



ASIA IN THE GLOBAL TRANSITION TO NET ZERO

ASIAN DEVELOPMENT OUTLOOK 2023
THEMATIC REPORT

APRIL 2023

ASIA IN THE GLOBAL TRANSITION TO NET ZERO

ASIAN DEVELOPMENT OUTLOOK 2023
THEMATIC REPORT

APRIL 2023



Creative Commons Attribution 3.0 IGO license (CC BY 3.0 IGO)

© 2023 Asian Development Bank
6 ADB Avenue, Mandaluyong City, 1550 Metro Manila, Philippines
Tel +63 2 8632 4444; Fax +63 2 8636 2444
www.adb.org

Some rights reserved. Published in 2023.

ISBN 978-92-9270-117-8 (print); 978-92-9270-118-5 (electronic); 978-92-9270-119-2 (ebook)
Publication Stock No. FLS230135-2
DOI: <http://dx.doi.org/10.22617/FLS230135-2>

The views expressed in this publication are those of the authors and do not necessarily reflect the views and policies of the Asian Development Bank (ADB) or its Board of Governors or the governments they represent.

ADB does not guarantee the accuracy of the data included in this publication and accepts no responsibility for any consequence of their use. The mention of specific companies or products of manufacturers does not imply that they are endorsed or recommended by ADB in preference to others of a similar nature that are not mentioned.

By making any designation of or reference to a particular territory or geographic area, or by using the term “country” in this publication, ADB does not intend to make any judgments as to the legal or other status of any territory or area.

This work is available under the Creative Commons Attribution 3.0 IGO license (CC BY 3.0 IGO) <https://creativecommons.org/licenses/by/3.0/igo/>. By using the content of this publication, you agree to be bound by the terms of this license. For attribution, translations, adaptations, and permissions, please read the provisions and terms of use at <https://www.adb.org/terms-use#openaccess>.

This CC license does not apply to non-ADB copyright materials in this publication. If the material is attributed to another source, please contact the copyright owner or publisher of that source for permission to reproduce it. ADB cannot be held liable for any claims that arise as a result of your use of the material.

Please contact pubsmarketing@adb.org if you have questions or comments with respect to content, or if you wish to obtain copyright permission for your intended use that does not fall within these terms, or for permission to use the ADB logo.

Corrigenda to ADB publications may be found at <http://www.adb.org/publications/corrigenda>.

Notes:

In this publication, “\$” refers to United States dollars.
ADB recognizes “China” as the People’s Republic of China.

Cover design by Anthony Victoria.

Cover artwork by lofranco/2018.

CONTENTS

Tables, Figures, and Boxes	iv
Foreword	vii
Preface	viii
Acknowledgments	ix
Definitions	x
Abbreviations	xi
HIGHLIGHTS: Asia in the Global Transition to Net Zero	1
1 Asia's Special Stake in the Global Climate Crisis	7
1.1 Climate Change Is a Critical Threat to Asia	8
1.2 Climate Change Cannot be Addressed without Asia	12
1.3 Developing Asia is Beginning to Respond to the Climate Challenge	16
2 Asia's Transformation during the Global Transition to Net Zero	19
2.1 Key Choices for Climate Change Mitigation	19
2.2 Emission Pathways	25
2.3 Sources of Mitigation	28
2.4 Land Use Responses	28
2.5 Transformation of the Energy Sector	30
2.6 Investment Needs to Transform the Energy Sector	45
3 Socioeconomic Consequences of the Global Transition to Net Zero	47
3.1 Framework for Considering the Costs and Benefits of Climate Change Mitigation Policies	47
3.2 Policy Costs of the Low-Carbon Transition	47
3.3 Factors and Policies Affecting Decarbonization Costs	52
3.4 Benefits versus Costs of Deep Decarbonization for Asia	55
3.5 Equity Implications of Mitigation Policies	60
4 Policies for an Efficient and Equitable Global Transition to Net Zero	66
4.1 Reforming Prices	67
4.2 Facilitating Decarbonization Responses	76
4.3 Ensuring Fairness during the Transition	85
References	89
Appendix: Comparison of Modeling Results with the Sixth Assessment Report of the Intergovernmental Panel on Climate Change	97

TABLES, FIGURES, AND BOXES

TABLES

1.1	Submissions and Pledges Made by Paris Agreement Parties from Developing Asia	17
2.1	Climate Scenario Matrix	19
3.1	Cities with the Highest Population-Weighted Annual Average Particulate Matter 2.5 Exposures, 2019	58
4.1	Renewable Energy Targets and Policies in Developing Asia	78
4.2	Minimum Energy Performance Standards and Energy Labels in Developing Asia	79
4.3	Revenue Use in Carbon Pricing Schemes in Developing Asia	87

FIGURES

1.1	Total Economic Losses from Climate Change under a High Emissions Scenario by World Regions by 2100	8
1.2	Economic Losses from Climate Change in Developing Asia under a High Emissions Scenario by 2100	12
1.3	Global Annual Greenhouse Gas Emissions, 1990–2019	13
1.4	Historical Cumulative Net Anthropogenic Carbon Dioxide Emissions by Region, 1850–2021	14
1.5	Greenhouse Gas per Capita Emissions by Region, 1990–2019	14
1.6	Carbon Intensity in Developing Asia and the World, 1990–2019	15
1.7	Greenhouse Gas Emissions by Sector in Developing Asia, 2019	15
1.8	Expansion of the Middle Class by Region, 2015 and 2030	16
2.1	Climate Scenarios by Level of Climate Action and Global Coordination	22
2.2	Global Emission Pathways under the Modeled Scenarios, 2005–2100	26
2.3	Developing Asia's Emission Pathways under the Modeled Scenarios, 2005–2100	26
2.4	Greenhouse Gas Emission Pathways by Subregions of Developing Asia under Modeled Scenarios, 2005–2100	27
2.5	Decomposition of Mitigation Sources in Developing Asia under the Accelerated Global Net Zero Scenario, 2030–2060	29
2.6	Change in Forest Cover in Developing Asia, 1992–2019	30
2.7	Share of Forest, Cereal Crops, and Energy Crops in Land Cover in Developing Asia under Modeled Scenarios, 2020–2100	31
2.8	Energy Intensity of Gross Domestic Product in Developing Asia under Modeled Scenarios, 2020–2050	32
2.9	Primary Energy Mix in Developing Asia under Modeled Scenarios, 2020–2100	34
2.10	Electricity Mix in Developing Asia under Modeled Scenarios, 2020–2100	37
2.11	Levelized Cost of Electricity by Technology, 2010 and 2020	40
2.12	Installed Costs by Technology in Developing Asia under the Accelerated Global Net Zero Scenario, 2020–2100	40
2.13	Electrification of Services under Modeled Scenarios, 2025–2100	42

2.14	Share of Electricity in Road Transport in Developing Asia under the Accelerated Global Net Zero Scenario	45
2.15	Average Annual Investment in Power Supply in Developing Asia under Modeled Scenarios, 2020–2050	46
2.16	Annual Average Power Supply Investment Required in Developing Asia under the Accelerated Global Net Zero Scenario, 2020–2050	46
3.1	Global Carbon Prices under the Modeled Global Net Zero Scenarios	48
3.2	Policy Costs for the Modeled Scenarios in Developing Asia, Excluding Benefits, Relative to Current Policies, 2030, 2050, and 2070	49
3.3	Policy Costs for the Modeled Scenarios in Developing Asia Excluding Benefits, Relative to Current Policies, 2020–2100	49
3.4	Distribution of Policy Costs Against Per Capita Gross Domestic Product under the Modeled Scenarios, 2050	50
3.5	Fossil Fuel Trade in Developing Asia under the Modeled Scenarios, 2020–2100	51
3.6	Trade Balance of Greenhouse Gas Emission Offsets under the Accelerated Global Net Zero Scenario, 2020–2070	53
3.7	Policy-Cost Decomposition in Developing Asia of the Accelerated Global Net Zero Scenario	53
3.8	Policy Costs of the Accelerated Global Net Zero Scenario in Developing Asia if Carbon Dioxide Removal Technologies Are Unavailable	54
3.9	Maximum Temperature Change over the 21st Century Compared to Average Historical Temperature, 1980–2000	55
3.10	Sum of Policy Costs and Climate Benefits in Developing Asia for the Modeled Scenarios under Specific Climate Damage Functions, 2020–2100	56
3.11	Annual Net Policy Costs and Climate Benefits of the Modeled Scenarios, 2020–2100	57
3.12	Avoided Annual Premature Deaths Due to Outdoor Particulate Matter 2.5 and Ozone under the Modeled Scenarios Relative to the Current Policies Scenario, 2030 and 2050	59
3.13	Avoided Annual Crop Loss from Ozone in Developing Asia under the Modeled Scenarios Relative to the Current Policies Scenario, 2030 and 2050	60
3.14	Annual Net Policy Costs, Climate Benefits, and Air Quality Co-Benefits in Developing Asia of the Accelerated Global Net Zero Scenario Relative to the Current Policies Scenario, 2020–2100	61
3.15	Total Direct Energy Sector Full-Time Equivalent Employment in Developing Asia under Modeled Scenarios, 2050	62
3.16	Differences in Full-Time Direct Energy Sector Employment in Developing Asia by Type of Energy between the Current Policies and Accelerated Global Net Zero Scenarios, 2030–2050	63
3.17	Differences in Full-Time Direct Energy Sector Employment in Developing Asia by Activity between the Current Policies and Accelerated Global Net Zero Scenarios, 2050	63
3.18	Food Price Index in Developing Asia under the Current Policies and Accelerated Global Net Zero Scenarios, 2020–2100	63
3.19	Differences in Household Food and Energy Expenditure in Developing Asia between the Current Policies to Accelerated Global Net Zero Scenarios	64
3.20	Household Expenditure Shares on Energy for Housing and Transportation per Income Decile in India and the People’s Republic of China, 2012–2013	65
3.21	Household Consumption Impact of the Accelerated Global Net Zero Scenario Compared to the Current Policies Scenario under Alternative Redistribution of Carbon Pricing Revenues by Decile in India and the People’s Republic of China	65

4.1	Three Policy Pillars to Achieve Developing Asia's Low-Carbon Transition	66
4.2	Carbon Pricing Coverage Globally, 1990–2022	69
4.3	Coverage of Global Greenhouse Gas Emissions by Carbon Pricing, 2021	70
4.4	Carbon Prices Applied in Emissions Trading and Carbon Taxes in 2022	71
4.5	Compounded Annual Growth Rate of Carbon Pricing Initiatives, 2017–2022	71
4.6	Fossil Fuel Subsidies in Developing Asian Economies, 2019–2021	73
4.7	Fossil Fuel Subsidies in Developing Asia, 2010–2021	74
4.8	Fossil Fuel Subsidies in Developing Asia in 2021 Compared with the Policy Costs Found for the Accelerated Net Zero Scenario	74
4.9	Agriculture Subsidy Rates in Developing Asia's Three Biggest Economies, 2010–2021	75
4.10	Fossil Fuel and Renewable Energy Subsidies in India and the People's Republic of China, 2017	81
4.11	Global Public Spending on Energy Research and Development	82
4.12	Patents in Renewable Energy and Enabling Technologies, 2000–2020	83
4.13	Issuance of Green and Transition Debt Finance in Developing Asia, 2018–2022	84
4.14	Obstacles to Issuing Green Bonds in Southeast Asian Countries	85

BOXES

1.1	Co-designing the Assessment of Climate Change Costs Project	11
2.1	Burden-Sharing Frameworks for Mitigating Greenhouse Gas Emissions	21
2.2	Energy in the World Induced Technical Change Hybrid Model	23
2.3	Evolution of Integrated Assessment Models	24
2.4	Phasing Out Coal-Fired Power Generation	39
2.5	Adoption of Battery Electric Vehicles in Developing Asia	43
4.1	Carbon Taxes versus Emissions Trading Systems	68

FOREWORD

Development in Asia and the Pacific depends on effective action to address climate change. The region faces increasing climate shocks that are affecting the livelihoods, food security, and health of millions of people, especially women. At the same time, the region accounts for a growing share of annual global greenhouse gas emissions. Achieving the goals of the 2015 Paris Agreement depends on whether the region can shift from carbon-intensive growth to low-carbon development.

Governments in Asia and the Pacific have joined global efforts to contain the climate threat. All developing Asian economies have submitted nationally determined contributions under the Paris Agreement, which aims to limit global warming to well below 2°C above preindustrial levels. A growing set of regional economies, including the largest emitters, have also made ambitious pledges to achieve net-zero emissions by the mid- to late-21st century.

Asia in the Global Transition to Net Zero explores what a global net-zero transition could mean for developing Asia. It models emission pathways based on commitments and pledges under the Paris Agreement and compares them with more optimal routes to net zero. The pathways considered will require dramatic transformations in energy and land use, with wide-ranging implications.

The report finds that early action and international coordination are critical to ensure a low-cost and equitable net zero transition. With efficient policies, the benefits of the transition from averted climate damages and improved air quality could outweigh climate mitigation costs by five times. Conversely, if policies are not carefully designed, some economies, industries, communities, and populations could be adversely affected. Yet, failure to address the climate crisis would have consequences that would be even more regressive. To avoid these outcomes, deep decarbonization is needed.

To support these crucial actions, the Asian Development Bank has scaled up its ambition to deliver climate financing to its developing member countries to \$100 billion over 2019–2030. This is an important contribution but still a fraction of the finance that the report finds will be needed to decarbonize the region. ADB stands ready to support the region's climate goals through innovative finance, technology, knowledge, and partnerships.



MASATSUGU ASAKAWA

President

Asian Development Bank

PREFACE

With each passing year, the effects of climate change are increasingly visible in developing Asia—from unprecedented floods to extreme droughts and devastating storms. The region is one of the world’s most vulnerable to climate change, and it is the poorest people in the region who will bear many of the costs. Climate losses will be concentrated in subregions that contain the highest numbers of poor people and in sectors on which they primarily depend, such as agriculture. This is occurring even as developing Asia continues to rapidly increase emissions and develop energy from fossil fuels. At the same time, there are signs of hope that the region is changing course. Under the Paris Agreement, all economies in the region have committed to decarbonize, and the largest emitters have more recently pledged to reach net zero emissions.

This report explores the changes that need to happen in the region to avoid a climate catastrophe, with a focus on meeting the Paris Agreement goals of keeping warming well below 2 degrees Celsius. It finds that dramatic changes are needed. Energy efficiency needs to rise sharply; the adoption of renewables needs to be accelerated, especially in power generation; coal needs to be phased out quickly; and forests need to be conserved and expanded. This transformation will require hundreds of billions of dollars of additional annual investment in power supply alone.

Yet, if the right policies are adopted, economic costs can be kept relatively low. The report shows that the costs of contributing to achieving global net zero can be the equivalent of a few months of economic growth over the 21st century for developing Asia—without counting the benefits of reduced climate change or cleaner air. When those benefits are considered, they are five times the costs, with the greatest payoff for the lowest-income regions. Employment in the energy sector also rises with deep decarbonization. Moreover, the sooner that action starts, the lower are the costs and the higher the benefits.

Realizing this potential requires substantial action. Carbon pricing is the most efficient way to cut emissions, yet pricing coverage, levels, and exposure of emissions sources remain low. Subsidies of emitting fuels and activities remain far higher than those for clean energy. A policy mix that reforms pricing, regulations, and incentives, and mobilizes private financing, is needed to put developing Asia on a low-carbon path. These policies also need to be complemented by support measures to those negatively affected to ensure a fair and politically sustainable transition.



ALBERT F. PARK
Chief Economist
Asian Development Bank

ACKNOWLEDGMENTS

Asia in the Global Transition to Net Zero, the Asian Development Outlook 2023 Thematic Report, was prepared by staff of the Economic Research and Regional Cooperation Department (ERCD) of the Asian Development Bank (ADB). ADB's Sustainable Development and Climate Change Department (SDCC) and the regional departments provided support via background materials and suggestions.

This report was authored by an ADB team of ERCD economists: David Anthony Raitzer, Manisha Pradhananga, and Shu Tian.¹ They worked in partnership with a team of coauthors from the RFF-CMCC European Institute on Economics and the Environment: Johannes Emmerling, Laurent Drouet, and Lara Aleluia Reis, who modeled the scenarios. Abdul Abiad, ERCD director, led the production of this report. Daryll Naval, Iva Sebastian-Samaniego, Lotis Quiao, Mai Lin Villaruel, and Vanessa Mae O. Pepino provided research support. The report benefited from inputs from Donghyun Park, Gemma Estrada, Kate Hughes, Leonardo Garrido, Madhavi Pundit, Virender Kumar Duggal, and Yothin Jinjarak.

Guidance and support were provided by ERCD management, including Chief Economist Albert Park, Deputy Chief Economist Joseph E. Zveglic Jr., Deputy Director General Chia-Hsin Hu, and Director Lei Lei Song. The report also benefited from the advice of Noelle O'Brien and Toru Kubo. Charles Rodgers, Diana Bianca S. Cobilla, Dorothy Geronimo, Katherine A. Hughes, Kristian Rosbach, Omer Zafar, Pradeep Tharakan, Rabindra P. Osti, Rana Hasan, and Yolanda Fernandez Lommen provided suggestions as reviewers. Declan Magee supported interdepartmental coordination.

The report draws on background papers and notes listed at the end of the report, which Ricardo Chan edited. The report also benefitted from technical support and comments from the SDCC's transport, urban, and water sector groups; ADB's Office of President; and the Asian Development Bank Institute.

Alastair McIndoe edited the report. Alvin Tubio did the typesetting and graphics. The art direction for the cover was by Anthony Victoria, with artwork from Jojo Lofranco. Kevin Nellies designed the landing webpage. Editha Lavina, Elenita Pura, Mai Lin Villaruel, and Priscille Villanueva provided administrative support. A team from the Department of Communications, led by David Kruger and Terje Langeland, supported the report's dissemination.

¹ Listed by alphabetical order of first name.

DEFINITIONS

The economies discussed in this report are classified by major analytic or geographic group. For the purposes of this publication, the following apply:

- **Central Asia** comprises Armenia, Azerbaijan, Georgia, Kazakhstan, the Kyrgyz Republic, Mongolia, Tajikistan, Turkmenistan, and Uzbekistan.
- **South Asia** comprises Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka. Rest of South Asia excludes India.
- **Southeast Asia** comprises Brunei Darussalam, Cambodia, Indonesia, the Lao People's Democratic Republic, Malaysia, Myanmar, the Philippines, Singapore, Thailand, Timor-Leste, and Viet Nam. Rest of Southeast Asia excludes Indonesia.
- **The Pacific** comprises the Cook Islands, the Federated States of Micronesia, Fiji, Kiribati, the Marshall Islands, Nauru, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, and Vanuatu.

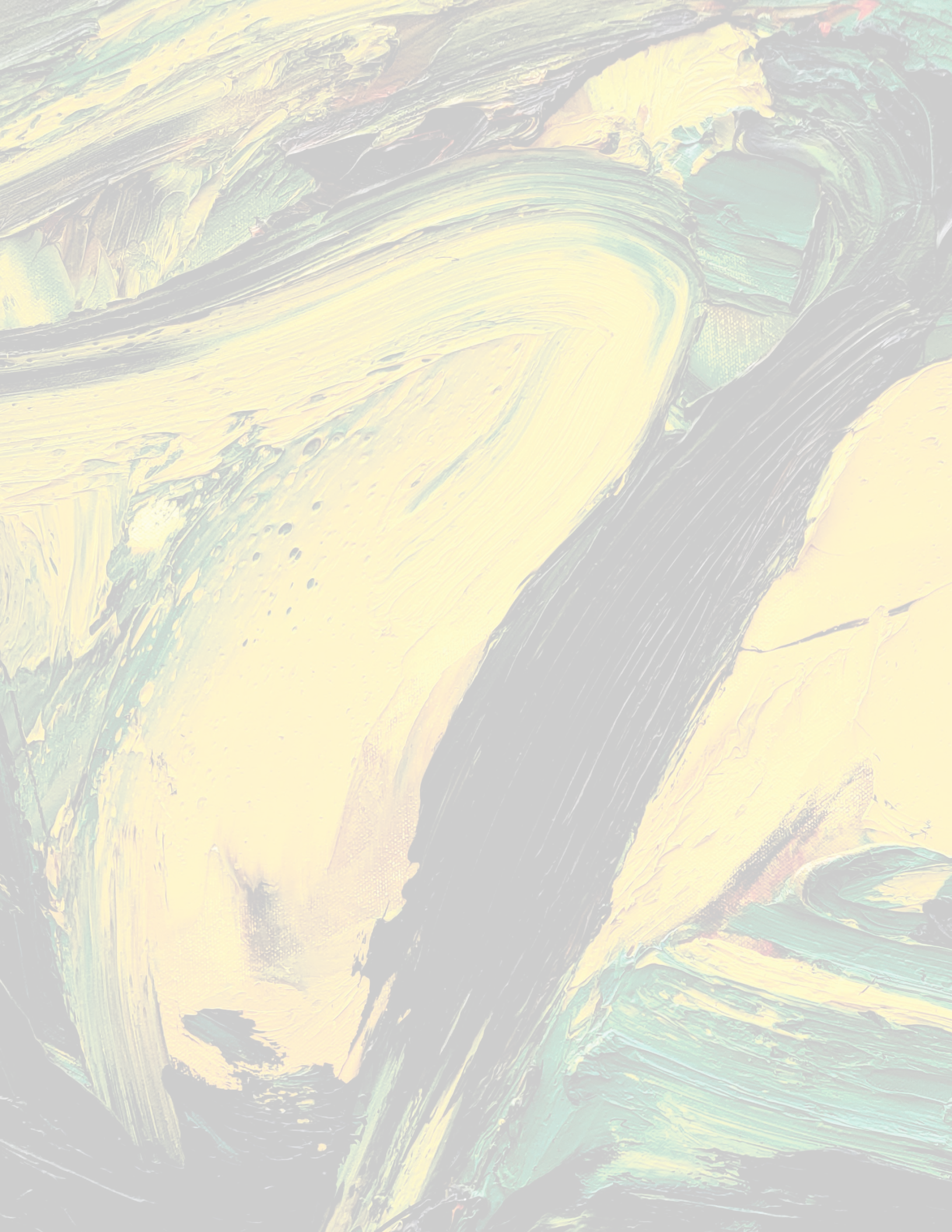
Unless otherwise specified, the symbol "\$" and the word "dollar" refer to US dollars.

ABBREVIATIONS

AR6	Sixth Assessment Report
BECCS	bioenergy with carbon capture and storage
BEV	battery electric vehicle
CBAM	carbon border adjustment mechanism
CCS	carbon storage and capture
CO ₂	carbon dioxide
DAC	direct air capture
ESCO	energy service company
ESG	environmental, social, and governance
ETS	emissions trading system
EU	European Union
EV	electric vehicle
FIT	feed-in tariff
GDP	gross domestic product
GHG	greenhouse gas
IAM	integrated assessment model
ICEV	internal combustion engine vehicle
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
LCOE	levelized cost of electricity
MEPS	minimum energy performance standard
NDC	nationally determined contribution
PRC	People's Republic of China
PV	photovoltaic
REDD	reduced emissions from deforestation and forest degradation
SLR	sea level rise
WITCH	World Induced Technical Change Hybrid

WEIGHTS AND MEASURES

°C	degree Celsius
EJ	exajoule
gCO ₂ /km	gram of carbon dioxide per kilometer
GtCO ₂	billion tons of carbon dioxide
GtCO ₂ e	billion tons of carbon dioxide equivalent
GW	gigawatt
ha	hectare
kWh	kilowatt-hour
MtCO ₂ e	metric tons of carbon dioxide equivalent
PM 2.5	fine particulate matter
tCO ₂	ton of carbon dioxide
tCO ₂ e	ton of carbon dioxide equivalent
TWh	terawatt-hour



HIGHLIGHTS

Asia in the Global Transition to Net Zero

1 *Asia's Special Stake in the Global Climate Crisis*

- **Developing Asia is highly vulnerable to climate change.** Given its geographic features and socioeconomic circumstances, developing Asia is vulnerable to climate-related risks. The region faces increasing frequency and severity of storms, flooding, heat waves, and droughts under climate change. About 70% of the global population susceptible to sea level rise is in Asia. Natural resource-based sectors, such as agriculture and fisheries, that are directly conditioned by climate, account for around a third of total employment in the region. Beyond threatening the livelihoods of Asia's poor, climate change may also put at risk regional and global food security. Climate change will increase the spread of vector-borne and waterborne diseases, and deaths due to cardiovascular stress. Climate change under a high emissions scenario could impose gross domestic product (GDP) losses of 24% in the whole of developing Asia, 35% in India, 30% in Southeast Asia, and 24% in the rest of South Asia by 2100.
- **Asia accounts for an increasing share of global greenhouse gas (GHG) emissions.** Although historical emissions from developing Asia were low, they have been growing faster than the global average. The region's share of global GHG emissions doubled from 22% in 1990 to 44% in 2019 and is expected to remain at this share until mid-century under current policies. At current levels of GHG emissions, the region would by itself exhaust the remaining global carbon budget consistent with limiting warming to 1.5 degrees Celsius (°C) by 2040.
- **Achieving global climate goals depends on Asia's development path.** Growth in the region has relied heavily on emission-intensive activities, with the emission intensity of GDP currently 41% higher than the rest of the world. Developing Asia is starting its decarbonization at relatively low income levels and faces large development needs. A billion people in the region were still living on less than purchasing power parity of \$3.20 a day in 2017 and 940 million lack reliable power supply. Meeting development goals while avoiding catastrophic climate risks cannot be achieved without transforming Asia's growth patterns.
- **Governments across developing Asia have made increasingly ambitious climate pledges, but there remains substantial scope to accelerate decarbonization.** All parties from developing Asia have submitted nationally determined contributions (NDCs) under the Paris Agreement, and 19 economies, accounting for about 80% of the region's 2019 emissions, have pledged to achieve net zero emissions. Ten economies, including the largest emitters, have submitted long term strategies. Yet, sector plans and policies often have yet to be aligned with climate pledges.

2 Asia's Transformation during the Global Transition to Net Zero

- **Key climate policy choices include the degree of mitigation ambition, timing of mitigation, and extent of international cooperation, especially via carbon markets.** The Paris Agreement represents a global consensus that the world must act to keep global warming well below 2°C. However, there is little agreement on how this goal should be achieved. Individual economies have made mitigation pledges that are intended to be strengthened over time, while elements to foster international coordination are only slowly emerging. Key mitigation decisions are embodied in five core scenarios of implementing (i) current policies, (ii) NDCs, (iii) uncoordinated pathways toward national net zero pledges after NDCs, (iv) NDCs followed by coordinated action toward global net zero to achieve well below 2°C of warming, and (v) accelerated action toward global net zero to achieve well below 2°C of warming. The modeling is performed using the World Induced Technical Change Hybrid global integrated assessment model, adapted to study the region's large economies and different subregions.
- **Fragmented climate policies to date are unlikely to meet Paris Agreement goals.** Under current policies, mean global warming of 3.0°C is modeled by 2100. Implementing submitted NDCs reduces this to 2.4°C, which misses Paris Agreement goals due to insufficient collective ambition. National net zero pledges, if fully achieved, would take the world closer to Paris Agreement goals with 2.0°C of mean warming, but the costs are much higher than scenarios with more global coordination—and the costs fall disproportionately on lower-income countries.
- **Land use and energy efficiency are vital to reducing emissions in the short run, while decarbonization of energy is critical in the long run.** Of the modeled scenarios, only the global net zero scenarios are consistent with Paris Agreement goals. In the near term to 2030, under the accelerated global net zero scenario increased energy efficiency would account for 44% of emissions reduction in developing Asia. The transition of energy to cleaner sources would account for 17% of emission reduction until 2030, and increases to 45% by 2050 as cleaner energy becomes the predominant source of decarbonization in the long term. In Southeast Asia, land use could be a major source of mitigation, particularly in Indonesia, where under the accelerated global net zero scenario it would account for 72% of emissions reduction by 2030.
- **A global transition to net zero may lead to bold changes in patterns of land use, with vastly expanded forest area and land area used to grow crops for bioenergy.** In much of developing Asia, the potential exists to reduce emissions from land use at low cost, while generating co-benefits for climate adaptation. Under the accelerated global net zero scenario, forest cover in the region would increase by 95 million hectares (ha), reaching 30% of land cover by 2050. About half of the total increase in forest area in the region is concentrated in the People's Republic of China. Land area devoted to growing food crops would decrease by 36 million ha, while about 39 million ha of land would be used to grow energy crops by 2050.
- **The share of coal in primary energy will decline even under modest climate action.** Developing Asia's total primary energy supply increased threefold from 1991 to 2020, with more than half of this growth provided by coal. Coal is the largest source of energy emissions in developing Asia, accounting for about 70%, followed by oil (20%) and gas (10%)—a structure that has remained largely unchanged since the 1990s. Under the current policies scenario, the share of coal in primary energy will decline from about half to less than a quarter by 2050 and to 13% under more ambitious climate action.

- **Even under current policies, renewable energy could dominate electricity generation in developing Asia by 2040, while ambitious climate policy would lead renewables to supply almost all of the region's power needs.** Growth in solar and wind energy over the past decade has been remarkable. Developing Asia has led the world in solar and onshore wind capacity additions, supported by dramatic cost reductions in these technologies. Renewable energy would account for 63% of electricity generation by 2040 even under the current policies scenario. Under the accelerated net zero scenario, by 2040 renewable sources would account for nearly all electricity generation, while coal would be virtually absent from the region's power sector. The potential rapid transformation in how energy is supplied is unprecedented.
- **Transformation of the energy sector requires an increase in investments and a reallocation toward cleaner sources.** In 2021, \$468 billion was invested in power supply in developing Asia, of which \$397 billion was in renewable energy, electricity networks, and storage infrastructure. The People's Republic of China accounted for 63% of clean-electricity investments in the region. To achieve Paris Agreement goals, the modeling finds that average annual investments until 2050 would need to increase to \$707 billion, corresponding to between 1.5%–2.7% of GDP for the economies and subregions analyzed.

3 Socioeconomic Consequences of the Transition to Net Zero

- **Asia stands to gain from ambitious climate action, with benefits from avoided climate change damage far greater than costs associated with the transition.** Meeting Paris Agreement goals requires drastic transformations of energy and land use in developing Asia. While the transformation has cost implications for economic activity, it will deliver non-climate co-benefits in the short run and economic benefits from reduced climate damage over the medium to longer term. Under the accelerated global net zero scenario, the net present value of benefits is found to be five times the cost for developing Asia.
- **Paris Agreement goals can be met with modest mitigation costs, which are lowest for the least developed regions of Asia.** Even the most costly global net zero scenario of aggressive decarbonization would entail the loss of less than 1 year of economic growth over the 21st century for developing Asia when all benefits are excluded. The overall cost of pursuing global net zero is found to be around 1% of GDP during the 21st century if efficient policies are adopted. Fossil fuel-exporting regions, including the Caucasus and Central Asia, would experience more reduction in economic activity than fossil fuel importers and low-income countries. Carbon dioxide removal through avoided deforestation, direct air capture, and biomass with carbon storage and capture can help to keep costs contained, but even without these options, costs can remain below 3% of GDP.
- **Enhanced international coordination could substantially lower the costs of achieving the Paris Agreement goals.** Beyond NDCs, climate policies currently rely on achieving individual countries' net zero pledges, which are not necessarily determined by market or economic mechanisms that allocate mitigation according to abatement costs. There is ample opportunity to improve the efficiency of mitigation through market mechanisms, including international carbon trading. Many poorer countries in developing Asia, especially in South Asia, could benefit the most from international carbon trading, with revenues from carbon-offset exports potentially greater than the cost of decarbonization.

- **Early action can minimize the long-term cost of mitigation.** Analysis in this report finds that NDCs are not ambitious enough, even in the short run, to achieve Paris Agreement goals. The overall cost of achieving net zero decarbonization can be reduced by 10%–20% if aggressive decarbonization starts immediately, rather than waiting until after the current NDC pledge period of 2030.
- **In the near term, developing Asia can realize substantial co-benefits from ambitious mitigation.** Co-benefits from aggressive decarbonization are initially much larger than climate benefits. Under the accelerated global net zero scenario, 346,000 lives in developing Asia would be saved annually by 2030 as a result of reduced air pollution. In addition, millions of tons of annual rice and wheat production would be saved from air pollution damage.
- **In the long run, Asia's avoided damage from climate change would be far greater than the mitigation costs.** Aggressive decarbonization is in developing Asia's interest, as the region is highly vulnerable to climate change. Expected losses from climate change are highest in Asia's lowest-income countries and will harm the poorest people. Climate benefits alone would be 260% of mitigation costs for developing Asia under the accelerated global net zero scenario.
- **Ambitious mitigation could lead to large increases in energy sector employment, with 1.5 million additional jobs potentially created in Asia by 2050.** The modeling finds that aggressive decarbonization leads to the loss of 1.4 million jobs in the fossil fuel sector in Asia by 2050, while over 2.9 million jobs would be created, mostly in manufacturing, installing, and operating solar photovoltaic and wind power generation. The employment generated tends to be higher skilled than the jobs lost, although the new roles may not match the skills and locations of the people facing job losses.
- **Ambitious mitigation may divert land from food production, which could adversely affect food security.** Reduced fossil fuel use and increased demand for land during climate change mitigation could result in higher food prices, leading to food security concerns. The accelerated global net zero scenario could potentially lead to 22% of land planted with cereals to be converted to forests and bioenergy. This may increase food prices by up to 34% if not accompanied by appropriate land use and agricultural policies.
- **The costs of decarbonization could be regressive if redistribution policies are not implemented.** Phasing out carbon-intensive energy will lead to increases in residential energy and food costs, which will have larger effects on poorer households. These regressive effects, however, can be more than offset by simple redistribution measures, such as recycling carbon revenues as universal basic income on an equal per capita basis.

4 Policies for an Efficient and Equitable Transition to Global Net Zero

- **Asia can attain a low-carbon development pathway via three policy pillars.** These are: (i) reforming prices via carbon pricing and subsidy reductions; (ii) facilitating low-carbon responses via regulations and incentives, and mobilizing finance for decarbonization; and (iii) ensuring fairness internationally and domestically. Each pillar contains multiple policy opportunities to redirect development.

- **Carbon pricing is critical to achieving a net zero world at attainable cost.** The inability of markets to account for the full social, economic, and environmental cost of GHG emissions remains the fundamental market failure that has led to carbon-intensive growth and climate change. A carbon price of \$70 per ton of carbon dioxide equivalent by 2030 and \$153 by 2050 is found to be able to trigger a transition to low-carbon growth and achieve global net zero. Ambitious mitigation can be attained without carbon pricing, but the cost would be higher as carbon pricing is more efficient. Although progress is being made in the adoption of carbon prices, barriers often prevent prices from affecting investment and consumption decisions in developing Asia. If the region's economies do not proactively adopt carbon pricing, they risk being subjected to carbon border adjustment tariffs and other measures that could put trade at a disadvantage.
- **Cutting carbon subsidies can offset much of the cost of deep decarbonization.** Developing Asia spent \$116 billion in 2021 on subsidizing fossil fuels, and these subsidies are much higher than subsidies for renewables. The cost of fossil fuel subsidies, at around 1% of GDP, is near the policy cost of this report's most ambitious decarbonization scenario. Artificially low prices incentivize the overconsumption of fossil fuels and discourage the development of renewables. Similarly, concessions that enable subsidized timber extraction create incentives for emissions from deforestation, and agricultural input subsidies often encourage the overuse of emission-intensive inputs. Removing these subsidies should be the first step toward low-carbon growth and redirecting valuable public resources for other development priorities.
- **Proactive policies are needed to create conditions for low-carbon innovation and investment.** Reaching net zero emissions will require the widespread use of technologies that are still under development. Many of these technologies can benefit from investment in upstream research and development to generate public goods, as well as adaptive research by private companies. Incentives such as preferential taxation and targeted and time-bound subsidies, and mandates can enhance the competitiveness of low-carbon technologies and proactively create markets for low-carbon products.
- **Innovative risk sharing and financial instruments can mobilize private capital for the low-carbon transition.** The investments needed to innovate and scale up low-carbon technologies carry certain risks, which can make these investments less attractive to the private sector. To catalyze private capital, governments can adopt innovative risk-sharing mechanisms such as guarantees and insurance. Removing extra costs, developing taxonomies and market ecosystems, and enhancing information disclosure and transparency can also help to scale up sustainable finance as a source of investments for the transition.
- **An international emissions-allocation framework could enable fairer outcomes for developing Asia.** The lowest-cost GHG emissions mitigation opportunities are often in countries with low levels of historical per capita emissions and low levels of economic development. Both development and decarbonization objectives can be achieved when higher-income economies with higher mitigation costs support the low-carbon growth of low income, low emissions countries. Use of principles embedding fairness to allocate emissions, in combination with global carbon trade, could achieve a low-carbon future more efficiently and equitably than the current internationally fragmented approach. This could enable lower income, lower per capita emissions countries to be better compensated for keeping emissions low.

- **Progressive climate policies are needed to ensure fairness.** Although the low-carbon transition can create many net benefits, they are unequally distributed, and some groups may be adversely affected through energy and food prices or via changes to employment. Progressive revenue recycling can offset potentially regressive effects of climate policies. Workers affected during the low-carbon transition, such as those in coal mining, will need to be both offered social protection and reequipped with new skills to access opportunities in the low-carbon economy. Agriculture is essential to the livelihoods of many of the poorest people in Asia, yet it faces simultaneous pressures posed from mitigation policies and unmitigated climate change. For Asia's future to be fair, agriculture must be equipped to face these challenges through investments in public services and improvement of land rights.

1 Asia's Special Stake in the Global Climate Crisis

Climate change is a unique global challenge. Policy makers around the world have agreed under the Paris Agreement that warming must be contained to well below 2 degrees Celsius (°C) above preindustrial levels by 2100. Yet, emissions continue to rise, as does the share of years setting new temperature records. The Paris Agreement sets out a mechanism for countries to pledge individual emission reduction targets, but it does not solve the fundamental externality problem that individual country gains from averting climate change depend on whether other countries act in concert. Any country that acts unilaterally to reduce emissions quickly delivers climate benefits that principally go to the rest of the world, while incurring the costs individually. Yet, if countries act together, nearly all countries can gain from reducing emissions.

A wide range of countries made pledges after the Paris Agreement to attain net zero greenhouse gas (GHG) emissions by specific target years within the mid to late 21st century. This is an unprecedented development for international climate policy. While the pledges are nonbinding and exceed the expected terms of office of the policy makers who made them, they can be considered as newfound recognition that the world must achieve net zero emissions on an accelerated timeframe.

The climate change challenge is of special relevance to developing Asia. The region, by many measures, stands to lose much more from unmitigated climate change than the rest of the world. At the same time, as developing Asian economies are projected to account for a majority of global economic activity by 2050 (Leimbach et al. 2017), the region will have a massive economic footprint that can determine the global GHG emissions trajectory.

This report explores what a global transition to net zero could mean for developing Asia. It begins by taking stock of Asia's stake in climate change, examining the implications of Asia's development trajectory, and reviewing commitments and pledges to reduce emissions. Section 2 considers potential future emissions paths, which include current policies, nationally determined contributions (NDCs), net zero pledges, and optimal paths to global net zero. It then analyzes how major emitting sectors would evolve under these pathways. Section 3 examines the potential socioeconomic consequences of the low-carbon transition in terms of policy costs, benefits from reduced climate change, co-benefits, labor market outcomes, and implications for equity. Analyses in Sections 2 and 3 are conducted for developing Asia's largest emitters and subregions, with a focus on the expected transformation in energy and land use. Section 4 offers policy insights on how to ensure the transition is efficient and equitable.

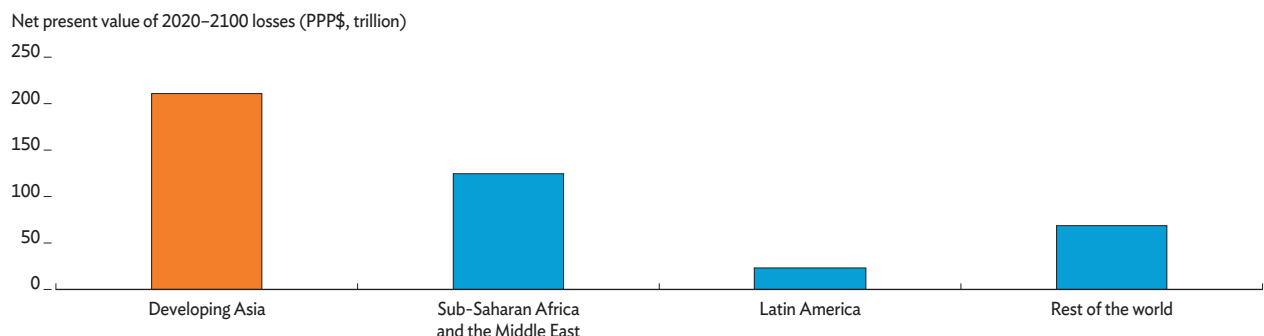
This report offers four new contributions on decarbonization in developing Asia. First, it brings an up to date focus on the role of developing Asia using a leading global model that includes interactions with other regions. Second, the Asia focus uses net zero pledges and pathways, rather than previous assumptions that carbon dioxide removal will eventually clean up the "overshoot" of carbon budgets. Third, it analyzes a broader series of consequences of the low-carbon transition using a consistent framework, including not only efficiency implications but also labor market and distributional consequences. Fourth, it offers an updated stocktaking of key policies needed for Asia's decarbonization.

1.1 Climate Change Is a Critical Threat to Asia

Developing Asia has the most vulnerable populations to climate change in the world. By 2020, global average temperature had already increased to 1.1°C above preindustrial levels, rising at a rate faster than at any point in recorded history (IPCC 2021). The region's geographic features and socioeconomic conditions expose much of the population to climate-related risks and stresses, while limited economic development constrains the coping-ability of billions of people. Rising temperatures, increased frequency of heatwaves and large storms, more variable precipitation levels, and sea level rise (SLR) will increasingly constrain the region's development unless climate change is contained. Developing Asia will experience large economic losses if climate change is not addressed (Figure 1.1).

Figure 1.1 Total Economic Losses from Climate Change under a High Emissions Scenario by World Regions by 2100

Developing Asia will experience large economic losses if climate change is not addressed.



PPP = purchasing power parity.

Notes: Values are for Representative Concentration Pathway 8.5/Category 8 pathway in 2010 values, discounted at 3%. Developing Asian values exclude the Pacific and the Republic of Korea, due to the regional aggregation of the model providing estimates.

Source: Authors' calculations from van der Wijst, K. et al. 2023. [New Damage Curves and Multimodel Analysis Suggest Lower Optimal Temperature](#). *Nature Climate Change* 1777.

Developing Asia is already exposed to risks amplified by climate change. From 2000 to 2022, the region accounted for more than half of multi-hazard global average annual losses, most of which were climate related (UNESCAP 2022). Based on the 2021 Climate Risk Index, six out of the top 10 countries most affected by weather-related loss events (i.e., storms, floods, landslides, and heatwaves) over 2000–2019 were in developing Asia. During this period, 82,000–140,000 casualties and \$233 billion–\$1.5 trillion worth of loss and damage to property were recorded in the region (Eckstein, Künzle, and Schäfer 2021). Flooding is the largest source of losses, and the frequency of “atmospheric river” events with extreme rainfall is rising in Asia (WMO 2022). In 2021, flooding caused \$18.4 billion worth of damage in the People's Republic of China (PRC), while unprecedented flooding in Pakistan in 2022 affected around 33 million people with estimated total damages exceeding \$14.9 billion (World Bank 2022). These events not only directly put lives and property at risk but also lead to larger indirect supply chain and business disruptions.

1.1.1 Sector Vulnerabilities

Asia's highly populated low-lying coastal zones makes the region the most exposed globally to SLR, storm surges, flood events, and land subsidence. Under a high emissions scenario, SLR will put as much as 16% of Southeast Asia's capital stock at risk, even after adaptation investments (Bachner et al. 2022). Unmitigated climate change by 2080 could lead to economic losses of \$168 billion–\$338 billion from SLR caused migration in Asia, and 70% of the global population affected by SLR will be in the region (IPCC 2022a).

More than 62% of transport infrastructure assets in the region with publicly available information are highly exposed to inland flooding (ADB 2022a), and many of the region's mega cities are in areas at risk from SLR and storm surges.

Natural resource-based sectors, such as agriculture and fisheries, that are directly conditioned by climate account for around a third of total employment in the region. Rising temperatures, changing precipitation levels, droughts, heat stress, flooding, SLR, and salinity intrusion disrupt agriculture production through delays in crop harvesting, declining yields and product quality, and increasing incidence of pests and diseases (ADB 2020a). India emerges as the most vulnerable in the region with yields potentially reduced by 18% by 2070. Beyond threatening the livelihoods of Asia's poor, climate change may also put at risk both regional and global food security, as the region accounted for 67% of 2014 global agricultural production (Mendelsohn 2014).

Asia is dependent on the fisheries sector, which climate change will severely affect through ocean warming and acidification. Asia's fisheries and aquaculture constituted 75% of global production in 2019. In Southeast Asia, projections suggest that ocean warming and acidification will affect 99% of coral reefs by 2030, with 95% highly threatened by 2050 (IPCC 2022a). The degradation of coral reefs in the Pacific from severe bleaching and tropical storms could result in a 90% reduction in live coral cover by the end of century (Townhill et al. 2020).

Climate change will harm tourism in developing Asia. Tourism in the region employs many people, with employment shares reaching 7.4% in Thailand and 11.5% in the Philippines (ILO 2021). There is an optimal temperature range for tourism that could be exceeded during more months in Asia due to climate change. This would lead to losses of up to 40% of tourism expenditure in the region's warmer countries, such as the Philippines (Hamilton et al. 2005). Climate change effects on ecotourism attractions, such as coral reefs and tropical forests, as well as the increased frequency of extreme weather events, may amplify these losses.

Climate change will increase energy demand and hinder energy supply. While energy demand for heating may generally fall with climate change, the increase in energy needed for cooling is much larger. By one estimate, annual cooling demand in the 2050s could reach up to 75% of current electricity demand in parts of Asia (Sherman, Lin, and McElroy 2022). In addition, with higher temperatures, thermal energy generation loses efficiency, changes in surface flows and evaporation may adversely affect hydropower, and increased storm events may damage transmission and distribution infrastructure.

Climate change will reduce labor productivity and working hours in climate-exposed sectors. Developing Asia has peak humidity-adjusted temperatures that are at the upper limits of the conditions permitting physical labor. Sectors such as agriculture that cannot easily be subject to cooling will experience substantial productivity losses. Climate change will cause these limits to be exceeded for much longer periods, leading to a potential loss of 3.1% of working hours by 2030 (ILO 2019).

Higher temperatures will increase morbidity and mortality. Climate change will increase the spread of vector- and waterborne diseases and deaths due to cardiovascular stress in developing Asia. It may also amplify nutritional deficits, injuries from extreme weather events, and other health hazards (McMahon and Gray 2021; Deschenes 2018). The cost of mortality risk caused by climate change has been estimated to reach 3.2% of global gross domestic product (GDP), which disproportionately affects low-income and warm countries (Carleton et al. 2022). Econometric analyses find significant associations between temperature increases and mortality, with estimates suggesting that mortality in developing Asia will increase by 46% as a result of temperature increases reached by the late 21st century (Deschenes 2018).

1.1.2 Economy-wide Vulnerability

The combined effects of individual channels could be enormous, even if quantification is daunting.

Econometric attempts have been made to proxy short-term weather variations—principally temperature—for climate change and project associations with economic activity as the basis for losses due to change in mean temperatures, but such an approach is very sensitive to choices of regression specification (Newell, Prest, and Sexton 2021). More fundamentally, unpredictable weather shocks may not be a good proxy for predictable changes in mean conditions, and estimated macroeconomic coefficients on temperature tell little about the mechanisms of loss. Van der Wijst et al. (2023) conducted a process-based modeling exercise to integrate into economy-wide global models. Their modeling estimates detailed up-to-date representations of climate change consequences, such as river-based flooding and SLR, and for specific sectors, including energy, agriculture, and transport (Box 1.1). The results are illustrative of the risks posed to the region, as they avoid many of the concerns about climate-econometric macroeconomic damage functions.

In the absence of climate action, the region will bear a heavy cost from climate change. Processed estimates from van der Wijst et al. (2023) under the high emissions climate scenario of the Intergovernmental Panel on Climate Change (IPCC) show that developing Asia stands to lose 24% of GDP by 2100. India and Southeast Asia have mean losses of, respectively, 35% and 32%, of GDP by 2100, while the rest of South Asia has losses of 24% and the PRC losses of 8% (Figure 1.2).¹ It should be noted that these losses are far higher than those projected by previous attempts to estimate losses under process-based modeling, which typically have reported losses under similar scenarios of less than 15% of GDP for subregions of Asia (Raitzer et al. 2015; Ahmed and Suphachalasai 2014; Westphal, Hughes, and Brommelhorster 2013). The higher losses are directly driven by advancements in how the sector shocks have been considered.

In the near term, river flooding losses are found to be the dominant channel of loss across most of developing Asia, while agricultural losses rise in importance over longer periods. Long-term losses have different drivers by location, with agricultural losses dominant in India and the rest of South Asia, flooding and SLR dominant in Southeast Asia, and changes to energy demand and labor productivity dominant in the PRC. Flooding and SLR, as well as losses in agriculture, are found to disproportionately damage areas outside the PRC. The dominant damage shares are also likely to disproportionately affect poor people, as they are more likely to live in areas at risk of flooding, depend on agriculture, and work in manual sectors affected by peak temperatures. As a majority of female employment in India and the rest of South Asia is in agriculture, the large impacts on the sector in the subregions may exacerbate gender inequality.

The modeled channels are only a subset of the effects expected from climate change because many omitted channels remain important. For example, the analysis does not consider climate change effects on mortality, complex ecosystem services, such as pollination, or increased climate variability beyond flooding. It also does not include the ecological tipping points or feedbacks that may cause climate change by altering biogeochemical cycles in ways that amplify warming. This means the losses actually remain lower-bound estimates. Clearly, the region has much to gain if global climate change is addressed.

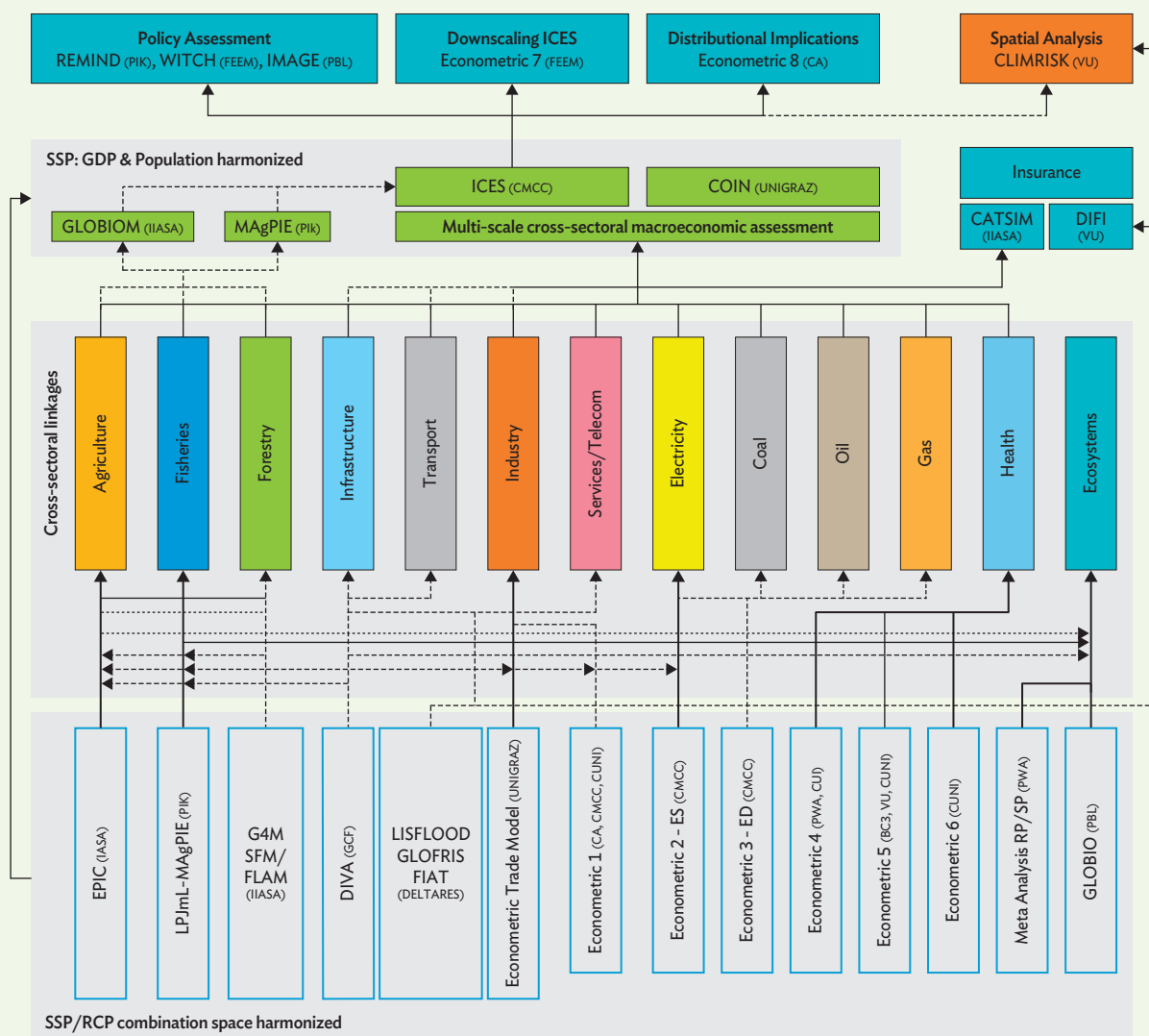
¹ The high emissions scenario is termed Representative Concentration Pathway 8.5 in the IPCC's 5th Assessment Report and the Category 8 pathway in the 6th Assessment Report.

Box 1.1 Co-designing the Assessment of Climate Change Costs Project

Damage functions connect global or local temperature increases to loss of income or consumption. The Co-designing the Assessment of Climate Change Costs (COACCH) Project developed a set of damage functions based on detailed modeling for nine impact sectors: agriculture, forestry, fisheries, sea level rise, riverine floods, road transportation, energy supply, energy demand, and labor productivity by 13 partner institutes. These sector shocks are fed into two computable general equilibrium models: Intertemporal Computable Equilibrium System (ICES) and Cost of Inaction (COIN) (box figure). This allows the analysis of these physical damages on economic losses and captures the linkages between sectors and trade flows of domestic and international goods and services.

This analysis was done for a range of future warming scenarios to consider uncertainty, as well as future socioeconomic development, and it took further account of climate model uncertainty through scenario variations. This report makes use of relationships estimated from COACCH based on averaging the pooled set of scenarios and model runs.

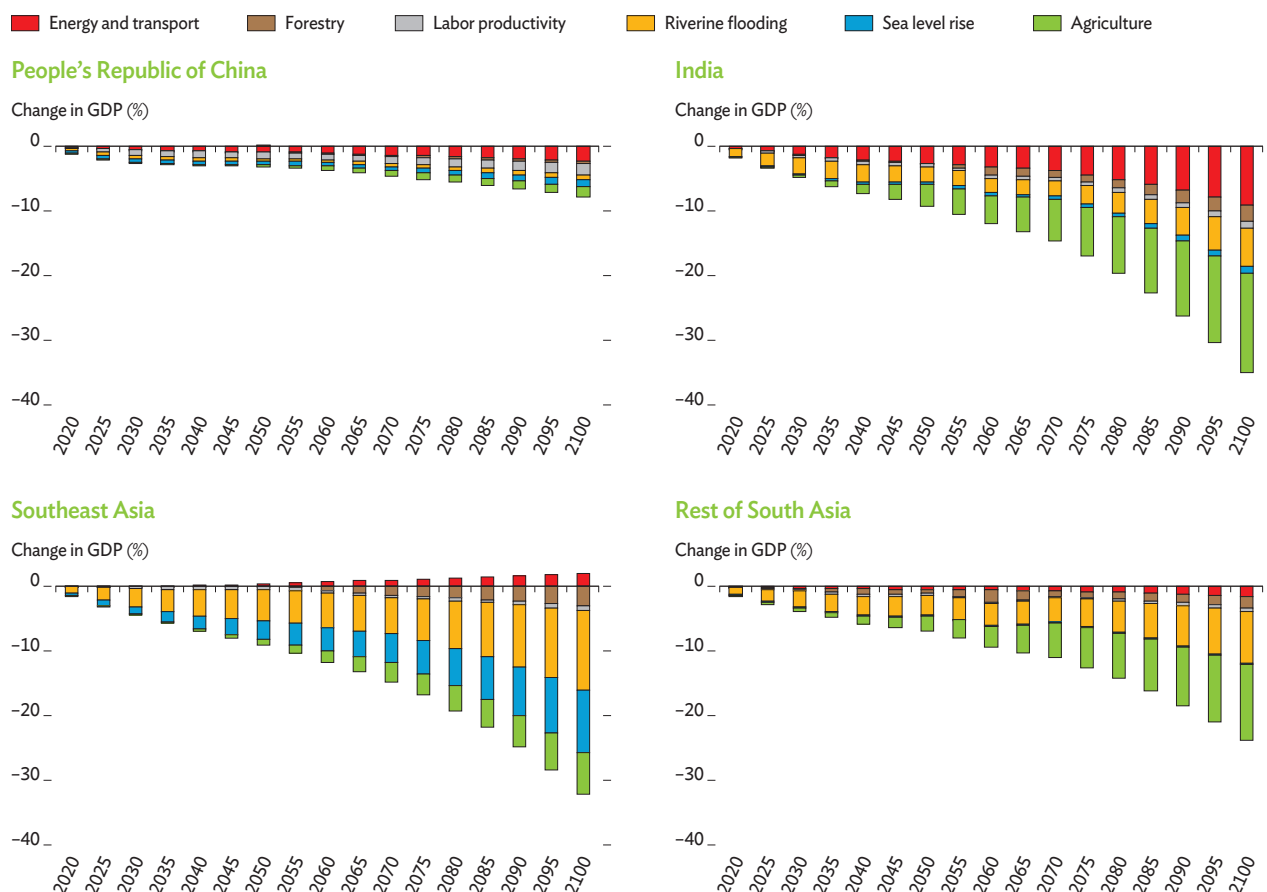
Structure of the Co-designing the Assessment of Climate Change Costs Project Modeling Approach to Gauge Climate Change Impacts



Source: CO-designing the Assessment of Climate Change costs. 2021. D5.7 [Climate Change Impacts & Policy Synthesis](#).

Figure 1.2 Economic Losses from Climate Change in Developing Asia under a High Emissions Scenario by 2100

Without climate policies, developing Asia will face large losses.



GDP = gross domestic product.

Notes: Change in GDP (%) is relative to the scenario without climate change. Scenario results are for Intergovernmental Panel on Climate Change Representative Concentration Pathway (RCP) 8.5/Category 8 Pathway. Mean losses over the period are generated by harmonizing to RCP 8.5 via reported damage functions, averaging across results of reported individual model runs, and extrapolating aggregate losses from 2070 to 2100 via damage functions. The sector composition of losses is held constant over 2070–2100, as damage functions are only reported at the aggregate level. For this reason, the sector composition of losses after 2070 should be interpreted with caution.

Source: Authors' calculations from van der Wijst, K. et al. 2023. [New Damage Curves and Multimodel Analysis Suggest Lower Optimal Temperature. Nature Climate Change 1777.](#)

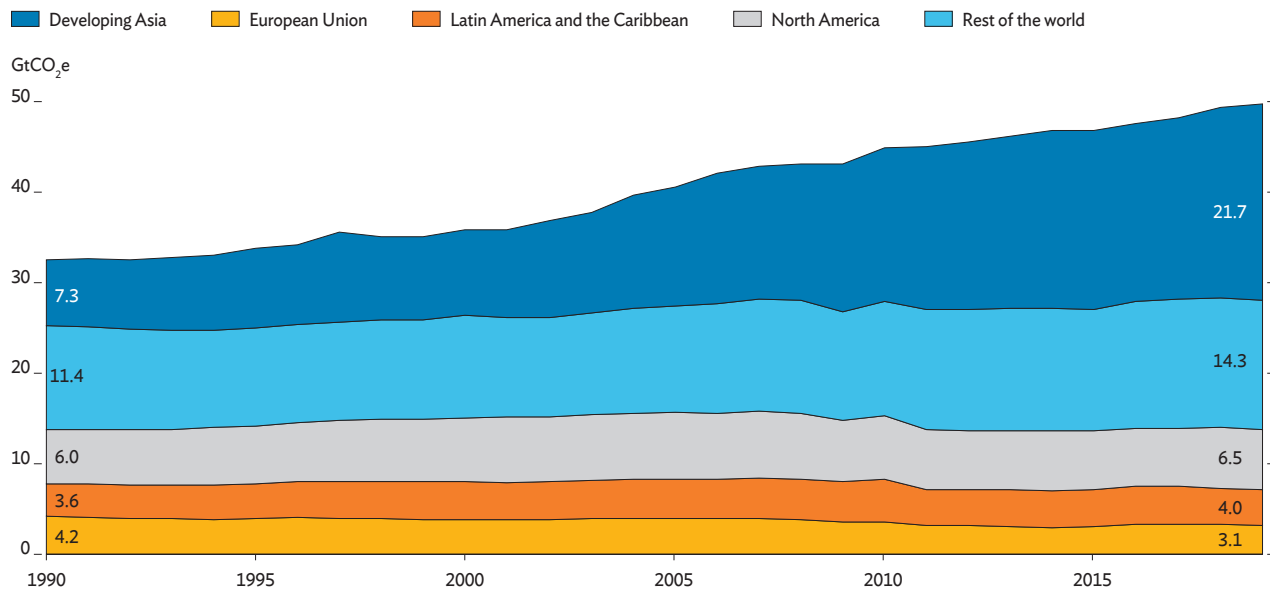
1.2 Climate Change Cannot be Addressed without Asia

Developing Asia is increasingly a contributor to the global climate crisis. The region's GHG emissions have been growing much faster than the global average since the 1980s. In 2019, the world emitted approximately 50 billion tons of carbon dioxide equivalent (GtCO₂e), 50% greater than the level of around 33 GtCO₂e in 1990. During this period, developing Asia's GHG emissions increased rapidly, from 7.3 GtCO₂e in 1990 to 21.7 GtCO₂e in 2019 (Figure 1.3), while other global regions' GHG emissions were either increasingly moderately or, in the case of the European Union (EU), decreasing. As a result, developing Asia's share of global GHG emissions doubled from 22% in 1990 to 44% in 2019 and is expected to remain at this level until mid-century if current policies continue. At current levels of GHG emissions of 21.7 GtCO₂e per year, Asia would by itself exhaust the global remaining carbon budget consistent with under 1.5°C warming by 2040.²

² Climate Analytics and NewClimate Institute. [Climate Action Tracker](#) (accessed 20 February 2023).

Figure 1.3 Global Annual Greenhouse Gas Emissions, 1990–2019

Emissions from developing Asia have been rapidly increasing.



GtCO₂e = billion tons of carbon dioxide equivalent.

Notes: Emissions from land use change and forestry, which can be positive or negative, are included. Developing Asia includes all ADB member economies except for Hong Kong, China; and Taipei, China for lack of data.

Source: World Resources Institute. [Climate Watch](#) (accessed 10 January 2023).

The top three emitters in developing Asia account for around one-third of 2019's global GHG emissions.

The top 10 emitters globally account for more than 60% of total GHG emissions, while the bottom 100 account for less than 3%. In developing Asia, the PRC, India, and Indonesia are the largest emitters, accounting for 23%, 6.8%, and 3.9% of global GHG emissions, respectively, in 2019.

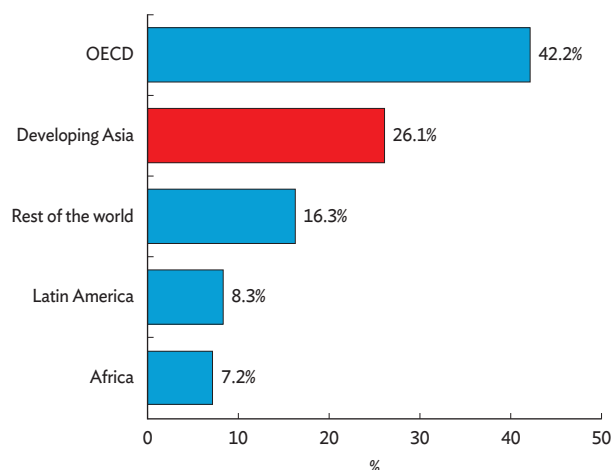
The increasingly dominant proportion of global GHG emissions generated by developing Asia contrasts sharply with limited historical emissions from the region. Global cumulative historical GHG emissions in the postindustrial revolution era have been estimated at 2,400 GtCO₂e. Developed countries contributed about 42% of those emissions, whereas economies in developing Asia contributed only about a quarter over the same period, despite having a much larger population (Figure 1.4).³

Although aggregate emissions are rising sharply, developing Asia's per capita emissions remain below the global average. During the past 3 decades, the region's per capita emissions have doubled, from 2.6 tons of carbon dioxide equivalent (tCO₂e) in 1990 to 5.3 tCO₂e in 2019, largely due to increases in the PRC. Nevertheless, per capita GHG emissions in developing Asia remain lower than the global average of 6.4 tCO₂e per person in 2019 and are a fraction of those of advanced economies (Figure 1.5). From a population perspective, developing Asia has yet to be an equal contributor to climate change, although rapid economic growth in the region is changing this.

³ The authors conducted the calculation using data from Global Carbon Budget 2022. [Global Carbon Budget 2022](#). *Earth System Science Data* 14(11).

Figure 1.4 Historical Cumulative Net Anthropogenic Carbon Dioxide Emissions by Region, 1850–2021

Developing Asia economies contributed more than a quarter of cumulative CO₂ emissions.

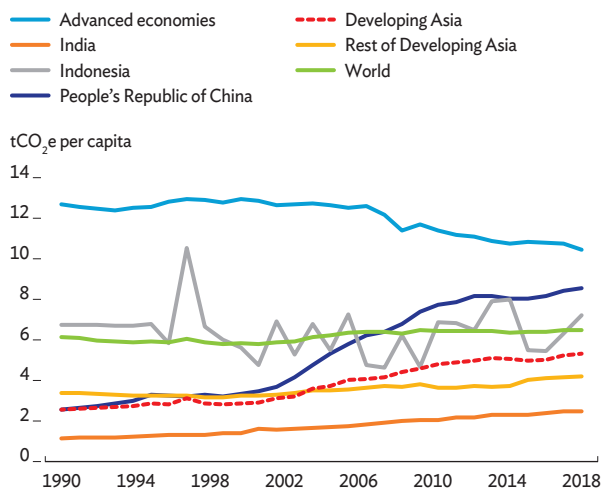


CO₂ = carbon dioxide, OECD = Organisation for Economic Co-operation and Development.

Source: Integrated Carbon Observation System. Data supplement to the *Global Carbon Budget 2022* (accessed 10 February 2023).

Figure 1.5 Greenhouse Gas per Capita Emissions by Region, 1990–2019

Developing Asia's per capita emissions remain below the global average level.



tCO₂e = tons per carbon dioxide equivalent.

Notes: Greenhouse gas emissions including land use, land use change, and forestry. Developing Asia includes all ADB developing member economies excluding Cook Islands; Hong Kong, China; Taipei, China; and Niue for lack of data. Rest of developing Asia excludes India, Indonesia, and the PRC.

Source: World Resources Institute. *Climate Watch* (accessed 13 February 2023).

Developing Asia's carbon intensity continues to be higher than the world average, despite declining substantially during the 1990s and early 2000s.⁴

The region's carbon intensity is 41% higher than the average of the rest of the world and more than double that of North America and the EU in 2019. The high carbon intensity of GDP amplifies the effect of economic growth on emissions. Carbon intensity dropped by 66% from 1990 to 2019 globally, with the largest declines in formerly planned and fast-growing economies. This decline in carbon intensity is driven by an increasing share of services in economies, efficiency improvements, and the adoption of cleaner energy. Within developing Asia, although carbon intensity fell rapidly in the 1990s and early 2000s in the Caucasus and Central Asia and the PRC, with more modest declines in Indonesia during the same period, carbon intensity has remained stable since 2010 (Figure 1.6). Unless carbon intensity falls further, developing Asia's emissions will grow dramatically as economies in the region expand.

The energy sector accounts for three-fourths of GHG emissions from the region. Within the sector, electricity and heat production is the largest and fastest-growing source of emissions, accounting for about 40% of emissions in 2019 (Figure 1.7). Other major sources include manufacturing (18%) and agriculture, land use change, and forestry (13%). Emission sources vary significantly across the region. In the Caucasus and Central Asia, fugitive emissions (leaks, losses, or other releases of GHG) from the oil and gas industry are important. Agriculture and land use change and forestry contribute the most GHG emissions in the Pacific and Southeast Asia.

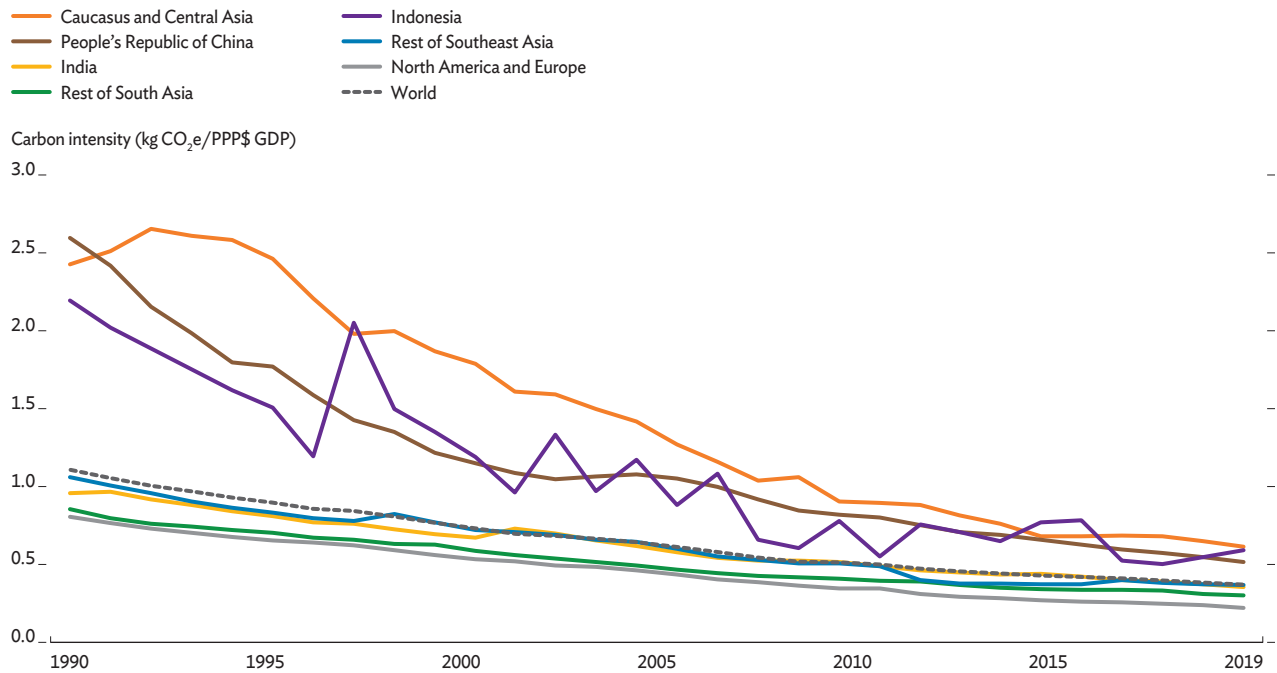
Employment and production in developing Asia rely heavily on activities that are carbon-intensive, such as manufacturing, transportation, and energy. From 2015 to 2021, these sectors accounted for 43% of GDP and 42% of employment in the region, which is significantly higher than in other parts of the world.⁵

⁴ Emission intensity is defined as the total amount of GHG emissions emitted for every unit of GDP.

⁵ Authors' calculations based on data from CEIC Data Company.

Figure 1.6 Carbon Intensity in Developing Asia and the World, 1990–2019

Carbon intensity has fallen over time in developing Asia, but at a reducing rate.



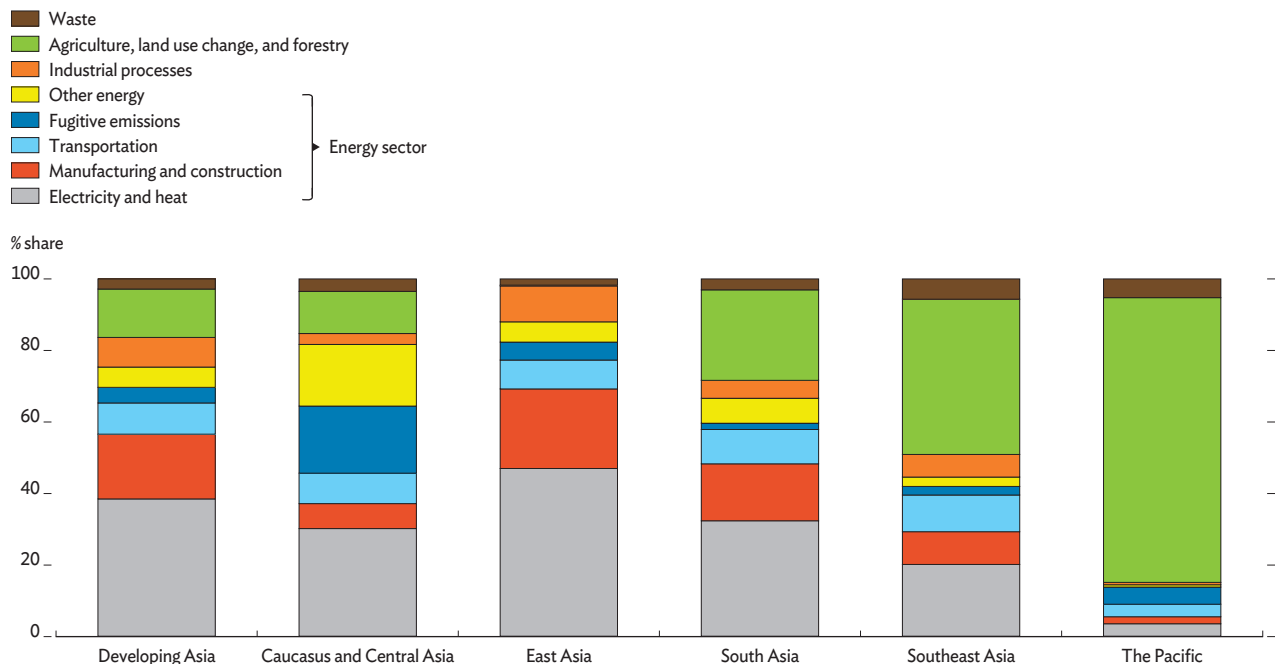
GDP = gross domestic product, kgCO₂e = kilogram per carbon dioxide equivalent, PPP = purchasing power parity.

Note: Emissions from land use change and forestry, which can be positive or negative, are included.

Source: World Resources Institute. [Climate Watch](#) (accessed 13 February 2023).

Figure 1.7 Greenhouse Gas Emissions by Sector in Developing Asia, 2019

Sources of emissions differ by subregion.



Notes: Emissions from land use change and forestry, which can be positive or negative, are included. Developing Asia includes all ADB member economies excluding Hong Kong, China; and Taipei, China for lack of data.

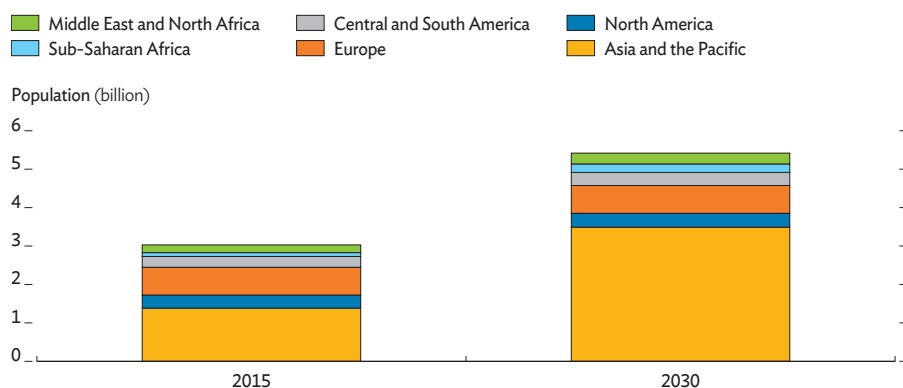
Source: World Resources Institute. [Climate Watch](#) (accessed 13 February 2023).

In the United States, these activities contributed 18% to GDP, 23% in the euro area, and 24% each in Latin America and Sub-Saharan Africa. A substantial share of emissions in these sectors, particularly from the PRC, are for products exported to other regions. If emissions arising from trade are considered coming from destination markets, the PRC's emissions are about 10% lower and EU's emissions about 15% higher than conventional estimates in 2018 (OECD 2021a).

Asia's growth trajectory will have important implications for achieving global climate goals. A billion people in the region were still living on less than purchasing power parity (PPP) of \$3.20 a day in 2017. Although developing Asia made rapid progress in the last 2 decades in providing access to electricity, an estimated 940 million people experience frequent interruptions and about 350 million do not have an adequate supply (IEA 2020). As households in the region become wealthier, demand for energy will increase. Asia's projected growth in middle-class consumers dwarfs all other world regions (Figure 1.8). With the associated expansion in spending will come a growing carbon footprint. For example, in India, the top 20% of households emitted seven times the emissions of poor households (Lee et al. 2021). If this pattern of growth continues as households move up the income ladder, Asia's emissions will be enormous.

Figure 1.8 Expansion of the Middle Class by Region, 2015 and 2030

The number of middle-class people in developing Asia is growing rapidly.



Notes: Middle class is defined as households with per capita income of \$10–\$100 per person per day in 2005 purchasing power parity terms. Asia and the Pacific includes both developed and developing economies in the region.

Source: Recreated based on Kharas, H. 2017. *The Unprecedented Expansion of the Global Middle Class: An update*. Brookings.

1.3 Developing Asia is Beginning to Respond to the Climate Challenge

1.3.1 Framework Set by the Paris Agreement

Climate change is increasingly recognized as important by governments around the world, including in developing Asia. In 2015, the landmark Paris Agreement was agreed by 196 parties, including 45 developing economies in Asia. Its goal is to limit global warming to well below 2°C and pursue efforts to 1.5°C compared to preindustrial levels. To achieve this goal, the Paris Agreement sets up a process in which parties submit commitments to reduce future GHGs and increase adaptation to climate change through NDCs. These were initially submitted in 2015 with coverage until 2030. The NDCs are intended to be updated every 5 years, and the first update was in 2020. Each subsequent submission is intended to increase ambition for climate action, especially on mitigation. All parties from developing Asia have submitted NDCs, and most have submitted updates or second NDCs (Table 1.1). Those with second NDCs tend to be smaller emitters, such as Bhutan, the Marshall Islands, Nepal, Papua New Guinea, Samoa, and Thailand. While most of those submitting second NDCs increased their ambitions, the NDCs still collectively fall short of what is needed to achieve the agreed-on goals of limiting temperature change to well below 2.0°C or 1.5°C (UNFCCC 2022).

Table 1.1 Submissions and Pledges Made by Paris Agreement Parties from Developing Asia*Most developing Asian economies have submitted NDCs, but fewer have submitted long-term strategies.*

Party	Most Recent NDC Submission		Long-Term Strategy Submission	Net Zero	Status
Afghanistan	2016	First NDC	NS	2050	Declaration/Pledge
Armenia	2021	Updated first NDC	NS	2050	Declaration/Pledge
Azerbaijan	2017	First NDC	NS	NS	
Bangladesh	2021	Updated first NDC	NS	NS	
Bhutan	2021	Second NDC	NS	2030	Achieved
Cambodia	2020	Updated first NDC	2021	2050	In policy document
People's Republic of China	2021	Updated first NDC	2021	2060	In policy document
Cook Islands	2016	First NDC	NS	2040	In policy document
Fiji	2020	Updated first NDC	2019	2050	In law
Georgia	2021	Updated first NDC	NS	NS	
India	2022	Updated first NDC	2022	2070	Declaration/Pledge
Indonesia	2022	Updated first NDC	2021	2060	In policy document
Kazakhstan	2016	First NDC	NS	2060	In policy document
Kiribati	2016	First NDC	NS	2050	Declaration/Pledge
Kyrgyz Republic	2021	Updated first NDC	NS	2050	Declaration/Pledge
Lao PDR	2021	Updated first NDC	NS	2050	In policy document
Malaysia	2021	Updated first NDC	NS	2050	In policy document
Maldives	2020	Updated first NDC	NS	2030	In law
Marshall Islands	2020	Second NDC	2018	2050	In policy document
Micronesia, Federated States of	2022	Updated first NDC	NS	2050	Declaration/Pledge
Mongolia	2020	Updated first NDC	NS	NS	
Myanmar	2021	Updated first NDC	NS	2050	Declaration/Pledge
Nauru	2021	Updated first NDC	NS	2050	In policy document
Nepal	2020	Second NDC	2021	2050	In policy document
Niue	2016	First NDC	NS	...	
Pakistan	2021	Updated first NDC	NS	2050	Declaration/Pledge
Palau	2016	First NDC	NS	2050	Declaration/Pledge
Papua New Guinea	2020	Second NDC	NS	2050	Declaration/Pledge
Philippines	2021	Updated first NDC	NS	NS	
Samoa	2021	Second NDC	NS	2050	Declaration/Pledge
Solomon Islands	2021	Updated first NDC	NS	2050	In policy document
Sri Lanka	2021	Updated first NDC	NS	2060	In policy document
Tajikistan	2021	Updated first NDC	NS	NS	
Thailand	2022	Second NDC	2022	2065	In policy document
Timor-Leste	2022	Updated first NDC	NS	NS	
Tonga	2020	Updated first NDC	NS	2050	Declaration/Pledge
Turkmenistan	2016	First NDC	NS	NS	
Tuvalu	2016	First NDC	NS	2050	Declaration/Pledge
Uzbekistan	2021	Updated first NDC	NS	2050	In policy document
Vanuatu	2022	Updated first NDC	NS	2050	Declaration/Pledge
Viet Nam	2022	Updated first NDC	NS	2050	In policy document

Lao PDR = Lao People's Democratic Republic, NDC = nationally determined contribution, NS = not submitted/declared/pledged.

Notes: Color corresponds to NDC submission and net zero pledge status. Status as of end 2022. Excludes Brunei Darussalam and the newly industrialized economies of Hong Kong, China; the Republic of Korea; and Taipei, China.

Sources: UNFCCC. 2023. [NDC Registry](#); [Net Zero Tracker](#); [Climate Action Tracker](#); [CAT Net Zero Tracker](#) (all accessed 20 February 2023); UNEP. 2022. [Emissions Gap Report 2022](#).

The Paris Agreement is an important milestone, but it left many details about international coordination to be defined in the future. As submissions are by individual governments, there is no mechanism to ensure that collective ambitions match the stated goals of the agreement. Submissions are intended to increase in mitigation ambition during every revision, in response to a periodic global stocktake of gaps between NDCs and mitigation needs to reach Paris Agreement goals. However, there is no mechanism to enforce or guide the intended ratcheting up of mitigation contributions. Nor is there a well-defined way to ensure that mitigation occurs where it is most cost-effective. Elements of a global carbon market are present, such as the ability of developing countries to differentiate unconditional climate action undertaken with own resources, compared with action conditional on international support. The agreement's Article 6 establishes space for countries to bilaterally trade in mitigation outcomes and for eventual multilateral trade in emission reductions. However, rules governing carbon markets were not agreed until 2021, and progress on actual market implementation remains nascent.

1.3.2 A Growing Global Consensus to Achieve Net Zero

A growing number of countries have made net zero pledges. Achieving Paris Agreement goals will heavily depend on what happens in the decades after the 2030 end-date of most NDCs. The agreement stipulates there should be a global aim for net zero GHG emissions by calling for a “balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century.” In response, a growing number of parties have individually pledged to achieve net zero emissions by specific dates. As of late 2022, 140 countries worldwide—representing 90% of global emissions—had announced or were considering net zero targets.⁶ This includes 19 developing Asian economies, accounting for about 80% of the region's 2019 total GHG emissions. This share of emissions is higher than the corresponding 61% share in Latin America and the Caribbean. Eight lower and middle-income developing Asian economies have submitted long-term strategies under the Paris Agreement, as have the Republic of Korea and Singapore, and these strategies serve to formalize the pledges.

Net zero pledges and goals take many forms. Most are political pledges made by heads of state or an ambition written into a policy document. Only a few net zero pledges are actually written into law, and only a small share of governments in developing Asia have developed long-term strategies.⁷ In general, there is no enforcement mechanism to make the pledges binding under the Paris Agreement. Thus, although they remain important statements of ambition, whether they are followed is subject to much uncertainty. Most net zero pledges also imply faster rates of decarbonization than are expressed in unconditional NDCs.

1.3.3 Gaps between Climate Ambitions and the Current Situation

Important gaps remain between many NDCs and tangible plans and policies. By one measure, 65% of economies in developing Asia have yet to update existing strategies to support the implementation of recent NDC submissions (UNESCAP 2022). Only a handful of economies in developing Asia mention climate change targets in their national development plans. Gaps between climate ambitions and specific policies are often clearest in the power sector. India, Indonesia, the PRC, and the region's other major economies continue to develop new coal-fired power generation where coal is a particularly carbon-intensive fuel. New records were set in 2021 in the PRC for coal extraction, while coal remains a top export for Indonesia. The region accounts for 94% of the global pipeline of coal-fired power plants under construction, planned or announced.

Developing Asia faces a climate policy crossroads. Although its economies have embraced high-level and long-term ambitions for carbon neutrality, growth remains fossil fuel- and carbon-intensive. For Asia to avoid catastrophic climate change that puts its own development at risk, a major shift in its development trajectory is needed.

⁶ Climate Analytics and NewClimate Institute. [Climate Action Tracker](#).

⁷ Section 2 provides more details on net zero pledges in the region covered in this report.

2 Asia's Transformation during the Global Transition to Net Zero

Developing Asia will play a critical role in the global effort to limit global warming. This section examines the key climate mitigation choices the world and developing Asia face in five core climate policy scenarios. An integrated assessment model (IAM) is used to analyze the main transformations required for land use and the energy sector in the region under the different scenarios, along with investment needs.

2.1 Key Choices for Climate Change Mitigation

Although the world reached a consensus in 2015 through the Paris Agreement to keep global warming to well below 2°C, there is little agreement on how this goal should be achieved. Individual economies have made mitigation pledges in the form of NDCs that are intended to be strengthened over time, but elements to foster coordination among countries are only slowly emerging. This means that decisions about the actual level of mitigation by specific countries, how fast mitigation should happen, how much mitigation can be deferred to carbon removal technologies, whether carbon trade is mainstreamed, and the level of international cooperation are key policy choices facing the world. These choices will not only determine whether the world will be able to meet Paris Agreement goals and avoid climate catastrophe but also how the costs and benefits of the transition to net zero will be distributed across and within countries and over time.

2.1.1 Scenarios

This report uses a detailed model with five core scenarios that embody the key policy choices for climate action and examines their implications for developing Asia. All five scenarios (Table 2.1) follow the “middle of the road” shared socioeconomic pathway agreed by the international modeling community for population and economic growth (Riahi et al. 2017).

Table 2.1 Climate Scenario Matrix

The scenarios embody key policy choices for climate action.

Scenario	NDCs until 2030	2030 to Net Zero Year	International Carbon Trade	Carbon Emissions 2020–2100
Current policies	No	Current policies	No	3,270 GtCO ₂ (endogenous)
NDC effort	Unconditional	NDCs extrapolation	No	2,650 GtCO ₂ (endogenous)
Uncoordinated net zero	Unconditional	Pledged transition	No	1,420 GtCO ₂ (endogenous)
Global net zero	Unconditional	Fast transition	Yes	1,150 GtCO ₂
Accelerated global net zero	Beyond NDCs	Fast transition	Yes	1,150 GtCO ₂

GtCO₂ = billion tons of carbon dioxide, NDC = nationally determined contribution.
Source: Authors.

The first set of scenarios can be considered extensions of “bottom up” policy directions taken to date nationally and under the Paris Agreement:

- **Current policies** assumes no additional effort on climate change mitigation beyond what is already included in energy and climate policies up to 2020. This scenario serves as a reference against which all the other scenarios are compared. Where NDCs and more specific sector policies diverge, this scenario reflects sector policies rather than NDCs.⁸
- **NDC effort** assumes the implementation of unconditional NDCs until 2030, with gradual strengthening thereafter.⁹ NDCs in the form of emission reduction targets and renewable energy targets (both shares and capacity) are included in the scenario. As NDCs cover emission reductions only until 2030, this scenario assumes a gradual strengthening of pledges after 2030 through increases in implicit carbon prices at the social discount rate, which is approximately 3%.¹⁰
- **Uncoordinated net zero** assumes an uncoordinated global effort that relies on voluntary pledges, without considering if such pledges are sufficient or the most efficient way to achieve Paris Agreement goals. This scenario implements unconditional NDCs until 2030 followed by national net zero pledges for countries with pledges to attain net zero emissions by a given date. For countries without pledges, NDCs are strengthened gradually after 2030, similar to the NDC effort scenario just described.¹¹

The following two scenarios can be considered as more optimal alternatives to the current bottom-up approaches to climate policy in a world where global climate policy is more coordinated than has been the case so far.

- **Global net zero** assumes unconditional NDCs until 2030 and a coordinated global effort thereafter to stay within a carbon budget of 1,150 billion tons of carbon dioxide (GtCO₂).¹² A carbon budget is the maximum amount of cumulative carbon emissions that would limit global warming to a given level.¹³ After reaching the budget, emissions need to stay at or close to zero to achieve well below 2°C of peak warming or average peak warming of 1.7°C.¹⁴ This is unlike many previous studies that allowed for an overshoot of the carbon budget and relied on risky assumptions about negative emissions technology being able to draw down GHG concentrations in the late 21st century (Drouet et al. 2021; Riahi et al. 2021). Under the global net zero scenario, a global carbon market starts in 2030 and allocates emission allowances among countries via a “contraction and convergence” framework that transitions from grandfathered emission shares to equal per capita allowances by 2050 (Meyer 2004).

⁸ This is similar to how the IPCC’s 6th Assessment Report (AR6) defines current policies.

⁹ Unconditional NDCs are pledges that countries commit to implement from their own resources; conditional NDCs are pledges that countries would undertake if international support is provided or other conditions are met. This report considers pledges submitted to the United Nations Framework Convention on Climate Change (UNFCCC) portal until 22 June 2022. For a complete list of NDCs and policies in the scenario, see Emmerling et al. (2023) and Reis and Tavoni (2023).

¹⁰ Imposing carbon prices is the policy trigger in the modeling framework, hence strengthening NDCs is implemented through an increase in carbon prices.

¹¹ Global net zero emissions are achieved when anthropogenic emissions of greenhouse gases in the atmosphere are balanced by anthropogenic removals over a specific period (IPCC 2018). National net zero pledges seek to achieve a balance of emissions at the national level. In this report, net zero refers only to net zero of CO₂ emissions, and this is a standard approach in the literature, for example, Riahi et al. (2021). Only national net zero pledges that are tagged “achieved,” “documented,” and “declared” in the UNFCCC’s [long-term strategies website](#) and the World Resources Institute [Net-Zero Tracker](#) and confirmed by documents and online national and international media are considered. See Emmerling et al. (2023) for a list of national net zero pledges included in the model.

¹² Unconditional NDCs are used to help illustrate the difference between early and delayed action toward global net zero, as conditional NDCs would have less of a contrast in the period up to 2030. The compensation needed for conditional NDCs to be implemented also is not clearly identified enough to easily model.

¹³ The total carbon budget is expressed relative to 2020.

¹⁴ Well below 2°C is interpreted as a higher than 67% probability of staying below 2°C peak temperature increase. This is based on climate category C3 of the IPCC AR6 Working Group III report (IPCC 2022b). The peak temperature is reached in 2080 in the net zero scenarios.

Emissions respond to a global carbon price that triggers optimal abatement for the world to stay within the global carbon budget. Countries that emit less than their allowances are compensated based on the carbon price by those countries that emit more than their allowances. Box 2.1 gives more details on the different emission allocation frameworks and how they relate to current developments under the Paris Agreement.

- **Accelerated global net zero** follows the global net zero scenario, with the difference that global efforts accelerate from 2023, rather than after 2030. Additional subscenarios explore the difference that key technologies can make to outcomes by excluding CO₂ removal technologies.

Box 2.1 Burden-Sharing Frameworks for Mitigating Greenhouse Gas Emissions

A major challenge for climate policy is to determine how greenhouse gas emission mitigation burden should be allocated among countries with different levels of economic development, historical responsibility, and current emissions to help achieve globally agreed goals to contain warming. Various burden-sharing frameworks have been proposed to determine the share of emissions reduction by countries. Key proposals include the following:

- Grandfathering allocates emission rights based on historical national emissions under the principle that prior resource use establishes a right to future resource use. However, this is distributionally regressive because low emitters are penalized (Rose et al. 1998).
- Equal per capita emissions grant national allocations based on national population. This approach is distributionally progressive but poses large adjustment costs to current emitters (Baer et al. 2000).
- Contraction and convergence allocates emissions progressively from historical levels to equal per capita allowances by a set date, often 2050 (Meyer 2000).
- Ability to pay assigns emission allowances based on gross domestic product (GDP) for countries above a minimum threshold of per capita GDP, with extra allocations for countries with per capita GDP below the global average (Vattenfall 2006).
- Historical responsibility, or the Brazilian Proposal, assigns the mitigation burden of countries in direct proportion to the share of cumulative emissions that each country has made to date (Rosa, Muylaert, and Campos 2003).

Of these approaches, contraction and convergence has the advantage of simplicity and transparency, while blending equity and efficiency and taking account of adjustment considerations. It also has had the widest support base, including statements at various times from top officials of developed countries, including France, Germany, Japan, and the United Kingdom, and developing countries, including Indonesia and the Philippines. Yet, international climate negotiations have not been able to achieve a full consensus on any specific framework and left mitigation proposals to the bottom-up nationally determined contribution (NDC) process under the Paris Agreement. As a result, NDCs submitted so far reflect divergent interpretations of appropriate burden sharing. However, it could still be possible for groups of countries to come together to submit future NDC revisions under burden-sharing frameworks that coordinate their levels of ambition.

References:

- ADB (Asian Development Bank). 2015. *Southeast Asia and the Economics of Global Climate Stabilization*.
 Baer, P., et al. 2000. Equity and Greenhouse Gas Responsibility. *Science* 289.
 Meyer, A. 2000. *Contraction and Convergence: The Global Solution to Climate Change*. Green Books.
 Rosa, L. P., M. S. Muylaert, and C.P.D. Campos. 2003. *The Brazilian Proposal and Its Scientific and Methodological Aspects*. International Institute for Sustainable Development.
 Rose, A., et al. 1998. International Equity and Differentiation in Global Warming Policy. An Application to Tradeable Emission Permits. *Environment and Resource Economics* 12.
 Vattenfall. 2006. *Curbing Climate Change: An Outline of a Framework Leading to a Low Carbon Emitting Society*. Vattenfall.

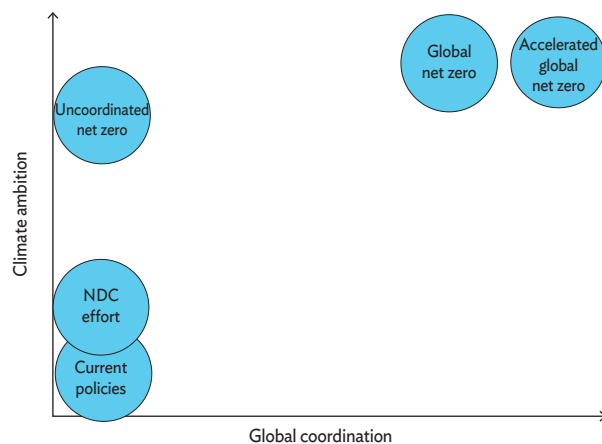
Source: Authors based on ADB (2015).

The five scenarios differ in the degree of climate ambition and global coordination. The accelerated global net zero scenario is the most ambitious scenario modeled in this report and has a high level of international coordination, while the global net zero scenario is high on climate ambition with slightly lower global coordination, as global coordination only starts after 2030 (Figure 2.1). The uncoordinated net zero scenario is relatively high on climate ambition (due to net zero pledges by individual countries), but low on international coordination. The current policies and the NDC effort scenarios have relatively low levels of climate ambition and international coordination.

Most of the analysis of the transformations needed to achieve deep decarbonization focuses on the contrasts between the accelerated global net zero and the current policies scenarios. Analyses of the costs, benefits, and tradeoffs of different levels of mitigation ambition and types of international cooperation draw on the complete set of scenarios in this report.

Figure 2.1 Climate Scenarios by Level of Climate Action and Global Coordination

The scenarios assume different levels of climate ambition and global coordination.



NDC = nationally determined contribution.

Source: Authors.

2.1.2 Modeling Framework

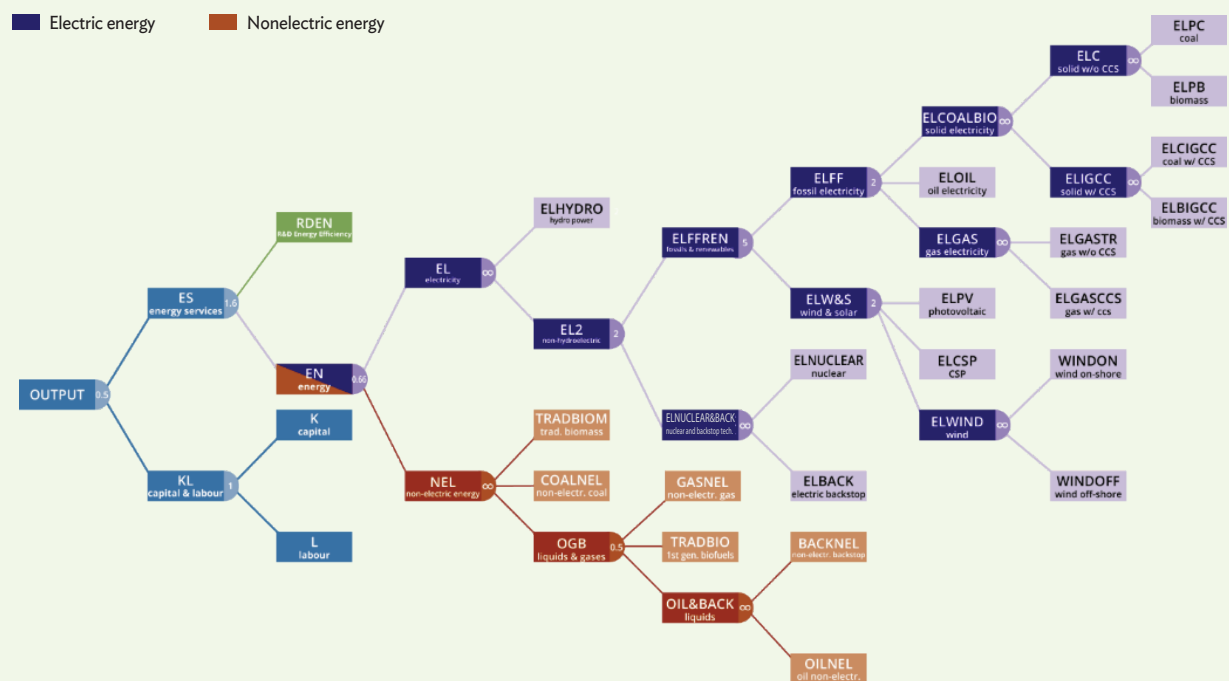
The modeling uses the World Induced Technical Change Hybrid (WITCH) model, a leading global IAM that is customized to better represent developing Asia. WITCH is a dynamic optimization model of the world economy designed to assess climate change mitigation policies. It can find optimal mitigation pathways and actions for a particular climate objective. The model features detailed representation of energy generation technologies, a rich array of fuel types (Box 2.2), energy trade, and policy interactions among regions. Uniquely among global models, WITCH incorporates technical change through research, spillovers, and learning by doing to respond to climate policy, which, in turn, affects energy efficiency, costs, and the deployment of advanced energy technologies. WITCH is linked to the Global Biosphere Management Model to include emissions from forestry, land use change, and agriculture, and to the Model for the Assessment of Greenhouse Gas Induced Climate Change (MAGICC) to translate emissions into global temperature changes. This interlinkage with climate is what makes WITCH an IAM, as discussed in Box 2.3. For this report, the geographic resolution has been expanded to 18 regions, including the major subregions of developing Asia. As a result, it has the most detailed representation of Asia among global economic IAMs focused on mitigation policy analysis that were used by the IPCC in its 6th Assessment Report (AR6).¹⁵

¹⁵ The Pacific is part of Oceania in the WITCH model. Because Oceania is dominated by Australia and New Zealand, it is not a modeling focus in this report. The newly industrialized economies of Hong Kong, China; the Republic of Korea, Singapore; and Taipei, China are also not included in results reported from the model for developing Asia, as they are included in a region with Japan.

Box 2.2 Energy in the World Induced Technical Change Hybrid Model

The [World Induced Technical Change Hybrid \(WITCH\)](#) model includes a wide range of technologies for the generation of energy. Within energy, the highest-level distinction is between electric and nonelectric energy. Electricity is generated using a range of fossil fuel-based technologies and nonfossil alternatives (box figure). Fossil fuel-based electricity includes natural gas combined cycle, fuel oil, pulverized coal, and integrated gasification combined cycle coal power plants. Nonfossil sources include onshore and offshore wind turbines, solar photovoltaic panels, concentrated solar photovoltaics, hydroelectric, biomass, nuclear, and two carbon-free backstop technologies, which represent technological options far from commercialization for long-term scenarios.

World Induced Technical Change Hybrid Model Structure



∞ = infinity, BACKNEL = backstop for nonelectric energy, COALNEL = coal for nonelectric energy, EL = electric energy, ELBACK = electricity generated with backstop, ELBIGCC = electricity generated with biomass with carbon capture and storage, ELC = electricity generation with pulverized coal and biomass without carbon capture and storage, ELIGCC = electricity generated with coal integrated gasification combined cycle plus carbon capture and storage, ELCOALBIO = electricity generated with coal and biomass, ELCS = electricity generated with concentrated solar power, ELFF = fossil fuel electricity, ELFFREN = fossil fuel and renewable electricity, ELGAS = electricity generated with gas, ELGASCS = electricity generated with gas with carbon capture and storage, ELGASTR = electricity generated with gas with gas turbines, ELIGCC = electricity generated with integrated gasification combined cycle coal plus carbon capture and storage, ELHYDRO = electricity generated with hydroelectric, ELNUCLEAR = electricity generated with nuclear, ELNUCLEAR&BACK = electricity generated with nuclear and backstop, ELOIL = electricity generated with oil, ELPB = electricity generated with biomass, ELPC = electricity generated with pulverized coal, ELPV = electricity generated with photovoltaics, ELWIND = electricity generated with wind energy, ELW&S = electricity generated with wind turbines and photovoltaic panels, EL2 = electricity generation, EN = energy, ES = energy service, GASNEL = gas for nonelectric energy, K = capital invested in the production of the final good, KL = capital-labor aggregate, L = labor, NEL = nonelectric energy, OGB = oil, backstop, gas, and biofuel, OILNEL = oil for nonelectric energy, OIL&BACK = oil and backstop for nonelectric energy, RDEN = energy research and development capital, TRADBIOM = traditional biomass, TRADBIO = traditional biofuels, WINDON = electricity generated with onshore wind, WINDOFF = electricity generated with offshore wind.

Notes: Numbers refer to elasticities of substitution. Biofuels are traditional and advanced biofuels.

Source: Authors based on WITCH. [Evaluating Climate Change Impacts and Solutions](#).

continued on next page

Box 2.2 Continued

Carbon capture and storage can be added to coal, gas, and biomass, with several technical options included for coal. Investment costs, capital depreciation, operation and maintenance costs (including for nuclear waste), utilization factors, and fuel efficiencies are incorporated, as are end-of-pipe air pollution controls and emission factors. Grid integration is modeled considering flexibility constraints by type of generation, capacity constraints (as intermittent shares of generation rise), and grid storage and capital. Beyond electricity, the use of coal, oil, and traditional biomass are incorporated both generally and for transport, including by international aviation, shipping, and road. Road transport considers stocks of vehicles used for transport and freight by vehicle type, fuel type, and technology. Research and development, spillovers, and learning by doing affect energy efficiency, backstop technologies, and energy storage costs, whereas wind and solar costs are conditioned by learning by doing.

Source: Authors.

The WITCH model is coupled to additional models to evaluate implications of climate policy for health, labor markets, and equity. It is linked to the FAsT Scenario Screening Tool (FASST) air pollution model that simulates pollution distribution from the energy sector, and changes in ambient pollutant concentrations are applied in crop and epidemiological models to quantify effects on crops and human health. Results from WITCH's energy module are used in a detailed model of employment in the energy sector to quantify implications for jobs in the sector. Prices are used in detailed micro-household models for India and the PRC to explore implications for equity.

Box 2.3 Evolution of Integrated Assessment Models

Integrated assessment models (IAMs) combine different strands of knowledge to provide insights on how the global economy, along with energy, land, and agriculture systems interact with the environment. There are two broad types of IAMs that serve very different purposes in their applications (Weyant 2017). The first group of cost-benefit IAMs is used to estimate the social cost of carbon. These IAMs are simpler and have limited representation in biophysical and energy systems. They focus on the damage function that determines the relationship between increasing temperature and gross domestic product. The second group of process-based IAMs has detailed representations of the economy and the energy system, as well as a more complex climate system that includes air pollutant emissions and land use systems, among other factors. Process-based IAMs seek to provide regional and sectoral disaggregated results. They are highly diverse in the detail in which the energy sector or the economy is represented, assumptions on technological change, and socioeconomic factors, among other factors.^a

IAMs provide the bulk of evidence relied on by the Intergovernmental Panel on Climate Change Working Group III for insights into alternative mitigation strategies and their feedbacks and tradeoffs. Due to their prominent role in the panel's assessments, IAMs get widespread attention—and criticism. Pindyck (2017) argues that IAM results depend on many arbitrary assumptions; that there is uncertainty in the climate system, especially the relationship between temperature increases with concentrations of carbon dioxide and damage functions; and that IAMs do not model the potential role of tipping points and catastrophic risks. Stern, Stiglitz, and Taylor (2022) argue that IAMs ignore market failures, which result in an overwhelming importance of carbon pricing and a bias against other policy actions. Others criticize IAMs for their inadequate representation of behavior changes, policies, processes, and spatial, socioeconomic, and technological heterogeneity (Krey 2014; Skea et al. 2020; Gambhir et al. 2019).

continued on next page

Box 2.3 Continued

Several of these criticisms have been addressed in recent IAMs by improving the modeling tools. For example, the World Induced Technical Change Hybrid (WITCH) model has gone through significant improvements. Notably, it is now possible to use WITCH to consider technological and damage uncertainty, including tipping points (Emmerling et al. 2020). WITCH is one of the few IAMs that allows for political economy considerations through coalition formation and different cooperation models (Bosetti et al. 2013). The number of assumptions on cost functions and parametrizations have been significantly improved to match the latest empirical data and expert elicitations (Krey et al. 2018). The damage-function discussion has also been addressed by considering the widest range possible of estimates and model results that can be linked to the modeled scenarios (Drouet et al. 2021).

Like any other model, IAMs will neither perfectly capture nor predict future climate pathways, given the complexities and uncertainties in climate science, human behavior, technological progress, and land and economic systems. Despite these limitations, IAMs will continue to play an important role in climate policy, as few alternatives exist that can provide a comprehensive and internally consistent interaction of a complex social, economic, technical, and physical system (Keppo et al. 2021). Policy makers should, however, interpret IAM results cautiously. The scenarios and pathways are not meant to be prescriptive roadmaps, but are best used to understand potential tradeoffs and feedback effects of different mitigation strategies that may not be obvious otherwise.

^a See Keppo et al. (2021) and IPCC (2022) for more details.

References:

- Bosetti, V., et al. 2013. [Incentives and Stability of International Climate Coalitions: An Integrated Assessment](#). *Energy Policy* 55.
- Drouet, L., et al. 2021. [Net Zero-Emission Pathways Reduce the Physical and Economic Risks of Climate Change](#). *Nature Climate Change* 11.
- Emmerling, J., et al. 2020. [Climate Thresholds and Heterogeneous Regions: Implications for Coalition Formation](#). *Review of International Organizations* 16(4).
- Gambhir, A., et al. 2019. [A Review of Criticisms of Integrated Assessment Models and Proposed Approaches to Address These, through the Lens of BECCS](#). *Energies* 12(9).
- IPCC (Intergovernmental Panel on Climate Change). 2022. *Climate Change 2022: Mitigation of Climate Change*.
- Keppo, I., et al. 2021. [Exploring the Possibility Space: Taking Stock of the Diverse Capabilities and Gaps in Integrated Assessment Models](#). *Environmental Research Letters* 16(5).
- Krey, V. 2014. Global Energy-Climate Scenarios and Models: A Review. *WIREs Energy and Environment* 3(4).
- Krey, V., et al. 2018. [Looking Under the Hood: A Comparison of Techno-Economic Assumptions across National and Global Integrated Assessment Models](#). *Energy* 172.
- Pindyck, R. S. 2017. [The Use and Misuse of Models for Climate Policy](#). *Review of Environmental Economics and Policy* 11(1).
- Skea, J., et al. 2021. [Outlooks, Explorations and Normative Scenarios: Approaches to Global Energy Futures Compared](#). *Technological Forecasting and Social Change* (168).
- Stern, N., J. Stiglitz, and C. Taylor. 2022. [The Economics of Immense Risk, Urgent Action and Radical Change: Towards New Approaches to the Economics of Climate Change](#). *Journal of Economic Methodology* 29(3).
- Weyant, J. 2017. [Some Contributions of Integrated Assessment Models of Global Climate Change](#). *Review of Environmental Economics and Policy* 11(1).

Source: Authors.

2.2 Emission Pathways

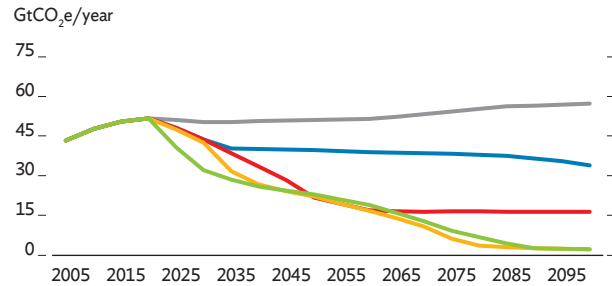
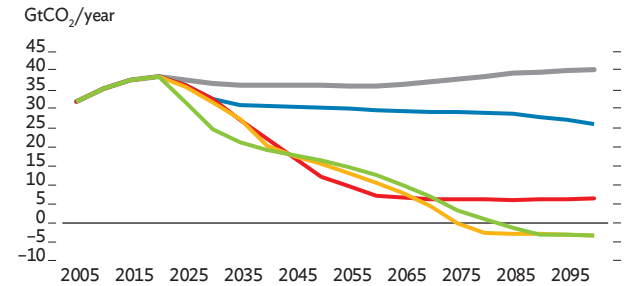
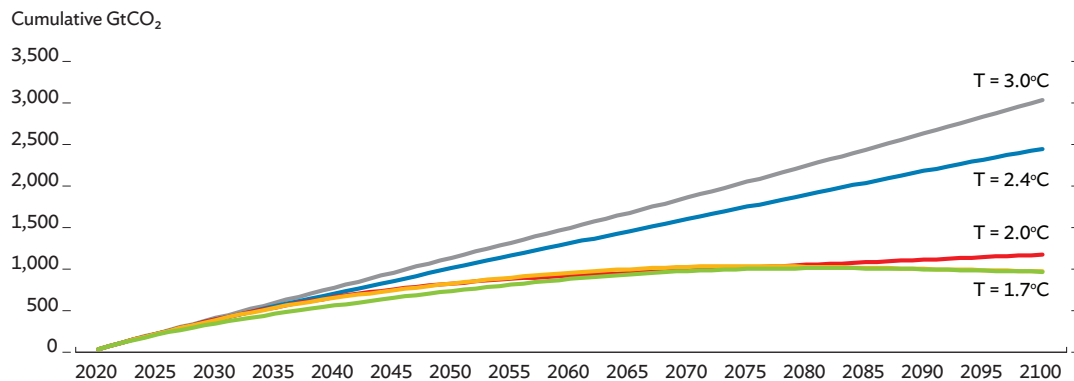
Although climate action has gained momentum globally, climate policies remain fragmented and unlikely to meet Paris Agreement goals. This subsection discusses global and Asian emission pathways under the modeled scenarios. Under the current policies scenario, cumulative global emissions are projected to reach 3,270 GtCO₂, leading to mean warming of 3.0°C by the end of the century (Figure 2.2). Emissions from developing Asia will hover at around 22 GtCO₂e per year, accounting for 44% of global emissions until mid-century (Figure 2.3). Emissions from the PRC, the region's largest emitter, will peak in 2025, while emissions from the second largest emitter, India, will continue to increase and account for more than a quarter of emissions from the region (Figure 2.4). Under the NDC effort scenario, cumulative global emissions decline slightly to 2,650 GtCO₂. However, as broadly recognized, this is insufficient to reach Paris Agreement goals, with modeling indicating 2.4°C of mean warming.

Figure 2.2 Global Emission Pathways under the Modeled Scenarios, 2005–2100

Achieving Paris Agreement goals require dramatic reductions in global GHG emissions.

a. GHG Emission Pathways

— Current policies — NDC effort
— Uncoordinated net zero — Global net zero
— Accelerated global net zero

**b. CO₂ Emission Pathways****c. Global Cumulative CO₂ Emissions and Average Temperature Increase by 2100**

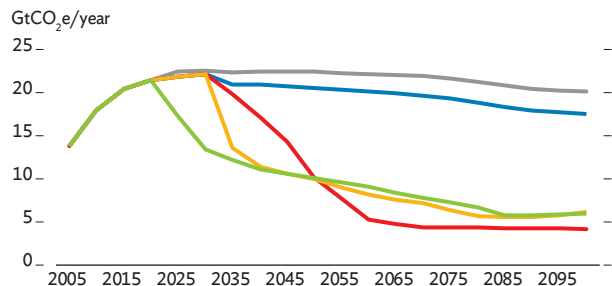
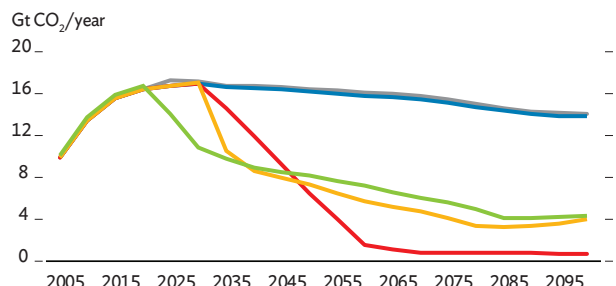
CO₂ = carbon dioxide, GHG = greenhouse gas, GtCO₂ = billion tons of carbon dioxide, GtCO₂e/year = billion tons of carbon dioxide equivalent per year, MAGICC = Model for the Assessment of Greenhouse Gas Induced Climate Change, NDC = nationally determined contribution, T = temperature in 2100.
Notes: International shipping and aviation emissions are not included in the global CO₂ emission pathways. All temperature calculated with MAGICC v6 model.
Source: Authors.

Figure 2.3 Developing Asia's Emission Pathways under the Modeled Scenarios, 2005–2100

Immediate climate action will allow for a smoother transition to global net zero in the future.

a. GHG Emission Pathways

— Current policies — NDC effort
— Uncoordinated net zero — Global net zero
— Accelerated global net zero

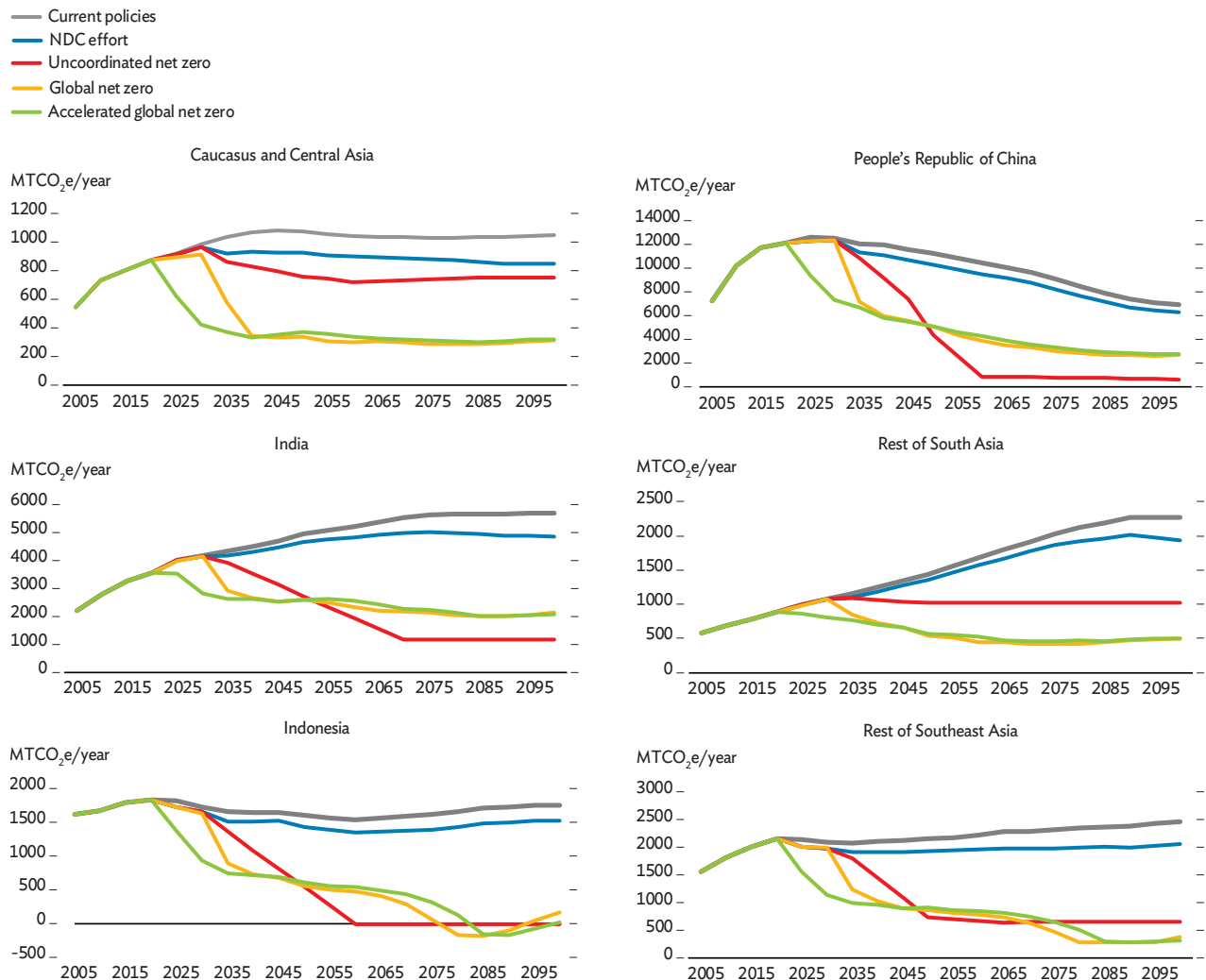
**b. CO₂ Emission Pathways**

CO₂ = carbon dioxide, GHG = greenhouse gas, GtCO₂/year = billion tons of carbon dioxide per year, GtCO₂e/year = billion tons of carbon dioxide equivalent per year, NDC = nationally determined contribution.

Source: Authors.

Figure 2.4 Greenhouse Gas Emission Pathways by Subregions of Developing Asia under Modeled Scenarios, 2005–2100

The burden to reduce emissions will disproportionately fall on countries with net zero pledges in the absence of global coordination.



MtCO₂e/year = million tons of carbon dioxide equivalent per year, NDC = nationally determined contribution.

Source: Authors.

The uncoordinated net zero scenario takes the world closer to Paris Agreement goals with cumulative emissions of 1,420 GtCO₂ and 2.0°C of mean warming. This shows that voluntary net zero pledges, if implemented, represent a major step toward achieving the Paris Agreement goals. This scenario has an uncertain probability of staying within the 2°C goal of the Paris Agreement, so it does not technically achieve the agreement's goal. Due to a lack of global coordination on climate action, the burden to reduce emissions falls disproportionately on countries with net zero pledges. Figure 2.4 shows that emissions from the PRC, India, Indonesia, and the rest of Southeast Asia decline sharply to meet their respective net zero pledges. These national pledges mean the overall reduction in emissions in developing Asia is higher than in the global net zero and accelerated global net zero scenarios, where mitigation is allocated based on lowest cost through global carbon markets.

The global net zero scenarios would lead to mean warming of 1.7°C by the end of the century and a higher than 67% probability of staying below 2°C, which is consistent with the Paris Agreement goal. Under the global net zero scenario, emissions drop rapidly only after 2030. Under the accelerated global net zero scenario, emissions from the region decline by more than 40% by 2030 compared to the current policies scenario. Immediate climate action allows for a smoother transition in the future, while the global net zero scenario requires more stringent climate action in the future to stay within the carbon budget.¹⁶

2.3 Sources of Mitigation

The modeling shows that increased energy efficiency and land use abatement can dominate mitigation in developing Asia before 2040.¹⁷ Energy efficiency in the region is the most important source of emission reductions before 2040 under the accelerated net zero scenario, followed by non-CO₂ abatement, which largely consists of emission reductions from agriculture and land use.¹⁸ Emission reductions from the increased shares of low-carbon power generation take longer to have effects because building sufficient capacity of renewables takes time. In contrast, energy efficient behavior and energy efficient consuming devices can be adopted faster, and many land use emissions from agricultural practices and deforestation can be curtailed quickly. Land use mitigation is most important in Indonesia and rest of Southeast Asia, where deforestation is a large source of emissions (Figure 2.5).

From 2040, decarbonization of energy is the major source of emissions reduction. As forest cover gets depleted, deforestation rates fall, so there is less potential to reduce modeled emissions in the long run, although land use mitigation remains important in Indonesia. As energy demand grows, the energy mix radically alters toward cleaner sources, thus reducing emissions. The modeling shows that changing the energy mix to cleaner sources will account for 37% of mitigation in developing Asia by 2040, rising to 45% by 2050. In the PRC and South Asia, the transition of energy to cleaner sources accounts for more than 50% of mitigation by 2050. Emerging and costly technologies, such as CCS, will only play an important role after 2050. CCS accounts for only 13% of mitigation in the region in 2040, which increases to 25% in 2060. CCS is particularly important in PRC in the medium term, where it will account for about a third of mitigation in 2060.

2.4 Land Use Responses

Since the 1990s, Southeast Asia has experienced large-scale deforestation. Most of Asia's forest cover loss between 1992 and 2019 was in Indonesia—1.3 million hectares (ha)—and the rest of Southeast Asia (0.6 million ha) on average annually. In contrast, the PRC added 22 million ha of forest cover since 1990. Recent reforms in Indonesia have helped to substantially decrease the rate of deforestation, but the rest of Southeast Asia is struggling with this challenge (Figure 2.6). Deforestation, combined with forest fires and peatland degradation on deforested areas, has driven overall emissions from land use in Indonesia and the rest of Southeast Asia. Elsewhere in developing Asia, emissions associated with land use mostly come from agriculture (FAO 2021). These emissions arise from methane released during paddy cultivation and from livestock, and the release of other GHGs from soil degradation and chemical inputs.

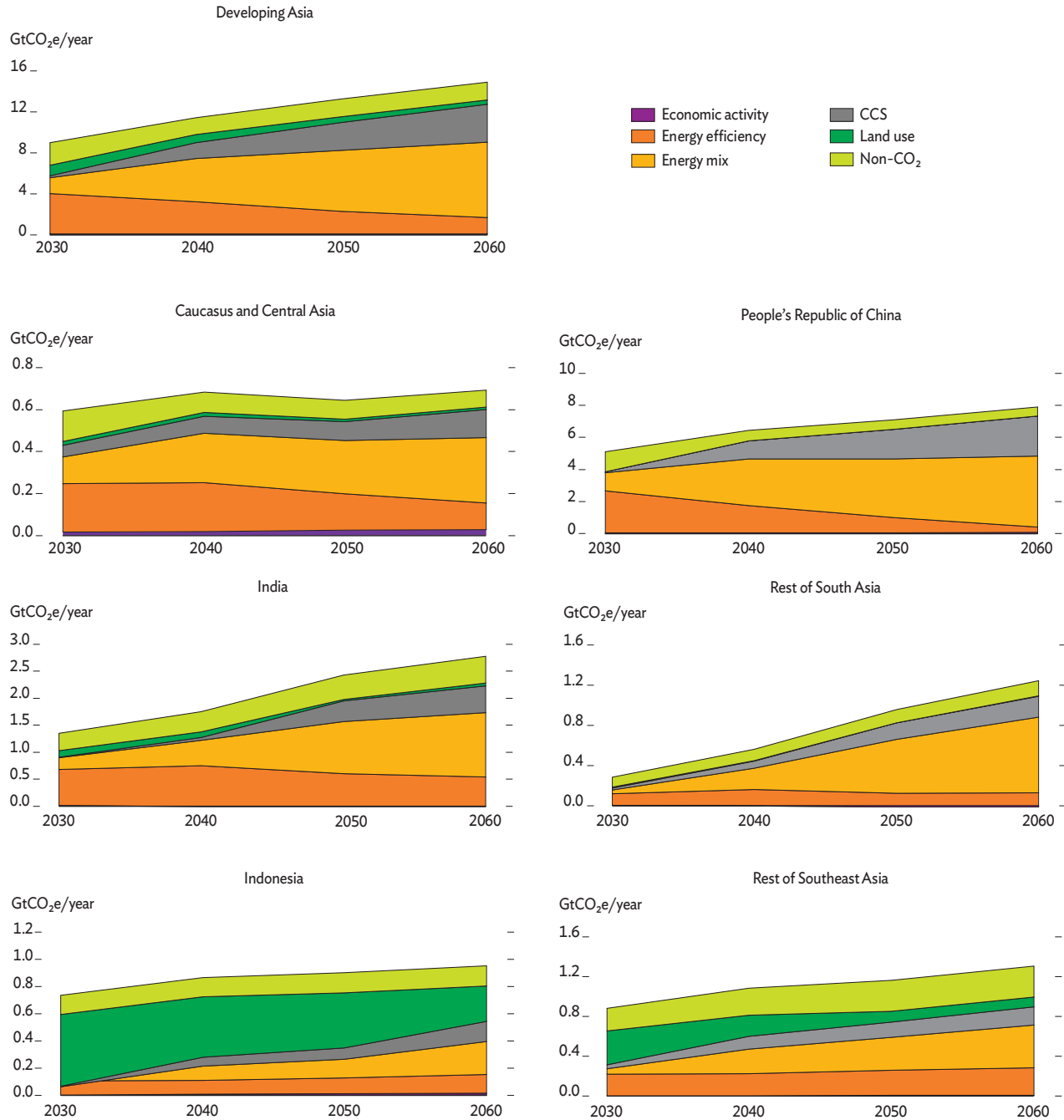
¹⁶ The delay in climate action under the global net zero scenario implies that net zero CO₂ emissions need to be reached by 2075 to stay within the carbon budget due to more mitigation after 2030. The accelerated global net zero scenario reaches net zero by 2085, since more mitigation takes place during the higher emissions period before to 2030.

¹⁷ Land use here includes emissions and removals of GHGs from settlements and commercial and agricultural uses of land, land use change, and forestry.

¹⁸ Non-CO₂ gases include ammonia, nitrous oxide, and fluorinated GHGs. These gases have higher warming potential than CO₂. The various sources of non-CO₂ emissions include energy, agriculture, waste, and industry.

Figure 2.5 Decomposition of Mitigation Sources in Developing Asia under the Accelerated Global Net Zero Scenario, 2030–2060

Energy efficiency and changes in land use will drive emissions reduction until 2030, while the transition to clean energy will be important in the longer run.

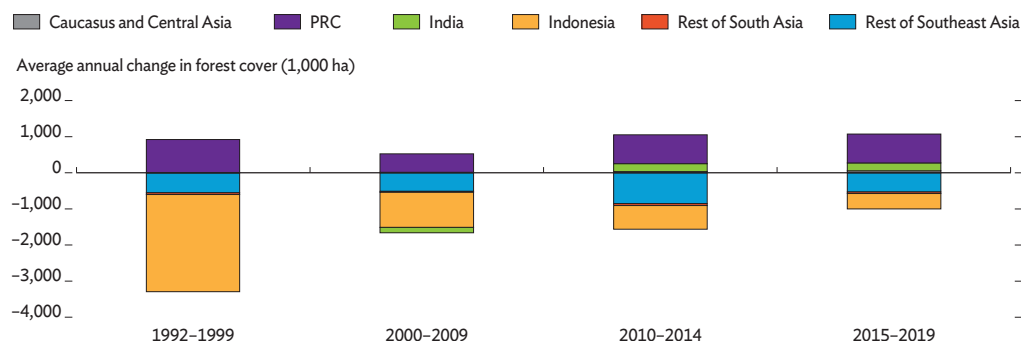


CCS = carbon capture and storage, CO₂ = carbon dioxide, GtCO₂e/year = billion tons of carbon dioxide equivalent per year.

Source: Authors.

Figure 2.6 Change in Forest Cover in Developing Asia, 1992–2019

The region has lost tropical forests that were an important carbon sink.



ha = hectare, PRC = People's Republic of China.

Source: Authors based on Badan Pusat Statistik for Indonesia. [Statistik Kehutanan](#) (accessed 14 February 2023); Food and Agriculture Organization of the United Nations. [FAOSTAT](#) (accessed 14 February 2023).

The transition to net zero may lead to bold changes in patterns of land use, with vastly expanded forest area and cultivation of bioenergy crops. The potential exists in much of developing Asia to reduce emissions from land use at low cost, while generating co-benefits for climate adaptation. The current policies and the NDC effort scenarios imply very little change in land use patterns, with forest cover at 26% and the share of cereal cropland at 12% until 2050.¹⁹ Under the accelerated global net zero scenario, forest cover in the region increases by 95 million ha, reaching 30% of land cover by 2050 (Figure 2.7). About half of the total increase in forest area in the region is concentrated in the PRC. By 2050, forest cover increases by 19 million ha in India, by 11 million ha in Indonesia, and 16 million ha in the rest of Southeast Asia.

Some land use mitigation, such as afforestation and bioenergy, will intensify competition for land. Under the accelerated net zero scenario, the land area for growing food crops in developing Asia decreases by 36 million ha by 2050 and 58 million ha by 2070. Most of this is driven by a boom in biomass cultivation for electricity with CCS to create negative emissions. About 39 million ha of land, accounting for about 2% of the region's land area, is used to grow energy crops by 2050, which more than doubles to 97 million ha (5% of the land area) by 2070.²⁰ Most bioenergy crops will be concentrated in the PRC, with 26 million ha of land used for this in 2050 and 7 million ha in India.

2.5 Transformation of the Energy Sector

As the largest source of GHG emissions, the energy sector will need to undergo a rapid transformation for the world to be able to achieve Paris Agreement goals. The energy system accounts for about 75% of developing Asia's GHG emissions.²¹ There is broad consensus that the energy transition will include more efficient use of energy, limited use of fossil fuels, decarbonization of electricity, and widespread electrification of end uses, such as transport services (IPCC 2022b). It is important to recognize that the energy transformation in developing Asia will take place in the context of existing development gaps. Although the region has made rapid progress in electrification rates, reaching 97% in 2020, access is hampered by unreliable supply.²² Per capita electricity consumption remains low in much of the region, especially in the Pacific and South Asia.

¹⁹ The model includes both natural and managed forests.

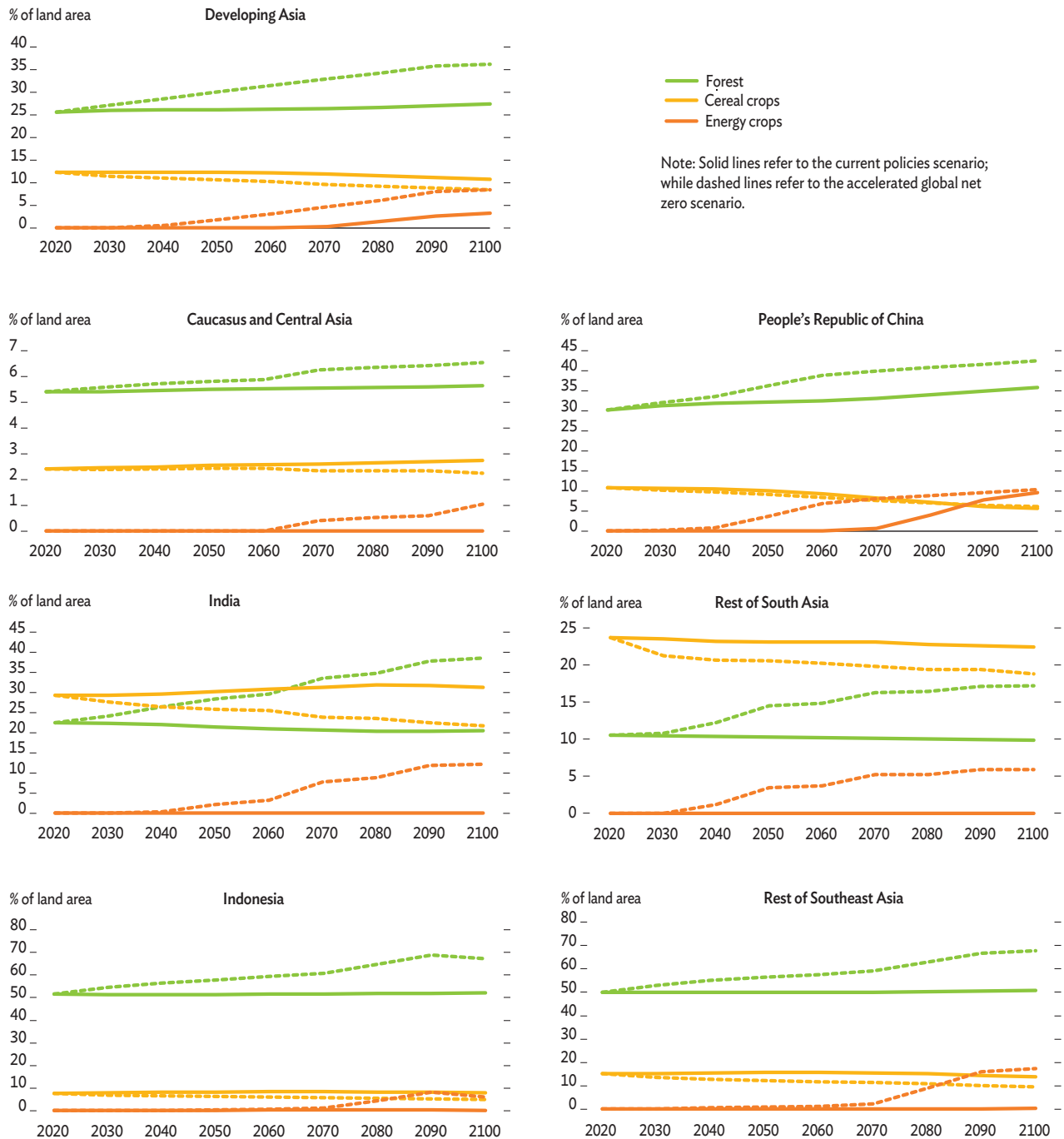
²⁰ The model includes conventional energy crops, such as rapeseed, sugarcane, sunflower, crops and grass residues, and short-rotation tree plantations of poplar, willow, and eucalyptus.

²¹ The energy system includes energy supply (primary energy, conversion, and transmission) and the use of energy to provide energy services in transport, buildings, industry, and agriculture.

²² World Bank. [World Development Indicators](#) (accessed 1 February 2023).

Figure 2.7 Share of Forest, Cereal Crops, and Energy Crops in Land Cover in Developing Asia under Modeled Scenarios, 2020–2100

The global transition to net zero can entail large increases in land for forests and energy crops.



Source: Authors.

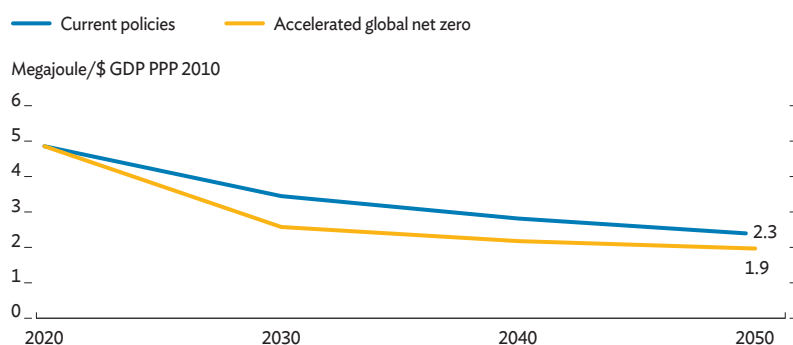
2.5.1 Energy Demand and Energy Efficiency

Developing Asia's rapid growth since the 1990s was accompanied by rising energy needs. Since 1991, total primary energy supply increased threefold in the region, even though energy efficiency grew steadily.²³ Total primary energy supply reached 243 exajoules (EJ) in 2020, accounting for 43% of the global share.²⁴ This increase was driven mainly by the PRC, where energy needs increased fourfold to 145 EJ from 1991 to 2020. During the same period, the energy intensity of GDP in developing Asia almost halved to 5.2 megajoules per US dollar, which implies that economies are becoming more efficient in consuming energy.²⁵ However, energy intensity in the region is still higher than the world average, and it is especially high in the Caucasus and Central Asia, particularly Kazakhstan, Turkmenistan, and Uzbekistan. The PRC's energy intensity is also well above the world average, despite declines over time.²⁶

The modeling results indicate that future increases in energy consumption need to be tempered by more efficient use of energy to ensure climate-compatible growth. Under the current policies scenario, the total primary energy supply in the region will increase by about 50% to 316 EJ in 2070, but will reach 288 EJ under the accelerated global net zero scenario. Primary energy grows more slowly for two reasons. First, fossil fuel power generation has large thermal losses, so more final energy can be delivered relative to primary energy when nonthermal renewables are a larger share of the energy mix. Second, energy efficiency improves in response to climate policy. Both reasons are reflected in a faster decline in the energy intensity of GDP under the accelerated global net zero scenario compared to the current policies scenario (Figure 2.8). Energy efficiency improvements, through energy efficient behavior and efficient energy consuming devices, have the potential to relieve tensions between economic development and climate objectives by reducing the energy inputs required to provide basic energy services, such as lighting, cooking, heating, and cooling. This can also reduce pressure on households and national budgets and improve the reliability of power systems. With the right price signals, investment in technologies for efficiency increases and more efficient products end up on the market, amplifying this effect.

Figure 2.8 Energy Intensity of Gross Domestic Product in Developing Asia under Modeled Scenarios, 2020–2050

The transition to global net zero will require faster reductions in the energy intensity of GDP.



GDP = gross domestic product, PPP = purchasing power parity.

Source: Authors.

²³ Primary energy refers to energy in its raw form before it has been subjected by humans to other forms of energy, such as electricity, heat, and transport fuel.

²⁴ 1 exajoule = 10^{18} joules.

²⁵ Energy intensity refers to the physical energy required to generate each unit of GDP. Energy intensity is commonly used as an indicator of energy efficiency. It is, however, an imperfect measure because energy intensity can be affected by several factors not necessarily linked to efficiency.

²⁶ [Global Energy & CO₂ Data](#) (accessed 15 March 2023).

2.5.2 Decarbonization of Primary Energy

Developing Asia's energy has historically been reliant on coal. Coal provided about half of the total primary energy supply in the region in 2020, followed by crude oil at about 20% and natural gas at about 10%. Consequently, coal is the largest source of energy emissions in the region, accounting for about 70% of emissions from energy, followed by oil and gas—a structure that has remained largely unchanged since the 1990s. Within developing Asia, the PRC has the highest share of coal in primary energy at 60%, followed by India at 45%. In Indonesia and rest of Southeast Asia, coal and oil provide about half of energy supply. Natural gas is more important in the rest of South Asia. Despite rapid growth in the last decade, the share of wind and solar is still small in the region and provides less than 2% of total primary energy supply in 2020. Biomass is an important source of energy in the Caucasus and Central Asia and India and the rest of South Asia.

Modeling results show the share of coal in primary energy in the region will decline even under modest climate action. Under the current policies scenario, the share of coal in primary energy will decline from about half to less than a quarter by 2050. Under more ambitious climate action, it will decline to 13% of primary energy. These results are in line with those of other models in the AR6 database (see the [Appendix](#) for a comparison of modeling results with the AR6 database). Under the current policies scenario, renewable sources of energy, such as solar, wind, hydro, and biomass, will provide about a quarter of the region's energy needs by 2050 and 40% under the accelerated global net zero scenario. By 2070, renewables will provide about half of the region's energy needs (Figure 2.9).

2.5.3 Changes in Electricity Generation

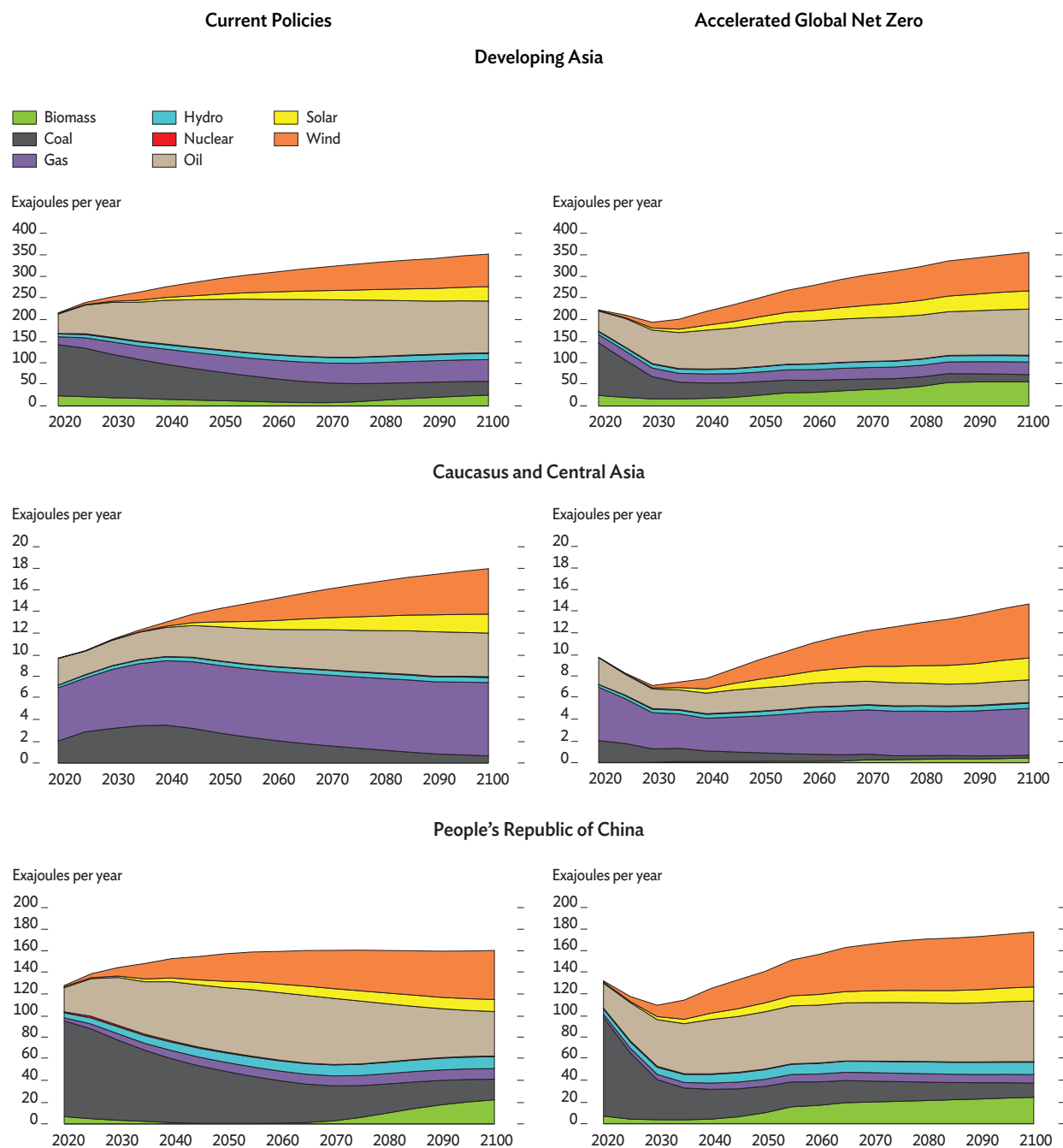
Electricity demand in developing Asia has been growing rapidly. Total electricity supply in the region increased at an annual average rate of 7% from 1990 to 2020, more than twice the global growth rate over the same period.²⁷ Average per capita electricity consumption in 2020 was 2,570 kilowatt-hours (kWh), well below the Organisation for Economic Co-operation and Development average of 7,282 kWh. Within the region there are large differences, with per capita consumption ranging from 4,981 kWh in the PRC to just 486 kWh in South Asia (excluding India). Under the current policies scenario, electricity demand in developing Asia will reach 28,000 TWh by 2070 and 33,000 TWh under the accelerated global net zero scenario, with an average annual growth rate of 1.9%. Per capita electricity consumption in the region will increase by 2.7 times from 2020 levels to about 7,750 kWh by 2070. India's electricity consumption per capita will grow by threefold and fivefold in the rest of South Asia. This growth makes the decarbonization of power generation essential to reducing emissions.

Although electricity generation in developing Asia is dominated by fossil fuels, renewable energy already shows potential to dominate electricity generation. Coal remains the primary source of power in the region, accounting for about 60% of generation, although its share started to decline in the 2010s. Developing Asia's three biggest economies—the PRC, India, and Indonesia—continue to rely on coal for electricity production. Yet developing Asia has shown remarkable growth in solar and wind energy since 2010, with the region leading the world in capacity additions of these energy sources. Although coal and gas generate two-thirds of global electricity, solar and wind energy are dominant in terms of new generation capacity. From 2010 to 2021, the cumulative capacity of solar photovoltaic (PV) systems worldwide increased 21-fold to 855 gigawatts (GW), and global cumulative capacity of onshore wind rose fourfold to 770 GW. Developing Asia accounted for about 50% of new capacity in both energy sources. Globally, the PRC is at the forefront of renewable power. From 1991 to 2020, its share in global wind power production increased from 0.2% to 32.9% and solar electricity production from 0.2% to 29.2%. As a result of these capacity additions, the share of solar and wind in developing Asia's total power output increased from about 1% in 2010 to 8% in 2020 (IRENA 2021).

²⁷ Global total electricity supply increased at an average of 2.7% per year during 1991–2000, 3.4% during 2001–2010, and 2.3% during 2011–2020.

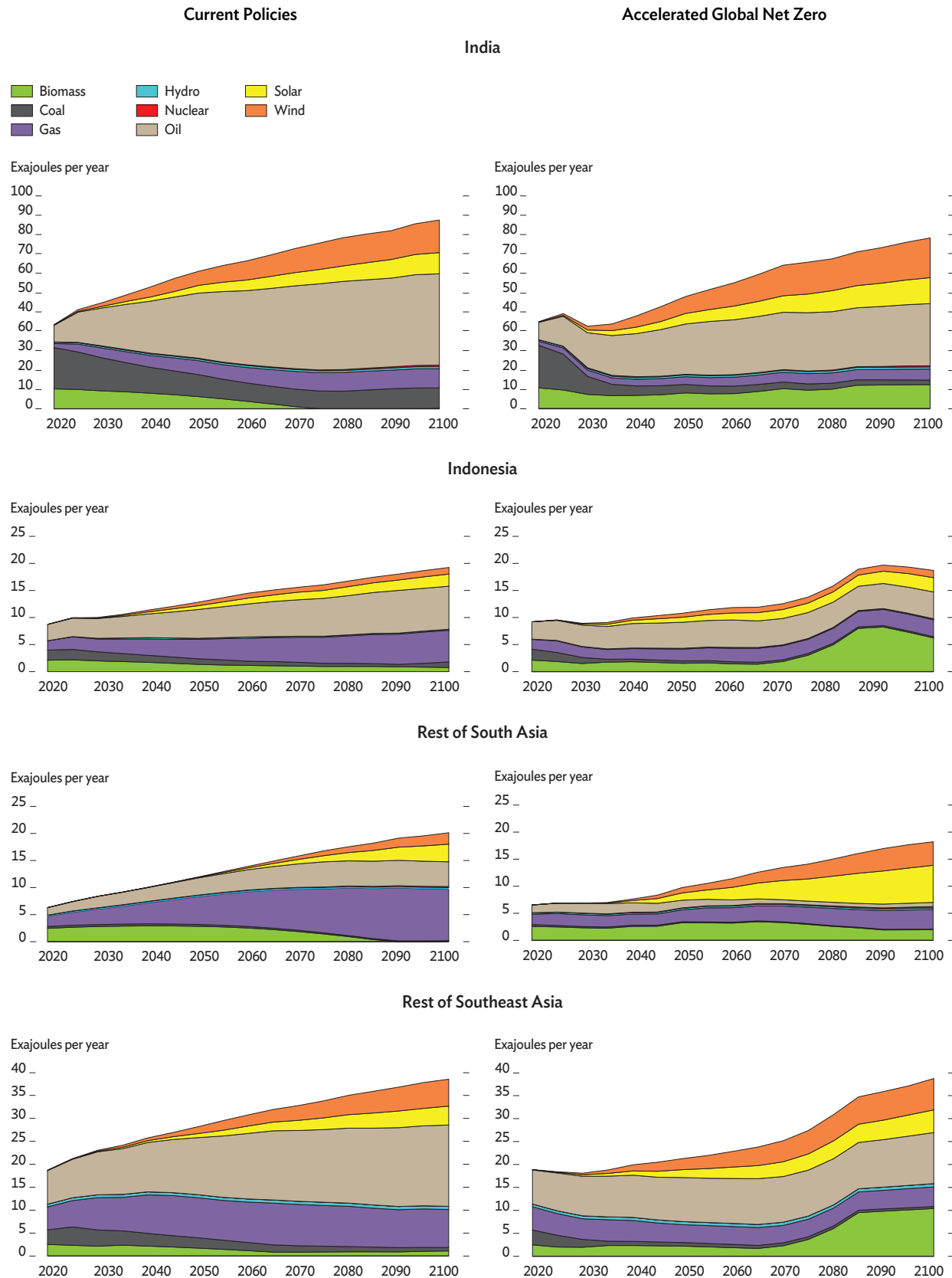
Figure 2.9 Primary Energy Mix in Developing Asia under Modeled Scenarios, 2020–2100

Achieving Paris Agreement goals entails a decrease in primary energy demand and a shift toward cleaner sources.



continued on next page

Figure 2.9 Continued



Source: Authors.

The electricity sector will undergo faster decarbonization under the accelerated net zero scenario, with coal virtually absent from the region's power sector by 2035. The share of coal in electricity generation will decline even under the current policies scenario to 17% by 2050 and to 7% by 2070. With more ambitious climate action, coal will have virtually no share in Asia's electricity sector (Figure 2.10). Under the accelerated global net zero scenario, wind and solar power will provide about three-fourths of the region's energy needs by 2040. For regions with a high reliance on fossil fuels, CCS could provide an economical option after 2035. For example, in the Caucasus and Central Asia, South Asia, and Southeast Asia, natural gas with CCS will provide 5%–11% of power needs. In Indonesia, negative emissions from biomass with CCS will be important, and hydropower plays an important role in the rest of Southeast Asia, as well as the PRC and the Caucasus and Central Asia.

Barriers to phasing out coal from the electricity sector need to be addressed for the transformation to happen at a speed that is compatible with Paris Agreement goals. The phaseout of coal-fired generation found in this report is primarily driven by economic considerations, including the imposition of carbon prices. A review of IAMs indicates that scenarios consistent with keeping global warming well below 2.0°C or 1.5°C require coal power plants to retire 1 to 3 decades earlier than their historical lifetimes (Fofrich et al. 2020). This implies a transformation in how energy is supplied at an unprecedented speed. Box 2.4 discusses the market rigidities that may slow the retirement of coal in developing Asia and some proposed innovative solutions.

2.5.4 Technological Progress in Power Generation from Renewables

Rapid increases in solar and wind capacity have been supported by dramatic cost reductions. The global weighted-average total installed cost for solar PVs fell by 81% from 2010 to 2020, and the cost for offshore and onshore wind by about 30%. India and the PRC have some of the lowest weighted-average total installed cost of utility-scale solar PVs in the world. The levelized cost of electricity, which includes capital and operation and maintenance costs, has fallen sharply, making solar and wind competitive against fossil fuels. The levelized cost of electricity for utility-scale solar PVs has fallen by 85% since 2010 and by 52% for onshore wind. India and the PRC have some of the lowest of these costs in the world for onshore wind, while some other economies in Asia have some of the highest (Figure 2.11).

Cost reductions for renewables can accelerate further. The modeling results show that under the accelerated global net zero scenario, the installation cost of solar PVs in developing Asia will decline by 76% to \$238/kilowatt (kW) by 2050 and onshore wind by 66% to \$492/kW (Figure 2.12). These results are being driven by technological change, modeled through two channels: the deployment of technology (learning by doing) and research and development investment (learning by researching). Learning by doing considers the learning rates of technologies, which measure cost reductions for each doubling of installed capacity.²⁸ It should be noted that continued cost reductions over time will depend on widespread access to critical materials and minerals, the production of which are concentrated in a few economies (IEA 2021a).

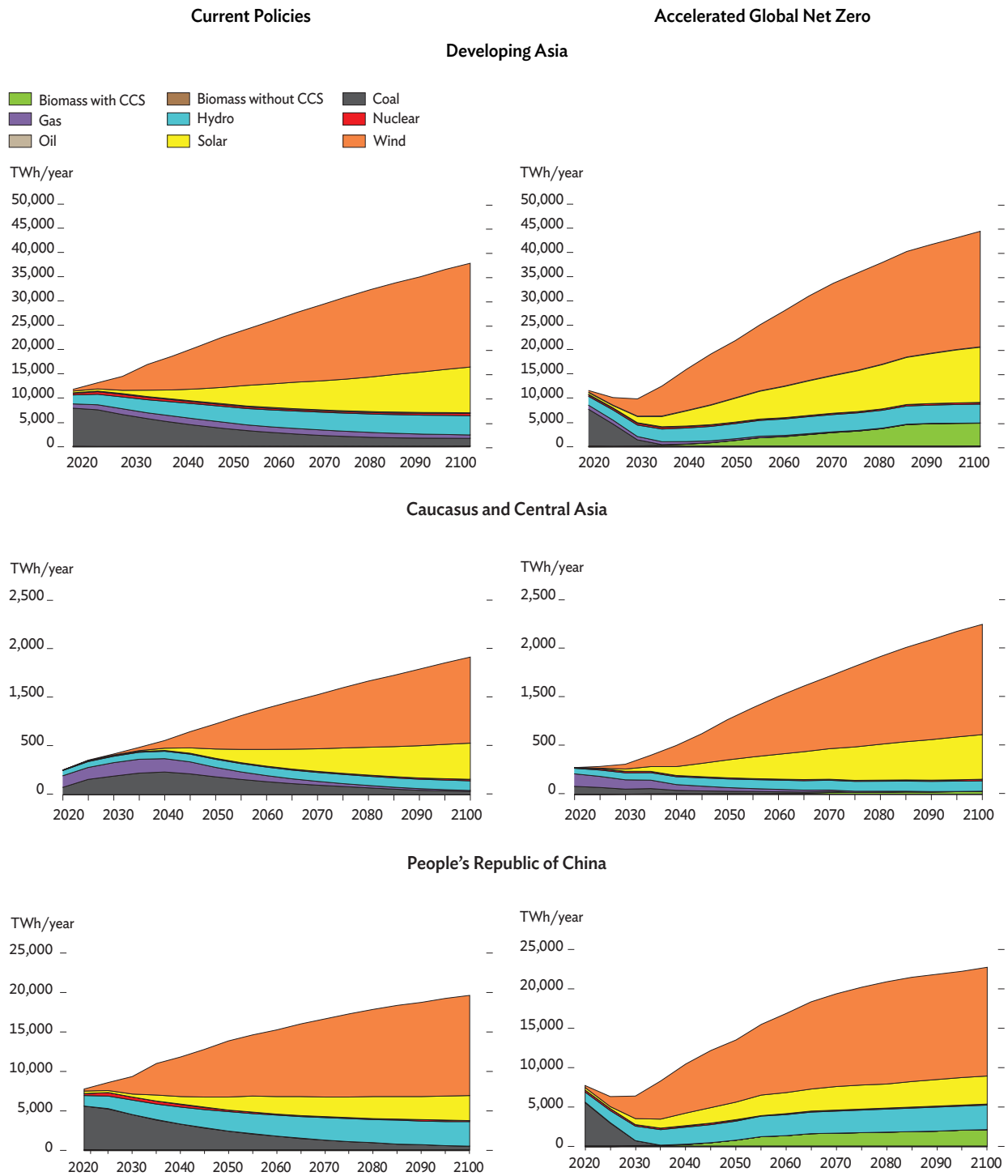
A stable power supply critically depends on cost and performance improvements in storage technology.

Solar and wind sources provide variable or intermittent power—the output fluctuates based on solar radiation and wind speed. To reduce this and integrate solar and wind power with the grid requires storage technology that can store and release power when needed. Pumped hydro is the most widely used storage technology. In 2021, total installed capacity was 160 GW, providing about 90% of electricity storage. The use of utility-scale battery technology for short term storage solutions has been growing in recent years. Total installed capacity was 16 GW in 2021, most of which was added in the last 5 years (IEA 2022e). The cost of lithium-ion batteries, the most prevalent and mature battery technology, has fallen by 97% since the 1990s, while their performance has improved (Zeigler and Trancik 2021). Batteries can also provide ancillary services to the grid—such as frequency regulation and transmission and distribution congestion relief. They can also defer investments in peak generation and grid reinforcement (IRENA 2019).

²⁸ For example, IRENA (2020) estimates the learning rate for utility-scale solar PV during 2010–2020 at 36%. This implies that for every doubling of global solar PV installed capacity, total installation costs decrease by 36%.

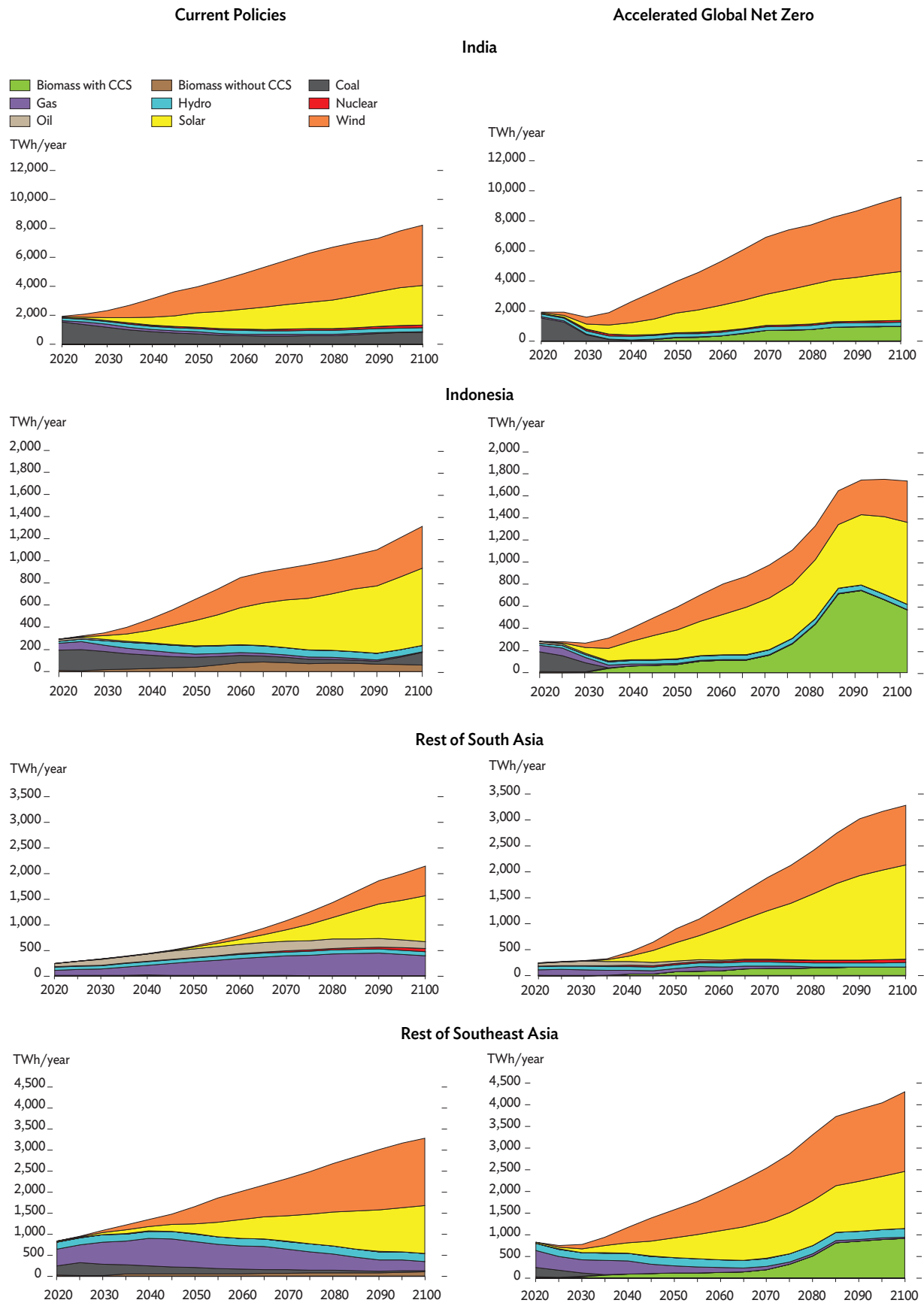
Figure 2.10 Electricity Mix in Developing Asia under Modeled Scenarios, 2020–2100

Solar and wind energy will dominate power generation under the accelerated global net zero scenario.



continued on next page

Figure 2.10 Continued



CCS = carbon capture and storage, TWh = terawatt-hour.

Source: Authors.

Box 2.4 Phasing Out Coal-Fired Power Generation

Coal's rapid phaseout from the electricity sector in this report under the current policies scenario is primarily driven by economic considerations. These include the marginal cost of operating coal power plants, and the levelized cost of new technologies, such as wind and solar. In the net zero scenarios, imposing carbon pricing triggers a faster transition toward cleaner energy sources by changing the relationships between operating costs for coal and other energy sources. These results should not be interpreted to imply that phasing out coal at the speed and scale required to meet Paris Agreement goals will be inevitable or easy. This is because of three main reasons.

First, although carbon pricing is the most cost-efficient policy tool, pricing coverage in developing Asia is limited and levels are low. Second, as a major source of power generation, coal is insulated from many market forces. Coal generation is protected from market competition through long-term contracts, such as power purchase agreements and policies that insulate coal fuel costs from market price developments. According to Calhoun et. al. (2021), 93% of the world's coal plants are insulated from market pressure through incentive structures, thus passing the cost to consumers or taxpayers. Third, countries with significant coal mining may face strong resistance from affected workers and communities.

Several innovative programs have recently been proposed to accelerate coal's phaseout.^a These programs, however, will not be effective unless accompanied by a commitment to not build new coal-fired power plants. The Asian Development Bank's Energy Transition Mechanism, launched in 2021 in partnership with the Government of Indonesia and the Government of the Philippines, pools funds from sources that could include governments, multilateral banks, philanthropies, and the private sector to incentivize the early retirement and repurposing of coal power plants and to support the deployment of renewable energy. The Energy Transition Mechanism's lower cost of capital allows it to alter the cash flows of power plants so they can repay debt and equity investors faster. It also enables the accelerated retirement or repurposing of plants. The precedent transaction in Indonesia is expected to refinance a 660-megawatt coal-fired power plant for early retirement.

A key challenge of a coal phaseout program is information asymmetry—power plant owners have more information on the cost of operating the plant, hence their expected future profits, than regulators. This means determining the right compensation amount is not trivial. The use of auctions has been suggested as a possible market-based solution to tackle information asymmetry (Gillich, Hufendiek, and Klemp 2020; Jotzo and Mazouz 2015). Germany is the first country to use auctions to phase out coal-fired power plants. The auction is part of a wider program to close down all coal-fired power plants in the country under a coal exit law adopted in 2020.^b Owners of hard coal-fired and lignite-fired power plants (below 150 megawatts) power plants can tender capacity volumes to be taken offline. A maximum compensation amount is specified, which declines with each auction round, to spur early retirement. Depending on the round, plants must stop burning coal from 1 month to 3 years after auction results are announced. From 2027, authorities can mandate decommissioning without compensation. An analysis based on five auction rounds suggests the program has been able to keep costs per ton of carbon dioxide equivalent emissions avoided low (Tiedemann and Muller-Hansen 2023).

^a See Nedophil, Mengdi, and Ulrich (2022) for brief descriptions of coal retirement initiatives.

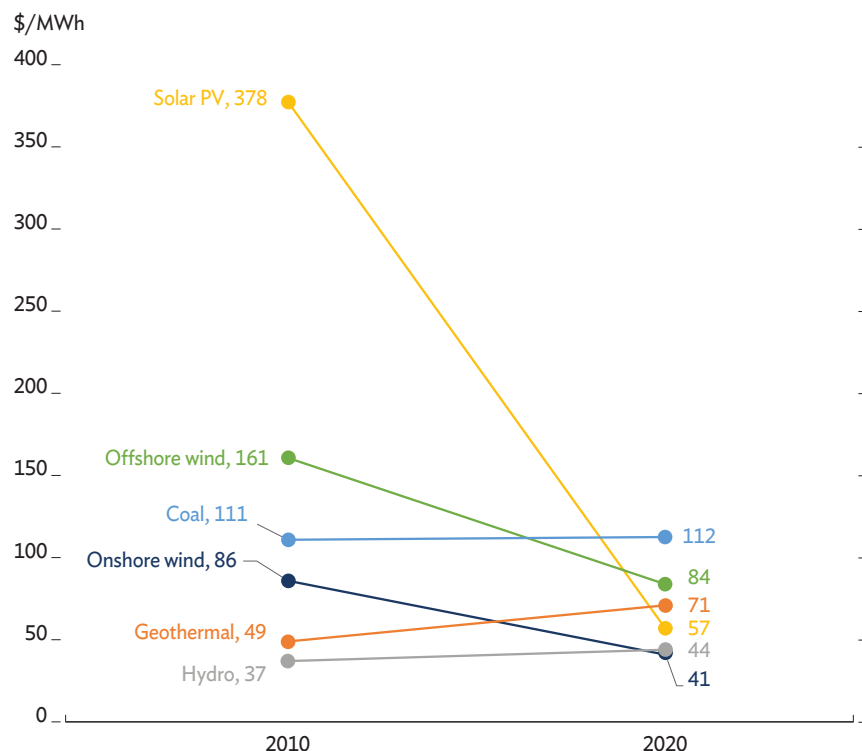
^b A separate program targets the retirement of large lignite-fired power plants, which has a greater effect on coal mining regions and workers. Contracts have been negotiated with coal operators providing €4.4 billion by 2030 to phase out 16.8 gigawatts of capacity. Affected workers will receive a maximum of €5 billion by 2048 (see Federal Government. [Ending Coal-Generated Power](#)).

References:

- Calhoun, K., et al. 2021. [Financing the Coal Transition: Pragmatic Solutions to Accelerate an Equitable, Clean Energy Future](#). Rocky Mountain Institute.
- Gillich, A., K. Hufendiek, and N. Klemp. 2020. [Extended Policy Mix in the Power Sector: How a Coal Phase-Out Redistributed Costs and Profits among Power Plants](#). *Energy Policy* 147.
- Jotzo, F., and S. Mazouz. 2015. [Brown Coal Exit: A Market Mechanism for Regulated Closure of Highly Emissions Intensive Power Stations](#). *Economic Analysis and Policy* 48.
- Nedophil, C., Y. Mengdi, and V. Ulrich. 2022. [Global Practices for Financing of Early Coal Retirement for Accelerated Green Energy Transition](#). Green Finance & Development Center at FISF Fudan University, Shanghai and SOAS University of London.
- Tiedemann, S., and F. Muller-Hansen. 2023. [Auctions to Phase Out Coal Power: Lesson Learned from Germany](#). *Energy Policy* 174.

Figure 2.11 Levelized Cost of Electricity by Technology, 2010 and 2020

The cost of solar and wind energy has fallen dramatically since 2010.



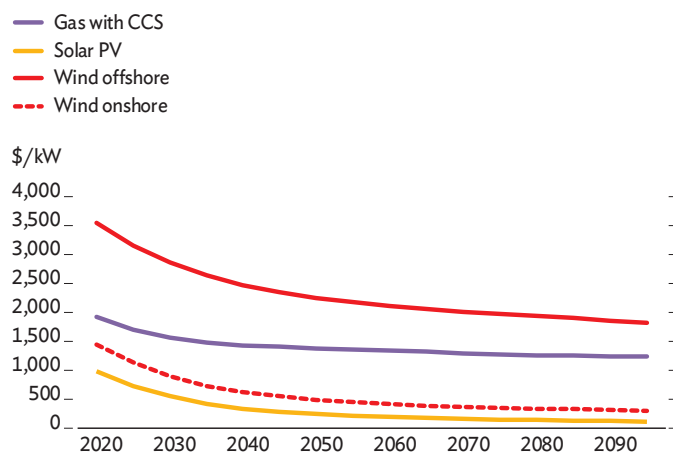
\$/MWh = US dollar per megawatt-hour, PV = photovoltaic.

Note: Global weighted-average levelized cost of electricity.

Sources: International Renewable Energy Agency. 2020. [Renewable Power Generation Costs in 2020](#); coal LCOE from Lazard. 2020. [Lazard's Levelized Cost of Energy Analysis - Version 14.0](#).

Figure 2.12 Installed Costs by Technology in Developing Asia under the Accelerated Global Net Zero Scenario, 2020–2100

Technological developments are expected to further reduce the cost of renewable energy.



CCS = carbon capture and storage, kW = kilowatt, PV = photovoltaic.

Source: Authors.

2.5.5 Electrification of Services

Electricity is the form of energy with the greatest possibilities for decarbonization at scale. Achieving a low-carbon transition depends on the widespread electrification of end uses, including transport services. This needs to be complemented by a rapid scaling up of renewables to provide clean energy to ensure enough supply to displace fossil fuels and meet growing demand from rising incomes and the electrification of services. Modeling suggests the share of electricity in final energy will increase from about a quarter in 2020 to more than half by 2070 under the accelerated global net zero scenario. Coal will be more rapidly phased out from industrial use, with electricity providing almost three-quarters of total final energy for industry by the end of the century. Oil will have similar declines in road transport. By the end of the century, electricity will provide 74% of final energy in the sector under the accelerated global net zero scenario, compared to just 30% under the current policies scenario (Figure 2.13).²⁹

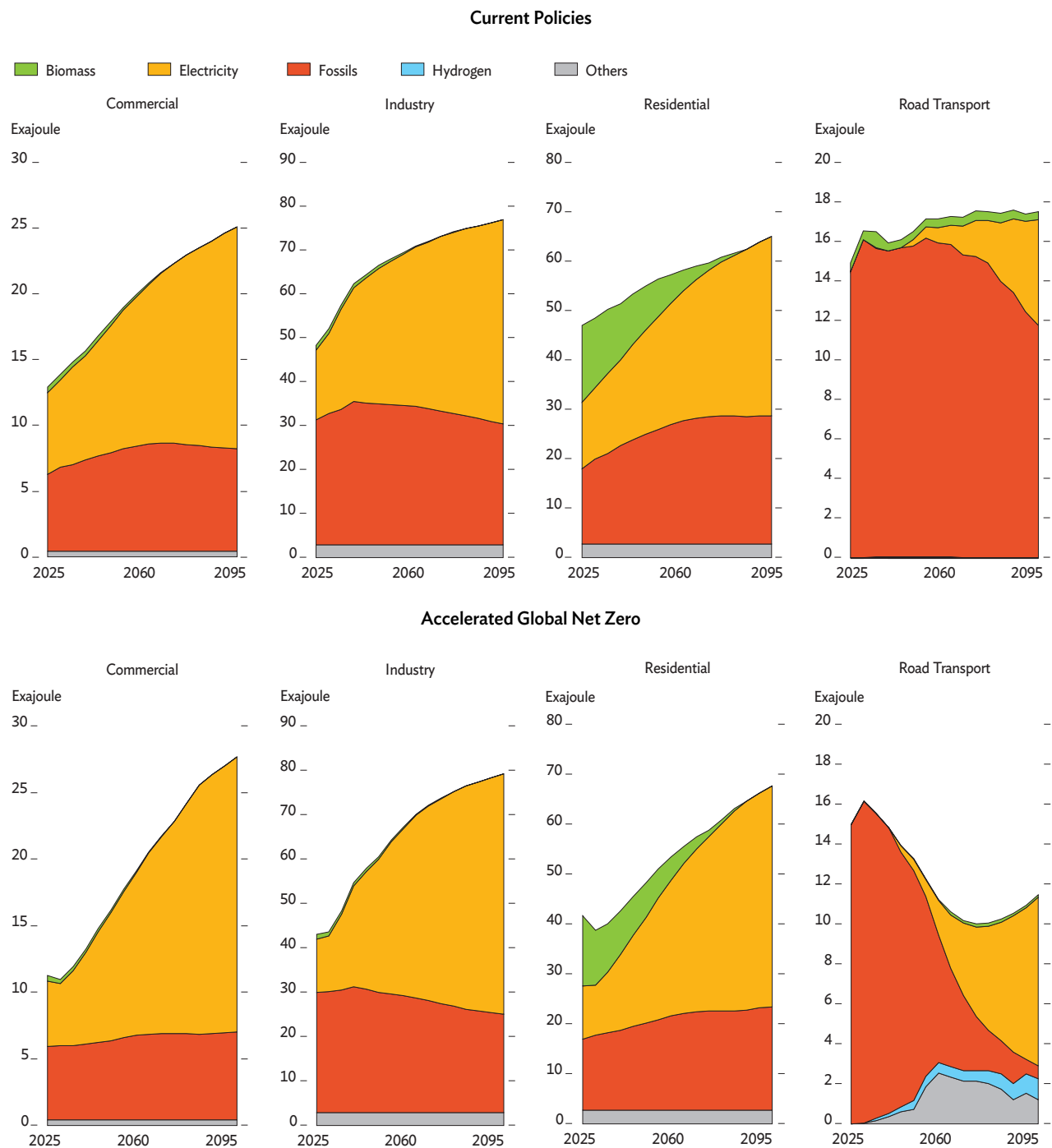
The decarbonization of transport in developing Asia needs to take place in the context of increasing mobility. In 2019, about 560 million rural residents, about 25% of Asia's rural population, still did not have all-season access to road networks, while 1.4 billion urban residents, 75% in Asia, lacked efficient access to urban public transit (ADB 2022f; Gota and Huizenga 2023). This is an additional challenge, but it also creates opportunities. Much of the needed transport infrastructure does not yet exist, and a large part of the vehicle fleet has not yet been manufactured and sold. Policy makers in developing Asia can avoid creating a car-dependent transport system with a large carbon footprint by opting for policies that stimulate the construction of low-carbon transport infrastructure and vehicles. Urban policy and planning can help develop compact decongested cities that promote the use of public transportation and are pedestrian and bike friendly.

Electrification of transportation services will proceed at a faster pace in developing Asia than in the rest of the world. Sales of electric vehicles (EVs) have increased rapidly since 2017, with global sales of light duty EVs at 10.5 million units in 2022. The PRC accounted for more than half of global EV sales (Box 2.5). However, EVs as a percentage of the total vehicle stock is still low, and it could take 10–15 years for its share to rise because of the relatively long lifespan of vehicles currently on the road (Gota and Huizenga 2023). Modeling results for the accelerated global net zero scenario indicate the PRC will continue its lead in EV adoption, with electricity providing more than a quarter of final energy in road transport by 2050 and 87% by 2070. In India and the rest of South Asia, electricity will provide more than half of energy for road transport by 2070 (Figure 2.14).

²⁹ Road transport includes passenger transport and freight.

Figure 2.13 Electrification of Services under Modeled Scenarios, 2025–2100

The net zero transition requires widespread electrification of end uses.



Source: Authors.

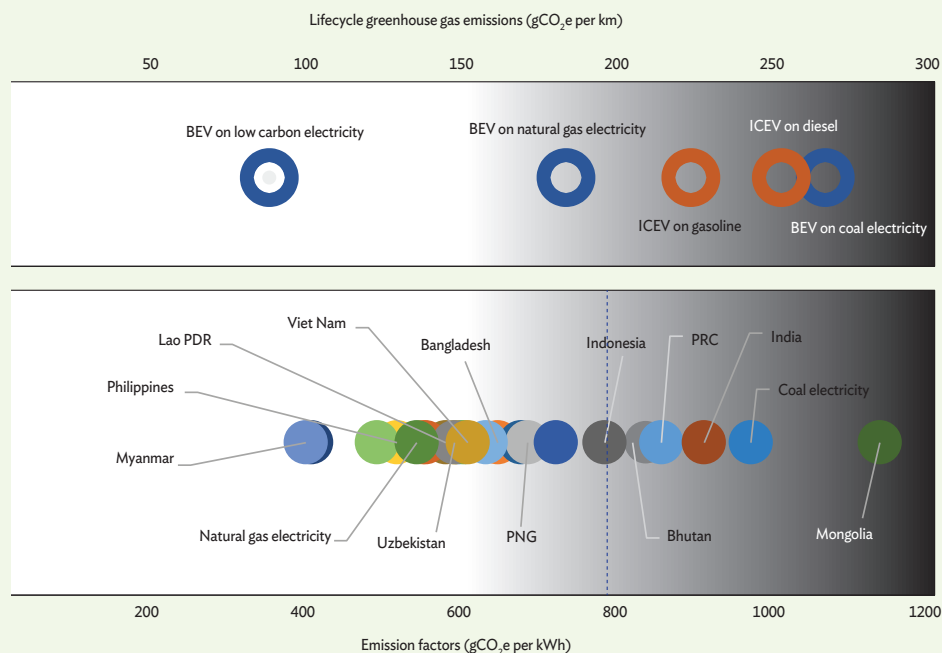
Box 2.5 Adoption of Battery Electric Vehicles in Developing Asia

The climate change mitigation potential of battery electric vehicles (BEVs) depends on the source of electricity used for charging. BEVs charged on low-carbon electricity produces lower life-cycle emissions than traditional internal combustion engine vehicles (ICEVs), while BEVs charged with coal-based electricity have higher life-cycle emissions than ICEVs.^a

Box figure 1 compares emission factors of the electricity grid in 24 developing Asian countries for which data are available with the median life-cycle emissions of four-wheeled light duty BEVs (IPCC 2022). The dashed line in the figure represents the emission factor—785 grams of carbon dioxide equivalent per kilowatt-hour of electricity generated—that would make the life-cycle emissions of BEVs equal to that of gasoline ICEVs. This was computed based on data and assumptions from IPCC (2022). In most countries (20 out of the 24) the grid-emission factor is lower than the dashed line, suggesting that BEV adoption can help to reduce emissions. However, the grid emission factor does not include emissions from the entire fuel value chain, so a one-on-one comparison of life-cycle emissions is not possible. With increasing shares of renewables in the grid, the potential for mitigating the emissions of BEVs will improve further.

1 Emissions from Battery Electric and Internal Combustion Engine Vehicles

The grid emissions factor determines the climate change mitigation potential of battery electric vehicles.



gCO₂e = grams of carbon dioxide equivalent emissions, km = kilometer, kWh = kilowatt-hour, BEV = battery electric vehicle, ICEV = internal combustion engine vehicle, Lao PDR = Lao People's Democratic Republic, PNG = Papua New Guinea, PRC = People's Republic of China.

Notes:

1. The blue dashed line represents the emission factor that would make the lifecycle emissions of BEVs equal to that of gasoline ICEVs.
2. The median lifecycle GHG emissions are for mid-sized light duty vehicles based on IPCC (2022). The following assumptions were used for the estimation: vehicle life is 180,000 km; occupancy rate is 1.5; and emission factors in gCO₂e/kWh or grams of carbon dioxide equivalent per megajoule are 965 for coal electricity, 537 for natural gas electricity, 9.3 for low-carbon electricity, and 92 for gasoline and diesel.
3. Low-carbon electricity includes solar, hydro, and wind.
4. Emission factors of countries refer to their electricity grid emissions.

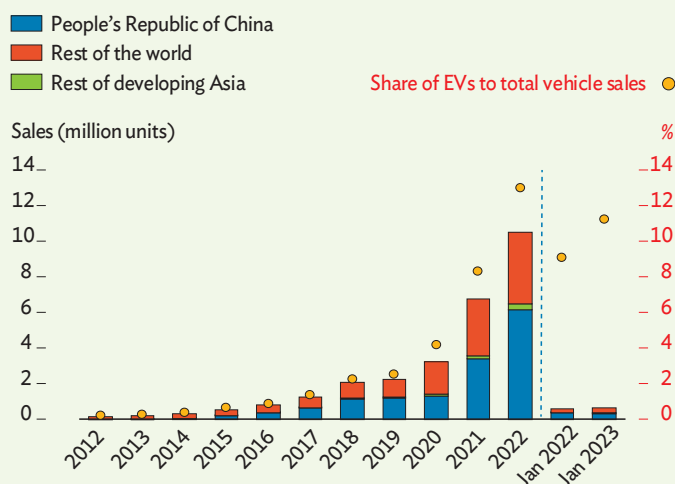
^a Life cycle emissions include emissions from vehicle manufacturing and fuel; they may also include emissions from vehicle maintenance and end of life.

Sources: Institute of Global Environmental Strategies. [IGES List of Grid Emission Factors](#) (accessed 10 November 2022). Version 11.1; Intergovernmental Panel on Climate Change. 2022. *Climate Change 2022: Mitigation of Climate Change*.

continued on next page

Box 2.5 Continued

Global sales of light duty electric vehicles (EVs) increased by more than 50% from 6.8 million units in 2021 to 10.5 million units in 2022. In 2023, 14.3 million EVs are expected to be sold, accounting for 17% of global vehicle sales. The People's Republic of China (PRC) leads the world in the total number of EVs adopted. In 2022, about 6.2 million light duty EVs were sold in the PRC, and sales volumes are expected to hit 8 million in 2023. The expansion of the PRC's EV market has been remarkable—from less than 2% of total vehicle sales in 2016, EVs accounted for 27% of vehicle sales in 2022 (box figure 2). Several factors—including availability of affordable EVs, accessible charging infrastructure, and favorable policies for EV buyers—have contributed to the successful penetration of EVs in the PRC. Charging infrastructure is widely available, and consumer subsidies have effectively brought down the cost of buying an EV there.

2 Global Sales of Light Duty Electric Vehicles, 2012–Jan 2023

EV = electric vehicle.

Note: Data include battery electric vehicles and plug-in hybrid electric vehicles.

Source: [EV-Volumes](#).

Outside the PRC, the Republic of Korea had the second largest EV sales in developing Asia in 2022 at 1.7 million units. In India, close to 50,000 units were sold in 2022, a more than threefold increase on 2021's 15,000. EV sales surged in Indonesia in 2022, with more than 10,000 units sold after less than 1,000 in 2021.

The future demand for EVs will depend on the availability of publicly accessible charging stations. The PRC has the most, with about 927,600 stations, accounting for 63% of the world's EV chargers. The country, however, still does not meet the International Energy Agency's recommended 10 EVs per charger. Li et al. (2021) find that investing in charging infrastructure is much more cost-effective for promoting the adoption of EVs than subsidizing the purchase of electric vehicles.

References:

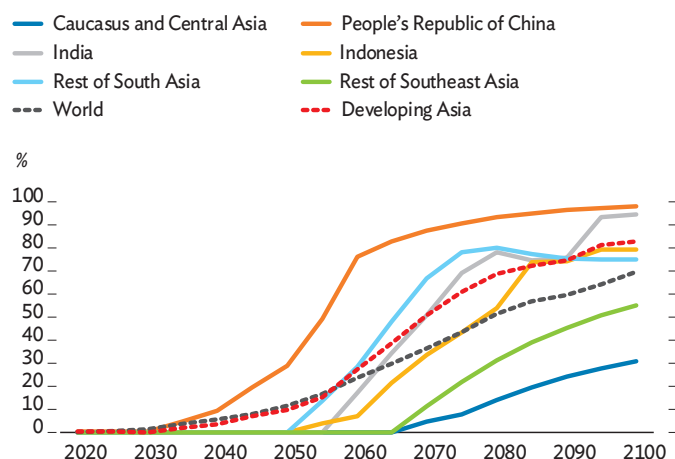
IPCC (Intergovernmental Panel on Climate Change). 2022. *Climate Change 2022: Mitigation of Climate Change*.

Li, S., et al. 2021. The Global Diffusion of Electric Vehicles: Lessons from the First Decade. *Policy Research Working Paper No. 9882*. World Bank.

Source: Authors.

Figure 2.14 Share of Electricity in Road Transport in Developing Asia under the Accelerated Global Net Zero Scenario

Electric vehicles will dominate road transport in much of the region.



Notes: Road transport includes freight and passenger transport. Two- and three-wheelers are not included in the model.

Source: Authors.

2.6 Investment Needs to Transform the Energy Sector

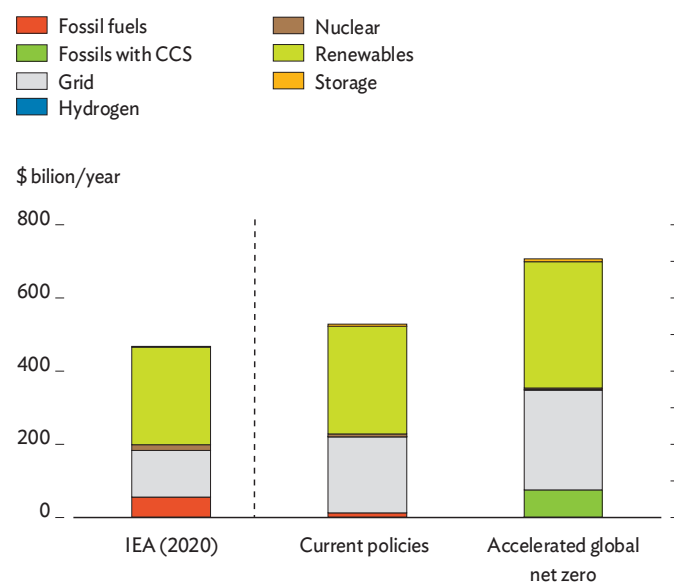
Clean energy investment to date has been concentrated in advanced economies and the PRC. In 2021, the world invested \$926 billion in power supply, with \$119 billion in fossil fuel generation and \$764 billion in clean energy.³⁰ About 80% of all clean electricity supply investments were concentrated in advanced economies and the PRC. Overall clean energy investment in developing countries is lagging behind. In 2021 developing Asia invested \$468 billion in power supply, of which \$397 billion was in clean energy. The PRC accounted for about 63% of all 2021 clean electricity investments in the region (IEA 2022a).

The future transformation of the power sector requires higher total investment and a reallocation toward cleaner energy sources across developing Asia. Average annual investments need to increase to an estimated \$707 billion under the accelerated global net zero scenario and to \$529 billion under the current policies scenario. Of this investment under the accelerated global net zero scenario, \$345 billion is needed in renewable sources of energy, \$282 billion in transmission and distribution network and storage to facilitate the increase in power from renewables, and \$74 billion in fossil fuel with CCS (Figure 2.15). These estimates are consistent with comparable scenarios in the AR6 (Appendix). Overall annual investment of 2.2% of GDP is required in the region, with a slightly higher GDP share of 2.6%–2.7% in India and the Caucasus and Central Asia. Indonesia and rest of Southeast Asia require annual investments of 1.5%–1.6% of GDP (Figure 2.16).

³⁰ Clean electricity supply includes generation investment in renewables, electricity networks, and storage.

Figure 2.15 Average Annual Investment in Power Supply in Developing Asia under Modeled Scenarios, 2020–2050

The transition to clean energy requires substantial increases in power supply investment.

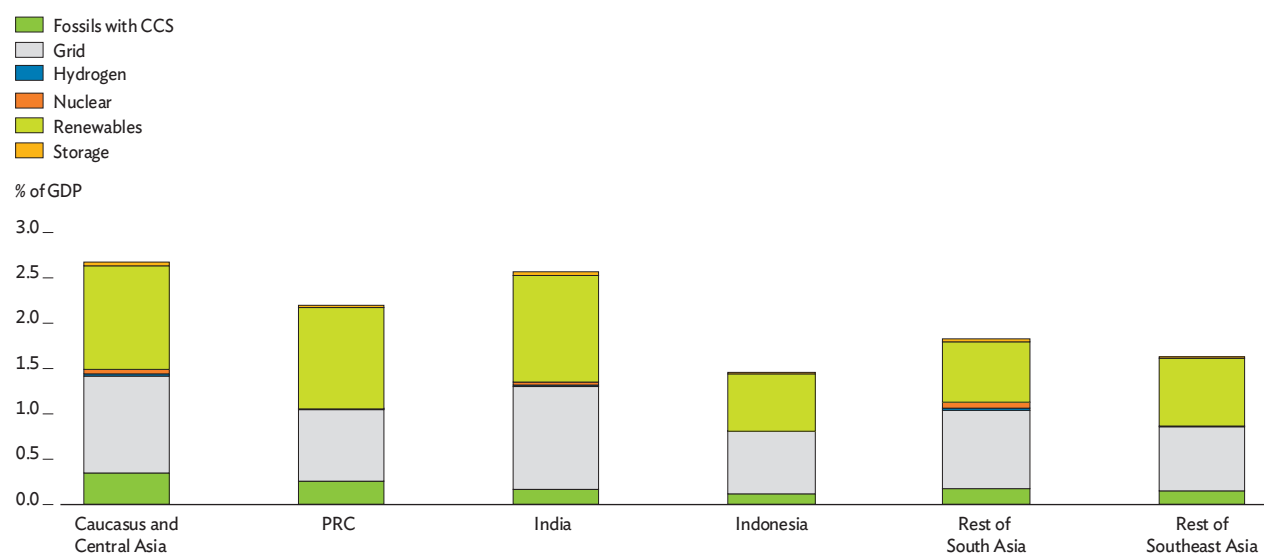


Notes: Renewables include solar, wind, hydro, and biomass. International Energy Agency (IEA) data have been downscaled using weights and aggregated to the reported region definitions.

Sources: Authors; International Energy Agency. [Access to Electricity Database](#) (accessed 10 February 2023).

Figure 2.16 Annual Average Power Supply Investment Required in Developing Asia under the Accelerated Global Net Zero Scenario, 2020–2050

The transition to clean energy requires substantial power supply investment.



CCS = carbon capture and storage, GDP = gross domestic product, PRC = People's Republic of China.

Note: Renewables include solar, wind, hydro, and biomass.

Source: Authors.

3 Socioeconomic Consequences of the Global Transition to Net Zero

3.1 Framework for Considering the Costs and Benefits of Climate Change Mitigation Policies

The transition to global net zero encompasses a profound set of changes across sectors, activities, and consumption patterns, with many different economic and social outcomes. Changes require price signals that trigger rapid substitution of fuel types, investments, infrastructure, and behavior. That substitution not only imposes an adjustment cost but also unleashes new opportunities for efficiency gains and a lower foreign exchange requirement for fuel imports. To achieve these opportunities, investments need to be radically redirected to new forms of infrastructure, which require new skills and make old job roles obsolete.

The costs of the transition are an investment in the future, as climate stabilization avoids the potential for enormous climate risks. Damages from climate change take time to occur because of inertia in the climate system from previous emissions. However, the co-benefits of climate action, such as cleaner local air, happen much more quickly. To understand the costs and benefits of ambitious mitigation, the complete effects on both climate and the co-benefits must be considered against the costs. When all the effects are accounted for, investments in well-designed and ambitious climate policies will yield high returns. However, whether the most vulnerable bear disproportionate costs of climate policies also depends on details of how these policies are designed. This section shows how those consequences can play out, drawing on results of the scenario modeling introduced in Section 2. The section first discusses various aspects of policy costs without accounting for climate benefits or co-benefits, then examines the benefits from reduced climate change, and supplements this with co-benefits. A discussion on distributional effects via labor markets and prices closes the section.

3.2 Policy Costs of the Low-Carbon Transition

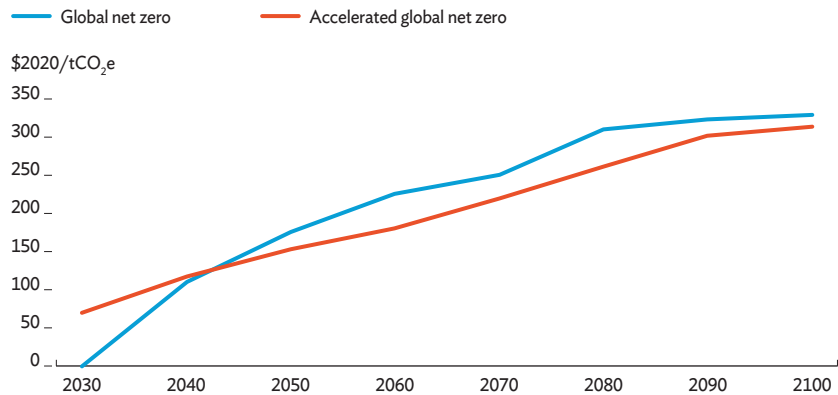
3.2.1 Modeled Carbon Prices to Achieve Climate Goals

Carbon prices are the trigger for decarbonization in the modeled scenarios. Those prices are also an important indicator of policy costs, as the marginal abatement cost to achieve the last unit of emissions reduction in line with the policy target. Under the accelerated global net zero scenario, prices in 2030 are found to be \$70/tCO₂e and \$153/tCO₂e in 2050 (Figure 3.1). In 2022, Sweden was already imposing a carbon tax of \$137/tCO₂e, and the EU's emissions trading system (ETS) price exceeded \$100/tCO₂e in 2023, which suggests these prices are attainable. That the transition to net zero can be achieved at attainable prices suggests the accelerated global net zero scenario is feasible. The NDC effort, in contrast, requires little pricing as it does not have substantial ambition beyond the current policies scenario. The accelerated global net zero scenario has higher carbon prices than the global net zero scenario initially, but lower prices by 2040, since early mitigation is more cost effective than delayed action.

The prices found in this report for the accelerated global net zero scenario are generally well aligned with the broader literature. For example, the 2017 *Report of the High-Level Commission on Carbon Prices* recommends prices in the \$50–\$100 range by 2030 to keep warming well below 2°C. However, values in line with those recommendations are only found to hold in this analysis if action starts early and in a globally coordinated manner.

Figure 3.1 Global Carbon Prices under the Modeled Global Net Zero Scenarios

Carbon prices stay within feasible levels in the net zero scenarios.



tCO₂e = ton of carbon dioxide equivalent.

Source: Authors' estimates.

3.2.2 Economic Costs of the Climate Change Mitigation Scenarios

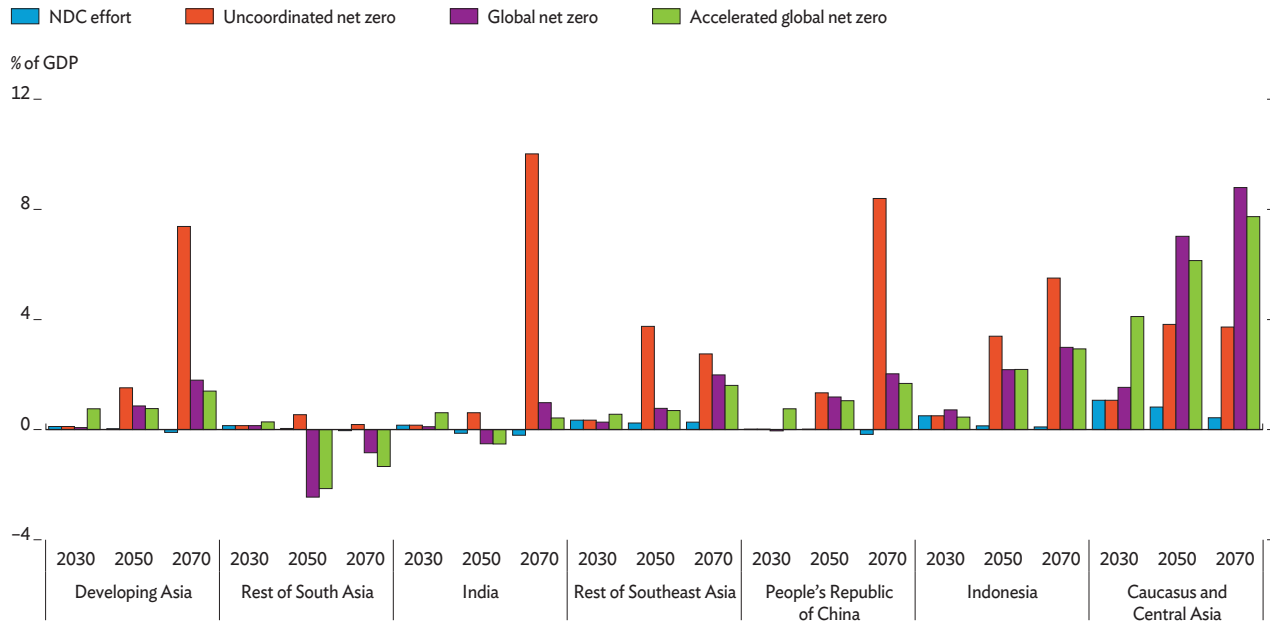
Achieving a profound transformation of energy and land use systems has important costs, but these can be contained by an efficient policy approach. The costs arise via altered investment; changes to energy, land, and food prices; and production and consumption responses to price shifts. The scenario modeling finds the overall cost of pursuing global net zero, without counting any climate benefits or co-benefits, is 0.8% of GDP for developing Asia as a whole in 2030, 0.8% in 2050, and 1.4% in 2070 if the world acts quickly and adopts an economically efficient distribution of mitigation effort (Figure 3.2). Put another way, the growth rate of GDP would be reduced by 0.035 percentage points from 2020 to 2100. This arrangement, however, does have unequal distribution of costs, as fossil fuel-exporting regions, including the Caucasus and Central Asia, have greater reductions in economic activity than do fossil fuel importers and countries that start from low levels of per capita emissions.³¹ Subregions and countries in the latter category, such as India and the rest of South Asia, tend to have much lower average levels of economic development, so costs are low or even negative for the poorest subregions and countries. Indonesia and the PRC have higher costs than the regional average, as a result of starting at higher carbon intensities. The modeling finds that the cost of the global transition to net zero increases substantially in most subregions by 2050 if ambitious mitigation waits until current NDCs expire, compared with the accelerated global net zero scenario. This saving dwarfs very minor increases in nearer-term 2030 costs.

Nearly all countries can benefit from acting quickly to decarbonize, as long as the rest of the world does so in a coordinated way. Early action lowers overall costs because paths to low-carbon emissions are more continuous than the paths needed if fast decarbonization waits another decade. However, discontinuous and rapid decarbonization over short periods by only some countries under the uncoordinated net zero scenario imposes much higher costs for economic adjustment, as there are more problems of stranded assets and conversion of energy capacity before the end of service life (Figure 3.3). NDC costs are negligible, in line with the relatively small difference that NDCs make to emissions, as described in Section 2.

³¹ Under the contraction and convergence framework described in Section 2, emissions are allocated on a per capita basis by 2050. This means that countries with lower per capita emissions need to reduce emissions less than countries with higher per capita emissions.

Figure 3.2 Policy Costs for the Modeled Scenarios in Developing Asia, Excluding Benefits, Relative to Current Policies, 2030, 2050, and 2070

Policy costs stay low for most of the region in all but the uncoordinated net zero scenario, with low or even negative costs in India and the rest of South Asia.

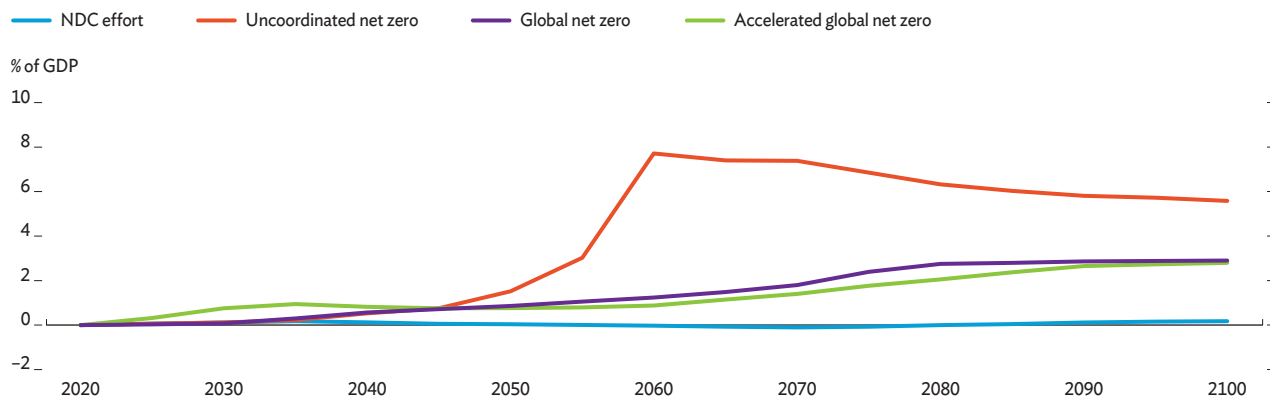


GDP = gross domestic product, NDC = nationally determined contribution.

Source: Authors' estimates.

Figure 3.3 Policy Costs for the Modeled Scenarios in Developing Asia Excluding Benefits, Relative to Current Policies, 2020–2100

Only the uncoordinated net zero scenario imposes a high-cost mid-century.



GDP = gross domestic product, NDC = nationally determined contribution.

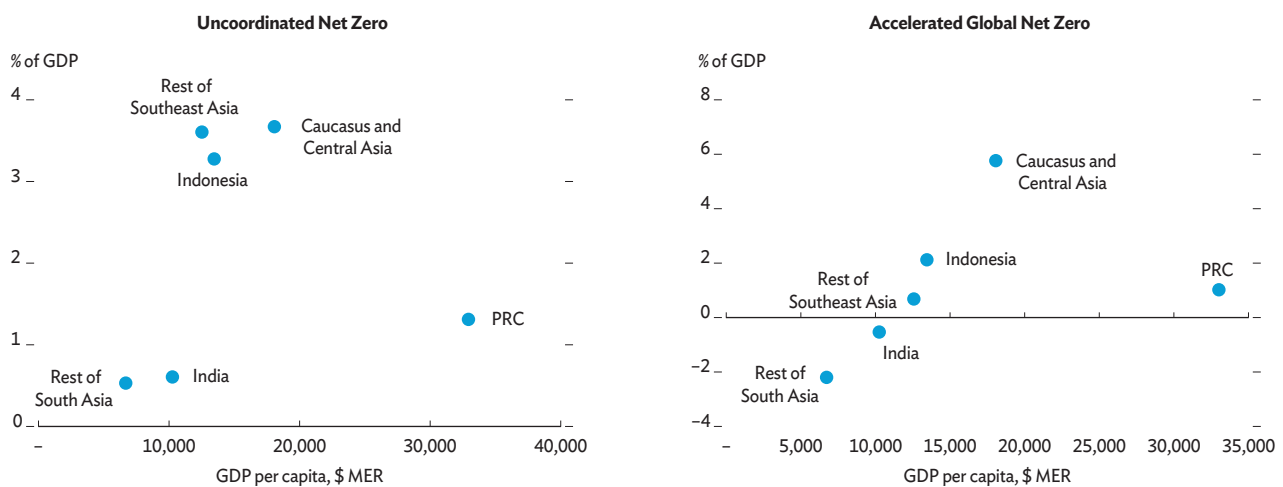
Source: Authors' estimates.

Pursuing individual country net zero pledges in an uncoordinated manner leads to higher overall costs for lower levels of mitigation, compared with more coordination. This is because effort is not allocated to ensure that mitigation occurs where it is cheapest. The uncoordinated pledges impose a steep cost to try to transition rapidly from low-ambition NDC pathways to high-ambition net zero pathways in specific countries. In particular, the individual pledges are found to lead to particularly high costs in population-dense countries that ambitiously

aim for net zero, such as India (Figure 3.4). Countries with high population densities have less potential for carbon removal through bioenergy with carbon capture and storage (BECCS) and afforestation, which are key mitigation responses illustrated in Section 2, so costs are higher. Meanwhile, countries without pledges are free-riders with disproportionately low costs. Although most large emitters have net zero pledges, there are also many smaller emitters that have not put forward pledges both within the region and the rest of the world, which collectively constitute an important share of global emissions (Table 1.1). Abrupt transitions, free-rider issues, and the inefficient allocation of effort mean there is almost no relationship between income levels and policy costs in the uncoordinated net zero scenario. In the accelerated global net zero scenario, the distribution is “just,” as lower-income countries—which mostly have lower historical responsibility for climate change—have lower relative policy costs than higher-income countries.

Figure 3.4 Distribution of Policy Costs Against Per Capita Gross Domestic Product under the Modeled Scenarios, 2050

Fairness for developing Asia is improved by a globally coordinated approach.



GDP = gross domestic product, MER = market exchange rate, PRC = People's Republic of China.

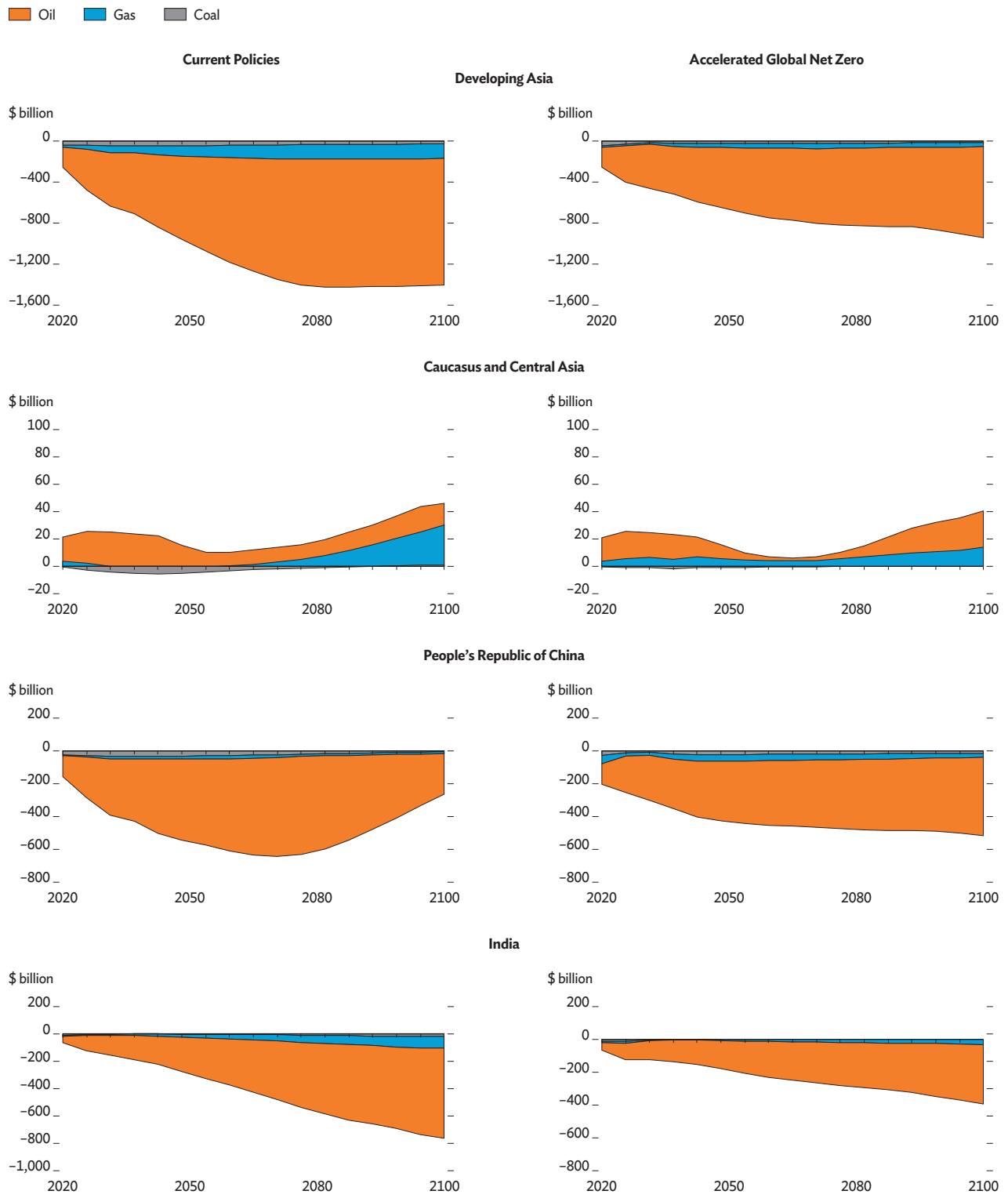
Source: Authors' estimates.

Policy costs in this report are expressed as a reduction in GDP to be consistent with the literature, but this costing has limitations. This type of accounting is an imperfect way to consider the costs of climate policy, although there is no widely accepted better solution. The measure is imperfect because—other things being equal—the reduction in fossil fuel production, transportation, storage, processing, and sales is reflected as a loss of the respective values, even if the energy service such as heating or transportation remains consumed at the same level. The same applies to assets that are more durable, as a reduction in the need for maintenance or replacement counts as a cost rather than a benefit. More broadly, the market value of production in an economy does not necessarily correspond to the welfare that most of the population enjoys from that production. Despite these limitations, GDP is a convenient measure of policy costs, even if the costs to welfare from climate change mitigation are likely to be lower than costs to GDP.

Ambitious mitigation can change the balance of fossil fuel trade dramatically. All subregions in developing Asia except the Caucasus and Central Asia are found to be large and increasing importers of fossil fuels under the current policies scenario (Figure 3.5). Results for the accelerated global net zero scenario show dramatic declines in imports. For example, fossil fuel imports in 2050 are comparatively reduced by 71% in South Asia, 45% in Southeast Asia, and 36% in India—and across subregions, declines continue to grow throughout the century. These savings have other benefits, including increasing domestic energy security and retaining foreign exchange.

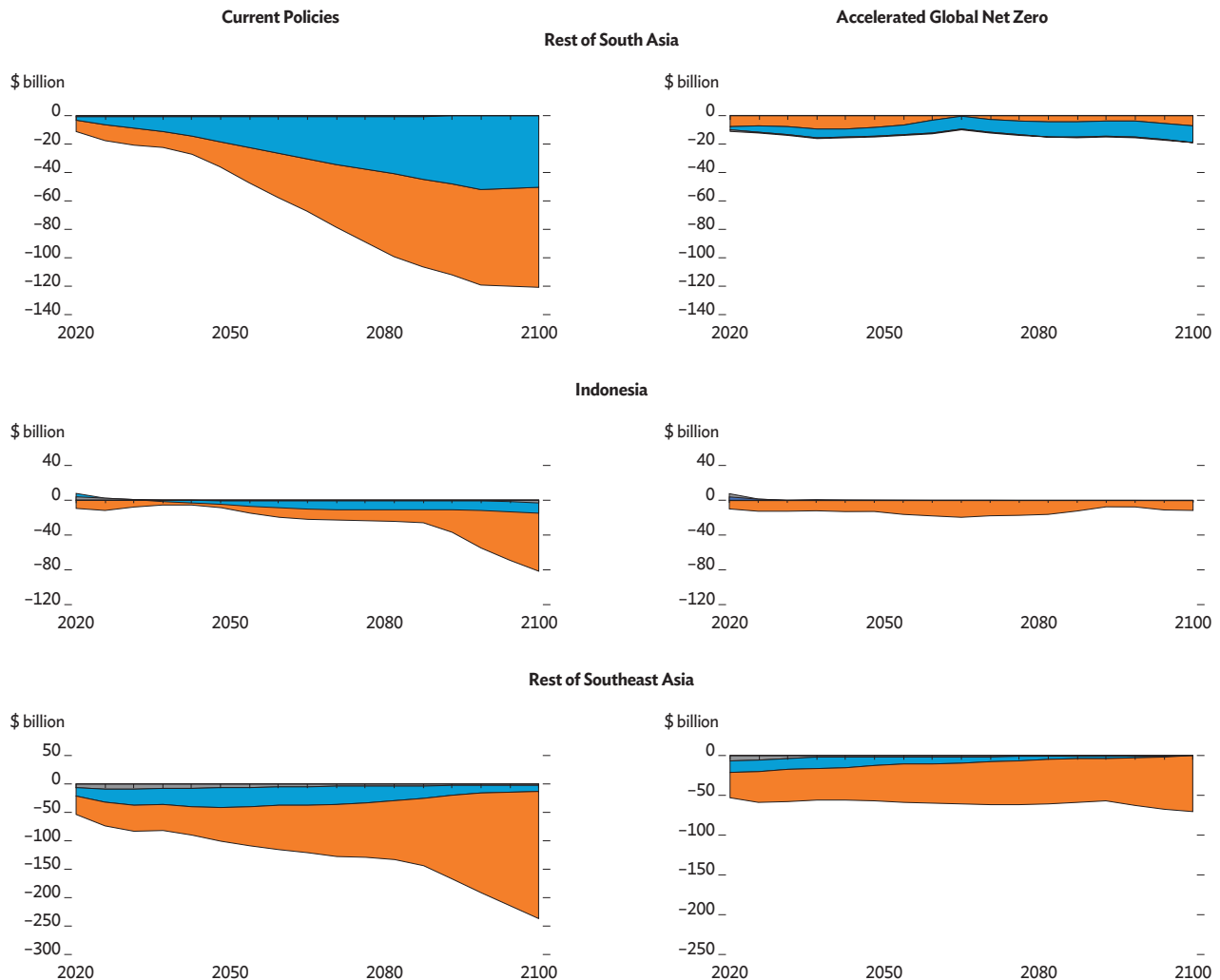
Figure 3.5 Fossil Fuel Trade in Developing Asia under the Modeled Scenarios, 2020–2100

Fossil fuel imports are reduced in the accelerated global net zero scenario.



continued on next page

Figure 3.5 Continued



Note: Positive value means exports, and negative value means imports.
Source: Authors' estimates.

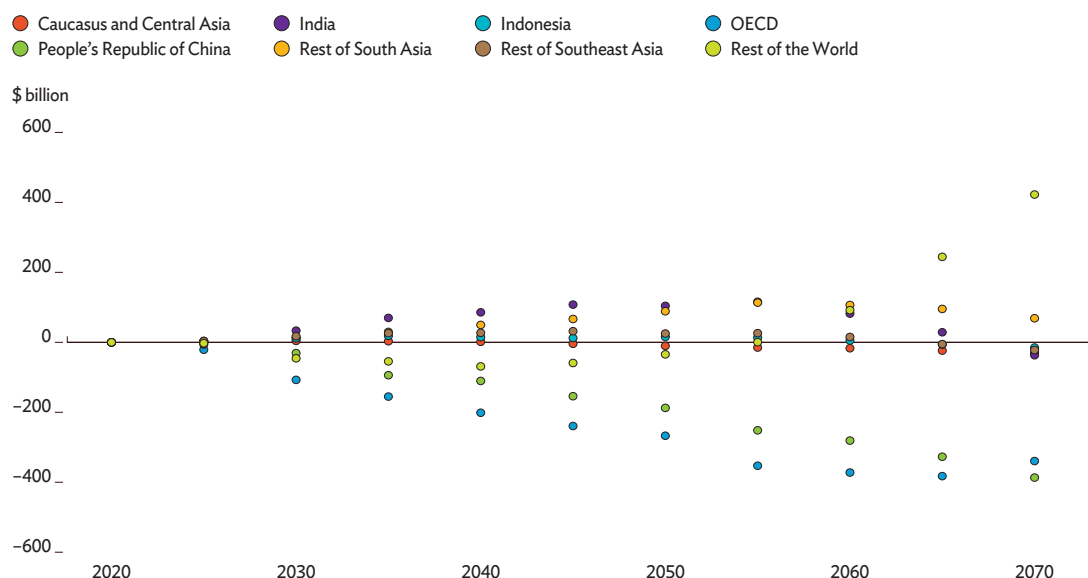
3.3 Factors and Policies Affecting Decarbonization Costs

3.3.1 Role of Carbon Trade in Redistributing Costs

Carbon trade can help to smooth the distribution of costs among countries. The modeled scenarios find that developing Asia will have both major carbon exporters and carbon importers if the world were to gradually transition to equal per capita emission quotas under the net zero scenarios (Figure 3.6). Generally, the poorer parts of Asia are those that end up being exporters of offsets, whereas the importers are richer regions. Throughout much of the century, India and the rest of South Asia will be leading exporters of allowances, whereas the primary purchasers are higher-income Organisation for Economic Co-operation and Development countries and the rest of the world, followed by the PRC. At the aggregate level, the modeling finds that developing Asia will be a slight potential importer of carbon offsets from the rest of the world under a contraction and convergence scenario over the entire century, so some policy costs are compensation to other regions (Figure 3.7). At the same time, revenues from exports of offsets turn aggregate costs negative for South Asia and help reduce costs in Indonesia and the rest of Southeast Asia.

Figure 3.6 Trade Balance of Greenhouse Gas Emission Offsets under the Accelerated Global Net Zero Scenario, 2020–2070

Developing Asia's lowest-income regions can be potential carbon exporters.



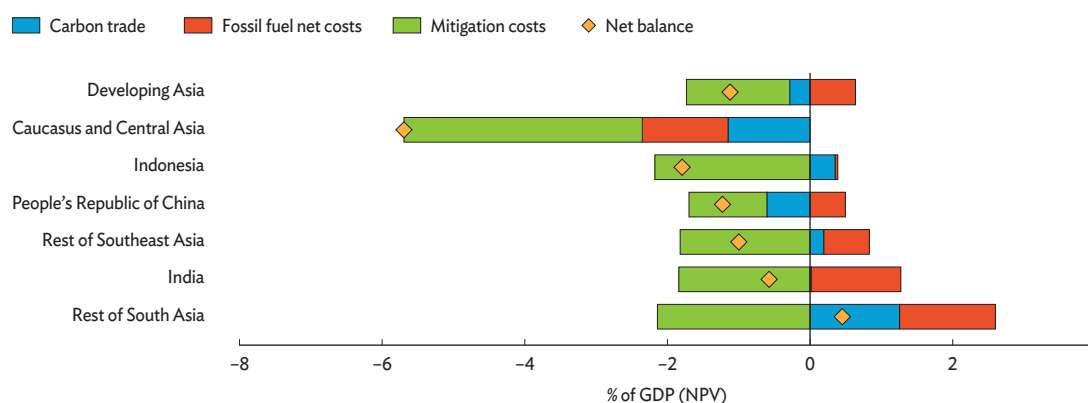
OECD = Organisation for Economic Co-operation and Development.

Note: Positive value means exports, and negative value means imports.

Source: Authors' estimates.

Figure 3.7 Policy-Cost Decomposition in Developing Asia of the Accelerated Global Net Zero Scenario

Carbon trade can help to cushion the costs of decarbonization in much of Asia.



GDP = gross domestic product, NPV = net present value.

Notes: Discounted at 3%. Values are expressed as a share of the net present value of GDP. Negative values are costs.

Source: Authors' estimates.

Reliance on nonmarket measures, such as regulations or subsidies, would have far higher costs than the policies modeled. The results for both with and without trade for the accelerated global net zero scenario assume that the world is responding to a global carbon price measure. A carbon price measure ensures that abatement occurs where it is least costly, whereas command and control regulations have no mechanism to assure that they target the lowest-cost opportunities to decarbonize. Subsidies similarly have no market to guide their targeting, have some degree of fungibility, and often lead to deadweight welfare losses.

Empirical evidence affirms that carbon pricing, in practice, leads to much more cost-effective mitigation than relying on subsidies (Gugler, Haxhimusa, and Liebensteiner 2021). As climate change models are built to reflect economic logic, it is not easy to show the full costs that would emerge if ambitious climate policy were to mostly rely on inefficient policy approaches.

3.3.2 Sensitivity of Costs to Technological Assumptions

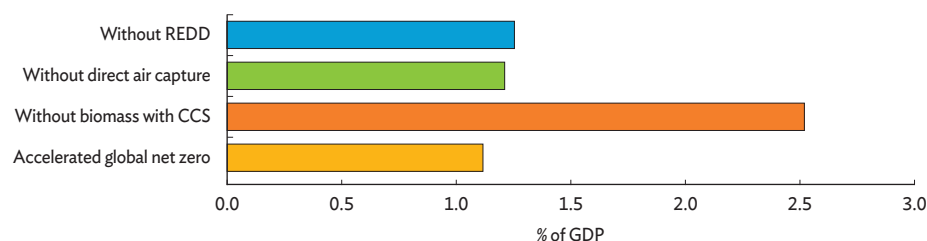
The scenarios modeled are for long periods, and they rely on various assumptions about technologies that are not yet mature or available for carbon dioxide removal. This removal is important because it allows for greater emissions from other sources such as remaining fossil energy to be offset, which reduces the degree of decarbonization required. To understand the degree of dependence on negative emissions technology assumptions, subscenarios were run that eliminate the use of reduced emissions from deforestation and forest degradation (REDD), BECCS, and direct air capture (DAC) from the accelerated global net zero scenario to determine effects on policy costs. Each of these removal options has issues that require resolution to be viable at scale:

- **REDD**, in theory, can eliminate substantial land use emissions at low or even negative cost, as deforestation often generates few economic benefits relative to emissions (Angelsen 2008). However, deforestation is often driven by political economy dynamics that are hard to correct through formal markets, as those who capture the rents of clearance are often politically empowered (Burgess et al. 2012).
- **BECCS** depends on developing new types of supply chains and land use governance to ensure that cultivation is not at the expense of natural ecosystems or food security and the appropriate technical means for storing captured carbon chemically or below ground (Fajardy et al. 2019).
- **DAC** is an approach to sequester carbon out of the air that is currently prohibitively inefficient to be cost effective, compared with capturing carbon at a point source (Shayegh, Bosetti, and Tavoni 2021).

Carbon dioxide removal technologies are found to be important for decarbonizing at low cost, but decarbonization remains feasible without them. The cost over 2020–2100 to developing Asia of the accelerated global net zero scenario more than doubles if all options are unavailable. The biggest contribution comes from BECCS, which drives most of the difference (Figure 3.8). REDD and DAC make smaller, but still important differences, as developing Asia’s costs rise by 12%—and by 8% if the technologies are not available. This implies that achieving progress on these frontier technologies is critical to cost-efficient decarbonization. At the same time, policy costs are still less than 3% of GDP with all options removed, which means that the technologies are not essential to the feasibility of a low-carbon future. However, developing the means to use these technologies effectively can clearly make decarbonization easier to attain.

Figure 3.8 Policy Costs of the Accelerated Global Net Zero Scenario in Developing Asia if Carbon Dioxide Removal Technologies Are Unavailable

These technologies can reduce the policy cost of decarbonization.



CCS = carbon capture and storage, GDP = gross domestic product, REDD = reduced emissions from deforestation and forest degradation.

Notes: Discounted at 3%. Values are expressed as a share of the net present value of GDP. All scenarios are based on the accelerated global net zero scenario.

Source: Authors' estimates.

3.4 Benefits versus Costs of Deep Decarbonization for Asia

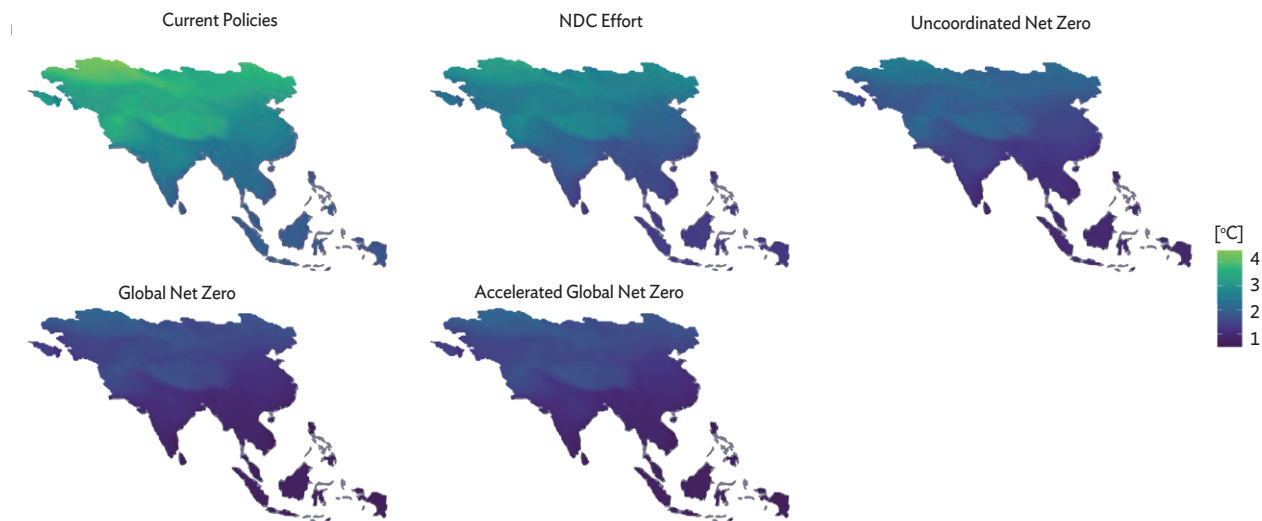
3.4.1 Climate Benefits

The direct payoff to incurring decarbonization policy costs is a reduction in losses from climate change that would be expected to occur under the current policies scenario. Losses from climate change for a given subregion in developing Asia are determined by exposure, in terms of the degree of climate change that would occur in the subregion; and vulnerability, in terms of how much loss occurs for each degree of change. For illustrative purposes, this analysis uses damage functions—which are reduced-form representations of vulnerability in relation to average temperature change—in conjunction with estimates of mean warming per scenario over time.

The different scenarios lead to different levels of warming in Asia. Under the current policies scenario, countries from the Caucasus and Central Asia, followed by the PRC, India, and the rest of South Asia, have the largest degree of average warming, whereas average temperature changes are more limited in Indonesia and the rest of Southeast Asia (Figure 3.9). The two coordinated global net zero scenarios cut the levels of warming within the 21st century approximately in half.

Figure 3.9 Maximum Temperature Change over the 21st Century Compared to Average Historical Temperature, 1980–2000

Reductions in global warming are strongest in northern and western Asia.



NDC = nationally determined contribution.

Note: The map shows ADB developing member economies.

Source: Authors' estimates.

Damage functions can project what reductions in climate change mean for developing Asia. Econometric estimates of climate damage functions have proliferated in recent years. These are estimated based on relationships between temperature variations and fluctuations in economic activity levels or growth. To encompass a range of estimates, six damage functions are applied to temperature changes under the scenarios to project changes in losses from climate change. Five functions are econometric: growth damage functions of linear temperature with persistent damage (Dell, Jones, and Olken 2012); growth damage functions of quadratic temperature with persistent damage (Burke, Hsiang, and Miguel 2015); specification refinements to Burke, Hsiang, and Miguel (2015) in

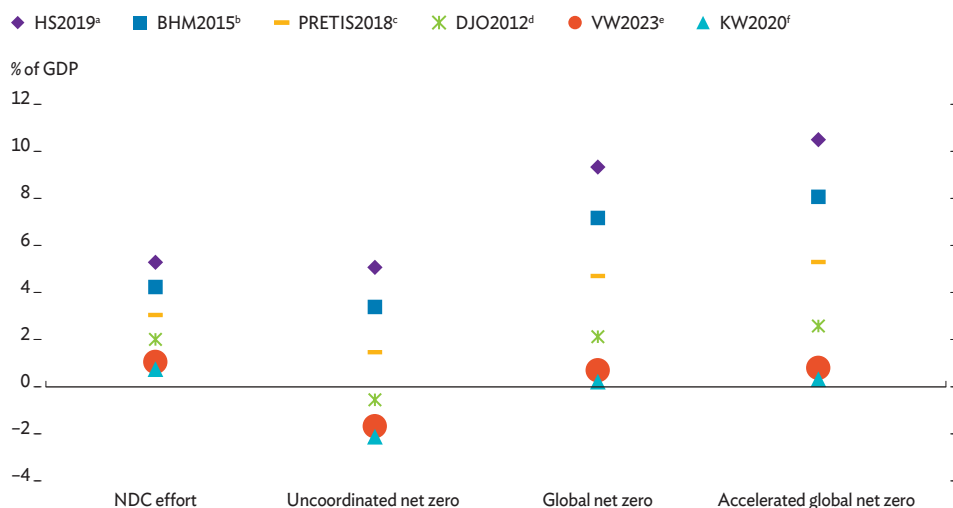
Henseler and Schumacher (2019); inclusion of within-year temperature variation in the Burke, Hsiang, and Miguel (2015) type of model (Pretis et al. 2018); and a growth-based damage function of regional temperature and annual temperature variation (Kalkuhl and Wenz 2020). Yet, recent literature has also called into question the econometric approach. For example, using economic growth rate as the dependent variable leads to higher estimates than using economic activity levels, but regressions using the growth rate are unstable, with many plausible specifications finding no effect (Newell, Prest, and Sexton 2021). Econometric approaches proxying weather fluctuations for climate change may also inappropriately extrapolate from unpredictable shocks to longer-term foreseeable trends. To address these limitations, damage functions from a computable general equilibrium model embedding sectoral impacts are also used (van der Wijst et al. 2023).

Developing Asia stands to benefit from the accelerated global net zero and NDC effort scenarios under all damage functions even if only the consequences of reduced climate change are considered against costs.

At the same time, there is a wide range of estimates of net economic effects (Figure 3.10). The uncoordinated net zero scenario has costs in excess of benefits for developing Asia under three of the six damage functions because of the much higher costs of an uncoordinated policy that imposes steep decarbonization after only modest action under NDCs until 2030. Although at the lower end of the range of estimates, the van der Wijst et al. (2023) damage functions are unique as process-based functions derived from considering a relatively comprehensive series of losses in specific sectors and synthesizing these shocks via two leading computable general equilibrium models.

Figure 3.10 Sum of Policy Costs and Climate Benefits in Developing Asia for the Modeled Scenarios under Specific Climate Damage Functions, 2020–2100

Although damage functions vary, they all show net benefits from ambitious, coordinated climate action.



GDP = gross domestic product, NDC = nationally determined contribution.

^a Henseler, M., and I. Schumacher. 2019. *The Impact of Weather on Economic Growth and Its Production Factors*. *Climatic Change* 154(3).

^b Burke, M., S. M. Hsiang, and E. Miguel. 2015. Global Non-Linear Effect of Temperature on Economic Production. *Nature* 527(7577).

^c Pretis, F. et al. 2018. *Uncertain Impacts on Economic Growth when Stabilizing Global Temperatures at 1.5°C or 2°C Warming*. *Philosophical Transactions of the Royal Society A*.

^d Dell, M., B. F. Jones, and B. A. Olken. 2012. *Temperature Shocks and Economic Growth: Evidence from the Last Half Century*. *American Economic Journal: Macroeconomics* 4(3).

^e van der Wijst, K. et al. 2023. *New Damage Curves and Multimodel Analysis Suggest Lower Optimal Temperature*. *Nature Climate Change* 1777.

^f Kalkuhl, M., and L. Wenz. 2020. *The Impact of Climate Conditions on Economic Production: Evidence from a Global Panel of Regions*. *Journal of Environmental Economics and Management* 103.

Note: Discounted at 3%. Values are expressed as a share of the net present value of GDP.

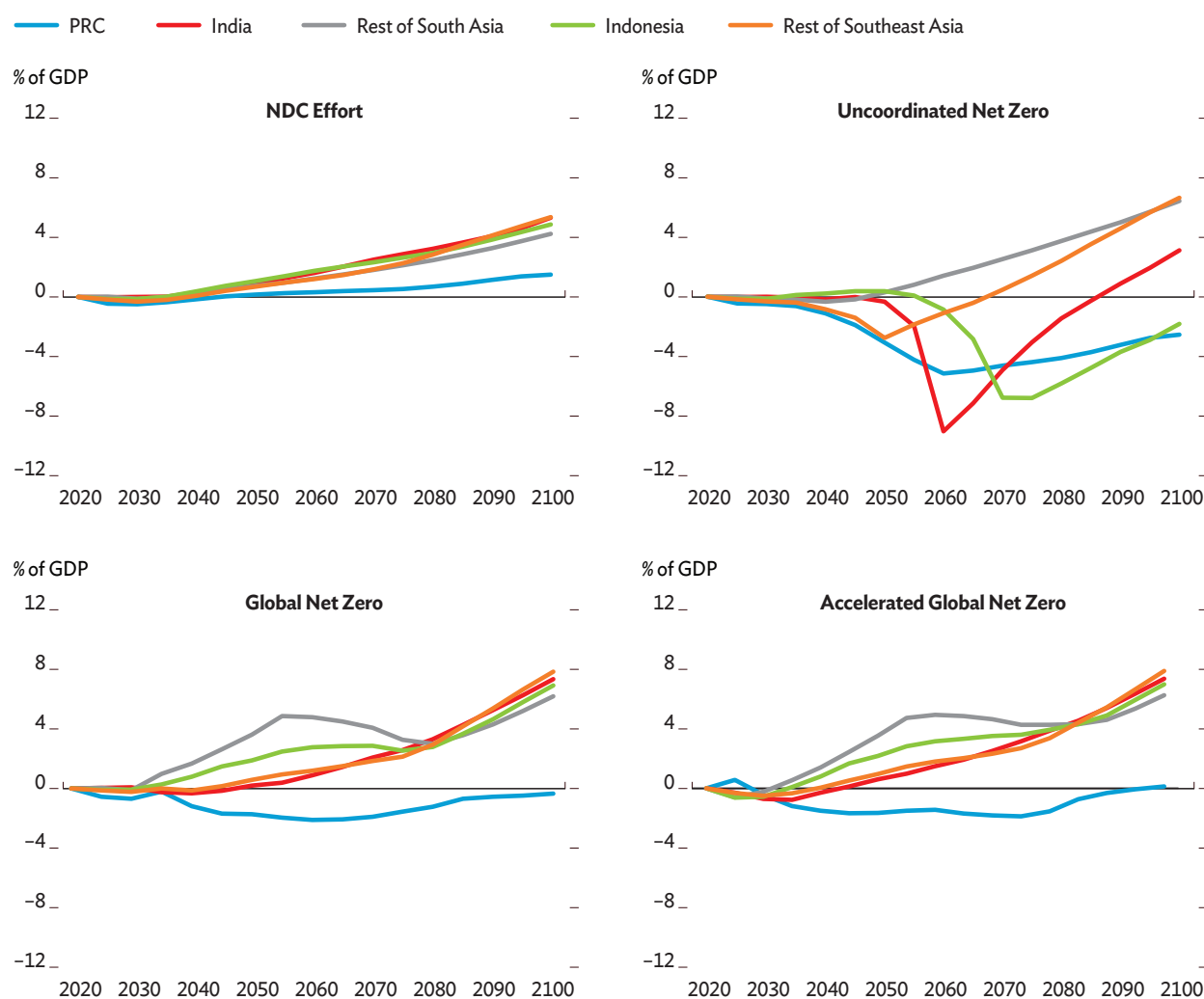
Source: Authors' estimates.

The results have a basis that is less sensitive to arbitrary specification choices that plague macroeconomic regression-based damage functions, so they are treated as the basis for further analysis here. Unfortunately, van der Wijst et al. (2023) only considered the Caucasus and Central Asia and the Pacific within aggregates that are dominated by non-Asian countries, so the results that can be drawn are limited to the remaining subregions in developing Asia.

This report's preferred damage function shows large and rapid potential payoffs to ambitious decarbonization for most of developing Asia before accounting for co-benefits. The damage function shows that the NDC effort scenario not only has the lowest policy costs but also the lowest level of benefits from averted climate change among the mitigation scenarios (Figure 3.11). The uncoordinated net zero scenario also has lower net benefits, and this is especially the case in the PRC, India, and Indonesia—Asia's three largest economies—which all have ambitious pledges.

Figure 3.11 Annual Net Policy Costs and Climate Benefits of the Modeled Scenarios, 2020–2100

Ambitious decarbonization can have rapid payoffs for much of developing Asia.



GDP = gross domestic product, NDC = nationally determined contribution, PRC = People's Republic of China.

Note: Benefits from reduced climate change are generated using damage functions from van der Wijst, K. et al. 2023. [New Damage Curves and Multimodel Analysis Suggest Lower Optimal Temperature](#). *Nature Climate Change* 1777.

Source: Authors' estimates.

The accelerated global net zero scenario has higher costs and higher benefits that are realized more rapidly, compared with the global net zero scenario. Benefits generally increase over time, due to a widening difference between warming under the current policies and other scenarios. All countries and regions other than the PRC reach net benefits by the end of the 2030s in the accelerated global net zero scenario, while Indonesia reaches net benefits by mid-century. In present value terms, benefits are 260% of costs over the 21st century for developing Asia. It should be noted that these values are inherently conservative as they do not fully account for the potentially tremendous value of reductions in the probability of high-consequence, low-probability events in the climate system (Weitzmann 2009).

3.4.2 Co-Benefits of Mitigation

Decarbonization generates important co-benefits beyond climate. A principal co-benefit is improved air quality. In 2019, one in nine deaths worldwide were caused by fine particulate matter (PM 2.5) and ozone (O₃) air pollution (HEI 2019). Fossil fuel-based energy generates a range of air pollutants that are damaging to health and natural ecosystems. Although pollution-control technology has improved, it is still no match for energy technologies that do not depend on combustion, such as wind and solar, and energy efficiency improvement.

Air pollution is particularly damaging in developing Asia, as there are megacities in the region with concentrated populations close to emitting activities. Six of the 10 cities with the world's highest exposure to population-weighted fine particulate matter are in developing Asia (Table 3.1). Cities in South Asia and the PRC on average had higher PM 2.5 exposure than the least stringent World Health Organization interim target of 35 micrograms per cubic meter (HEI 2020).

Table 3.1 Cities with the Highest Population-Weighted Annual Average Particulate Matter 2.5 Exposures, 2019

Six of the 10 cities with the highest air pollution levels globally are in developing Asia.

Rank	City, Country	Population-Weighted PM 2.5 (µg/m ³)
1	Delhi, India	110
2	Kolkata, India	84.0
3	Kano, Nigeria	83.6
4	Lima, Peru	73.2
5	Dhaka, Bangladesh	71.4
6	Jakarta, Indonesia	67.3
7	Lagos, Nigeria	66.9
8	Karachi, Pakistan	63.6
9	Beijing, People's Republic of China	55.0
10	Accra, Ghana	51.9

PM = particulate matter, µg/m³ = micrograms per cubic meter.

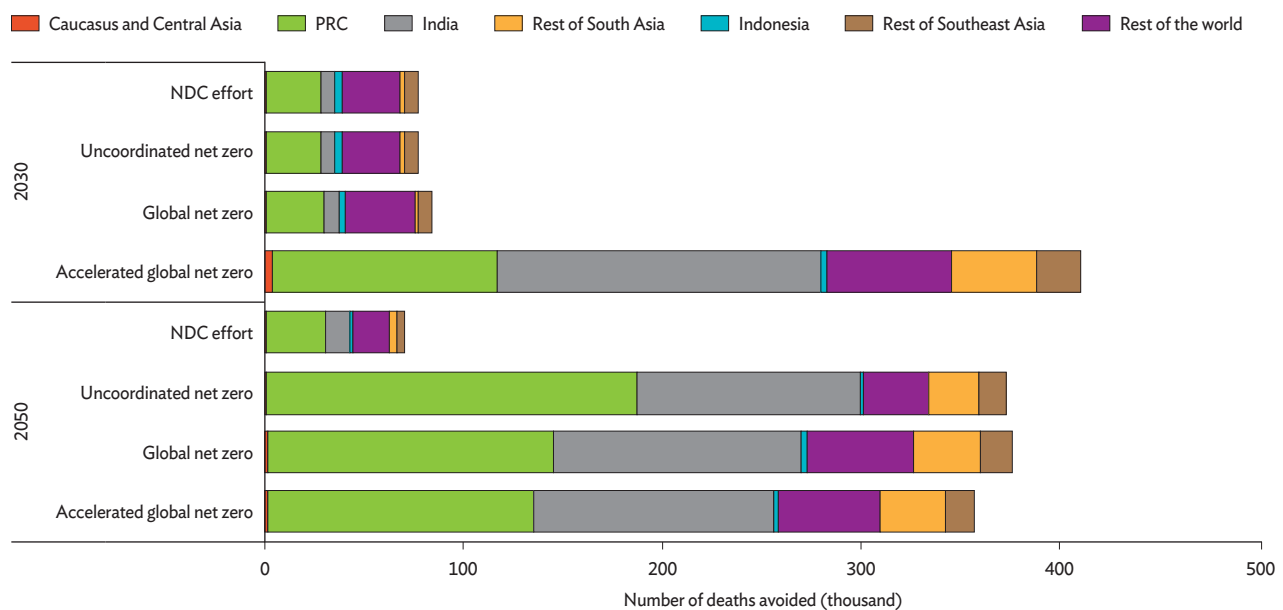
Source: Health Effects Institute. 2020. *State of Global Air 2020. Special Report.*

Air pollution is affected by the same actions that affect GHG emissions, but it can be addressed separately through “end-of-pipe measures” that remove pollutants after fossil fuel combustion. The modeling framework considers both pathways, as it reflects improving emission standards for fossil fuel combustion over time, up to a maximum feasible reduction, based on pollutant abatement costs in the current policies scenario. Emissions from the WITCH model are fed into the FASST source-receptor model to model air pollutant dispersion and regional mortality from ozone and fine particulate matter, as well as a crop model to evaluate effects on agriculture. This allows for reductions in mortality due to improved air quality under a cleaner energy mix to be quantified.

The exercise finds that, under the accelerated global net zero scenario, 346,000 premature deaths from outdoor air pollution could be avoided annually by 2030 in developing Asia. All other scenarios achieve only a small fraction of these health benefits by 2030, even with increased use of end-of-pipe measures (Figure 3.12). Avoided mortality in the region accounts for 85% of avoided mortality globally, and most averted mortality occurs in India and the PRC. In contrast, other scenarios avoid at most 49,000 deaths in developing Asia by 2030. By 2050, all net zero scenarios avoid 300,000–340,000 deaths annually, although the NDC effort scenario continues to avoid only a small fraction. In 2050, developing Asia continues to account for the vast majority of lives saved globally.

Figure 3.12 Avoided Annual Premature Deaths Due to Outdoor Particulate Matter 2.5 and Ozone under the Modeled Scenarios Relative to the Current Policies Scenario, 2030 and 2050

The accelerated global net zero scenario helps to reduce air pollution mortality quickly.



NDC = nationally determined contribution, PRC = People's Republic of China.

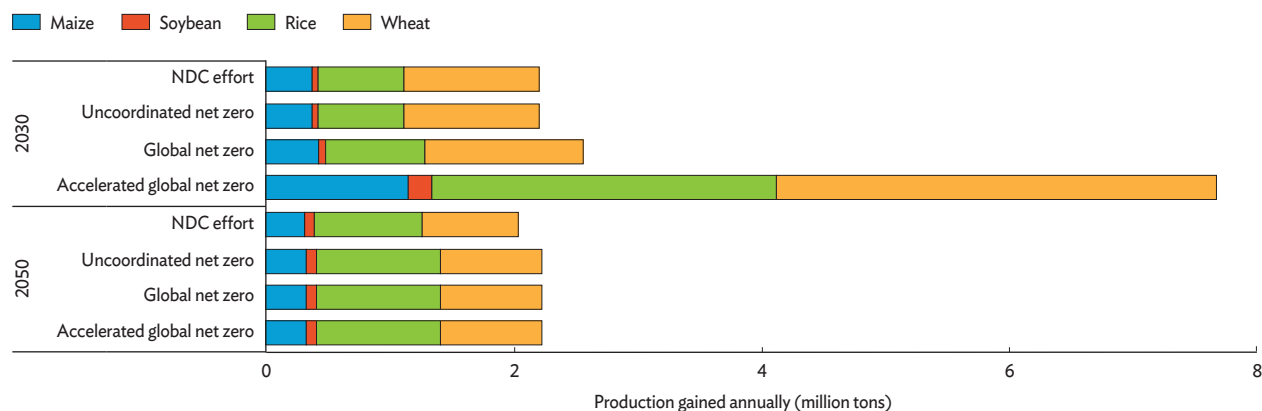
Source: Authors' estimates.

Reducing air pollution delivers benefits beyond human health. Cleaner air benefits quality of life, natural ecosystems, and sectors that depend on environmental services, such as agriculture. Not all the benefits of reduced air pollution can easily be quantified, but for illustrative purposes, effects on crop yields from changes in ozone can be assessed. Figure 3.13 shows that nearly 8 million tons of annual agricultural production can potentially be saved by improved air quality by 2030 under the accelerated global net zero scenario. Although this is only a fraction of the agricultural losses expected from climate change, it nevertheless illustrates that better air quality benefits terrestrial systems. This is only one of many environmental co-benefits that will arise from decarbonization.

Co-benefits are an important complement to benefits from averted climate change losses, because they are realized more quickly. As a result, when co-benefits are considered, the aggregate of co-benefits and climate benefits exceeds policy costs rather rapidly. For illustrative purposes, the value of statistical life is applied following the recommendation of Robinson et al. (2019) to use a value of 160 times per capita gross national income to be able to compare flows of policy costs, climate benefits, and co-benefits.

Figure 3.13 Avoided Annual Crop Loss from Ozone in Developing Asia under the Modeled Scenarios Relative to the Current Policies Scenario, 2030 and 2050

The accelerated global net zero scenario helps to reduce crop losses from air pollution quickly.



NDC = nationally determined contribution.

Source: Authors' estimates.

Overall, the net present values of co-benefits and benefits are from three to 11 times policy costs for developing Asia's subregions under the accelerated global net zero scenario. For developing Asia as a whole, co-benefits and benefits are five times the policy costs. In the PRC, air quality benefits are particularly important in making climate policy pay off quickly, as the country faces lower climate vulnerability than many other parts of Asia (Figure 3.14). As the accelerated global net zero has both lower overall costs and starts flows of benefits and co-benefits earlier than the other net zero scenarios, early coordinated ambitious action is in the region's interest.

3.5 Equity Implications of Mitigation Policies

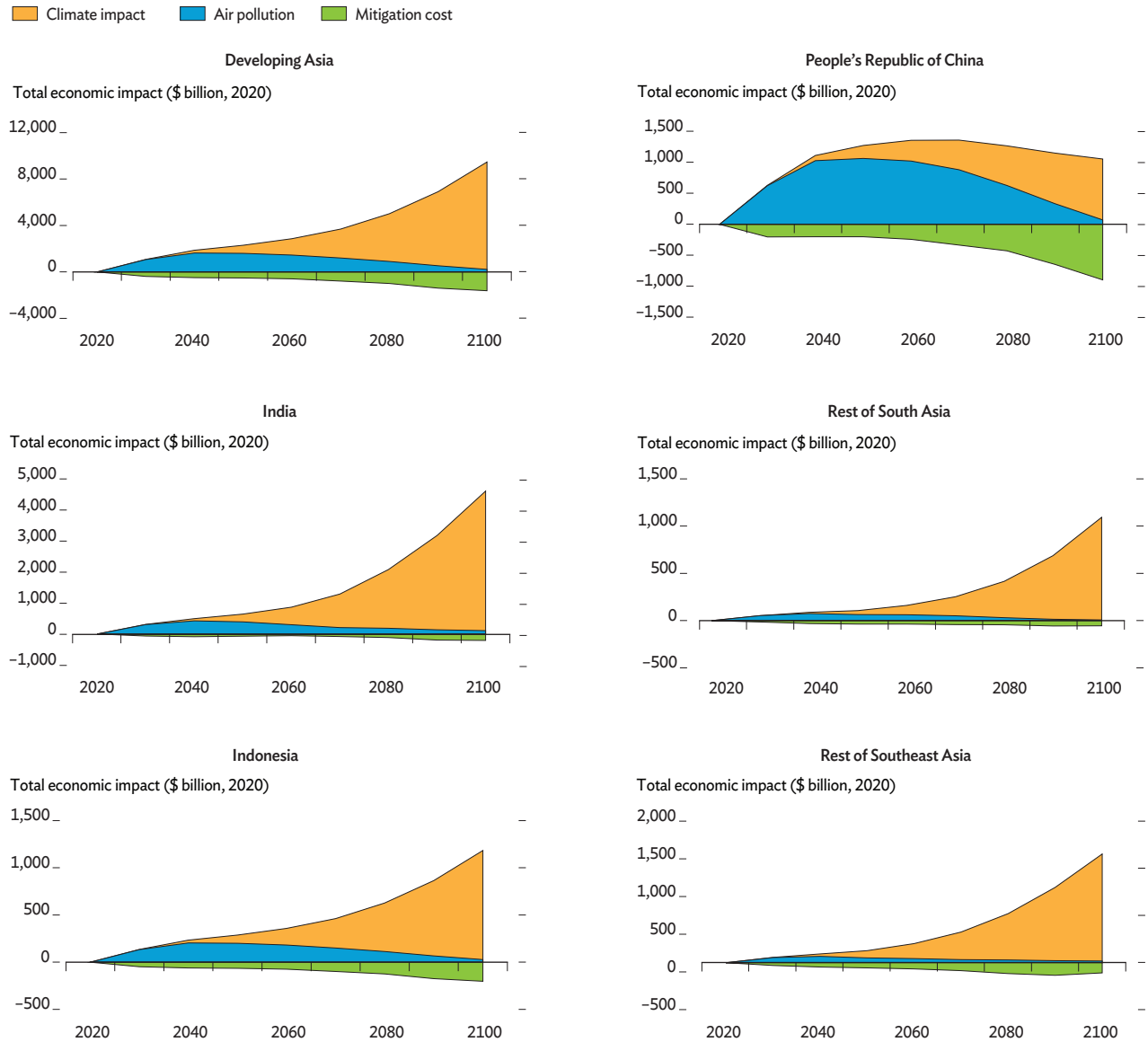
Although ambitious decarbonization can create benefits far in excess of costs for developing Asia, the policies required to do so will create winners and losers. This is because profound shifts in energy and land use will affect demand for skills in the workforce and consumer prices.

3.5.1 Employment Consequences

Perceptions that decarbonization will adversely affect workers in the energy sector may hinder the adoption of low-carbon policies. The scenarios considered here show that employment in the energy sector may be enhanced rather than reduced by ambitious decarbonization, as reflected in the accelerated global net zero scenario. Changes to the types of energy consumed under ambitious decarbonization lead to corresponding shifts in employment. With less consumption of fossil fuels, especially coal, jobs in fuel extraction decline. In developing Asia, however, this effect will be more than offset by the rise of new types of employment. This trend is already evident, as almost all employment growth in the energy sector from 2019 to 2022 was in renewables, which now accounts for a majority of jobs in the power sector (IEA 2022d). To assess these effects, results from the scenario modeling are coupled to an employment module constructed from a dataset of job intensities in 11 energy technologies and five job categories in over 50 countries (Pai et al. 2021). Changes in employment was modeled based on the relative changes in the use of each energy source and technology in each country multiplied by the respective job intensity.

Figure 3.14 Annual Net Policy Costs, Climate Benefits, and Air Quality Co-Benefits in Developing Asia of the Accelerated Global Net Zero Scenario Relative to the Current Policies Scenario, 2020–2100

Ambitious and coordinated climate action has large overall net benefits for the region.



PRC = People's Republic of China.

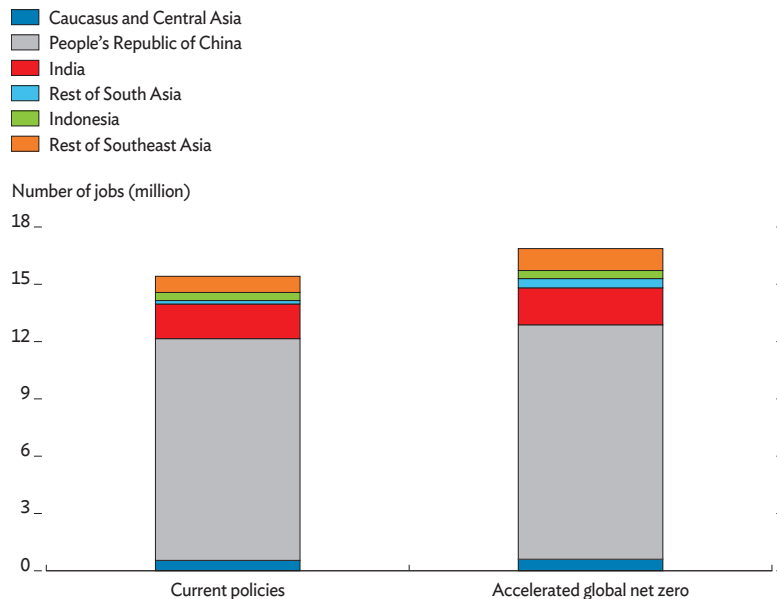
Notes: Developing Asia includes only the regions depicted in the figure. Benefits from reduced climate change are generated using damage functions from van der Wijst, K. et al. 2023. [New Damage Curves and Multimodel Analysis Suggest Lower Optimal Temperature](#). *Nature Climate Change* 1777.

Source: Authors' estimates.

All developing Asian subregions can have increased energy sector employment under ambitious decarbonization. The model reflects 11.9 million full-time equivalent direct energy sector jobs in 2020 in the region, which increases to 15.5 million by 2050 under the current policies scenario and to 17 million in the accelerated global net zero scenario, so that 1.5 million additional jobs are created (Figure 3.15). Although the largest number of additional jobs is generated in the PRC, relative employment growth is largest in South Asia.

Figure 3.15 Total Direct Energy Sector Full-Time Equivalent Employment in Developing Asia under Modeled Scenarios, 2050

The accelerated global net zero scenario increases energy sector jobs in all of developing Asia.



This increase also implies a substantial shift in the energy sector workforce across technologies, job types, and regions. Compared with the current policies scenario, about 1.4 million coal jobs are lost in developing Asia under the accelerated net zero scenario by 2050, but 2.9 million jobs are created, mostly for solar PV and wind generation (Figure 3.16). These results are generally consistent with International Energy Agency (IEA) (2022d), which also finds that global employment in the energy sector rises by 22% under a global net zero scenario by 2030.

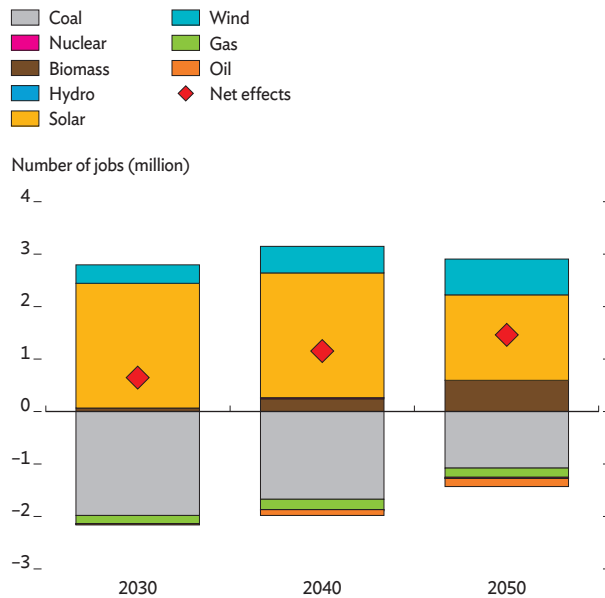
Most of the jobs created are in the manufacturing of solar and wind generation equipment, operation and maintenance of clean energy and smart grids, and construction. Most of the lost jobs are in fossil fuel extraction, especially coal mining (Figure 3.17). Here, work tends to be high risk and unpleasant compared with jobs in manufacturing and installation, so this shift also increases the quality of employment in the region. Energy sector employment generally requires much higher levels of skills than general employment in the workforce (IEA 2022d), so the expansion of energy jobs will lead to more formalized, professional employment in the region.

3.5.2 Food Price Consequences

Pursuing ambitious decarbonization can lead to large changes in land use, which affects agriculture and food affordability. Deforestation is reduced, afforestation is pursued to help sequester carbon, and the cultivation of biomass under BECCS becomes widely adopted in the two global net zero scenarios, as described in Section 2. Although the expansion of forests can enhance many important environmental services, the combined effect of these changes increases competition for land at the expense of the cultivated area for agriculture. Reducing cultivated area, in turn, adversely affects agricultural production—and with reduced production, food prices rise.

Figure 3.16 Differences in Full-Time Direct Energy Sector Employment in Developing Asia by Type of Energy between the Current Policies and Accelerated Global Net Zero Scenarios, 2030–2050

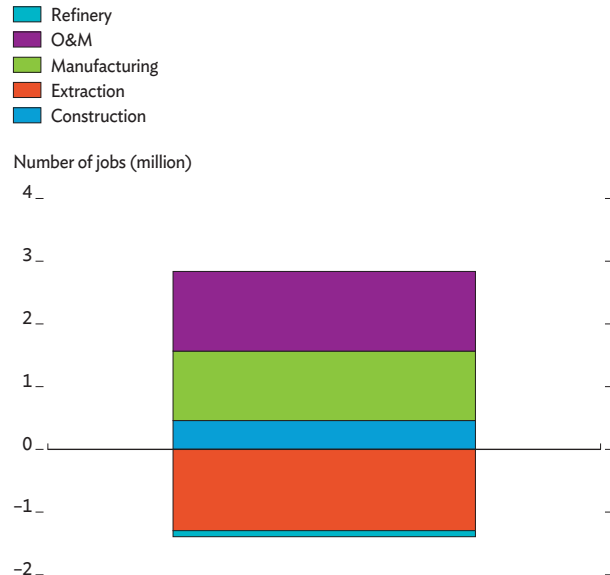
Jobs in renewables more than compensate for losses of extractive jobs.



Source: Authors' estimates.

Figure 3.17 Differences in Full-Time Direct Energy Sector Employment in Developing Asia by Activity between the Current Policies and Accelerated Global Net Zero Scenarios, 2050

Most jobs created are in manufacturing and operation and maintenance of renewables.



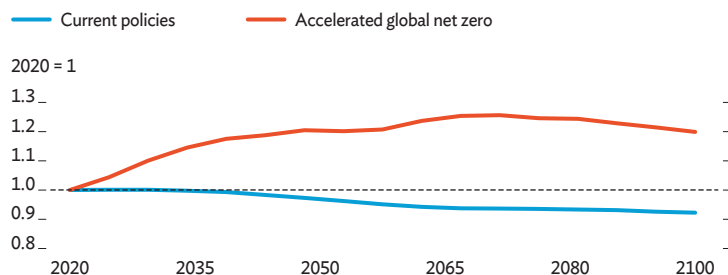
O&M = operation and maintenance.

Source: Authors' estimates.

Under the current policies scenario, food prices fall in real terms, whereas the net zero scenarios lead to price increases of approximately 25% by mid-century. The gap between the two scenarios reaches 34% in 2065 (Figure 3.18). As poorer households spend higher shares of their income on food, this effect will be distributionally regressive unless appropriate policies are introduced to offset it. This increase in food prices, driven by a reduction in planted area for food crops, may put food supply and security at risk, particularly in Asia's lower-income regions.

Figure 3.18 Food Price Index in Developing Asia under the Current Policies and Accelerated Global Net Zero Scenarios, 2020–2100

Ambitious decarbonization substantially increases food prices.



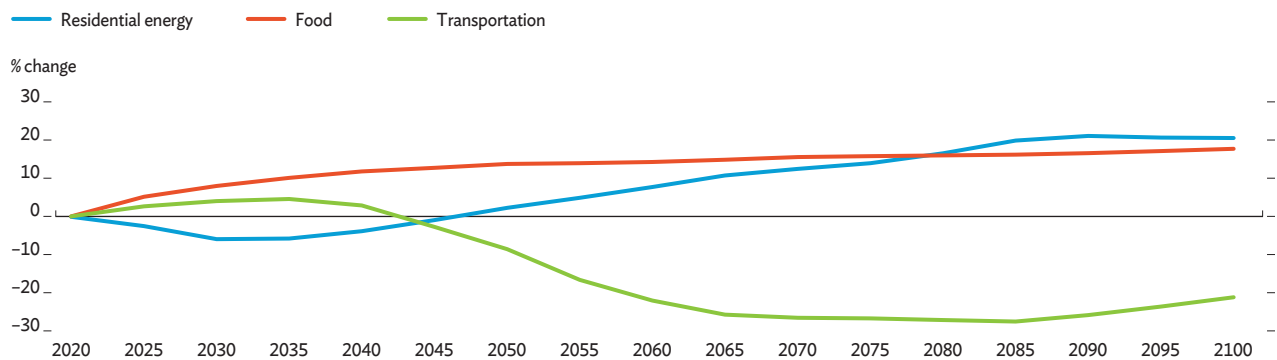
Source: Authors' estimates.

3.5.3 Household Expenditure Consequences

Beyond food prices, ambitious climate change mitigation policy principally affects households via policy and price signals in the energy sector. The modeled scenarios find that transportation costs initially increase under ambitious decarbonization to cover the costs of changes to transport infrastructure and the electrification of vehicle fleets, even though those shifts save spending in the longer term (Figure 3.19). Although energy efficiency allows savings from residential consumption, the conversion of land use to formal bioenergy comes at the expense of the availability of traditional biomass for household energy, so that energy used for heating and cooking becomes more costly. Climate policy increases the cost of gas and coal for heating and cooking, in order to foster the use of electricity. It also forces power generation to diverge from the lowest market price path, so that electricity prices may be higher than the current policies scenario.

Figure 3.19 Differences in Household Food and Energy Expenditure in Developing Asia between the Current Policies to Accelerated Global Net Zero Scenarios

Household food and residential energy expenditure may be increased by climate policy.



Source: Authors' estimates.

In most regions of Asia, lower-income households spend a higher share of expenditure on energy than do higher-income households. Moreover, the share of expenditure spent on residential energy use relative to transport also tends to be higher among low-income households. This makes the modeled increase of residential energy costs affect lower-income households more strongly, even as the modeled fall in transportation costs benefits mostly those with higher income. Similarly, those with low income spend a much higher share of consumption on food, thus facing higher prices. Figure 3.20 shows how energy and food expenditure shares fall per income decile in India and the PRC, although the individual contributions to expenditure across income categories vary between the two countries.

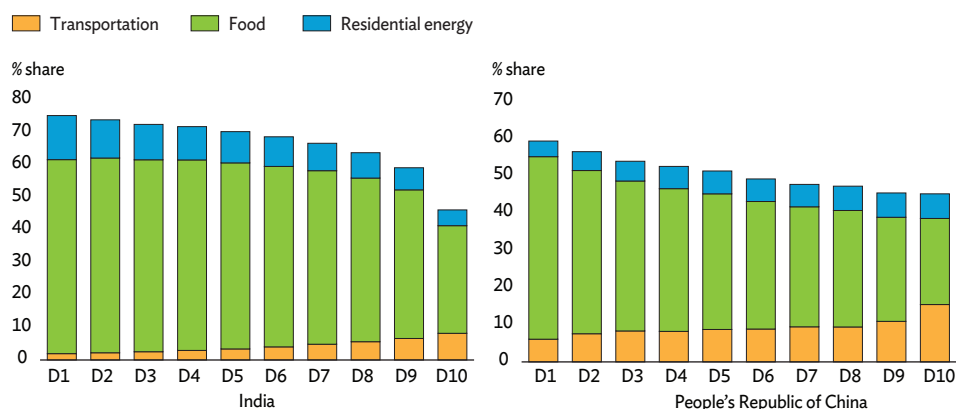
The effect of price changes for aggressive decarbonization could be collectively regressive, unless redistributive measures are taken. To assess this effect using the results in this section, food and energy price effects are considered using a microeconomic model based on microdata from India³² and the PRC.³³ This allows household energy and food consumption to be computed at the decile level of income distribution (Malerba and Emmerling 2022). Combining these results with energy price trajectories, socioeconomic scenarios, and carbon prices shows that lower-income households are much more affected by climate policy-induced price changes than higher income households (blue line in Figure 3.21).

³² Ministry of Statistics & Program Implementation, Government of India. [Household Consumer Expenditure, Type 1: July 2011–June 2012, NSS 68th Round](#).

³³ Beijing Normal University. [Chinese Household Income Project, 2013 Wave](#) (in Chinese).

Figure 3.20 Household Expenditure Shares on Energy for Housing and Transportation per Income Decile in India and the People's Republic of China, 2012–2013

Household expenditure affected by climate policies constitutes most lower-income household consumption.

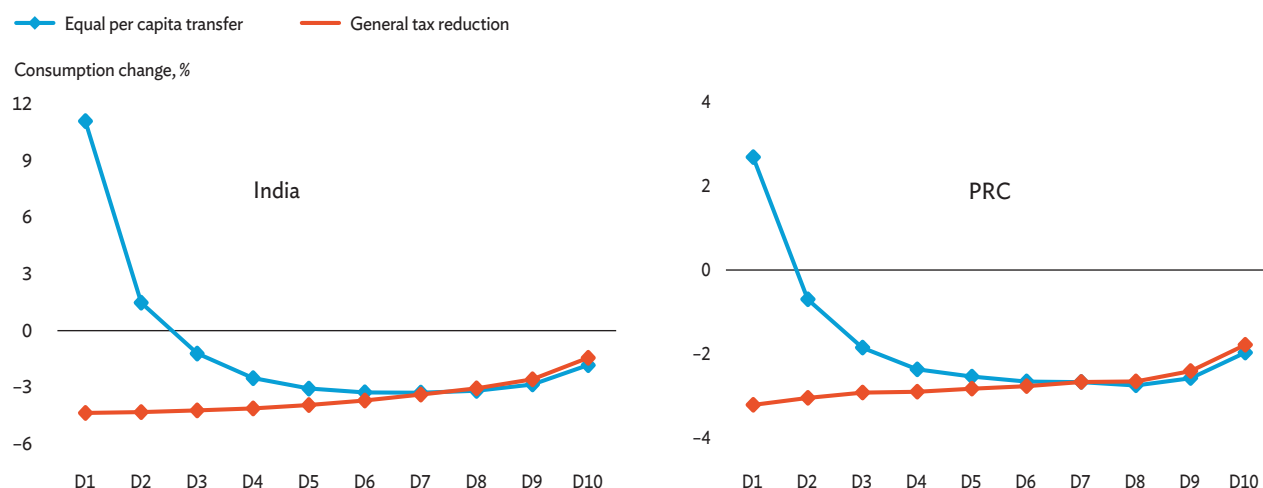


D = decile.

Sources: Ministry of Statistics & Program Implementation, Government of India. [Household Consumer Expenditure, Type 1: July 2011–June 2012, NSS 68th Round](#); Beijing Normal University. [Chinese Household Income Project, 2013 Wave](#) (in Chinese).

Figure 3.21 Household Consumption Impact of the Accelerated Global Net Zero Scenario Compared to the Current Policies Scenario under Alternative Redistribution of Carbon Pricing Revenues by Decile in India and the People's Republic of China

Carbon revenue recycling can determine whether climate policy has regressive or progressive effects.



D = income, PRC = People's Republic of China.

Source: Authors' estimates.

Deep decarbonization policies can also enable progressive distributional outcomes. The analysis in this section considers carbon revenues as simply being recycled into government coffers to reduce the general taxation burden with no redistribution. This is not the only option for how carbon revenues could be used. It is also possible to use more progressive policies, such as supporting social protection or universal basic income. One approach to do this is through a simple climate dividend of equal per capita transfers to households, as proposed by Budolfson et al. (2021). The red line in Figure 3.21 illustrates how such a policy can change distributional effects of the modeled policies to be progressive rather than regressive, with consumption gains rather than losses for the lowest deciles.

4 Policies for an Efficient and Equitable Global Transition to Net Zero

Developing Asia has much to gain from an ambitious and internationally coordinated approach to achieving the goals of the Paris Agreement. This will ensure that transition costs are kept limited, co-benefits are realized quickly, and long-term damages from climate change are contained. However, achievement of climate goals will not happen without policies that are more ambitious in driving decarbonization than those adopted to date.

Faster decarbonization compared with commitments to date is in Asia's interest. NDCs globally, as well as in developing Asia, are not aligned with the goals of the Paris Agreement. This analysis finds that the cost of attaining Paris Agreement goals is substantially reduced if countries accelerate action immediately, rather than wait until after the 2030 coverage period of NDCs to work toward global net zero. To do so, a range of policies needs to be strengthened to drive rapid transformations in land and energy systems.

Key policies for driving the low-carbon transformation can be considered within the three mutually reinforcing pillars of reforming prices, facilitating low-carbon responses, and ensuring fairness. The following briefly describes the three pillars, which are illustrated in Figure 4.1:

- The **reforming prices** pillar focuses on solving the problem that climate externalities are not reflected in market decisions. It includes actions to tax carbon, establish emissions trade, and remove negative carbon prices arising from subsidies and market distortions.
- The **facilitating low-carbon responses** pillar focuses on policies that reduce barriers to decarbonization. These include using regulations and clean energy subsidies to offset fossil fuel subsidies and establish demand for clean technologies, leveraging private investment, and investing in technology.
- The **ensuring fairness** pillar focuses on measures that ensure equitable international distribution of costs and shield lower-income groups and vulnerable people from the costs of climate policy. This includes carbon revenue sharing, facilitating labor market transitions, and investing in public services for vulnerable sectors.

Figure 4.1 Three Policy Pillars to Achieve Developing Asia's Low-Carbon Transition

The region can decarbonize via targeted policy reforms.

Reforming Prices	Facilitating Low-Carbon Responses	Ensuring Fairness
<ul style="list-style-type: none">• Putting a price on carbon emissions• Removing subsidies that promote emissions	<ul style="list-style-type: none">• Implementing regulations and incentives for decarbonization• Leveraging finance for low-carbon activities	<ul style="list-style-type: none">• Working toward fair international mitigation burden sharing• Compensating and protecting vulnerable groups• Helping the affected to adjust

Source: Authors.

4.1 Reforming Prices

The inability of markets to account for the full social, economic, and environmental costs of GHG emissions remains the fundamental failure that has led to the climate crisis. Prices are the core signals that drive market outcomes. Only when climate externalities are reflected in prices can market outcomes sufficiently embed low-carbon solutions. The failure to reflect climate externalities arises from two elements: (i) the gap between free market prices and prices inclusive of climate effects and (ii) the gap between free market prices and financial prices that arises from subsidies and market distortions. Both need to be addressed for decarbonization to occur efficiently.

4.1.1 Expanding Carbon Pricing

Carbon pricing is the only policy that can ensure mitigation is allocated efficiently across many possibilities so that emissions reduction occurs at lowest cost. Any other policy approach entails substantially higher costs to reach climate mitigation goals, and those costs can easily be prohibitive if policies are not carefully optimized. Pricing can be directly achieved through carbon taxation or an emissions trading system (ETS) with equal potential for economic efficiency, although each approach has different requirements (Box 4.1).

Although the world has made progress toward pricing carbon globally, pricing coverage remains partial. Globally, pricing coverage expanded from 8% of total GHG emissions in 2012 to 23% in 2022, and the number of geographic units with pricing rose from 24 to 70 (Figure 4.2). However, this still leaves most emissions unpriced, and the current rate of progress would take until the mid-2040s to reach pricing of more than half of emissions. Political acceptance of carbon pricing—especially via taxation—remains challenging, as pricing policies have led to backlash, particularly in contexts of high inequality (Furceri, Ganslmeier, and Ostry 2021). Perceptions about increasing the burden of taxation, costs, regressive effects, and ineffectiveness may constrain public support (Carattini, Carvalho, and Fankhauser 2018). Redistribution of carbon revenues (discussed later in this section) may help to allay some of these concerns if accompanied by appropriate information to help shift public opinion.

Carbon Pricing Coverage in Asia Can Be Broadened

Some of developing Asia's higher-income countries have initiated carbon pricing policies. ETSs are implemented in the PRC (both nationally and for key “pilot” cities), Kazakhstan, and the Republic of Korea. Singapore has a carbon tax. The PRC's national ETS was launched in 2021 as the world's largest carbon market. Initially covering 2,225 entities in the power generation industry, the ETS regulates annual emissions of around 4,000 million tons of carbon dioxide (tCO₂). A total of 179 million allowances were traded during 2021, initially at low prices, but with some increases over time. The PRC's ETS includes a free initial allowance allocation based on benchmarks and a mix of carbon emissions intensity and production. As a result, CO₂ emission reductions from 2020 to 2030 may mainly result from shifting from less to more efficient coal-fired technologies (Duggal 2023). Intensity benchmarks used to allocate allowances have been relatively loose, with many power producers receiving surplus allowances and penalties capped for exceeding allowances. Thus, the ETS imposes limited overall mitigation pressure (Yin 2023).

Policy makers in other economies in the region are also gradually progressing toward adopting carbon pricing. Indonesia is launching ETS arrangements. In 2023, the Ministry of Energy and Mineral Resources is introducing a mandatory ETS for 99 coal powerplants above the capacity of 100 megawatts. India launched its carbon-trading platform in August 2022 as a step toward a national carbon market. Viet Nam's 2022 Law on Environmental Protection sets the foundation for establishing a mandatory ETS by 2028. According to the International Carbon Action Partnership, policy makers in Pakistan; the Philippines; Taipei, China; and Thailand are considering adopting domestic ETSs (ICAP 2023 and 2022). Brunei Darussalam has identified carbon pricing as one of the country's key strategies for driving the transition toward achieving a low-carbon economy in its 2020 National Climate Change Policy.

Box 4.1 Carbon Taxes versus Emissions Trading Systems

Carbon taxes and emissions trading systems (ETSs) are the two market-based instruments for pricing carbon. Under a carbon tax, the government controls prices of emissions, incentivizing emitters to reduce emissions. Under an ETS, the government sets the quantity of emissions (or the cap), allowing emission prices to be determined by the market. Although both approaches have the same outcomes when there is complete information on the marginal costs of emission reductions, in reality information is incomplete (Weitzman 1974). In that context, economic and institutional factors may affect the choice of carbon pricing instruments, including administrative costs and the complexity of instruments, carbon price volatility, legislative difficulties, and uncertainty about abatement costs (He 2023).

Administrative costs and complexity of instruments. Introducing an ETS requires a new set of administrative structures for distributing carbon allowances, tracking transactions and information disclosure, and holding auctions. In comparison, the administrative costs and the complexity of introducing a carbon tax can be reduced by basing the tax on fossil fuel taxation.

Carbon price volatility. Unlike a carbon tax that sets a fixed carbon price, ETSs may have volatile carbon prices as market conditions change (Duggal 2023). This introduces additional uncertainty and costs to businesses and represses long-term investments. However, an ETS is inherently countercyclical, in that the demand and the price of allowances will go down in a recession—just when regulated firms need relief. A carbon-price floor can help to reduce volatility and ensure stability of pricing signals in an ETS.

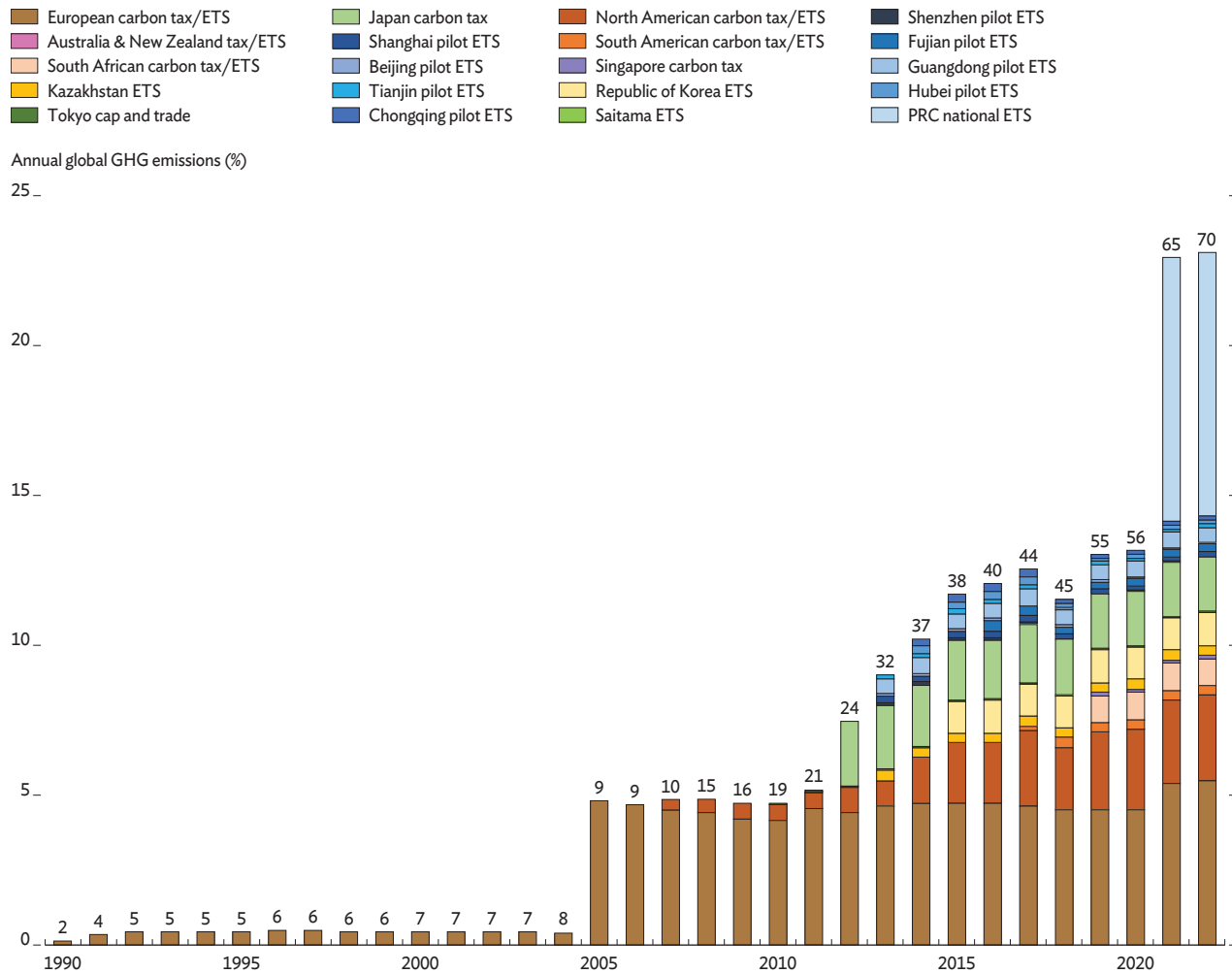
Legislative difficulties. Getting carbon taxes passed into law can be politically challenging, as they can lead to political backlash (Sterner and Robinson 2018). In contrast, such repercussions have not been observed where ETSs have been adopted.

Uncertainty about abatement costs. Under an ETS, the emissions outcome is set by policy makers, and the carbon price required to achieve the outcome is determined by the market. This makes the approach easy to reconcile with overall mitigation pledges. Under a carbon tax, the carbon price is known to policy makers, but the emissions outcome is only revealed after the policy is set, so experimentation and iteration may be needed to determine the appropriate price level.

References:

- Duggal, V. K. 2023. Carbon Pricing Development and Dynamics. Background Paper. *Asia in the Global Transition to Net Zero*. Asian Development Outlook Thematic Report 2023. Asian Development Bank.
- He, G. 2023. Climate Policy: Evidence and Way Forward for Developing Asia. Background Paper. *Asia in the Global Transition to Net Zero*. Asian Development Outlook Thematic Report 2023. Asian Development Bank.
- Sterner, T., and E. Robinson. 2018. Selection and Design of Environmental Instruments. In P. Dasgupta, S. K. Pattanayak, and V. K. Smith, eds. *Handbook of Environmental Economics*. Vol. 4. Elsevier.
- Weitzman, M. 1974. Prices vs. Quantities. *Review of Economic Studies* 41.

Source: Authors.

Figure 4.2 Carbon Pricing Coverage Globally, 1990–2022*Coverage is growing but remains limited.*

ETS = emissions trading system, GHG = greenhouse gas, PRC = People's Republic of China.

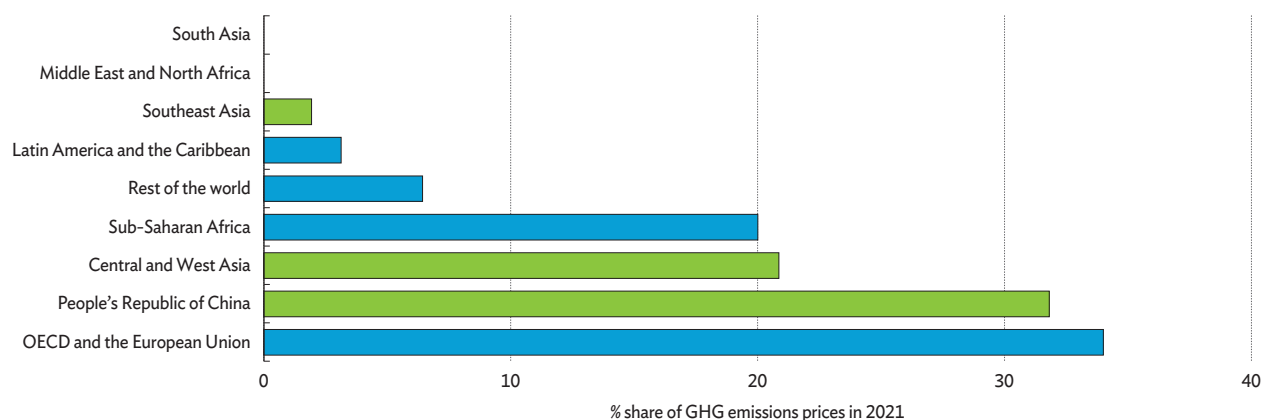
Note: Numbers above bars indicate numbers of geopolitical units with pricing.

Source: World Bank. [Carbon Pricing Dashboard](#) (accessed 3 March 2023).

Although developing Asia is making progress toward carbon pricing, the pace must be accelerated for the benefits of the global net zero scenarios found in this report to be realized. Those benefits will be greatest if action starts immediately with a carbon price that enables decarbonization to occur where it is cheapest both within all emitting activities of national economies and across countries. To date, 21% of developing Asia's GHG emissions are priced, compared with 34% in the EU and the Organisation for Economic Co-operation and Development, but nearly all of that pricing coverage is in the PRC (Figure 4.3). Moreover, countries in the region with pricing mostly price only powerplants. Other emitting activities, such as transportation and industry, usually remain to be subject to carbon pricing.

Figure 4.3 Coverage of Global Greenhouse Gas Emissions by Carbon Pricing, 2021

Only the PRC has substantial carbon pricing coverage in developing Asia.



EU = European Union, GHG = greenhouse gas, OECD = Organisation for Economic Co-operation and Development.
Source: World Bank. [Carbon Pricing Dashboard](#) (accessed 3 March 2023).

Carbon Pricing Levels Can be Increased

Carbon pricing levels in developing Asia must rise rapidly to be aligned with a global transition to net zero.

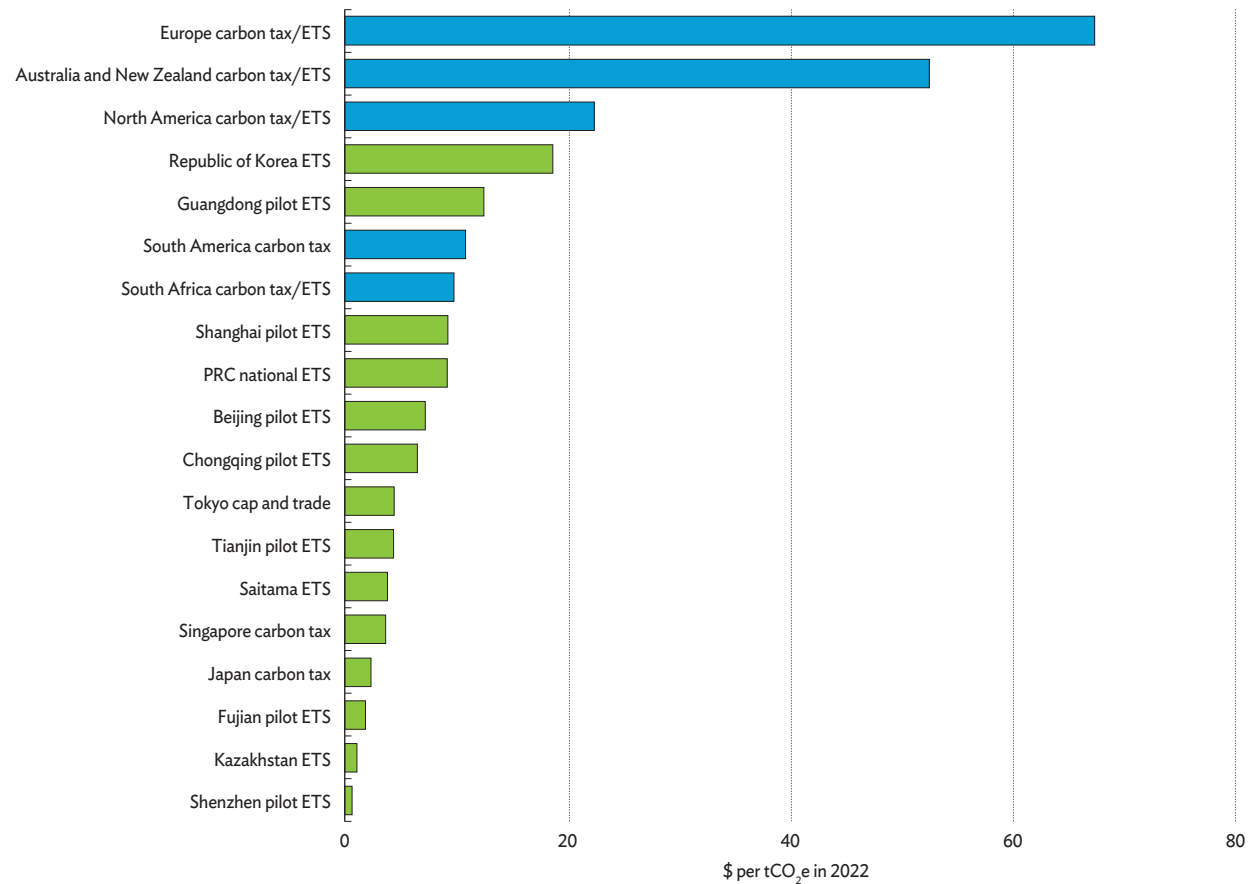
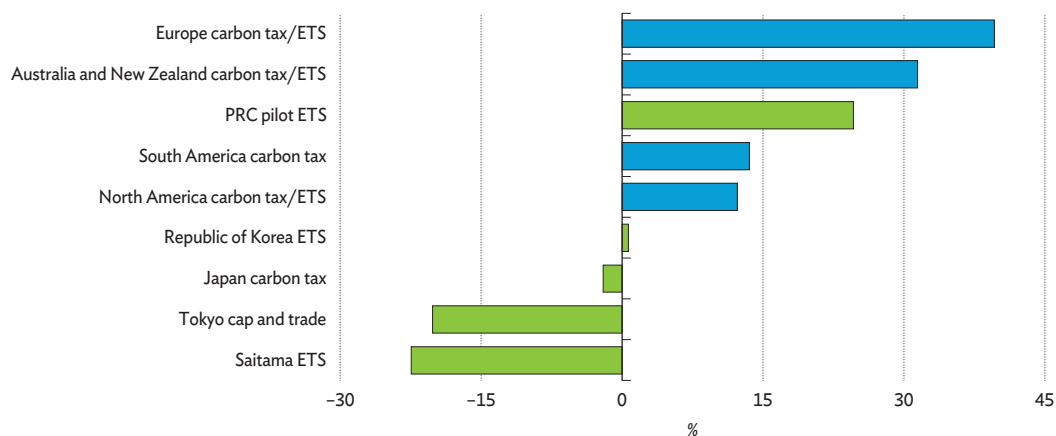
Results presented in Section 3 indicate that a global carbon price, applied to all sectors, of \$70/tCO₂e by 2030 and \$153/tCO₂e by 2050 can potentially trigger mitigation in line with the lowest-cost approach to global net zero. Globally, carbon pricing remains well below those levels, even though developing Asia's carbon prices are among the lowest in the world when applied (Figure 4.4). Carbon pricing directly reflects the level of mitigation ambition, as larger GHG emission reduction targets lead to higher prices to achieve abatement responses.

Although carbon pricing levels are generally low, many carbon prices are increasing. Globally, the highest-value trading market, which is the EU's ETS, had the fastest increase in prices, with 39% annual growth from 2017 to 2022 (Figure 4.5). However, pricing in the PRC pilots is not far behind in terms of growth rates, with 25% annual growth in the same period. If this growth momentum is maintained and expanded to a broader share of emissions across developing Asia, the types of benefits quantified in this report can be realized.

Carbon Pricing Transmission Can Be Improved

Even in the limited sectors covered by carbon pricing, barriers often prevent prices from affecting investment and consumption decisions in developing Asia. As noted earlier, the principal focus of carbon pricing is the power sector. This is logical as an initial focus because the sector is a major emissions source with low-cost abatement possibilities. The sector also typically consists of relatively few large fossil-based emitters, which are easy to monitor. However, the major ETSs implemented so far in the region have limited penalties for exceeding emissions allowances. Moreover, the way the power sector is typically governed and organized in the region insulates power producers from the effects of pricing.

Power markets are often fully or partially regulated in developing Asia, which leads to rigidities that weaken carbon pricing signals. For these price signals to have effects on capacity additions, technical choices must be based on market signals. Yet, in developing Asia, capacity is often contracted under tenders that specify older technologies (Acworth et al. 2018). Under regulated electricity generation, electricity dispatch may be based on criteria other than cost including carbon price. Regulated wholesale prices may be set ad hoc with little consideration for the underlying production costs. Long-term power purchase agreements may lock in wholesale prices that predate carbon pricing for decades for power producers, so that existing capacity is insulated from carbon prices.

Figure 4.4 Carbon Prices Applied in Emissions Trading and Carbon Taxes in 2022*Carbon prices in developing Asia trail other markets.*ETS = emissions trading system, PRC = People's Republic of China, tCO₂e = ton of carbon dioxide equivalent.Source: World Bank. [Carbon Pricing Dashboard](#) (accessed 3 March 2023).**Figure 4.5 Compounded Annual Growth Rate of Carbon Pricing Initiatives, 2017–2022***Carbon prices are rising rapidly.*

ETS = emission trading system, PRC = People's Republic of China.

Source: World Bank. [Carbon Pricing Dashboard](#) (accessed 3 March 2023).

Regulated tariffs in the region are often set to reflect average generation costs or perceived capacity to pay, rather than marginal costs. As a result, there is limited transmission of the carbon cost to end consumers—and so incentives for efficiency are missed.

Rigidities can be addressed directly or indirectly to improve the transmission of carbon prices. Many pricing transmission barriers can be reduced through power sector reforms, such as replacing prescriptive capacity tendering with more flexible auctioning, revising dispatch and pricing policies, tariff reform, and revising the terms of power purchase agreements. Where these reforms are not possible, ETS coverage could be expanded to include indirect emissions of large electricity consumers, such as office buildings, industrial facilities, and hotels (Acworth et al. 2018). Alternatively, a consumption charge could be introduced to facilitate downstream abatement, which reflects the carbon price based on the carbon intensity of the electricity consumed.

Carbon Markets Can Be Better Integrated

Achieving a global transition to net zero at limited cost requires that mitigation occurs not only in the sectors where it is cheapest but also in the locations where opportunities are lowest-cost. International carbon markets are the only policy mechanism that can assure that mitigation is allocated to the geography where costs are lowest. These markets can also potentially enable substantial financial flows to low-emission countries where both mitigation costs and historical responsibility for climate change are lowest, so that the distribution of costs is more just, as illustrated in Section 3. Developing Asia has a wealth of experience in participating in international carbon markets, since approximately 80% of all multilateral carbon market projects under the Kyoto Protocol Clean Development Mechanism (Amarjargal et al. 2020) and 90% of bilateral carbon trade projects under the Joint Crediting Mechanism have been hosted in the region.³⁴

Article 6 of the Paris Agreement provides opportunities for developing Asia to rejuvenate its participation in international carbon markets. The rules governing the article, agreed in late 2021, alleviate a major bottleneck to developing international carbon markets. The region could actively cultivate a series of specific proposals for decarbonization bilaterally, financed as “Internationally Traded Mitigation Outcomes” under Article 6.2, as well as more specific project proposals under Article 6.4’s provisions for multilateral carbon trade under the oversight of the United Nations Framework Convention on Climate Change. A first step toward the market can be to link ETSs in the region as more become operational to minimize mitigation costs over a wider range of mitigation opportunities. The modeling for this report finds that developing Asia may contain both potential importers and exporters of carbon offsets, so there is substantial potential for carbon trade within the region under regional-linked ETSs or regional markets. Over the longer term, developing Asia could help to push for a set of governing principles for the allocation of emissions across NDCs in line with Paris Agreement targets, so that mitigation burden is better coordinated internationally as a basis for fairer global carbon trade.

If developing Asia does not act to broaden and escalate carbon pricing, it may be subjected to carbon pricing by export markets. Policy makers in the EU and economies elsewhere that apply comparatively higher carbon prices than the global average are concerned about carbon “leakage” via imports from countries that lack carbon pricing. To remedy this leakage and expose all products consumed within EU borders to carbon pricing, the bloc has agreed to a carbon border adjustment mechanism (CBAM), starting in 2026. The CBAM imposes a tariff reflecting the price of carbon associated with selected imports from countries lacking sufficient domestic carbon pricing. Magacho et al. (2022) systematically assess the multidimensional exposure, both direct and indirect, of countries to the CBAM and find that exporting countries subject to the mechanism could suffer a loss in export revenues, employment and wage shares, and fiscal revenues. Although developing Asia is not expected to be heavily affected by the imports initially covered by the CBAM—aluminum, cement, electricity, hydrogen, fertilizers, iron, and steel—potential future expansion could put the region at risk (ADB 2023). Accelerated carbon pricing and actions to move toward a global carbon market could help to avoid potential adverse consequences for the region.

³⁴ Institute for Global Environmental Strategies. 2023. [IGES Joint Crediting Mechanism Database](#) (accessed 13 March 2023).

4.1.2 Eliminating Negative Carbon Pricing

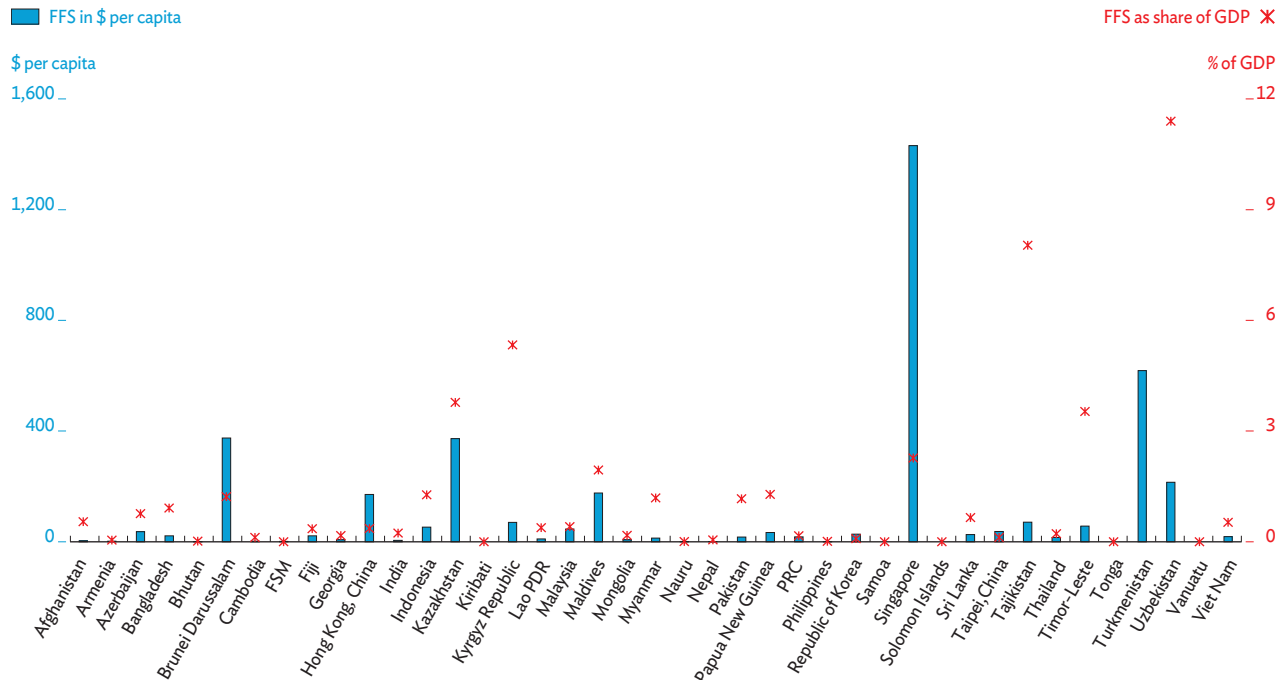
Fossil Fuel Subsidies Consume the Resources that Could Enable Decarbonization

Fossil fuel subsidies are effectively negative carbon prices, so removing these subsidies is a necessary step toward carbon pricing. In 2021, developing Asia provided at least \$119 billion in fossil fuel subsidies, accounting for 16% of the global share.³⁵ Most of the subsidies set below-market energy prices for consumers directly or through tax reductions or exemptions. About 45% of consumer subsidies went to petroleum products, followed by natural gas (26%) and electricity (24%). Figure 4.6 shows that Kazakhstan, the Kyrgyz Republic, Tajikistan, Timor-Leste, and Uzbekistan dedicate a substantial share of national resources to fossil fuel subsidies. Singapore has the largest per capita fossil fuel subsidy in the region.

Fossil fuel subsidies cost governments in developing Asia 0.7% of GDP in 2021, which is near to the 1.1% GDP cost of the most ambitious decarbonization scenario modeled in this report (Figure 4.7). In India and the rest of South Asia, as well as Indonesia, the cost of subsidies exceeds that of the accelerated global net zero scenario (Figure 4.8). Subsidies are highest in the Caucasus and Central Asia and lowest in the PRC. Although fossil fuel subsidies fell over 2010–2015 across most of developing Asia, progress has stalled since then. By 2021, the overall subsidy share of GDP was 40% higher than in 2015, with a pronounced increase from 2020 to 2021.

Figure 4.6 Fossil Fuel Subsidies in Developing Asian Economies, 2019–2021

Many economies in the region have high fossil fuel subsidy rates.



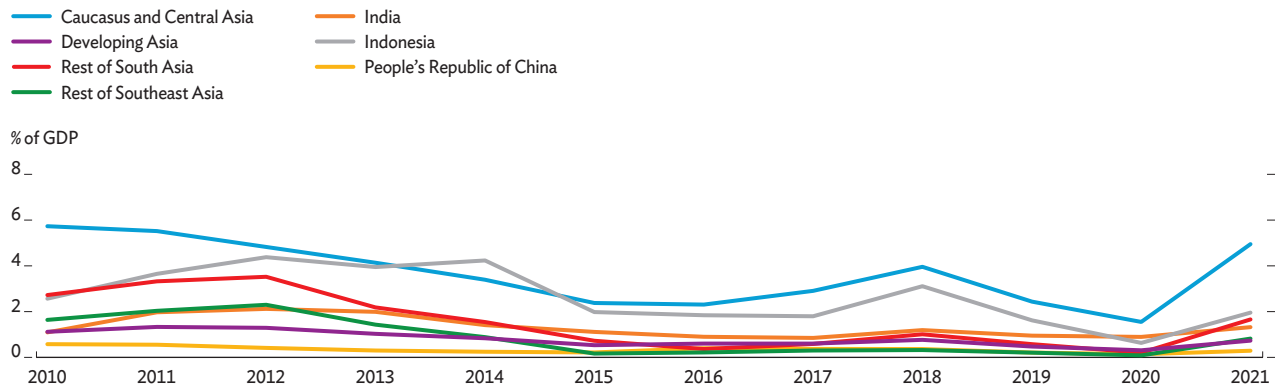
FFS = fossil fuel subsidy, FSM = Federated States of Micronesia, GDP = gross domestic product, Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China.

Sources: Asian Development Bank. 2022. *Asian Development Outlook 2022: Mobilizing Taxes for Development*; Organisation for Economic Co-operation and Development; International Institute for Sustainable Development. *Fossil Fuel Subsidy Tracker* (accessed 6 February 2023).

³⁵ *Fossil Fuel Subsidy Tracker* (accessed 20 February 2023).

Figure 4.7 Fossil Fuel Subsidies in Developing Asia, 2010–2021

Fossil fuel subsidy rates remained stable in the region.

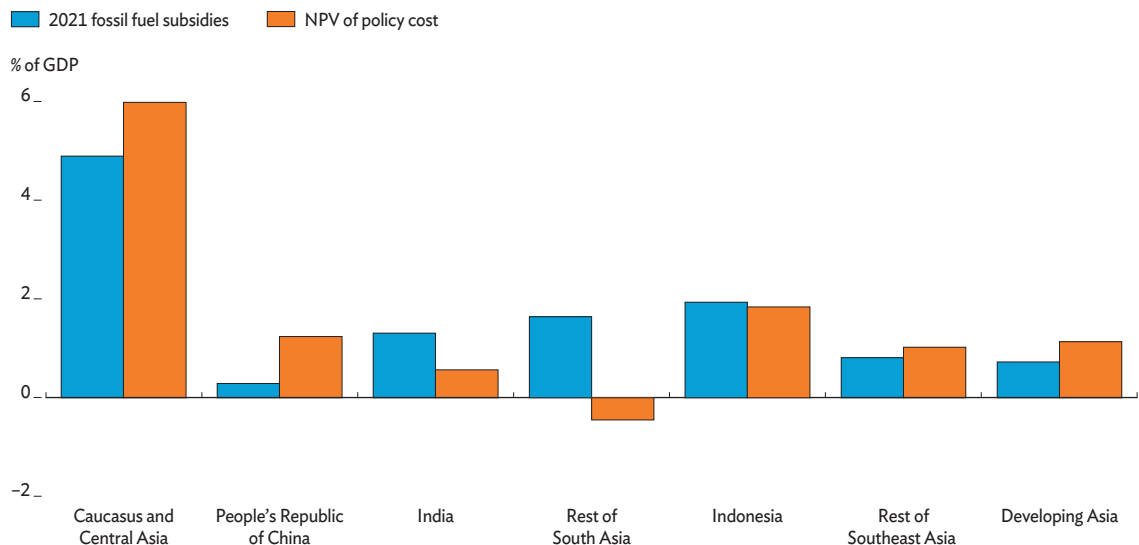


GDP = gross domestic product.

Source: International Energy Agency. [Fossil Fuels Subsidy Database](#) (accessed 12 March 2023).

Figure 4.8 Fossil Fuel Subsidies in Developing Asia in 2021 Compared with the Policy Costs Found for the Accelerated Net Zero Scenario

Subsidies already cost developing Asia nearly as much as the low-carbon transition.



GDP = gross domestic product, NPV = net present value.

Note: Discounted at 3%.

Sources: Authors' estimates; International Energy Agency. [Fossil Fuels Subsidy Database](#) (accessed 12 March 2023).

Fossil fuel subsidies are regressive, encourage overconsumption, and impede the transition to clean energy.

Fossil fuel subsidies skew the playing field by artificially increasing the returns to investments in carbon-intensive energy and by encouraging excess consumption. Although subsidies are often used to make energy affordable for low-income households, untargeted subsidies benefit medium- and high-income consumers more than those with lower incomes. For example, Coady et al. (2015) find that only \$1 out of \$10 in gasoline subsidies and \$1 out of \$30 in liquified petroleum gas subsidies went to the bottom 40% of households in Asia and the Pacific.

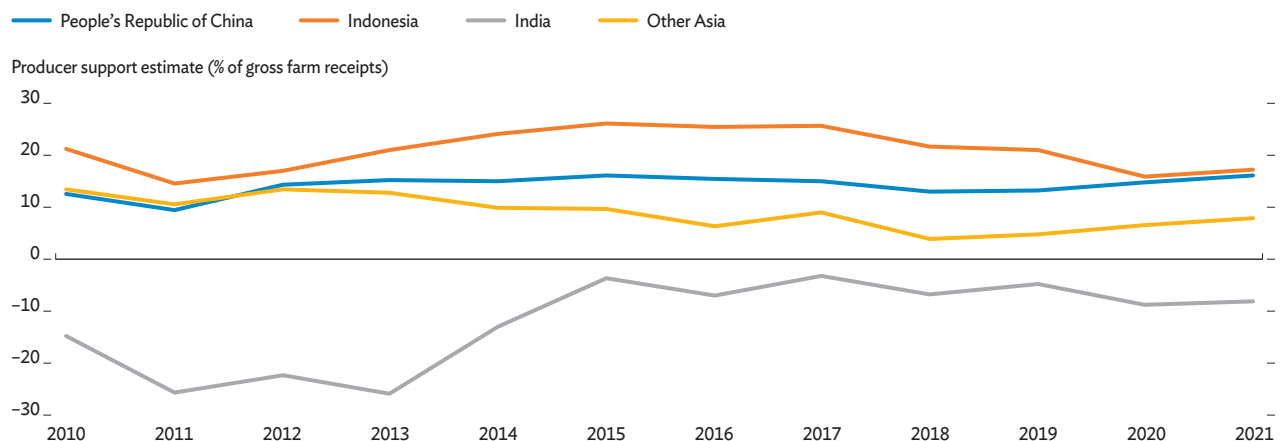
Although fossil fuel subsidies often benefit better off households more than poorer ones, concerns about effects on lower-income households often impede subsidy reform. A “remove, target, swap” approach can be used to lower negative regressive impacts and ensure energy access for the poorest people. This strategy immediately *removes* subsidies with no relevance for energy access; *targets* subsidies that are important for energy access, which typically only applies to consumer support for cooking and electricity; and *swaps* savings to strengthen social protection and promote clean energy, permanently removing the need for fossil energy support (Zinecker et al. 2018).

Greenhouse Gas Emissions from Agriculture and Land Use Are Heavily Subsidized

Negative carbon prices are also often created by subsidies for agriculture and land use change. After energy, land use is the largest source of GHGs in developing Asia, with emissions from agriculture and deforestation heavily influenced by subsidies and market distortions. Globally, agriculture is estimated to have received \$777 billion in distorting subsidies in 2021, which exceeds the \$638 billion in estimated fossil fuel subsidies.³⁶ The PRC spends more on agricultural subsidies than any other country, and accounts for 37% of subsidies globally. Agriculture in developing Asia has extensive subsidies for fertilizers, irrigation water, and diesel fueled machinery, as well as subsidized support prices for output. Fertilizers are fossil fuel intensive to produce. Overuse of irrigation water under subsidized pricing leads to substantial methane emissions, especially from rice cultivation (Rahut 2023; Giardino, Wilson, and Hart 2023). Diesel machinery generates emissions from energy use, as well as carbon loss from excess soil tillage. Subsidized output prices incentivize application rates of these inputs at higher levels than are economically optimal by raising the intersection of marginal financial cost and the marginal value of output, leading to additional emissions. Output price subsidies often favor agricultural products that are relatively carbon intensive (Vos, Martin, and Resnick 2022). Subsidy rates have remained stable across much of developing Asia from 2010 to 2021 (Figure 4.9).

Figure 4.9 Agriculture Subsidy Rates in Developing Asia’s Three Biggest Economies, 2010–2021

Agricultural subsidies remained stable and substantial in much of developing Asia.



Notes: Negative producer support estimates for India are largely driven by domestic prices falling below international prices for reference commodities. The value of this differential is greater than that of input subsidies and other transfers to producers, even though input subsidies are substantial.

Source: Organisation for Economic Co-operation and Development. [Agricultural Support Database](#) (accessed 13 March 2023).

³⁶ Organisation for Economic Co-operation and Development. [Agricultural Support Database](#) (accessed 13 March 2023); International Energy Agency. [Fossil Fuels Subsidy Database](#) (accessed 13 March 2023).

Land and timber markets in the tropical forest-rich countries of developing Asia are often subject to distortions that effectively subsidize emissions from deforestation. Forest areas are typically state-owned and allocated to companies under concession systems at low prices (Palmer 2001). These systems often are intended to replace forests designated as “degraded” with plantations or development projects, with the timber harvested from forests clearance subject to minimal royalties because timber volumes are not officially recorded and royalties that are collected are typically below market values (Brown 1999). This means concession holders can capture most of the value of cleared timber, so that they are subsidized to clear the forest. For example, according to Indonesia’s Corruption Eradication Commission (2015), the \$3 billion timber royalties collected from 2001 to 2013 is dwarfed by the \$61 billion–\$81 billion of timber royalties that were not collected in the same period. Most of the timber with unpaid royalties is assessed as coming from forest clearance in concessions allocated for oil palm and pulp and paper plantation development. Similarly, Raitzer, Samson, and Nam (2015) find empirically that a majority of forest clearance in Myanmar during 2006–2010 was driven by state concession allocation.

The environmental and social values of subsidized natural resources can be many times higher than the market values. For example, whereas the global value of timber from illegal logging is estimated at up to \$157 billion annually, the environmental services lost by illegal forest clearance are estimated at up to \$1.7 trillion annually (World Bank 2019). Specifically in Asia, much of the tropical deforestation driven by subsidies has been on peatlands where thousands of tons of carbon are stored per hectare, with values orders of magnitude higher than that of the timber cleared (Jaenicke et al. 2008). Similarly, for irrigation water, the environmental value of water is often far higher than the financial marginal cost of delivering water.

Reform of subsidies that promote emissions from land use and agriculture can potentially unlock substantial mitigation at negative or low economic cost. Some of these subsidies are created in contexts where markets and property rights are not well defined, and substantial investment is needed to create the conditions for markets to function. For example, pricing irrigation according to water consumption to reduce methane emissions requires extensive additional metering and billing infrastructure compared with traditional surface irrigation systems. Eliminating timber-clearance subsidies requires developing competitive land markets that set incentives for sustainable land management and developing monitoring capacity for forest cover. Agricultural input subsidies are often motivated in part by disparities between farm and nonfarm income (Anderson, Rauser, and Swinnen 2013), which can be exacerbated in the context of land-market rigidities that prevent farms from consolidating during structural transformation. Subsidy reforms often need to be accompanied by land reforms to allow farm sizes to grow to levels sufficient to sustain livelihoods and for providing non-distorting public services to enable productivity to remain competitive (Vos, Martin, and Resnick 2022). Food security goals can be met much more sustainably and cost-effectively by targeted investment in agricultural innovation and public infrastructure for irrigation and transportation than by massive investment in variable input subsidies and output price support (OECD 2021b).

4.2 Facilitating Decarbonization Responses

Nonmarket measures, incentives, and investment policies have been the main tools used to promote decarbonization in Asia, rather than strong carbon pricing signals. Although carbon pricing is the only instrument that can maximize the economic efficiency of decarbonization, it is not the only policy that can effectively lead to the reduction of emissions. Moreover, even if carbon pricing is robust, complementary policies are often needed to facilitate market adjustments in response to price signals. These policies include command and control regulations to stipulate the adoption of technologies, labeling, subsidies, and incentives to attract private sector investment in clean energy and other low-carbon infrastructure. It is important that these regulations, incentives, and financing all work together to promote decarbonization. Inconsistent and contradictory policies may create barriers and delay the low-carbon transition. For example, local content requirements on solar panels and wind turbines make renewables more expensive domestically (Probst et al. 2020), thus undermining other policies and incentives that are put in place to promote renewable energy. Another example is that subsidies introduced for renewables are often outweighed by continued subsidies to fossil fuels.

4.2.1 Regulations and Incentives

Developing Asia has deployed an array of command-and-control regulations and economic incentives to help drive low-carbon growth, but there remains substantial scope to strengthen how the policy mix is applied.

Table 4.1 summarizes common regulations and incentives in the region.

Command-and-control regulations are the core of environmental policies in most countries worldwide.

These policies either directly prescribe exactly what a firm must do, such as use specific abatement equipment or production processes (technology standards), or they specify environmental results and leave the choice of technology to producers (performance standards). Technology standards are easier to inspect and monitor compared with performance standards, which is probably why they are common in many countries (Sterner and Robinson 2018). Performance standards give entrepreneurs more freedom to choose from different technology options, which may encourage innovation (Montero 2002). Compared to market-based instruments such as carbon pricing, standards and regulations are more expensive because they are not based on abatement costs across different sources (Greenstone and Nath 2020; Holland, Huges, and Knittle 2009). Command and control technology standards may also not be effective in reducing emissions if indirect and rebound effects are not considered. For example, research has shown that biodiesel from palm oil often has higher lifecycle emissions than fossil fuels, yet the Government of Indonesia mandates aggressive biodiesel substitution for transport (Meijide et al. 2020). Major command and control regulations used in the region include:

- **Renewable portfolio standards** require utilities or companies to generate a certain portion of their supply from renewable energy. These standards, however, are used by only a few countries in the region. Five provinces in the PRC—Fujian, Gansu, Guangzhou, Shaanxi Jiangxi, and Zhejiang—have rooftop solar PV mandates at 20% for residential, 30% for commercial and industrial, 40% for public facilities, and 50% for government buildings.
- **Building heating and cooling policies** tend to focus on enhancing the efficiency of new buildings. The global building stock is expected to increase by 75% from 2020 to 2050, 80% of which is projected to be in emerging and developing countries (IEA 2021b). In India, for example, based on the current policy setting, two-thirds of the buildings that will exist in 2040 are yet to be built (IEA 2021b). In developing Asia, building policies thus tend to target new buildings. Building energy codes, which seek to improve efficiency for the construction and maintenance of buildings, are gaining popularity in developing Asia. Some economies in the region have mandatory or voluntary building codes, while several others are in the process of developing them. The certification of building energy use or more broadly for green building can complement building energy codes. Globally, green building assessment tools and certification schemes have been developed, such as the Building Research Establishment Environmental Assessment Method and the Leadership in Energy and Environmental Design. Some countries have also developed national certification schemes, such as Assessment Standards for Green Buildings in the PRC and Green Mark in Singapore. Compared to advanced economies, however, large-scale adoption of such certification and schemes is lacking (Zhou 2023).
- **Average fuel economy standards** in the transport sector are a common way of seeking to improve efficiency. For example, in 2017, India set fuel-efficiency standards for heavy-duty commercial vehicles. Phase 1 came into effect in 2018 and Phase 2 in 2021. These standards aim to reduce fuel consumption and GHG emissions from diesel-powered trucks and buses with a gross vehicle weight of 12 tons or greater. The government also set CO₂ emission standards for light-duty vehicles at the equivalent of 130 grams of carbon dioxide per kilometer (gCO₂/km) in 2017 and 113 gCO₂/km in 2022 (He 2023).
- **Biofuel mandates** are another common policy measure to decarbonize the transport sector. Several economies in the region have biofuel mandates, and some are quite ambitious. Indonesia increased its target for biodiesel blending to 35% in 2023, and has a target of 20% ethanol blend by 2025. India has a goal of 20% ethanol blending in petrol by 2025. Other biofuel mandates being implemented include Malaysia's 10% mandate for biodiesel and the Philippines' 10% ethanol mandate.

Table 4.1 Renewable Energy Targets and Policies in Developing Asia

The region has deployed an array of regulations and incentives to drive low-carbon growth.

Economy	Renewable Energy Targets	RPS	Building Energy Codes	Transport Biofuel Mandate	Feed-in Tariffs	Auctions ^a	Net Metering
Afghanistan	X		V				
Azerbaijan	P		X		X	X	
Bangladesh	X	X	X	X	X*	X	X
Bhutan	X					X	
Brunei Darussalam	X		V			X	
Cambodia	X		D		X	X	
People's Republic of China	X	X	X	X	X*	X	
Taipei, China	X			X	X*	X	
Fiji	X			X	X	X	
Georgia	X		D		X		X
India	X	X	X*	X	X	X	X*
Indonesia	X	X	V	X	X	X	X
Kazakhstan	X		X		X	X	X
Kiribati	X					X	
Republic of Korea	X	X	X	X	X		X
Kyrgyz Republic		X			X		
Lao People's Democratic Republic	X		D				
Malaysia	P	X	X	X			X
Maldives	X				X	X	X
Marshall Islands	X		D			X	
Mongolia	X			X	X		
Myanmar	X		D			X	
Nepal	X				X	X	
Pakistan	X		X		X	X	X
Palau	P	X	D				
Papua New Guinea	X						
Philippines	X	X	V	X	X		X
Samoa	X					X	
Singapore	P		X			X	X
Solomon Islands	X					X	
Sri Lanka	P	X	V	X	X	X	X
Tajikistan					X	X	
Thailand	X	X	X	X	X	X	X
Timor-Leste	X					X	
Tonga	P			X	X		
Turkmenistan			D			X	
Tuvalu	X		D				
Uzbekistan	P					X	
Vanuatu	X			X	X	X	
Viet Nam	X	X	X	X	X	X	X

D = under development, P = power sector only, RPS = renewable portfolio standards, V = voluntary, X = policy exists, X* = local government policies.

^a Auctions held, announced, or planned in 2021 and 2022.

Sources: Ren21. 2019. *Asia and the Pacific: Renewable Energy Status Report*; Ren21. 2022. *Renewables 2022: Global Status Report*.

- **Targets for EV adoption** have been set by many economies in the region, and some economies plan to ban internal combustion engine vehicles. Taipei, China will do so by 2040, and Singapore's Green Plan will cease registering diesel cars and taxis in 2025, and by 2030 only clean energy cars will be registered.
- **Consumer labels** provide information on the production and performance of goods, making it convenient for consumers to choose low-carbon and environmentally friendly products. The use of consumer labels has proliferated. The Ecolabel Index, a global directory of eco-labels, lists 450 labels in 199 countries and 25 industry sectors. Energy labels and supply-side energy efficiency policies, such as minimum energy performance standards (MEPS), are commonly used in developing Asia to promote energy efficiency (Table 4.2).³⁷ Consumers, however, may not pay attention to fuel or electricity costs while buying appliances, focusing instead on the sales price. A carefully designed energy label can make information on the efficiency of appliances salient and increase demand for energy-efficient products.

Table 4.2 Minimum Energy Performance Standards and Energy Labels in Developing Asia

Energy labels and supply-side energy efficiency policies are commonly used in the region.

Economy	Energy labels	Minimum Energy Performance Standards			
		Air conditioner	Refrigerator	Washing machine	Television
Brunei Darussalam		X	X	X	X
Bangladesh	X	X	X		
Cambodia		X	X	X	X
People's Republic of China	X	X	X	X	X
India	X	X	X		X
Indonesia	X	X	X	X	X
Malaysia	X	X	X	X	X
Philippines	X	X	X		
Singapore	X	X	X		X
Thailand	V	X	X	X	X
Viet Nam	X	X	X	X	X

V = voluntary, X = energy labels or minimum energy performance standards exist.

Sources: Yau, C.F. 2020. Legislative Framework. In S. Kimura, P. Han, and S. M. Leong, eds. *Energy Efficiency and Conservation Master Plan of Cambodia*. Economic Research Institute for ASEAN and East Asia; International Energy Agency. [Policies Database](#).

- **Energy service companies (ESCOs)** can play an important role in scaling-up energy efficiency by providing energy-saving technical advice and financing solutions. ESCOs perform in-depth analysis of energy consumption; design energy-efficient solutions; and procure, install, or retrofit devices. ESCOs typically guarantee a level of energy savings to consumers, and they are paid for their services from the resulting cost savings. In many cases, ESCOs also provide project financing. Globally, ESCO projects are estimated to deliver energy savings of more than 25%. ESCOs operate in India, Indonesia, Malaysia, the Philippines, the PRC, Singapore, and Thailand, among other countries in the region (IEA 2018, Shrestha et al. 2021). The PRC has the world's largest ESCO market, most of it in the hands of the private sector for industrial and nonresidential consumers (IEA 2018).

³⁷ MEPS provide performance requirements for energy-related products that effectively limit the maximum amount of energy consumed by a product. Countries ban products from being bought or sold that do not meet MEPS.

Many standards and regulations could be further strengthened and better enforced. Although regulations and standards are present in much of developing Asia, they are often not as stringent or comprehensive as in developed countries. For example, MEPS for appliances do not always reflect current market and technology trends, and there are coverage gaps.³⁸ Building energy codes are not mandatory, have limited coverage, and are not strictly enforced in many countries. Fuel efficiency standards for vehicles are absent in most of the region. Energy efficiency can be enhanced and emissions reduced by regularly updating standards and aligning them to international benchmarks. Ambitious energy efficiency standards, together with promoting ESCOs as a one-stop solution for financing and technical needs, have the potential to deliver energy efficiency projects at scale.

Behavioral insights could enhance labeling and communications to encourage efficient choices. Although there is substantial evidence that efficiency labels can have significant effects on consumer behavior, evidence is growing that the details of label design strongly condition their effectiveness. For example, environmental framing can enhance the effectiveness of appliance-efficiency labels in the Philippines, whereas framing in terms of cost savings can reduce effectiveness (Kuhn, Kutzner, and Thøgersen 2022). In India, consumer willingness to pay for higher efficiency labeling was observed for air conditioners, which have more apparent effects on power bills due to seasonal use than refrigerators with continuous usage. This suggests that labeling is more effective for appliances where the relationship of usage and energy costs is more visible (Jain, Rao, and Patwardhan 2018). Beyond static labels, nudges, such as providing information about consumption in comparison to neighbors with utility bills, can lead to improvements in household energy efficiency (Allcott 2011; Mi et al. 2019; Never 2023).

Low or absent carbon prices and the presence of fossil fuel subsidies mean that renewable energy subsidies may have an important role to play in leveling the playing field. The International Renewable Energy Agency estimates that in 2017, 70% of the \$634 billion global energy subsidies were allocated to fossil fuels, while renewable energy accounted for only \$166 billion. Figure 4.10 shows that in India, fossil fuel subsidies were more than 10 times larger than renewable energy subsidies, while in the PRC they were three times larger. As fossil fuels are associated with externalities related to global warming and air pollution, implementing carbon pricing and removing fossil fuel subsidies would be an efficient way to correct this market failure. However, given the slow progress and associated political challenges, carefully targeted subsidies to support renewable energy can improve efficiency by encouraging a shift toward clean technologies (Taylor 2020; GTZ 2009). Subsidies can be effective to promote the adoption of new technologies and spur market demand. For example, subsidies are credited for increasing solar PV adoption (Gerarden 2022; Hughes and Podolsfsky 2015; Mundaca and Samahita 2020; Gillingham and Tsvetanov 2019).

Subsidies and fiscal incentives are used in the region to encourage the deployment of low-carbon technologies. Policies commonly utilized in the region include:

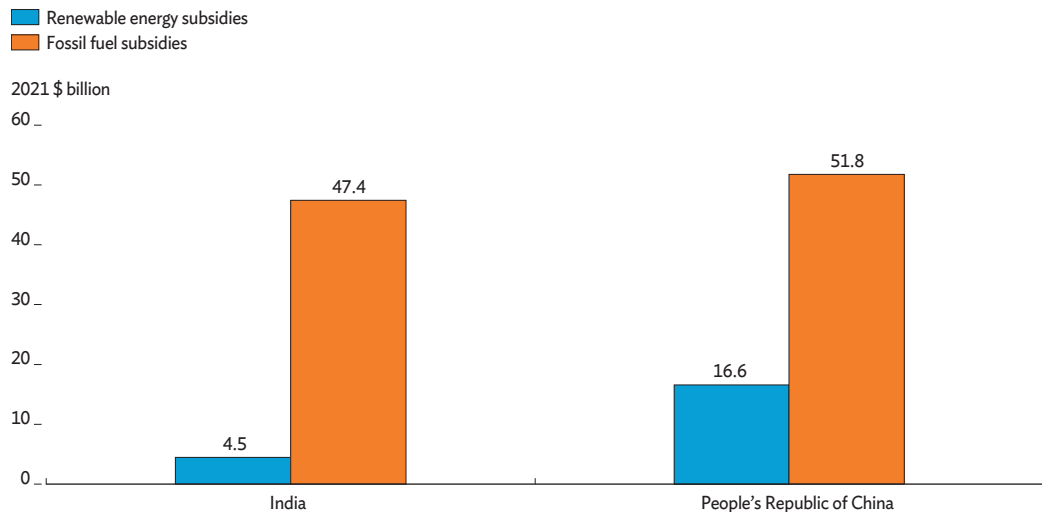
- **Feed-in tariffs (FITs)** are popular for scaling-up renewable energy. The mechanism obliges utilities to buy electricity generated from a powerplant at a predetermined tariff (set above the market price) and guaranteed for a specified period, thus providing a reasonable return while reducing risk through long-term contracts. In 2021, 92 economies globally had in place some form of FIT. With declines in the cost of renewables, FITs are gradually being discontinued or replaced by competitive pricing strategies, such as auctions and tenders. The PRC's National Energy Administration stopped approving FITs for new renewable energy projects in 2018, as the country moves toward a grid-parity model, where renewable energy and coal plants sell electricity to the grid at the same price. In 2021, 131 economies were using auctions or tenders for renewable energy.³⁹ Several economies in developing Asia successfully implemented auctions in recent years.

³⁸ For example, see ASEAN Center for Energy (2023) for a discussion on MEPS in Association of Southeast Asian Nations countries.

³⁹ FITs can still be used by regional governments in the PRC.

Figure 4.10 Fossil Fuel and Renewable Energy Subsidies in India and the People's Republic of China, 2017

Fossil fuel subsidies in both countries are much larger than renewable energy subsidies.



Source: Taylor, M. 2020. *Energy Subsidies: Evolution in the Global Energy Transformation to 2050*. International Renewable Energy Agency.

In Cambodia, auctions are credited for achieving one of the lowest tariffs at the time in 2019 among Association of Southeast Asian Nations members for grid-connected solar PV, which is lower than the estimated average electricity cost in the country (Climate Investment Fund 2020). In India, holding auctions resulted in a nearly 50% drop in the tariff rate compared to FITs (ADB 2021a).

- **Net metering** allows reverse sales by households and actors with small-scale renewable power generation to the grid and has been introduced in some countries. For example, the Indian states of Kerala and West Bengal introduced new net metering programs for rooftop solar PV. A similar program was launched in Malaysia that allows residential customers to export 100 megawatts of surplus solar generation to the grid.
- **Subsidies and other financial incentives** are provided by many countries for buying new EVs, which has increased EV sales (IEA 2022c). India, Japan, the PRC, and the Republic of Korea have subsidies, and Japan and the PRC also subsidize the establishment of charging stations. Many governments in developing Asia provide preferential taxation or different degrees of tax relief on EVs. Armenia lifted import customs duty on EVs. Delhi provides financial incentives for electric two- and three-wheelers and cars, and registration fees and road tax waivers. India's Tamil Nadu state exempts motor vehicle tax for battery-operated vehicles for 2 years. Thailand provides incentives for automakers and component suppliers through reduced import tariffs on machinery, raw material privileges, and corporate income tax exemptions for locally produced EVs and their components.

Subsidies within competitive markets are not efficient, can easily be mistargeted, and are difficult to remove. An extensive line of literature documents that most subsidies are inframarginal—that is, many subsidy recipients will adopt the clean and energy-efficient technology anyway. For example, Chen, Hu, and Knittel (2021) find that 56% of consumers subsidized by the PRC's largest national subsidy program for fuel-efficient vehicles were inframarginal. Clean energy subsidies are often criticized for lowering the end-user price of energy rather than raising it, which encourages more energy consumption (Stern and Robinson 2018). Energy subsidies may increase inequality by disproportionately benefiting high-income households. Once subsidies are started, they are often difficult to remove—even if they do not achieve intended outcomes (Inchauste and Victor 2017). For these reasons, subsidies should be considered as a second-best solution to setting prices that internalize climate externalities and are best deployed in a temporary and targeted manner to help defray costs and frictions, such as those associated with the initial adoption of new technologies (He 2023).

Local content requirements and other implicit taxes on decarbonization investments may neutralize the effects of supportive policies.

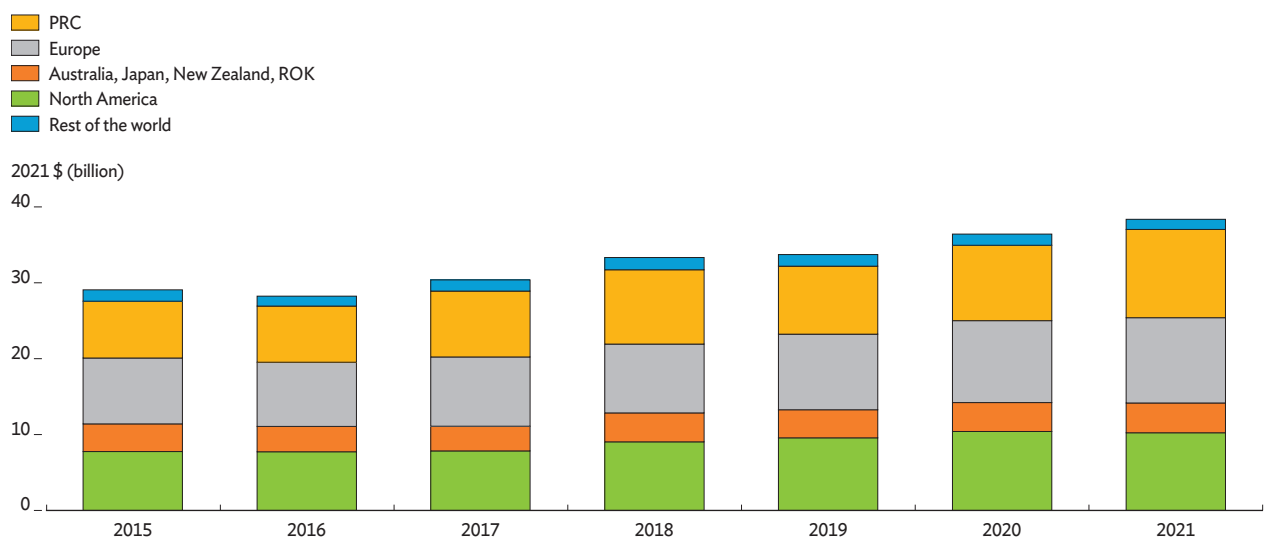
It is popular in many countries globally, as well as in developing Asia's larger economies, to require a certain minimum share of domestically sourced goods and services in renewable energy and related infrastructure projects that are open to auctioning or receive FITs. Although intended to help spur the development of local industries, local content requirements are a barrier to imports that may be cheaper, technologically superior, or even necessary to scale up clean energy generation. The result is that clean energy is less competitive than fossil fuels. For example, the cost of solar generation in India is found to be 6% per kilowatt hour higher because of local content requirements (Probst et al. 2020), and in Indonesia, local content requirements in the context of high local production costs are a constraint to developing renewable energy markets (ADB 2020b).

Support to public goods-oriented research on low-carbon technologies should be increased from low current levels in Asia.

The low-carbon transition depends on clean energy becoming cheaper and new technologies becoming available for deploying renewables, electrifying end uses, improving energy efficiency, and creating new opportunities for CO₂ removal. Although these technologies will be ultimately commercialized by the private sector, they depend on public sector investment in upstream energy research to generate innovations as public goods that can be used broadly by companies. Unlike private goods, these public goods will receive suboptimal investment by competitive markets, so public sector investment is strongly needed. Only the PRC is currently a major investor in this type of research in developing Asia (Figure 4.11). This has stimulated companies headquartered in the PRC to account for 35% of global private sector energy research and development (IEA 2022a), which has resulted in a majority of global renewable energy patents in recent years coming from the country (Figure 4.12). The rest of the developing Asia has minimal public investment in energy research. This not only misses opportunities to help accelerate decarbonization but also risks locking much of the region out of rapidly growing markets for clean energy technologies.

Figure 4.11 Global Public Spending on Energy Research and Development

Spending is concentrated in advanced countries and the PRC.

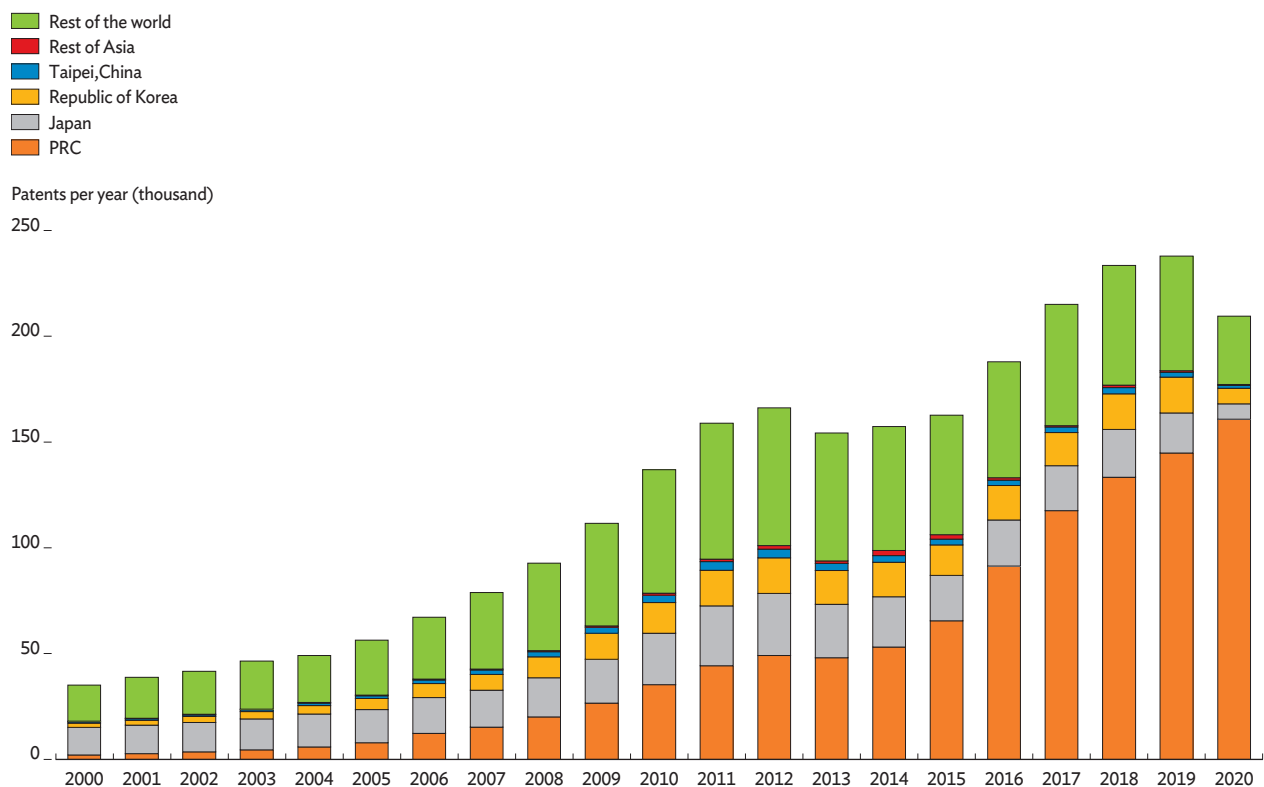


PRC = People's Republic of China, ROK = Republic of Korea.

Source: International Energy Association. 2022. [Spending on Energy R&D by Governments, 2015–2021](#). Updated 21 October.

Figure 4.12 Patents in Renewable Energy and Enabling Technologies, 2000–2020

The PRC accounted for about 40% of all patents in renewable energy and enabling technologies in the last 2 decades.



PRC = People's Republic of China.

Notes: In this figure, Rest of Asia comprises Georgia; Hong Kong, China; India; Indonesia; Kazakhstan; Malaysia; the Philippines; Singapore; Tajikistan; Viet Nam. Renewable energy comprises bio, geothermal, hydropower, solar, wind, and ocean energy. Enabling technologies comprise batteries, blue hydrogen, carbon capture and storage, cross-cutting, energy efficiency, electromobility, energy storage, fuel cells, hydrogen storage and distribution and applications, smart grids, and thermal energy storage.

Source: International Renewable Energy Agency. [INSPIRE Platform](#) (accessed 3 March 2023).

4.2.2 Accelerating Finance for the Low-Carbon Transition

Achieving global net zero requires massive finance, much of which will need to come from the private sector.

This report finds that \$707 billion of annual electricity supply investment is needed in developing Asia under the accelerated global net zero scenario during 2020–2050, compared with \$529 billion under the current policies scenario. Additional investment needs may be nearly twice as high, or \$1.4 trillion, when investments to electrify and modify energy end-use are considered (IEA 2022a). These investments are too large for the public sector to finance. IEA (2021c) estimates that to ensure the global energy sector achieves net zero by 2050, 70% of clean energy investment over the 2020s will need to be carried out by private developers, consumers, and financiers. However, the public sector remains the major player in climate finance, accounting for 51% of the global total (Buchner et al. 2021).

Low-carbon projects can be attractive to investors if risks are addressed. Although low-carbon investments have many benefits, they are more affected by certain risks. Renewable energy projects have higher front-loaded costs than fossil projects and are more capital intensive. Viability depends on reversible policies and complementary investments in grid integration, which amplifies political and regulatory risks. Low-carbon projects may depend on new technologies or technologies that are new to the project context, which increases technological risks.

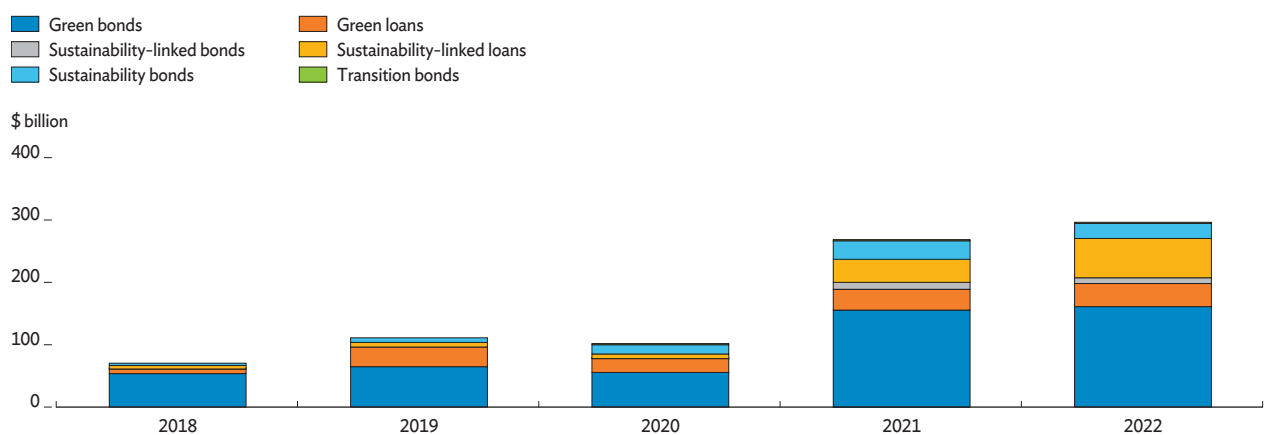
Uncertainties about resource supplies and variability may be higher, particularly for biomass or wind energy. For example, IEA (2022c), a stakeholder survey in five major emerging economies, shows the key factors driving up risk premiums in renewable energy projects include regulatory risk, political risk, off-taker risk, land acquisition risk, currency risk, inflation risk, transmission risk, and lack of project pipelines. To effectively direct private capital to low-carbon projects, governments and multilateral development banks can purposely reduce the risks associated with these projects to improve their risk-return profile.

Public resources can de-risk green projects to improve their risk-return profiles and attract private capital to low-carbon investments. Given limited public resources, fiscal constraints, and competing use of public funds for climate adaptation measures, it is important to efficiently leverage private capital for decarbonization investments. Public finance can catalyze private capital via de-risking or risk-sharing schemes, which are more resource efficient than directly financing projects. For example, governments can use public funds to set up insurance or guarantee schemes to compensate losses when certain unfavorable conditions occur. De-risking mechanisms thus improve risk-return profiles and make projects financially more attractive to private investors. The public sector can also set up blended finance facilities by taking on more risks or claiming lower returns via mechanisms such as subordinated debt and concessional finance to leverage private capital.

Rapidly expanding green and transition finance can help to encourage more low carbon investments in developing Asia, but this form of finance still faces challenges. Green and transition finance is reserved for low carbon and decarbonization investments that are designated to meet environmental standards. Tapping this finance sends signals of being environmentally responsible, which makes fund-raising easier among a broader set of investors (Lins, Servaes, and Tamayo 2017; Flammer 2021). In developing Asia, the annual issuance of green and sustainability-linked loans and bonds, sustainability bonds, and transition bonds rose more than threefold, from \$70 billion in 2018 to \$295 billion in 2022 (Figure 4.13). Of the \$295 billion finance in 2022, 89% (\$264 billion) was from the private sector. The market for sustainable finance in developing Asia, despite rapid growth, is still small. For example, sustainable bonds accounted for only 1.8% of bonds in the region in 2022. The shares of local currency financing and long-tenor financing in developing Asia's sustainable bond market are also lower than corresponding levels in the EU's sustainable bond markets (ADB 2022e).

Figure 4.13 Issuance of Green and Transition Debt Finance in Developing Asia, 2018–2022

Green and transition finance has expanded rapidly in developing Asia.



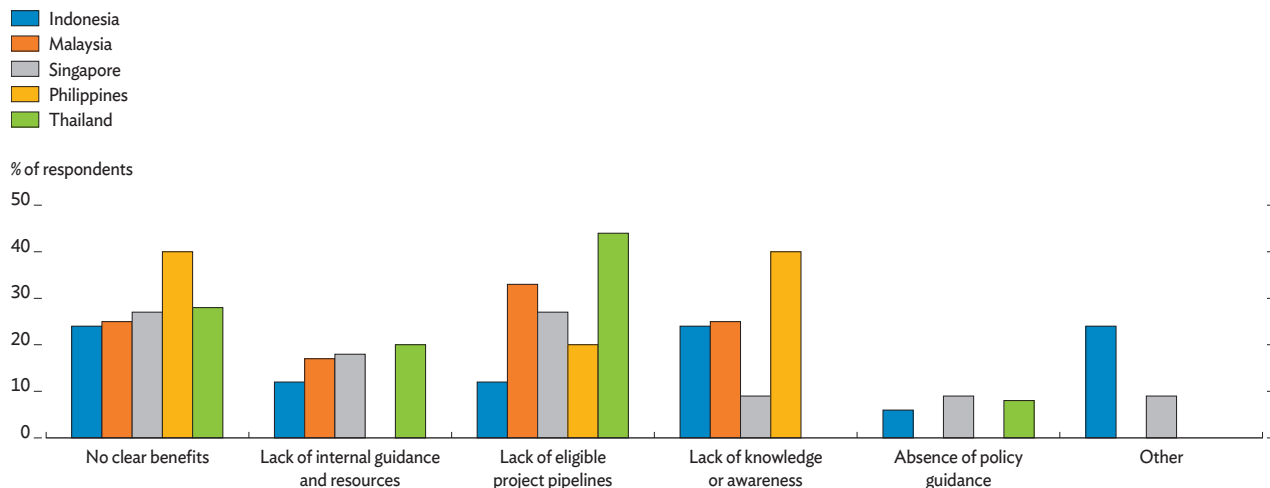
Sources: Asian Development Bank. [AsianBondsOnline](#) (accessed 15 March 2023).

Public resources can help lower transaction costs for green and transition finance and lead the development of this market.

Extra transaction costs are incurred for tapping green and transition finance compared to conventional finance. Among these are the extra resources and capacity needed to identify eligible projects, evaluate environmental impacts, and obtain external verification and labels. These additional resource requirements discourage participation in green and transition finance (Figure 4.14). Governments can provide incentives or administrative support to lower transaction costs, especially for first-time market participants (G20 2022). For example, governments can subsidize costs, such as fees for green certification or third-party opinion, and needed training and capacity building. Developing Asia needs to develop more elements of a functioning green and transition finance market. A clear green taxonomy is critical to help identify and classify low-carbon projects. Many developing Asian economies have national taxonomies, but more harmonization and consistency is needed to accelerate market development in the region. The market ecosystem remains underdeveloped in regional green and transition finance markets. For example, capacity is limited for providing independent verification; impact assessments; environmental, social, and governance (ESG) ratings; and similar services in the region. Moreover, a regulatory framework that incorporates climate-related risks and ESG performance into investment decisions and disclosures will support market development (ADB 2021b).

Figure 4.14 Obstacles to Issuing Green Bonds in Southeast Asian Countries

Incentives and eligible pipelines are needed to tap green bond markets.



Source: Asian Development Bank. 2022. [Developing the Sustainable Bond Market in ASEAN+3: Challenges and Opportunities](#). ADB Briefs 234.

4.3 Ensuring Fairness during the Transition

A low-carbon transition must be just to succeed. For low-carbon growth to be maintained long term, climate change mitigation policies must be able to sustain political support. Measures, such as carbon pricing, are most politically acceptable in the presence of generous social insurance and low inequality (Furceri, Ganslmeier, and Ostry 2021). This suggests that decarbonization policies may lead to political backlash and reversal when effects are regressive or unaccompanied by measures to ensure that vulnerable people are insulated from shocks. Similarly, a major stumbling block in international climate policy negotiations is the perception of whether the distribution of costs among countries is fair (Tørstad and Sælen 2018). Only if the transition is kept just can mitigation policies maintain sufficient political support over the long periods necessary to achieve net zero emissions.

4.3.1 Ensuring Fairness Internationally

An international emissions allocation framework can enable fairer climate policy outcomes for developing Asia and the world than the current fragmented approach. Global climate agreements have not resolved how the global mitigation burden should be allocated among countries. Cost-optimal policies unfairly place most mitigation burden on lower-income countries with little historical responsibility for climate change, while policies that emphasize equity of emissions rights lead to prohibitively costly mitigation concentrated in higher-income countries (van den Berg et al. 2020). However, leaving the issue unresolved will also not lead to a just outcome. As illustrated in Sections 2 and 3, individual country net zero pledges under the Paris Agreement lead to the allocation of mitigation effort across countries that is neither cost optimal nor progressive in the distribution of decarbonization costs relative to income. In contrast, use of clear emissions allocation principles in combination with global carbon trade can achieve mitigation more efficiently and equitably as lower income, lower per capita emissions countries could be better compensated for keeping emissions low. It is in Asia's interest to replace the current fragmented approach with an allocation framework that balances realism with equity as the basis for carbon trade and international financial flows under Article 6 of the Paris Agreement. These flows can potentially finance low-carbon approaches to meet development needs in the region's lowest-income countries. Given that contraction and convergence has more international support among developed and developing countries than any other allocation principle, it is a promising candidate for renewed attention (Raitzer et al. 2015).

In the absence of a coordinated climate policy, CBAMs may penalize lower-income countries with lower historical responsibility for climate change. Higher-income regions with more ambitious carbon pricing policies are discussing or implementing CBAMs with the stated purpose of tackling carbon leakage via imports from countries that lack carbon pricing. Within developing Asia, carbon pricing is absent in the lowest-income countries and is being expanded in middle- and upper-income economies. In the EU, which is planning to introduce a CBAM by 2026, revenues are to be recycled internally, so that the mechanism may effectively function as an import tariff against poorer countries, with regressive distributional effects. For CBAMs to have progressive effects, revenues should be recycled back into low-carbon investments in lower-income countries with lower historical responsibility for climate change. CBAMs could also be accompanied by efforts to help developing countries formulate pricing arrangements so that the carbon revenues are collected domestically, rather than by developed country importers.

4.3.2 Ensuring Fairness Domestically

Potential regressive effects of decarbonization policies need to be managed. As illustrated in Section 3, climate policies, although effective to reduce emissions, may adversely affect low-income households due to the higher costs of essential goods and services, such as food, energy, and transport, which comprise the bulk of their household spending. Economic inequality may also rise when climate policies have regressive impacts through reduced employment opportunities and limited access to natural resources, such as land for agriculture.

Carbon revenue recycling can enable progressive outcomes from climate policies. Carbon pricing policies can lead to large revenues as prices escalate and emissions coverage grows. These revenues can help to fund measures to compensate vulnerable people for the costs of climate policies. However, revenue recycling to date in developing Asia is usually to general public expenditures or to companies, rather than to vulnerable people (Table 4.3). In Latin America and some other regions, more carbon revenues are targeted to helping lower-income households through social programs. Policies such as direct transfers, tax rebates, and other exemptions and carve-outs to low-income households can cushion the negative distributional impacts on poor households. Evidence suggests that lump-sum rebates or transfers often benefit lower-income households more than tax cuts (Timilsina et al. 2021). Tax discounts or temporary exemptions to vulnerable sectors can help to smooth adjustment of affected industries (IMF 2021; ADB 2022b).

Table 4.3 Revenue Use in Carbon Pricing Schemes in Developing Asia*Economies in the region tend to use carbon revenues for public expenditure.*

Carbon Pricing Scheme	Use of Auction/Tax Revenue
Republic of Korea, ETS	Revenues will be reinvested to support SMEs and a climate-response fund that includes support for mitigation equipment, low-carbon innovation, and technology development of ETS-covered entities.
PRC, Guangdong pilot ETS	Revenues are attributed to the provincial treasury, which is exploring using auction revenues to promote further mitigation actions, carbon finance, and low-carbon industrial development.
PRC, Hubei pilot ETS	Revenues are attributed to the provincial treasury.
PRC, Shanghai pilot ETS	Revenues are deposited into the state treasury.
PRC, Shenzhen pilot ETS	Revenues are attributed to the city treasury to support, among other purposes, the mitigation activities of companies, promoting the market service of institutions, capacity building, and ETS management.
PRC, Tianjin pilot ETS	Revenues are deposited into the city treasury, and the main purpose of their use is to support work related to the control of GHG emissions.
Singapore, carbon tax	Revenue is recycled back to support companies to implement energy efficiency measures.

ETS = emissions trading system, GHG = greenhouse gas, PRC = People's Republic of China, SMEs = small and medium-sized enterprises.
Source: Duggal, V.K. 2023. Carbon Pricing Development and Dynamics. Background Note for *Asia in the Global Transition to Net Zero*. Asian Development Outlook Thematic Report 2023. Asian Development Bank.

Jobs created by the transition to net zero will require new skills. Section 3 showed that 1.5 million additional direct energy sector jobs would be created by the accelerated net zero scenario in developing Asia, compared with the current policies scenario. IEA (2021b) finds 9 million net job gains globally by 2030, including indirect employment, and McKinsey (2022) estimates 15 million net job gains globally by 2050. The creation of net jobs, however, masks the reality that traditional jobs related to fossil fuel extraction, such as in coal mining, will be lost. Jobs created by renewables in manufacturing and installation will often be urban and comparatively higher skilled, whereas lost jobs will be rural and low skilled, so the workers who lose employment are unlikely to find jobs from the new demands for labor. Those losing jobs will need to be reskilled to find other occupations (IEA 2021b).

Support to affected workers can smooth labor market transitions. Training and reskilling schemes can help to integrate those adversely affected by the low-carbon transition into growth industries. Labor markets can be supported by public services to help information flow on new training and job opportunities, as well as reforms to ensure that barriers to labor mobility are removed. During the transition, social protection, including unemployment benefit schemes, are needed so that workers can smoothly transition to new job opportunities (Garrido and Hughes 2023). To avoid gaps in coverage and to shorten periods of skill mismatches, these measures should be put in place before adverse effects occur.

A just transition depends on ensuring food security. Food is the single largest household expenditure among lower-income households in developing Asia, with those households typically spending at least three times as much on food as compared with energy. Yet, as illustrated in Section 2, deep decarbonization may depend on the use of bioenergy with carbon capture and storage and expanding forest cover at the expense of agricultural area, which, in turn, reduces food supply and increases food prices. Increases in food prices under ambitious climate policies are several times higher than increases in household energy prices. As a result of higher prices, food affordability and consumption will fall, with around 60 million people potentially pushed into hunger in developing Asia by 2050 by efforts to meet Paris Agreement goals (Fujimori et al. 2019). As food insecurity is more prevalent among women than men in developing Asia, this may exacerbate gender inequality (Akter 2019). Avoiding this outcome sustainably requires revamped investment in agricultural productivity.

Investing in agriculture is central to safeguard the welfare of vulnerable people during the transition.

As of 2019, around 600 million people were employed in agriculture in developing Asia, whereas the region had only about 13 million direct energy sector jobs in the same period.⁴⁰ Agriculture is the sector employing the largest share of the female workforce, and it is also the sector on which most of Asia's poor depend for livelihoods. As shown in Section 2, about 22% of the area devoted to cereal crops in developing Asia under the current policies scenario may be replaced by energy crops and forests by 2070 under ambitious decarbonization, potentially affecting the livelihoods of tens of millions of poor people. As illustrated in Section 1, agricultural losses are also the primary pathway by which climate change is expected to harm the lowest-income regions of Asia. Equipping agriculture in Asia to deal with the simultaneous pressures posed by climate change mitigation policy and unmitigated climate change will be critical for protecting the livelihoods of many of Asia's poor. In addition to investments in public services, land rights need to be strengthened to ensure that farming- and forest-dependent communities are not displaced by increased demand for land.

Only a low-carbon future has the potential to be fair. As shown in Section 1, a carbon-intensive future will come at great cost to developing Asia. Its lowest-income subregions will bear the brunt of this cost, with more than a third of GDP at risk to climate change under a conservative and partial estimate. Within developing Asia, those who stand to lose most are people on low incomes—those working in agriculture, living in areas vulnerable to the effects of storms and flooding, and doing manual labor under hot conditions. The benefits of ambitious climate policy disproportionately accrue to those who are most in need and who have the least historical responsibility for the climate crisis. Long-term fairness for developing Asia requires climate policy to be cost-effective enough to be ambitious, with sufficient redistributive measures in place to protect vulnerable people and maintain political support.

⁴⁰ International Labor Organization (ILO). ILOSTAT. <https://ilostat.ilo.org/>.

REFERENCES

- Acworth, W., et al. 2018. [Emissions Trading and Electricity Sector Regulation: A Conceptual Framework for Understanding Interactions between Carbon Prices and Electricity Prices](#). International Carbon Action Partnership.
- ADB (Asian Development Bank). 2020a. [Food Security in Asia and the Pacific amid the COVID-19 Pandemic](#). *ADB Briefs*. 139.
- . 2020b. [Renewable Energy Tariffs and Incentives in Indonesia](#).
- . 2021a. [Greening Markets: Market-Based Approaches for Environmental Management in Asia](#).
- . 2021b. [Asian Development Outlook 2021: Financing a Green and Inclusive Recovery](#).
- . 2022a. [Climate Change and Earthquake Exposure in Asia and the Pacific: Assessment of Energy And Transport Infrastructure](#).
- . 2022b. [Asian Development Outlook 2022: Mobilizing Taxes for Development](#).
- . 2022c. [Green Bond Market Survey](#) reports.
- . 2022d. [Developing the Sustainable Bond Market in ASEAN+3: Challenges and Opportunities](#). *ADB Briefs* 234.
- . 2022e. [Asia Bond Monitor](#). November 2022.
- . 2022f. [2021 Report on the Status of Transport Related SDG Targets in Asia and the Pacific](#).
- . 2023. [Asian Economic Integration Report 2023: Trade, Investment, and Climate Change in Asia and the Pacific](#).
- Ahmed, M., and S. Suphachalasai. 2014. [Assessing the Costs of Climate Change and Adaptation in South Asia](#). Asian Development Bank.
- Akter, S. 2019. [Gender Inequality and Food Insecurity in the Asian Food System during the COVID-19 Pandemic](#). Background Paper for Asian Development Outlook 2021 Update: Transforming Agriculture in Asia. Asian Development Bank.
- Allcott, H. 2011. [Social Norms and Energy Conservation](#). *Journal of Public Economics* 95.
- Amarjargal, B., et al. 2020. [Achieving Nationally Determined Contributions through Market Mechanisms in Asia and the Pacific](#). *ADB Sustainable Development Working Paper Series No. 64*. Asian Development Bank.
- Anderson, K., G. Rausser, and J. Swinnen. 2013. [Political Economy of Public Policies: Insights from Distortions to Agricultural and Food Markets](#). *Journal of Economic Literature* 51(2).
- Angelsen, A., ed. 2008. [Moving Ahead with REDD: Issues, Options and Implications](#). Center for International Forestry Research.

- ASEAN Centre for Energy. 2023. [A Study of Energy Savings with Focus on Demand Side Management in ASEAN](#).
- Bachner, G., et al. 2022. [The Macroeconomic Effects of Adapting to High-End Sea-Level Rise via Protection and Migration](#). *Nature Communications* 13.
- Brown, D. W. 1999. Addicted to Rent: Corporate and Spatial Distribution of Forest Resources in Indonesia; Implications for Forest Sustainability and Government Policy. Report No. PFM/EC/99/06. Indonesia-UK Tropical Forest Management Programme.
- Buchner, B., et al. 2021. [Global Landscape of Climate Policy 2021](#). Climate Policy Initiative.
- Budolfson, M., et al., 2021. [Protecting the Poor with a Carbon Tax and Equal per Capita Dividend](#). *Nature Climate Change* 11.
- Burgess, R., et al. 2012. [The Political Economy of Deforestation in the Tropics](#). *Quarterly Journal of Economics* 127(4).
- Burke, M., S. M. Hsiang, and E. Miguel. 2015. [Global Non-Linear Effect of Temperature on Economic Production](#). *Nature* 527.
- Carattini, S., M. Carvalho, and S. Fankhauser. 2018. [Overcoming Public Resistance to Carbon Taxes](#). *Wiley Interdisciplinary Reviews: Climate Change* 9(5).
- Carleton, T., et al. 2022. [Valuing the Global Mortality Consequences of Climate Change Accounting for Adaptation Costs and Benefits](#). NBER Working Paper No. 27599. National Bureau of Economic Research.
- Chen, C., W. Hu, and C. Knittel. 2021. Subsidizing Fuel-Efficient Cars: Evidence from China's Automobile Industry. *American Economic Journal: Economic Policy* 13(4).
- Climate Investment Fund. 2020. [From Carbon to Competition: Cambodia's Transition to a Clean Energy Development Pathway](#). CIF-GDI Delivery Challenge Case Study, June.
- COACCH (Co-designing the Assessment of Climate Change Costs). 2021. [D5.7 Climate Change Impacts & Policy Synthesis](#).
- Coady, D., et al. 2015. [How Large Are Global Energy Subsidies?](#) *IMF Working Paper* WP/15/105. International Monetary Fund.
- Corruption Eradication Commission. 2015. Preventing State Losses in Indonesia's Forestry Sector: An Analysis of Non-Tax Forest Revenue Collection and Timber Production Administration.
- Dell, M., F. Jones, and B. A. Olken. 2012. [Temperature Shocks and Economic Growth: Evidence from the Last Half Century](#). *American Economic Journal: Macroeconomics* 4(3).
- Deschenes, O. 2018. [Temperature Variability and Mortality: Evidence from 16 Asian Countries](#). *Asian Development Review* 35(2).
- Drouet, L., et al. 2021. [Net Zero-Emission Pathways Reduce the Physical and Economic Risks of Climate Change](#). *Nature Climate Change* 11.

- Duggal, V. K. 2023. Carbon Pricing Development and Dynamics. Background Paper for *Asia in the Global Transition to Net Zero*. Asian Development Outlook Thematic Report 2023. Asian Development Bank.
- Eckstein, D., V. Künzel, and L. Schäfer. 2021. [Global Climate Risk Index 2021: Who Suffers Most from Extreme Weather Events? Weather-Related Loss Events in 2019 and 2000–2019](#). Briefing Paper. Germanwatch.
- Emmerling, J., et al. 2023. The Net Zero Transition in Asia: Opportunities and Challenges Ahead. Background Paper for *Asia in the Global Transition to Net Zero*. Asian Development Outlook Thematic Report 2023. Asian Development Bank.
- Fajardy, M., et al. 2019. [BECCS Deployment: A Reality Check](#). *Briefing Paper* No. 28. Grantham Institute for Climate Change.
- FAO (Food and Agriculture Organization of the United Nations). 2021. The Share of Agri-Food Systems in Total Greenhouse Gas Emissions: Global, Regional and Country Trends 1990–2019. *FAOSTAT Analytical Brief* 31.
- Flammer, C. 2021. Corporate Green Bonds. *Journal of Financial Economics* 142(2).
- Fofrich, R. et al. 2020. Early retirement of power plants in climate mitigation scenarios. *Environmental Research Letters* 15.
- Fujimori, S., et al. 2019. [A Multi-Model Assessment of Food Security Implications of Climate Change Mitigation](#). *Nature Sustainability* 2.
- Furceri, D., M. Ganslmeier, and J. Ostry. 2021. [Are Climate Change Policies Politically Costly?](#) *IMF Working Papers* WP 2021/156. International Monetary Fund.
- G20 (Group of 20). 2022. [The Sustainable Finance Market in ASEAN+3: Development, Opportunities and Future Steps](#). *Policy Brief*.
- Garrido, L., and K. Hughes. 2023. Policy Options for Just Transitions in Asia. Background Paper for *Asia in the Global Transition to Net Zero*. Asian Development Outlook Thematic Report 2023. Asian Development Bank.
- Gerarden, T. 2023. [Demanding Innovation: The Impact of Consumer Subsidies on Solar Panel Production Costs](#). *Management Science* 0(0).
- Giardino, A., W. Geoffrey Wilson, and C. Hart. 2023. Decarbonizing the Water Sector. Background Paper for *Asia in the Global Transition to Net Zero*. Asian Development Outlook Thematic Report 2023. Asian Development Bank.
- Gillingham, K., and T. Tsvetanov. 2019. [Hurdles and Steps: Estimating Demand for Solar Photovoltaics](#). *Quantitative Economics* 10(1).
- Global Carbon Budget 2022. [Global Carbon Budget 2022](#). *Earth System Science Data* 14(11).
- Gota, S., and C. Huizenga. 2023. The Contours of a Net Zero Emission: Transport Sector in Asia. Background Paper for *Asia in the Global Transition to Net Zero*. Asian Development Outlook Thematic Report 2023. Asian Development Bank.

- Greenstone, M., and I. Nath 2020. [Do Renewable Portfolio Standards Deliver Cost-Effective Carbon Abatement?](#) Working Paper No. 2019-62. Becker Friedman Institute for Economics, University of Chicago.
- GTZ (Deutsche Gesellschaft für Technische Zusammenarbeit). 2009. [Energy Subsidies: Why, When and How? A Think Piece](#).
- Gugler, K., A. Haxhimusa, and M. Liebensteiner. 2021. [Effectiveness of Climate Policies: Carbon Pricing vs. Subsidizing Renewables](#). *Journal of Environmental Economics and Management* 106(1).
- Hamilton, J., et al. 2005. [Effects of Climate Change on International Tourism](#). *Climate Research* 29(3).
- He, G. 2023. Climate Policy: Evidence and Way Forward for Developing Asia. Background Paper for *Asia in the Global Transition to Net Zero*. Asian Development Outlook Thematic Report 2023. Asian Development Bank.
- HEI (Health Effects Institute). 2019. [State of Global Air 2019](#).
- . 2020. [State of Global Air 2020](#). Special Report.
- Henseler, M., and I. Schumacher. 2019. [The Impact of Weather on Economic Growth and Its Production Factors](#). *Climatic Change* 154(3).
- High-Level Commission on Carbon Prices. 2017. [Report of the High-Level Commission on Carbon Prices](#). World Bank.
- Holland, S., J. Hughes, and C. Knittel. 2009. Greenhouse Gas Reductions under Low Carbon Fuel Standards? *American Economic Journal: Economic Policy* 1(1).
- Hughes, J. E., and M. Podolefsky. 2015. Getting Green with Solar Subsidies: Evidence from the California Solar Initiative. *Journal of the Association of Environmental and Resource Economists* 2(2).
- ICAP (International Carbon Action Partnership). 2022. [Emissions Trading Worldwide: International Carbon Action Partnership \(ICAP\) Status Report 2022](#).
- . 2023. [Emissions Trading Worldwide: International Carbon Action Partnership \(ICAP\) Status Report 2023](#).
- IEA (International Energy Agency). 2018. [Energy Service Companies](#).
- . 2020. [World Energy Outlook 2020](#).
- . 2021a. [The Role of Critical Minerals in Clean Energy Transitions](#).
- . 2021b. [Net Zero by 2050: A Roadmap for the Global Energy Sector](#).
- . 2021c. [The Cost of Capital in Clean Energy Transitions](#).
- . 2022a. [World Energy Investment 2022](#).
- . 2022b. [Cost of Capital Observatory](#).
- . 2022c. [Global EV Outlook 2022](#).

- . 2022d. *World Energy Employment*.
- ILO (International Labour Organization). 2019. *Working on a Warmer Planet: The Impact of Heat Stress on Labour Productivity and Decent Work*.
- . 2021. *COVID-19 and Employment in the Tourism Sector in the Asia-Pacific Region*. Briefing Note.
- IMF (International Monetary Fund). 2021. *Fiscal Policies to Address Climate Change in Asia and the Pacific*.
- Inchauste, G., and D. Victor. 2017. *The Political Economy of Energy Subsidy Reform*. Directions in Development. World Bank.
- IPCC (Intergovernmental Panel on Climate Change). 2021. *Climate Change 2021: The Physical Science Basis*. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.
- . 2022a. *Climate Change 2022: Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.
- . 2022b. *Climate Change 2022: Mitigation of Climate Change*. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.
- IRENA (International Renewable Energy Agency). 2019. *Utility-Scale Batteries: Innovation Landscape Brief*.
- . 2020. *Renewable Power Generation Costs in 2020*.
- . 2021. *Renewable Capacity Statistics 2021*.
- Jaenicke, J., et al. 2008. Determination of the Amount of Carbon Stored in Indonesian Peatlands. *Geoderma* 147.
- Jain, M., A. Rao, and A. Patwardhan. 2018. *Appliance Labeling and Consumer Heterogeneity: A Discrete Choice Experiment in India*. *Applied Energy* 226.
- Kalkuhl, M., and L. Wenz. 2020. *The Impact of Climate Conditions on Economic Production: Evidence from a Global Panel of Regions*. *Journal of Environmental Economics and Management* 103.
- Kuhn, S., F. Kutzner, and J. Thøgersen. 2022. *How to Make Energy Efficiency Labels More Effective: Insights from Discrete Choice Experiments in Ghana and the Philippines*. *Energy Research and Social Science* 84.
- Lee, J., et al. 2021. *The Scale and Drivers of Carbon Footprints in Households, Cities and Regions across India*. *Global Environmental Change* 66.
- Leimbach, M. et al. 2017. *Future Growth Patterns of World Regions—A GDP Scenario Approach*. *Global Environmental Change* 42.
- Lins, K. V., H. Servaes, and A. Tamayo. 2017. *Social Capital, Trust, and Firm Performance: The Value of Corporate Social Responsibility during the Financial Crisis*. *Journal of Finance* 72(4).
- Magacho, G., et al. 2022. *Low-Carbon Transition in Latin America: What Are the Risks and the Main Constraints?* OECD Development Matters. Organisation for Economic Co-operation and Development.

- Malerba, D., and J. Emmerling. 2022. Modelling the Interaction Between Climate Mitigation and Income Inequality: The Use of Integrated Assessment Models and the Case of India. In *Governing the Interlinkages between the SDGs*. Routledge.
- McKinsey. 2022. [The Net-Zero Transition: What It Would Cost, What It Could Bring](#).
- McMahon, K., and C. Gray, C. 2021. [Climate Change, Social Vulnerability and Child Nutrition in South Asia](#). *Global Environmental Change* 71.
- Meijide, A., et al. 2020. [Measured Greenhouse Gas Budgets Challenge Emission Savings from Palm–Oil Biodiesel](#). *Nature Communications* 11.
- Mendelsohn, R. 2014. [The Impact of Climate Change on Agriculture in Asia](#). *Journal of Integrative Agriculture* 13(4).
- Meyer, A. 2004. Contraction and Convergence: Proceedings of the Institute of Civil Engineers. *Engineering Sustainability* 157(4).
- Mi, L., et al. 2019. [Using Goal and Contrast Feedback to Motivate Chinese Urban Families to Save Electricity Actively: A Randomized Controlled Field Trial](#). *Journal of Cleaner Production* 226.
- Montero, J. P. 2002. Permits, Standards, and Technology Innovation. *Journal of Environmental Economics and Management* 44.
- Mundaca, L., and M. Samahita. 2020. [What Drives Home Solar PV Uptake? Subsidies, Peer Effects and Visibility in Sweden](#). *Energy Research & Social Science* 60.
- Never, B. 2023. Behavioural Changes during Asia's Net Zero Transition Evidence from Middle Class Households' Consumption. Background Paper for *Asia in the Global Transition to Net Zero*. Asian Development Outlook Thematic Report 2023. Asian Development Bank.
- Newell, R., B. Prest, and S. Sexton. 2021. [The GDP-Temperature Relationship: Implications for Climate Change Damages](#). *Journal of Environmental Economics and Management* 108.
- Organisation for Economic Co-operation and Development (OECD). 2021a. [CO₂ Emissions Embodied in International Trade](#).
- . 2021b. [Agricultural Policy Monitoring and Evaluation 2021: Addressing the Challenges Facing Food Systems](#).
- Pai, S., et al. 2021. [Meeting Well-Below 2°C Target Would Increase Energy Sector Jobs Globally](#). *One Earth* 4.
- Palmer, C. 2001. [The Extent and Causes of Illegal Logging: An Analysis of a Major Cause of Tropical Deforestation in Indonesia](#). *CSERGE Working Paper*. Centre for Social and Economic Research on the Global Environment.
- Pretis, F., et al. 2018. [Uncertain Impacts on Economic Growth When Stabilizing Global Temperatures at 1.5°C or 2°C Warming](#). *Philosophical Transactions of the Royal Society A*.
- Probst, B., et al. 2020. [The Short-Term Costs of Local Content Requirements in the Indian Solar Auctions](#). *Nature Energy* 5.

- Raitzer, D., et al. 2015. [Southeast Asia and the Economics of Global Climate Stabilization](#). Asian Development Bank.
- Raitzer, D., J. Samson, and K. Nam. 2015. [Achieving Environmental Sustainability in Myanmar](#). Asian Development Bank.
- Rahut, D., et al. 2023. Opportunities and Challenges during Low Carbon Transition: A Perspective from Asia's Agriculture Sector. Background Paper for *Asia in the Global Transition to Net Zero*. Asian Development Outlook Thematic Report 2023. Asian Development Bank.
- Reis, L. A., and M. Tavoni. 2023. Glasgow to Paris—The impact of the Glasgow commitments for the Paris climate agreement. *iScience* 26(2): p. 105933.
- Riahi, K., et al. 2017. [The Shared Socioeconomic Pathways and Their Energy, Land Use, and Greenhouse Gas Emissions Implications: An Overview](#). *Global Environmental Change* 42.
- Riahi, K., et al. 2021. [Cost and Attainability of Meeting Stringent Climate Targets without Overshoot](#). *Nature Climate Change* 11.
- Robinson, L., et al. 2019. [Valuing Mortality Risk Reductions in Global Benefit-Cost Analysis](#). *Journal of Benefit-Cost Analysis* 10(S1).
- Shayegh, S., V. Bosetti, and M. Tavoni. 2021. [Future Prospects of Direct Air Capture Technologies: Insights from an Expert Elicitation Survey](#). *Frontiers in Climate* 3.
- Sherman, P., H. Lin, and M. McElroy. 2022. [Projected global demand for air conditioning associated with extreme heat and implications for electricity grids in poorer countries](#). *Energy and Buildings* 268.
- Shrestha, R. M., et al. 2021. [Energy Efficiency in South Asia: Opportunities for Energy Sector Transformation](#). Asian Development Bank.
- Sterner, T., and E. Robinson. 2018. Selection and Design of Environmental Instruments. In P. Dasgupta, S. K. Pattanayak, and V. K. Smith, eds. *Handbook of Environmental Economics*.
- Taylor, M. 2020. [Energy Subsidies: Evolution in the Global Energy Transformation to 2050](#). International Renewable Energy Agency.
- Timilsina, G., et al. 2021. [Carbon Tax in an Economy with Informality: A Computable General Equilibrium Analysis for Cote d'Ivoire](#). *Policy Research Working Paper* No. 9710. World Bank.
- Tørstad, V., and H. Saelen. 2018. [Fairness in the Climate Negotiations: What Explains Variation in Parties' Expressed Conceptions?](#) *Climate Policy* 18(5).
- Townhill, B., et al. 2020. [Communicating Marine Climate Change Impacts in the Caribbean and Pacific Regions](#). *Marine Pollution Bulletin* 150.
- UNESCAP. 2022. [2022 Review of Climate Ambition in Asia and the Pacific: Raising NDC Targets with Enhanced Nature-Based Solutions with a Special Feature on Engagement of Children and Youth in Raising National Ambition](#).
- UNFCCC. 2022. [2022 NDC Synthesis Report](#).

- . 2023. [NDC Registry](#).
- van den Berg, N., et al. 2020. [Implications of Various Effort-Sharing Approaches for National Carbon Budgets and Emission Pathways](#). *Climatic Change* 162(4).
- van der Wijst, K., et al. 2023. [New Damage Curves and Multimodel Analysis Suggest Lower Optimal Temperature](#). *Nature Climate Change*.
- Vos, R., W. Martin, and D. Resnick. 2022. Repurposing Agricultural Support: Creating Food Systems Incentives to Address Climate Change. Chapter 2 in [2022 Global Food Policy Report: Climate Change and Food Systems](#). International Food Policy Research Institute.
- Weitzman, M. L. 2009. On Modeling and Interpreting the Economics of Catastrophic Climate Change. *Review of Economics and Statistics* 91.
- Westphal, M., G. Hughes, and J. Brömmelhörster. 2013. [Economics of Climate Change in East Asia](#). Asian Development Bank.
- World Bank. 2019. [Illegal Logging, Fishing, and Wildlife Trade: The Costs and How to Combat It](#).
- . 2022. Pakistan: Flood Damages and Economic Losses over USD 30 Billion and Reconstruction Needs over USD 16 Billion: New Assessment. Press release. 28 October.
- WMO (World Meteorological Organization). 2022. Provisional State of the Global Climate in 2022.
- Yin, I. 2023. [China relaxes compliance carbon market rules for coal-fired power plants](#). S&P Global Commodity Insights.
- Yin, Y. 2023. [Introducing Consignment Auctions of Emission Allowances to China's National ETS](#). *Law and Economy* 2(2).
- Zeigler, M. S., and J. E. Trancik. 2021. [Re-examining Rates of Lithium-ion Battery Technology Improvement and Cost Decline](#). *Energy Environmental Science* 14.
- Zhou, W. 2023. Accelerating Net Zero Transition of the Buildings and Construction Sector in Developing Asia and the Pacific. Background Paper for *Asia in the Global Transition to Net Zero*. Asian Development Outlook Thematic Report 2023. Asian Development Bank.
- Zinecker, A., et al. 2018. [Getting on Target: Accelerating Energy Access through Fossil Fuel Subsidy Reform](#). International Institute for Sustainable Development.

Comparison of Modeling Results with the Sixth Assessment Report of the Intergovernmental Panel on Climate Change

As part of the Intergovernmental Panel on Climate Change's Sixth Assessment (AR6) Report, the authors of Working Group III on mitigating climate change comprehensively collected and assessed quantitative, model-based scenarios. The call for scenarios was open from September 2019 to July 2021, with updates possible until October 2021. The compilation and assessment of the scenarios, collectively referred to as the AR6 Scenario Explorer and Database, is hosted by the International Institute for Applied Systems Analysis. The database contains 3,131 scenarios, 188 models, and data on 1,775 variables on socioeconomic development, greenhouse gas emissions, and sectoral transformations across energy, land use, transportation, and industry.

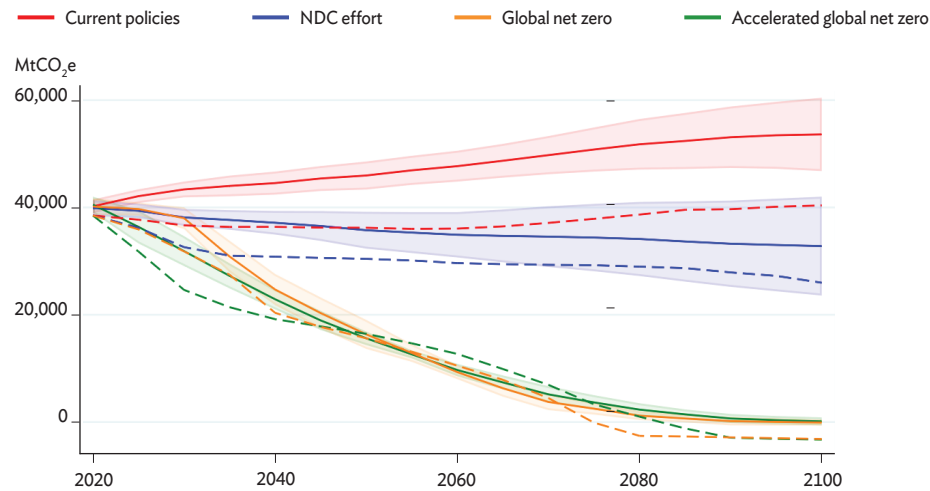
This appendix compares modeling results presented in this report with that of comparable scenarios in the AR6 database. To select comparable scenarios from the database, scenarios that did not pass historical and future vetting were excluded. In terms of shared socioeconomic pathways (SSPs) that determine population and growth projections, only scenarios consistent with the SSP2 “middle of the road” category were included. The remaining scenarios were then filtered based on the policy category name that best matched the scenarios modeled in this report. The net zero scenarios were further filtered by the carbon budget that is consistent with 1.7°C of mean warming. Scenarios that allowed for overshooting the carbon budget beyond what is required for well below 2°C were excluded.

Appendix figure 1 shows global carbon dioxide emission pathways from the modeling in this report and comparable scenarios from the AR6 database. Overall, the emission pathways modeled in this report are consistent with the AR6 database. For the current policies and the nationally determined contributions (NDC) effort scenarios, emissions modeled in this report are somewhat lower, as they take into account recent more ambitious policies and updated NDCs compared to slightly older versions in the AR6 database.

The boxplots in panel A of appendix figure 2 show that the median value of total primary energy supply for developing Asia excluding the Caucasus and Central Asia—under the comparable accelerated global net zero scenario from the AR6 comparison—is 250 exajoules (EJ) in 2050, increasing to 270 EJ by 2070. The results from modeling for this report fall within the range of the AR6 model comparison.

The boxplots in panel B show the share of different sources of primary energy supply for developing Asia excluding the Caucasus and Central Asia under the accelerated global net zero scenario. In 2050, the median value for the share of coal in primary energy across the models is 13.3% and 41.2% for renewables. These results are comparable to 12.6% for coal and 39.8% for renewables modeled in this report.

1 Global Carbon Dioxide Emission Pathways under the Sixth Assessment Report Scenario Database and the Modeled Scenarios



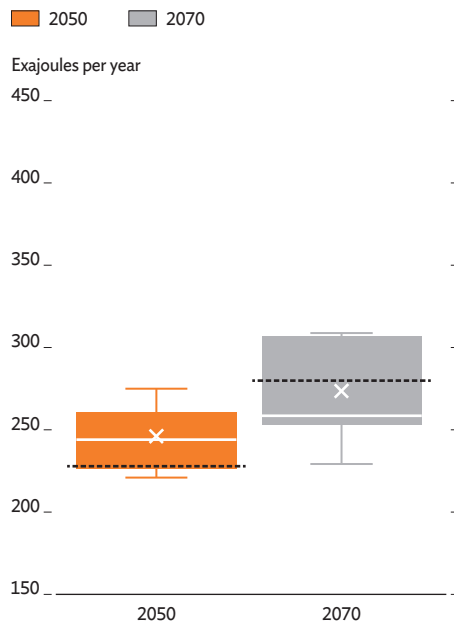
AR6 = Sixth Assessment Report of the Intergovernmental Panel on Climate Change, MtCO₂e = metric tons of carbon dioxide equivalent.

Note: Solid lines are Sixth Assessment Report scenarios and dash lines are scenarios modeled in this report.

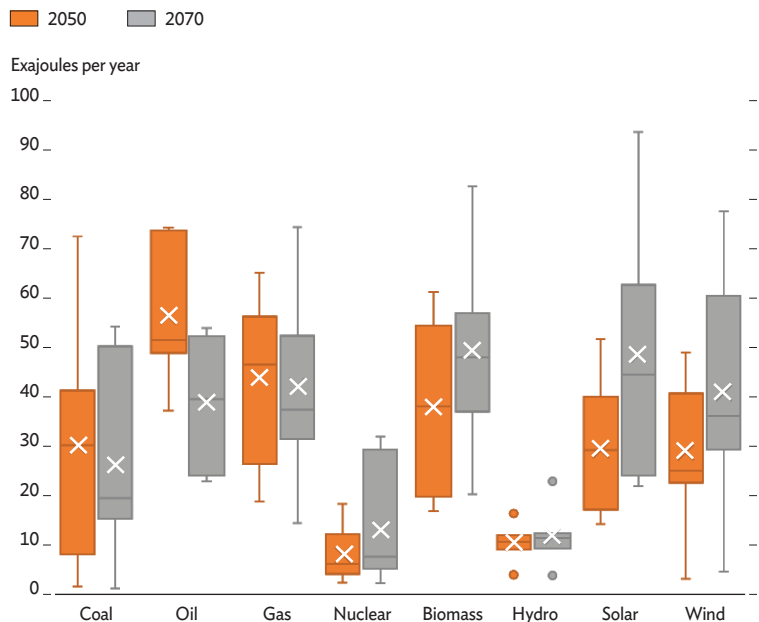
Source: Authors based on the AR6 scenario explorer hosted by the [International Institute for Applied Systems Analysis](#).

2 Primary Energy Supply in Developing Asia in the Sixth Assessment Report Scenario Database, 2050 and 2070

A. Total Primary Energy Supply



B. Primary Energy Supply by Source



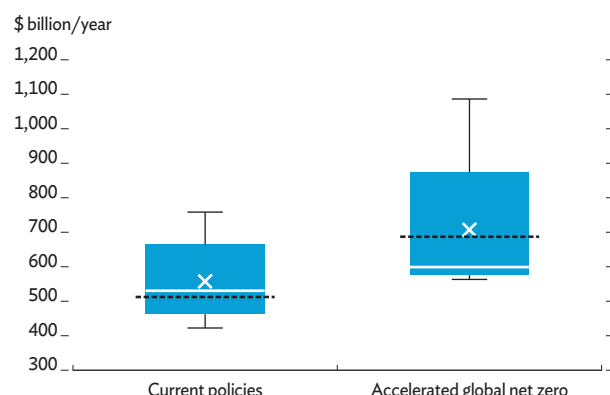
Notes: X is mean, the solid line is median, boxes are the range of values between the first and third quartile, and whiskers are minimum and maximum data from the AR6 comparison. The dashed line represents modeling results presented in this report. Developing Asia does not include Caucasus and Central Asia.

Source: Authors based on the Sixth Assessment Report of the Intergovernmental Panel on Climate Change scenario explorer hosted by the [International Institute for Applied Systems Analysis](#).

The boxplots in appendix figure 3 show the average annual investments in power supply in developing Asia excluding the Caucasus and Central Asia under the current policies and the accelerated global net zero scenarios. Overall, the results of this report are consistent with the AR6 database.

The cost of mitigation found in this report aligns with the AR6 database. Although most previous studies pay less attention to developing Asia, they report costs for the region that are in aggregate similar to the results of this analysis. Appendix figure 4 compares the results in this report with similar scenarios from four other leading integrated assessment models. The long-term costs under the accelerated global net zero scenario are slightly higher in the AR6 database compared to this report. Many of the scenarios in the AR6 database were run before the current policies scenarios became more ambitious and the pace of cost reductions in renewables picked up, as they have in recent years. Those trends have brought down the cost of decarbonization.

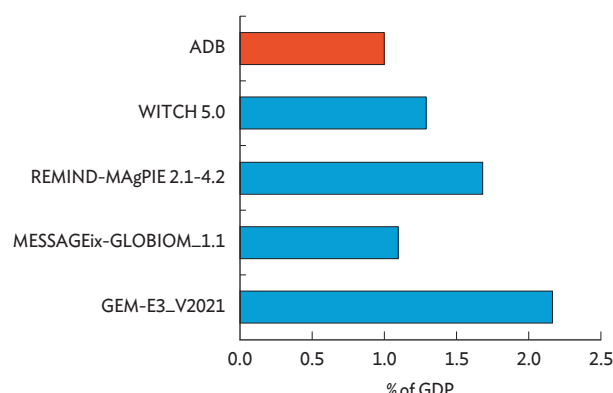
3 Average Annual Investment in Power Supply in Developing Asia in the Sixth Assessment Report Scenario Database, 2020–2050



Notes: X is mean, the solid line is median, boxes are the range of values between the first and third quartile, and whiskers are minimum and maximum data from the AR6 comparison. The dashed line represents modeling results presented in this report. Developing Asia does not include the Caucasus and Central Asia.

Source: Authors based on the Sixth Assessment Report of the Intergovernmental Panel on Climate Change scenario explorer hosted by the [International Institute for Applied Systems Analysis](#).

4 Long-Term Policy Costs of Modeled Scenarios for Developing Asia in the Sixth Assessment Report Scenario Database, 2020–2100



Notes:

1. ADB is the results from the modeling presented in this report, GEM-E3_V2021 is the general equilibrium model for economy-energy-environment version 2021, MESSAGEix-GLOBIOM_1.1 is the Model for Energy Supply Strategy Alternatives and their General Environmental Impact Global Biosphere Management Model version 1.1, REMIND-MAgPIE 2.1-4.2 is the Regional Model of Investment and Development-Model of Agricultural Production and its Impacts on the Environment version 2.1-4.2, WITCH 5.0 is the world induced technical change hybrid version 5.0.

2. Discounted at 3%.

3. Developing Asia does not include Caucasus and Central Asia.

Source: Authors based on the Sixth Assessment Report of the Intergovernmental Panel on Climate Change scenario explorer hosted by the [International Institute for Applied Systems Analysis](#).

Asia in the Global Transition to Net Zero

Asian Development Outlook 2023 Thematic Report

Developing Asia faces a climate policy crossroads. The region is highly vulnerable to climate change, even as it is an increasing contributor to the global climate crisis. Pledges to achieve long-term climate goals require a strong shift away from the carbon-intensive development paths taken so far. This report explores what a transition to global net zero emissions could mean for developing Asia under global climate policy scenarios that contrast current policies, national pledges, and greater international cooperation. It examines transformations of the energy and land use sectors needed for decarbonization and assesses socioeconomic implications, in terms of policy costs, climate benefits, air quality co-benefits, labor market outcomes, and equity. Policies in the region to achieve efficient and fair transition are examined, and potential enhancements are recommended.

About the Asian Development Bank

ADB is committed to achieving a prosperous, inclusive, resilient, and sustainable Asia and the Pacific, while sustaining its efforts to eradicate extreme poverty. Established in 1966, it is owned by 68 members—49 from the region. Its main instruments for helping its developing member countries are policy dialogue, loans, equity investments, guarantees, grants, and technical assistance.



ASIAN DEVELOPMENT BANK

6 ADB Avenue, Mandaluyong City

1550 Metro Manila, Philippines

www.adb.org