligible. This applies as well to solar energy; despite a large increase at present from the 2010 levels, its generation in 2050 is projected to become much smaller.

All throughout 2010–2050, GHG emissions are found to grow more than twofold, with the electricity sector accounting for almost half of national emissions. There will be a slight increase in share of emissions linked to household consumption, and the share of emissions from land use will shrink to a very marginal level. Overall emissions will increase but grow less in proportion to GDP, resulting in reductions in carbon intensity of 56% and in energy intensity of 58%. Malaysia is projected to have lost almost 1/4th of its 2011 forest area by 2050 (Figure 4).

Table 2: Malaysia's Baseline Annualized GDP Growth Rate, 2011–2050 (left) and Population (right)

	GDP (yearly growth rates)	
	ICES simulated	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

Note: Projections refer to ADB (2011b) data integrated with information from local experts.

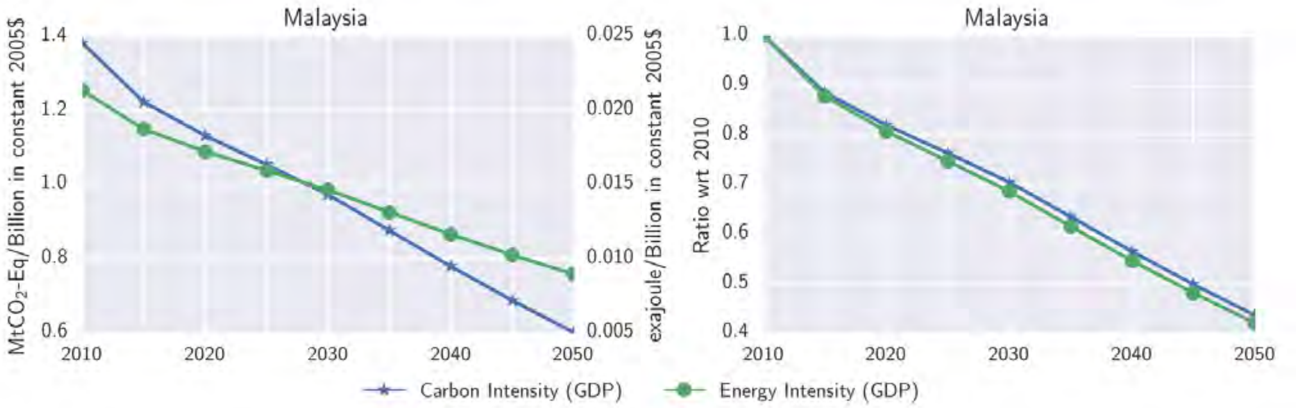


Figure 3: Malaysia's Baseline Carbon and Energy Intensity, Levels* (left) and Indexed, 2010 = 1 (right)

GDP = gross domestic product.

Note: * Carbon intensity expressed in MtCO2eq/$ billion (left axis), energy Intensity expressed as EJ/$ billion (right axis)

a) Forest area (2010 = 100) b) Cumulative deforestation (thousand hectares)

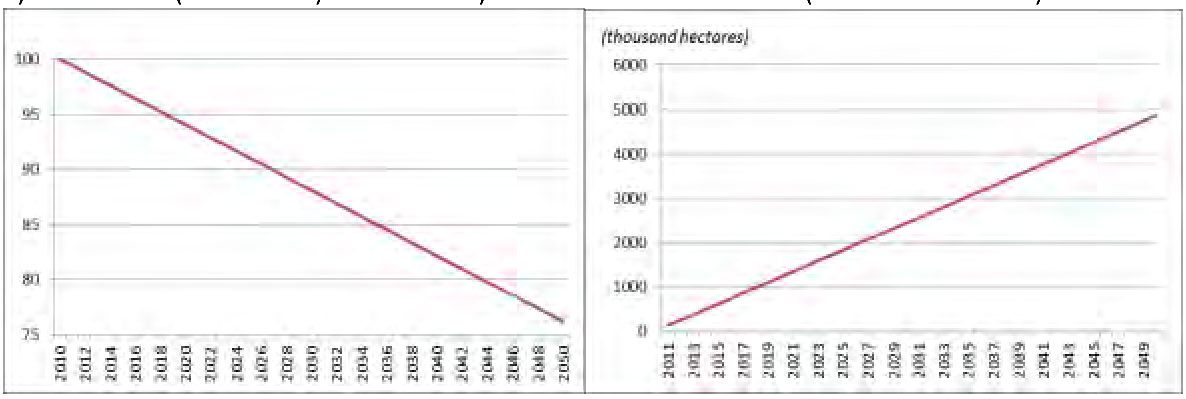


Figure 4: Malaysia's Baseline Deforestation Pathways

2.3 Philippines

In 2010, with a population of 93.3 million, the Philippines was the second most heavily populated among the DA5 countries (Table 3, right). Its GDP ranked fourth at $0.118 trillion (Figure 42), and the level of its GHG emissions, at slightly below 160 Mt CO_2 equivalent, was the lowest among the DA5. The main sources of GHG emissions were transportation services, 35%; fossil-fuel burning for electricity generation, 20%; heavy industries, 10%; and rice and livestock production, 2.4% and 2.7%, respectively (Figure 44). Of paramount importance in the country's economic activity was the service sector, which at 55% had the highest share of value added among the DA5 countries; industry and agriculture followed at 32% and 12%, respectively.

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 energy intensity and carbon intensity of the country's GDP in 2010 were 0.011 and 0.76, respectively, and the emission per capita was 1 t CO_2e.

For 2010–2050, the projected development trends for the Philippines would make it the third fastest growing economy among the DA5. GDP is expected to reach $1.1 trillion in 2050, primarily supported by the growth of the service sector; heavy industries would slightly increase their share in the total value added. The contribution of agriculture to the total value added is expected to consistently shrink from the initial 11% in 2010 to 7.7% in 2050. Given this development scenario, energy consumption is projected to increase more than threefold over the next 40 years, peaking at 4.3 exajoule in 2050. The energy consumption mix will remain dominated by fossil sources, which will account for over 90% of the total, with hydropower expected to double by 2050.

Mirroring this development scenario, GHG emissions in the Philippines will increase from 150 Mt CO_2 equivalent in 2010 to 400 Mt CO_2 equivalent in 2050. Following the sectoral recomposition of the economy, there will be 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 agricultural sectors is projected to decline from around 28% to 6.4%. Improvements in energy efficiency and productivity growth are expected to foster reduction in the carbon intensity and energy intensity of country's GDP by roughly 60% between 2010 and 2050 (Figure 5).

Table 3: The Philippines' Baseline Annualized GDP Growth Rate, 2011-2050 (left) and Population (right)

	GDP (yearly growth rates)	
	ICES simulated	Projections
2011–2020	6.2%	6.0%
2021–30	5.2%	5.5%
2031–40	5.7%	5.5%
2041–50	6.0%	5.5%

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

Note: Projections refer to ADB (2011b) data, integrated with information from local experts

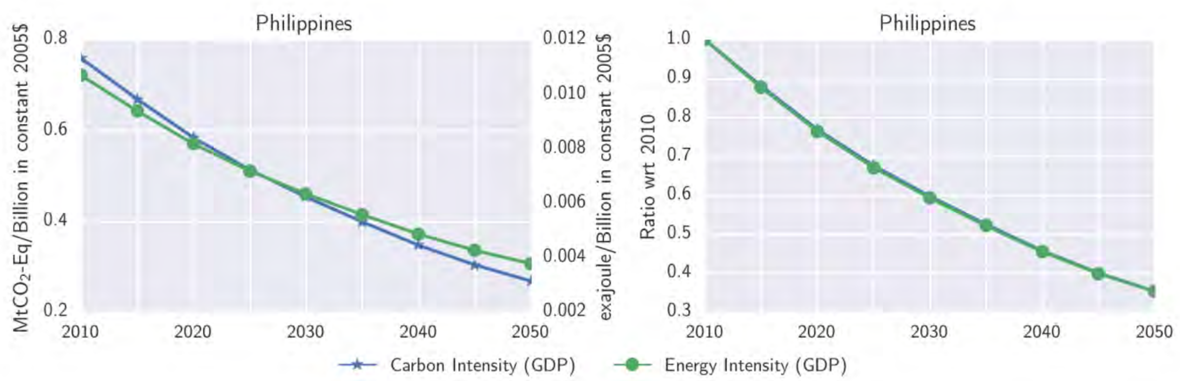


Figure 5: The Philippines' Baseline Carbon and Energy Intensity, Levels* (left) and Indexed, 2010 = 1 (right)

GDP = gross domestic product.

Note: *Carbon intensity expressed in MtCO2eq/$ billion (left axis), energy Intensity expressed as EJ/$ billion (right axis)

2.4 Thailand

In 2010, Thailand ranked second among the DA5 in terms of both GDP and GDP per capita. Its economic structure was dominated by industry and services, with almost equal contributions to total value added at 43% and 45%, respectively. Agriculture accounted for roughly 12% of the total value added. 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.

The largest source of emissions was electricity generation from fossil sources, followed by transportation and industrial processes. The agricultural sector, primarily through rice cultivation, was also an important source of emissions. In the baseline scenario, Thailand's GDP is expected to exhibit rather uniform average yearly growth rates, ranging from 4.1% to 4.6% (Table 4). By mid-century, national GDP is expected to reach $1.2 trillion, an 6-fold increase from 2010. Alongside the growth of all sectors, heavy industries are projected to grow in relative importance in the production of value added, but this will be at the expense not only of agricultural activity but partly of services as well, with the former's share in total value added reduced from 12% in 2010 to 7.7% in 2050, and the latter's share from 45% to 38.4%. To meet the requirements of the fast-growing GDP of Thailand, the baseline scenario projects a primary energy consumption of almost 10 exajoule in 2050, which is more than twice the 2010 levels.

All of Thailand's primary energy requirements come from fossil sources, even if a slight fuel preference favoring natural gas emerges after 2020. GHG emissions will then move toward a twofold increase during the period. However, this will be lower in terms of the corresponding increase in the county's GDP. Indeed, both the carbon intensity and energy intensity of Thailand's GDP are eventually expected to decline by roughly 60% by 2050 (Figure 6).

Table 4: Thailand's Baseline Annualized GDP Growth Rate, 2011–2050 (left) and Population (right)

	GDP (yearly growth rates)	
	ICES simulated	Projections
2011–2020	4.1%	4.2%
2021–30	4.4%	4.2%
2031–40	4.5%	4.3%
2041–50	4.6%	4.2%

	Population (Millions)
2010	69.1
2020	72.1
2030	73.3
2040	73.0
2050	71.0

Note: Projections refer to ADB (2011b) data, integrated with information from local experts

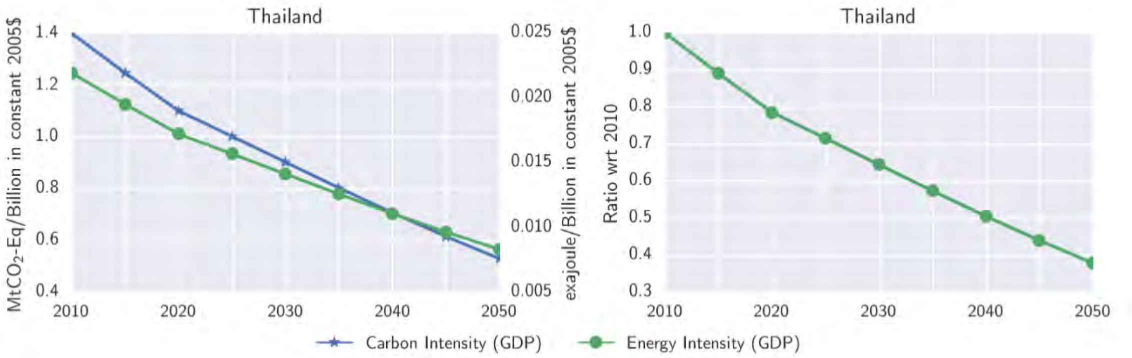


Figure 6: Thailand's Baseline Carbon and Energy Intensity, Levels* (left) and Indexed, 2010 = 1 (right)

GDP = gross domestic product.

Note: *Carbon intensity expressed in MtCO2eq/$ billion (left axis), energy Intensity expressed as EJ/$ billion (right axis)

2.5 Viet Nam

In 2010, Viet Nam recorded a GDP of $69 billion, the lowest among the DA5, and a population of 87 million, the third highest among them. In per capita terms, it was also the poorest economy in the DA5. Industry at roughly 41% and services at 38% accounted for the bulk of total value added; agriculture at 21% represented the highest agriculture share among the DA5. Total energy consumption amounted to 1.7 exajoule, 95% of which was provided by fossil sources, principally oil, and the remaining 5% by hydropower. The country's GHG emissions of 200 MtCO2 equivalent in 2010 were driven mainly by rice production, heavy industry, electricity generation from fossil sources, and transportation services. The carbon intensity and energy intensity of Viet Nam's GDP are the highest across the DA5, and its emissions per capita (excluding those from land use) place Viet Nam as fourth in the group.

In the 2010–2050 baseline, Viet Nam is expected to be the second fastest growing economy among the DA5 (Table 5). Its GDP in 2050 could reach $1 trillion, or 14 times larger than in 2010. 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. 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. 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 7).

Table 5: Viet Nam's Baseline Annualized GDP Growth Rate, 2011-2050 (left) and Population (right)

	GDP (yearly growth rates)	
	ICES simulated	Projections
2011–2020	6.8%	6.7%
2021–30	7.6%	7.7%
2031–40	7.2%	7.1%
2041–50	6.5%	6.6%

	Population (Million)
2010	87.8
2020	97.2
2030	104.2
2040	108.1
2050	110.0

Note: Projections refer to ADB (2011b) data, integrated with information from local experts.

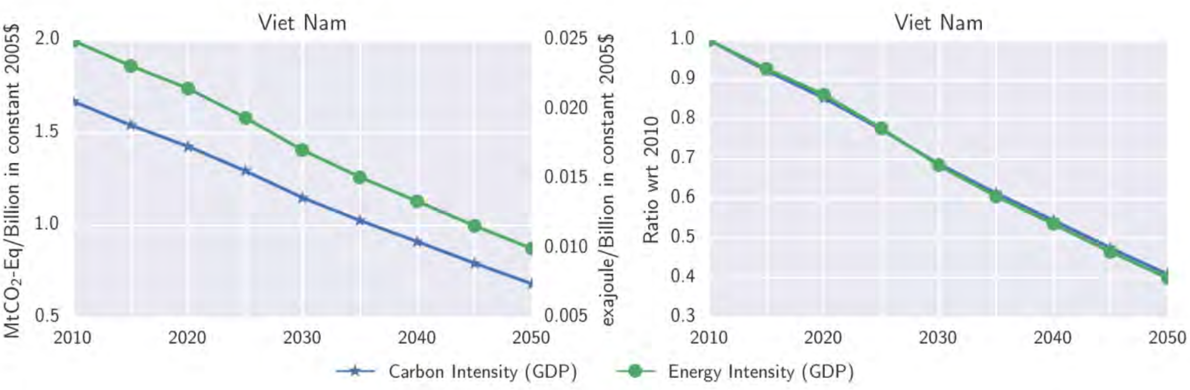


Figure 7: Viet Nam's Baseline Carbon and Energy Intensity, Levels (left) and Indexed, 2010 = 1 (right)

GDP = gross domestic product.

Note: *Carbon intensity expressed in MtCO2eq/$ billion (left axis), energy Intensity expressed as EJ/$ billion (right axis)

3. The climate scenarios

The intention of the scenarios modelled in this study is to represent alternative potential outcomes of the UNFCCC climate negotiations, and to identify the implications of these outcomes for Southeast Asia. The basic possibilities that are captured include:

1. Climate policies fail - Business as usual (climate action is not prioritized by any government)
2. International climate negotiations fail - Fragmented national climate policies (countries continue to pursue national climate actions at their current level of ambition)
3. International climate agreement reached with moderate ambition (a global climate agreement comes into place in 2020 with a moderate target)
4. International climate agreement reached with high ambition (a global climate agreement comes into place in 2020 with an ambitious target)

As current UNFCCC negotiations target the post 2020 period for implementation of a global climate agreement, 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 South East Asian countries aim to pursue by 2020 as stated in their respective official national plans. The second analyzes the implications of various GHGs emission reduction strategies to be deployed after 2020 until the end of the century, assuming different degrees of stringency and levels of global coordination.

To date, the only international expression of greenhouse gas emissions targets for developing countries in Asia is through the 2009 United Nations Framework Convention on Climate Change (UNFCCC) Copenhagen Accord, which covers the period until 2020. This periodic round of climate negotiations under the auspices of the UNFCCC aims to promote and facilitate dialogue on climate-change strategies among UN member countries. 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 targets: a more ambitious target known as "high Copenhagen pledge" and a less ambitious one known as "low Copenhagen pledge." Both targets are considered in this study. These Copenhagen pledges, expressed in terms of the 2020 policy scenarios, are described in Table 6.

Table 6: Copenhagen Pledges for 2020 Policy Scenarios

Region	Period of reference	Low Cop Pledges	High Cop Pledges
European Union	1990	-20%	-30%
Japan	1990	-25%	-
United States	2005	-17%	-
Russia	1990	-15%	-25%
Australia	2000	-5%	-25%
New Zealand	1990	-10%	-20%
Brazil	BAU	-36%	-39%

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

Mexico	BAU	-30%	-
Republic of Korea	BAU	-30%	-
Indonesia	BAU	-26%	-
Canada	2005	-17%	-
South Africa	BAU	-34%	-
People's Republic of China*	2005	-40%	-45%
India*	2005	-20%	-25%

BAU = business as usual, CoP = Conference of Parties.

Source:

Note: *on carbon intensity of gross domestic product.

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 are still formulating their climate change and energy policies that seek to promote decarbonization of their respective economic systems so as to reduce the environmental impact of intense fossil-fuel use.

Table 7 describes the mitigation, energy efficiency, and carbon-efficiency targets of the policy scenarios of four countries. The sources of these targets are their respective national official documents (Hoa et al., 2010; IEA, 2010; Olz et al., 2010; Philippines Climate Change Commission, 2010; Vinluan, 2012).

Table 7: DA4 Country Decarbonization Targets for 2020

Country	Target description
Malaysia	40% CO_2eq emissions reduction per unit of GDP relative to 2005 (i.e., +19.8% CO_2eq emissions increase from 2010)
Philippines	CO2eq Emissions reduction from 10% energy savings from all sectors, 2009-2030 (i.e., -5.7% CO_2eq emissions increase from 2010)
Thailand	8% reduction of energy intensity by 2015 and 25% by 2030 compared with 2005 (i.e., +18.0% CO_2eq emissions increase from 2010)
Viet Nam	CO_2eq Emissions reduction from total energy consumption savings by 3% to 5% by 2010 and by 5% to 8% by 2015 compared with 2006 (i.e., +15.0% CO_2eq emissions increase from 2010)

CO_2eq = carbon dioxide equivalent, GDP = gross domestic product.

Sources: IEA, 2010; Olz et al., 2010; Vinluan, 2012; Hoa et al., 2010; Philippines Climate Change Commission, 2010

Note: In brackets is the target in terms of % change of GHG emissions with respect to 2010.

The country targets are expressed with different metrics: (i) in terms of emission reductions with respect to the BAU for Indonesia; (ii) in terms of emission intensity of GDP compared to a reference year for Malaysia; (iii) in terms of emission reduction and consequent energy saving strategies for the Philippines and Viet Nam; and (iv) in terms of reduction in energy intensity for Thailand. To make these different country targets comparable, they have been translated in Table 7 in terms of the common metrics for emission reduction with respect to 2010. What follows are modeling results starting from the baseline emissions, emissions, and energy intensity of the ICES model. Three long-term policy scenarios for the DA5 countries are 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 the scenario 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 concentrations of GHG gases plus aerosols of two levels, namely at 500 ppm carbon dioxide equivalent (CO_2eq) and 650 ppm CO_2eq. The first and more stringent scenario, 500 ppm CO_2eq, would lead to a median temperature increase of 2°C with respect to preindustrial level by the end of the century; the second scenario, 650 ppm CO_2eq, to a median temperature increase of 2.4°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 grandfathered permits. Regional and country allowances are determined according to "contraction and convergence" criteria; that is, allowances are initially calculated considering the share of each country of total GHG emissions in 2020 (including land use and peatland), which then linearly tend to a per-capita criterion that is fully implemented in 2050.

In the climate stabilization scenarios, emission reductions that are generated by 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 (see Box 3), and the performance of REDD is not well understood, different assumptions on the feasibility of REDD 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 also more generally relevant to global climate policy in the context of the potential supply of REDD reduction from Latin American countries. In a "Higher REDD cost" case, the cost of implementing REDD activities is assumed to increase by 150% with respect to that used as the standard in the models. This specific increase takes into account, in addition to opportunity costs, the transaction costs, potential project failures, and leakage that could result from overoptimistic reference levels or from REDD activities that simply displace deforestation or substitution effect. In the "No REDD" case, REDD is excluded altogether. Table 8 summarizes the seven policy scenarios considered.

Table 8: Definitions of the Policy Scenarios in the Present Study

<table>
<tr><td rowspan="3" colspan="2">Scenario matrix</td><td colspan="4">POLICY STRINGENCY</td></tr>
<tr><td rowspan="2">BAU</td><td>Fragmented</td><td>International Climate Agreement (high ambition)</td><td>International Climate Agreement (mid ambition)</td></tr>
<tr><td>Low Copenhagen Pledges in 2020 and extrapolation thereafter</td><td>High Copenhagen Pledges in 2020 and long-term GHG concentration at 500 ppm CO2 eq</td><td>Low Copenhagen Pledges in 2020 and long-term GHG concentration at 650 ppm CO2 eq</td></tr>
<tr><td rowspan="2">POLICY IMPLEMENTATION</td><td>All GHGs, Full REDD potential</td><td>1 (BAU)</td><td>2 (Fragmentation)</td><td>3 (500 ppm-eq High REDD)</td><td>4 (650 ppm-eq High REDD)</td></tr>
<tr><td>All GHGs, higher REDD cost</td><td></td><td></td><td>5 (500 ppm-eq Low REDD)</td><td>6 (650 ppm-eq Low REDD)</td></tr>
</table>

	All GHGs, No REDD			7 (500 ppm-eq No REDD)	8 (650 ppm-eq No REDD)

BAU = business as usual, eq = equivalent, GHG = greenhouse gas, ppm = parts per million, REDD = reduced emissions from forest degradation and deforestation.

4. Results

This section presents country-specific results that exploit the higher sectoral detail offered by the ICES model. In this section, the analysis of decarbonization policy costs is divided into (i) a 2020 assessment that investigates the implications of short-term targets for DA5 countries, and (ii) a long-term assessment that delves on the economic consequences of long-term decarbonization paths. In so doing, it should be recognized 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 can be expected to be biased upwards over long timeframes, as many dynamics that reduce decarbonization costs are omitted. However it does offer insights into the distribution of economic effects among different sectors, which is valuable, even if the level of GDP costs that it generates over long timeframes should be interpreted with caution.

4.1 Indonesia's 2020 Emissions Reduction Target

The 2020 target for Indonesia is a 26% reduction of GHGs with respect to baseline emissions (Figure 8). 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 as well as overall energy consumption levels. 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.

4.2 Indonesia in the Long-term Stabilization Scenarios

Emissions reductions pathways

Figure 8 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 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.

Mechanisms of emissions reductions

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. 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). 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 .

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/tCO2eq and $205/tCO2eq 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/tCO2eq against almost $554/tCO2eq in the no-REDD case.
Indonesia's position in the global carbon market is dependent on REDD. 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.

Economic consequences of emissions reductions

Ultimately, Indonesian GDP costs reach 9.4% and 12.5% in the full REDD and no REDD cases, respectively, in the 500 stabilization. They are lower in the 650 stabilization, ranging between 2.9% for the full REDD case and 4.6% for the no-REDD case. REDD exerts larger impacts before 2030, when deforestation is most rapid and fall once clearance has finished. In 2030, for instance, REDD would reduce Indonesia's 500 decarbonization cost from 7.4% of GDP to 2.9%.

Costs are less sensitive to REDD by mid-century for the most adversely affected sectors. By 2050, fossil fuel industries would be losing 57% and 35%, and the industrial sector 17% and 9% of their production in the 500 and 650 stabilization scenarios, respectively, with respect to the baseline with both full and no-REDD The service sector benefits from REDD activities. Its losses in 2050 would be roughly half of those in the no-REDD case.

REDD strongly conditions sectoral impacts and offers good potential for Indonesia to reduce emissions at low economic cost, especially for particular sectors. The agricultural sector benefits from REDD. The likely reduction in the expansion of agricultural area due to REDD, a development that could constrain agricultural activities, is more than compensated for by the beneficial effect on Indonesia's GDP of selling REDD credits in the carbon market. Although agricultural sector production losses in the no-REDD case are 3.8% and 0.2% with respect to the baseline by 2050 in the 500 and 650 stabilization scenarios, respectively, there are gains in the full REDD case of 3.3% and 3.6% in the 650 and 500 stabilization scenarios.

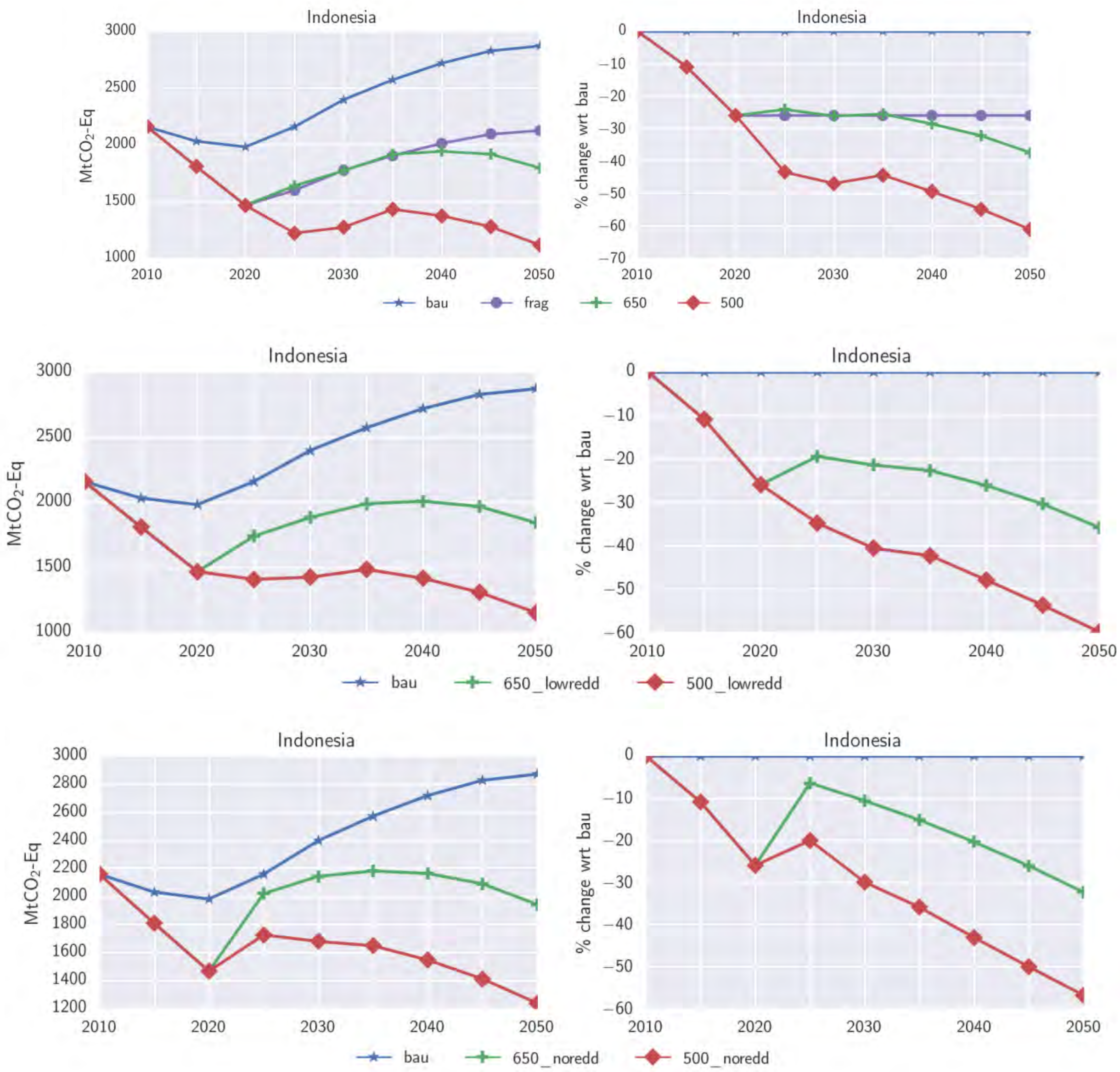
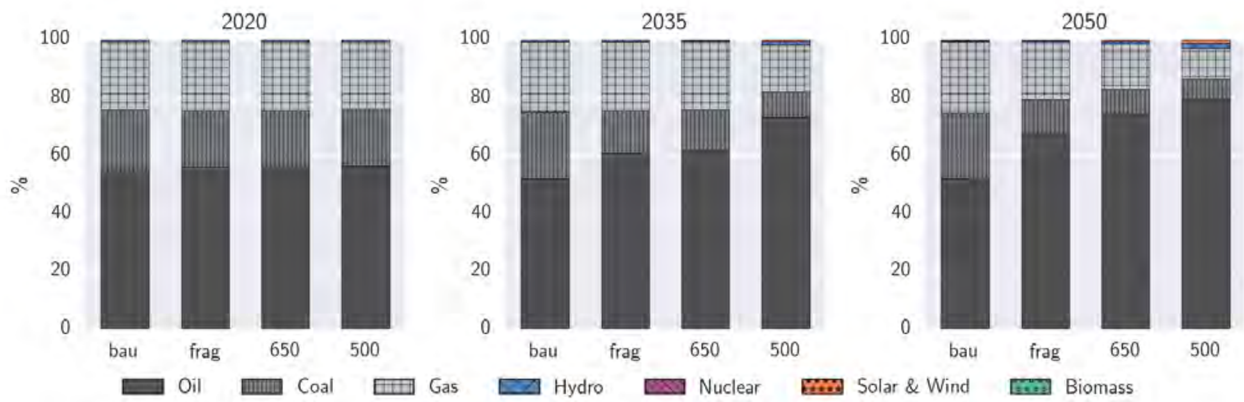


Figure 8: Indonesia GHG emissions Changes from Baseline with Full REDD (top), Low REDD (middle) and No REDD (bottom), Quantity (left), % Change from bau (right)

bau = business as usual, ccs = carbon capture and storage, frag = fragmented (policy), redd = reduced emissions from forest degradation and deforestation.



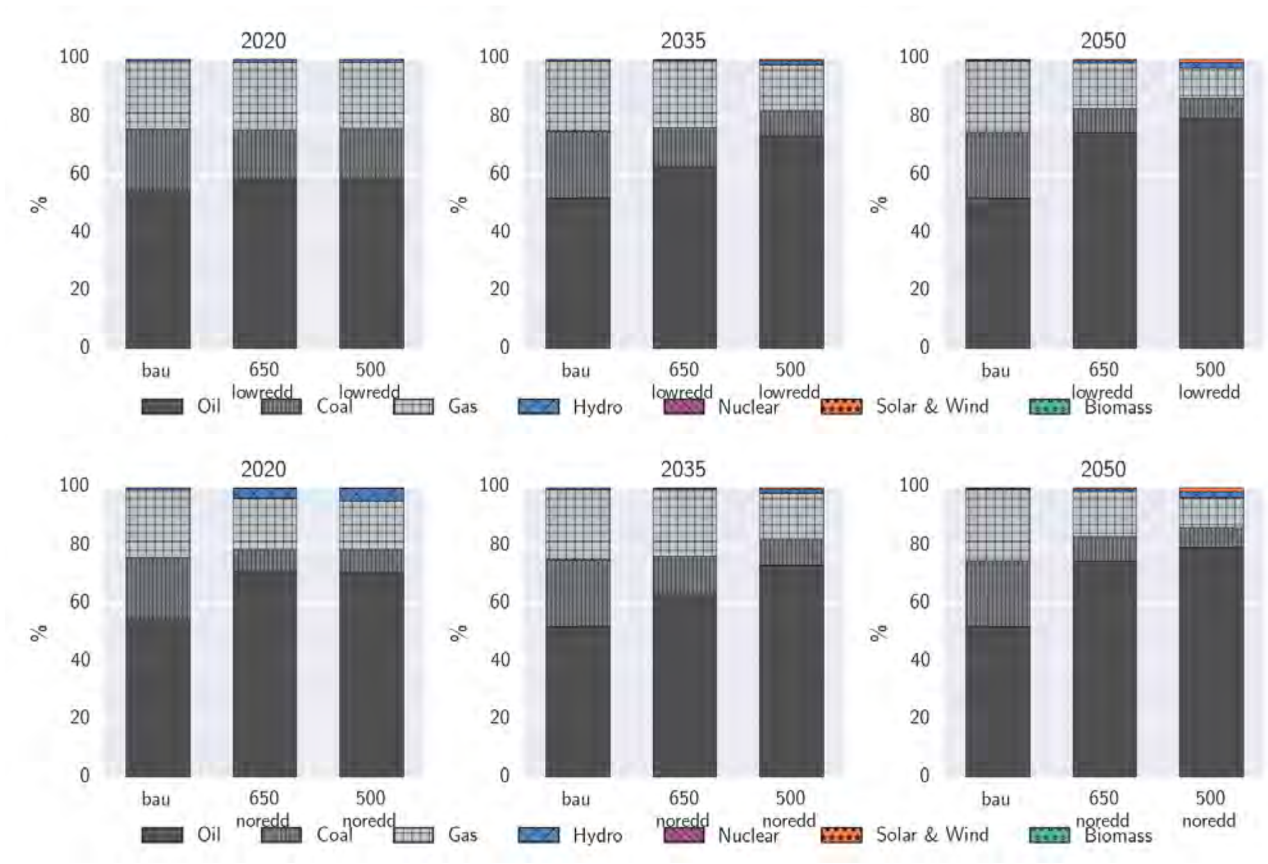


Figure 9: Primary Energy Mix Projections for Indonesia, Full REDD (top), Higher REDD cost (middle), No-REDD (bottom)

bau = business as usual, ccs = carbon capture and storage, frag = fragmented (policy), REDD = reduced emissions from forest degradation and deforestation.

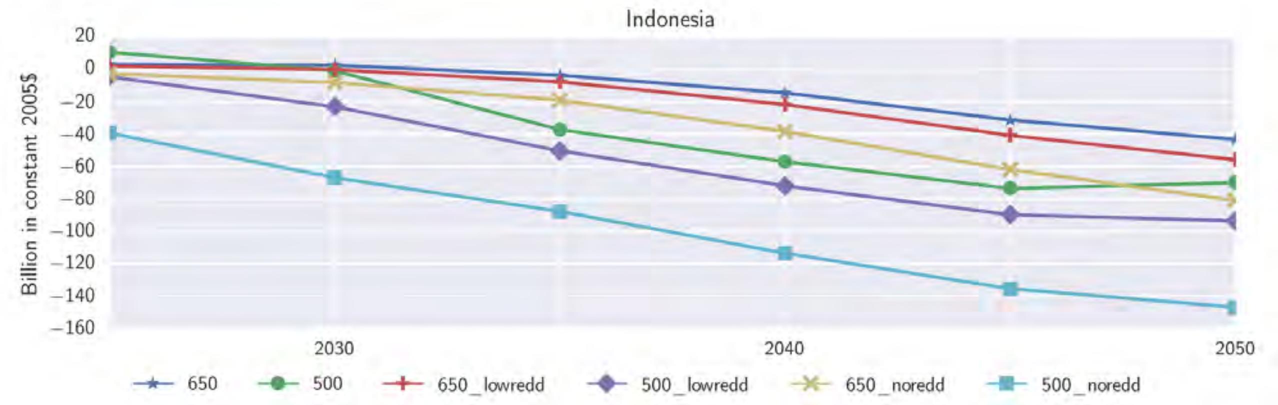


Figure 10: Projections of Carbon Permits Trade in Indonesia, Full REDD (top), Higher REDD Cost (center), No REDD (bottom) (> 0 selling < 0 buying)

REDD = reduced emissions from forest degradation and deforestation.

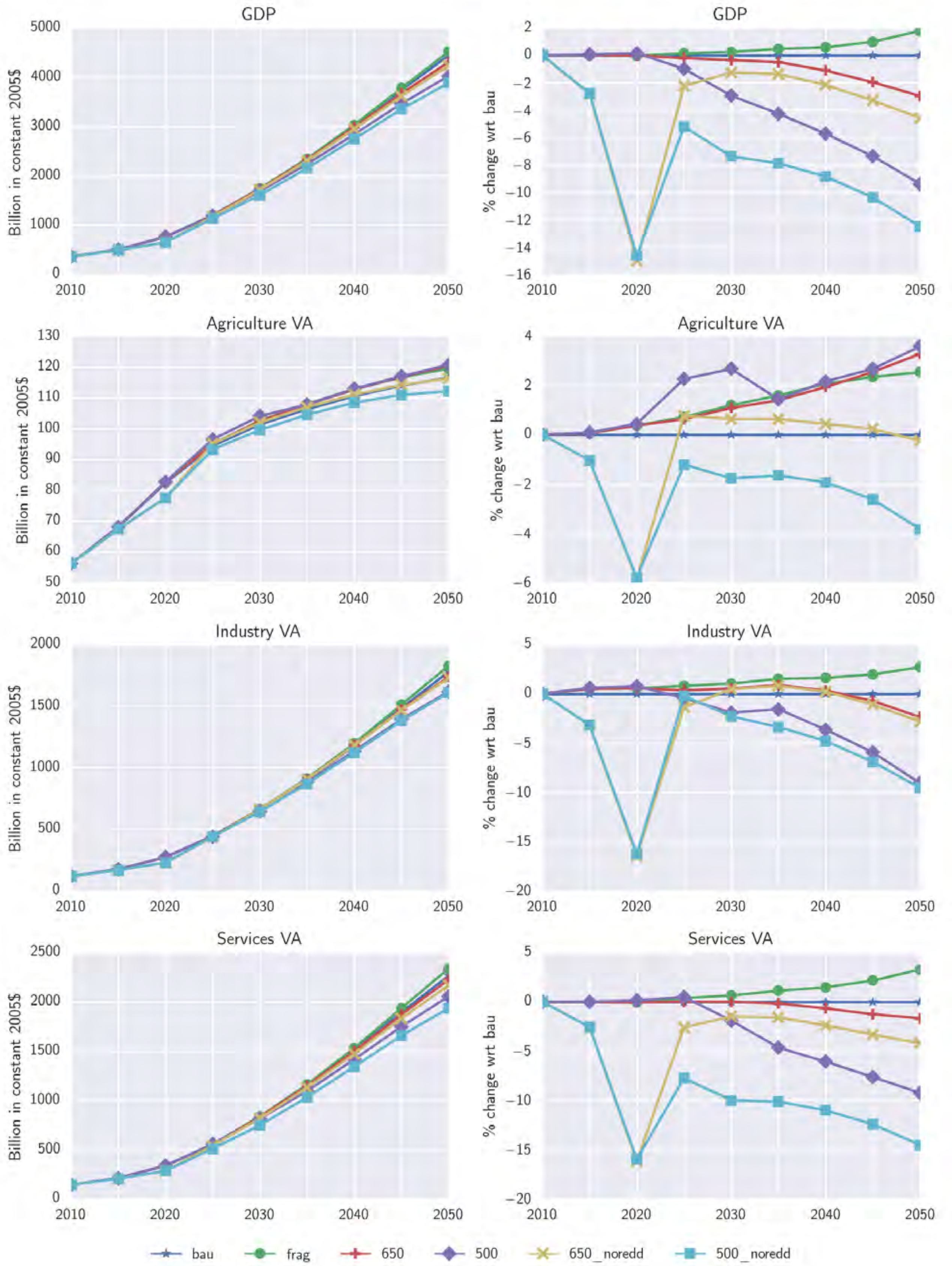


Figure 11 – Real GDP and Sectoral Value Added in Indonesia, Value (left), % Change from bau (right)

bau = business as usual, frag = fragmented (policy), REDD = reduced emissions from forest degradation and deforestation.

4.3 Malaysia's 2020 Emissions Reductions Targets

The 2020 target for Malaysia is a 40% CO_2 eq. emissions reduction per unit of GDP from 2005 levels. Given that the baseline emissions growth path to 2020 leads to a similar level of decarbonization in ICES as the target, the target does not imply substantial emissions reduction, compared with business as usual. However, minor differences can be noted in sectoral production, with slight generalized gains.

This is the effect of international spillovers to Malaysia from the actions of other countries. Malaysia can pursue its baseline trend when other countries have committed to voluntary emission reductions that are more stringent. This can produce leakage effects that benefit countries do not reduce emissions compared with business as usual.

4.4 Malaysia in the Long-term Stabilization Scenarios

Emissions reductions pathways

Figure 12 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 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.

Mechanisms of emissions reductions

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 13). 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.

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 15). 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.

Economic consequences of emissions reductions

Ultimately, Malaysia's GDP costs are at the higher end of the DA5. In the 500 stabilization scenario for 2050, they range from 10.4% to 12.4% loss in the full REDD and no-REDD cases, respectively. They are much lower in the 650 stabilization, ranging from 3.2% of the full REDD case to 4% of the no-REDD case. As in the case of Indonesia, the use of REDD exerts larger impacts on Malaysia before 2030, when the bulk of

deforestation activities that have taken place in the past become less relevant in the longer term. In 2030, REDD reduces Malaysia's 500 decarbonization cost from 4.6% to 3% of GDP.
In common with Indonesia, the Malaysian agricultural sector benefits from REDD. For both the 500 and 650 stabilization scenarios, the expected loss by the sector is lower in the full REDD than in the no-REDD case. REDD allows Malaysia to import and spend less in emission permits as well as to reduce GDP contraction, maintaining overall demand for agricultural commodities and other products. This is in keeping with a general trend that all sectors would be slightly better off (through lower production contraction) in the full REDD than in the no-REDD case.

Fossil-fuel producing sectors are the most adversely affected (production contraction of -65% and -40% in the 500 and 650 stabilization scenarios, respectively). The services sector (which includes transport) is next most affected, followed by industry, and agriculture when REDD is absent. However, agriculture has minor negative impacts when REDD is in place.

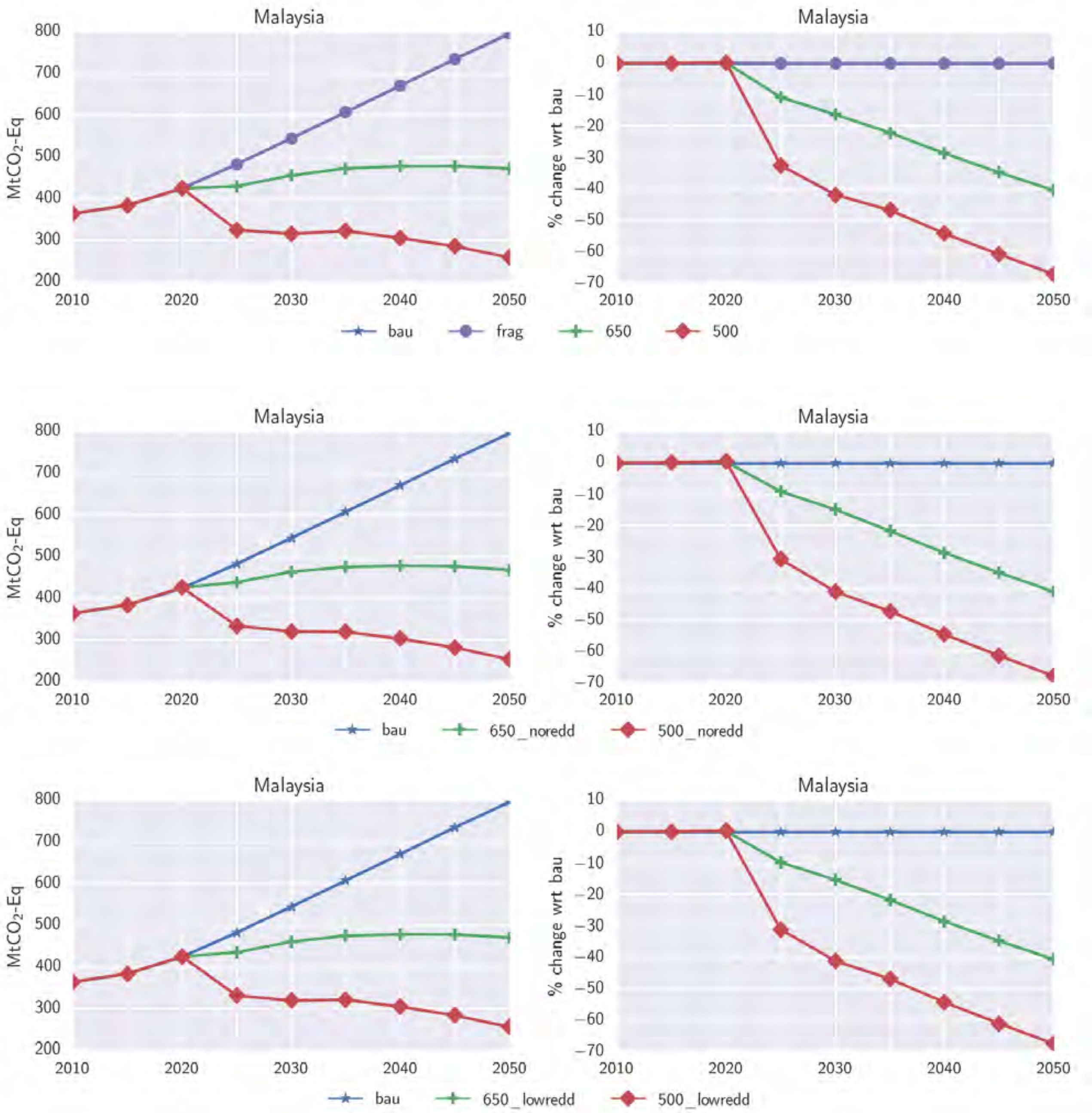


Figure 12 - GHG Emission Projections for Malaysia, Quantity (left), % Change over bau (right) for Full REDD (top), higher REDD cost (middle), no REDD (bottom)

bau = business as usual, frag = fragmented (policy), REDD = reduced emissions from forest degradation and deforestation.

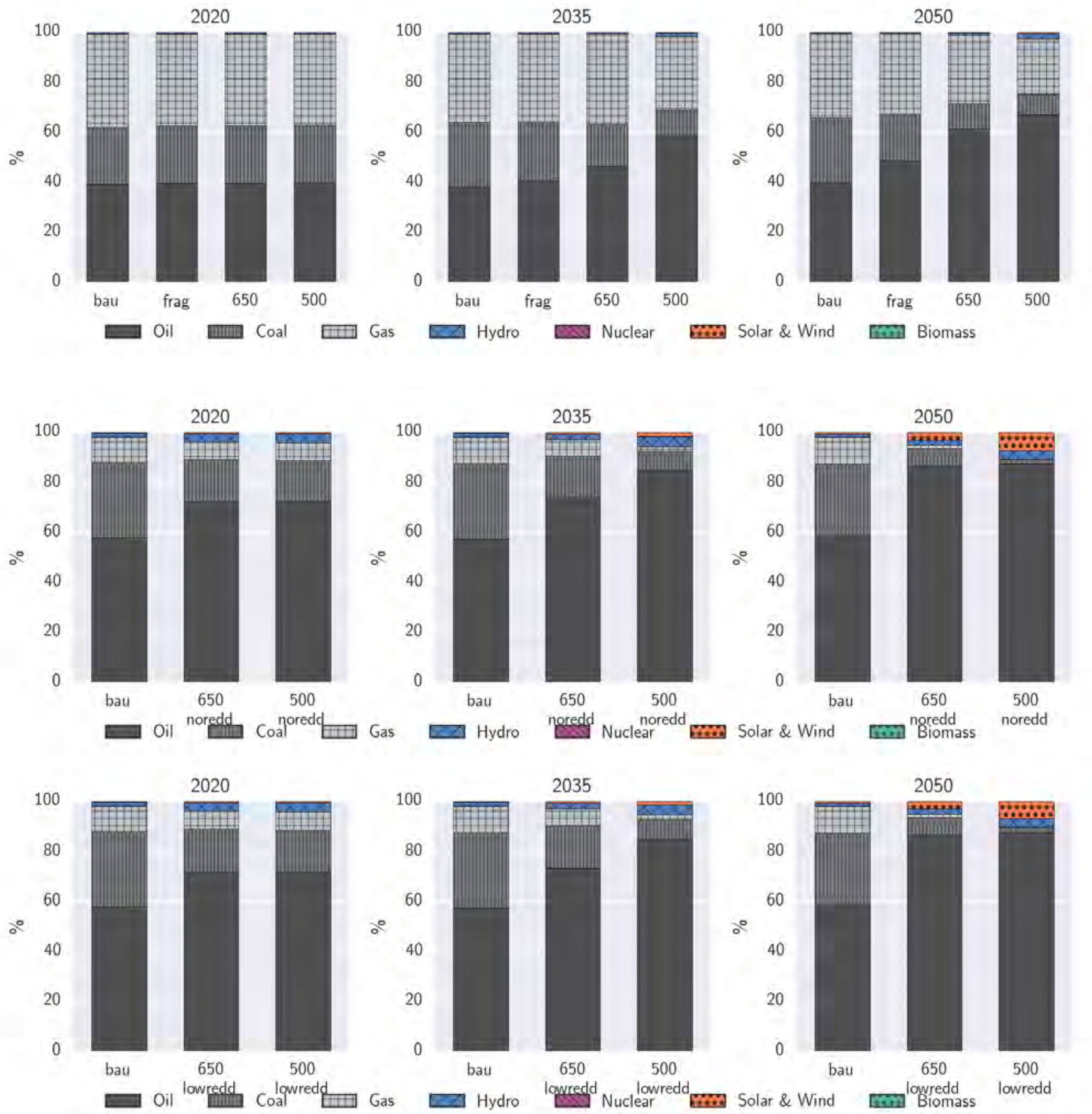


Figure 13 - Primary Energy Mix Projections for Malaysia, Full REDD (top), Higher REDD cost (middle), No-REDD (bottom)

bau = business as usual, ccs = carbon capture and storage, frag = fragmented (policy), REDD = reduced emissions from forest degradation and deforestation.

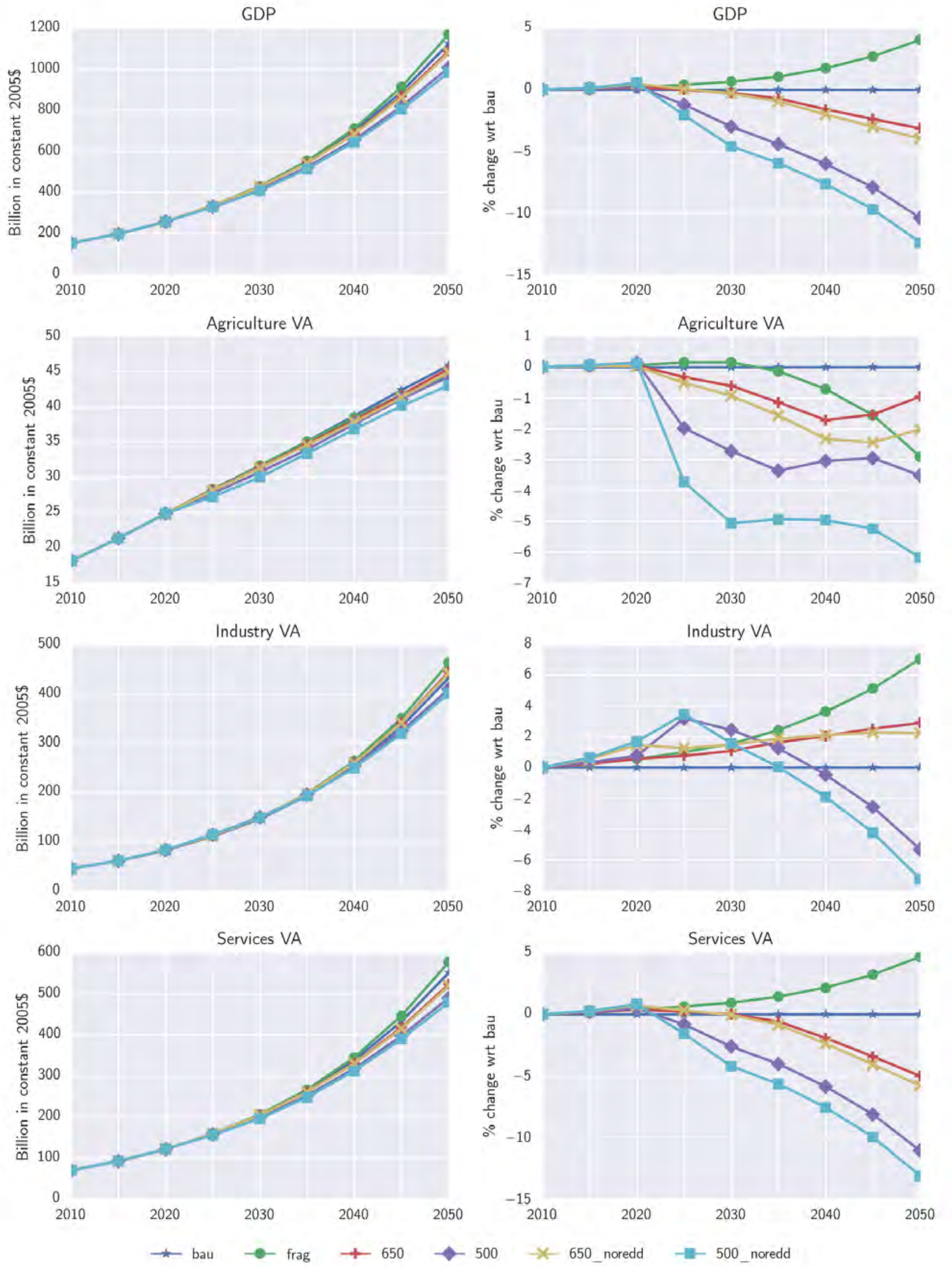


Figure 14 – Real GDP and Sectoral Value Added for Malaysia, Value (left), % Change from bau (right)
bau = business as usual.

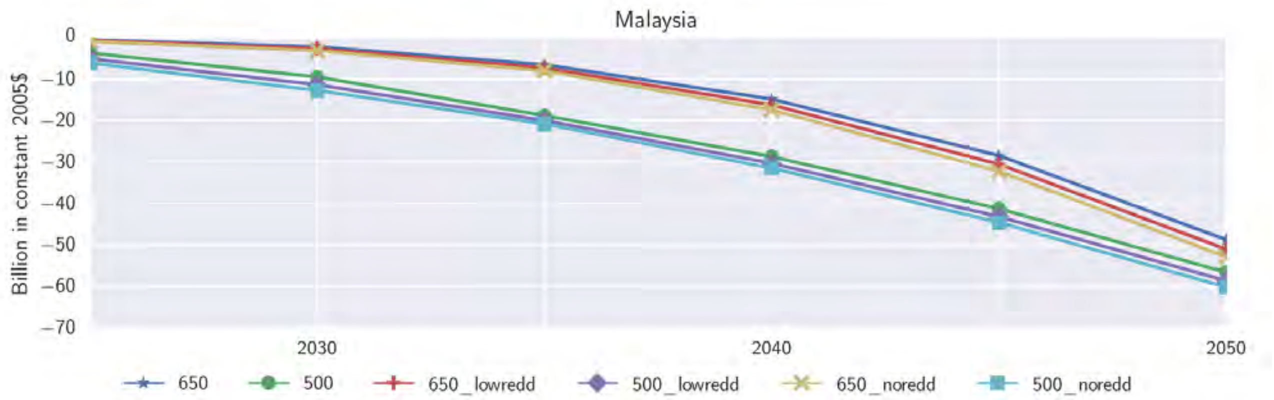


Figure 15: Projections of Carbon Permits Trade in Malaysia (> 0 selling < 0 buying)

REDD = reduced emissions from forest degradation and deforestation.

4.5 Philippines' 2020 Emissions Reduction Targets

The interpreted goal (based on energy sector targets) for the Philippines is 5.7% reduction of CO2 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 16), 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. 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.

4.6 Philippines in the long-term stabilization scenarios

Emissions reductions pathways

Figure 16 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.

Mechanisms of emissions reductions

Both the 500 ppm and 650 ppm decarbonization scenarios imply large carbon and energy intensity declines 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. Oil is the dominant energy source in all scenarios (Figure 17). 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.

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 18). 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.

Economic consequences of emissions reductions

GDP costs in the Philippines are estimated to reach -2.6%, -1.7% and 3.3% with respect to the baseline in 2050 in the fragmented, 650 and 500 stabilization scenarios respectively (Figure 19). It is interesting to note that the 650 stabilization scenario depicts lower costs than 2020 target until 2047, while the 500 stabilization scenario until 2028. This illustrates that the 2020 goal for the Philippines is relatively stringent.

The long term trends in sectoral production mimic what is observed in 2020, with a notable exception of the services sector. In 2050, industrial sector contracts (-28.3%, -17.4% in the 500 and 650 stabilizations respectively, with little sensitivity to REDD) followed by agriculture (-7.5%, -2.7%) in the 500 and 650 stabilizations, respectively). Clearly, the burden of the reduction falls primarily on carbon and energy intensive sectors. The service sector on the contrary, after a slight 2020 contraction with respect to the baseline grows more rapidly to be ultimately 13.5% and 10.8% higher than the baseline in the 500 and 650 stabilizations scenarios respectively. The Philippines has the highest baseline share of total value added from services among the DA5 group. The stabilization regime thus has relatively large potential to re-compose of economic activity towards that important sector. Given that the services sector usually grows in importance as economies develop, this also means that decarbonization can actually help to foster the expansion of sectors of the Philippine economy that are most vital to long-term development.

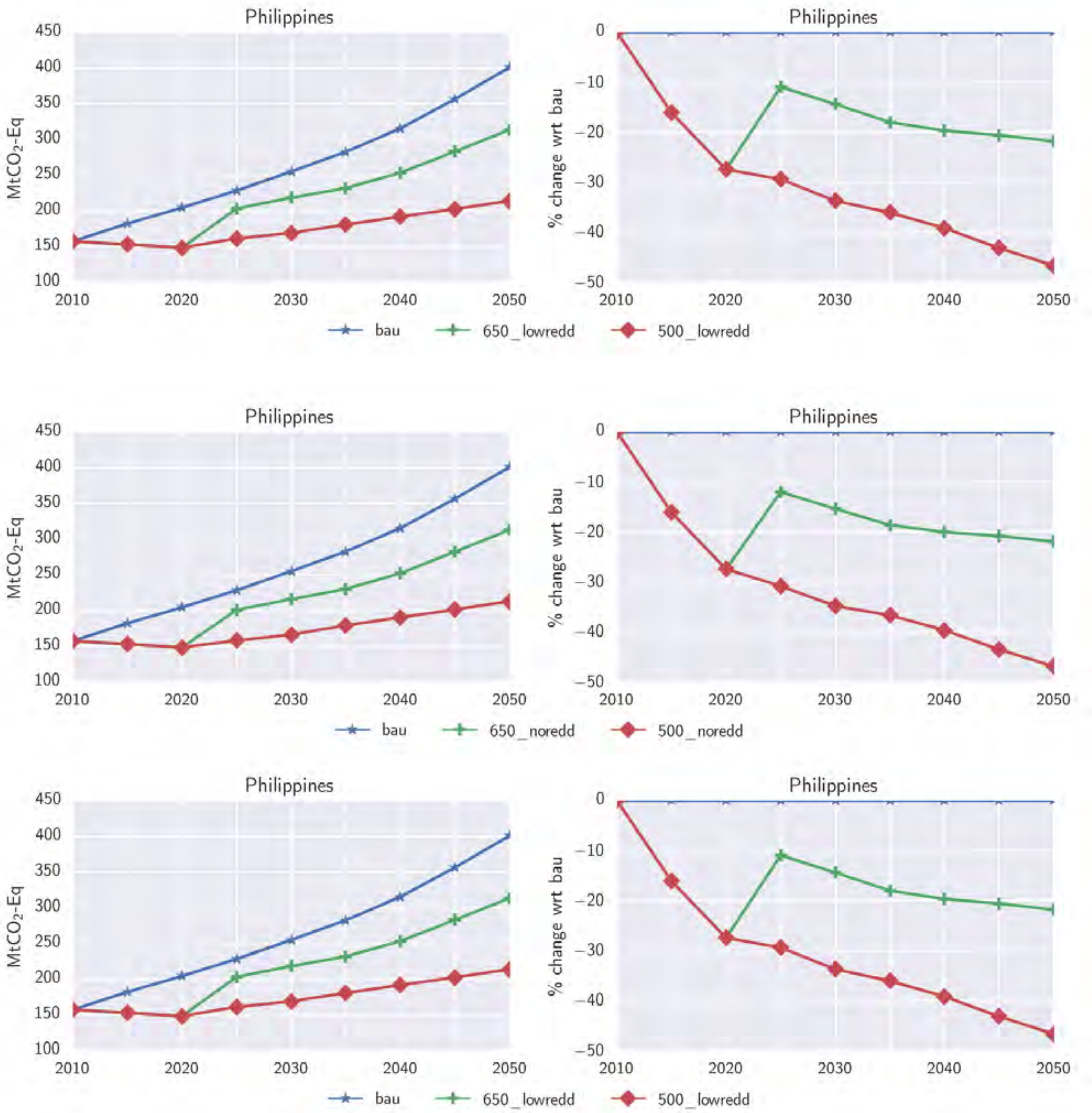


Figure 16 - GHG Emission Projections for the Philippines, Quantity (left), % Change over bau (right) for Full REDD (top). higher REDD cost (middle), no REDD (bottom).

bau = business as usual, frag = fragmented (policy), REDD = reduced emissions from forest degradation and deforestation.

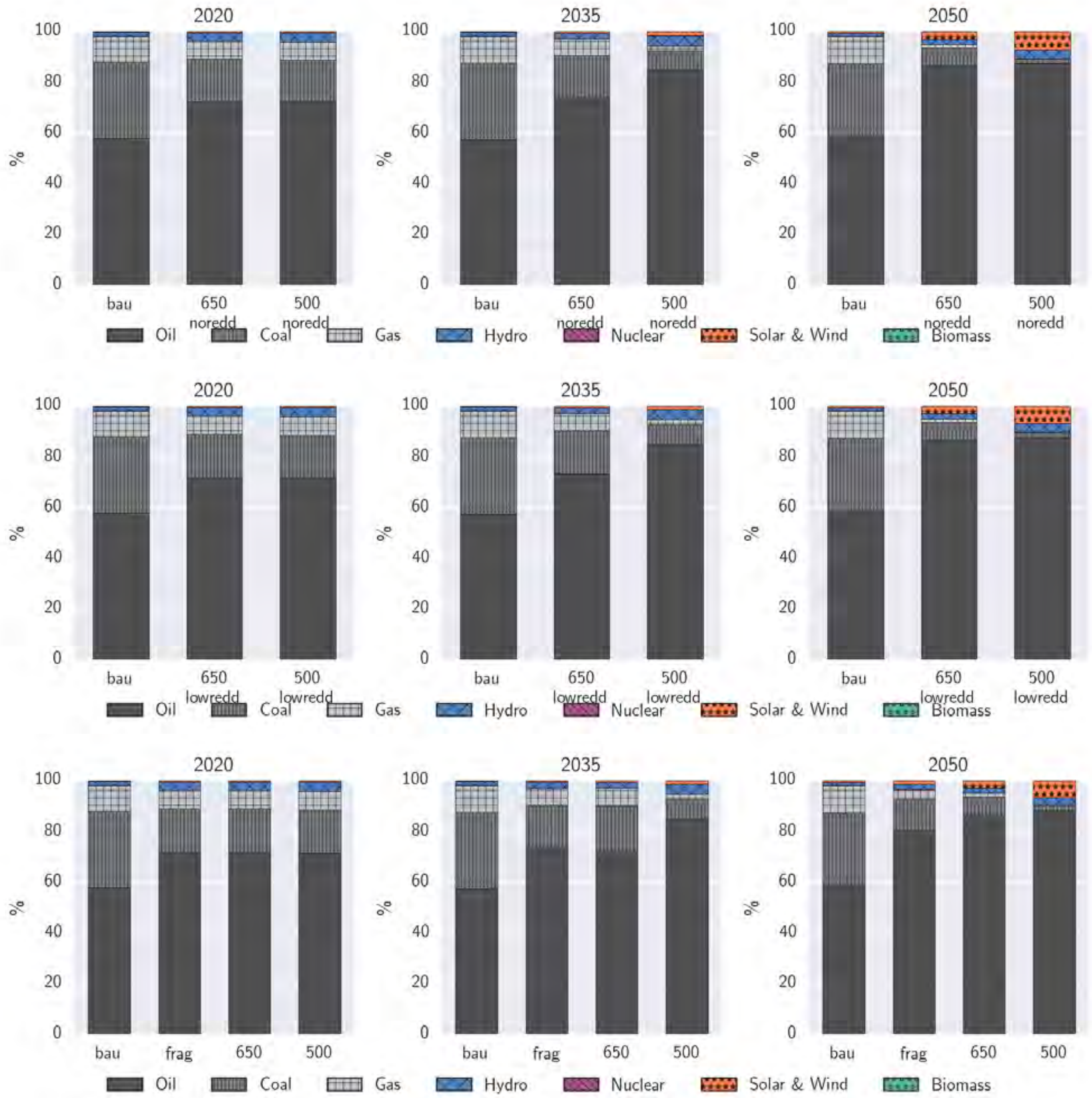


Figure 17 - Primary Energy Mix Projections for the Philippines, Full REDD (top), Higher REDD cost (middle), No-REDD (bottom)

bau = business as usual, ccs = carbon capture and storage, frag = fragmented (policy), REDD = reduced emissions from forest degradation and deforestation.

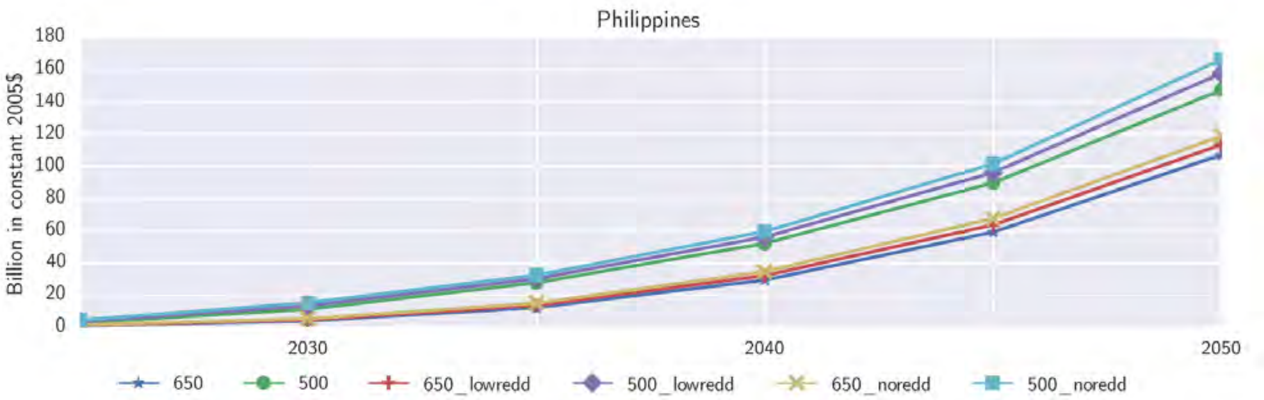


Figure 18 - Projections of Carbon Permits Trade in the Philippines, Full REDD (top), Higher REDD Cost (middle), No REDD (bottom) (> 0 selling < 0 buying)

REDD = reduced emissions from forest degradation and deforestation.

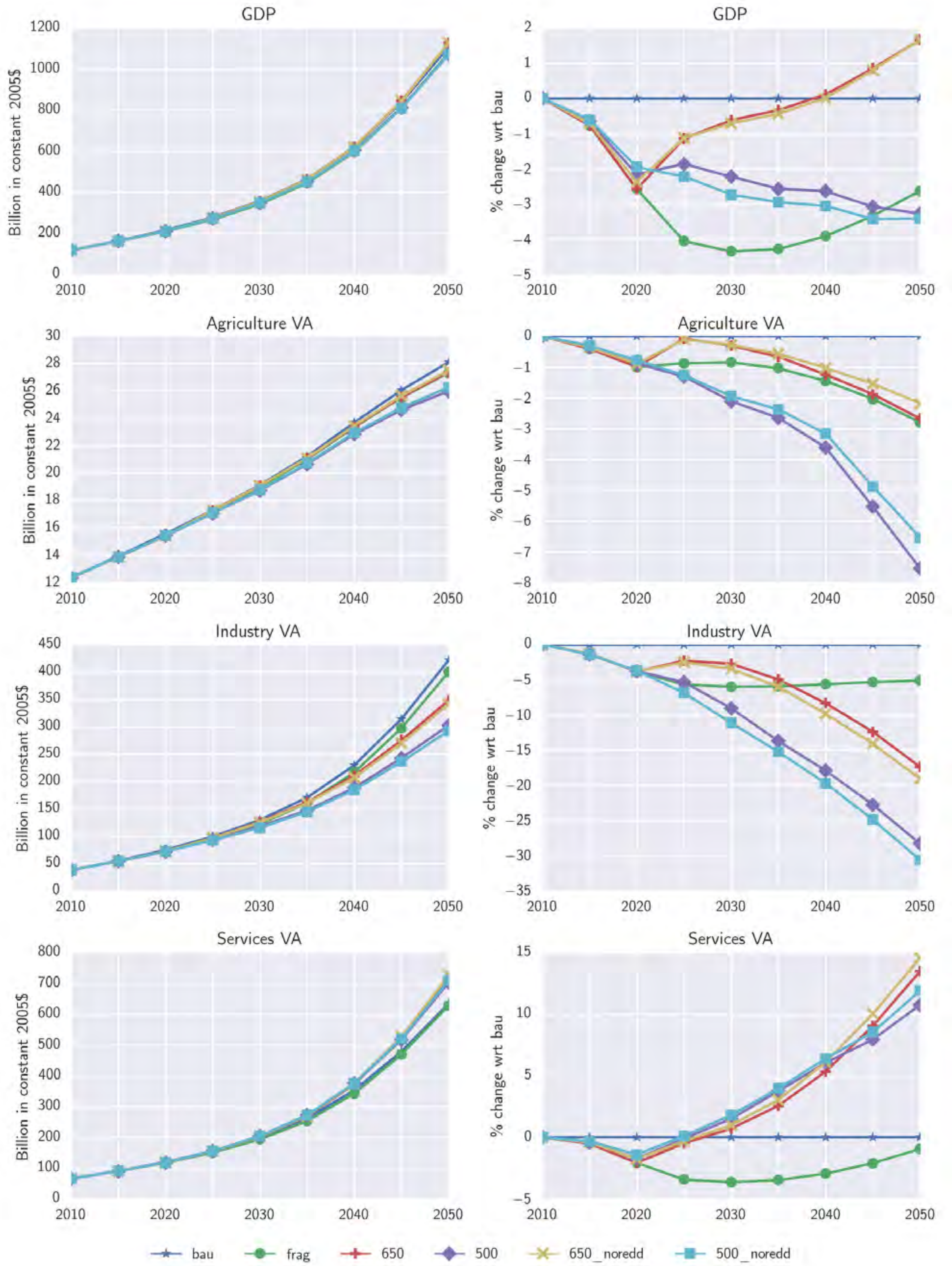


Figure 19 – Real GDP and sectoral Value Added in the Philippines, Value (left), % Change from bau (right)

bau = business as usual, frag = fragmented (policy), REDD = reduced emissions from forest degradation and deforestation.

4.6 Thailand's 2020 Emissions Reduction Targets

Thailand's policy target consists in a reduction in energy intensity of GDP by 8% by 2015 and 25% by 2030, compared with 2005 levels. These goals are similar to how Thailand is already performing in the baseline, according to ICES. Therefore, carbon and energy intensities do not diverge significantly from baseline levels, so that the energy mix is unchanged. This would also imply very little additional action and low cost for the country to meet its policy objectives.

Furthermore, the model finds that Thailand, due to the low level of decarbonization effort compared with the baseline scenario, can benefit from spillover effects from decarbonization in the rest of the world, and could become relatively more competitive. Eventually, the country can experience a small GDP increase especially in the no REDD case when the Copenhagen abatement effort imposes other countries a relatively higher decarbonization action. The benefiting sectors are industry (0.4%), services (0.5%) and agriculture with an increase of 0.1% (mainly rice and livestock) with respect to the baseline.

4.7 Thailand in the long-term stabilization scenarios

Emissions reductions pathways

Figure 20 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.

Mechanisms of emissions reductions

In terms of primary energy, oil is the fossil fuel that is least sensitive to emissions policies. All energy sources decline in quantity 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 (Figure 21). 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.

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 MtCO2eq in 650 ppm and 500 ppm, respectively (Figure 22).

Economic consequences of emissions reductions

After 2020, costs to GDP increase substantially, with 3% for 650 and 12.6% for 500 scenarios with REDD in place at low cost (Figure 23). The availability of REDD credits from other countries lowers the costs in 2050 (3% vs. 4.3% and 12.6% vs. 15% in the 650 and 500, respectively).

At the sectoral level, stabilization scenarios would entail larger production contraction in heavy industry. Services and agriculture are affected similarly.

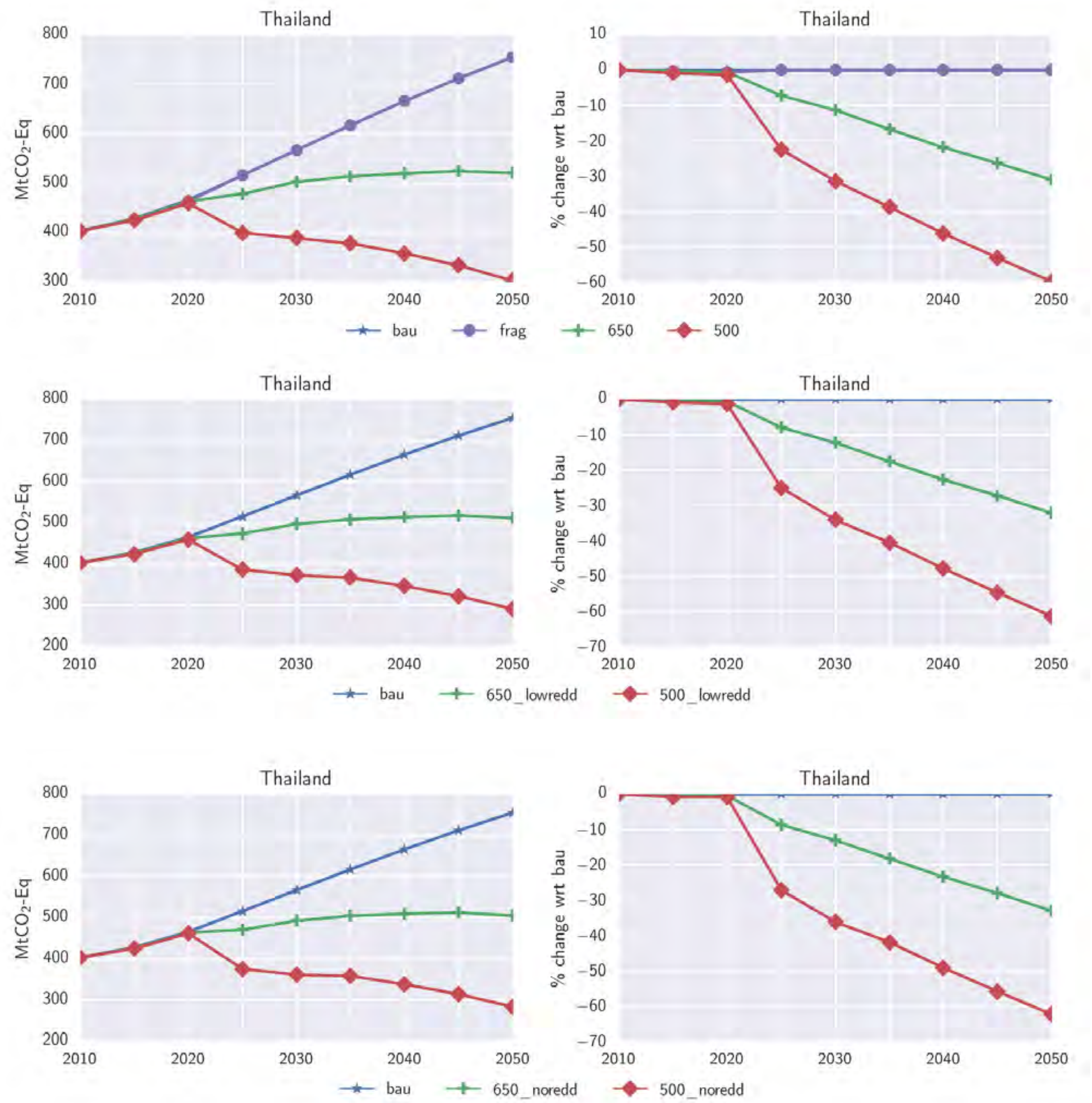


Figure 20 - GHG Emission Projections for Thailand, Quantity (left), % Change over bau (right) for Full REDD (top), higher REDD cost (middle), no REDD (bottom)

bau = business as usual, frag = fragmented (policy), REDD = reduced emissions from forest degradation and deforestation.

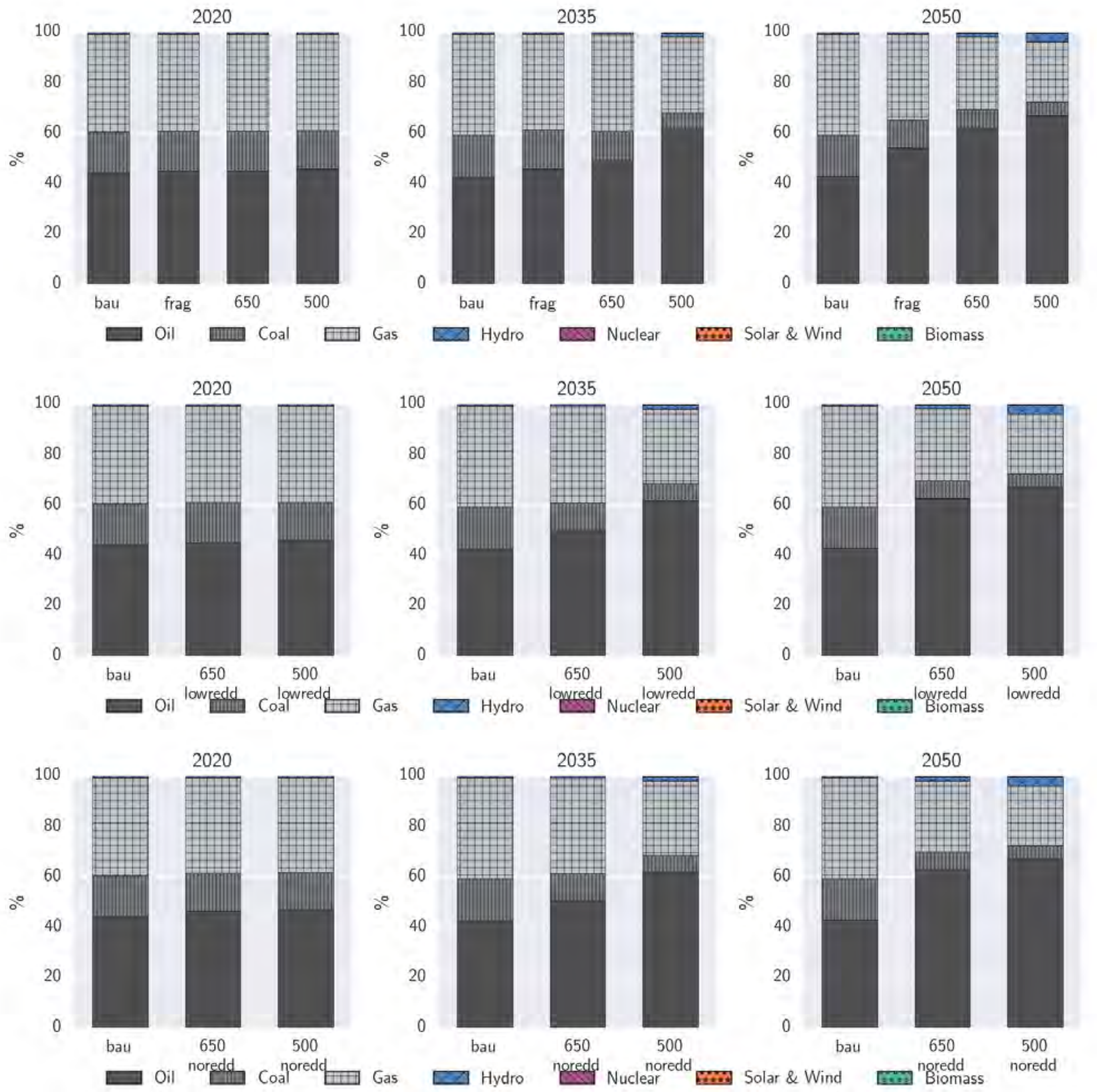


Figure 21 - Primary Energy Mix Projections for Thailand, Full REDD (top), Higher REDD cost (middle), No-REDD (bottom)

bau = business as usual, ccs = carbon capture and storage, frag = fragmented (policy), REDD = reduced emissions from forest degradation and deforestation.

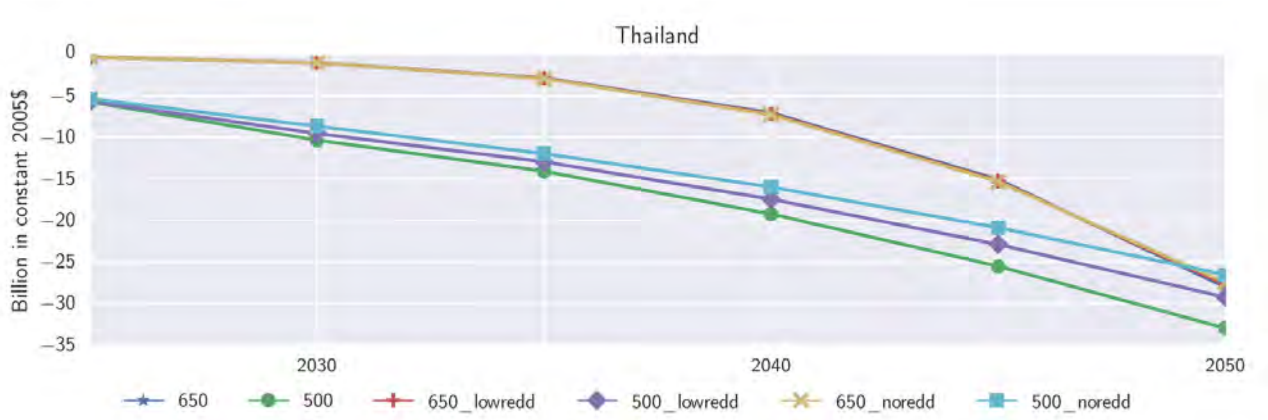


Figure 22 - Projections of Carbon Permits Trade in Thailand, Full REDD (top), Higher REDD Cost (middle), No REDD (bottom) (> 0 selling < 0 buying)

REDD = reduced emissions from forest degradation and deforestation.

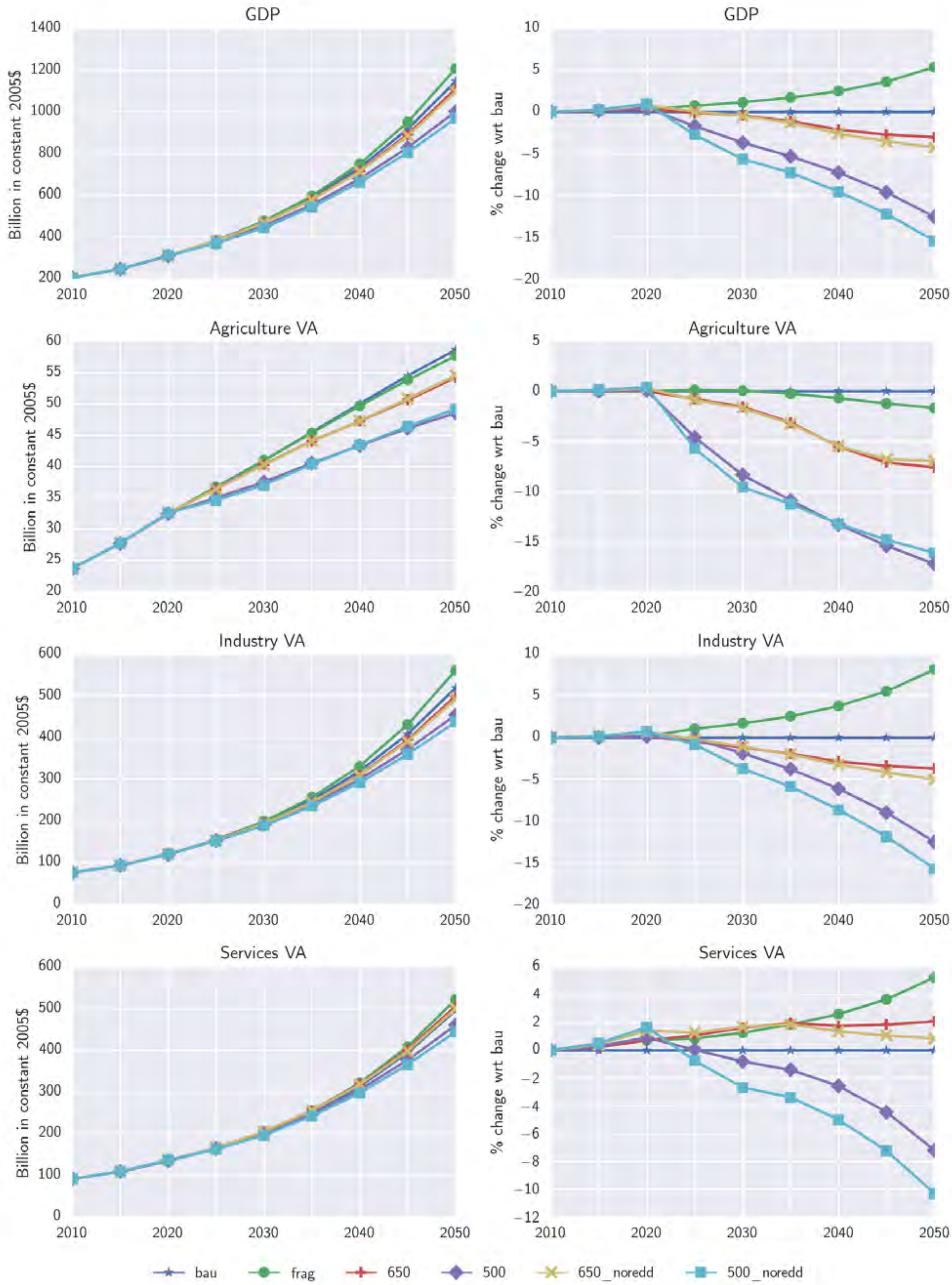


Figure 23 – Real GDP and Sectoral Value Added in Thailand, Value (left), % Change from bau (right)

bau = business as usual, frag = fragmented (policy), REDD = reduced emissions from forest degradation and deforestation.

4.9 Viet Nam's 2020 emissions reduction targets

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%).

4.10 Viet Nam in the Long-term Stabilization Scenarios

Emissions reductions pathways

Figure 24 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, 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.

Mechanisms of emissions reductions

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. 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% (Figure 25). In the absence of REDD, coal and gas energy use declines, but effects on renewable energy are minor.

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 MtCO2eq and 53 MtCO2eq in 650 ppm full-REDD and 500 ppm no-REDD scenarios, respectively (Figure 26).

Economic consequences of emissions reductions

GDP costs relative to baseline under the 500 scenario increase through 2030 to 6.4% with REDD and 8.7% without it, after which the rate of increase declines to reach 2.6% and 5.3% respectively in 2050. Under the 650 scenario, costs do not exceed those of the fragmented scenario reaching 0.6% in 2050 vs 2.7% of the fragmented (Figure 27).

Higher costs are experienced by the more emissions intensive sectors, heavy industry with a contraction of 6.7%. The services sector declines by 0.2% in the 500 REDD scenario, but much of this decline is an artifact of reduction in use of fossil fuel powered transport. In contrast, the policy burden only marginally affects agriculture, especially rice and livestock, with a slight decrease.

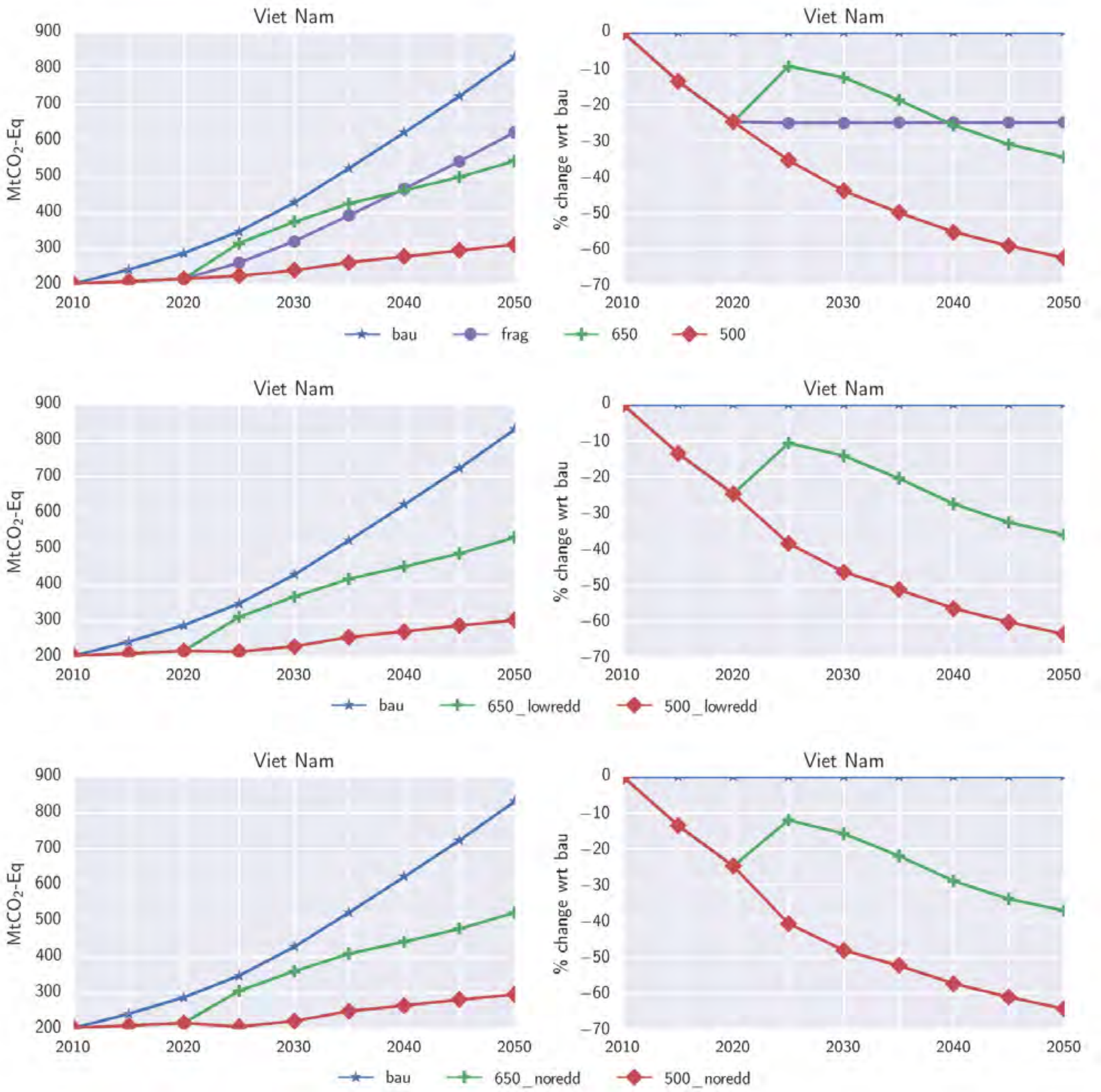


Figure 24 - GHG Emission Projections for Viet Nam, Quantity (left), % Change over bau (right) for Full REDD (top). higher REDD cost (middle), no REDD (bottom)

bau = business as usual, frag = fragmented (policy), REDD = reduced emissions from forest degradation and deforestation.

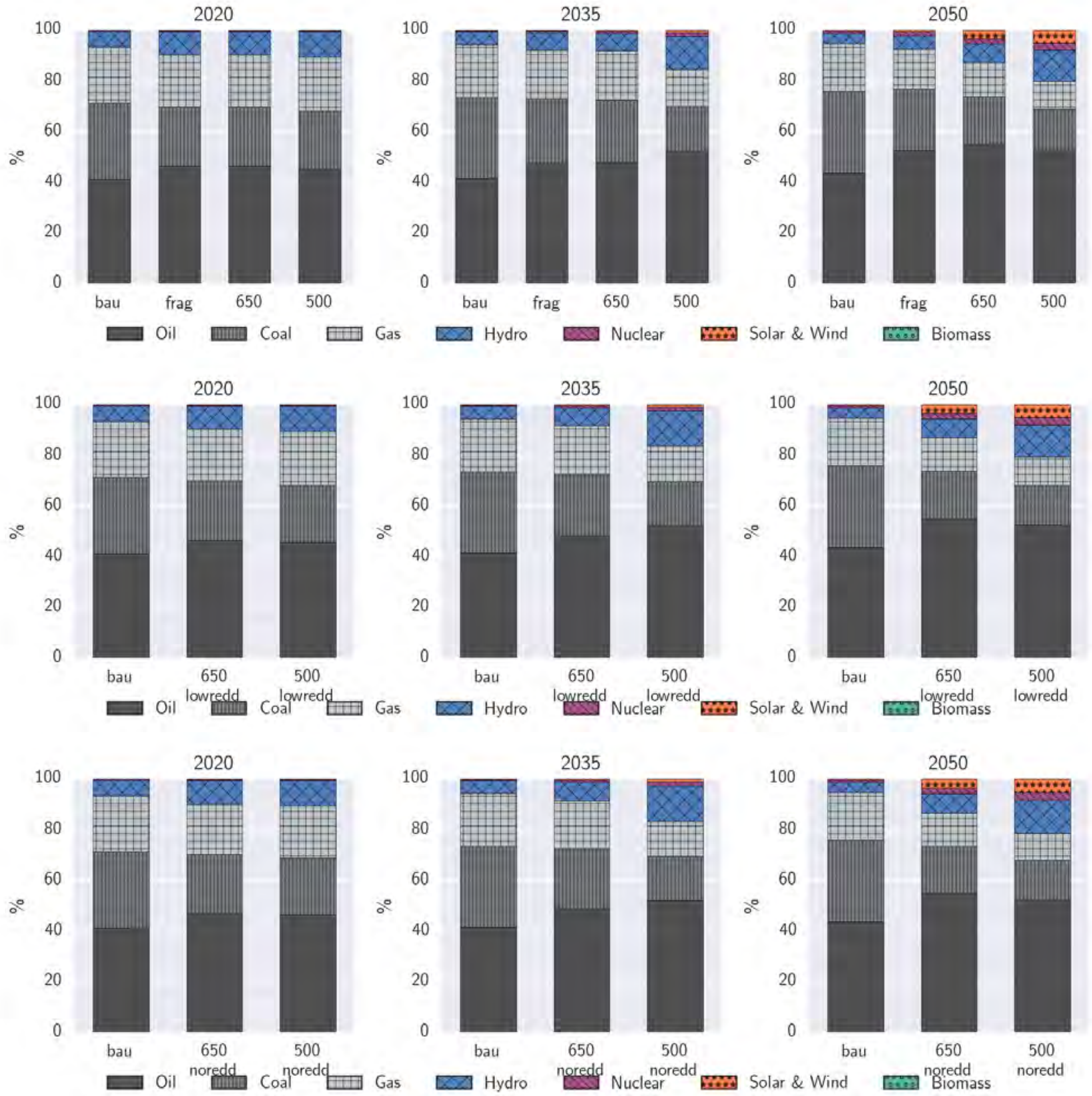


Figure 25 - Primary Energy Mix Projections for Viet Nam, Full REDD (top), Higher REDD cost (middle), No-REDD (bottom)
bau = business as usual, ccs = carbon capture and storage, frag = fragmented (policy), REDD = reduced emissions from forest degradation and deforestation.

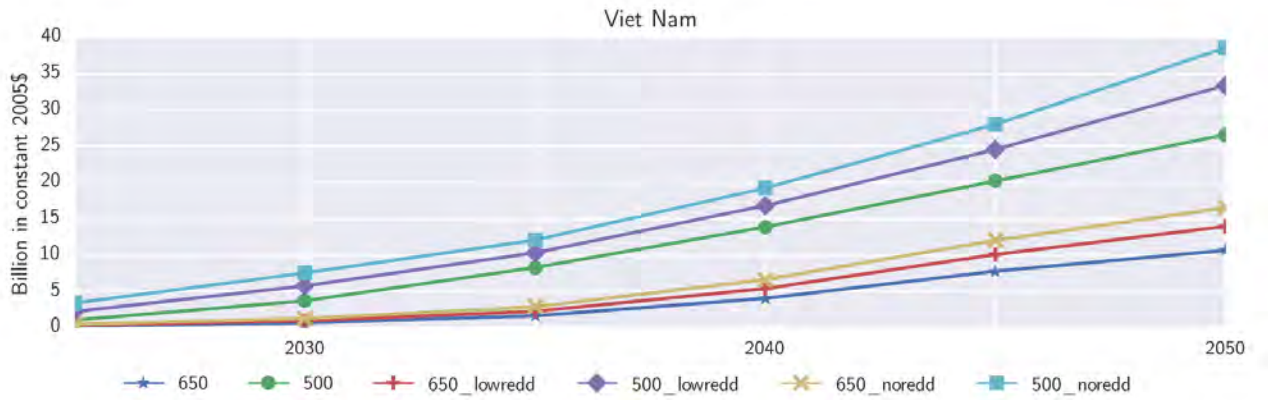


Figure 26 - Projections of Carbon Permits Trade in Viet Nam, Full REDD (top), Higher REDD Cost (middle), No REDD (bottom) (> 0 selling < 0 buying)

REDD = reduced emissions from forest degradation and deforestation.

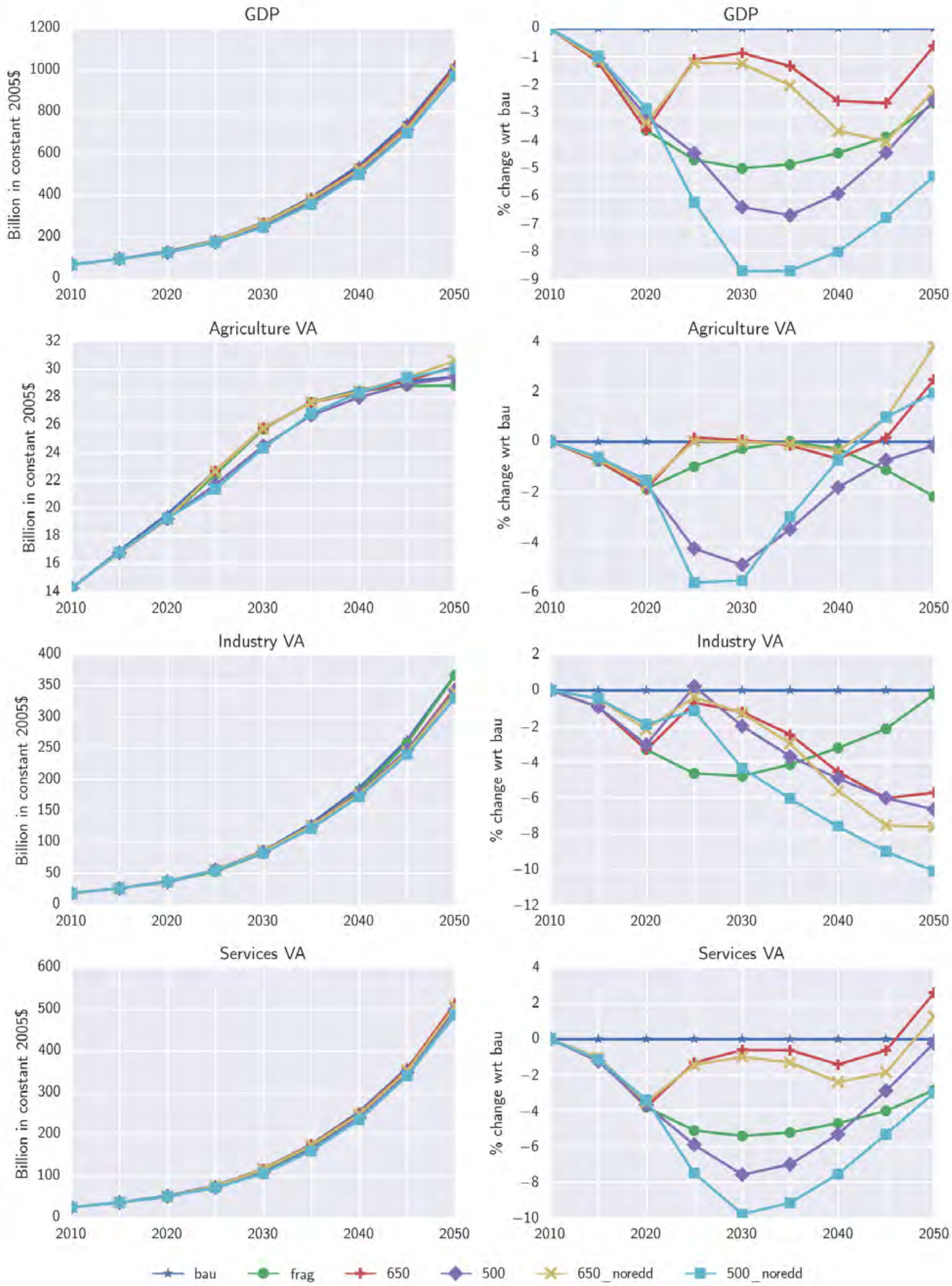


Figure 27 – Real GDP and Sectoral Production in Viet Nam, Value (left), % Change from bau (right)

bau = business as usual, frag = fragmented (policy), REDD = reduced emissions from forest degradation and deforestation.

5. Conclusions

The Southeast Asian region is particularly exposed to climatic changes and vulnerable to their adverse consequences, with expected economic losses that are much higher than the world average. In this context, it is critical to improve understanding of decarbonization dynamics, costs, and potentials. Prior mitigation policy cost assessments provide little detail on effects for Southeast Asia, and often do not reflect potential global mitigation policy timing and arrangements. Moreover, crucial characteristics, such as peat emissions for Indonesia, are often omitted or mischaracterized. There are in fact important commonalities, as well as substantial differences, in these country responses to climate stabilization policies.

The level of overall reduction that occurs is sensitive to REDD only in Indonesia. A majority of cumulative emissions reduction (55%–68%) under 500 ppm stabilization occurs even under the less stringent 650 ppm target across all the countries. The policy costs are highest in Viet Nam and Thailand in the case of REDD and are highest in Indonesia in the case of no REDD, where REDD allows GDP costs to be halved over the period. However, in all countries, REDD helps to lower GDP costs of climate stabilization. Given that Indonesia is by far the largest emitter in the region, this highlights the critical need for reduction of deforestation for the region's role in climate stabilization at acceptable cost, even if the global stabilization target is not highly stringent.

Similarly, Indonesia can export a cumulative discounted $288 billion of carbon credits with REDD in place under a 500 ppm scenario; these exports virtually disappear when REDD is absent. In the absence of REDD, however, other major carbon credit exporters in the region respond to globally higher carbon prices and increase exports. Although the Philippines has the highest unit GDP cost for emissions reduction, it has the highest export value relative to GDP. This is due to two factors: its baseline emissions growth is lower than that of the other countries while at the same time its baseline population growth is higher than that of other countries. Given that the emissions allocation criterion is based on emissions per capita this implies that it has excess permits to sell.

However, REDD also requires upfront investment in policies and institutions. The forestry sector in Southeast Asia currently has many problems of tenure, perverse incentives, and corruption. 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 that ensure that REDD is effective, efficient and equitable.

Industry is the most heavily affected sector across the countries, although Thailand has little differentiation in impacts among sectors under 500 ppm stabilization. Agriculture is positively affected when REDD is present in Indonesia, as are services in the Philippines, while industry is particularly negatively affected in the latter. The presence of REDD generally reduces policy costs for industry and services in all countries.

Global and coordinated action is found to be critical to the cost effectiveness of emissions stabilization policies. Coordination, in the form of a carbon market, allows abatement to be concentrated where it is cheapest, so as to minimize total abatement cost. As a result, 650 stabilization has a similar cost to the region to current fragmented targets, but achieves much higher levels of emissions reductions.

Finally, the analysis also showed that only some of the countries have short-term emissions targets that are consistent with a stabilization scenario at 650ppm: these are Indonesia, Philippines and Viet Nam. None of the countries' mid-term targets are coherent with more ambitious stabilization scenario at 500ppm.

References

ADB, (2011a), “Key Indicators for Asia and the Pacific 2011”. 42nd edition, Asian Development Bank, Manila.

ADB (2011b), “Long-Term Projections of Asian GDP and Trade”. Asian Development Bank, Manila.

ADB (2009), “The Economics of Climate Change in Southeast Asia: A Regional Review”. Asian Development Bank, Manila.

Akashi O., Hijioka Y, Masui T, Hanaoka T, Kainuma M. (2012), “GHG emission scenarios in Asia and the world: The key technologies for significant reduction”. Energy Economics, 34 (2012) S346-S358.

Anthoff, D., Nicholls, R.J., & Tol, R.S.J. (2010) The economic impact of substantial sea-level rise. Mitigation and Adaptation Strategies for Global Change, 15, 321-335

Avetisyan, Misak, A. Golub, T. Hertel, S. Rose and B. Henderson (2011), Why a Global Carbon Policy Could Have a Dramatic Impact on the Pattern of the Worldwide Livestock Production, Applied Economic Perspectives and Policy, pp. 1–22 at http://web.ics.purdue.edu/~hertel/data/uploads/publications/avetisyan-et-al-aepp.pdf

Blanford G.J., Rose S. K., Tavoni M. (2012), “Baseline projections of energy and emissions in Asia”. Energy Economics, 34, Supplement 3, S284–S292.

Bohringer, C., Fisher, C. and K.E. Rosendahl (2010), “The global effects of subglobal climate policies”. The B.E. Journal of Economic Analysis & Policy 10(2 (Symposium)), Article 13.

Bohringer C., Rutherford T. and Tol R., (2009), “The EU 20/20/20 targets: an Overview of the EMF22”. Energy Economics 31, 268–273.

Bosello, Francesco, Eboli, Fabio and Pierfederici, Roberta, Assessing the Economic Impacts of Climate Change (February 10, 2012). FEEM (Fondazione Eni Enrico Mattei), Review of Environment, Energy and Economics (Re3),http://dx.doi.org/10.7711/feemre3.2012.02.002

Bosello, Francesco and Parrado, Ramiro, Climate Change Impacts and Limited Market-driven Adaptation (September 25, 2014). Review of Environment, Energy and Economics (Re3), http://dx.doi.org/10.7711/feemre3.2014.09.004

Bosello, F., Eboli F., Parrado R. and Rosa R. (2010), “REDD in the Carbon Market: A General Equilibrium Analysis”. FEEM Note di Lavoro 2010.142.

Bosello, F., Lazzarin, M., Roson, R. and R.S.J. Tol (2007), “Economy-wide estimates of climate change implications: sea-level rise”, Environment and Development Economics, 37:549–571.

Bosello, F., Roson, R. and R.S.J. Tol (2006), “Economy wide estimates of the implications of climate change: human health” Ecological Economics, 58, 579-591.

Burniaux, J.-M., Truong, T.P., (2002), “GTAP-E an energy-environmental version of the GTAP model”. GTAP Technical Papers, No. 16. Center for Global Trade Analysis, Purdue University, West Lafayette, Indiana, USA 47907-1145.

Busch, J., Lubowski, R., Godoy, F., Steininger, M., Yusuf, A., Austin, K., Hewson, J., Juhn, D., Farid, M., Boltz, F. (2012) “Structuring economic incentives to reduce emissions from deforestation within Indonesia”. Proc. Natl. Acad. Sci. USA 2012, 109, 1062–1067.

Calvin, K., Clarke. L., Krey, V., Blanford, G., Jiangd, K., Kainuma, M., Kriegler, E., Luderer, G., Shukla, P.R., (2012a), “The role of Asia in mitigating climate change: Results from the Asia modeling exercise”. Energy Economics, 34 (Supplement 3) S251-S260.

Calvin, K., Fawcett, a., Kejung, J., (2012b), Comparing model results to national climate policy goals: Results from the Asia modeling exercise, Energy Economics, 34, Supplement 3, S306-S315.

Calzadilla, A., Rehdanz, K., Tol, R. (2008), “The Economic Impact of More Sustainable Water Use in Agriculture: A CGE Analysis”. Research Unit Sustainability and Global Change, FNU-169. Hamburg University.

Chaturvedi V., Waldhoff S., Clarke L., Fujimori S., (2012). “What are the starting points? Evaluating base-year assumptions in the Asian Modeling Exercise”. Energy Economics, 34 (2012) S251-S260.

Ciscar, J., A. Iglesias, L. Feyen, L. Szabó, D. Van Regemorter, B. Amelung, R. Nicholls, P. Watkiss, O.B. Christensen, R. Dankers, L. Garrote, C.M. Goodess, A. Hunt, A. Moreno, J. Richards, and A. Soria, (2011), “Physical and economic consequences of climate change in Europe”. Proceedings of the National Academy of Sciences of the United States of America, 108(7), 2678-2683.

Corruption Eradication Commission. 2013. Integritas Sektor Publik Indonesia 2012: Fakta Korupsi Dalam Layanan Publik. Jakarta: Corruption Eradication Commission.

Darwin, R. F. and Tol, R. S. J. (2001), “Estimates of the Economic Effects of Sea Level Rise”. Environmental and Resource Economics, 19, 113-129.

Deke, O., Hooss, K. G., Kasten, C., Klepper, G., Springer, K. (2002), “Economic Impact of Climate Change: Simulations with a Regionalized Climate-Economy Model”. Kiel Institute of World Economics, Kiel, 1065.

Dixon P., Rimmer M. (2002), “Dynamic general equilibrium modeling for forecasting and policy”. North Holland.

DNPI, (2010), “Indonesia’s greenhouse gas abatement cost curve”. National Council for Climate Change. Jakarta.

Dowling P., Russ P., (2012), “The benefit from reduced energy import bills and the importance of energy prices in GHG reduction scenarios”. Energy Economics, 34 (Supplement 3) S429-S435

Eboli, F., Parrado, R. and R. Roson (2009), “Climate Change Feedback on Economic Growth: Explorations with a Dynamic General Equilibrium Model”. Environment and Development Economics, Volume 15 (5), pp 515 -533.

Eliasch, Johann (2008), “Climate Change: Financing Global Forests”, Norwich, UK: The Stationery Office.

Energy Modeling Forum 21, 2006. John Weyant and Francisco C. de la Chesnaye. Multi-Greenhouse Gas Mitigation and Climate Policy. The Energy Journal

European Commission (2008), “Package of implementation measures for the EU’s objectives on climate change and renewable energy for 2020”. Commission Staff working document SEC (2008) 85 II.

European Commission (2010), “Analysis of options to move beyond 20% greenhouse gas emission reductions and assessing the risk of carbon leakage”. Commission Staff working document SEC (2010) 650.

FAO (2001), “Global Forest Resources Assessment 2000”. Main report, FAO Forestry paper 140, ISSN 0258-6150, Rome.

FAO (2006), “Global Forest Resources Assessment 2005: Progress towards sustainable forest”. management”. FAO Forestry paper 147. Food and Agricultural Organization. Rome, Italy.

FAO (2010), “Global forest resources assessment 2010 country reports”. Food and Agriculture Organization, Rome, Italy.

Golub, Alla., Thomas Hertel, Huey-Lin Lee, Steven Rose, Brent Sohngen (2009), “The opportunity cost of land use and the global potential for greenhouse gas mitigation in agriculture and forestry,” Resource and Energy Economics 31 pp 299-319.

Golub, Alla., B. Henderson, T. Hertel, S. Rose, M. Avetisyan, B. Sohngen (2010), “Effects of GHG Mitigation Policies on Livestock Sectors”. GTAP Working Paper No.62.

Gusti, M., Havlik, P., Oberstenier, M., (2008), “Technical description of the IIASA model cluster”, International Institute for Applied System Analysis (IIASA).

Hafner, S. (2003), Trends in maize, rice, and wheat yields for 188 nations over the past 40 years: a prevalence of linear growth, Agriculture, Ecosystems & Environment. 97(1–3): 275-283.

Hanaoka, T., Kainuma, M., (2012), “Low-carbon transitions in world regions: comparison of technological mitigation potential and costs in 2020 and 2030 through bottom-up analyses”, Sustainability Science, Volume 7, Issue 2, pp 117-137.

Hoa, N. T., Gomi, K., Matsuoka, Y., Fujino, J., Kainuma, M., Shrestha, R. M.: Sustainable Low-carbon development towards 2030 in Vietnam, available at http://2050.nies.go.jp/LCS, February 2010.

Hooijer A, Page S, Canadell JG, Silvius M, Kwadijk J, Wosten H, Jauhiainen J (2010), "Current and future CO2 emissions from drained peatlands in Southeast Asia". Biogeosciences 2010, 7:1-10.

IEA, (2009), “World energy outlook 2009”. International Energy Agency, Paris.

IEA, (2011), “World energy outlook 2010”. International Energy Agency, Paris.

IEA, (2012), “World energy outlook 2011”. International Energy Agency, Paris.

IEA, (2013), “Dataset: World - Renewable and Waste Energy Statistics”. Data extracted on 18 Sep 2013 13:12 UTC (GMT) from OECD iLibrary.

IPCC (1996), “Climate Change 1995. Economic and Social Dimensions of Climate Change, Contribution of Working Group III to the Second Assessment Report of the Intergovernmental Panel on Climate Change” Bruce, J.P., Lee., H., Haites, E.F. (eds.), Cambridge University Press , Cambridge, UK

IPCC (2001), “Climate Change 2001: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change”, McCarthy, J., Canziani O.F., Leary, N.A., Dokken, D.J., White, K.S. (eds), Cambridge University Press, Cambridge, UK.

IPCC (2007), “Climate Change 2007: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change”, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson (eds), Cambridge University Press, Cambridge, UK.

IPCC (2014) “Climate Change 2014: Mitigation of Climate Change”. Contribution of Working Group III to the fifth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge.

Kindermann GE, Obersteiner M, Sohngen B, Sathaye J, Andrasko K, Rametsteiner E, Schlamadinger B, Wunder S, Beach R (2008), “Global cost estimates of reducing carbon emissions through avoided deforestation”. Proc. Natl. Acad. Sci. USA 105(30):10302-10307.

Kriegler E, Tavoni M, Aboumahboub T, et al. (2013) What does the 2°c target imply for a global climate agreement in 2020? the limits study on durban platform scenarios. Clim Change Econ 04:1340008. doi: 10.1142/S2010007813400083

Kriegler E., Weyant J.P., Blanford G.J., Krey V., Clarke L, Edmonds J., Fawcett A., Luderer G., Riahi K., Richels R., Rose S.K., Tavoni M., van Vuuren D. P. (2014), “The role of technology for achieving climate policy objectives: overview of the EMF 27 study on global technology and climate policy strategies”. Climatic Change, Volume 123, Issue 3-4, pp 353-367.

Labriet M., Kanudia A., Loulou R. (2012), “Climate mitigation under an uncertain technology future: A TIAM-World analysis”. Energy Economics, 34 (2012) S366-S377

Luderer. G., Pietzcker, R., Kriegler, E., Haller, M., Bauer, N., (2012), “Asia's role in mitigating climate change: A technology and sector specific analysis with ReMIND-R”. Energy Economics, 34 (2012) S378-S390.

Luderer G., Pietzcker R.C., Kriegler E., Haller M., Bauer N. (2012), “Asia's role in mitigating climate change: A technology and sector specific analysis with ReMIND-R”. Energy Economics, 34 (Supplement 3), S378-S390.

Massetti, E. and M. Tavoni (2012), “A Developing Asia emission trading scheme (Asia ETS)”. Energy Economics, 34 (Supplement 3), S436–S443.

McKinsey (2009) “Pathways to a Low-Carbon economy. Version 2 of the global greenhouse gas abatement cost curve”. McKinsey and Company, Seattle, WA.

Michetti M., Parrado R. (2012), “Improving Land-use modelling within CGE to assess Forest-based Mitigation Potential and Costs”. Working Paper No. 2012.019.

Ministry of Energy (2009), “Thailand’s renewable energy and its energy future: opportunities and challenges”. Ministry of Energy, Bangkok.

Mi R., Ahammad H., Hitchins N., Heyhoe E. (2012), “Development and deployment of clean electricity technologies in Asia: A multi-scenario analysis using GTEM”. Energy Economics, 34 (Supplement 3), S399-S409

Narayanan, G.B. and T.L. Walmsley, Eds. (2008), “Global Trade, Assistance, and Production: The GTAP 7 Data Base”. Center for Global Trade Analysis, Purdue University.

Nelson, G.C., Rosegrant, M.W., Palazzo, A., Gray, I., Ingersoll, C., Robertson, R., Tokgoz, S., Zhu, T., Sulser, T.B., Ringler, C., Msangi, S., and You, L., (2010) "Food Security, Farming, and Climate Change to 2050: Scenarios, Results, Policy Options" International Food Policy Research Institute.

Nguyen Thai Hoa, Kei Gomi and Yuzuru Matsuoka (2010), "A scenario for Sustainable Low-carbon Development in Viet Nam towards 2030".

Nordhaus, W. (2007) "The Stern Review on the Economics of Climate Change"
Nordhaus, D. W, J. Boyer (2000), "Warming the World: Economic Models of Global Warming." The MIT Press

Office of the President of the Philippines (2011), "National Climate Change Action Plan 2011-2028". Climate Change Commission.

Okagawa, A., Masui, T., Akashi,O., Hijioka, Y., Matsumoto, K., Kainuma,M., (2012), Assessment of GHG emission reduction pathways in a society without carbon capture and nuclear technologies), Energy Economics, 34 (Supplement 3), S391–S398.

Olz, S., Beerepoot, M., (2010), "Deploying Renewables in Southeast Asia: Trends and Potentials". International Energy Agency/OECD, Paris.

Orecchia, C., Parrado, R. (2013), "A Quantitative Assessment of the Implications of Including Non-CO2 Emissions in the European ETS". FEEM Working Paper No. 100.2013.

Paltsev S., Morris J., Cai Y., Karplus V., Jacoby H. (2012), "The role of China in mitigating climate change". Energy Economics, 34 (Supplement 3), S444-S450.

Paltsev, S., Reilly, J.M., Jacoby, H.D. and K.H. Tay (2007), "How (and why) do climate policy costs differ among countries?", in Schlesinger, M., Kheshgi, H., Smith., J., de la Chesnaye, F., Reilly, J.M., Wilson, T. and C. Kolstad (eds.) "Human induced climate change: An interdisciplinary assessment", Cambridge University Press, Cambridge.

Pant, H., Tulpule, V. and B.S. Fisher (2004), "The welfare consequences of emission trading with pre-existing taxes", ABARE Conference Paper 04.05.

Phdungsilp, A., Wuttipornpun, T., (2013), Analyses of the decarbonizing Thailand's energy system toward low-carbon futures, Renewable and Sustainable Energy Reviews, Volume 24, August 2013, Pages 187–197.

Philippine Climate Change Commission 2010. "National Framework Strategy on Climate Change 2010-2022"

Rogelj J., M. Meinshausen and R. Knutti (2012), "Global warming under old and new scenarios using IPCC climate sensitivity range estimates", Nature Climate Change, DOI: 10.1038/NCLIMATE1385

Ronneberger, K., Berrittella, M., Bosello, F. and R.S.J. Tol (2009), "KLUM@GTAP: introducing biophysical aspects of land use decisions into a general equilibrium model. A coupling experiment", Environmental Modelling and Assessment, Vol. 14, n. 2.

Rose, S., Finn, S., Scheele, E., Mangino, J., Delhotal, K., (2007), "Detailed greenhouse gas emissions data for global economic modeling". US Environmental Protection Agency, Washington, DC.

Rose, S.K., Avetisyan, M., and Hertel, T. W (2010), "Development of the Preliminary Version 7 Non-CO2 GHG Emissions Dataset", GTAP Research Memorandum No. 17. Center for Global Trade Analysis, Purdue University.

Rose SK, et al. (2012), "Land-based mitigation in climate stabilization". Energy Econ 34: 365–380.

Roson, Roberto and van der Mensbrugghe, Dominique, Climate Change and Economic Growth: Impacts and Interactions (April 23, 2010). University Ca' Foscari of Venice, Dept. of Economics Research Paper Series No. 07_10. Available at SSRN: http://ssrn.com/abstract=1594708 or http://dx.doi.org/10.2139/ssrn.1594708

Saveyn, B., Paroussos, L., Ciscar, JC., (2012), "Economic analysis of a low carbon path to 2050: A case for China, India and Japan, Energy Economics". Energy Economics, 34 (Supplement 3), S451–S458.

Shrestha R.M., Shakya S.R., (2012), "Benefits of low carbon development in a developing country: Case of Nepal". Energy Economics, 34 (Supplement 3), S503-S512.

Stern, N., S. Peters, V. Bakhshi, A. Bowen, C. Cameron, S. Catovsky, D. Crane, S.Cruickshank, S. Dietz, N. Edmonson, S.-L. Garbett, L. Hamid, G. Hoffman, D. Ingram, B. Jones, N. Patmore, H. Radcliffe, R. Sathiyarajah, M. Stock, C. Taylor, T. Vernon, H. Wanjie, and D. Zenghelis (2006), Stern Review: The Economics of Climate Change, HM Treasury, London, at http://www.hm treasury.gov.uk/stern_review_report.htm

Stiglitz, J. A. Sen and J.P. 2009. Report of the commission on the measurement of economic performance et social progress. CMEPSP, Paris, France.

Tavoni M, Kriegler E, Aboumahboub T, et al. (2013) The distribution of the major economies' effort in the durban platform scenarios. Clim Change Econ 04:1340009. doi: 10.1142/S2010007813400095

Thepkhun, P., Limmeechokchai, B., Fujimori, S., Masui, T., Shresta, R., (2013), Thailand's Low-Carbon Scenario 2050: The AIM/CGE analyses of CO2 mitigation measures, Energy Policy 62(2013)561–572

Tol, R.S.J. (2002a), 'New Estimates of the Damage Costs of Climate Change, Part I: Benchmark Estimates', Environmental and Resource Economics, 21 (1), 47-73.

Tol, R.S.J. (2002b), 'New Estimates of the Damage Costs of Climate Change, Part II: Dynamic Estimates', Environmental and Resource Economics, 21 (1), 135-160.

Tol, R. S. J. (2008), "The Social Cost of Carbon: Trends, Outliers and Catastrophes", Economics: The Open-Access, Open-Assessment E-Journal, 2, pp. 2008-2025

Tol, R.S.J. (2009), "An Analysis of Mitigation as a Response to Climate Change", Paper prepared for the Copenhagen Consensus on climate Center

Tol, R.S.J. (2009), The Economic Impact of Climate Change, Journal of Economic Perspectives, 23 (2), 29-51.

van der Mensbrugghe (2010), "Climate Change Policy Options for Asian Economies: Findings from an Integrated Assessment Model". Asian Economic Policy Review, 5, 63–83.

van Ruijven B.J., van Vuuren D.P., van Vliet J., Beltran A.M., Deetman S., den Elzen Michel G.J. (2012), "Implications of greenhouse gas emission mitigation scenarios for the main Asian regions".
Energy Economics, 34 (Supplement 3), S459-S469

van Vuuren, D.P (2011) The representative concentration pathways: an overview. Climatic Change (2011) 109:5–31

van Vliet, O., V Krey, D McCollum, S Pachauri, Y Nagai, S Rao, K Riahi, 2012. Synergies in the Asian energy system: Climate change, energy security, energy access and air pollution
Energy Economics 34, S470-S480

Vinluan R. M. (2012), "Preliminary Low Carbon Policies and Targets", Presentation for the 3rd Regional Consultation Meeting of the Asian Development Bank' project "Strengthening Planning Capacity for Low Carbon Growth in Developing Asia".

United Nations, Department of Economic and Social Affairs, Population Division (2011). World Population Prospects: The 2010 Revision, CD-ROM Edition.

van Ruijven, B.J., van Vuuren, D.P., van Vliet, J., Mendoza, A, Deetman, S., den Elzen, M.G.J., (2012), Implications of greenhouse gas emission mitigation scenarios for the main Asian regions, Energy Economics, 34 (Supplement 3), S459–S469.

Wada, K., Sano, F., Akimoto, K., Homma, T., (2012), Assessment of Copenhagen pledges with long-term implications, Energy Economics, 34 (2012) S481-S486.

Webster, M., Paltsev, S. and J. Reilly (2010), "The hedge value of international emission trading under uncertainty", Energy Policy, 38, 1787-1796

World Bank (2012), "World Development Indicators 2012". Washington, D.C., The World Bank. April 2012.

WHO 2014. World Health Statistics

WRI (World Resources Institute) 2012. Climate Analysis Indicators Tool (CAIT), version 9.0. Washington DC. http://cait.wri.org/.

Appendix

The ICES model: basic structure

ICES is a recursive-dynamic CGE model. It solves recursively a sequence of static equilibria linked by endogenous investment determining the growth of capital stock from 2004 to 2050. The calibration year is 2004. As in all CGE models, ICES makes use of the Walrasian perfect competition paradigm to simulate adjustment processes, although the inclusion of some elements of imperfect competition is also possible. Industries are modeled through representative firms, minimizing 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 CES functions. Domestic and foreign inputs are imperfect substitutes, according to the so-called "Armington" assumption.

The Economy

A representative consumer in each region receives income, defined as the service value of national primary factors (natural resources, land, labor, and capital). Capital and labor are perfectly mobile domestically, but immobile internationally. Land and natural resources are industry-specific. The income is used to finance three classes of expenditure: aggregate household consumption, public consumption, and savings (see Figure 28). The expenditure shares are generally fixed, as the top-level utility function has a Cobb-Douglas specification.

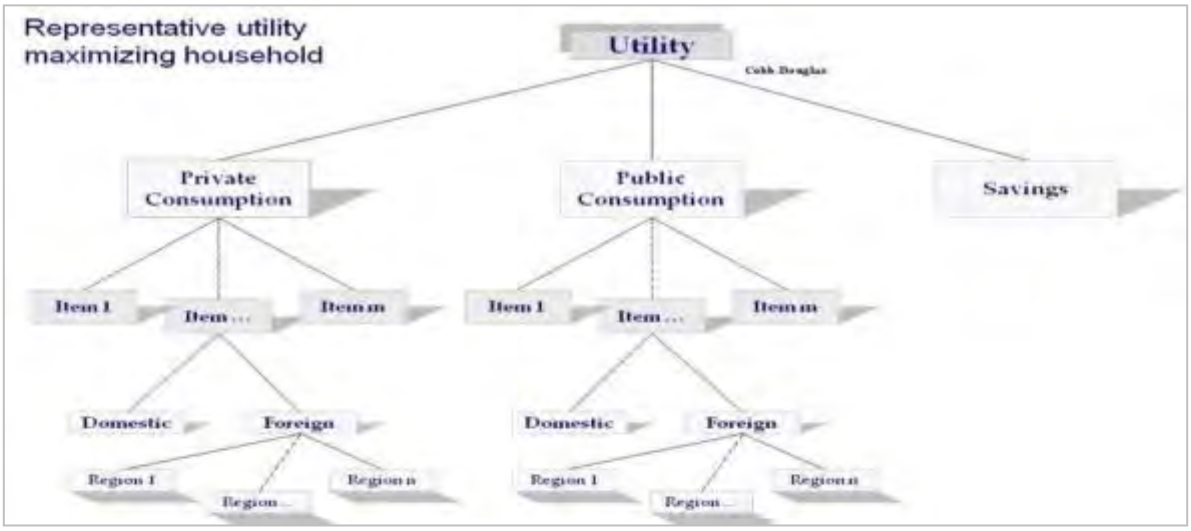


Figure 28: ICES Model Nested Consumption Function

Public consumption is split in a series of alternative consumption items, also according to a Cobb-Douglas specification. However, almost all expenditure is actually concentrated in one specific industry: non-market services.

Private consumption is analogously split in a series of alternative composite Armington aggregates. These postulate the imperfect substitutability across domestic and imported commodities. However, the functional specification used at this level is the Constant Difference in Elasticities form: a non-homothetic function, which is used to account for possible differences in income elasticities for the various consumption goods.

Investment is internationally mobile: savings from all regions are pooled and then investment is allocated so as to achieve equality of expected rates of return to capital. As a result, savings and investments are equalized at the world, but not at the regional, level. Because of accounting identities, any financial imbalance mirrors a trade deficit or surplus in each region.

The ICES production tree, represented by each node in the tree, combines single or composite factors of production in a constant elasticity of substitution (CES) production function.

All sectors use primary factors such as labor and capital-energy, and intermediate inputs. In some sectors (fossil fuel extraction industries and fishery), primary factors include natural resources (e.g., fossil fuels or fish) and land. The nested production structure depicted in Figure 29 is the same across all sectors, and diversity in production processes as well as technologies is captured through sector-specific productivity and substitution elasticity parameters.

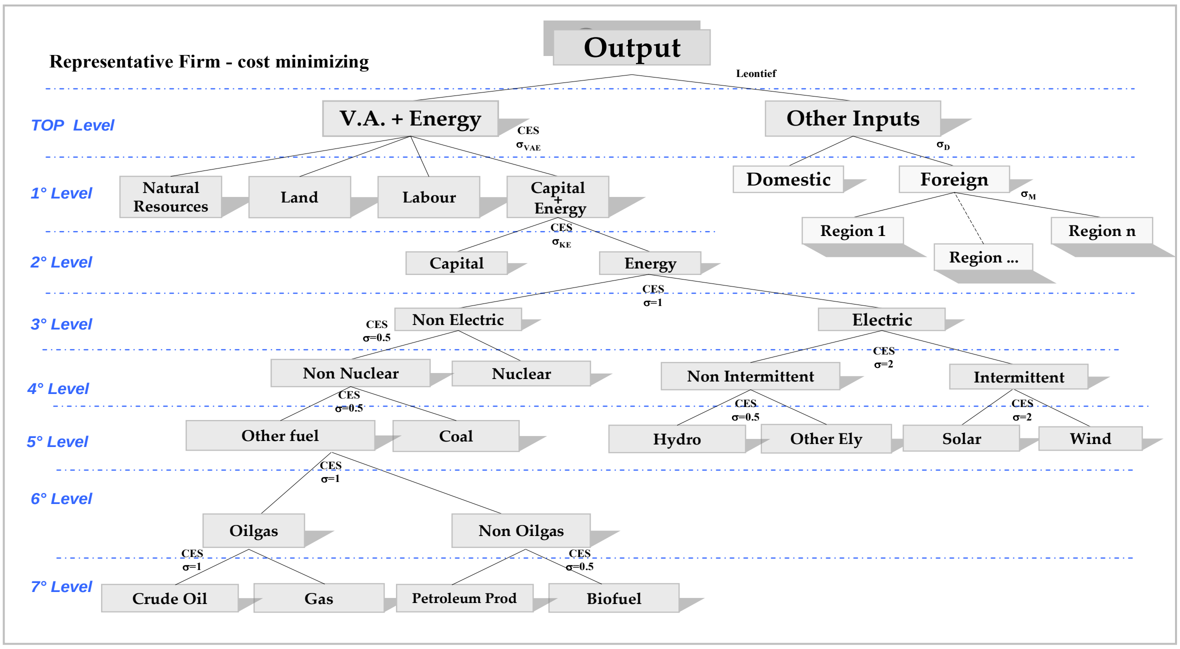


Figure 29: ICES Model Nested Production Function

The regional specification singles out Indonesia and considers “rest of Southeast Asia” (SEA). This allows more specific analysis of the economic implications of medium- and long-term decarbonization policies in these country/region. Most relevant international players, globally and in the area, have been also distinguished to highlight trade patterns and policy spillover effects from the region. The production tree emphasizes energy-producing sectors, given that they are the major industries impacted by mitigation/decarbonization policies. The depiction of agriculture and of “other industries and services” remains less detailed, although agriculture singles out the timber sector, which can be more directly affected by deforestation patterns.

Table 9: Regional and Sectoral Detail of the ICES Model

Countries/Regions		
Organisation for Economic Co-	**Non-OECD**	**Developing Asia**

operation and Development (OECD)		
United States (USA)	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	Vietnam
	People's Republic of China (PRC)	
	Rest of Southeast Asia (SEA)	
	Latin America (LACA)	
Sectors		
Agriculture/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	
	Hydro	
	Solar	
	Wind	
	Other Electricity	
Biofuels		

The Energy Sector

Renewable energy sources (hydro, solar, wind) are stand-alone sectors providing electricity to the rest of the economic system. The intermittency of solar and wind is accounted for by low substitution with other energy sources, which limits their penetration over time in the energy mix.

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.

Other GHGs and Land Use

Avoided deforestation is introduced as an additional abatement option. Country-specific equations link different carbon prices to different abatement levels that can be accomplished by REDD practices. The parameterization of these equations derives from the International Institute for Applied Systems Analysis (IIASA) model cluster (Gusti et al., 2008) prepared for the Eliasch (2008) report. The cluster model, however, does not specify REDD abatement opportunities for Indonesia, only for Southeast Asia as a whole. Country abatement has been estimated by downscaling Southeast Asia data proportionally to the national share of emission from deforestation in the regional total.

Avoided deforestation, triggered by sufficiently high carbon prices, impacts agriculture, forestry, and pasture land use. In particular, lower deforestation might imply a lower expansion of land for farming and grazing. This effect is also considered, and the relation between lower emissions from REDD, lower number of hectares deforested, and lower expansion of agricultural land has been estimated by coupling the data from the IIASA cluster model with those of UN FAO (2006, 2001). In particular, to calculate the amount of land entering large-scale agriculture after deforestation, the parameters from UN FAO (2001) are applied. According to the FAO study, around 10% of deforestation in Africa was due to conversion to this type of land use, while for Latin America and Asia these were 46% and 30%, respectively.

In the simulations, the forest land-using sectors (agriculture and timber) are compensated to reduce deforestation. In other words, it is assumed that avoided deforestation takes place only if it is profitable. This is done in the model through a subsidy to land-using industries equal to the value of the avoided emissions from REDD.

In Indonesia, a large share of deforestation emissions is associated with peatland drainage following clearance of deep peat swamp forests. Peatlands are deposits of plant residuals and water formed over thousands of years, which contain thousands of tons of carbon per hectare. The peat is drained during deforestation, setting off a process of oxidation, as well as a risk of peat fires, which have enormous emissions potential. Emissions can continue for decades after clearance and even if deforestation is falling, aggregate emissions may continue to increase, as the rate of carbon loss from peat has a lagged effect. Accordingly, reducing deforestation of peat swamp forests will also reduce the specific peatland emissions. In addition, it is possible to abate peatland emissions with specific measures implemented directly on already deforested peatland areas, such as peatland restoration and rehabilitation, fire prevention, and water management.

To account for this deforestation-associated source of emissions, ICES explicitly consider peatland emissions in Indonesia as part of total emissions (see section 5 for the relative baseline assumptions), drawing on parameters on peatland deforestation and emissions reported in Busch et al., (2011), with emissions assumed to take place over a 25-year timeframe. The country abatement potential has also been tailored to capture the opportunities that might come either from reduced deforestation in peatland areas or from peatland restoration and rehabilitation, fire prevention, and water management of peatland deforested areas. The first was modeled by increasing Indonesian emission reduction potential from REDD proportionally to the share of deforested land on peatland over total deforested land, while the second was implemented through an aggregated marginal abatement cost curve for peat rehabilitation using information reported in DNPI (2010).

The model is updated with sectoral emissions from CO2 CH4, N2O, PFCs, HFCs, and SF6 derived by Rose et al. (2010). A further extension is the introduction of a carbon market involving all GHGs and not only CO2. This feature allows the possibility of exploiting lower-cost abatement options in non-CO2 gases or emitting sectors.

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