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Planning for a Low Carbon Future

LOW CARBON GROWTH COUNTRY STUDIES PROGRAM

LESSONS LEARNED FROM SEVEN COUNTRY STUDIES

LOW CARBON GROWTH COUNTRY STUDIES PROGRAM

CONTENTS

The Annexes for this report are available at
http://www.esmap.org/esmap/node/2053

FOREWORD

Energy is at the center of global efforts to respond to climate change. If greenhouse gas emissions are to be kept to globally accepted safe levels, energy efficiency must be dramatically improved and the energy sector must undergo a substantial shift towards renewable sources of power. On the adaptation side, energy systems must be able to withstand changing rainfall and temperature patterns as well as extreme weather events. At the same time, developing countries will continue to have an overriding imperative to reduce poverty. To address this dual challenge, the Energy Sector Management Assistance Program (ESMAP) has provided support to its developing country clients since 2007 to analyze the opportunities for low carbon growth.

This report reviews the first group of seven low carbon development country studies conducted with support from ESMAP, most of which were completed in 2010. It attempts to distill the lessons learned from this work to help inform future studies while also providing an overview of the policy conclusions that have emerged.

Low carbon development planning is still a work in progress. While these seven studies were some of the earliest examples, they are by no means the last word on the subject. Lessons will soon emerge from on-going work supported by ESMAP in Morocco, Nigeria, and Vietnam. A number of other organizations and agencies are now supporting similar work, including the Climate and Development Knowledge Network (CDKN), the Global Green Growth Institute (GGGI), the Low Emissions Development Strategies (LEDS) Global Partnership, and the United Nations Development Program (UNDP). Furthermore, as this report makes clear, low carbon planning and the data collection and modeling work that it entails should be seen as a **continuous process that eventually becomes part of the broader economic planning cycle within governments.** For this, strong internal modeling capacity and access to high quality data and tools is critical, and this is an area where donors, development institutions, and specialist providers should be ready to offer well-coordinated and customized support. For its part, ESMAP has developed a suite of low carbon development planning and modeling tools, now being actively used by a number of client countries.

However, there is only so much that can be done at the economy-wide level. Moving on to more in-depth sectoral analysis, and then following up with policy design and implementation, is likely to be the logical next step for many countries. There is also a real need to make low carbon development 'investable' in the near term—whether by local investors, international private capital, bilateral donors, or multilateral development banks.

ESMAP will continue to provide support across this spectrum of activities in response to client country demand. We will also continue to develop our suite of tools, and plan to make these tools 'open access'—freely available for continuous improvement by clients and other stakeholders. We will work with other organizations that are active in this field to ensure that lessons and knowledge is widely shared, and to encourage coordination in the support being provided to our clients.

Rohit Khanna
ESMAP Program Manager

LIST OF CONTRIBUTORS

This report draws on work from a large number of people, including a series of unpublished technical papers, a previous ESMAP publication from the start of the program, and the country-specific low carbon studies that were the main outputs in each case.

The low carbon growth country studies program was led from 2007–2010 by Jane Ebinger who also authored or edited many of the outputs on which this report is based. Substantial inputs were provided by John Rogers and Maria Shkaratan. This final synthesis report was edited, and a number of sections written, by Oliver Knight. Peer review was provided by Pierre Audinet, Carter Brandon, Istvan Dobozi, Christophe de Gouvello, Richard Hosier, Rohit Khanna, John Rogers, Chandra Shekhar Sinha, Chandrasekeren Subramaniam, and Xiadong Wang. Final editing and production of the report was undertaken by Nick Keyes and Heather Austin.

The individual country studies involved the following World Bank contributors:

- **Brazil |** Team led by Christophe de Gouvello, and including Adriana Moreira, Alexandre Kossoy, Augusto Jucá, Barbara Farinelli, Benoit Bosquet, Fernanda Pacheco, Flavio Chaves, Fowzia Hassan, Francisco Sucre, Garo Batmanian, Govinda Timilsina, Jennifer Meihuy Chang, Mark Lundell, Mauro Lopes de Azeredo, Megan Hansen, Paul Procee, Rogerio Pinto, and Sebastien Pascual
- **China |** Team lead by Ranjit Lamech during concept stage and by Carter Brandon during implementation. The team included Ximing Peng and Noureddine Berrah (renewables), Feng Liu and Carter Brandon (cement industry), and Beatriz Arizu de Jablonski, Defne Gencer, Ximing Peng, and Lijin Zhang (power dispatch)
- **India |** Team initially led by Kseniya Lvovsky and in a subsequent phase by Kwawu Mensan Gaba with Charles Cormier as co-leader of the task team. The team included Bela Varma, Gaurav Joshi, John Allen Rogers, Kirstan Sahoo, Kumudni Choudhary Masami Kojima, Mustafa Zahir, Muthukumara Mani, Richard Damania, and Rohit Mittal
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- **Mexico |** Team led by Todd Johnson, and including Claudio Alatorre, Feng Liu, and ZayraRomo
- **Poland |** Team led by Erika Jorgensen, and including Ewa Korczyc, Gary Stuggins, John Rogers, Leszek Pawel Kasek, and Ryszard Malarski
- **South Africa |** Team led by Xiaodong Wang and subsequently Karan Capoor, and including Brian Henderson, Dilip Limaye, Grayson Heffner, Luiz Maurer, Reynold Duncan, and Victor Loksha

Finally, this work would not have been possible without the input and participation of a wide range of stakeholders from each of the seven countries involved, including government officials, academics, local consultants, and representatives from industry, civil society, and technology suppliers.

EXECUTIVE SUMMARY

Developing countries are faced with the dual challenge of reducing poverty while improving management of natural capital and mitigating the emission of greenhouse gases (GHGs) and local pollutants. The challenge is particularly acute for large, rapidly growing economies, such as India, China, and Brazil. In response to this challenge, ESMAP and the World Bank began in 2007 to provide support to countries to develop long-term frameworks for reducing GHG emissions in a way that is compatible with economic growth objectives and tied to national and sectoral plans. In total, seven studies were conducted between 2007 and 2010, for the following countries: Brazil, China, India, Indonesia, Mexico, Poland, and South Africa. This report collates the lessons learned from these studies and is intended as a practical guide for government officials, practitioners, and development agencies involved in low carbon development planning.[1]

The low carbon studies were tailored to the individual needs of each country involved. In Brazil, India, Indonesia, Mexico, and Poland the studies took the form of an economy-wide analysis of low carbon growth potential, employing a range of data and modeling tools. The governments of China and South Africa conducted their own analyses, but requested the assistance of ESMAP and the World Bank for peer review and to get international expertise on specific focus areas, such as energy efficiency and renewable energy. The combined outputs, and the modeling tools developed as part of the program, represent a significant contribution to international efforts on climate change mitigation and low carbon development.

COUNTRY-LEVEL OUTCOMES

- **Potential to avoid large volumes of GHG emissions.** In all of the countries studied, there is potential for large-scale reductions in GHG emissions against business-as-usual trajectories while maintaining economic growth targets. However, achieving these reductions will require action across economies, covering energy supply and demand, land use, and forestry, urban development and planning, and sustainable transport.
- **Many interventions will pay for themselves.** A significant percentage of the emissions savings come at negative cost, meaning they will actually contribute to economic growth and competiveness. This includes measures such as increasing cogeneration, improving vehicle efficiency, and reducing electricity system losses. However, even win-win investments frequently face hurdles that require a concerted policy response.

[1] Another common and analogous term is 'low emission development strategies' (LEDS).

- **Developing countries are already acting.** These low carbon studies have contributed to an ongoing process within each country to identify opportunities for green growth, while limiting the risks associated with being locked into high carbon development. Countries are incorporating the findings from this work into their development planning, and this is helping to influence some of their policy and investment decisions.

IMPLICATIONS FOR INTERNATIONAL CLIMATE POLICY

- **More ambitious global action is still required.** Although the measures outlined in these seven studies are ambitious in the country context, much greater global action will be needed to limit the average temperature rise to 2°C. Changing this will require stronger efforts at the international level to bring down technology costs, support the development of new technologies, scale up private sector financing, and provide climate finance to developing countries in support of additional action.
- **Support the mainstreaming of climate change.** As an economy-wide challenge, low carbon development requires the active engagement of a wide range of government ministries and agencies—not just environment ministries. International support for low carbon planning should therefore avoid the creation of parallel initiatives and reporting mechanisms, and instead seek to improve the capacity of countries to mainstream climate change across their policy-making processes.
- **Studies are a first step; support for implementation is required.** As countries undertake low carbon development studies, and improve their capacity in this area, there is likely to be an increase in demand for policy and technical advice to design and implement measures targeting specific sectors. With a number of initiatives supporting economy-wide planning, follow-up support for more detailed sectoral analysis may be required.

LESSONS LEARNED FOR FUTURE LOW CARBON STUDIES

- **Countries must take the leading role.** Demand for low carbon studies starts with the host country, and countries must take a leading role if such studies are to be effectively executed and implemented. Agreeing to the objectives, scope, and process, gaining access to accurate data, and then translating the findings and recommendations from the study into action all require leadership from the host Government.
- **Adopt a flexible approach and build a multi-disciplinary team.** Every country interested in low carbon planning will have different questions that need answering or sectors that need particular attention. The process must therefore be flexible to these needs and successful at bringing low carbon development or modeling experts together with those responsible for mainstream development planning; a group of low carbon experts working in isolation is unlikely to have much traction.

- **Stakeholder engagement and consensus building is essential.** An important and often understated element of this work was the dialogue and consensus building that occurred across different sectors, often involving multiple ministries, agencies, and stakeholders that would not routinely be in contact with each other. Different priorities and interests were reconciled through this process, and the study's findings became richer and more robust.
- **Allow sufficient time and resources.** The experience with these economy-wide low carbon studies suggests that such work cannot be rushed. The average length of time was around 30 months from start to finish, with a resource requirement of US$ 0.5 to 1.5 million per study. Where detailed scenario modeling is required across multiple sectors, the costs can be even higher.
- **Investments in data and tools will continue to be needed.** In many countries, data availability and accuracy is a major limiting factor. Investments in data collection and reporting, and the modeling tools and capacity needed to use and interpret it, is crucial for governments to be able to undertake low carbon planning and design effective policies and regulations. Furthermore, the tools available to countries could be simplified and made easier to access, with a stronger emphasis on data transparency and openness.

1 | NATIONAL RESPONSES TO A GLOBAL CHALLENGE

GLOBAL CONTEXT

Reversing the steady growth of GHG emissions, and thereby reducing the risk of dangerous climate change, is arguably the biggest challenge facing humanity in the 21st century. It will require a revolution in how we source and use energy that will radically reshape the global economy to one that supports much greater resource efficiency. But this must be achieved in the context of huge development needs—in particular, lifting billions of people out of poverty. Reflecting this, the overriding policy goal for many developing countries is economic growth. Sustaining economic growth, while breaking the historic link between growth and GHG emissions, presents not just a huge challenge but also a major opportunity.

With non-OECD (Organization for Economic Co-operation and Development) countries responsible for over 50 percent of current emissions, and projected to account the bulk of the increase in emissions to 2035, if current policies continue, abatement will need to occur in both developed and developing countries for emissions to be kept under 450 ppm CO_2e (International Energy Agency, 2011). Furthermore, coinciding with the 20-year anniversary of the UN Conference on Sustainable Development, or 'Rio+20', in June 2012, attempts are being made to better integrate action on climate change into the broader concept of 'green growth'.

International environmental considerations are not the only reason why countries are exploring low carbon development pathways. There are significant opportunities to benefit from the growth of new industries—and avoid the risks associated with high carbon lock in. Developing countries, particularly those that are rapidly industrializing, could be major beneficiaries of the transition to a global low carbon economy through the development and commercialization of new technologies, by reducing their exposure to volatile fossil fuel prices, and by deploying cleaner, cheaper, and smarter forms of physical infrastructure and basic service provision.

Because carbon dioxide, the most important GHG from a climate change mitigation perspective, is a product of virtually all forms of economic activity, low carbon planning is necessarily an economy-wide undertaking. This, combined with the multiple policy and regulatory tools available to governments and the need to motivate behavioral change in individuals and organizations, introduces a high degree of complexity and uncertainty into attempts to analyze the potential for low carbon development.

NATIONAL STUDIES

Over the period 2007–2010, seven major economies—Brazil, China, India, Indonesia, Mexico, Poland, and South Africa—undertook low carbon studies aimed at identifying opportunities and related financial, technical, and policy requirements to move towards low carbon development pathways. Together these countries represent 33 percent of global CO_2 emissions in 2007 (World Bank, 2011a), and just three of them (Brazil, China, and India) were responsible for over 40 percent of global investment in renewable energy in 2010 (UNEP, 2001). Their collective importance to climate change mitigation is highly significant.

These studies, supported by ESMAP, helped the governments of these countries to assess their development goals and priorities alongside opportunities for the reduction of GHG emissions, and better understand the additional costs and benefits of low carbon growth. While some of these countries, notably India and Mexico, undertook economy-wide analyses of low carbon growth paths, others, such as China, opted for more focused and deeper technical analysis of specific sector-based issues to lower the energy intensity of their economy. The motivations for undertaking this work were mixed: some countries were interested in understanding how low carbon development could support their broader development goals by reducing the energy intensity of gross domestic product (GDP) growth or increasing energy security; others were interested in building the evidence to support their negotiating position in the United Nations Framework Convention on Climate Change (UNFCCC) negotiations.

Taken together, the experiences of these seven countries demonstrate that structured engagement across a country's economy can build consensus across different ministries and government agencies: agreeing baselines, policy objectives, abatement options, trade-offs, and costs, often covering multiple sectors. Thanks to dedicated funding from the United Kingdom's Department for International Development (DFID), the program was able to invest in detailed scenario modeling, generating a wealth of knowledge and tools that can be applied in other countries, reducing the prospective cost of subsequent studies.

As Table 1.1 shows, 10 countries have benefited from ESMAP support for low carbon planning activities through the World Bank and a wide range of countries are conducting similar activities with support from other organizations.[2]

Table 1.1 | Countries Undertaking Low Carbon Development Planning with ESMAP Support

COUNTRY	STATUS
Brazil	✓ Completed 2010
China	✓ Completed 2010
India	✓ Completed 2010
Indonesia	✓ Completed 2010
Macedonia	Expected 2012
Mexico	✓ Completed 2010
Nigeria	✓ Completed 2012
Poland	✓ Completed 2010
South Africa	✓ Completed 2010
Vietnam	Expected 2013

Source | Author.

PURPOSE OF THIS REPORT

With this report, ESMAP aims to support low carbon development activities that are underway or being planned in an increasing number of developing countries by sharing the key lessons, findings, and policy conclusions that can be drawn from these seven original country studies. ESMAP also hopes that this report will contribute to the global debate over how best to facilitate the preparation and imple-

[2] The Coordinated Low Emissions Assistance Network (CLEAN) maintains a database of ongoing activities on the Open Energy Information wiki sponsored by the US Department of Energy.

mentation of low carbon development strategies and Nationally Appropriate Mitigation Actions (NAMAs) as part of the process under the UNFCCC. The intended audience is developing country decisionmakers, low carbon planning practitioners, and donor country representatives interested in supporting action on climate change. The diversity of the audience is reflected in the breadth of the content, and in the detail afforded to issues such as scenario modeling and data collection. However, this report is intended to provide an accessible summary of the outputs and outcomes from this work, while providing practitioners with sufficient detail to add value to ongoing or future studies.

Including this introduction, the report has five chapters, plus an Executive Summary. Chapter 2 provides a summary of the methodological and process issues, including the scope of the studies and key lessons learned. Chapter 3 explains the importance of scenario modeling to many of the studies, and describes the options and process for undertaking such work, including the modeling tools developed by ESMAP. Chapter 4 outlines the headline results from each of the seven studies, and the policy or investment outcomes where evidence exists. Finally, Chapter 5 attempts to draw out the policy conclusions from this work, including the possible implications of following a low carbon development pathway, ways to support implementation, the need for international processes to reflect realities on the ground, and priorities for future work.

ADDITIONAL RESOURCES

This report draws on a large body of supporting material, including the low carbon studies and supporting papers, a number of accompanying briefing papers, and a range of publications and outputs produced externally to this work program. A wide range of material is available on the ESMAP website at www.esmap.org, including two of the tools described in this report.

2 | IMPLEMENTING THE LOW CARBON DEVELOPMENT PROCESS

OBJECTIVES AND SCOPE

When ESMAP began supporting low carbon studies in 2007, the country context was quite different from what it was today. For example, all the countries undertaking the low carbon studies were involved in detailed negotiations on the Bali Action Plan and in the run up to the 2009 UNFCCC Conference in Copenhagen. For several of the countries, this introduced political sensitivities that affected the scope and timing of this work, for example, related to defining baseline scenarios that could then be used as the basis for discussions over mitigation commitments in the context of international negotiations.

This backdrop, combined with the starting point of each country, their policy aims, their internal capacity, and in some cases analysis that was already ongoing, meant that the objective and scope of each of the studies differed, as outlined in Table 2.1. This, and subsequent experience at ESMAP and the World Bank, suggests that support for low carbon planning must be as flexible as possible to fit with country priorities and capacity. Trying to apply a rigid view of low carbon development, or rolling out a particular methodological framework, is unlikely to be successful in building consensus around feasible policy and investment options.

Two broad categories can be identified from the seven studies undertaken: (i) economy-wide low carbon planning, and (ii) support for the identification and implementation of low carbon options in particular sectors or subsectors. Only two of the seven countries considered here fall into the latter category (China and South Africa). The five studies that could be categorized as economy-wide low carbon planning generally took a long-term view out to 2030. Although all of these countries already had climate change plans or strategies, this work allowed a more detailed exploration of the costs and benefits of different abatement scenarios, trade-offs, and associated policy options. Scenario modeling was a significant component, with major investments made in new models and tools as a result of the work in Brazil, India, and Poland. This is described in more detail in Chapter 3.

LESSONS LEARNED ON PROCESS

The seven studies were supported by World Bank specialists working within their respective regional departments, with advice and funding provided by ESMAP. This helped ensure that the work was well grounded within the existing country dialogue, and allowed the methodology to be customized according to each country's needs. However, a number of lessons emerged that were common to the successful completion of the studies, and these are summarized below.

Table 2.1 | Starting Point, Objective, and Scope of Each Low Carbon Study

	STARTING POINT	OBJECTIVE	SCOPE
Brazil	National Plan on Climate Change (2008)	Assess opportunities to reduce GHG emissions while fostering economic development	Land use, land use change, and deforestation; energy supply and demand; transport; waste management
China	National Climate Change Program (2007); 11th Five-Year Plan (2006–10)	Support policy/strategy development to reduce energy intensity	Energy efficiency and renewable energy
India	Integrated Energy Policy (2006); 11th Five-Year Plan (2007–12); National Action Plan on Climate Change (2008)	Identify low carbon growth opportunities for India and contribute to global climate change mitigation	Power generation, transmission and distribution; household electricity consumption; non-residential buildings; energy intensive industries; road transport
Indonesia	National Action Plan on Climate Change (2007)	Address macroeconomic questions of costs and effects of low carbon development on economic growth	Strategic options for development
Mexico	National Climate Change Strategy (2007)	Identify and analyze low carbon options, policies, and strategies	Comprehensive low carbon program
Poland	Energy Policy of Poland until 2030 (2006)	Determine how to transition to a low carbon emissions economy	Integrates bottom-up engineering analysis with top-down economy-wide modeling
South Africa	National Climate Response Strategy (2004); Long-Term Mitigation Scenario (2007)	Review Long-Term Mitigation Scenarios and develop implementation strategies in key sectors	Implementation support for energy efficiency

Source | Author.

Supporting National Goals

For low carbon planning to be a useful and relevant exercise, it is crucial that the process responds to, and informs, national policy goals. The objectives and scope of each of the seven country studies was determined by government and local stakeholders and tailored to the country's economic circumstances. The studies drew on available national policy paper(s) and goals for climate change, growth, and sector development to define the scope and work plan. This began a dialogue on low carbon development that made use of established lines of communication, national climate change discussions, and related sector activities. Cross-sector analysis—including the interfaces and trade-offs among agriculture, land use, energy supply, residential and industrial energy use, transport, and waste management—while sometimes difficult to carry out, was critical for a comprehensive assessment of mitigation opportunities.

Identifying a Focal Point and a Champion

The importance of having a strong and influential institutional focal point through which external assistance and internal inputs could be coordinated emerged as a key factor in gaining buy-in to the process. For example, in India the study was coordinated by the Planning Commission, with the Ministry of Power playing a prominent role (since approximately 50 percent of the coun-

Table 2.2: Partnerships at the Country Level

COUNTRY	LEAD INSTITUTION(S)	COORDINATING BODY
Brazil	Ministry of Foreign Affairs, Ministry of Environment, Ministry of Science and Technology	Inter-Ministerial Committee on Climate Change (1999)
China	National Development and Reform Commission	National Development and Reform Commission
India	Planning Commission, Ministry of Environment and Forests, and Ministry of Power	Prime Minister's Council on Climate Change (2007)
Indonesia	Ministry of Finance, National Council on Climate Change	National Council on Climate Change (2008)
Mexico	Inter-Ministerial Committee: Energy, Environment and Finance	Inter-Secretarial Commission on Climate Change (2005)
Poland	Ministry of Economy	
South Africa	Department of Environmental Affairs and Tourism, Department of Energy, Eskom, National Energy Efficiency Agency	Department of Environmental Affairs and Tourism

Source | Author.

try's CO_2 emissions are under their jurisdiction), and the Ministry of Environment and Forests (which is the lead agency in the international climate change negotiations), the Ministry of New and Renewable Energy, and the Ministry of Finance also involved. Several layers of coordination were necessary to conduct the study as it was clear that a low carbon study in India would significantly benefit from the active involvement of the three levels of governance: at the federal, state, and substate levels. The role played by planning and finance ministries in several of the countries reflects a growing recognition that climate change is much more than simply an environmental issue.

Representatives from the ministries of finance, planning, environment, and foreign affairs, among others, took up the role of focal point and provided an interface with domestic climate change committees (see Table 2.2). Although some committees already existed, others were created during the study; a number included interministerial representation. These committees provided a useful platform to discuss the study, its findings and establish contacts. For example, in Mexico's case, an interministerial committee on climate change was established in 2005, which has been instrumental in developing the country's climate change strategy and was consulted extensively in the preparation of the low carbon study for Mexico.

A champion is far more than a figurehead; he or she is vital to the success of the project. Sometimes a number of local champions may also be needed, although more important than the number of champions is their commitment, capacity, and standing.

Creating a network of stakeholders can be a lengthy process. In Brazil, this process went quite smoothly because key individuals could be contacted directly, without any official coordination from the government; the World Bank project team felt that this streamlined the process. In China's case, due to three separate studies being conducted, there were several champions—at national and provincial levels and in both public and private sectors.

Engaging with a Broad Group of Stakeholders

The economy-wide nature of low carbon development necessitates the engagement of a broad range of institutions and stakeholders beyond the national focal point. Government stakeholders in the seven country studies included the key economic ministries (finance, planning), as well as the other ministries and agencies representing GHG-emitting sectors included in the study (such as energy, environment, and transport). Public and private institutions, civil society leaders, and groups positioned to catalyze action across multiple sectors of the economy (e.g., regulators and trade associations) were often included in the process. Nongovernmental organizations (NGOs) and representatives of labor, women, minorities, and rural interests ensured an integrated response to climate change, while communications efforts supported information flow and broad ownership of the eventual results. Box 2.1 highlights some of the differences in stakeholder engagement between the seven studies.

Early stakeholder engagement is particularly important for agreement on the objectives, goals, and success criteria for the study, for gaining access to data sources, and for getting agreement on underlying assumptions. Thereafter, regular meetings with government counterparts and stakehold-

BOX 2.1

Differences in Stakeholder Engagement between the Seven Studies

In Brazil, a consultation round was organized early in the process, which enabled the participation of stakeholders from government, academia, and civil society. During the first few months, a round of bilateral meetings was organized to present the context of the study, identify the existing knowledge in various national institutions and centers of excellence, and build the team and consensus around the work program. Another workshop was organized after the consultation round to bring together the most relevant stakeholders in the process.

The consultations ensured that views from the private sector, academia, and NGOs were taken into account The project team also included some members from the private sector, academia, and a federation of industries.

In India, Indonesia, and Poland, various stakeholders were involved at different stages of the process to build understanding about low carbon options as well as a stronger constituency for the study results. In India, NGOs and experts participated as peer reviewers and provided inputs to the materials presented to them. In India, the private sector participated through, for instance, the development of the analysis of renewable energy related issues as well as the identification of relevant funding mechanisms for mitigation options. In Indonesia, the study team had many opportunities to share information with think tanks, universities, NGOs, and donors. In Poland, think tanks and the private sector were closely involved.

Because of the sector-specific nature of the studies in South Africa and China, there was less of a need for broad consultations. Sector-specific agencies were consulted and involved. The stakeholders were more narrowly defined and the need for public consultations was diminished.

ers were held to maintain communication, present preliminary results, and solicit feedback.

Involving stakeholders in the data identification and collection process is critical. It can support better access and understanding of the data and its limitations, and ensure sustainability of low carbon development efforts. It is important to understand where data can be sourced as decisionmakers in the sectors being modeled are among the key stakeholders involved in data collection. These include the national statistical agency, ministerial units responsible for data collection, research entities both within the government and with academia/universities, NGOs, consulting firms and other private sector entities.

RESOURCE REQUIREMENTS

The participatory nature of the process certainly brought significant gains—local ownership, study relevance, sustainability beyond the study, and development of human capacity—but at significant cost in terms of time and resources. On average, the cost of each study varied from US$ 0.5 million to US$ 1.5 million and took 30 months to implement. This allowed time for meaningful stakeholder participation, a transparent and sustainable study process, and local capacity building. For example, the first year of the Mexico study was spent agreeing to the objectives and scope of the study and engaging team members, while the second year was devoted to analysis and delivery of results. In the cases of Brazil and India, significant effort was devoted to developing analytic models for land use and energy planning, respectively, that was not available when the studies began. In a number of the studies, additional time was required to manage multiple funding streams that complicated study administration, reporting, and delivery. Such costs must be budgeted for from the start.

Securing human resources was also crucial. Study teams gathered data, conducted analysis, and worked to maintain stakeholder engagement throughout the process and into implementation. Team composition was important and became a key discussion with government counterparts at the outset to reach consensus on desired local representation, and to identify gaps in expertise and establish international support requirements. In India, the government sought international expertise to complement existing low carbon growth assessments. In Brazil, the government was explicit about using local experts. Across the seven countries, study teams were generally comprised of local experts supported by targeted technical assistance. Given the cross-sectoral nature of the work, multiple teams were sometimes engaged, requiring coordination, integration of results, and scheduling of deliverables. Good communication between teams was essential.

BUILDING LASTING CAPACITY

In each of the seven countries, ESMAP support was requested to build technical and strategic capacity and to promote dialogue on cross-sectoral low

carbon policies and mitigation strategies beyond traditional boundaries. For example, finance and economic planning ministries needed to better understand the emissions profile of the economy and the interactions between sectors—such as the relationship between transport and energy demand.

Capacity building was facilitated through structured, regularly scheduled interactions among team members, government ministries, experts, and stakeholders, as well as through workshops and meetings that provided space for cross-sectoral discussions. By doing so, the low carbon studies brought the climate dialogue from ministries of environment (traditionally responsible for international dialogue on climate change issues) to other parts of governments (national and subnational), particularly those ministries and agencies dealing with finance, and sectors having significant opportunities for carbon mitigation or sequestration (e.g., energy ministries). This cross-sectoral communication builds on existing expertise and knowledge in individual sectors to support more holistic policy development.

Regional and international meetings and conferences further enabled national teams to share action plans with their neighbors and peers globally. This was supplemented by informal knowledge exchange across the country studies. For instance, Brazil participated in the peer review of South Africa's Long-Term Mitigation Scenarios (LTMS), while Indonesia and Brazil used the transport planning model initially developed for India. Courses and technical collaboration were organized and funded through bilateral and multilateral institutions to provide focused educational opportunities.

3 | MODELING LOW CARBON DEVELOPMENT

Scenario modeling is an important part of the low carbon planning process. It typically focuses on the national level and on sectors with high GHG emission levels—energy, transport, land use, forestry, agriculture, and waste management. Modeling helps understand where a country or sector currently stands and the direction in which it is moving with respect to the level of GHG emissions. It helps to identify emission drivers, the measures and resources required for GHG abatement, and where a country wants to be at a particular point in time and what may be needed to achieve this. But, perhaps, equally as important is the process of learning and consensus building that modeling entails.

This chapter discusses various modeling approaches applied in support of low carbon planning, drawing on the experiences of the seven country studies.

MODELING APPROACHES

There are many ways in which modeling can support low carbon planning, and a range of different approaches and tools are available to the analyst. The first step in the process is to define the questions that need to be answered, and the scope (number of sectors, depth, timeline, etc.). Scenario modeling can then be used to help understand where a country or sector currently stands, the direction in which it is developing, the impact of this development on the level of GHG emissions, the resources that would be needed for different levels of abatement, and finally the policies and measures that might be required to trigger the requisite investments.

When selecting modeling approaches and tools for a low carbon study, it is important to understand the types of models that are available and the questions that each can address. This is not always straightforward as modeling tools are numerous, often proprietary, and may have limitations on the extent to which assumptions can be interrogated. A suite of models is usually required to answer different questions; no single model covers everything. For the purposes of low carbon planning, modeling approaches may be best classified as 'bottom-up' or 'top-down'.

Bottom-Up Models

Bottom-up approaches use micro-level data that reflects individual activity or household behavior. Bottom-up models are 'engineering style' models (in that they make use of real-world technical data) that can focus on a large number of specific abatement options, but cannot take into account feedback effects from adjustment in prices or transaction costs for the adoption/implementation of a specific abatement option. They can be used to examine efficiency scenarios from an engineering or sector point of view (e.g., in the power and transport sectors, it would focus on ownership and usage level of energy-consuming devices/vehicles), and they have the benefit of enabling analysis across different heterogeneous subgroups.

Three subcategories of bottom-up models can be identified—optimization, simulation, and accounting—which have different functions and focus as described below (see Box 3.1 for a more detailed example from the power sector):

- **Optimization models** are typically used to estimate the results from various decision alternatives given a set of constraints (e.g., minimizing the cost of supply investments under constraints of satisfying specific energy demand). Optimization models have the advantage of providing the solution that best achieves the specified objective, but they often lack the flexibility to take many real-world limitations into account.
- **Simulation models** offer more flexible structures than those typically possible with optimization models and can accept large amounts of real-life data and assumptions. By their nature, however, these models are non-optimizing and do not by themselves guarantee that the best solution was identified. This is achieved by running multiple scenarios and choosing among them.
- **Accounting models,** rather than simulating behavior, are used to manage data and evaluate the impact of changes in activities on the GHG emissions that they produce.
- Based on these three types of models, various hybrids can also be created.

A key advantage of the bottom-up modeling approach is that it allows sharing and assessment of practical data and scenarios that all stakeholders can easily identify. For example, in on-road transport it allows comparison of vehicle ownership, technology, usage, and modal shift to other means of transport as well as the impact of other economic (GDP growth, prices), demographic (population growth, urbanization), and geographical (rural/urban and regional/state) factors. Since bottom-up modeling does not forecast based on historic time-series data, it can easily accommodate the significant departures from historic tendencies that need to be analyzed in low carbon studies if substantial improvements in energy efficiency are to be achieved.

A core difference between the bottom-up and top-down modeling approaches is the type of input information used. In a bottom-up model, data is gathered from energy consumers and about equipment and appliances in a country. It could be, for example, all power plants or all types of cars that are in use. This data is then integrated by the model to provide an assessment of the total energy consumed and produced. Since it does not project supply and demand from historic tendencies, it can react quickly to changes in technology and policy that are modeled in each scenario. Therefore, the model can be directly used for planning improvements. Bottom-up models tend to be conservative in their outputs since they are grounded in current practical realities.

Top-Down Models

Top-down models are macroeconomic models that assess economy-wide impacts of GHG policies and actions, based on international data correlations.

BOX 3.1

Strengths and Weaknesses of Bottom-Up Modeling Approaches: Examples from the Power Sector

OPTIMIZATION MODELS

Examples | MARKAL, EFOM, WASP (electricity sector). Typically use linear programming to identify energy systems that provide the least expensive means of providing an exogenously specified demand for energy services. Optimization is performed under constraints (e.g., technology availability, supply = demand, emissions, etc.). Models usually choose between technologies based on their lifecycle costs. A least-cost solution also yields estimates of energy prices (the 'dual' solution).

Strengths | Powerful and consistent approach to analyze the costs of meeting a certain policy goal. Especially useful when many options exist.(e.g., identifying the least-cost combination of efficiency, fuel switching, emissions trading for meeting a CO_2 emissions limit).

Weaknesses | Generally assume perfect competition (e.g., no monopolistic practices, no market power, no subsidies, all markets in equilibrium) and usually do not take real practice into account. Assumes energy is the only factor in technology choice. Unless carefully constrained, they tend to yield extreme allocations. They can be relatively complex and data intensive, and therefore hard to apply for less expert users. For this reason, they are less useful in capacity building efforts. They are often difficult for stakeholders to understand in other sectors, and are not well suited to examining policy options that go beyond technology choice, or hard-to-cost options. They can appear to be a 'black-box' to non-modelers without a basic understanding of the modeling process.

SIMULATION MODELS

Examples | ENPEP/BALANCE, Energy 20/20. These models simulate the behavior of energy consumers and producers under various signals (e.g., price, income levels, limits on rate of stock turnover).

Strengths | Not limited by assumption of 'optimal' behavior. They do not assume energy is the only factor affecting technology choice (e.g., BALANCE uses a market share algorithm based on price and 'premium multipliers' that simulate consumer preference for some commodities over others).

Weaknesses | They tend to be complex, opaque, and data intensive. Hard to apply for non-expert users, therefore less useful in capacity building efforts. Behavioral relationships can be controversial and hard to parameterize, particularly where future policy looks to change historic behavioral relationships (such as in defining a low carbon development pathway). Future forecasts can be very sensitive to starting conditions and parameters.

ACCOUNTING MODELS

Examples | EFFECT, LEAP, MEDEE, MESAP. Physical, engineering-style description of the energy system. Evaluate the outcome of scenario-based policy decisions that are defined outside of the model. They explore the resource, environment and social cost implications of alternative future "what if" energy scenarios.

Strengths | Simple, transparent and flexible, lower data requirements. Do not assume perfect competition. Capable of examining issues that go beyond technology choice or are hard to value. Especially useful in capacity building applications.

They are used to predict economy-wide effects but cannot evaluate in detail the specific abatement technologies that reduce emissions.

In contrast to bottom-up modeling, a top-down model uses aggregated national data such as total electricity production, or overall sales of gasoline; this makes it easy to start using the model. The downside is that the accuracy of the model is heavily linked to the assumptions made and behavior correlations. These are often based on non-country-specific data and historic tendencies that the low carbon study is looking to change. Mitigation possibilities from these models can often be optimistic and unsupported by technical and operational feasibility.

There is a wide experience of using computable general equilibrium (CGE) modeling, a form of top-down modeling, for environmental policies both on country and multi-country level. CGE modeling is widely used in ex-ante policy assessments and the assessment of long-run impacts. There are several advantages of this approach, including tractability, computability, and a well-established modeling tradition, as well as availability of software (GAMS and GEMPACK). CGE models have since been joined by dynamic stochastic general equilibrium (DSGE) models, which are increasingly used for mainstream macroeconomic analysis. DSGE modeling has evolved as the unification of the real business cycle approach with macroeconomics of market frictions and imperfections. Due to computational issues, DSGE models are typically limited with respect to the number of variables under consideration (i.e., to the available disaggregation).

When selecting a top-down model for low carbon economy-wide analysis, it is important to have stakeholder confidence in the model and for the results to be country specific. The model that is selected needs to be consistent with:

- Availability and quality of data, in particular emissions and energy data that can be matched to national accounts and other economic data
- Capacity of local modelers/government staff who may want to maintain and use the model subsequently since a simpler model may serve policy-makers better than a more complete but complex model that is proprietary and cannot be easily shared or updated
- Existing macro models or energy models in the country that might be expanded to include climate analysis
- The scope of questions that will be the model's focus, such as the degree of sector disaggregation that is needed, the importance of international trade dimensions, and the importance of global or regional scenarios (such as setting of global GHG targets)
- The data source for global models; for any particular country the data may not be very high quality or up-to-date

Many global models draw their data from the Global Trade Analysis Project (GTAP), which divides the world into 113 countries and regions, of which 95 are countries and the other region-based aggregations. The database divides global production into 57 sectors—with extensive details for agriculture and food and energy (coal mining, crude oil production, natural gas production, refined oil, electricity, and distributed natural gas). This makes GTAP an easy choice for multi-country analysis focused on the interaction between economies because of the consistency of this data set. However, due to numerical and algorithmic constraints, a typical model is limited to 20 to 30 sectors and 20 to 30 regions. Another limitation is the selection of 2004 as the base year, which might not be ideal for an individual country analysis.

Linking Bottom-Up and Top-Down Approaches

While some studies use bottom-up and top-down modeling as complementary approaches, very few set such an ambitious goal as to link them together. The Poland low carbon study managed to combine both approaches. In this study, the outputs of the cost-benefit analysis at the micro level were translated into inputs for a DSGE Model, which then estimated the impact of abatement scenarios on GDP, welfare, and employment. See Annex B for further details.

Selecting a Modeling Approach

In selecting a modeling approach, there are a number of factors to consider:

- **Simplified, open, and transparent accounting tools are available for bottom-up modeling** that have the benefit of supporting the engagement of multiple stakeholders in the planning process, sharing assumptions, and scenario analysis while building ownership and consensus at the same time. It may be useful to start the data collection and modeling effort with a bottom-up approach to help build this ownership.
- It is likely that **several models will need to be used and integrated in the low carbon development study,** and that there may be significant differences in the scenarios generated by bottom-up and top-down models over the period of analysis (e.g., 20+ years). Each model will approach the question of what might be a realistic low carbon development pathway from a different angle, illuminating important aspects of the economics of GHG mitigation and implementation strategies. Policymakers will need to be ready to consider outcomes from various models to answer different questions, rather than a single variant.
- There are often a number of **specialized models** in different sectors (e.g., for power planning or for developing a transport master plan) and the outputs from these models can serve as inputs to the kind of integrated modeling framework used for economy-wide low carbon development planning analysis.
- Any modeling exercise needs to be designed at the outset so that **models can be maintained and updated in subsequent years.** The ease of use of models and local capacity and resources needed to update the low carbon scenarios are, therefore, an important consideration in selecting an approach. Over a period of decades—the scope of most low carbon studies—assumptions about efficiency improvements within sectors, how the development of one sector will affect other sectors, as well as shifts towards less carbon-intensive activities as part of normal development will have a large impact on results. Policymakers will need to think carefully about country-specific sector development in far more detail than is presently covered in economy-wide models.

Differences in Modeling Outcomes

The approaches and assumptions that are used in modeling for a given country will reflect differences in study objectives, methodologies used for sector analysis or modeling, variations in the start and end dates for low carbon modeling and alternative approaches for defining baseline or business-as-usual scenarios to name a few.

As an example, the Indonesian study did not use a discount rate to value GHG emissions. Mexico and India applied a fixed rate of 10 percent while the Brazil study instead looked at real agents for implementation (the private sector) and their rates of return to assess a break-even price for carbon, an approach developed in cooperation with a local financial institution. These differences impact results—including estimates of incremental costs of GHG reduction—and limit comparability between studies conducted in the same country by different bodies, as well as across countries. These issues can be further complicated by proprietary modeling concerns or data transparency issues. However, the International Institute for Applied Systems Analysis showed that, for a given country, when baseline assumptions and implementation periods are harmonized, bottom-up and top-down models produce similar results (IIASA, 2009).

SCENARIO MODELING

Carrying out scenario modeling is a systematic process with multiple feedback loops. Some generic steps are outlined below by way of guidance.

STEP 1 | Identify Data Needs

The quantity and extent of the data needed will depend on the scope of the low carbon development study, government plans for low carbon development, and the ongoing programs or plans within each GHG-intensive sector. Thus, the scope of the analysis will define whether the data requirement will cover the whole economy, only one sector, or a sector specific development program. Data requirements also depend on the type of modeling used: bottom-up or top-down.

Whatever models are selected to build and analyze low carbon scenarios, data will need to be collected to get a valid output. Most models require general data on economic development, such as:

- Planning horizon or timeframe for the reference and low carbon scenarios—typically 20 to 25 years
- Population size and annual growth rate, with a separation of data for both urban and rural populations
- Number of households and household size, considering separately both urban and rural households
- Annual GDP and the GDP growth rate for the modeling horizon
- Inflation and other macroeconomic data
- Social and private discount rates

- Per capita and household expenditure and their respective growth rates in both the urban and rural populations
- Fuel characteristics

Additionally, all bottom-up models will need sector-specific data for each sector included in the low carbon study. For the power sector, for example, data is needed on the age, capacity, usage, efficiency, and fuel type of each of the power-producing units in a country. Data is also needed on operating and maintenance costs, outage frequencies, fuel costs, planned investment in new capacity, and projected technical and commercial losses over time. Load-duration curves are required that represent the time profile (such as the peaks and troughs) of electricity demand and the associated dispatch of power plants. Further information on data sources is available in Annex A. National and sectoral expertise in relation to data availability, accessibility, and quality of various sources should be used at this stage to adjust the general data needs to the specifics of the country.

For low carbon planning to be an ongoing process rather than a one-off output, the data and assumptions used in the modeling effort will need to be updated periodically to take into account the changes and advances that occur over time. Thus, it is important when selecting data sources to promote those that will be updated in the future. It may be preferable to spend time gathering reliable and sufficient data for a limited number of key sectors or subsectors, while in the process building capacity to continue this work, rather than embarking on an ambitious program covering all areas of analysis based on unreliable or insufficient data.

STEP 2 | Gather and Validate Data

Data collection needs to be planned with a very clear understanding of the type of modeling to be done and policy questions to be answered, for which good stakeholder engagement is crucial. The process can be very time consuming, especially when many different sectors and agencies are involved, and sufficient time should be built into the project plan from the start.

Getting agreement on sharing data between ministries or with external stakeholders is often not straightforward. Officially published data may not be the only dataset available, and others may be more accurate or have greater granularity. However, there may be institutional barriers to sharing data between ministries, and data holders may see their data as confidential. None of the seven low carbon studies went as far as publishing raw data on the internet, but with increasing interest in open data initiatives and open access modeling tools, future studies may want to explore this option.

When data is missing, one option is to use sampling or some other data collection process to specifically address the gaps. The objective of data validation is to check data reliability and consistency, and minimize fragmentation and data gaps. Data gaps are common and can be addressed by using substitute or surrogate data, expert estimates, or proxies (similar indicators) or imputations based on available data, such as averages for particular types of locations or types of households. Inferior quality data may need to be eliminated and the best available data prioritized for modeling. Further details on conducting data validation and sectoral data checks are provided in Annex A.

STEP 3 | Establish a Baseline and Reference Scenario

Firstly, a baseline picture of the sector or economy should be developed from which it will be possible to forecast the future impact of development objectives and national strategies relating to GHG emissions mitigation. Following from this, the macroeconomic outlook can be developed, which entails forecasting population, GDP, and other macroeconomic variables for a predefined time horizon—typically 20 or 25 years.

The reference scenario (also called the 'business as usual' or 'best business' scenario) is a forecast for the defined time horizon that takes into account of current development plans and constraints. The reference scenario includes a description of demand for primary energy resources like coal, oil, gas, biomass, wind, geothermal, and nuclear power and demand for electricity. It identifies how those resources are used for electricity production and for other purposes, such as steam production in industry, air conditioning and space heating in buildings, and transport. A reference scenario is built by evaluating the business decisions that would happen in future years based on existing policies, as well as commitments and targets 20 to 25 years into the future, without taking into account the need to reduce GHG emissions. It describes primary energy resources and their uses, as well as the GHG emissions, by sector. The reference scenario also describes other energy uses and GHG emissions from other sources, such as agriculture, land use change, and industrial emissions. It establishes the most likely developmental path.

STEP 4 | Develop Low Carbon Scenarios

This step helps identify where the mitigation potential lies. It includes an assessment of financial and economic costs, institutional capacity, and barriers to arrive at a series of low carbon scenarios. Analysis is done by modifying the reference or best business scenario to include the opportunities for climate change mitigation with an objective of minimizing GHG emissions. This step involves selecting policy actions and investments from all the possible interventions aligned with the national development objectives that would lower GHG emissions. Scenarios are built as combinations of interventions. At this stage, the costs and benefits of low carbon measures are calculated and the impacts of uncertainties and possible slippage are included in the analysis through sensitivity analyses and other analytical tools.

The preliminary low carbon scenarios should be presented to the steering group and the technical specialists that have not been involved in the analysis. The objective is to solicit feedback on the inputs, assumptions used, and on the results, including comments on whether they are realistic and what sensitivity analysis need to be done.

STEP 5 | Prioritize Mitigation Measures

When cost and benefit analysis is completed, mitigation measures (such as technological interventions, policy, regulatory, and institutional frameworks) can be prioritized. This is not a purely technical process, but incorporates other factors, such as existing commitments, political priorities, and institutional strengths and weaknesses. A marginal abatement cost curve is one tool that helps prioritize options. It maps CO_2 emission reduction potential against the abatement cost, for a range of technologies. However, it has to be used in conjunction with other tools and data since it does not, by itself, convey the magnitude and timing of any investment needs, the difficulty of implementation, and any transaction costs.

Once mitigation measures are prioritized the financing required to mobilize resources and fund incremental costs associated with each low carbon scenario is estimated. In many cases, mobilization of private sector resources will require other actions to create an enabling environment.

USE OF MODELING IN THE LOW CARBON STUDIES

All of the seven studies have made use of scenario modeling (in some cases prior to the work funded by ESMAP), which involved the selection of modeling tools with international validity that could be best adapted to sector needs and national objectives, and the subsequent development of reference and low carbon scenarios. The choice of model, bottom-up or top-down, depended on the scope of the analysis, the sector(s) studied, and the resources and data available locally (see Table 3.1 and Box 3.2).

It is likely that countries will employ a range of models and tools for scenario modeling and analysis. The following text discusses two models that were developed by ESMAP to support one or more of the low carbon studies,

Table 3.1 | Selection of Models Used for the Low Carbon Studies

COUNTRY	MODEL	ORIGIN	QUESTIONS	COMMENT
BRAZIL	BLUM (Brazilian Land Use Model), a partial equilibrium econometric model that operates at two levels: (i) supply and demand of final crops and (ii) land allocation for agricultural products, pasture, and production forests	Commissioned by the study team and developed by the Institute for International Trade Negotiations	• What is the future land area allocation and land usage? Are these major drivers? • What are the expected impacts of proposed low carbon policies, in particular with respect to livestock productivity improvements, ethanol export expansion and mandatory forest restoration in terms of deforestation and carbon balance? • What are the least cost mitigation options (including for carbon uptake through improved land use practices)? What incentives/carbon price would be needed for the private sector to be willing to implement these options?	• Additional existing models used for energy and waste sectors. • A suite of models (TransCAD, EMME, MANTRA, and COPERT) was used to simulate scenarios in the transport sector regarding: (i) the demand of freight and passenger trips, (ii) impact of infrastructure investment and allocation of trips, and (iii) associated GHG emissions. • A simple input-output based macroeconomic impact model was used to assess the impact of low carbon investments on macroeconomic parameters, such as GDP, employment, and gross output.
	SIM Brazil (Simulate Brazil), a geo-referenced spatialization model which calculates above and below the ground carbon balances, structured and implemented according to the Environment for Geoprocessing Objects (EGO) Dynamic, a free integrated software platform	Commissioned by the study team and developed by the Remote Sensing Center of the Cartography Department at the University of Minas Gerais		
	MACTool (Marginal Abatement Cost Tool; prototype version), which was used to develop marginal abatement cost curves from both social and private perspective for 40 possible interventions	Developed by the study team		
	EFFECT (Energy Forecasting Framework & Emissions Consensus Tool), a bottom-up Excel/ Visual Basic model that was used in Brazil to model road transport emissions	Developed by the study team for the India low carbon study and adapted for the Brazilian case		
CHINA	CRESP (China Renewable Energy Scale-up Program) Economic Evaluation Model, a bottom-up model generating provincial renewable energy supply curves	Originally developed under the guidance and support of the World Bank in 2002–2005, the model was revised and updated	• How much renewable energy is justified with and without externalities? How is the target best achieved for the country and why? • Other than economic efficiency, how do various policy options perform (e.g., in terms of employment, supply diversification, or practical application); what criteria should be considered in this evaluation?	Supply curve developed for each of the 31 provinces and municipalities, relating cost per kWh to the level of electricity production. The cost of coal-based power generation was broken down into production and environmental costs.
INDIA	EFFECT, a bottom-up, user-friendly, Excel/ Visual Basic model	Developed by the study team	• What are the low carbon growth opportunities in the major sectors of the economy? What is projected fuel use? • What are CO_2 emission levels under different scenarios?	EFFECT is described in the next section
INDONESIA	Built on existing CGE and MARKAL (MARKet ALlocation) modeling work	Used existing models		Modeling work undertaken prior to the ESMAP-funded study

Table 3.1, *continued*

COUNTRY	MODEL	ORIGIN	QUESTIONS	COMMENT
MEXICO	Expert-based systems approach used to identify high-priority low carbon interventions across energy consumption and land-use activities. Project- and program-based cost-benefit analysis used to evaluate interventions.	Developed and carried out by national and international experts	• What are the low-carbon opportunities in Mexico in the short and medium term that can be included as part of the country's climate investment program? How much do such interventions cost (US$ /tCO_2e)? How much upfront investment is required, and what can be implemented in the near term? How do interventions between sectors compare? • What is the trend in energy-sector emissions from Mexico to the year 2030? • What are the macroeconomic impacts of undertaking a series of low carbon activities over the next 20 years in Mexico?	Cost-benefit analysis used to generate MAC curves by sector and for the country as a whole. Externalities incorporated where possible, and significant in some sectors (e.g., transport).
	LEAP (Long-range Energy Alternatives Planning system), an input/output, bottom-up model, was used to estimate the baseline scenario	Developed by the Stockholm Environment Institute		
	Macroeconomic CGE model was used to cross-check the economy-wide impacts of the interventions proposed in the study	Developed by Boyd and Ibarrarán		
POLAND	A modified (Poland-specific) version of TREMOVE to model on-road transport	The original version of TREMOVE was developed with funding from the European Commission	What is Poland's potential to reduce GHG emissions, sector by sector? What are the macroeconomic and fiscal costs of abatement scenarios? What is the impact of EU 20-20-20 strategy on Poland? What is the impact of mitigation policies on transport emissions?	Detailed bottom-up sectoral work was integrated with top-down macroeconomic modeling to provide specific recommendations for the most efficient low carbon technologies for Poland and related investment measures
	Micro-MAC, used to develop marginal abatement cost curves	Developed by McKinsey & Company		
	MEMO, a dynamic stochastic general equilibrium model	Developed by the local think tank Institute for Structural Research, starting from an existing general model		
	ROCA, a computable general equilibrium model	Developed by Prof. Christoph Böhringer, starting from existing multi-region CGE model, adjusted for Poland		
SOUTH AFRICA	MARKAL was used to model energy-related emissions	Modeling work undertaken by the Energy Research Centre as part of developing Long Term Mitigation Scenarios		Analyzed implications for national GHG emissions trajectories

Source | Author.

BOX 3.2

Examples of Modeling Approaches Used in the Low Carbon Studies

In China, the low carbon study used bottom-up modeling to focus on the power sector and related government plans to develop renewable generation. China's coal-based power sector is a major source of GHG emissions and the government is actively promoting the development of renewable energy resources. Low carbon modeling was focused on comparing the economic and environmental costs of power production from renewable sources versus coal, as well as estimating an economically optimal level of renewable energy supply. Consequently, detailed plant-level cost data was required for existing coal-based power generation and renewable development.

In Brazil, land use—in particular agriculture and forestry—is the largest source of GHG emissions. Reforming this sector became the focus of the government's low carbon agenda. While low carbon modeling centered on land use, other GHG emitting sector—transport, energy, and urban waste—were also included in the analysis, but on a smaller scale. A very detailed dataset was collected on the forestry and agricultural sector that was complemented with data on other emission sources and with macroeconomic data (e.g., GDP, population and GDP growth). Two models—bottom-up and top-down—of emissions from land use, agriculture, and forestry were developed to facilitate this analysis. The process was costly in terms of time and resources to gather data, ensure its reliability and transparency, and allow easy access, understanding, and verification of information.

In Poland, the government examined low carbon scenarios for the entire economy and was particularly interested in evaluating the macroeconomic impact of low carbon implementation on the economy. The comprehensive nature of this study called for a set of modeling instruments (two bottom-up and two top-down models) and several different data sets. First, data was collected to create a list of GHG abatement measures, mostly in energy and transport. Costs and benefits were estimated and the net present value of each was calculated through bottom-up modeling (marginal abatement curve or MAC). Next, a top-down dynamic stochastic general equilibrium (DSGE) model that described the Polish economy helped calculate the macroeconomic impact of the GHG abatement measures. About 2,000 variables consisting of economy level indicators, such as production factors, public expenditure components, and variables for 11 economic sectors of the economy, formed the basis of the DGSE dataset. Additionally, a regional computable general equilibrium (CGE) model (top-down approach) was used to analyze the macroeconomic impact of implementing the European Union's (EU) climate mitigation package. A range of policy and macroeconomic indicators, such as taxes and other instruments, and some sector data were collected for this modeling. A bottom-up model was also used to analyze the effect of transport policies on GHG emissions from this sector, requiring detailed information on road and transport pricing, vehicle stock, and other sector data.

highlighting the rationale for their development and use, and providing insights into their application. A more detailed description of the modeling approaches and tools used in three of the studies (Brazil, Indonesia, and Poland) can be found in Annex B.

EFFECT

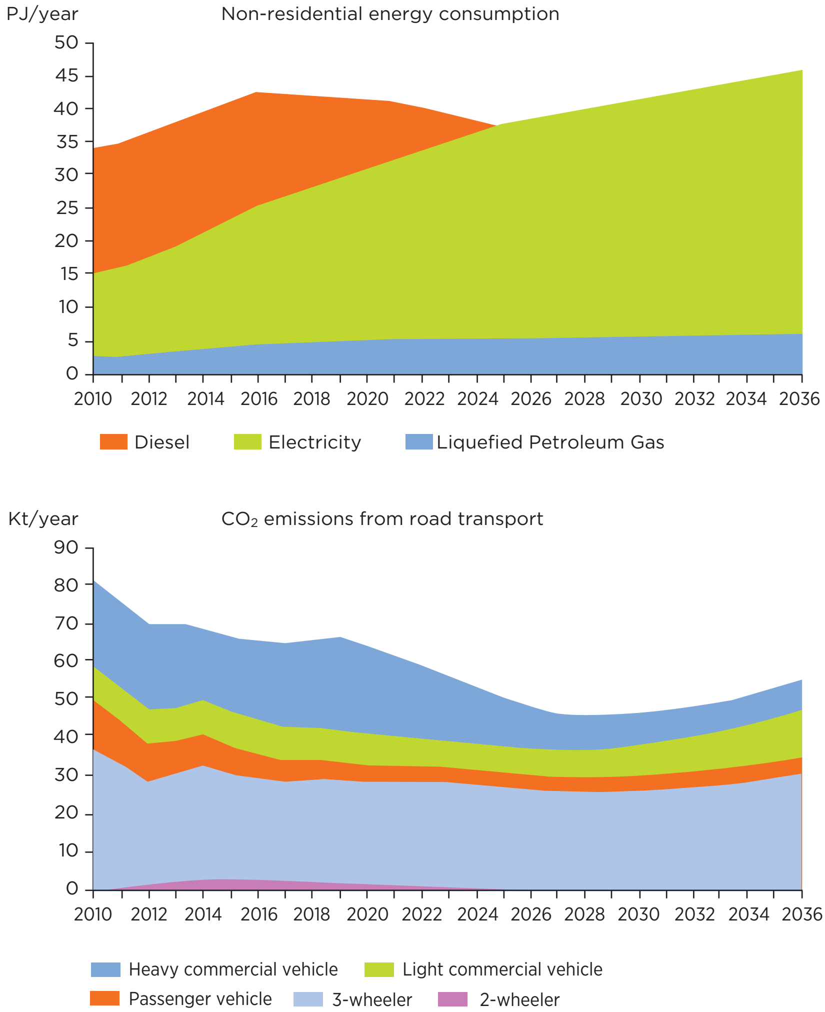
The Energy Forecasting Framework and Emissions Consensus Tool (EFFECT) is an open and transparent modeling tool used to forecast GHG emissions from a range of scenarios in low carbon development. It focuses on sectors that contribute to and are expected to experience rapid growth in emissions. The model was initially developed by ESMAP and the South Asia Energy Department of the World Bank while working with the Government of India on an analysis of their national energy plan. The decision to develop a new tool was taken after a thorough analysis of existing tools concluded that none offered the combination of transparency, inclusiveness, free access, and ease of use that was needed to help build consensus among multiple stakeholders from different sectors of the economy on the optimal development path to follow. EFFECT has since been used in 11 countries, including Brazil, Poland, Georgia, Macedonia, Nigeria, and Vietnam.

EFFECT forecasts GHG emissions for given development scenarios or policy choices. Figure 3.1 illustrates two typical final outputs from EFFECT. In addition to forecasting GHG emissions, EFFECT enables consensus building among disparate government departments, and forecasts energy balances and amounts of energy generating/consuming assets in a country or sector. Sectors covered currently include agriculture, households, industry, non-residential sectors, power, and transport.

The EFFECT model provides the following outputs by pairing different scenarios (from a range of multiple scenarios) against each other:

- Annual energy use at the point of consumption in each sector (e.g., power generation unit, appliance use, vehicle fuel consumption) from the initial year to the terminal year (e.g., 2008 to 2030)
- Annual GHG emissions resulting from energy consumption in each sector on an annual basis over the modeling period
- Local pollutant emissions from transport for each time period
- Process emissions from industry on an annual basis over the modeling period
- Investment, operating and maintenance costs, and fuel costs by energy point of consumption in each sector for each time period
- Fuel consumption and costs by point of consumption in each sector for each time period
- Costs for each of the scenarios of reducing GHG emissions in net present value
- Data for the construction of marginal abatement cost curves

Figure 3.1 | Example of Outputs from EFFECT



Source | ESMAP.

Technically, EFFECT is a hybrid accounting and optimization, bottom-up model whose inputs are derived from energy consuming/supplying assets in the country. It sums up the influence of each asset to provide national or sectoral results. As an Excel-based model, EFFECT can be customized to fit many different applications. Further information on how to obtain EFFECT is available on the ESMAP website at www.esmap.org. Several forms of training are provided, including a self-paced e-learning course, facilitated courses and 1-to-1 or 1-to-many training sessions to teams interested in using EFFECT.

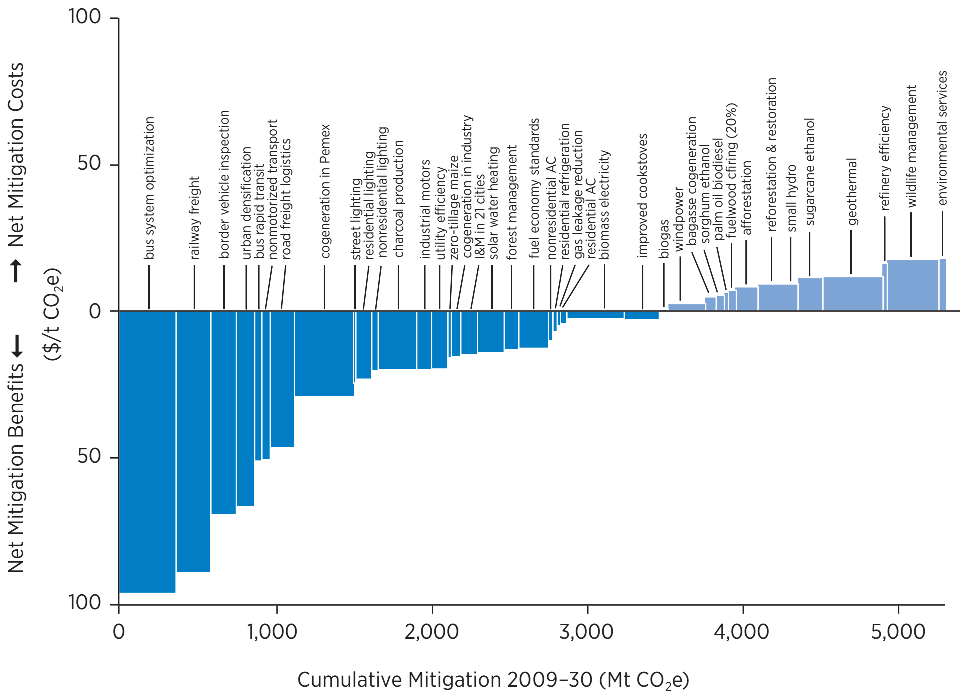
BOX 3.3

Marginal Abatement Cost Curves

The marginal abatement cost curve is a graphical representation of cost-benefit analysis of the GHG abatement options that could be employed in a particular country or sector. The curves are used by policymakers to select abatement options that are most beneficial for the economy—those that maximize GHG emission reduction per dollar of net present value of associated cost of abatement. The curves depict abatement options sorted by cost, thus making a clear picture of comparative advantage of some options versus the others. Most MAC curves include a range of abatement options with negative net present cost (or net profit), which should be attractive investment opportunities, yet are not implemented by the private sector. This is likely to reflect a range of well-understood barriers, such as the lack of incentive for rental property owners to improve energy efficiency, or poor awareness of energy efficiency savings at the board level within organizations.

Various agencies have produced MAC curves, including Bloomberg New Energy Finance, Enerdata and Institute of Energy, Policy, and Economics (LEPII-CNRS), ICF International, McKinsey & Company, the US Environmental Protection Agency, and the Wuppertal Institute for Climate, Environment and Energy.

Figure 3.2 | Marginal Abatement Cost Curve for Mexico (ESMAP, 2010a)



Source | ESMAP, 2010b.

MACTool

The Marginal Abatement Cost Tool (MACTool) is a transparent and flexible software tool that provides an easy way to build marginal abatement cost curves and calculate break-even carbon prices. It has a user-friendly interface which guides the user through a simple data entry process, from which it automatically generates the desired outputs. The graphical outputs are Excel-based, and therefore simple to embed in reports and presentations. MACTool was developed by ESMAP through the low carbon studies carried out in Brazil and Mexico. Although other marginal abatement cost tools exist, none of those surveyed offered an 'open-box' solution that would allow the client to scrutinize and vary the underlying assumptions, or the ability to model scenarios based on public and private discount rates. MACTool is currently being used in Colombia, Macedonia, Nigeria, Uruguay, and Vietnam.

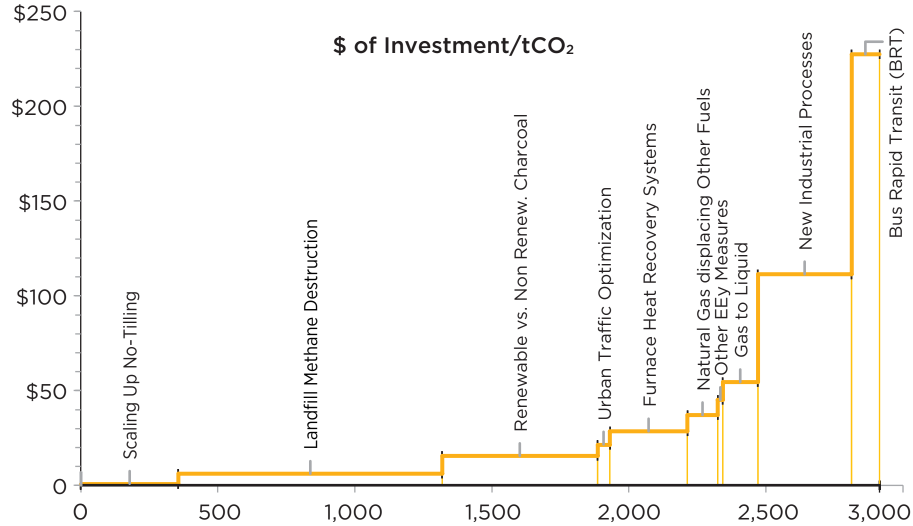
MACTool can assist leaders and decisionmakers in answering a number of challenging questions:

- What are the best ways to achieve GHG reduction targets efficiently?
- Which abatement options should we choose from the pool of available options?
- What are the potential results associated with each option?
- What does it cost to implement each option?
- Would the private sector be interested in implementing the chosen option?
- Would it make sense to implement a domestic cap and trade system?

The tool helps users compare the costs and benefits of emission reduction options that can be used to build low carbon scenarios at a national or subnational level. It provides a cost-benefit comparison of these options using a social discount rate by calculating the marginal abatement costs and an estimate of the incentive needed to make these options attractive from a private sector perspective by determining the 'break-even carbon price'. It also enables governments to assess the total investments needed to shift towards low carbon development scenarios and the physical sectoral outputs (for instance installed power capacity) associated with the low carbon options. MACTool can also be used to test the possible scope of domestic cap and trade systems by exploring which sectors are likely to respond to a given carbon price, either on the demand side or the supply side of carbon offsets.

Further information on how to obtain MACTool is available on the ESMAP website. MACTool also comes with embedded videos which take the user step-by-step through the process of using the tool. Additionally, ESMAP provides training and varying levels of operational and technical support to teams using MACTool.

Figure 3.3 | Example of Output from MACTool—Investment Requirements for Brazil Low Carbon Scenario



Investment Needed	Scaling Up No-Tilling	Landfill Methane Destruction	Renewable vs. Non Renew. Charcoal	Urban Traffic Optimization	Furnace Heat Recovery Systems	Natural Gas displacing Other Fuels	Other EEy Measures	Gas to Liquid	New Industrial Processes	Bus Rapid Transit (BRT)
$Million	**252**	**5,957**	**8,794**	**972**	**8,074**	**4,088**	**827**	**6,986**	**37,995**	**23,290**

Source | ESMAP.

4 | RESULTS AND OUTCOMES OF THE LOW CARBON STUDIES

This chapter reviews the results and conclusions of the low carbon studies, including outcomes, such as investments and changes in policy, where these can be identified. Near-term evaluation is difficult as such outcomes unfold over years. Such outcomes also may not exactly reflect the recommendations of the studies, given the wide range of factors that influence government policy-making and the timescales involved.

BRAZIL

The Brazil low carbon study (de Gouvello, 2010) focused on four areas with substantial potential to lower carbon emissions, namely:

- Land use, land-use change, and forestry (including deforestation)
- Energy production and use
- Transport systems
- Waste management

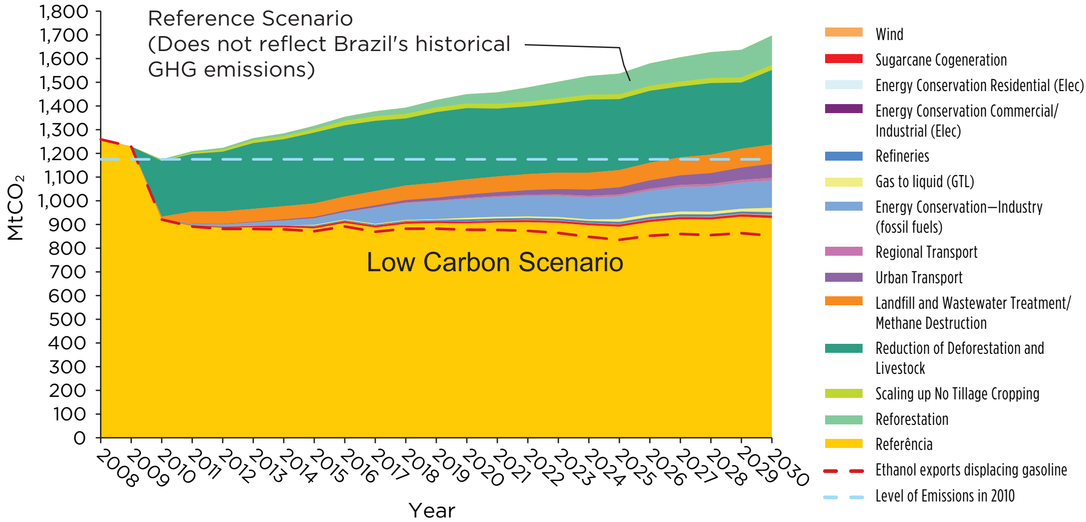
The study built first a coherent reference scenario to anticipate the evolution of the country's GHG emissions, taking into account existing economic growth projections, development objectives, and long-term planning exercises in these four sectors. It then explored opportunities to achieve the same growth and development objectives while reducing emissions.

Brazil's reference scenario estimated gross GHG emissions of about 26,000 $MtCO_2e$ over the period 2010 to 2030, with deforestation remaining the key driver at 400 to 500 $MtCO_2$ per year. However, energy sector emissions were projected to increase by 97 percent from a relatively low baseline to 458 $MtCO_2$ in 2030, pushing deforestation's contribution to overall emissions down from 40 percent to 30 percent. Transport and waste management had projected annual emissions of 245 $MtCO_2$ and 99 $MtCO_2$ by 2030, respectively. Overall, emissions were projected to reach 1,717 $MtCO_2$ per year by 2030, up from 1,288 $MtCO_2$ in 2008.

Large Potential for Absolute Reductions

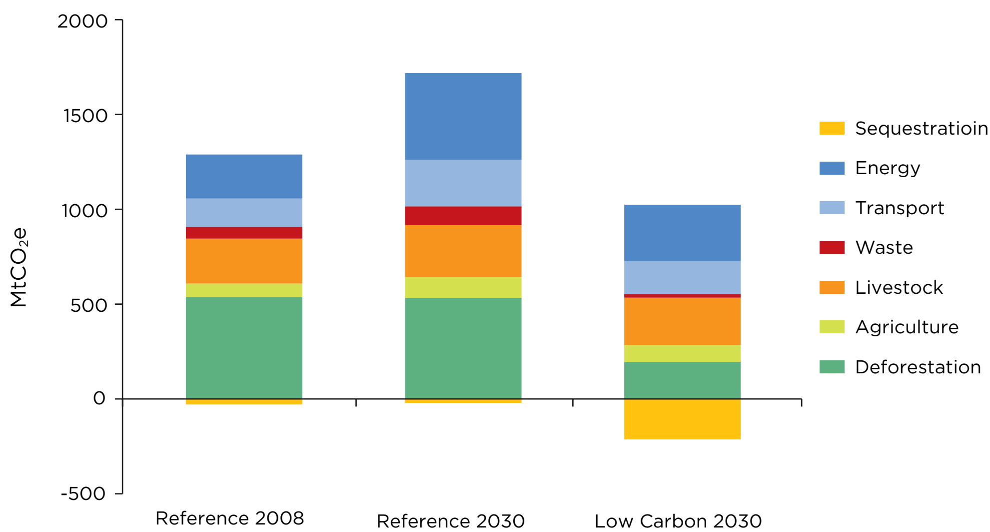
Brazil's GHG emissions profile is unique as a result of the declining but still very significant influence of deforestation combined with relatively low per capita emissions from the energy sector. The challenge for Brazil is to continue with the recent progress made on reducing deforestation, while coping with increasing pressure for new land for agriculture and livestock expansion, growing demand for fossil fuels (particularly from industry and transportation), and a major increase in solid and liquid waste collection and treatment due to plans for the universalization of basic sanitation services.

Figure 4.1 | Opportunities for GHG Mitigation, 2008–30



Source | ESMAP, 2010b.

Figure 4.2 | Comparison of Contributions by Sector to Gross Emissions in the Reference and Low Carbon Scenarios, Brazil, 2008–30



Source | ESMAP, 2010b.

Despite these strong trends underlying the reference scenario, the modeling of mitigation and carbon removal options carried out for the Brazil low carbon study showed potential for absolute reductions in emissions from 1,717 $MtCO_2$ to 1,023 $MtCO_2$ per year by 2030 while preserving the planned economic growth trajectory. Tackling deforestation, mainly by freeing up pasture through improved livestock productivity to accommodate agriculture expansion, proved to be the most effective at reducing emissions, with a pos-

sible emissions reduction of 80 percent by 2017 compared to the 1996-2005 average, a key target adopted by the Brazilian government. Another area that showed potential was enforcing legal obligations of restoring forest reserves and developing production forests, which taken together could reduce emissions by more than 3,000 $MtCO_2e$ along the period. Other mitigation measures related to land-use included zero-tillage cultivation, which lowers direct emissions from agriculture and increases the carbon uptake of soils. In the energy sector, absolute emissions are expected to rise quickly in the reference scenario because of the exceptionally low carbon content of the current energy matrix, but this should not mask significant abatement opportunities to reduce energy sector emissions up to 35 percent compared to the reference scenario, with an emphasis on industrial energy efficiency and fuel switching in industry and the power sector. Modal shifts, traffic management, and fuel switching could prevent substantial increase of emissions in the transport sector in the low carbon scenario, despite the rising demand, and in waste management the low carbon scenario suggests emissions savings of up to 80 percent in 2030 through the destruction of landfill gases, better facilities planning, and a range of management improvements.

Although 80 percent of the emission reduction potential under the low carbon scenario (or 9,000 $MtCO_2$ over the period 2010–30) requires incentives of just US$ 6 per tCO_2 or less, this still amounts to US$ 21 billion per year on average. Nevertheless, a simple analysis of the macroeconomic effects of these measures using an input-output approach suggests that the low carbon scenario should not negatively affect economic growth, and could even raise GDP and employment due to spillover effects associated with low carbon investments. While the incremental investment financing needs are significant, they represent less than 10 percent of national investments in 2008.

Supporting a Robust National Dialogue

The final synthesis report was launched in June 2010 and special sectoral reports were published jointly with key public agencies. The study has facilitated substantial interactions and capacity building across government and public agencies, including the use of the main study and the sectoral technical reports as reference materials in their work and policy engagement. The ongoing dissemination of special sectoral reports has created additional sector-specific opportunities to share and discuss recommendations with both federal and local governments (in particular São Paulo State and São Paulo City), with public agencies (e.g., EMBRAPA, EPE, CETESB), and with private sector organizations (such as industry federations).

The Brazil low carbon study has played a significant role in the ongoing and growing national debate on climate change, including in the national consultative debate that laid out the implementation of the national climate change plan and the law that contains voluntary commitments presented by Brazil to the international community at the UNFCCC Conferences in Copenhagen (2009) and Cancún (2010). It is expected that this study will influence the design and execution of future projects in Brazil, including those supported by international development institutions, such as the World Bank. The study has facilitated a policy dialogue around potential investments in low carbon opportunities and for the preparation of a new US$ 99 million World Bank technical assistance program requested by the Ministry of Mines and Energy. The first tranche of this financing—US$ 49.6 million—was approved by the World Bank Board of Directors on December 20, 2011. Recently, as a follow-up of the policy dialogue that developed under the low carbon study, the Ministry of Finance joined the Partnership for Market Readiness (PMR). A new PMR project is now under preparation to support the implementation of the climate change agenda, in particular the definition and piloting of domestic market instruments to mitigate climate change.

CHINA

The low carbon study for China involved developing three policy notes to review the major policies and plans adopted by Chinese agencies and to provide suggestions for further action. Two key government targets framed the work: increasing the supply of non-fossil fuel energy to meet 15 percent of primary energy consumption by 2020, and reducing energy consumption per unit of GDP by about 20 percent in the 11th Five-Year Plan (2006–10). The three policy notes, which have been finalized and endorsed by counterpart institutions in China, covered: (i) An analysis of the optimal renewable energy development targets in comparison to the targets set by the government; (ii) improvements in power dispatch efficiency; and iii) improvements in cement sector efficiency.[3]

[3] This note was funded by the Asia Sustainable and Alternatively Energy Program (ASTAE).

Accelerating Renewable Energy Deployment

The first policy note, *China's Envisaged Renewable Energy Target: The Green Leap Forward* (World Bank, 2010a), evaluated the existing and envisaged government renewable energy targets through an optimization analysis drawing on two contrasting scenarios for estimates of local environmental costs under the same economic and technical assumptions. Second, it assessed the existing policies and their ability to achieve the government targets and the scale-up of renewable energy overall. The note provided high-level policy recommendations that could be considered to promote renewable energy development in China.

According to the analysis, the envisaged government target, if confirmed, would constitute major progress in addressing local and global environmental issues. It would put the energy sector on track to achieve the target of 15 percent of energy consumption being met by non-fossil fuels by 2020. The implicit local and global environmental benefits underlying the envisaged target include substantially increased action on reducing local pollution and addressing climate change, as well as strong support to build a world-class renewable energy industry.

To help China achieve its target in the most effective manner, the policy note recommended the following actions:

- **Develop hydropower faster.** Hydropower rehabilitation and more rapid and environmentally and socially sound development could achieve the target at a lower cost because hydropower is already competitive with coal. Developing hydropower more quickly would allow for increasing the renewable energy target above the envisaged government target without increasing the incremental cost of the program.

- **Improving the performance of wind power rapidly.** China's experience has been less than optimal in planning wind farms, and ensuring operational integration and coordination between developers and grid operators. This considerably reduced the performance of the wind program. If not addressed adequately, these operational inefficiencies could increase the overall cost of the envisaged wind program and undermine it.
- **Promoting trade.** By making use of tradable green certificates, provinces could achieve their mandated targets at lower cost. Renewable energy transactions would amount to about 360 TWh, 42 percent of the total of the envisaged government target. And more importantly, trade would reduce the discounted cost of the envisaged renewable energy target by 56 to 72 percent.

The policy note was published in October 2010, and was widely quoted by both international and domestic media. China is currently revising its renewable energy plan, and the recommendations above are informing this process. The World Bank is also working continuously with the Government of China to support the renewable energy sector in China. China Renewable Energy Scale-up Program (CRESP) Phase II, which is endorsed by both the Government of China and the Global Environment Facility (GEF) Council, intends to provide US$ 30 million to the sector in the form of a GEF Grant, with a focus on renewable energy cost reduction, performance improvement, and grid integration.

Improving Power Dispatch

The second policy note (World Bank, 2009a) analyzed coal and emissions savings when power dispatch across a province-wide grid is managed to maximize efficiency rather than minimize costs. Power dispatch can be challenging when balancing many thermal power and hydropower plants; each with different fixed and variable cost structures, levels of plant and grid efficiency, and environmental impacts.

This study did detailed financial modeling across hundreds of power plants in three provinces, each with individual power purchase agreements. In the three provinces—Fujian, Shandong, and Guizhou—the study identified possible technical efficiency gains of up to 10 percent, achieved largely by replacing the dispatch of small- and medium-scale thermal by larger units. However, these technical gains do not come without large financial impacts, requiring compensation mechanisms to ensure the viability of small and medium units as reserves. Using three different policy models, the net savings in financial cost estimated by the study was less than 1 percent, in spite of the significant reduction in the use of coal. The lesson learned, as in other areas of possible energy efficiency gains, is that such gains are feasible but not 'easy'.

Energy Efficiency in the Cement Sector

The third policy note, *Improving Energy Efficiency in the Cement Sector of Shandong Province* (World Bank, 2009b), covers two important areas of energy efficiency intervention in the Chinese cement industry: (i) phasing out of obsolete production capacity (e.g., vertical shaft kilns, which accounted for about 40 percent of China's cement production capacity in 2008); and

(ii) energy efficiency investment potential and options in plants with modern new suspension preheater (NSP) dry process technologies. Reflecting the fact that Shandong is the largest cement-producing province in China, the policy note was prepared as an input for the Shandong Provincial Government and the National Development and Reform Commission (NDRC) to inform the development of energy efficiency investment programs in the mainstream NSP plants, as well as in assessing the social and economic impacts of phasing out vertical shaft kilns.

The study identified key energy efficiency improvement opportunities among NSP plants built in the past 20 years:

- Average primary energy savings of 12 percent can be achieved if the surveyed plants operate at domestic best-practice levels, and average primary energy savings of 23 percent can be achieved if the plants operate at international best-practice levels.
- The cost-effective electricity-saving potential is about 16 percent of total electricity use in the surveyed cement plants. The cost-effective fuel-saving potential is about 8 percent of total fuel consumption.

The social and economic impact assessments of phasing out obsolete vertical shaft kilns concluded that, although there are significant net energy savings and environmental benefits, the phasing out of obsolete plants would lead to significant net job losses in the cement sector, and it is difficult to reemploy the laid-off workers in new cement plants. However, the negative economic impacts were judged to be small and likely to be compensated by growth in other sectors.

To help Shandong and other provinces in China deal with cement sector restructuring and improve the sector's energy efficiency performance, the policy note recommended the following actions:

- **Provision of basic social safety nets for workers laid off due to the closing of obsolete cement plants.** Reemployment assistance such as job retraining will help but the effect may be limited by the fact that most of these workers have engaged in relatively low-skilled jobs and have passed their prime employment ages.
- **Additional financing for investments in high-efficiency motors and drives and in high-efficiency finish grinding systems.** This is necessary to prevent locking in inefficiency in new plants. These systems tend to be difficult to replace after they are installed. A combination of regulation (enforcing standards), education (informing lifecycle costs and benefits), and incentives (sharing incremental costs) could help address this issue
- **Broadly adopting energy management systems among NSP plants.** Among all fuel efficiency measures, energy management and process control systems in clinker production is generic and has broad replication potential. It is recommended that such systems become standard installation and training requirements for new plants.

The policy note was delivered to the counterparts, including the Shandong Provincial Economic Commission, NDRC, and the Ministry of Finance in May 2010. The underlying studies of the policy note informed the preparation of the Shandong Energy Efficiency Project of the World Bank.

INDIA

The India low carbon study (Gaba, Cormier, & Rogers, 2011) made extensive use of the EFFECT tool (see Chapter 3) to examine CO_2 emissions from energy use over the period 2007-2031. It focuses on five sectors and areas of the economy that together represent 75 percent of GHG emissions from energy use in India in 2007, as follows:

- Power generation, transmission, and distribution
- Electricity consumption by households
- Non-residential buildings
- Energy consumption in six energy intensive industries (iron and steel, aluminum, cement, fertilizers, refining, and pulp and paper)
- Fuel use in road transport

While multiple scenarios were investigated, the report's findings are based on three scenarios and their sensitivity analyses: (i) Scenario 1—Five-Year Plans Scenario, which assumes full implementation of the Five-Year Plans and other projections and plans by the Government of India; (ii) Scenario 2—Delayed Implementation Scenario, which more closely follows historical performance in implementation of the Five-Year Plans; (iii) Scenario 3—All-Out Stretch Scenario, which builds on Scenario 1 by increasing energy efficiency and energy from low carbon sources.

Table 4.1 | Summary of Scenarios in India Low Carbon Study

ASSUMPTION CATEGORIES	SCENARIO 1 Five-Year Plans	SCENARIO 2 Delayed Implementation	SCENARIO 3 All-Out Stretch
Average annual GDP growth in 2009–2031	7.6%	7.6%	7.6%
Grid generation life extension and efficiency enhancement	As defined in Five-Year Plans	Same as Scenario 1	Enhanced program
New grid generation capacity expansion	As defined in Five-Year Plans	50% slippage in new capacity addition for higher efficiency coal, hydropower, wind, and biomass	Additional 20 GW of solar and 20 GW of imported hydropower
Technical loss reduction in transmission and distribution	From 29% in 2005 to 15% in 2025	Delayed by 5 years to 2030	Accelerated by 10 years to 2015
Industry, household, nonresidential, transport	Projected, based on historical trends and government energy efficiency targets	Same as Scenario 1	Additional energy efficiency measures in each sector
Sensitivity Analyses	***A.*** As Scenario 1 but with a GDP growth rate of 6.6%	***B.*** As Scenario 2 but with 20% slippage in new capacity addition for higher efficiency coal, hydropower, wind, and biomass	***C.*** As Scenario 3 but with only 5 year acceleration (to 2020) of technical loss reduction in transmission and distribution ***D.*** Additional fossil fuel power generation replaced with carbon-neutral generation capacity relative to Scenario 3

Source | ESMAP, 2011a.

All scenarios studied show that emissions of CO_2 equivalent from the sector studies are likely to increase—from 1.1 billion tons in 2007 to between 3.2 and 5.1 billion tons in 2031. This should be set against a backdrop of a relatively low carbon footprint, both now and under future scenarios, and reductions in carbon intensity of 32 percent by 2031 under Scenario 1 and 43 percent under Scenario 3. India's unique development challenges—for example, providing lifeline power to the 400 million people who are currently without—and an average annual GDP growth rate of 7.6 percent both require substantial increases in electricity generation in a country with limited domestic resources. This, combined with a growing middle class, leads to substantial upward pressure on GHG emissions, despite large-scale adoption of a range of abatement measures.

Meeting Multiple Development Challenges

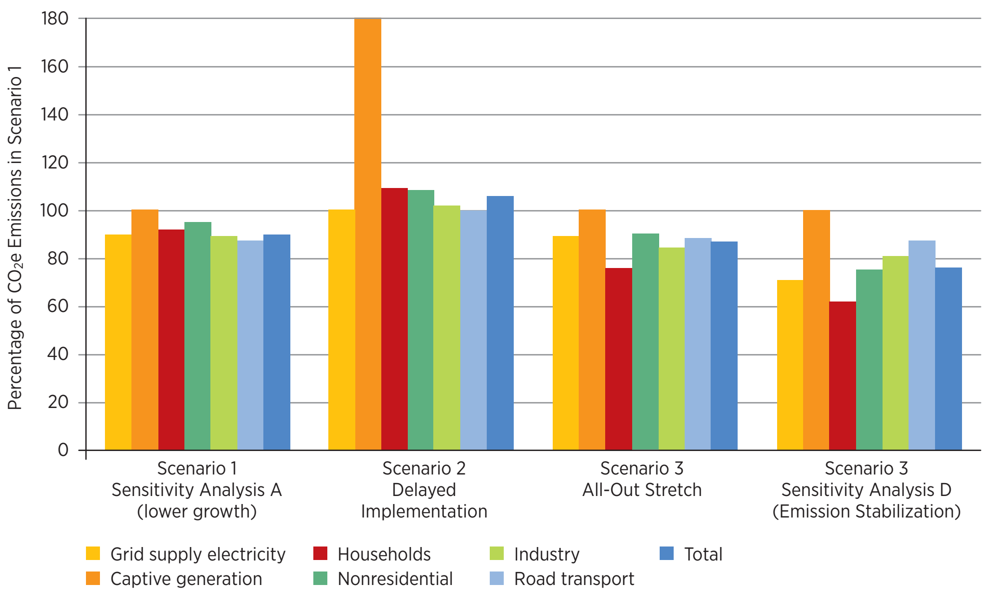
Expansion needs for power generation up to 2031 are vast, with increases estimated from four-fold to as much as six-fold. This means that, even under the All-Out Stretch assumptions of Scenario 3, grid electricity supply accounts for 53 percent of the increase in GHG emissions from 1.1 to 3.7 billion tCO_2 by 2031. This is primarily due to the continued dominance of coal in the generation mix, at 71 percent in 2031 under Scenario 3, down from 73 percent in 2007. Nevertheless, the same scenario envisages large-scale expansion of hydropower and significant potential for cost-effective reductions in transmission and distribution losses. Failing to meet the targets implied under Scenario 1 leads to greater use of captive generation, resulting in higher costs to society overall.

Across sectors, energy efficiency can play a large role in constraining emissions growth. In the household sector, the total amount of electricity consumed by household lighting (30 percent of total residential use in 2007) is 70 percent lower in Scenario 3 compared to Scenario 1. In the industrial sector, small and medium enterprises represent a largely untapped source of abatement potential, particularly considering they represent approximately 60 percent of India's GDP. And finally, in the transport sector, where emissions are the fastest growing in India and are projected to increase by a factor of 6.6 in Scenario 1, a combination of model shift (particularly from cars to buses) and the introduction of more stringent fuel economy standards for light vehicles, could lead to a reduction in emissions of 19 percent under Scenario 3.

A Process of Consensus Building

The India low carbon study has been able to bridge the dialogue and knowledge gap between national and international policymakers. The study has thrown much light on what 'was, is and will ever be possible' in the context of India when development and implementation constraints are objectively integrated. To Indian policymakers, the key message was that policies are broadly in the right direction but focused attention is required on creating and enhancing conditions for successful implementation. To international policymakers, the report highlighted that the challenges are daunting and India would need more

Figure 4.3 | Comparison of Cumulative Emissions over 2007–31 Relative to Scenario 1 for India



Source | ESMAP, 2011a.

help and time than previously assumed. As a consequence, the policy drive to develop renewables, and in particular solar technology, would require massive funding and technology transfer to be realized. This assessment was further reinforced by a recent World Bank/ESMAP study (Sargsan, Bhatia, Banerjee, Raghunathan, & Soni, 2010)which estimates that achieving the Indian government's renewable energy goals for the next decade will cost US$ 10 to $ 64 billion in subsidies depending on the mix of renewables that is selected. The lower cost scenario is based on developing low-diversity, low-cost renewable energy sources, while the higher cost estimate is based on a renewable energy mix that is highly diverse and includes sources like solar. In addition, with India's limited renewable energy resource endowment, there is renewed interest in the development of regional cooperation to tap into regional energy resources.

INDONESIA

The low carbon study in Indonesia took the form of scenario analyses, policy briefs, seminars, and summary reports for the Ministry of Finance (MoF) and the National Climate Change Council (DNPI). The study was conducted during a period of internal flux and alongside a number of other programs taking place in conjunction with other ministries.

The objective was to support key counterparts in MoF and DNPI in their understanding of the economic implications of alternative climate change and development paths and specific policy options for lowering emissions in priority sectors. Within this wider engagement between the World Bank and the Government of Indonesia, ESMAP funding was used to provide insights on tax and spending policies, strategic investment approaches, financing sources, and fiscal incentives for low carbon action. The project also assisted the Government of Indonesia in establishing a climate change and fiscal policy website where several of the outputs from this work are available.[4]

[4] www.fiscalpolicyforclimatechange.depkeu.go.id. Further outputs are available from the ESMAP website.

Indonesia is among the top 25 GHG emitters from fossil fuel combustion. However, if emissions due to deforestation and land use change are included, Indonesia rises to among the top emitters. Indonesia's GHG emissions per capita are still low in comparison with other countries, but are rising faster than energy use per capita. From 1994 to 2004, Indonesia's CO_2 emission per capita from fossil fuels grew faster than China's and India's. On current trends, GHG emissions from fossil fuel combustion are expected to grow rapidly, doubling every 12 years. By 2030, these emissions would be four times higher, thus potentially off-setting any gains made through controlling Indonesia's forest and peat land destruction. The governance issues and underlying structural problems affecting Indonesia's energy sector have been extensively analyzed, and while climate change brings a new perspective and added urgency, the solutions are not fundamentally different to those previously identified.

One high-level conclusion from the work is that Indonesia's development can benefit from specific policy and technical choices in the application of fiscal instruments and technologies that help to reduce emissions, without reducing growth—whilst also providing secondary benefits. In the forestry sector, the work identified instruments and approaches that could be used to improve both policy incentives and revenue management and transparency—this has since been incorporated into the REDD+ initiative. In the transport sector, higher vehicle efficiency standards, improved fuel quality, switching to natural gas for certain public transport uses, restructuring of the vehicle taxation regime, CO_2 labeling for new vehicles, and improved public transport provision were all identified as possible options to avoid a projected doubling in emissions in less than 10 years.

Building Government Capacity and Stakeholder Awareness

Throughout the project several focus group discussions and seminars were conducted to disseminate the technical reports prepared under the low carbon study. In addition, inputs were collected from stakeholders to improve the final report through the provision of critical analysis of fiscal policy options for energy efficiency in manufacturing, transportation, geothermal, and natural gas opportunities to reduce the carbon intensity.

The work supported by ESMAP helped build capacity within the Ministry of Finance, both on climate finance and on fiscal policy issues. The Ministry of Finance is now playing an active policy role in discussions of how to modify incentives (e.g., an intergovernmental fiscal transfer mechanism, performance-based incentives to communities and investors) for local governments in relation to land use, forests, peat lands, and permitting. They are also now actively working with the Ministry of Energy and Mineral Resources and other agencies to design an approach and mechanism for improving pricing and compensation policies in the geothermal sector, key parts of an overall investment climate improvement effort. Work looking at the oil palm sector was not released as a standalone output but did contribute to a review of the oil palm sector by the World Bank Group (World Bank, 2010b), and to the Country Environmental Analysis that was undertaken by the World Bank and published in 2009 (World Bank, 2009c).

Indonesia is also using the results of this analytical work in prioritizing additional interventions and climate financing opportunities. The Government of Indonesia has successfully sought climate financing assistance through the Clean Technology Fund and the Forest Carbon Partnership Facility, and Indonesia has been selected as a pilot country under the Forest Investment Program. Indonesia's development partners are also providing technical assistance, analytical support, and capacity building through a range of mechanisms at the country level.

MEXICO

The Mexico low carbon study (Johnson, Alatorre, Romo, & Liu, 2010) provided an analysis of how the country could significantly reduce its emissions without hindering economic growth. By making a common cost-benefit analysis that included externality values where available, the study assessed low carbon interventions in five key sectors:

- Electric power—generation and distribution
- Oil and gas—extraction, processing, and distribution
- Energy end use—energy efficiency in the manufacturing and construction industries, and the residential, commercial, and public sectors
- Transport—primarily road transportation
- Agriculture and forestry—crop and timber production, forest land management, and biomass energy

Mexico is Latin America's largest fossil fuel-consuming country, with 61 percent of GHG emissions coming from energy consumption, with land-use, forestry and agriculture (21 percent) and waste management (10 percent) responsible for much of the rest. Demand for electricity power has been growing faster than GDP in recent decades and under a baseline scenario, using international energy costs but not valuing carbon, total emissions from power generation would increase by 230 percent between 2008 and 2030, to 312 Mt CO_2e. This is mainly as a result of a continued reliance on fossil fuels for power generation. Overall, GHG emissions in the baseline are estimated to grow from 660 Mt in 2008 to 1,137 Mt CO_2e in 2030.

Significant Savings from a Limited Sample

The study used a cost effectiveness analysis to assess 40 near-term priority mitigation measures, which taken together could avoid 477 Mt CO_2, costing Mexico approximately US$ 64 billion to 2030 (US$ 3b/year) to adopt. This could result in Mexico's GHG emissions being virtually the same in 2030 as they are today but with significant GDP and per capita income growth. Furthermore, this low carbon scenario is conservative as it is based on only 40 interventions and do not assume any major advances in technology.

The largest savings identified were from agriculture and forestry (150 Mt CO_2e), comprising reforestation, commercial plantations, and measures to reduce emissions from deforestation and forest degradation. A double dividend was observed where improved forest management can be combined with the substitution of fossil fuels with sustainable biomass. Transport was the second largest contributor to GHG emissions savings (131 Mt CO_2e), where rapidly expanding vehicle ownership has led to a four-fold increase in energy use since 1973. Here, integrated urban transport and land-use planning will be critical factors, alongside improvements in vehicle efficiency.

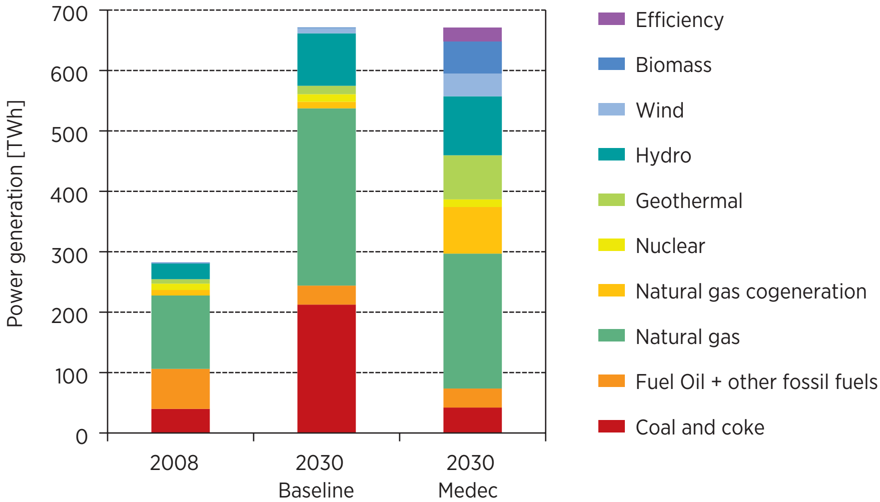
The study identified high priority actions with significant scale-up potential that could be undertaken over the next five years. These include wind farm development, particularly in Oaxaca State, bus rapid transit based on projects in Mexico and piloted in other parts of Latin America, cogeneration in Petróleos Mexicanos (PEMEX) facilities, avoided deforestation based on the Los Tuxtlas project in Veracruz, and an expansion of efficient lighting and appliances programs.

Turning Theory into Reality

The results and findings of the Mexico low carbon study have directly contributed to:

- The 2009 publication of Mexico's Special Climate Change Program 2009-2012, which identifies GHG savings of 51 Mt CO_2e by 2012, leading to an 11 percent absolute reduction in emissions from a 2000 baseline by 2020
- The investment plan submitted by Mexico to the Clean Technology Fund
- Two investment loans by the World Bank to Mexico on urban transport and energy efficiency
- The formulation of Mexico's Development Policy Loan (US$ 401 million) from the World Bank in 2010 for low carbon development, which supports policy measures for clean energy, sustainable transport, efficient housing, and sustainable forest management

Figure 4.4 | Baseline and Low Carbon Scenarios for Power Generation in 2030 in Mexico



Source | ESMAP, 2010a.

Mexico's long-term target is to achieve a 50 percent reduction in emissions from 2000 levels by 2050. Achieving this will involve, in the words of the Government of Mexico, "policy mainstreaming" across all areas of the economy and society, and priority-setting at the "highest level of all tiers of government."

POLAND

The Poland low carbon study (World Bank, 2011b) supported the government in assessing how the country could transition to a low carbon economy as successfully as it underwent the transition to a market economy in the early 1990s. Although Poland is not among the largest emitters of GHG globally, its economy is among the least carbon efficient in the European Union (EU), with per capita emissions similar to the EU average (10 tonnes per capita in 2007) but with a significantly lower income level. This is due to the high percentage of electricity generation from coal and lignite (around 90 percent, the highest in the EU), high rates of emissions growth from the transport sector, and energy efficiency performance that, although much improved over the last 20 years, have not yet caught up with Western European levels.

The Polish low carbon study used a suite of four scenario-modeling tools to link bottom-up analysis with top-down macroeconomic modeling. The analysis suggests that under a baseline scenario Poland's emissions in 2020 will be 20 percent above 2005 levels, rising to 30 to 40 percent higher by 2030. This should be set against Poland's commitments as part of the EU climate change and energy package, or the "20-20-20" targets, which will require Poland to contribute to a 21 percent EU-wide emission reduction target from the energy-intensive sectors by 2020 from 2005 levels.

Sizeable Emissions Abatement Possible

The analysis in Poland shows potential for sizeable emissions abatement with an economic impact that is negative, but appears to be affordable. Interestingly, the analysis finds that it is the switch to low carbon energy and fuel efficiency measures that provide the bulk of abatement, but that the technologies with the largest abatement potential are not necessarily associated with the biggest macroeconomic cost.

The main findings of the Poland low carbon study include the following:

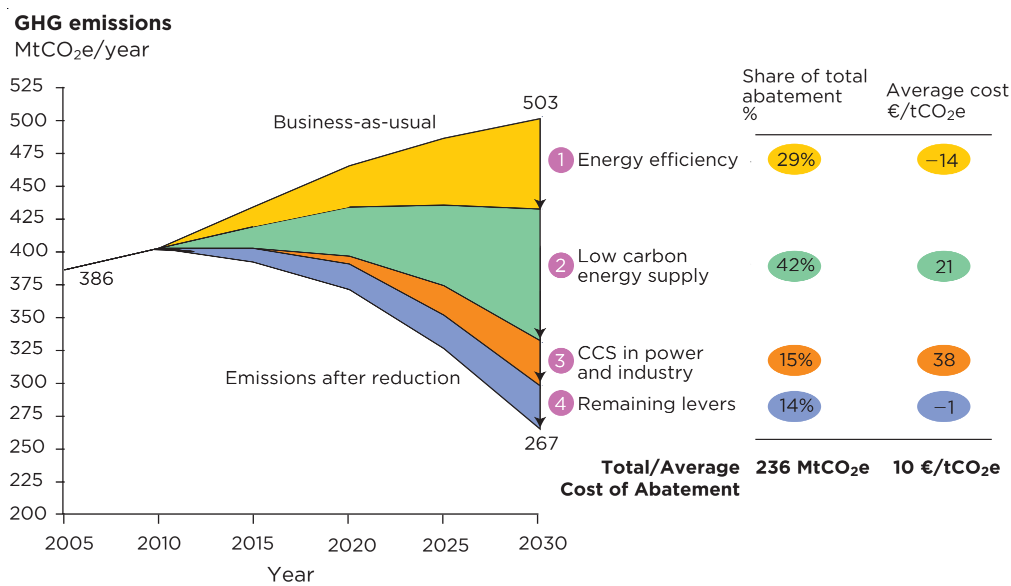
- Poland can cut its GHG emissions by almost a third by 2030 (compared to 2005 levels) by applying existing technologies, at an average cost of €10 to 15 per ton—this is equivalent to a 47 percent reduction against projected baseline emissions.
- Costs to the economy would peak in 2020; but by 2030, the shift towards low carbon would augment growth; overall, abatement measures would lower GDP by an average of one percent each year, but with the gap gradually diminishing towards 2030.

- The economic cost in terms of forgone output and employment of Poland's required abatement by 2020 under EU rules is higher than for the average EU country; and the restrictions on emissions trading between sectors aggravate that cost.
- The energy sector currently generates nearly half of Poland's emissions; but the transport sector—with precipitous growth and the need for behavioral change rather than adoption of new technologies—may end up posing the greater policy challenge.

Results from the study were used as references during the preparation of Poland's long-term economic strategies, in particular the pillar on energy security and the environment. The study helped strengthen intergovernmental cooperation between core agencies in Poland through several working-level seminars, and helped to inform the debate on targets and national and EU energy policies.

In August 2011, the Council of Ministers adopted a set of guidelines for Poland's low-emissions economy program, to which this analysis provided a substantial contribution. The low carbon study was also a key input to a US$ 750 million Energy Efficiency and Renewable Energy Development Policy Loan from the World Bank, which will support the Polish Government's efforts to decrease emissions through accelerating energy efficiency and targeted renewable energy interventions.

Figure 4.5 | Abatement Potential for Poland in 2030 by Groups of Intervention (MicroMAC curve)



Note: Energy efficiency includes measures in buildings, transport except switch to biofuels, and a few in industry, such as cogeneration.

Source | ESMAP, 2011d.

SOUTH AFRICA

South Africa's historically low cost of energy supply, together with the predominance of extractive industries, have combined to create a highly energy-intensive economy. At present, South Africa is the largest contributor to GHG emissions in Africa. On a per-capita basis, its GHG emissions are higher than in most other major emerging economies, including Brazil, China, and India.

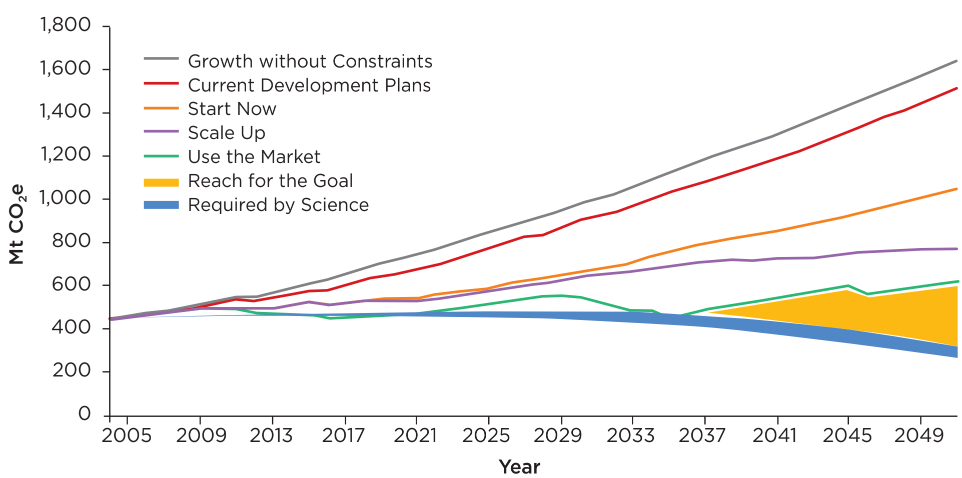
Since 2007, the World Bank, assisted by the UNDP and ESMAP, has supported implementation of South Africa's Long-Term Mitigation Scenarios (LTMS), which involved collaboration between the Department of Environmental Affairs and Tourism[5] and the University of Cape Town (University of Cape Town Energy Research Centre, 2007). The LTMS encompassed five scenarios, including a baseline scenario termed Growth without Constraints, to explore options for decreasing GHG emissions out to 2050, making use of the MARKAL optimization model for energy-related emissions (Hughes, Haw, Winkler, Marquard, & Merven, 2007). The support provided included an international peer review of the LTMS prior to submission to the Cabinet and the provision of substantial technical assistance on energy efficiency, demand-side management, and power rationing in light of the urgency of these issues due to the acute power crisis that struck South Africa in January 2008.

Low Cost Wins with Multiple Benefits

The gap between South Africa's baseline scenario and the ambitious Required by Science scenario of 60 to 80 percent cuts in GHG emissions is projected at 1,300 MtCO_2e by 2050, or more than three times current emission levels. Although achieving such cuts will require large-scale investment in low carbon electricity generation and structural reform, the work carried out suggests that early progress can be made through energy efficiency savings.

[5] Now, the Department of Environmental Affairs.

Figure 4.6 | Long-Term Mitigation Scenarios, South Africa



Source | ESMAP, 2011c.

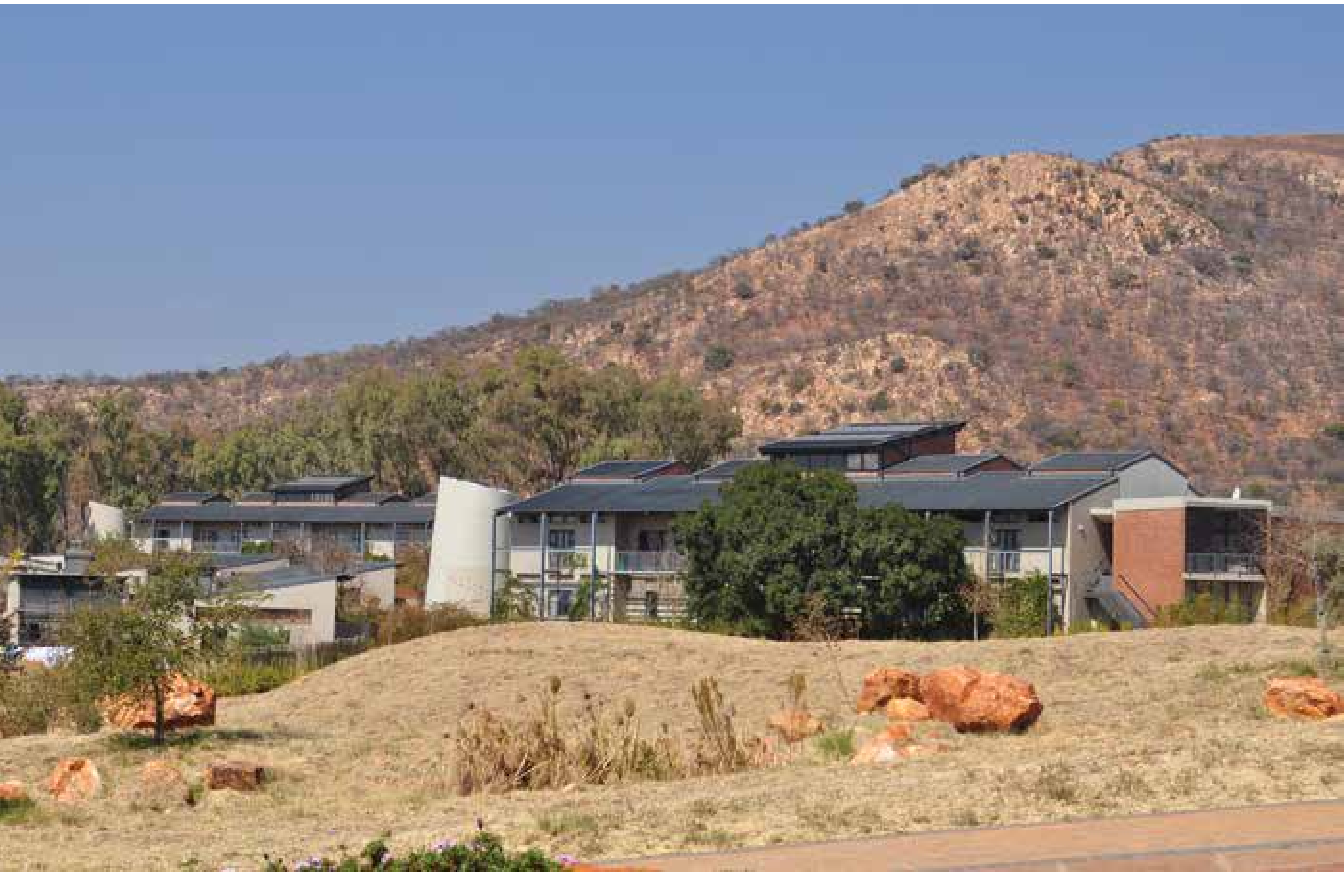
A large proportion of these savings would be obtained from a small number of industrial consumers through a Power Conservation Program (PCP), the title for a market-based power rationing system (ESMAP, 2011b). This was introduced to complement other emergency measures in response to the power crisis, including the Standard Offer approach described below and heightened customer awareness on the real-time status of the electricity system. The design of the PCP borrowed heavily from the experiences in Brazil and California which, like South Africa, suffered from many years of mispricing a scarce resource, impairing the power sector's ability to invest in new capacity. In Brazil, which faced an energy constraint, demand response was used to reduce power use (or MWh), while California had to confront a capacity crunch (a lack of power, or MW). South Africa was unique in the sense that the power system was both energy and capacity constrained, making the experiences from both places relevant.

After extensive consultations and drawing on international best practices, an interministerial committee formally agreed to develop a market-based program relying upon the experience in Brazil but customized to the objectives and constraints in South Africa. The decision was taken to start with the largest customers first and then move later to the whole customer base, if necessary. The goal of the PCP initiated by Eskom, the national electricity supply company, in early 2008 was a 10 percent reduction (equal to around 3,000 MW) in peak demand. The initial focus of the PCP was on large industrial users, particularly mines and smelters.

The PCP was very successful. In less than a month, the country was able to virtually eliminate load shedding. The quotas were applied to large customers only, as part of a phased implementation plan. By the end of 2008, as a result of the global economic slowdown, power demand in South Africa declined dramatically, which meant there was no need to increase quotas or include smaller customers. In terms of reductions in GHG emissions, the PCP helped promote changes in habits and foster investments in energy efficiency. These reductions would be unlikely to occur with rolling blackouts, which encourage customers to use as much as possible when power is available. A 10 percent reduction in the industrial load corresponds roughly to 6 percent of the country's electricity consumption, which over a six-month period translates into savings of 6.1 $MtCO_2$.

A second component to the work was the review and discussion of international best practices in implementation of energy efficiency and demand-side management, including the role of special purpose funds, such as the one operated by Eskom (ESMAP, 2011c). By analyzing the experiences of Australia, India, the United States (in particular, the states of New Jersey, New York, Texas, and California), and other countries, the work led to the recommendation of the Standard Offer approach, which is a mirror image of a feed-in tariff mechanism that can be used to create incentives for the delivery of energy efficiency improvements from a range of benchmarked technologies.

The Standard Offer would replace the previous approach whereby energy efficiency and demand-side management projects would bid into a central fund, with approval granted on a case-by-case basis. This process proved to be slow, cumbersome to administer, and non-transparent. As a result of the



work undertaken, the Standard Offer approach was adopted by the Government of South Africa in 2010 and further extended in 2011, for the following energy efficiency projects: government-owned buildings, commercial buildings, existing housing developments, solar water heating projects, and energy conservation in the industrial sector.

LESSONS LEARNED ON PROCESS

The seven studies were supported by World Bank specialists working within their respective regional departments, with advice and funding provided by ESMAP. This helped ensure that the work was well grounded within the existing country dialogue, and allowed the methodology to be customized according to each country's needs. However, a number of lessons emerged that were common to the successful completion of the studies, and these are summarized in the next chapter.

5 | POLICY CONCLUSIONS

As one of the first programs to support strategic low carbon planning in developing countries, the seven ESMAP-supported studies summarized in this report provide valuable lessons to inform similar activities now being undertaken or considered in other countries. Although very different in terms of scope, methodology, and results, all of the studies have had an impact on national policy development and investment decisions—the measures by which such work is best judged.

This chapter looks across the seven studies to draw out the key policy conclusions from this work—both from the perspective of international frameworks and processes, and in terms how low carbon development can actually be implemented on the ground.

THE POTENTIAL FOR COST-EFFECTIVE ABATEMENT IS SUBSTANTIAL

The studies help illustrate how, despite having very low per capita GHG emissions, many developing countries could still make substantial reductions in emissions and energy use against a business-as-usual trajectory with investments that, in many cases, will pay for themselves. For example, the analysis in Mexico showed that nearly half of the total potential for avoided emissions (26 interventions) would result in positive net benefits—such as improved vehicle efficiency, cogeneration, and more efficient household appliances. Overall, the measures proposed in the studies would lead to net costs (with the exception of Poland, which by 2030 would experience a margin net benefit), but these were generally seen as manageable in the context of continued GDP growth and the volume of financing already needed to support this.

From a climate change mitigation perspective, countries are keenly aware of the opportunities associated with green growth and the risks of being locked into high carbon infrastructure. Decoupling economic growth from carbon emissions is increasingly a policy goal being prioritized for national benefit rather than as a result of international pressures or concerns. Perhaps more importantly from the perspective of many developing countries, the studies show that low carbon development can support a range of other policy goals, including economic competitiveness, energy security, the development of new industries and jobs, investment in knowledge and innovation, and local environmental protection. It is this combination of reasons that helps explain the strong interest from many developing countries in low carbon growth trajectories.

BUT STRONGER INTERNATIONAL ACTION IS REQUIRED FOR 2°C

Although the conclusions from each low carbon study are ambitious when considered against the respective country's baseline, none would lead to the realization of a low carbon development pathway consistent with emissions of 2 tCO_2 per capita.[6] With the exception of Brazil and Poland, the overall picture is one of growth in GHG emissions, reflecting rapid increases in GDP and per capita income growth, and the associated demand for power, transport, and natural resources. Furthermore, the lack of substantial emissions reductions in developed countries, combined with the expectations in most developing countries for high emissions growth in the short term, means that the global emissions 'budget' (cumulative emissions are the key indicator from a climate change perspective) will continue to be used up at an alarming rate.

For developing countries to adopt even more ambitious abatement targets, international action will be required to reduce the costs of existing technologies, support the development of new technologies, achieve a wholesale shift in private sector investment, and provide additional climate financing. All countries will need to explore more radical approaches to economic development, including more holistic urban planning, stricter codes for new buildings, more aggressive standards for appliances, large-scale modal shifts to public transport, and the pricing of the environmental externalities of fossil fuel production and consumption. There is clearly a leadership role to be played by developed countries through strong domestic policies that can help bring about the investment in low carbon solutions that is required.

This is not to dismiss the importance of the studies, which should be seen as a starting point. Transitioning to a low carbon development pathway at the national level is a process; targets and political commitments can quickly change, but successful delivery requires strong institutional capacity to build scenarios, analyze policy options, and make recommendations. Implementing the relatively low cost abatement options identified in these studies will send a signal to investors and help to build the capacity needed for more ambitious action further down the line.

Finally, as national-level scenario modeling is unable to take account of external developments, such as the actions of other countries, and is largely based on existing and known technologies, it is likely to be conservative on the potential for emissions reductions, particularly in the outer years. An international paradigm shift towards a global low carbon economy could have major implications for the economic assumptions underpinning each country's development plan—for example by reducing the cost of key technologies, improving the incentives for energy efficiency, or creating markets for new products and services. This emphasizes the need to see low carbon planning as a continuous process that will respond over time to the interaction between domestic policy objectives and the external economic and political environment.

[6] This is the level of per capita emissions that is often associated with a 50 percent chance of keeping the global average temperature rise to less than 2°C.

LOW CARBON PLANNING CAN BE INTEGRATED INTO NATIONAL DEVELOPMENT POLICY

The studies have demonstrated that it is possible to integrate low carbon development objectives into sectoral plans, and across sectors—rather than treating climate change as an add-on to be solved through stand-alone policies and investment projects. Precisely because climate change is an economy-wide challenge, low carbon planning can help to build bridges between different parts of government, and the long-term perspective required can provide a useful challenge to the status quo. Making low carbon development a government-wide issue, rather than the preserve of any particular line ministry, was a key lesson coming from this work, and one that could have lasting consequences in terms of government coordination on climate change policy in the countries concerned.

Central to this was the strong priority given to intergovernmental and stakeholder engagement throughout the program. This was seen as particularly important in building consensus around data assumptions and in scenario modeling, which was used extensively in the Brazil, India, Mexico, and Poland studies. Despite the inherent complexity of the issue, stakeholder engagement helped enrich the work by challenging assumptions, agreeing to baselines, and providing feedback on the practicality of various technological and economic scenarios from a bottom-up perspective. The two modeling tools developed as a result of this work, EFFECT and MACTool, are both designed around a stakeholder engagement process, and have shown the practical value of consensus building for low carbon planning.

Such work can also be used to build lasting capacity within governments to obtain quality data, develop scenarios, and provide policy recommendations. This will have the highest chance of impact where such efforts are carried out as part of a country's ongoing scenario modeling and economic planning activities. However, low carbon planning does require a special dedicated effort, at least initially, to help build the understanding of how it challenges the conventional development model.

CLIMATE FINANCE MUST BE TRANSFORMATIVE AND WELL PRIORITIZED

The response of countries to the findings from this work demonstrates their strong interest in low carbon development and willingness to act. Outcomes so far range from policy shifts (in several cases supported by development policy loans) to investments in transformative interventions (for example, through the Climate Investment Funds). However, where low carbon planning has been successfully mainstreamed into development policy-making, longer term outcomes can be expected, such as helping to frame country mitigation offers within the UNFCCC process and informing the prioritization of measures within country investment plans.

Although there are many low or negative cost opportunities to reduce or avoid GHG emissions, there is still a net cost to adopting a low carbon pathway, even if this is relatively small in comparison to the economic growth that can be expected over the same period. In the case of Mexico, the cost of realizing the low carbon scenario was estimated at US$ 64 billion to 2030 (US$ 3 billion per year) and in India, the additional investment to achieve the 'all out stretch' scenario in terms of plant life extension, efficiency improvement, and new capacity for grid-supplied electricity was estimated to have a net present value of US$ 33 billion by 2031, equivalent to a 23 percent increase over the Delayed Implementation scenario.

The scale of funding required necessitates use of a wide range of financing mechanisms, including incentives where appropriate to direct investment into low carbon innovation and stimulate private sector investment. International climate finance will also be important, but recognizing its limitations in the face of such high demands, prioritization will be required. Based on the studies discussed in this report, funding for readiness activities (economy-wide and sector-specific low carbon planning), transformative policy changes (detailed implementation of the recommendations), and first-of-a-kind investments (for demonstration and to overcome real or perceived risks) are proposed as high priorities as they are likely to achieve the greatest return. Domestic, international private sector and multilateral financing can then be used to scale up low carbon investment.

SHIFT THE EMPHASIS FROM PLANNING TO IMPLEMENTATION

Political interest in low carbon development has grown substantially since 2007 because of the international climate change negotiations, rapid technological progress, as well as the increasing cost and price volatility of fossil fuels. Many countries are now undertaking, or are considering, low carbon planning studies to inform climate change strategies at the national level, or are putting together Nationally Appropriate Mitigation Actions (NAMAs) for submission to the UNFCCC. There are also a range of networks and organizations available to support developing countries in this process.

However, low carbon planning is only a means to an end, and is best seen as part of a modular and continuous process of policy development and investment at the country level. There is a risk that international processes and donor-funded programs could overemphasize the economy-wide planning stage at the expense of near-term investment planning and detailed policy development and implementation. A key conclusion from this work is the need for such programs to be flexible to local needs—as an example, two of the seven studies were actually sector-specific, leading to a very different output than the economy-wide analyses.

When it comes to the preparation of NAMAs, ESMAP's experience in working with these seven countries suggests that NAMAs would be best carried out as a conclusion to a much broader, more holistic process of low carbon development planning, rather than an end in itself. One way of viewing a NAMA would be to see it as an investment plan that outlines a country's objectives for the sector in question, the policies needed to implement it, and the individual investments needed to deliver it—broken down into those that will be government funded, those that require private sector investment, and finally those where international climate financing is required. Low carbon planning, undertaken at the sectoral level but with multi-sectoral coordination, would inevitably be central to informing this effort.

AN EXPANDED LOW CARBON PLANNING TOOLBOX IS NEEDED

As explained in Chapter 3, data sourcing and scenario modeling were central to several of the low carbon studies, and have been cited by those who worked on the studies as key components in the consensus building that took place. To be effective in this context, scenario-modeling tools need to be open access so that the assumptions can be scrutinized and to enable a degree of customization. In several cases, appropriate tools did not exist, leading ESMAP to make a number of significant, one-off investments in new modeling tools that are now being made available for others to use. It seems likely that, in a world where action on climate change is partially funded through international climate finance linked to the UNFCCC process, transparency in terms of data acquisition will also be crucial for the monitoring, reporting, and verification of actions undertaken at the country level.

Those involved in low carbon planning activities can help continue this effort by improving and consolidating the tools that are available, enhancing the capacity of countries to collect, verify, and incorporate useful data, and ensuring that best practice is shared.

Finally, there is increasing interest in integrating adaptation considerations into future work, potentially leading to low carbon, climate-resilient development planning. Many energy, transport, and agricultural systems are sensitive to climate impacts—for example, heat or water stress can change the viability of certain electricity generating options, or certain land uses, and sea level rise impact how cities and transport infrastructure are planned. As such investments are long term in nature, there are potential synergies in considering development pathways that deliver both low carbon and adaptation benefits.

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ABBREVIATIONS AND ACRONYMS

ASTAE	Asia Sustainable and Alternatively Energy Program
CCS	carbon capture and storage
CDKN	Climate & Development Knowledge Network
CGE	computable general equilibrium
CLASP	Collaborative Labelling and Appliance Standards Program
CLEAN	Coordinated Low Emissions Assistance Network
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
CRESP	China Renewable Energy Scale-up Program
DFID	Department for International Development (United Kingdom)
DGSE	dynamic stochastic general equilibrium
DNPI	National Climate Change Council (Indonesia)
EFFECT	Energy Forecasting Framework and Emissions Consensus Tool
ESMAP	Energy Sector Management Assistance Program
€	Euro (currency)
GDP	gross domestic product
GEF	Global Environment Facility
GGGI	Global Green Growth Institute
GHG	greenhouse gases
GTAP	Global Trade Analysis Project
GW	gigawatt
EU	European Union

Kt	kiloton
kWh	kilowatt hours
LEAP	Long-range Energy Alternatives Planning
LEDS	low emission development strategies
LTMS	Long-Term Mitigation Scenarios (South Africa)
MAC	marginal abatement cost
MACTool	Marginal Abatement Curve Tool
MARKAL	MARKet ALlocation
MoF	Ministry of Finance (Indonesia)
Mt	million tons
NAMA	nationally appropriate mitigation action
NDRC	National Development and Reform Commission (China)
NGO	non-governmental organization
NSP	new suspension preheater
OECD	Organization for Economic Co-operation and Development
PCP	Power Conservation Program (South Africa)
PJ	petajoule
ppm	parts per million
PMR	Partnership for Market Readiness
t	ton
TWh	terra watt hour
UNDP	United Nations Development Program
UNFCCC	United Nations Framework Convention on Climate Change
US$	Unites States dollar (currency)

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