Greenhouse Gas Mitigation in Developing Countries

Promising Options in China, Mexico, India, Brazil, South Africa, and South Korea

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June 9, 2009

Stockholm Environment Institute
Working Paper WP-US-0903

Abstract

International cooperation is a cornerstone of efforts to combat climate change. The achievement of global climate change mitigation goals will require significant investment in emissions reduction in developing countries. International cooperation will be essential in providing the needed finance, capacity building, and technology transfer and development. To help advance international discussions concerning priority sectors, technologies, and policies, this report identifies promising opportunities to support greenhouse gas mitigation efforts in China, India, Brazil, Mexico, South Africa, and South Korea. It projects future "business-as-usual" emissions scenarios, assembles existing estimates of emissions reduction potential, and assesses barriers and opportunities concerning reducing greenhouse gas (GHG) emissions in each country. The paper focuses particular attention on transportation, buildings, industry, and electricity production and suggests some sectors, technologies, and policies where international efforts could yield significant greenhouse gas emissions in light of each country's domestic priorities and programs.

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Acknowledgements

This report was prepared with funding from the U.S. Environmental Protection Agency, International Capacity Building Branch. The opinions expressed in the report, however, are the authors' and do not reflect, necessarily, the views of the International Capacity Building Branch. We express our great thanks to John F. Fitzgerald, EPA task order manager, for conceiving this report, and to Nimmi Damodaran of Stratus Consulting for serving as project manager.

The authors of this report gratefully acknowledge our colleague Clifford Polycarp and the following individuals for the research, valuable insights, and constructive feedback they provided. Please note that any opinions or conclusions presented herein, however, are solely those of the authors and not of those acknowledged below or of the United States Environmental Protection Agency.

Saliem Fakir, World Wildlife Fund, South Africa

David Fridley, Lawrence Berkeley National Lab

Todd Johnson, World Bank

Hoseok Kim, Korea Environment Institute

Suman Kumar, Confederation of Indian Industry, India

Ajay Mathur, Bureau of Energy Efficiency, Government of India

Jyoti Parikh, Integrated Research and Action for Development, India

Chella Rajan, Indian Institute of Technology – Madras, India

Simon Ratcliffe, Endeva Consulting, South Africa

Fakir Saliem, World Wildlife Fund, South Africa

Girish Sant, Prayas, India

Roberto Schaeffer, Federal University of Rio de Janeiro, Brazil

Xiaodong Wang, World Bank

Executive Summary

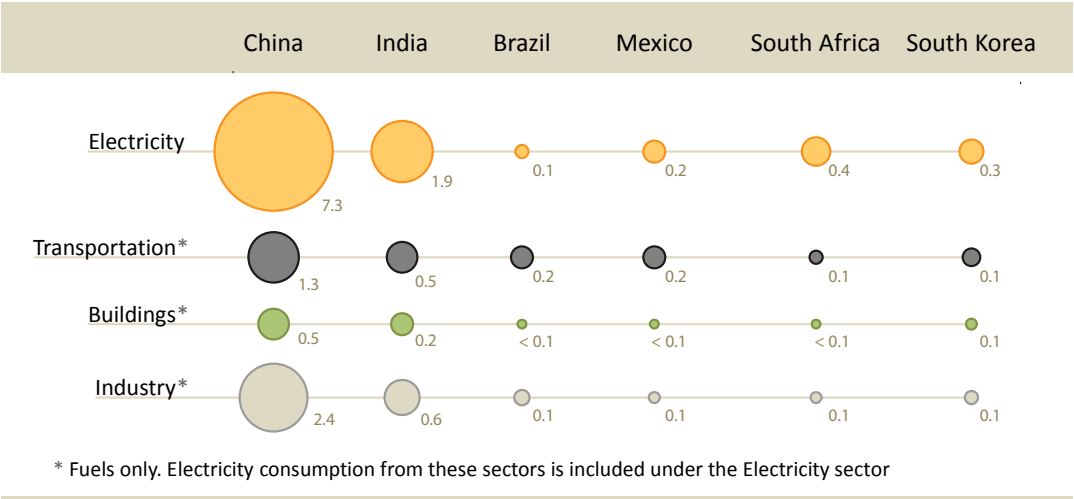
This report identifies promising opportunities to support greenhouse gas mitigation efforts in China, India, Brazil, Mexico, South Africa, and South Korea. It projects future "business-as-usual" emissions scenarios, assembles existing estimates of mitigation potential, and assesses barriers and opportunities concerning reducing greenhouse gas (GHG) emissions in each country. The report focuses on policies, measures, and/or technologies to reduce greenhouse gas emissions in the transportation, buildings, industry, and electricity production sectors. In particular, the report identifies broad areas where international support could prove instrumental in scaling up mitigation efforts in major developing countries, mindful of the barriers and interests that are specific to each country. Informed by experts and available mitigation studies, we suggest specific technology and policy options in each country that hold particular promise for international involvement.

Emission Projections and Mitigation Potentials

We have developed baseline emissions scenarios for each country using international energy, population, and economic activity data from the International Energy Agency, United Nations, World Energy Council, U.S. Energy Information Administration, and other sources. These estimates suggest that baseline energy-sector greenhouse gas emissions from the six countries in this study could double from today's level to about 17 metric gigatons (Gt) of carbon dioxide equivalent (CO_2e) by 2030. By then, these six countries could represent over 40% of global energy-related GHG emissions, and a similar fraction of the world's mitigation opportunities.[1]

We have also compiled and reviewed available estimates of mitigation potential for each of several greenhouse-gas-mitigation options, using existing studies by both in-country and international researchers. Our analysis focuses on opportunities to reduce energy-related emissions from energy supply, transportation, buildings, and industry. Figure 1, below, displays the projected relative baseline emissions from each of these four sectors in each of the six countries in the year 2030.

Figure 1. Projected 2030 Baseline Greenhouse Gas Emissions by Sector and Country
(Gigatons CO_2e; Energy-related sectors only; Projected emissions proportional to area of circle)



Based on further assessment of in-country initiatives and policy objectives, international support activities, barriers to implementation, and recommendations of other in-country and international policy studies, we

[1] Based on the 40 GtCO2 projected by IEA's World Energy Outlook for global energy related emissions, and on McKinsey 2009.

identify a suite of mitigation opportunities as having particular potential for each country. This analysis was also vetted (and in some cases compiled) with in-country research and government experts.

The options having high mitigation potential are summarized in Table 1 below.[2] Options with high mitigation potential for all countries include:

- Renewable energy promotion and development
- Adoption, extension, and enforcement of building and appliance energy codes; and
- Vehicle efficiency standards.

Options with high mitigation potential in at least 3 countries include:

- Carbon capture and storage (power sector);
- Coal- and other fossil-fuel-fired power plant efficiency;
- Nuclear energy;
- Biofuels (transportation sector);
- Increased public transport and other strategies to reduce vehicle miles travelled; and
- Industry agreements, standards, and incentives.

Although this study identifies numerous promising energy-related mitigation options, our efforts also suggest the need for further research to bolster and refine the assessment of mitigation potential. In particular, while energy sector mitigation analysis is particularly advanced for China and South Africa, there is room for significant improvement in all countries. Several existing studies quantify and compare greenhouse gas mitigation potential across the six countries. However, the limited depth, transparency of assumptions, and degree of involvement of key stakeholders in many studies suggest that substantial work is still needed, especially if such analyses are to provide the basis for comprehensive mitigation action plans. Indeed, experience suggests that such analyses can be important tools in motivating and guiding effective action.[3] Current international efforts such as the Low Carbon Country Case Studies of the World Bank, and other (in some cases bilateral) efforts, may help to address this gap.

In summary, this study suggests some sectors, technologies, and policies where international efforts could yield significant greenhouse gas emissions in light of each country's domestic priorities and programs. Further work is needed to provide analytical support for the development of comprehensive nationally appropriate low-carbon action plans, supported and enabled by international efforts.

[2] In general, options included in Table 1 have the potential to reduce greenhouse gas emissions by at least 1% of that country's projected 2030 baseline emissions, but with two broad exceptions. The first is the "Buildings & Appliances" category, for which the potential to reduce sector-wide emissions is estimated by the studies reviewed to be least 1% for all countries, and for which leading options under discussion in the country are listed regardless of whether they individually would meet the 1% threshold or not. This varying standard for Building and Appliances was used because many studies did not quantify reductions associated with individual options in this sector (or if they did, emission reductions from reduced electricity use are reported under electricity production). The second exception is for South Korea, for which insufficient information exists to apply this 1% threshold, so the options listed for this country are those included in its *Comprehensive Plan for Combating Climate Change* (Republic of Korea, 2008a).

[3] Many examples exist in industrialized countries. For examples, mitigation assessment studies have provided the impetus for many US state climate policies, such as California's AB32 legislation and related actions.

Table 1: High Potential Mitigation Options by Sector and Country
(as identified in available mitigation studies)

	China	India	Brazil	Mexico	South Africa	South Korea
Electricity Production	▪ Nuclear power ▪ Renewables ▪ Coal-fired power plant efficiency ▪ CCS	▪ Nuclear and renewable electricity ▪ Coal-fired power plant efficiency ▪ CCS ▪ Reduce trans-mission losses	▪ Wind power, small hydro, and sugar cane bagasse co-generation	▪ Renewables (especially solar, wind, and small hydro) ▪ Switching to natural gas from fuel oil ▪ Reduced trans-mission losses ▪ Nuclear ▪ CCS	▪ Renewables ▪ Coal-fired power plant efficiency ▪ CCS	▪ Nuclear ▪ Coal-fired power plant efficiency ▪ Renewables (wind, tidal, solar) ▪ Transmission and distribution efficiency
Transportation	▪ Vehicle efficiency standards ▪ Electric vehicles	▪ Vehicle efficiency standards ▪ Biofuels ▪ Enhanced public transport and urban planning	▪ Vehicle efficiency standards ▪ Ethanol from sugar cane	▪ Vehicle efficiency standards ▪ Second-generation biofuels ▪ Mode-shifting ▪ Optimized freight traffic	▪ Vehicle efficiency standards (including electric vehicles) ▪ Biofuels ▪ Mode-shifting	▪ Vehicle efficiency standards ▪ Government R&D for efficient vehicles
Buildings & Appliances	▪ Building codes and enforcement ▪ Appliance efficiency and labeling standards	▪ Extension of existing building codes ▪ Retrofits of existing buildings via ESCOs	▪ Adoption of building energy codes ▪ Appliance efficiency standards ▪ Fuel switching from wood and oil to LPG and natural gas	▪ New standards for lighting efficiency ▪ Expansion of existing energy efficiency programs, possibly to include building codes	▪ More-stringent building standards and mandatory efficiency targets (including use of solar hot water heaters)	▪ Energy efficiency standards (lighting) & ratings (appliances) ▪ Government R&D for efficiency technologies and cost-sharing for ESCOs
Industry	▪ Agreements, standards, and incentives for efficiency and CCS in iron/steel, cement, and chemical industries	▪ Tradable energy certificates and other incentives ▪ Energy efficiency in cement, iron/steel industries	▪ Use of sustain-able charcoal and CCS in iron/ steel industry ▪ Process and efficiency gains and CCS in cement industry	▪ Combined heat & power and CCS in steel, cement, sugar, and oil industries	▪ Stringent, mandatory energy efficiency activities and targets	▪ Industry-specific agreements, standards, and required audits
Other				▪ Proposed national cap-and-trade	▪ Study of escalating carbon tax	▪ National cap-and-trade under consideration

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Chapter 1. Introduction

Since the 1992 Earth Summit in Rio de Janeiro, Parties to the United Nations Framework Convention on Climate Change (UNFCCC) have developed strategies, policies, and measures to mitigate climate change and reduce greenhouse (GHG) emissions, both within and outside the Kyoto Protocol agreement. Parties are currently engaged in efforts through the Convention and Protocol to develop a "post-2012" agreement for further coordinated climate action.

International cooperation is a cornerstone of efforts to combat climate change. The achievement of global climate change mitigation goals will require significant investment in emissions reduction in developing countries. International cooperation will be essential in providing the needed finance, capacity building, and technology transfer and development. The UNFCCC Secretariat estimates that over $65 billion in additional mitigation investment and financial flows will be needed in developing countries by 2030 (UNFCCC, 2007), while the consulting firm McKinsey suggests that required flows could exceed $100 billion by 2015.[4] Mobilizing this investment will require a significant scaling up of international assistance, leveraging of private finance, and support for domestic policies and measures in the developing world. With this in mind, UNFCCC Parties agreed to the "Bali Action Plan" in December 2007, launching discussions to enhance "nationally appropriate mitigation actions by developing country Parties...supported and enabled by technology, financing and capacity-building".[5]

Currently, several institutions support GHG mitigation in developing countries. As the financial mechanism of the UNFCCC, the Global Environment Facility currently provides policy, finance, capacity, and technology support to developing country Parties' efforts to reduce GHG emissions. The Kyoto Protocol established the Clean Development Mechanism as means for industrialized countries to gain credit for financing emissions reduction projects in developing countries while delivering sustainable development and technology transfer benefits. In addition, various other multilateral (e.g. World Bank) and bilateral efforts play a key role in providing the capacity, finance, and technology to address GHG emissions.

To further advance U.S. and international discussions concerning support for greenhouse gas mitigation efforts of developing countries, SEI-US assembled this report of promising options in each of six developing countries: China, Mexico, India, Brazil, South Africa, and South Korea. For each country, we:

- **Assemble baseline greenhouse emissions projections through 2030** to provide estimates of "business-as-usual" emissions based on the latest international and country-specific data;
- **Quantify major emission reduction opportunities in each country through 2030** using recent studies of mitigation potential, and country-specific assessment of options and barriers; and
- **Assess potential priorities for engagement**, considering factors such as mitigation potential, mitigation cost, existing international support mechanisms, areas of overlap with each country's development objectives, and barriers (technical, financial, political) to implementing policies and measures.

This report includes three primary sections: a short overview of the study methodology (Chapter 2), an extended discussion of results for each of the six countries (Chapter 3 through Chapter 8), and, finally, an overview assessment of cross-cutting opportunities (Chapter 9).

[4] McKinsey, 2009. Pathways to a Low-Carbon Economy: Version 2 of the Global Greenhouse Gas Abatement Cost Curve, January. http://globalghgcostcurve.bymckinsey.com
See "works cited" at the end of Chapter 3 for UNFCCC, 2007 and other works cited in Chapters 1 and 2.

[5] http://unfccc.int/resource/docs/2007/cop13/eng/06a01.pdf#page=3

Chapter 2. Methodology

We utilized a three-part study methodology, closely following the project goals stated above, as follows.

1. Project Business-as-Usual Emissions

To begin, we created a single baseline scenario for each country intended to closely mirror the projections of the IEA's World Energy Outlook for 2008. For this task, we used the latest international energy, population, and economic activity data from the International Energy Agency (IEA), United Nations (UN), World Energy Council (WEC), U.S. Energy Information Administration (EIA) and other sources.

We assembled these scenarios using SEI's Long-range Energy Alternatives Planning (LEAP) system.[6] . A key strength of LEAP for this project is that it can act as a simple but comprehensive accounting framework within which a set of long range multi-country scenarios can be assembled. LEAP is able to comprehensively capture all energy use and GHG emissions across all six of the countries being studied. LEAP was also used as the analytical platform for a number of the studies reviewed for this report, such as Tsinghua University's study of mitigation potential in China (Tsinghua University, 2006). For further details of the data sources and methodology used to complete these projections, please see Appendix A.

2. Assemble Existing Data on Mitigation Potential and Costs

We conducted a literature review and interviewed contacts at international research and government organizations to assemble existing estimates of greenhouse gas mitigation potentials for promising options. We then standardized – to the extent possible – the units and time periods of the disparate estimates to enable a common comparison across options within and among countries. While we note the underlying methodologies of each study, we did not try to adjust or update other researchers' estimates. In some cases, when differing estimates for a given technology or sector are available from multiple studies, we select the estimate reflecting the more ambitious implementation strategy.[7] These mitigation potential estimates are then joined with the projections of business-as-usual emissions trajectories to develop a simplified comparison of baseline emissions to mitigation potential in the year 2030 for each country.[8]

Greenhouse gas (GHG) mitigation potential depends on the underlying assumptions, ambition and timing of reduction targets, the overlap among competing mitigation options, and, often, a subjective assessment of technical and social feasibility. For example, more ambitious reduction targets can shift the emphasis from technologies with less costly but often limited incremental mitigation potentials (e.g. fossil fuel power plant efficiency or current generation biofuels) to technologies that are more costly in the near term, but can deliver far lower GHG emissions per unit of output or service (e.g. solar power or advanced vehicle technologies). Readers should thus be mindful of the "scenario-dependence" implicit in estimates of emissions reduction potential.

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[6] LEAP is a widely-used software tool for energy policy analysis and climate change mitigation assessment, which has been adopted by hundreds of organizations in more than 150 countries worldwide. LEAP is designed around the concept of long-range scenario analysis. Scenarios are self-consistent storylines of how an energy system might evolve over time. Using LEAP, policy analysts can create and then evaluate alternative scenarios by comparing their energy requirements, their social costs and benefits and their environmental impacts.

[7] It is important to emphasize that the mitigation potential estimates provided here are intended to provide only "ballpark" estimates of mitigation potential (and cost) and should not be viewed as precise estimates. Note that compiling estimates from multiple studies does not yield fully consistent or comparable results, as underlying assumptions may differ and overlaps may exist between different study's estimates (e.g. two or more options may address the same BAU emissions source).

[8] While this approach allows us to represent multiple perspectives on mitigation potentials, as noted in footnote 7, the underlying baseline assumptions differ across the studies. Therefore, the reader should be mindful that mitigation estimates are not necessarily directly comparable to baseline emissions estimates shown.

While we report quantitative estimates of mitigation potential across countries, sectors, and technologies, for the purpose of assessing which options hold particular promise for international involvement, we utilize qualitative ratings to assess emissions reduction potential, given the uncertainties and scenario-dependence of existing estimates noted above. To this end, we developed the following rating scheme:

- **High:** Potential GHG reductions of at least 1% of the country's projected 2030 emissions;
- **Medium**: Potential GHG reductions of between 0.1% and 1% of projected 2030 emissions; and
- **Low**: Potential GHG reductions of less than 0.1% of projected 2030 emissions.

Similarly, for the cost of each mitigation option, we define broad ranges. While several studies provide specific mitigation cost-per-ton metrics, the uncertainty and variability in the underlying assumptions suggest that while these figures may be used as rough "guideposts", the cost metrics should not be interpreted as definitive. This is especially the case a) where technology costs could decline significantly over time due to learning-by-doing and learning-by-researching effects and b) where options involve the displacement of fossil fuels of highly uncertain future cost (e.g. oil and gas), since mitigation cost by definition is estimated relative to avoided fuel costs. This is the case for most options considered.

For these reasons, we use the following ranges:

- **High**: USD 50 per metric ton CO_2e or higher;
- **Med**: USD 5 to USD 50 per ton CO_2e; and
- **Low**: Less than 5 USD per ton CO_2e, including negative cost options.

Together, these two sets of high/med/low mitigation potential and cost ranges are likely to be more robust than precise quantifications for guiding broad identification of priorities.

3. Assess Barriers and Opportunities

To identify key mitigation actions already underway and under consideration, and to assess potential capacity to implement new policies or measures, we conducted a literature review of government plans and government, academic, and industry research studies. We summarize the research in an extensive table for each country that includes information on six criteria for each option: mitigation potential; relative cost; overlapping policy objectives; proposed or adopted policies, key barriers, and existing international support mechanisms. This literature review and country tables were then vetted using interviews with in-country research and government experts, and revised accordingly.[9] Based on this input and recommended policy directions of the studies reviewed, a set of promising options for further involvement were identified. The results of our assessment are included in the following sections – one chapter for each country.

Options Assessed

This report focuses on energy-related mitigation options: in particular, those related to energy supply, transportation, buildings, and industry. Due to the scope of this exercise, options related to forestry, agriculture, waste management, and other non-energy GHG sources and sinks were not reviewed. The following table describes the options assessed. Variations on the options below, as well as similar, more detailed options, were also considered in countries where data were available and will be noted in the chapters devoted to each country.

[9] Please refer to the acknowledgements section for the list of experts consulted.

Table 2. Description of the Mitigation Options Considered

Option	Description/Examples
ELECTRICITY	
Power Plant Efficiency	Renovation of existing electricity plants to increase output per unit of fuel or energy input; replacement of older, less-efficient plants with the latest technologies
Carbon Capture & Storage (CCS)	Capture of carbon dioxide at power plants and storage in long-term reservoirs (e.g. underground, geologic formations)
Fuel Switching	Replacement of coal (or oil) with natural gas as primary fuel for thermal electricity generation
Nuclear Power	Development of new nuclear power plants and/or increased operation of existing facilities
Hydropower	Development of large- or small-scale hydroelectric power plants and/or increased operation of existing facilities
Other Renewables	Development of new wind, solar, geothermal, and/or biomass generation
TRANSPORTATION	
Vehicle Efficiency	Various measures, such as vehicle efficiency standards, new vehicle labeling programs , or accelerated scrappage of older vehicles
Fuel Switching	Various options, such as incentives or requirements, to increase the penetration of electric vehicles, biofuels, or other lower GHG fuels (e.g., compressed natural gas)
Reductions in Vehicle Miles Travelled (VMT)	Expanded public transit; land use planning to encourage smart development; increased share of rail in freight transport
BUILDINGS & APPLIANCES	
Residential & Commercial	Demand-side management programs, building codes, home energy fuel switching, incentives or standards for appliance efficiency
INDUSTRY	
Cement	Application of more advanced plants, technologies, and processes; use of waste fuels; closure of older, less efficient plants
Iron/Steel	Application of more advanced plants, technologies, and processes; increasingly sophisticated energy management practices
Pulp & Paper	Application of efficiency technologies
Other	Increased use of co-generation (combined heat & power)

Chapter 3. China

With 1.3 billion residents in 2008, China is currently the world's most populous country. Many researchers believe that China is now also the world's largest emitter of greenhouse gases, recently surpassing the United States.[10] With a GDP growth of 13% in 2007 and expansion expected to continue in the coming decades (although at a slower rate in the near term, especially given the current global recession), China is likely to be the world's largest emitter of greenhouse gases for the foreseeable future.

The following table shows key economic and climate indicators for China relative to the U.S. and to other countries included in this study.[11]

Table 3: China Development Indicators Relative to Other Countries
(Source: World Bank's World Development Indicators, 2009)

	China	India	Brazil	Mexico	South Korea	South Africa	U.S.
Population, millions (2007)	1,320	1,120	192	105	48	48	302
GNI[12] Per Capita, PPP (2007)	$5,420	$2,740	$9,270	$13,910	$24,840	$9,450	$45,840
GDP Growth, Annual (2007)	13.0%	9.1%	5.4%	3.2%	5.0%	5.1%	2.0%
Energy use per capita, kg oil equivalent (2006)	1,433	510	1,184	1,702	4,483	2,739	7,768
CO_2 emissions per capita (2005)	4.3	1.3	1.7	4.1	9.4	8.7	19.5

Due to China's intense focus on development and its status as a top emitter of greenhouse gases, the country's energy and climate policy is relatively well-studied by both international and Chinese researchers. More recently, the Chinese government has also engaged the international community in thinking about its climate-related energy policies and targets. China has enacted numerous, assertive policies and programs to curb growth in energy intensity and greenhouse gas emissions.

Baseline Emissions Forecast

Figure 2, below, displays the estimated baseline emissions for China between now and 2030.[13]

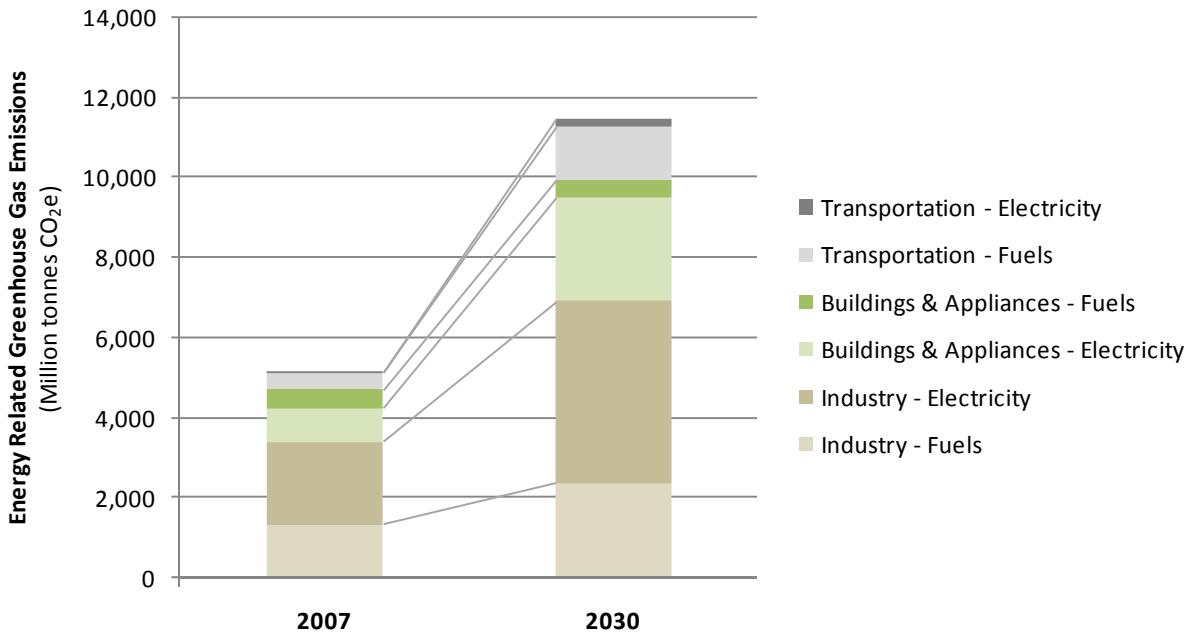
[10] The Chinese government, too, is aware of this possibility: at a recent news conference, Xie Zhenhua, deputy chief of China's National Development and Reform Commission, stated, "Based on information we have at hand, our total emissions are about the same as the United States." http://www.reuters.com/article/environmentNews/idUSTRE49S0GB20081029

[11] Note that in 2004 (the latest year for which comparable, international metrics are available), Chinese emissions per capita were much lower than in the United States. While they are still much lower, Chinese emissions per capita have been increasing rapidly such that overall Chinese emissions are now thought to be equivalent to those of the United States.

[12] GNI is Gross National Income and is reported here using the purchasing power parity (PPP) method of converting to international dollars.

[13] Please see the appendix for a description of our baseline projection methodology.

Figure 2. Projected Baseline Energy-sector Greenhouse Gas Emissions in China in 2030



Mitigation Potential

Many researchers have documented actions taken to date by Chinese government and industry or quantified near-term mitigation potential, but relatively few studies have assessed mitigation potential in China over one or two decades. Among the researchers that have or are currently assessing mitigation potential out to 2020 or 2030 are the following:

- **Tsinghua University** (2006). This study, *Greenhouse Gas Mitigation in China: Scenarios and Opportunities through 2030*, published by the Center for Clean Air Policy, is the most detailed published mitigation study reviewed for China.[14] The study includes detailed findings for costs and potentials of numerous technologies.

- **McKinsey & Company** (2009). In early 2009, McKinsey & Company released a detailed report on mitigation potential in China in 2030. Although the study includes little supporting documentation, it may now stand as the most ambitious and comprehensive analysis of energy and emission reduction options.

- **International Energy Agency** (2007). In their report *World Energy Outlook 2007: China and India Insights*, the IEA made its first attempt to examine energy prospects in detail for China and India alongside its usual focus on IEA countries. In the report, the IEA presents its Alternative Policy Scenario that assumes actions to "ensure that policies and measures are implemented fully, are enforced effectively and are supplemented by new measures where necessary." Most of the initiatives included are already set out in China's 11th *Five-Year Plan* (PRC, 2006) but the IEA assumes aggressive implementation of these measures and, in some cases, additional measures. The IEA study also quantifies investment needs necessary to enact the measures in the Alternative

[14] Findings from Tsinghua University's CCAP-funded study were also published as Cai et al (2008) with some relatively minor adjustments and additional policy insights. Where appropriate, additional items from Cai et al (2008) will be cited in this report but the more-detailed findings published in Tsinghua University (2006) will generally take precedence.

Policy Scenario. This report was further updated in the IEA's *World Energy Outlook 2008* report, which forms the basis for our baseline emissions projections.

- **Vattenfall and McKinsey** (both 2007). Two related research efforts, *Global Mapping of Greenhouse Gas Abatement Opportunities up to 2030* (Vattenfall, 2007) and *Leapfrogging to Higher Energy Productivity in China* (McKinsey Global Institute, 2007) both provide energy or greenhouse gas reduction estimates for particular technologies. Like the more recent Mckinsey analysis (2009), these assessments include little supporting documentation but nonetheless serve as valuable points of comparison relative to the more detailed work of Tsinghua University (2006).

- **International Energy Agency** (2008). In their *Energy Technology Perspectives* report, the IEA quantified a select number of energy-related options for China.

- **United Nations Framework Convention on Climate Change** (2007). This study, *Investment and Financial Flows to Address Climate Change,* quantifies emission reduction potential in industry and building efficiency in China through 2030, based on modeling work by IEA, as part of its assessment of investment and financial flows needed to address climate change.

- **Pew Center on Global Climate Change** (Chandler et al, 2002). This study, *Climate Change Mitigation in Developing Countries: Brazil, China, India, Mexico, South Africa, and Turkey,* included estimates of greenhouse mitigation through 2030 as assembled by China's Energy Research Institute. The study included aggregate totals for six options but few details.

- **Energy Research Institute** (2003). This study, *China's Sustainable Energy Future: Scenarios of Energy and Carbon Emissions,* provides an assessment very similar to the one presented in the Pew Study noted above (2002). The study focuses more on energy than on greenhouse gas emissions and provided little detail on specific options.

In addition to the sources listed above, our team also reviewed China's ***National Climate Change Program*** (2007) and ***Policies and Actions for Addressing Climate Change*** (2008), both released by the Republic of China's National Development and Reform Commission. These reports both focus more attention on short-term mitigation; although we reviewed them to help assess existing and planned actions in China, the documents' treatment of opportunities out to 2020 or 2030 was insufficient to support quantitative analysis.

Based on review of the studies above, we assembled estimates of mitigation potential for the following options in China, as listed in Table 4, below.

Table 4. Estimated Mitigation Potential in China, $MtCO_2e$/year, in 2030

Sector/Option	**Tsinghua University** (2006)[15]	**McKinsey** (2009)[16]	**Vattenfall** (2007)	**UNFCCC** (2007)	**IEA** (2007)
ELECTRICITY	680	2,800	1,700		800
Power Plant Efficiency	130	140	1,700		800
Carbon Capture & Storage (CCS)	10	730			
Fuel Switching	10				
Nuclear Power	240	470			
Hydropower	290	50			
Other Renewables	20	210 (onshore wind) 400 (offshore wind) 450 (solar PV) 200 (switchgrass) 150 (other)			
TRANSPORTATION	440	600			300
Vehicle Efficiency	400	270			300
Fuel Switching	20[17]	330[18]			
VMT Reduction – Smart Transit	20				
BUILDINGS & APPLIANCES	80	1,100		110	700
Residential & Commercial	80	1,100		110	700[19]
INDUSTRY	300	1,200	530	825	600
Cement	180	380[20]	270[21]	825[22]	600
Iron/Steel	120	350	260[21]		
Pulp & Paper	2				
Chemical Industry		450			

Note that in cases where estimates are presented by different researchers, the numbers above can vary substantially. As discussed above in the *Methodology* chapter, estimates of mitigation potential depend on numerous underlying assumptions that are not always transparent, let alone consistent. Furthermore,

[15] Tsinghua University presents results of their "Advanced Options" mitigation scenario relative to a "pre-2000 policy" baseline. In some cases, figures in this chart are based on linear extrapolation of Tsinghua's results from 2020 (the last year reported in some Tsinghua tables) to 2030.

[16] We have excluded McKinsey's options related to the waste and coal mining sectors to better match up with this study's definition of energy-sector.

[17] The fuel switching option included here is for buses to switch to compressed natural gas (CNG).

[18] McKinsey's (2009) fuel switching options was focused on electric vehicles.

[19] This figure of 700 is the total emissions savings from end-use electricity efficiency.

[20] Includes some non-energy CO2 savings.

[21] Estimates of industrial sector emissions by Vattenfall may include process and non-CO2 emission reductions not included in the Tsinghua University (2006) estimates.

[22] The UNFCCC figure of 825 is mitigation potential from combustion emissions only. Their study also included non-CO_2 and industrial process CO_2 emissions, which, when included, would bring the UNFCCC's industrial-sector mitigation potential estimate to over 1,300 $MtCO_2e$ in 2030.

additional, recent estimates of near-term emissions reduction due to government policies are, in some cases, significantly higher than the estimates for 2020 produced by Tsinghua University (Cai et al, 2008; Tsinghua University, 2006). For example, China's *Eleventh Five-Year Plan* calls for a 20% improvement in energy intensity by 2010 (PRC, 2006), a goal that would translate into 1,500 MMt CO2e reduction relative to the baseline in 2010, greater than the sum of all options assessed by Tsinghua University (2006).[23]

Figure 3, below, displays results from the three studies that included mitigation estimates from all four energy-related sectors addressed in this report.

Figure 3. Comparison of Alternative Estimates of 2030 Mitigation Potential in China
(Comparing studies that address all sectors)[24]

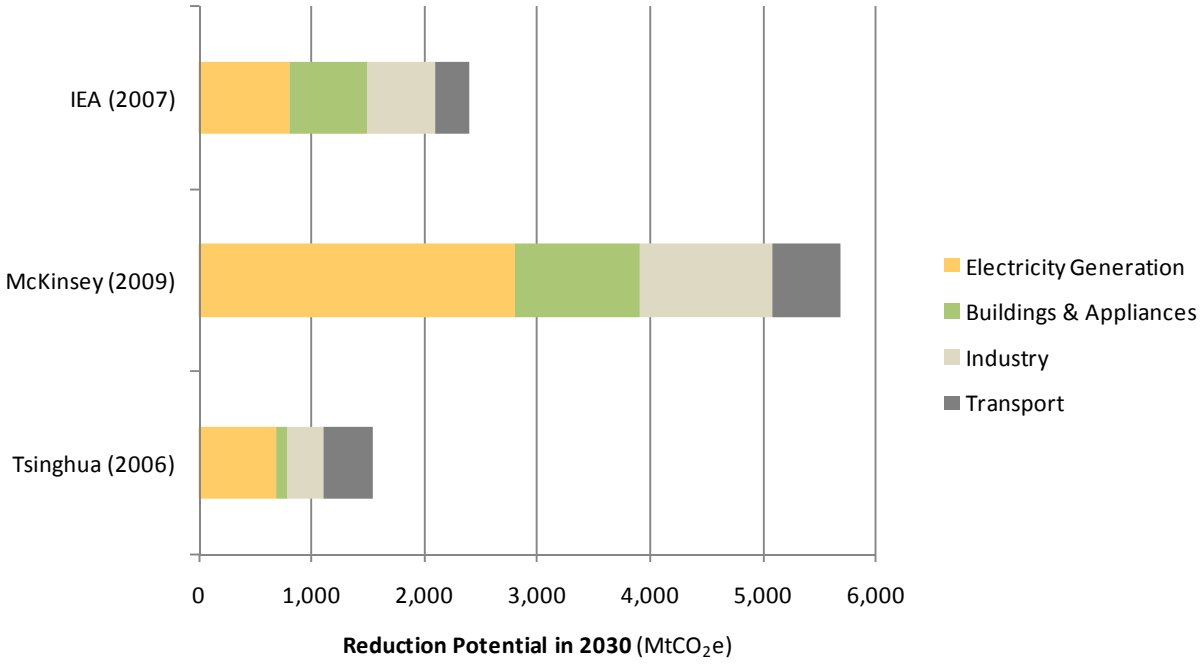
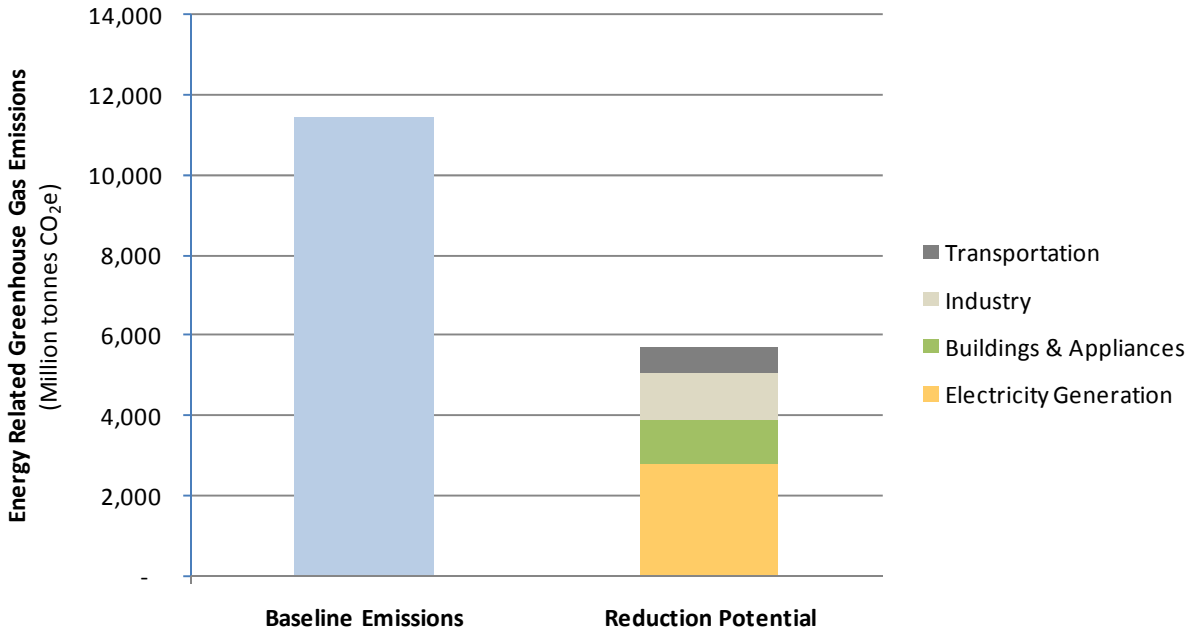


Figure 4, below, displays McKinsey's 2030 mitigation estimates relative to our projected 2030 baseline emissions in China. Note that McKinsey's projected baseline 2030 emissions for China are 14,500 million tones CO2e but include emissions from agriculture, forestry, waste, and industrial process emissions that are not included in our baseline. We have not attempted to further identify or reconcile any differing assumptions between the two baselines. In doing so, we recognize that differences in such assumptions would likely affect the mitigation potential estimates.

[23] Note that the *Plan*'s energy intensity target (energy per Yuan) can be achieved in part by shifting production to higher value and less energy intensive products and sectors, whereas this is not an option considered directly in the Tsinghua study..

[24] We have excluded McKinsey's options related to the waste and coal mining sectors to better match up with this study's definition of energy-sector.

Figure 4. Energy-related Greenhouse Gas Emissions in China in 2030 – Baseline Emissions and Reduction Potential
(Mitigation estimates as reported in McKinsey, 2009; Baseline scenario developed by SEI; see text for caveats regarding comparison of figures)



Assessment of Options

The options discussed above reflect estimates of the achievable greenhouse gas reductions for energy-related options in China. The success of efforts to implement these options will depend on numerous factors, including cost-effectiveness, extent of overlap with social or economic development objectives, extent of existing in-country experience with similar measures or policies, and potential international support mechanisms, among other factors.

We conducted a review of the available literature, as well as interviews with researchers focused on China, to summarize and assess the potential barriers and opportunities for each option. Table 5, below, provides results of this research, and is followed by high priority opportunities for potential involvement.

Table 5. Assessment of Mitigation Options in China

Option	Mitigation Potential in 2030[25]	Relative Cost	Overlapping Policy Objectives	Proposed or Adopted Policies	Key Barriers	Existing International Support Mechanisms
ELECTRICITY						
Power Plant Efficiency	*High* (Tsinghua, 2006; IEA, 2007; McKinsey, 2009)	*Medium* (Tsinghua, 2006; McKinsey, 2009)	▪ Supports objectives for cleaner air (Cai et al, 2008; Zou, 2007)	▪ "Eliminating backward production capacity" especially in small thermal units (PRC, 2008) ▪ Raising the efficiency of energy development and conversion (PRC, 2008) ▪ Existing promotion of "clean coal" (PRC, 2008)	▪ Highly fragmented and understaffed national energy agencies; corresponding decentralized sub-national decision-making (MIT, 2007) ▪ High cost for some technologies (Zou, 2007) ▪ China much more likely to pursue technologies that the country has developed and that don't require licensing, biasing the country towards ultra-supercritical technology over others (Fridley, 2008)	▪ China is co-chair of the Power Generation and Transmission Task Force and the Cleaner Fossil Energy Task Force of the Asia Pacific Partnership on Clean Development and Climate (Asia-Pacific Partnership, 2008) ▪ EU-China Partnership on Climate Change, including an agreement with the UK to build a near-zero-emissions coal plant (IEA, 2007) ▪ Carbon finance: six power plant efficiency projects in CDM pipeline as of November 2008 ▪ International Energy Agency's Implementing Agreement for a Clean Coal Centre (IEA, 2007) ▪ Global Environment Facility projects, including China Thermal Power Efficiency project
Carbon Capture & Storage (CCS)	*High*, (McKinsey, 2009), especially under ambitious targets	*High* (Tsinghua, 2006; McKinsey, 2009)		▪ Proposed R & D subsidies (Tsinghua, 2006) ▪ Proposed technology transfer (Tsinghua, 2006 ▪ Proposed promotion of CCS (PRC, 2008)	▪ Technology developments requiring up to two decades (UNFCCC, 2007) ▪ Energy required to run CCS (sometimes called its "power penalty") would require even more coal mining, with further environmental impacts (Fridley, 2008)	▪ Near Zero Emissions Coal Initiative of the EU-China Partnership (NZEC, 2008) ▪ China is co-chair of the Cleaner Fossil Energy Task Force of the Asia Pacific Partnership on Clean Development and Climate (Asia-Pacific Partnership, 2008) ▪ U.S.-led FutureGen project, which includes Huaneng, China's largest coal-based power company (Jiang et al., 2007; Pew 2007) ▪ China is a member of the Carbon Sequestration Leadership Forum

[25] Options characterized as *High* have the potential to reduce China's energy-related greenhouse gas emissions by at least 1% of China's 2030 energy-related emissions, or about 110 $MtCO_2e$. Options characterized as *Medium* have the potential to reduce 2030 emissions by 0.1%, or about 11 $MtCO_2e$.

Option	Mitigation Potential in 2030[25]	Relative Cost	Overlapping Policy Objectives	Proposed or Adopted Policies	Key Barriers	Existing International Support Mechanisms
						▪ IEA's Greenhouse Gas R&D Program; China is not a member
Fuel Switching (Coal to natural gas)	*Low* (Tsinghua, 2006)	*Medium* (Tsinghua, 2006)	▪ Conflicts with energy independence provide by increased use of coal ▪ Supports objectives for cleaner air (Zou, 2007)	▪ On-going significant government investment in infrastructure and exploration for natural gas (Jiang et al., 2007; Bradley and McMahon, 2007; Pew, 2007)	▪ Requires international gas supply and new pipelines given limited reserves in China – likely with potentially unstable regimes (Zou, 2007; Fridley, 2008)	▪ Carbon finance: 30 fossil fuel switching projects in CDM pipeline as of November 2008
Nuclear Power	*High* (Tsinghua, 2006; McKinsey, 2009)	*Low* (at the high implementation rates in McKinsey, 2009) to *Medium* (at more moderate implementation rates in Tsinghua, 2006)	▪ Supports objectives for cleaner air (Zou, 2007)	▪ Existing goal of quadrupling nuclear production capacity by 2020 in *China's National Energy Strategy Plan* (Pew, 2007) ▪ Existing efforts to develop market incentives for development of new nuclear capacity (PRC, 2008) ▪ Over 20 new nuclear plants have been planned and over 50 more have been proposed (IEA, 2008)	▪ Safety and long-term disposal ▪ Perceived environmental risks (Tsinghua, 2006) ▪ High capital and development costs (Tsinghua, 2006) ▪ Limited uranium reserves in China and further potential for tightening and competition in world markets (Fridley, 2008)	▪ China is part of the Generation IV International Forum (IEA, 2008), which aims to develop a future generation of nuclear energy systems that are competitively priced and reliable while addressing safety, waste, and proliferation issues. ▪ China participates in the International Project on Innovative Nuclear Reactors and Fuel Cycles, INPRO (IEA, 2008)
Hydropower	▪ *High* (Tsinghua, 2006, but their baseline did not include the Three Gorges Dam) ▪ *Medium* (McKinsey, 2009)	▪ *Medium* (Tsinghua, 2006; Wetzelaer et al, 2007) ▪ *Low* for small hydro power (McKinsey, 2009)	▪ Supports objectives for cleaner air (Zou, 2007)	▪ Existing renewables standards in the *Renewable Energy Law* (PRC, 2005) ▪ Existing goal of increasing pace of hydro developing, doubling hydro by 2020 in *Medium and Long-term Development Plan for Renewable Energies* (PRC,	▪ Huge capital requirements (Tsinghua, 2006) ▪ Cultural, economic, and ecosystem displacement (Tsinghua, 2006) ▪ Strained relations concerning water resources with downstream countries in south and southeast Asia (Fridley, 2008) ▪ Reliance on receding Himalayan glaciers	▪ Carbon finance: 730 hydro projects in CDM pipeline as of November 2008

Option	Mitigation Potential in 2030[25]	Relative Cost	Overlapping Policy Objectives	Proposed or Adopted Policies	Key Barriers	Existing International Support Mechanisms
				2008; PRC, 2007a)	(Fridley, 2008)	
Renewables	▪ *High* for wind power (McKinsey, 2009) ▪ *High* for solar PV: (McKinsey, 2009) ▪ *High* for switchgrass (McKinsey, 2009)	▪ *Medium* to *High* for wind power (McKinsey, 2009; Wetzelaer et al, 2007) ▪ *Medium* to *High* for solar PV (McKinsey, 2009) ▪ *High* for solar thermal (Wetzelaer et al, 2007; Tsinghua, 2006) ▪ *Medium* for switchgrass (McKinsey, 2009) although their analysis may not consider additional, significant opportunity cost of land for growing switchgrass (Fridley, 2009)	▪ Can support rural electrification (Jiang et al., 2007) ▪ Supports objectives for cleaner air (Zou, 2007)	▪ Existing goal of increasing renewables share in primary energy from 7% to 15% by 2020 in the 2005 *Law of Renewable Energy* (PRC, 2005) ▪ Existing long-term goal of 30% capacity from renewables in *Medium and Long-term Development Plan for Renewable Energies* (PRC, 2007a) ▪ Existing direct investment in large-scale wind farms and biomass in accordance with *Eleventh Five Year Plan* (PRC, 2006) ▪ Existing direct government investment in small-scale hydro (Jiang et al., 2007) ▪ Existing tax incentives for solar PV producers (Pew, 2007) and onshore wind (UNFCCC, 2007) ▪ Proposed fuel taxes (CCAP, 2007) ▪ Proposed removal of import tariffs (Price and Galitsky, 2006)	▪ Relatively high cost (Tsinghua, 2006) ▪ Highly fragmented and understaffed national energy agencies; corresponding decentralized sub-national decision-making (MIT, 2007) ▪ Regional nature of wind, solar resources and limited transmission infrastructure (Fridley, 2008; McKinsey, 2009) ▪ Relatively low cost of coal (Fridley, 2008) ▪ Existing preference for lowest-cost electricity bids limits renewables (Fridley, 2008) ▪ Requirement for wind power projects to have 70% domestic content; higher import duties on pre-assembled turbines (IEA, 2007) ▪ Devoting land to switchgrass would increase competition for limited arable land, leading to concerns over food security (Fridley, 2009)	▪ Carbon finance: 86 renewable energy projects in CDM pipeline as of November 2008 ▪ Global Environment Facility (GEF) funding, including China Renewable Energy Scale-up Program and Capacity Building for Commercialization of Renewable Energy ▪ Renewable Energy and Distribution Task Force of the Asia Pacific Partnership on Clean Development and Climate (Asia-Pacific Partnership, 2008)

Option	Mitigation Potential in 2030[25]	Relative Cost	Overlapping Policy Objectives	Proposed or Adopted Policies	Key Barriers	Existing International Support Mechanisms
TRANSPORTATION						
Vehicle Efficiency	▪ *High* for improved combustion engine efficiency (Tsinghua, 2006; McKinsey, 2009) ▪ *High* for electric vehicles (McKinsey, 2009)	▪ *Low* for improved combustion engine efficiency (Tsinghua, 2006; McKinsey, 2009) ▪ *High* for electric vehicles (McKinsey, 2009)	▪ Supports objectives for cleaner air (Zou, 2007)	▪ Existing, progressively tigthening fuel economy standards in 2005, 2006, 2008, and 2009 (Pew, 2007; CCAP, 2007) ▪ Existing vehicle excise taxes based on engine size (CCAP, 2007) ▪ Proposed fuel tax (Jiang et al., 2007) ▪ Proposed technology transfer (Tsinghua, 2006)	▪ Technology transfer: Chinese battery and hybrid technology development lagging Toyota and Honda (Zou, 2007; Fridley, 2008; McKinsey, 2009) ▪ Relatively high licensing and opportunity costs of using international technologies (Fridley, 2008)	
Fuel Switching – biofuels, electric, CNG	▪ Little research on biofuel potential available ▪ *High* potential for electric vehicles (McKinsey, 2009)	▪ *Medium* for biofuels (Tsinghua, 2006) ▪ *High* for electric vehicles (McKinsey, 2009)	▪ Growth in biofuels can conflict with goal of food security (Zou, 2007) ▪ Growth of biofuels can compete for limited supplies of water (Fridley, 2008) ▪ Growth in electric vehicle market would support goal of controlling urban pollution (McKinsey, 2009) ▪ Control of urban pollutants limits growth of diesel (Zou, 2007)	▪ Existing conversion of urban bus fleets to CNG and LPG (Tsinghua, 2006) ▪ Increasing interest but little policy movement on biofuel or electric vehicles (Tsinghua, 2006)	▪ Higher up-front vehicle costs (Tsinghua, 2006; McKinsey, 2009) ▪ Limited fuel infrastructure, especially for electric vehicles (McKinsey, 2009) ▪ Competition for arable land limits biofuel production (Zou, 2007; Fridley, 2008) ▪ Limited water resources to devote to ethanol production, which is very water-intensive (Fridley, 2008) ▪ Alternative fuel technologies still in early stage (e.g., electric, water, compressed air) (McKinsey, 2009) ▪ Low potential for CNG given high competition for natural gas and its relatively higher value in other sectors (Fridley, 2008)	▪ Existing bi-lateral exploration of cellulosic biofuels in partnership with U.S. (Price and Galitsky, 2006) ▪ Global Environment Facility funding, including Fuel Cell Bus Commercialization project

Option	Mitigation Potential in 2030[25]	Relative Cost	Overlapping Policy Objectives	Proposed or Adopted Policies	Key Barriers	Existing International Support Mechanisms
Reductions in Vehicle Miles Travelled (VMT)	Little research available to help quantify. Tsinghua (2006) reports *Low* for bus rapid transit but use a very limited scenario.	*Low* for bus rapid transit (Tsinghua, 2006)	▪ Could conflict with aggressive growth policy that favors economic output and personal mobility over efficiency	▪ Proposed fuel tax (Zou, 2007) ▪ Proposed focus on higher density, mixed-use development (UNFCCC, 2007) ▪ Proposed 80 billion USD spending on rail infrastructure as part of new stimulus package (Dan, 2008)	▪ Lagging public transit system (Tsinghua, 2006) ▪ Land use policies that fail to support public transit (Tsinghua, 2006) ▪ Insufficent rail freight infrastructure (Fridley, 2008)	▪ GEF-World Bank China Urban Transport Partnership Program
BUILDINGS & APPLIANCES						
Residential & Commercial	*Medium* (UNFCCC, 2007) to *High* (McKinsey, 2009)	*Low* (Wetzelaer et al, 2007; McKinsey, 2009)	▪ Efficiency and conservation can support economic development (PRC, 2008) ▪ Increased cost savings and building comfort (Richerzhager et al, 2008) ▪ Uncertainty concerning impacts on low-income populations: efficiency could lower bills but price reform could disproportion-ately affect low-income population (McKinsey, 2009)	▪ Existing State Council *Comprehensive Work Plan for Energy Conservation and Emission Reduction* (PRC, 2008) ▪ Existing, binding goal of reducing energy intensity by 20% below 2005 levels by 2010 in *Eleventh Five-Year Plan* (PRC, 2008; PRC, 2006) ▪ Existing building code demonstrations in six cities (CSEP, 2008) ▪ Existing appliance labeling and standards (PRC, 1997) ▪ Proposal to raise and broaden energy efficiency codes and standards (Jiang et al., 2007)	▪ Limited attractiveness of efficiency to developers compared to profits from new construction; little ability to recover investments in efficiency from buyer or tenant (Energy Foundation, 2007; McKinsey, 2009) ▪ Lax enforcement of existing codes and standards, especially in sectors with many producers, e.g. in lighting (Fridley, 2008; Richerzhager et al, 2008) ▪ Slow penetration of efficiency technologies given long building lifespans (UNFCCC, 2007) ▪ China's move away from a centrally planned economy has diluted effectiveness of central government mandates (Energy Foundation, 2007) ▪ Limited access to capital for efficiency improvements (CCAP, 2007; Richerzhager et al, 2008))	▪ Building and Appliances Task Force of the Asia Pacific Partnership on Clean Development and Climate (Asia-Pacific Partnership, 2008) ▪ GEF-sponsored projects, including *China Energy Conservation Project* establishing energy service companies (ESCOs) in three cities (UNFCCC, 2007) and China *Phasing-out of Incadescent Lamps & Energy Saving Lamps Promotion,* among others ▪ GEF-sponsored project *Provincial Energy Efficiency Scale-Up* ▪ Carbon finance: one commercial-sector energy efficiency project in the CDM pipeline as of November 2008

Option	Mitigation Potential in 2030[25]	Relative Cost	Overlapping Policy Objectives	Proposed or Adopted Policies	Key Barriers	Existing International Support Mechanisms
				▪ Fuel taxes (CCAP, 2007) ▪ Existing CFL distribution to residents, 50 million bulbs per year (PRC, 2008)	▪ Limited consumer preference for energy efficient lighting (McKinsey, 2009) ▪ Energy billing and pricing systems provide little information or incentives for efficiency investments (Richerzhager et al, 2008)	
INDUSTRY						
Cement	*High* (Tsinghua, 2006; McKinsey, 2009)	*Low* (Tsinghua, 2006; McKinsey, 2009)	▪ Corresponding reduction in other pollutants (McKinsey, 2009; Cai et al, 2008)	▪ On-going government-led phase-out of outdated plants (CCAP, 2007; Pew, 2007)	▪ Large number of enterprises limits ability to disseminate best practices and enforce standards (Fridley, 2008) ▪ Lack of human resources; limited technical talent (McKinsey, 2009) ▪ Cost of transition and "trial and error"; perception of low return-on-investment (McKinsey, 2009)	▪ Cement Task Force of the Asia Pacific Partnership on Clean Development and Climate (Asia-Pacific Partnership, 2008) ▪ International sectoral mechanisms under consideration ▪ Carbon finance: 9 projects in industrial end-use energy efficiency and 234 in industrial co-generation as of November 2008
Iron/Steel	*High* (Tsinghua, 2006; McKinsey, 2009)	▪ *Low* for some technologies (e.g., combined cycle plants, coal moisture control) (McKinsey, 2009) ▪ *Medium* to *High* for other technologies (McKinsey, 2009; Tsinghua, 2006)	▪ Corresponding reduction in other pollutants (McKinsey, 2009; Cai et al, 2008)	▪ On-going phase-out of outdated plants (CCAP, 2007; Pew, 2007) ▪ Government technical assistance (Tsinghua, 2006) ▪ Direct incentives for capital investments (Tsinghua, 2006) ▪ Government R&D support (Tsinghua, 2006) ▪ Technology transfer (TSINGHUA, 2006) ▪ CDM (CCAP 2007)	▪ Huge number of enterprises limits ability to disseminate best practices, enforce standards (Fridley, 2008) ▪ China produces mostly primary steel, inherently more energy-intensive than secondary steel (Fridley, 2008) ▪ Lack of human resources; limited technical talent (McKinsey, 2009) ▪ Cost of transition and "trial and error"; perception of low return-on-investment (McKinsey, 2009)	▪ Carbon finance: 9 projects in industrial end-use energy efficiency and 234 in industrial co-generation as of November 2008 ▪ International sectoral mechanisms under consideration ▪ Steel Task Force of the Asia Pacific Partnership on Clean Development and Climate (Asia-Pacific Partnership, 2008)
Other	Varies by sector	Varies by sector		▪ Existing practice of making energy	▪ Huge number of enterprises limits ability to	▪ Aluminum Task Force of the Asia Pacific Partnership on Clean

Option	Mitigation Potential in 2030[25]	Relative Cost	Overlapping Policy Objectives	Proposed or Adopted Policies	Key Barriers	Existing International Support Mechanisms
				efficiency improvements a performance evaluation criterion for local officials and heads of state-owned enterprises as part of Top-1,000 Enterprises Program (PRC, 2008; Pew, 2007) ▪ Existing energy consumption standards for market entry into high energy-consuming industries and for the production of 22 products (PRC, 2008) ▪ Existing export taxes for energy intensive products designed to conserve domestic energy sources (PRC, 2008; Pew, 2007; Bradley and McMahon, 2007)	disseminate best practices, enforce standards (Fridley, 2008) ▪ China's move away from a centrally planned economy has diluted effectiveness of central government mandates (Energy Foundation, 2007) ▪ Lack of human resources; limited technical talent (McKinsey, 2009) ▪ Cost of transition and "trial and error"; perception of low return-on-investment (McKinsey, 2009)	Development and Climate (Asia-Pacific Partnership, 2008) ▪ Carbon finance: 9 projects in industrial end-use energy efficiency and 234 in industrial co-generation as of November 2008; none in pulp & paper.

Barriers Cited in China's National Climate Change Programme (2007)

While the barriers cited in the table above were compiled from numerous researchers, the Chinese government, in its 2007 *National Climate Change Programme*, also cited the following:

- **Technology Transfer.** Chinese government and researchers refer to technology transfer as a leading barrier in reducing emissions. China's *National Climate Change Programme* (2007) and other researchers (e.g., Zou Ji, 2008) cite the need for both international and Chinese efforts to accelerate technology transfer. Chinese efforts mentioned include improved efforts to monitor, identify, adapt to, and assimilate transferred technologies. International efforts cited include pursuit of incentives and regulatory reform by developed countries to enable and encourage technology owners to transfer technologies to developing countries while addressing intellectual property rights, monopoly, and competitiveness issues.

- **Human Resources and Technical Capacity.** China's government and researchers both cite the need for enhanced training and professional development concerning climate change research, policy analysis, information system development, and CDM project management.

- **Public Awareness**. China's government and academic researchers indicate that public awareness of climate change and consumption patterns is a limiting factor and will need to improve for China to reduce emissions.

- **Information Systems**. China has identified a need for increased development and use of internet databases and other means of sharing climate change data, best practices, and technology case studies.

These themes were reiterated in China's 2008 White Paper on climate change (PRC, 2008).

Promising Opportunities

Several studies and institutions, including many of those discussed above, have proposed policy directions for China based on assessment of mitigation potential, China's development goals and social needs, and other factors. Table 6, below, highlights leading greenhouse gas mitigation policies as identified in several of these studies.

Table 6. Top Greenhouse Gas Mitigation Policies for China as Identified in Leading Studies

Sector	**Chinese Government** (PRC, 2008)	**Tsinghua University** (2006)[26]	**McKinsey** (2009)	**Energy Foundation** (2007)
Electricity Generation	▪ "Eliminate backward production capacity", i.e., government shut-down of small thermo-power plants ▪ "Quicken the pace of constructing large hydropower stations" ▪ Rapid development of wind power potential ▪ Active development of solar and nuclear ▪ Tax and import tariff reform	▪ Increased efficiency at existing coal-fired plants, including coal gasification ▪ Nuclear power ▪ Large-scale hydroelectricity	▪ Accelerated approval of nuclear power plants ▪ Incentives and mandates for wind and solar PV power ▪ Incentives and technology transfer for integrated gasification combined cycle coal plants (IGCC) and carbon capture and storage (CCS)	▪ Coal gasification ▪ Distributed generation incentives ▪ Carbon capture and storage ▪ Aggressive renewable energy deployment targets, including portfolio standards and other policies
Transportation	▪ Encourage production of vehicles with small displacement engines ▪ Continue to improve "fuel consumption restriction standard" for motor vehicles, with quick enforcement	▪ Vehicle efficiency improvements	▪ Enhanced vehicle efficiency and/or emissions standards ▪ Deployment of electric vehicles	▪ Stringent fuel economy standards and tighter emissions regulations ▪ Local air emissions monitoring and "zero emissions vehicle" incentives ▪ Bus rapid transit ▪ Transit-oriented development
Buildings & Appliances	▪ Increase direct state support of end-use energy efficiency projects ▪ 1,000 Enterprises energy-conservation campaign	[Study had little focus on building efficiency.]	▪ Enforce current energy-efficiency building codes ▪ Passive design for new buildings ▪ Retrofits of existing buildings ▪ Efficient HVAC ▪ Efficient lighting	▪ Residential and commercial building code development, implementation, and enforcement ▪ Appliance efficiency standards and labeling, including development, implementation, and enforcement ▪ Demand-side management programs

[26] Tsinghua University did not make explicit recommendations. The options listed in this table are those included in the study's "advanced options" scenario and that contribute to GHG reductions of at least 1% of China's 2030 energy-related emissions, or about 110 MMtCO2e. A follow-up paper by the Tsinghua University authors in *Energy Policy* (Cai et al, 2008) suggested transportation, electricity, and cement as "favorite" sectors for climate policy development.

Sector	**Chinese Government** (PRC, 2008)	**Tsinghua University** (2006)[26]	**McKinsey** (2009)	**Energy Foundation** (2007)
Industry	▪ Eliminate "backward production capacity" in 13 industries, particularly iron/steel, cement, paper, chemical, and printing/dyeing mills ▪ Compulsory energy restrictions in the making of 22 products ▪ Promulgate standards for market entry in high energy-consuming industries ▪ Adjust tax rebates and custom duties on high energy-consuming industries	▪ Efficiency and process improvements in the cement and iron/steel sectors	▪ Cement industry: clinker substitution and agricultural waste co-generation ▪ Steel industry: Increased use of combined-cycle power plants, coal moisture control, and thin-strip direct casting ▪ Chemical industry: advanced process control and switch to natural gas from coal ▪ Carbon capture and storage in steel, cement, and chemical sectors ▪ Partial relocation of steel production to Australia	▪ Energy efficiency performance agreements with industrial companies ▪ Tax and fiscal policy measures to catalyze improved energy efficiency ▪ Industrial equipment standards
Other	▪ Leading cadres in all provinces will be held accountable for achieving energy-conservation goals in 11th Five-Year Plan ▪ Further development of a recycling economy		▪ Incineration of municipal solid waste ▪ Fluorocarbon destruction	▪ Analytical tools to help China's energy planners anticipate future impacts of today's policy decisions

Conclusions

Numerous opportunities exist for China to mitigate its greenhouse gas emissions. As studies by Tsinghua University, McKinsey & Co., and others have shown, many of these options are available at low or negative marginal cost. Recognizing the economic benefits as well as supporting social and political benefits, China has been pursuing climate actions with increasing vigor. The country has communicated its intentions to the international community in its *National Climate Change Programme* (PRC, 2007b), *Policies and Actions for Addressing Climate Change* (PRC, 2008), and other documents. Many of its goals suggest a level of greenhouse gas mitigation on par – or even greater – than the technical studies summarized above. If and how China implements and enforces these already-proposed policies will be critical in determining the emissions trajectory realized by the country. The International Energy Agency has estimated, for example, that aggressive implementation of China's already-proposed policies would result in a decrease of 20% compared to business-as-usual emissions in 2030. Ambitious international goals, however, may necessitate much deeper reductions in China's emissions – as great, or greater, than the mitigation potential documented by McKinsey's recent report.

The actions and policies summarized above represent a range of possible areas for involvement by international actors. Significant reduction potential exists in all energy-related sectors of China's economy, and China has been open to international partnerships, as evidenced by the numerous agreements and collaborations already in place with the Global Environment Facility, other countries in Asia and Europe, and the United States, among others. Opportunities for additional engagement and support already exist, and may expand rapidly if and as bilateral and multilateral efforts are undertaken to address climate change. Our experience and ongoing involvement in international discussions, including with counterparts in China, suggest that technology transfer, financing, and technical assistance may be the greatest opportunities for industrialized countries to support the particular efforts highlighted above.

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Chapter 4. India

With 1.1 million people, India is the world's second most populous country, after China. Although the country has the lowest per capita emissions of the countries included in this study, India is developing rapidly, leading to corresponding growth in energy use and greenhouse gas emissions. India has been active in international climate negotiations, and is the site of over a quarter of emission reductions projects in the Clean Development Mechanism pipeline.[27] In 2008, the Government of India released its *National Action Plan on Climate Change.*

The following table displays several economic and climate indicators for India relative to the U.S. and to other countries included in this study.

Table 7: India Development Indicators Relative to Other Countries
(Source: World Bank's World Development Indicators, 2009)

	China	India	Brazil	Mexico	South Korea	South Africa	U.S.
Population, millions (2007)	1,320	1,120	192	105	48	48	302
GNI[28] Per Capita, PPP (2007)	$5,420	$2,740	$9,270	$13,910	$24,840	$9,450	$45,840
GDP Growth, Annual (2007)	13.0%	9.1%	5.4%	3.2%	5.0%	5.1%	2.0%
Energy use per capita, kg oil equivalent (2006)	1,433	510	1,184	1,702	4,483	2,739	7,768
CO_2 emissions per capita (2005)	4.3	1.3	1.7	4.1	9.4	8.7	19.5

Due to its rapid economic growth and corresponding increases in greenhouse gas emissions, India, like China, has been relatively well-studied by both domestic and international researchers, providing several sources of greenhouse gas mitigation potential estimates. Given the immediate concerns of sustainable growth and poverty alleviation to Indian policy makers, there is considerable analysis available on potential sustainable development trajectories to support both economic growth and emission reductions.

Baseline Emissions Forecast

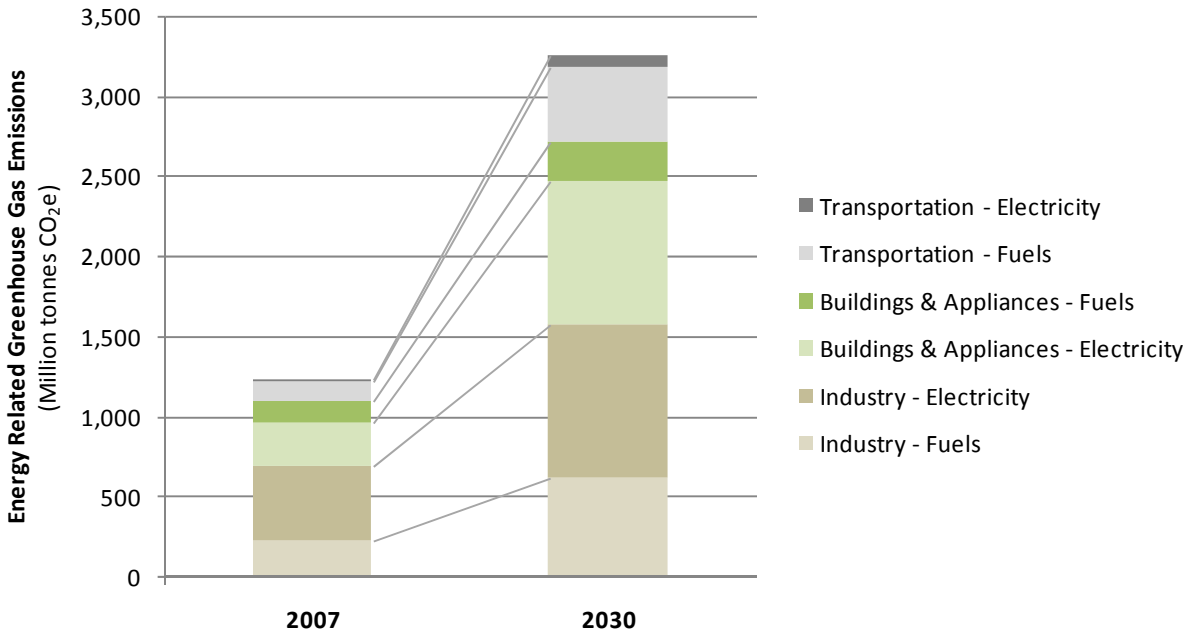
Figure 5, below, displays the projected baseline emissions for India between now and 2030.[29]

[27] http://cdmpipeline.org

[28] GNI is Gross National Income and is reported here using the purchasing power parity (PPP) method of converting to international dollars.

[29] For details on SEI's LEAP model and projection methodology, please see the appendix.

Figure 5. Projected Baseline Energy-sector Greenhouse Gas Emissions in India in 2030



Mitigation Potential

Several researchers have documented actions taken to date by India's government or industry, but relatively few studies have assessed mitigation potential in India over the coming two decades. Among the researchers that have or are currently assessing mitigation potential in 2020 through 2030, the following studies have provided estimates to help inform this study:

- **The Energy and Resources Institute (TERI)** (2006). Published by the Center for Clean Air Policy, TERI's study, *Greenhouse Gas Mitigation in India: Scenarios and Opportunities through 2031*, is the most detailed mitigation study reviewed for India. The study includes detailed findings for costs and potentials of numerous detailed options.

- **United Nations Framework Convention on Climate Change** (2007). This study quantifies emission reduction potential in industry and building efficiency in India through 2030, based on modeling work by IEA, as part of its assessment of investment and financial flows needed to address climate change.

- **International Energy Agency** (2007). In their report *World Energy Outlook 2007: China and India Insights*, the IEA develops an Alternative Policy Scenario for India that assumes stronger actions to "ensure that policies and measures are implemented fully, are enforced effectively and are supplemented by new measures where necessary." The IEA study a**l**so quantifies investment needs necessary to enact the measures in the Alternative Policy Scenario.

- **India's *Integrated Energy Policy Report*** (2006) The Government of India's *Integrated Energy Policy Report* provides some aggregated mitigation potential estimates for several scenarios through 2031. Although few results are presented for individual options (instead presenting aggregated scenarios), the findings do provide points of comparison to the studies listed above.

- **Pew Center on Global Climate Change** (Chandler et al, 2002). This study, *Climate Change Mitigation in Developing Countries: Brazil, China, India, Mexico, South Africa, and Turkey* includes

estimates of greenhouse mitigation through 2012 as assembled from multiple sources by researchers at the Indian Institute of Management.

In addition to these sources listed above, our team also reviewed documents by the Confederation of Indian Industry (2008), the United Nations Environment Programme (Shukla et al, 2007), the Massachusetts Institute of Technology (MIT, 2007), the Lawrence Berkeley National Lab (de la Rue de Can et al, 2008), India's *National Action Plan on Climate Change* (GOI, 2008), McKinsey's *Pathways to a Low-Carbon Economy: Version 2 of the Global Greenhouse Gas Abatement Curve* (McKinsey, 2009), and others. These studies provided information helpful for assessing potential viability of mitigation options, as discussed in the following section.

Based on review of the studies above, we assembled estimates of the mitigation potential for the following options in India, as listed in Table 8, below.

Table 8. Estimated Mitigation Potential in India, $MtCO_2e$/year, in 2030
(Underlined numbers are used to produce the combined mitigation estimate shown in Figure 7.)

Sector/Option	TERI (2006)[30]	UNFCCC (2007)	IEA (2007)[31]
ELECTRICITY	410		400
Efficiency at gas-fired plants	6		160
Fuel Switching (coal to gas)			
Nuclear Power	350		40
Hydropower	28		200
Other Renewables	28		
TRANSPORTATION	410		100
Vehicle Efficiency	130		100
Fuel Switching - Biodiesel	150		
Fuel Switching - CNG	10		
VMT Reduction - Public Transit	50		
VMT Reduction - Passenger and Freight by Rail	70		
BUILDINGs & APPLIANCES	0	74	150
Residential & Commercial	0[32]	74[33]	150[34]
INDUSTRY	150	150	170
Cement	47	150[35]	170
Iron/Steel	95		
Pulp & Paper	8		
Other			

Note that in cases where estimates are presented by different researchers, the numbers above can vary substantially.[36] Figure 6, below, displays results from the two studies that included mitigation estimates

[30] Figures here attributed to TERI (2006) are SEI calculations of greenhouse gas reductions for the year 2030 based on TERI estimates of avoided fuel use, new nuclear and renewable electricity generation, and linear interpolation or projection of CO_2 mitigation figures for other years. Note that mitigation estimates are relative to TERI's B2 "pre-2000" policy baseline due to the way the disaggregated options are presented in TERI's report. Some mitigation potential estimates in the TERI report use a baseline that assumes implementation of more recent policies and thus show less mitigation potential than presented in this table.

[31] For the most part, IEA's (2007) *Alternative Policy Scenario* assumes strong government action to implement and enforce existing and recently proposed policies but does not propose or quantify bold new policy proposals.

[32] The residential and commercial options presented in TERI (2006) generally focus on the increased use of LPG at the expense of biomass or electricity, which has negligible net greenhouse gas impact.

[33] This mitigation figure (74 MtCO2e) includes some emission reductions from electricity and so may overlap with mitigation from changes in electricity supply.

[34] This figure (150 MtCO2e) represents total emissions savings from end-use electricity efficiency, not all of which may be in buildings and which could overlap with mitigation from changes in electricity supply.

[35] This figure is mitigation resulting from combustion-related CO2 reductions only. The UNFCCC study also included reductions from industrial process emissions.

[36] As discussed in the Methodology chapter, estimates of mitigation potential depend on numerous underlying assumptions, which may not be consistent across studies. For example, as described in footnote 30, the TERI (2006) study referenced provided most (but not all) estimates relative to a pre-2000 policy baseline, unlike IEA (2007). In addition, TERI (2006) assumed aggressive vehicle efficiency gains, electrification of rail, and other measures in its transportation mitigation scenario.

for at least three of the four energy-related sectors addressed in this report. Note that the total energy-related mitigation potential suggested by these two studies – between 800 and 1000 $MtCO_2e$ – is substantially smaller than the 2,700 $MtCO_2e$ potential in 2030 suggested in McKinsey's recent *Pathways to a Low-Carbon Economy: Version 2 of the Global Greenhouse Gas Abatement Curve* (McKinsey, 2009). The McKinsey (2009) estimate includes mitigation from non-energy sources, such as industrial process chemicals and agriculture, but nonetheless appears significantly more ambitious than either TERI (2006) or IEA (2007) studies. A further, India-specific report by McKinsey (not released in time for this study's review) will help clarify the mitigation potential, as may the World Bank's upcoming Low-Carbon Country Case Study focused on India.

Figure 6. Comparison of Alternative Estimates of 2030 Mitigation Potential in India
(Comparing studies that address at least three of this study's four sectors)

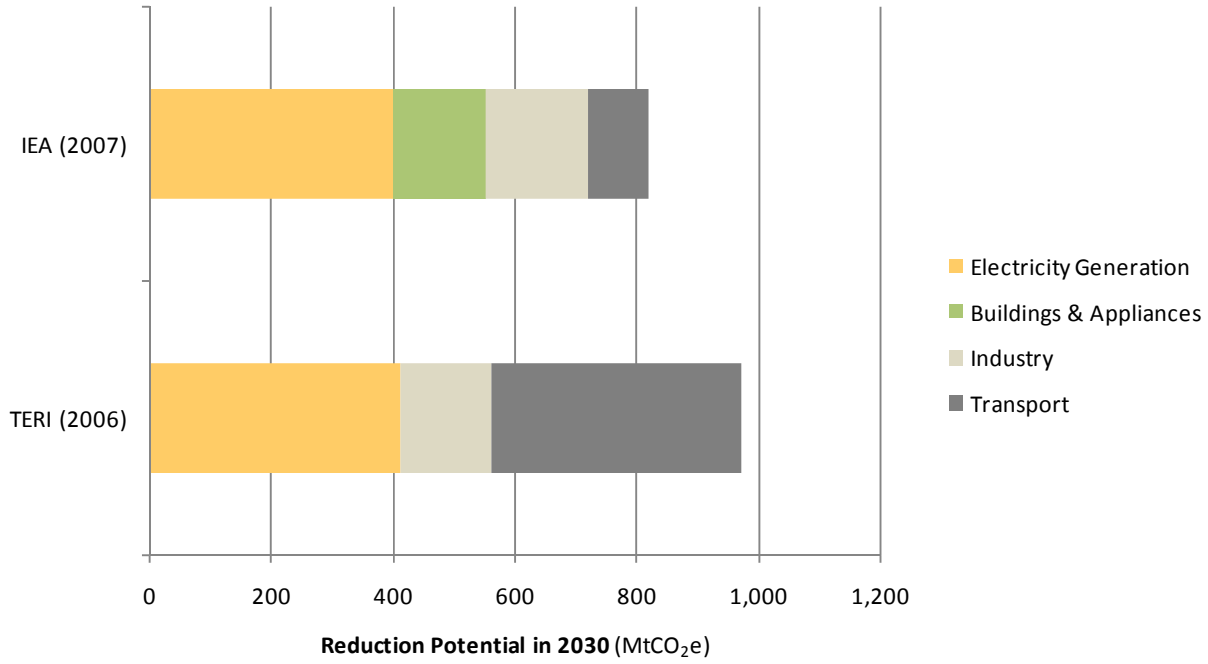
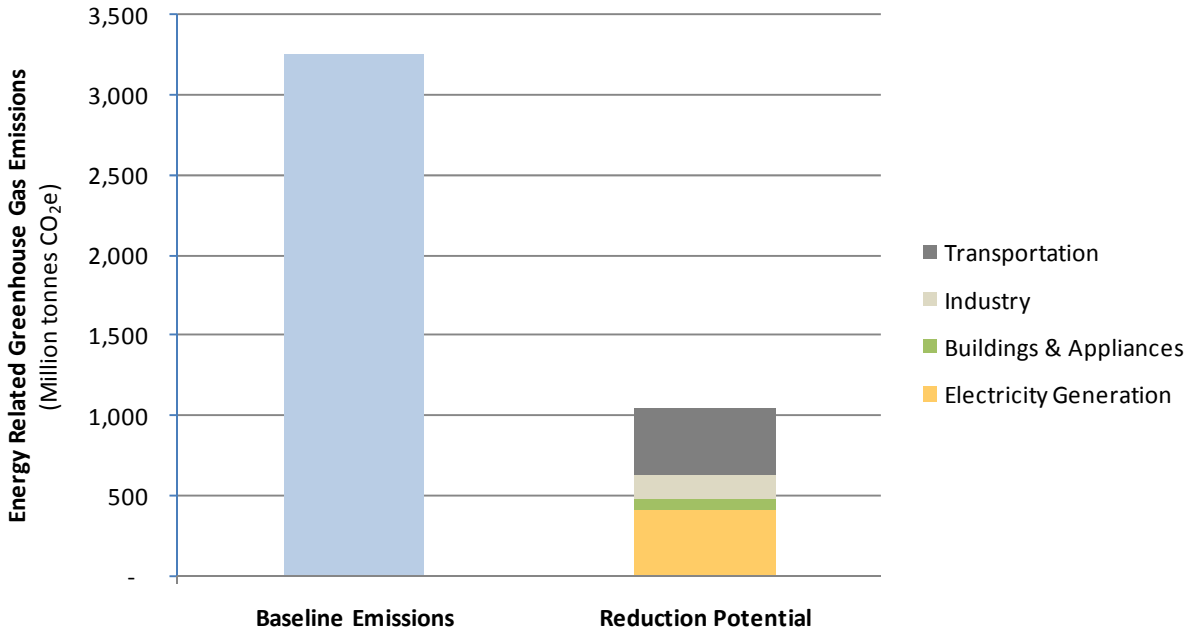


Figure 7, below, displays a composite 2030 mitigation scenario based on estimates from the TERI and IEA studies. Note that we combine aspects of these two scenarios for illustration purposes, but further work would be needed to determine how the two studies compare in terms of underlying assumptions and potential for double-counting between sectors (such as buildings and appliances and electricity generation), as well as between the baseline assumptions of those studies and the SEI-produced baseline displayed in the chart.

Figure 7. Energy-related GHG Emissions in India in 2030 – Baseline Emissions and Reduction Potential
(Baseline from SEI analysis; mitigation scenario from TERI, 2006 and UNFCCC, 2007; see text for caveats regarding comparison of figures)



Assessment of Options

The options in Table 8 reflect estimates of the achievable greenhouse gas reductions for energy-related options in India. The success of efforts to implement these options will depend on numerous factors, including cost-effectiveness, extent of overlap with social or economic development objectives, extent of existing country experience with similar measures or policies, and potentially international support mechanisms, among other factors.

Our team conducted a review of the available literature, as well as interviews with other researchers focused on India, to summarize and assess the potential barriers and opportunities for each option. Table 9, below, provides results of this research, and is followed by potential high priority opportunities for involvement.

Table 9. Assessment of Mitigation Options in India

Option	Mitigation Potential[37]	Relative Cost	Overlapping Policy Objectives	Proposed or Adopted Policies	Key Barriers	International Support Mechanisms
ELECTRICITY						
Power Plant Efficiency	*High* (IEA, 2007) but TERI (2008) reports *Low* under ambitious CO_2 reduction goals due to switch away from fossil-fuel-based generation	*Low* (TERI, 2006) but coal efficiency technologies not yet widely available and up-front cost often cited as a barrier	▪ Strong overlap with energy security given strong dependence on coal-based plants and extensive coal reserves (GOI, 2006; Shukla et al., 2007; MIT, 2007; Kumar et al, 2009)	▪ Recent shift to price coal based on gross calorific value (GCV), not useful heat value (UHV) (HBD, 2008) ▪ On-going government renovation and modernization of (and pilots in) existing coal-fired plants (Kumar et al, 2009; Shukla et al., 2007) ▪ Regulators proposing tariffs based on increasing efficiency (Mathur, 2008) ▪ Proposal to require minimum efficiency standards (GOI, 2006) ▪ Proposal to develop a stricter coal quality control regime (IEA, 2007) ▪ Proposed direct government R&D (GOI, 2006; Ockwell et al, 2007) ▪ Proposed R&D subsidies (GOI, 2006) ▪ Proposed reductions in coal subsidies (Chandler et al, 2002)	▪ Lagging development of cost-effective technologies (Kumar et al, 2009; IEA, 2007; GOI, 2006) ▪ High perceived risk for investors (GOI, 2006) due to high capital costs and limited operational experience with new technologies such as Integrated Gasification Combined Cycle (Ockwell et al, 2007) ▪ Lack of adequate financing (Kumar et al, 2009; Parikh, 2008; IEA, 2007) ▪ Fuel quality issues, e.g., high-ash coal (Rajan, 2008; IEA,2007) ▪ Advanced efficiency technology options (e.g. supercritical boilers) not cost-effective for modernization of old plants (Sant, 2008) ▪ Lack of technical and implementation capacity at the utilities as well as the availability of spare parts and equipment required to undertake renovation and modernization of old plants (Mathur, 2008) ▪ Lack of qualified energy service companies (ESCOs) and risk capital to finance the growth of ESCOs (Mathur, 2008) ▪ Poor financial health of State Electricity Boards (Kumar et al, 2009)	▪ Power Generation and Transmission Task Force of the Asia Pacific Partnership on Clean Development and Climate (Asia-Pacific Partnership, 2008) ▪ International Energy Agency's Implementing Agreement for a Clean Coal Centre (IEA, 2007) ▪ IBRD/GEF soft loan/grant for rehabilitation of old power plants resulting in energy efficiency, the India Coal Fired Generation Rehabilitation Project (GEF, 2009)
Carbon Capture & Storage	*High* (TERI, 2006) although not specifically quantified	*High* (TERI, 2006)	▪ Conflicts with energy access goals due to reduced efficiencies and	▪ Proposed government R&D (GOI, 2006) ▪ Proposed domestic pilots (TERI, 2006)	▪ Limited technologies currently available (GOI, 2006) ▪ India's government has not made CCS a priority (MIT, 2007) ▪ Separating carbon stream may be	▪ India is a member of the Carbon Sequestration Leadership Forum and U.S.-led FutureGen (MIT, 2007)

[37] Options characterized as *High* have the potential to reduce India's energy-related greenhouse gas emissions by at least 1% of India's 2030 energy-related emissions, or about 30 $MtCO_2e$. Options characterized as *Medium* have the potential to reduce 2030 emissions by 0.1%, or about 3 $MtCO_2e$.

Option	Mitigation Potential[37]	Relative Cost	Overlapping Policy Objectives	Proposed or Adopted Policies	Key Barriers	International Support Mechanisms
			additional energy needs for the implementation of CCS		infeasible with existing fuel and power generation options (Rajan, 2008) ▪ Perception that CCS is untested with risks of carbon re-release and that the additional energy required for the full-scale implementation of CCS is very high (Kumar, 2008)	▪ Cleaner Fossil Energy Task Force of the Asia Pacific Partnership on Clean Development and Climate (Asia-Pacific Partnership, 2008) ▪ India is a member in the IEA's Greenhouse Gas R&D Program ▪ EU-India Clean Coal Technology Working Group (EC, 2008)
Fuel Switching to Natural Gas	*Medium* (TERI, 2006)	*Low* (TERI, 2006)	▪ Conflicts with policies to use limited natural gas supplies preferentially for fertilizers, petrochemicals, and CNG (GOI, 2006) ▪ Reliance on imported fuels conflicts with desires for energy security (GOI, 2006)		▪ Stated policy is to use natural gas for fertilizer and chemical needs first, then for distributed generation. This severely limits its use for fuel switching (GOI, 2006). ▪ Limited domestic sources of natural gas (TERI, 2008; Rajan, 2008); political barriers to building pipeline with Iran; LNG facilities expensive and risky (Rajan, 2008)	
Nuclear Power	*High* (TERI, 2006; IEA, 2007)	*Low* (TERI, 2006)	▪ Use of thorium instead of uranium as a fuel would support energy security objectives, given India's large supply of thorium (GOI, 2006)	▪ Proposed government R&D for thorium-based reactors (GOI, 2006) ▪ India has over a dozen proposed new nuclear reactors (IEA, 2008)	▪ Lagging development of thorium-based reactors (GOI, 2006) ▪ Barring thorium, would likely rely on uranium imports from Nuclear Suppliers Group (GOI, 2006) ▪ Limited access to fast breeder technology (Kumar, 2008) ▪ Perceived environmental risks (GOI, 2006) ▪ High up-front cost (Ramana, 2007) ▪ Regulatory issues such as the lack of a nuclear liability law and limitations on the participation of private companies (Kumar, 2008) ▪ Site selection for nuclear power plants will be a challenge (Sant,	▪ India participates in the International Project on Innovative Nuclear Reactors and Fuel Cycles, INPRO (IEA, 2008) ▪ India is not part of the Generation IV International Forum (IEA, 2008), ▪ India is part of ITER, a joint international research and development project to demonstrate feasibility of fusion power (ITER, 2009)

Option	Mitigation Potential[37]	Relative Cost	Overlapping Policy Objectives	Proposed or Adopted Policies	Key Barriers	International Support Mechanisms
					2008)	
Hydropower	*High* (TERI, 2006; IEA, 2007))	*Medium* (TERI, 2006)	▪ Small hydro could support rural electrification (GOI, 2008) ▪ Could support increased access to water resources (GOI, 2004) ▪ Would support improved energy security and air quality (GOI, 2004; Shukla et al., 2007)	▪ Proposed, escalating renewable portfolio standard with tradeable certificates (GOI, 2008) ▪ Proposed Tradeable Tax Rebate Certificates for mini hydro (GOI, 2006) ▪ Proposed regulatory reform for grid tie-ins (GOI, 2006) ▪ Proposed market reform to facilitate hydro resources from Nepal/Bhutan (GOI, 2006)	▪ Requires resolution of water rights, resettlement of affected people, and environmental concerns (GOI, 2006; GOI, 2008; CII, 2008) ▪ Undeveloped markets and volatile prices for hydro resources from Nepal/Bhutan (GOI, 2006) ▪ Many hydropower sites in the northeast region are highly inaccessible, requiring new transmission infrastructure (Kumar, 2008) or raising maintenance concerns (Kumar et al, 2009) ▪ Political risks associated with violence and disputed territories in the northeast region make it unattractive for investments (Kumar, 2008)	
Renewables	*High* for wind (TERI, 2006) and solar (Wetzelaer et al, 2007)	▪ *Low* for wind (TERI, 2006 and Wetzelaer et al, 2007) in terms of marginal per-ton cost, but other studies cite cost as a primary barrier ▪ *High* for solar (TERI, 2006)	▪ Can support India's efforts to increase household energy security, gender equity, and entrepreneurial ventures for the poor (GOI, 2006) ▪ Would support improved energy security and air quality (GOI, 2004; Shukla et al, 2007) ▪ Solar can play a major role in planned rural electrification efforts such as the Rural Electrification Policy (GOI, 2008; Shukla et	▪ Proposed *National Solar Mission* announced in 2008 to include R&D plus specific production and deployment goals for solar thermal and PV (GOI, 2008) ▪ Proposed preferential tariffs or price support for renewables (GOI, 2008; GOI, 2006; Chandler et al, 2002; Shukla et al., 2007) ▪ Proposed, escalating renewable portfolio standard with tradeable certificates (GOI, 2008) ▪ Proposed regulatory reform for grid tie-ins (GOI, 2006) ▪ Proposed government restructuring to aid in renewables development, e.g. CASE, IREDA (GOI, 2006)	▪ Limited regulatory framework for grid tie-ins for distributed renewables (GOI, 2006) ▪ High cost (Kumar et al, 2009; GOI, 2008; GOI, 2006; Shukla et al, 2007) ▪ Challenges with continuity and intermittency (Shukla et al., 2007) ▪ Price of silicon and other PV materials rising; lack of sufficient research to find alternative materials (Kumar, 2008) ▪ Financing, exacerbated by uncertainty over future of CDM (Parikh, 2008) ▪ Realization that wind resources are limited (Parikh, 2008) and efficiencies are lower than was expected (Kumar, 2008) ▪ Budget constraints have limited government programs (TERI, 2008)	▪ Existing carbon markets: over 150 CDM-funded renewable energy projects underway (GOI, 2006) ▪ Renewable Energy and Distribution Task Force of the Asia Pacific Partnership on Clean Development and Climate (Asia-Pacific Partnership, 2008)

Option	Mitigation Potential[37]	Relative Cost	Overlapping Policy Objectives	Proposed or Adopted Policies	Key Barriers	International Support Mechanisms
			al, 2007)			
Transmission and Distribution Improvements	*High* (IEA, 2008; Chandler et al, 2002), as India has the greatest losses in Transmission and Distribution – up to 25% – of any country	*Medium* (Chandler et al, 2002)	▪ Can support rural electrification efforts (Shukla et al, 2007)	▪ Existing policy goal of reducing transmission and distribution losses (Shukla et al, 2006) ▪ Existing efforts to increase private sector involvement in distribution (GOI, 2008; GOI, 2006) ▪ Proposed reforms in Accelerated Power Development and Reforms Programme (APDRP) for intelligent meters, advanced data analysis (GOI, 2006)	▪ Outdated infrastructure (GOI, 2006) ▪ Existing cross-subsidies: industrial and commercial rates subsidize residential and agricultural rates, limiting financial viability of energy providers and precluding further use of such subsidies (GOI, 2006)	
TRANSPORTATION						
Vehicle Efficiency	*High* (TERI, 2006; IEA, 2007)	*Low* (TERI, 2006)	▪ Supports objective for cleaner urban air (GOI, 2008; Kumar et al, 2009)	▪ Proposed government R&D for vehicle batteries (GOI, 2006) ▪ Proposed price incentives for efficient vehicles (GOI, 2008) ▪ Proposed promotion of hybrid vehicles (GOI, 2006) ▪ Existing National Auto Fuel Policy of 2003 provides roadmap – but no official standards – for attaining vehicle emissions improvements (Kumar et al, 2009)	▪ Lack of vehicle efficiency standards (Kumar et al, 2009) ▪ Limited low-cost, efficient hybrid vehicles and batteries (Kumar et al, 2009; GOI, 2006) ▪ Lack of clear government roadmap for reducing carbon emissions to guide business investment and moderate perceived risks in vehicle efficiency technologies (Ockwell et al, 2007)	▪ Upcoming Global Environment Facility-sponsored project, Improving Energy Efficiency in the Indian Railway System
Fuel Switching	*High* (TERI, 2006)	*Low* (TERI, 2006)	Some fuels (e.g., CNG) can support objective for cleaner air in Delhi and other cities (GOI, 2008)	▪ Existing policies requiring 5% ethanol blends in several states (GOI, 2008) ▪ Existing biodiesel plantation pilots in 26 states as part of National Mission on Biodiesel (GOI, 2008) ▪ Proposed price incentives for alternative-fuel vehicles	▪ Biofuels competing with food crops for limited arable land and irrigation water (Kumar et al, 2009; GOI, 2008; Kumar, 2008; TERI, 2008) ▪ Uncertainty in yields from non-edible oils Jatropha and Karanj (GOI, 2006) ▪ Lagging development of algae-based and cellulosic biofuels (Kumar, 2008)	▪ Global Environment Facility sponsored projects, including India Electric 3-Wheeler Market Launch Phase

Option	Mitigation Potential[37]	Relative Cost	Overlapping Policy Objectives	Proposed or Adopted Policies	Key Barriers	International Support Mechanisms
				(GOI, 2008) ▪ Proposed tightening of enforcement on fuel economy standards (GOI, 2008) ▪ Existing Biodiesel Purchase Policy mandates biodiesel purchase by petroleum industry (GOI, 2008) ▪ Proposed Tradeable Tax Rebate Certificates linked to biodiesel/oilseed production (GOI, 2006) ▪ Proposed reduced import tariffs on vegetable oils for biodiesel production (GOI, 2006) ▪ Proposed removal of excise fees and levies for biodiesel (GOI, 2006) ▪ Proposed direct government R&D (GOI, 2006; TERI, 2006)		
Reductions in VMT	*High* (TERI, 2006)	*Low* (TERI, 2006)	▪ Can support goal of reduced urban congestion and improved air quality (Shukla et al., 2007; Kumar et al, 2009)	▪ Proposal to assist in capital financing of public transport systems (GOI, 2008) ▪ Existing National Urban Transport Policy emphasizes public and non-motorized transport as well as integrated transit and land use planning (Kumar et al, 2009; GOI, 2008; TERI, 2008) ▪ On-going efforts to expand mass transit in Delhi, Bangalore, and other cities (GOI, 2008) ▪ Proposed market reform of rail freight industry: rationalize rates, eliminate CONCOR monopoly (GOI,	▪ Inadequate institutional mechanisms for transport demand management in urban areas (Rajan, 2008) ▪ High capital costs for public transport systems and "myopic urban planning" (Kumar et al, 2009) ▪ Already-stressed rail infrastructure (Kumar et al, 2009)	▪ Global Environment Facility-sponsored projects, including GEB/IBRD project, India Sustainable Urban Transport Project

Option	Mitigation Potential[37]	Relative Cost	Overlapping Policy Objectives	Proposed or Adopted Policies	Key Barriers	International Support Mechanisms
				2006) ▪ Proposed congestion, pollution, and parking fees in city centres (GOI, 2006)		
BUILDINGS & APPLIANCES						
Residential & Commercial	*High* (UNFCCC, 2007)	*Low* (GOI, 2004)	▪ Can support India's social development goals (GOI, 2004) ▪ Can support improved air quality	▪ Proposed expansion of existing mandatory appliance rating and labeling beyond refrigerators and application of differential tax rates for these certified appliances (GOI, 2008) ▪ Proposal to make voluntary 2007 Energy Conservation Building Code mandatory for new commercial buildings (GOI, 2008) ▪ Proposal to establish public-private financing for energy efficiency investments in building sector (GOI, 2008) ▪ Proposed expansion of existing low-cost exchange of incandescent lamps for CFLs funded by CDM credits (GOI, 2008); note growth of CFL market from 20 million in 2002 to nearly 200 million in 2008 (Mathur, 2008) ▪ Proposed incentives to utilities for energy conservation (Shukla et al, 2007) ▪ Proposed adoption of a least-cost planning approach to enable fair competition of efficiency and demand-management initiatives against new	▪ Limited availability of newer, more efficient technologies (Shukla at al, 2007), requiring technology transfer from developed countries (TERI, 2008) ▪ Limited focus on energy efficiency by utilities (GOI, 2006; Shukla et al, 2007) ▪ Limited access to capital for efficiency improvements (Kumar et al, 2009; GOI, 2006) ▪ Bureau of Energy Efficiency is under-staffed (GOI, 2006) ▪ Need for testing laboratories to support verification and labeling (GOI, 2006) ▪ Undeveloped distribution system for commercial fuels (e.g., LPG, natural gas) in rural areas favors wood as fuel (de la Rue du Can et al., 2008) ▪ Lack of builders, architects and materials to scale up the building of energy efficient buildings (Mathur, 2008) ▪ Allocation of costs and benefits between the builders and the tenants are a problem despite the economic rationale (Mathur, 2008) ▪ Lack of qualified energy service companies (ESCOs) and risk capital to finance the growth of ESCOs (Mathur, 2008) ▪ Utilities lack the capacity to undertake demand-side management (DSM) activities (Sant, 2008)	▪ Building and Appliances Task Force of the Asia Pacific Partnership on Clean Development and Climate (Asia-Pacific Partnership, 2008) ▪ Global Environment Facility-sponsored projects on end-use efficiency, including on Refrigerators and Air-conditioners, Commercial Buildings, and Promoting Energy Efficiency and Renewable Energy in Selected Micro Small and Medium Enterpresises Clusters in India projects, and GEF/World Bank project Financing Energy Efficiency at Small and Medium Enterprises ▪ IEA Implementing Agreement on Demand-Side Management (IEA, 2007)

Option	Mitigation Potential[37]	Relative Cost	Overlapping Policy Objectives	Proposed or Adopted Policies	Key Barriers	International Support Mechanisms
				supply (GOI, 2006) ▪ Proposed rationalization of power rates (Chandler et al, 2002) ▪ Proposed building and industry energy benchmarking (GOI, 2006) ▪ Proposed support for Energy Service Companies, ESCOs (GOI, 2008)		
INDUSTRY						
Cement	*High* (TERI, 2006), the second-highest global potential in the cement industry (IEA, 2008)	*Low* (TERI, 2006)		▪ Proposed government-industry partnerships for modernization (TERI, 2006) ▪ Energy efficiency standards in development by Bureau of Energy Efficiency (GOI, 2006)	▪ Poor quality (high carbon content) of current fly ash available from coal-fired power plants for use as clinker substitute (IEA, 2007) and high cost of its transport (Kumar et al, 2009) ▪ Similar poor quality of available steel slag for use as clinker substitute (IEA, 2007) and high cost of its transport (Kumar et al, 2009) ▪ Low penetration of co-generation technology and practice (IEA, 2007) ▪ High opportunity cost of capital (Kumar et al, 2009)	▪ Existing carbon markets: CDM ▪ Cement Task Force of the Asia Pacific Partnership on Clean Development and Climate (Asia-Pacific Partnership, 2008)
Iron/Steel	*High* (TERI, 2006), and the fourth-highest global potential in the steel industry (IEA, 2008)	*High* (TERI, 2006)		▪ Proposed government-industry partnerships for modernization (TERI, 2006) ▪ Proposal to expand existing Steel Development Fund to further fund process improvements (TERI, 2006) ▪ Existing 2005 *National Steel Policy* encourages environmental life-cycle assessment (Shukla et al., 2007) ▪ Current efforts by Steel Authority of India to encourage operational efficiencies and technology (IEA, 2007)	▪ High opportunity cost of capital (Kumar et al, 2009)	▪ India is co-chair of the Steel Task Force of the Asia-Pacific Partnership on Clean Development and Climate (Asia-Pacific Partnership, 2008)

Option	Mitigation Potential[37]	Relative Cost	Overlapping Policy Objectives	Proposed or Adopted Policies	Key Barriers	International Support Mechanisms
Other				▪ Proposed *National Mission for Enhanced Energy Efficiency* that builds on 2001 Energy Conservation Act and proposes to implement an emissions trading scheme in top energy-consuming industries (GOI, 2008) ▪ Energy intensive industries to have energy efficiency standards and tradable certificates based on differentiated targets (Kumar, 2008) ▪ Existing requirement for energy audits by large energy consumers in nine industries (GOI, 2008) ▪ Existing government financial assistance for certain technologies in specific sectors for small and medium enterprises (Kumar et al, 2009) ▪ Proposed time-of-day tariffs (GOI, 2006) ▪ Proposed mandatory utility purchase of co-generated electricity (GOI, 2006) ▪ Proposed adoption of a least-cost planning approach to enable fair competition of efficiency and demand-management initiatives against new supply (GOI, 2006) ▪ Proposed building and industry energy benchmarking (GOI, 2006)	▪ Improving efficiency in small and medium-sized enterprises across industry due to lack of capacity to access or employ more efficient technologies (Mathur, 2008; Kumar, 2008) ▪ Heterogeneity of industry makes the introduction of standardized benchmarks very challenging, including in the power generation sector (Kumar, 2008)	▪ Existing carbon markets: at least 98 CDM-funded energy efficiency projects underway (GOI, 2006) ▪ Existing carbon markets; at least 15 CDM-funded fuel-switching project underway (GOI, 2006) ▪ Aluminum Task Force of the Asia Pacific Partnership on Clean Development and Climate (Asia-Pacific Partnership, 2008)

Promising Opportunities

Several studies and institutions, including many of those discussed above, have proposed policy directions for India based on assessment of mitigation potential, India's development goals and social needs, and other factors. Table 10, below, highlights leading greenhouse gas mitigation policies identified in three of these studies.

Table 10. Top Greenhouse Gas Mitigation Policies for India as Identified in Leading Studies

Sector	Government of India (2008) *National Action Plan*[38]	The Energy and Resources Institute (2006 and 2008) [39]	Confederation of Indian Industry (2008)[40]
Electricity Generation	▪ National Solar Mission to significantly increase share of solar PV and thermal generation in national energy mix ▪ Development of technology for producing energy from waste	▪ Increased nuclear power generation ▪ Increased hydropower generation ▪ Increased wind power generation ▪ Increased solar generation	▪ Government policy support to maintain momentum for renewables, especially wind and hydropower ▪ Efficiency technologies in existing coal plants ▪ Further development of nuclear power ▪ Develop legal and regulatory framework for carbon capture and storage and capacity assessment
Transportation	▪ Better urban planning and modal shift to public transport, including long-term transit plans	▪ Vehicle efficiency improvements ▪ Enhanced public transit ▪ Second-generation biofuels	▪ Fuel efficiency standards, regularly updated ▪ Government support for public transport ▪ Emission targets for aviation sector and policies to favor rail over air travel
Buildings & Appliances	▪ Tax incentives for energy efficiency appliances ▪ Extension of Energy Conservation Building Code for commercial buildings ▪ Promotion of Energy Service Companies (ESCOs)	▪ Increased deployment of demand-side efficiency technologies	▪ Develop Energy Conservation Building codes for additional sectors ▪ Extend energy efficiency standards to other products not currently covered ▪ Benchmarking and retrofitting of existing buildings
Industry	▪ Development of a system of tradable certificates for energy savings in large industry ▪ Public-private partnerships for demand-side management financing ▪ Promotion of Energy Service Companies (ESCOs)	▪ Energy efficiency advancements in the cement industry ▪ Energy efficiency improvements in the iron/steel industry ▪ Mulilateral financing mechanisms to facilitate inefficient and obsolete technologies	▪ Specific technical measures in cement, steel, aluminum, chemicals, and other industries ▪ Liberalization of the Indian economy to encourage competition and efficiency

[38] Many policies were included in India's *National Action Plan*, particularly in the appended *Technical Document*, where relative priorities were difficult to assess. The policies listed in this table are those included in the main body of the *Action Plan* (with additional details added from the *Technical Document* in some cases) and which are presumably higher priority for the Government of India. However, we encourage readers to review the full *Technical Document* for further indications of India's planned activities.

[39] Options presented in this table are generally those listed in TERI (2006)'s "advanced options" scenario and that were found in that study to contribute to GHG reductions of at least 1% of India's 2030 emissions, or about 30 MMtCO2e, but with select additions from TERI (2008), which placed additional emphasis on some options (i.e., solar electricity and demand-side energy efficiency), refined the technologies or approaches (e.g., focusing on second-generation biofuels rather than simply "biodiesel") and strongly stressed the need for technology transfer from developed countries for energy efficiency, vehicle, high-speed rail, industrial, and other mitigation technologies.

[40] The CII report presents an exhaustive list of potential actions but does relatively little to indicate priorities among them. The policies highlighted in this table are those highlighted in the CII report's executive summary.

Sector	Government of India (2008) *National Action Plan*[38]	The Energy and Resources Institute (2006 and 2008) [39]	Confederation of Indian Industry (2008)[40]
	▪ Fiscal incentives		
Other			▪ Further engagement of "civil society" ▪ Need to set up an Indian carbon market

Conclusions

Through its *Integrated Energy Policy Report of the Expert Committee* (2006), its *National Action Plan on Climate Change* (2008), and other efforts, the Government of India has been increasingly active in exploring measures that can yield significant greenhouse gas mitigation benefits. Current published documents share a thorough cataloguing of beneficial and needed actions and, in some cases, the assessment of key barriers. What the studies generally lack are detailed quantification and cost-effectiveness assessments for mitigation actions over the next two decades. Efforts by The Energy and Resources Institute (TERI) help fill this void to some degree but are limited in that they can only assess select groupings of technologies in detail.

Collectively, the message from the existing literature on mitigation efforts in India is that numerous options exist to reduce greenhouse gas emissions, and many of these options are – over the next two decades – available at low (even negative, in some of the technologies assess by TERI) marginal costs. Other options, however, will require significant up-front costs and technology learning over time but may still prove cost-effective. For example, the Government of India has announced a *National Solar Mission* as one of eight key components (and the only energy supply-related *Mission*) of its *National Action Plan on Climate Change*.

The actions summarized in this chapter represent a range of possible areas for involvement by India's international partners.

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Chapter 5. Brazil

South America's leading economic power, Brazil has extensive natural resources, including forest and mineral reserves, that have contributed to recent record trade surpluses and increasing standing in the world economy. At the same time, Brazil has the lowest energy-related emissions intensity (tCO2 per $GDP) of the countries studied, owing to its extensive reliance on hydroelectric power as well as use of ethanol in vehicles. While deforestation of the Amazon paralleled the growth of exports through 2004, Brazil has since reduced the rate of deforestation significantly, in part due to a national forest protection plan. Such actions have also helped reduce carbon dioxide emissions, but are not discussed in detail here, as this report focuses on energy-related emissions.

In late 2008, Brazil released its *National Plan on Climate Change*, which lays out specific objectives and actions for addressing climate change and builds on its previous white paper *Brazil's Contribution to Prevent Climate Change* (FRB, 2007) and its *First National Communication* (FRB, 2004). Brazil has also introduced numerous policies in the last several years focused on reducing energy-related emissions, from its 2002 *Program for Incentive of Alternative Energy Sources* to recent push on flex-fuel vehicles (CCAP, 2007). Brazil views its efforts to pursue a low-carbon development path as part of its broader pressing objective to reduce social inequity and increase economic development (FRB, 2008). Brazil has long had such a focus: in 1997, Brazil proposed the idea of the Clean Development Mechanism (originally proposed as the Clean Development Fund) during negotiations leading up to the Kyoto Protocol. The Clean Development Mechanism was included as Article 12 of the Kyoto Protocol and has since led to over 200 energy-related projects (and approximately 400 total projects) in the pipeline for Brazil.[41]

The following table displays several economic and climate indicators for Brazil relative to the U.S. and to other countries included in this study.

Table 11: Brazil Development Indicators Relative to Other Countries
(Source: World Bank's World Development Indicators, 2009)

	China	India	Brazil	Mexico	South Korea	South Africa	U.S.
Population, millions (2007)	1,320	1,120	192	105	48	48	302
GNI[42] Per Capita, PPP (2007)	$5,420	$2,740	$9,270	$13,910	$24,840	$9,450	$45,840
GDP Growth, Annual (2007)	13.0%	9.1%	5.4%	3.2%	5.0%	5.1%	2.0%
Energy use per capita, kg oil equivalent (2006)	1,433	510	1,184	1,702	4,483	2,739	7,768
CO_2 emissions per capita (2005)	4.3	1.3	1.7	4.1	9.4	8.7	19.5

While the majority of Brazil's greenhouse gas emissions (and recent reductions) occur due to forestry and other land management practices, the country has also been active in advancing policies to address emissions from energy use, which represent about one-quarter of overall emissions. The country is motivated in part by the desire to address social issues and increase economic development, as several greenhouse gas mitigation options both within the country and globally could have strong overlap with these concerns. For example, distributed renewable electricity generation can help bring electricity to the countryside, and greenhouse gas mitigation strategies that rely on Brazil's growing biofuels industry could support economic development. Furthermore, Brazil has a strong interest in preventing climate change to avoid bearing the likely significant impacts. A recent study by the World Bank suggested that climate

[41] http://cdmpipleline.org

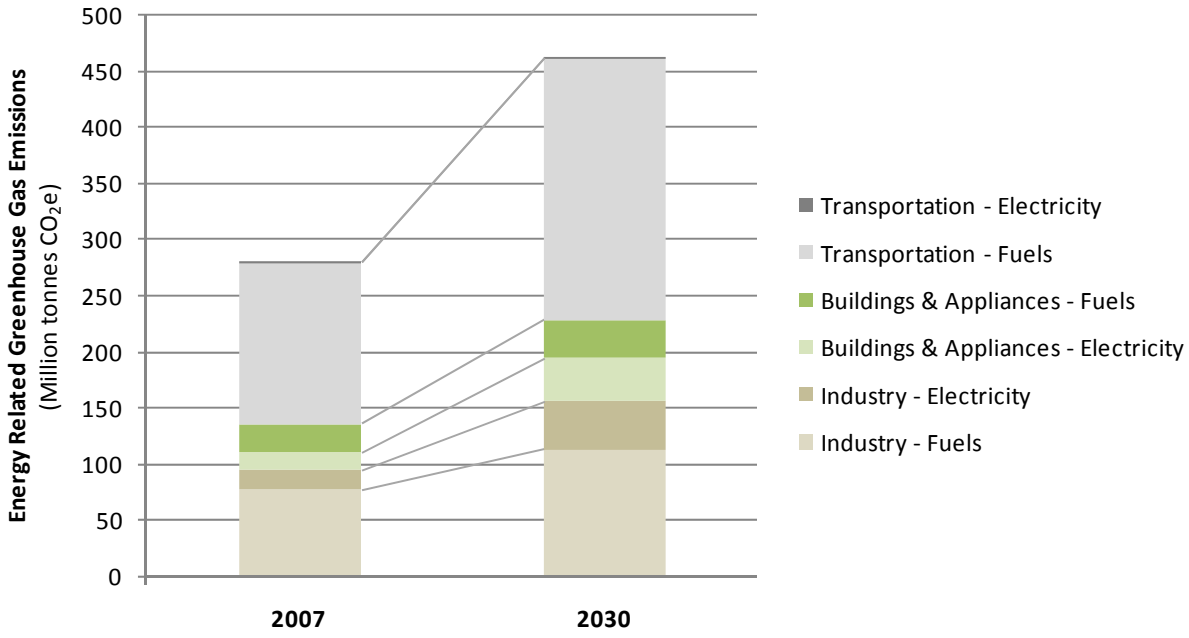
[42] GNI is Gross National Income and is reported here using the purchasing power parity (PPP) method of converting to international dollars.

change could decrease the country's agricultural productivity, with resulting significant increases in rural poverty (de la Torre et al, 2009).

Baseline Emissions Forecast

Figure 8 below, displays the estimated baseline emissions for Brazil between now and 2030.[43]

Figure 8. Projected Baseline Energy-sector Greenhouse Gas Emissions in Brazil in 2030



Mitigation Potential

Relatively few international studies have quantified greenhouse gas mitigation potential in Brazil's energy sector. Among those that have and provide useful data for this study include the following:

- **McKinsey & Company's *Pathways to a Low-Carbon Economy for Brazil*** (2009), released in the first half of 2009, presents Brazil-specific results from McKinsey's Global Abatement Cost Curve Version 2.
- **Centro Clima of the Federal University of Rio de Janeiro** (La Rovere et al, 2006), This study, *Greenhouse Gas Mitigation in Brazil: Scenarios and Opportunities through 2025*, published by the Center for Clean Air Policy, was the only comprehensive mitigation study reviewed for Brazil until the publication of McKinsey's report and is still the most thoroughly documented. The study includes detailed findings for costs and potentials of numerous specific options and presents its underlying assumptions and data more completely than McKinsey (2009).
- **United Nations Framework Convention on Climate Change** (2007). This study concerning the financial flows needed to address climate change used data from a variety of sources (including the

[43] Please see the Appendix for a description of our baseline projection methodology.

IEA) to quantify emission reduction potential in the industry and building efficiency sectors in Brazil through 2030.

- **International Energy Agency** (2008). In their *Energy Technology Perspectives* report, the IEA provided some limited data on mitigation potential in Brazil's biofuel and steel industries.

- **Pew Center on Global Climate Change** (Chandler et al, 2002). This study, *Climate Change Mitigation in Developing Countries: Brazil, China, India, Mexico, South Africa, and Turkey* included estimates of greenhouse mitigation through 2020 as generated by the Federal University of Rio de Janeiro. These estimates, however, are assumed to be made obsolete by the more recent work by the Federal University of Rio de Janeiro in partnership with CCAP, described above.

In addition to these sources listed above, our team also reviewed documents by the Brazilian government, including their ***National Plan on Climate Change*** **(**FRB, 2008), the country's White Paper ***Brazil's Contribution to Prevent Climate Change*** (FRB, 2007) and ***First National Communication*** (FRB, 2004) as well as publications by other researchers, including the United Nations Environment Programme (La Rovere et al, 2007), the Environmental Research Centre of the Netherlands (Wetzelaer et al, 2007), preliminary materials from the World Bank's low-carbon country case study of Brazil (de Gouvello, 2007), and several sector-specific studies published by researchers at the Federal University of Rio de Janeiro, among others. In general, these studies provided information helpful for assessing potential viability of mitigation options (as discussed in the following section) but few data able to support quantitative projections of mitigation potential.

Based on review of the studies above, we assembled estimates of mitigation potential for the following options in Brazil, as listed in Table 12, below.

Table 12. Estimated Mitigation Potential in Brazil in 2030, $MtCO_2e$/year

Sector/Option	Government of Brazil (2008)	McKinsey (2009)	Centro Clima (2006)[44]	UNFCCC (2007)	IEA (2008)	Schaeffer et al (2009)
ELECTRICITY		7	8[45]			
Efficiency at gas-fired plants						
Nuclear Power						
Small hydropower		7	8			
Other renewable (e.g., wind)			8			
Sugar-cane bagasse			8			
TRANSPORTATION		69	40[46]			
Vehicle Efficiency		58	10			
Fuel Switching – Biofuel		11	30			
VMT Reduction						
BUILDINGS & APPLIANCES	30	9	7	4		50
Residential	30[47]	5	6	4		50[48]
Commercial		4	1			
INDUSTRY		99	51	36[49]	15	
Cement		16[50]	24			
Iron/Steel		50	24		15	
Refining/Chemicals		33				
Pulp and Paper			3			

Note that in cases where estimates are presented by different researchers, the figures above can vary substantially. As discussed in the *Methodology* chapter, estimates of mitigation potential depend on numerous underlying assumptions that are not always transparent, let alone consistent. Figure 9, below, displays results from the two studies that included mitigation estimates for all four of the energy-related sectors addressed in this report. Note that the potential indicated in the McKinsey (2009) study is higher than that in the Centro Clima study (La Rovere et al, 2006) due in large part to more ambitious vehicle efficiency gains as well as the inclusion of petrochemical sector options and carbon capture and storage

[44] Figures here attributed to Centro Clima (2006) are SEI calculations of greenhouse gas reductions for the year 2030 based on extrapolating Centro Clima estimates of avoided fuel use or CO2 mitigation for years 2020 or 2025 to the year 2030. In most cases these estimates are calculated based on Centro Clima's mitigation results relative to their A2 "pre-2000 policy" but the baseline used in presentation of Centro Clima's results is not always specified. Mitigation estimates relative to Centro Clima's 2005 policy baseline are generally (but not always) lower.

[45] Using the method described in footnote 44 yields a potential of approximately 8 MtCO2e in 2030, which we assume could be met with any combination of small hydropower, renewables, and sugar cane bagasse.

[46] We assume that the two transportation options in Centro Clima's report (La Rovere et al, 2006) are additive.

[47] Brazil expects its *National Policy for Energy Efficiency* to reduce greenhouse gas emissions by 30 million tons of CO2 in 2030. This policy likely includes actions beyond the Buildings and Appliances sector, including Industry, but further details were not available.

[48] The figure of 50 is the technical potential. The authors cite the economic potential as 21 and the market potential as 12 MtCO2e.

[49] This figure is mitigation resulting from combustion-related CO2 reductions only. The UNFCCC study also included reductions from industrial process emissions.

[50] About half of this potential is in clinker substitution which reduces direct CO2 emissions from cement production but not energy-related emissions.

technologies within its industrial sector scenario. Upcoming results from World Bank's Low-Carbon Country Case Study focused on Brazil will provide additional detail, as the study will have detailed mitigation potential estimates in the industrial (including refining) sector (Schaeffer, 2009).

Figure 9. Energy-sector Mitigation Potential for Brazil in 2030
(McKinsey, 2009; Centro Clima estimates: La Rovere et al. 2006)

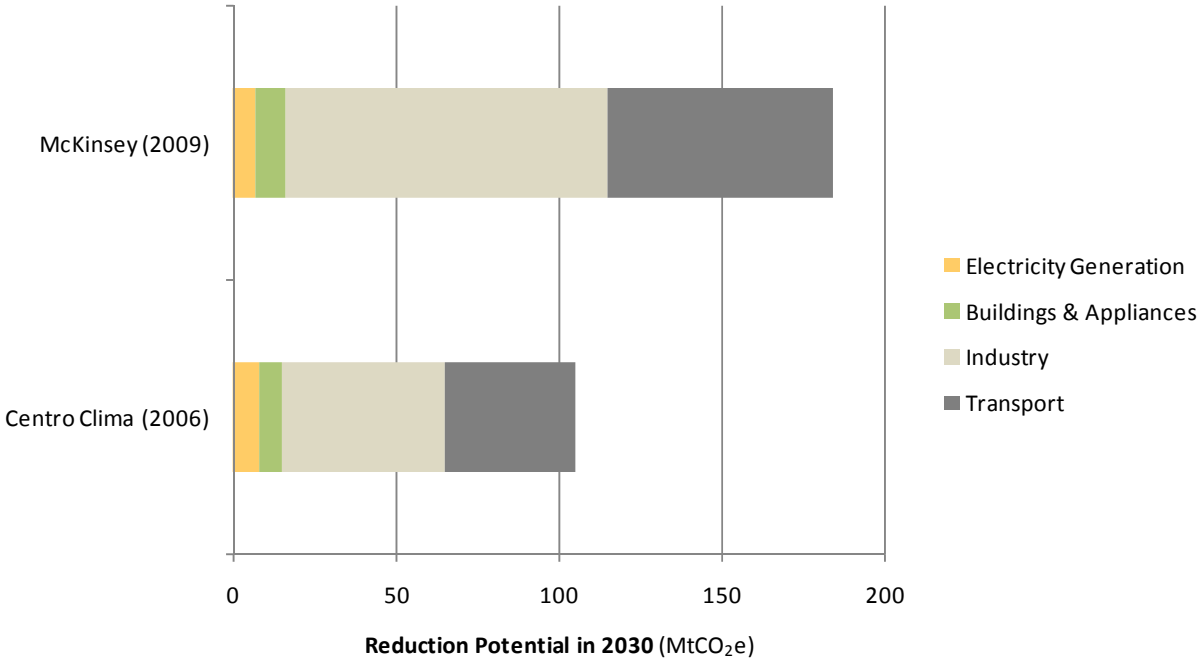
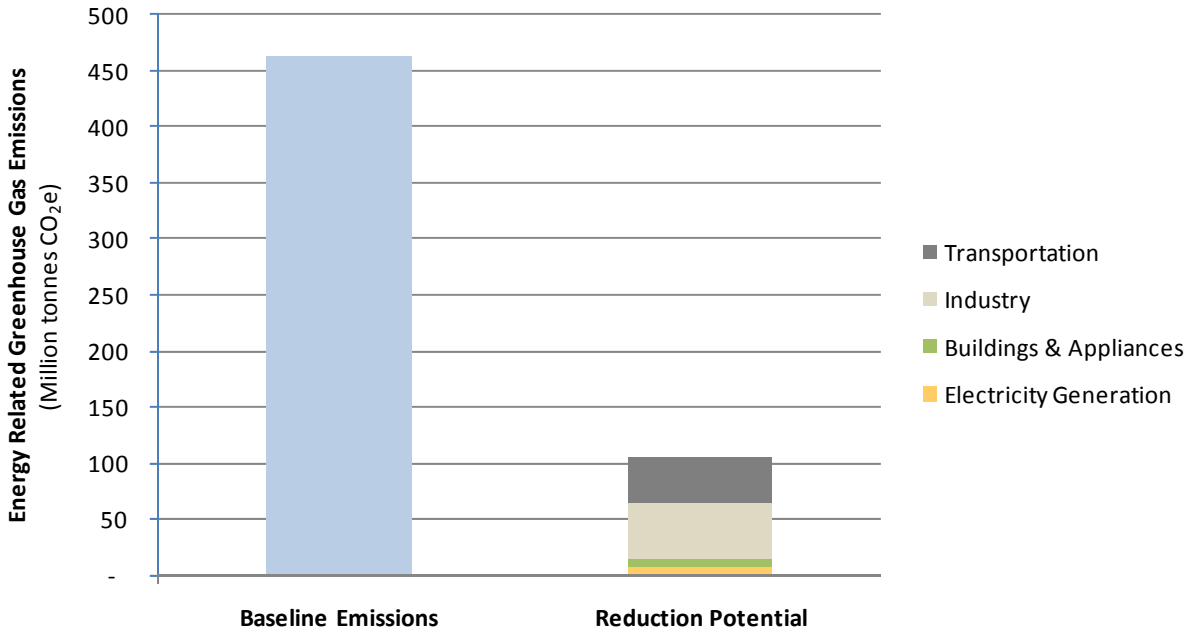


Figure 10, below, displays the mitigation potential estimates derived from Centro Clima (La Rovere et al, 2006) in the context of projected energy-sector baseline emissions. Note that no attempt was made to reconcile possible differences in the Centro Clima' baseline from our projected baseline – differences that would potentially alter the magnitude of the emission reductions shown. Nevertheless, the figure does display the general scale of emission reductions identified by Centro Clima relative to SEI's projected future energy-sector emissions in Brazil.

Figure 10. Energy-related Greenhouse Gas Emissions in Brazil in 2030 – Baseline Emissions and Reduction Potential
(Baseline from SEI analysis; reduction potential from La Rovere et al, 2006; see text for caveats regarding comparison of figures)



Assessment of Options

The options in Table 12 reflect estimates of the achievable greenhouse gas reductions for energy-related options in Brazil. The success of efforts to implement these options will depend on numerous factors, including cost-effectiveness, extent of overlap with social or economic development objectives, extent of existing country experience with similar measures or policies, and potentially international support mechanisms, among other factors.

We conducted a review of the available literature, as well as interviews with other researchers focused on Brazil, to summarize and assess the potential barriers and opportunities for each option. Table 13, below, provides results of this research, and is followed by our team's assessment of high priority opportunities for involvement.

Table 13. Assessment of Mitigation Options in Brazil

Option	Mitigation Potential in 2030[51]	Relative Cost	Overlapping Policy Objectives	Proposed or Adopted Policies	Key Barriers	International Support Mechanisms
ELECTRICITY						
Efficiency at coal and natural-gas fired plants plus Carbon Capture & Storage (CCS)	Not quantified by studies reviewed; likely significant due to growth in coal and natural gas in Brazil's energy mix	*High* based on studies in other countries	▪ Supports existing trend of increasing coal in national energy mix, given Brazil's ample deposits of low-grade coal (La Rovere et al, 2007) ▪ Increased use of coal may conflict with future demand for high quality water (IAEA, 2006)	▪ Existing research by Petrobras and ABCM on CCS and other "clean coal" technologies (de Gouvello, 2007; La Rovere et al, 2007)	▪ Expansion of coal would require either importing high-quality coal (Schaeffer, 2009) or addressing social and environmental liabilities in Brazil's South region, the source of most of the country's domestic coal (IAEA, 2006)	▪ Brazil is a member of the Carbon Sequestration Leadership Forum ▪ International Energy Agency's Implementing Agreement on Clean Coal Science -- Brazil is not a member
Fuel Switching to Natural Gas	Not quantified by studies reviewed	*Low* (Wetzelaer et al, 2007)	▪ Supports efforts to stabilize electricity generation by supplementing Brazil's hydro supply, especially at periods of peak demand (FRB, 2004) ▪ Supports efforts for cleaner air vis-à-vis fuel-oil-fired plants (FRB, 2004), but can conflict with efforts for improved urban air quality (IAEA, 2006)	▪ Existing, ongoing liberalization of the power market allows greater opportunities for natural gas fired plants (La Rovere et al, 2006; Chandler et al, 2002) ▪ Existing study of a natural gas pipeline connecting Argentina and Venezuela and providing supply to Brazil (La Rovere et al, 2006)	▪ Expansion of natural gas electricity supply requires new domestic and international natural gas supply (La Rovere et al, 2007; La Rovere et al, 2006) ▪ Plans to expand Bolivia-Brazil pipeline are on hold due to political instability in Bolivia and new discovery of additional domestic natural gas reserves (Schaeffer, 2009) ▪ Little research on effect of carbon value on fuel switching (de Gouvello, 2007)	▪ Carbon finance: 15 fossil fuel switching projects in the Clean Development Mechanism (CDM) pipeline as of November 2008
Nuclear Power	Not quantified by studies reviewed	Not quantified by studies reviewed	▪ Large, centralized nuclear power plants would conflict with country trend towards	▪ Several new nuclear power plants have been proposed in Brazil (IEA,	▪ Perceived safety and environmental risks (Costa, Cohen, and Schaeffer, 2007; La	▪ Brazil is part of the Generation IV International Forum (IEA, 2008), which aims to develop a future

[51] Options characterized as *High* have the potential to reduce Brazil's energy-related greenhouse gas emissions by at least 1% of Brazil's 2030 energy-related emissions, or about 5 $MtCO_2e$. Options characterized as *Medium* have the potential to reduce 2030 emissions by 0.1%, or about 0.5 $MtCO_2e$.

Option	Mitigation Potential in 2030[51]	Relative Cost	Overlapping Policy Objectives	Proposed or Adopted Policies	Key Barriers	International Support Mechanisms
			liberalizing power markets (FRB, 2004) ▪ Could support goal of increasing energy independence, given Brazil's uranium reserves (de Gouvello, 2007)	2008) ▪ Decision made to finish Angra III, Brazil's third nuclear power plant (Schaeffer, 2008) ▪ Plan to expand nuclear capacity through 2030 (EPE, 2007)	Rovere et al, 2006; FRB, 2004) ▪ Would require fundamental changes in policy and social attitudes for nuclear to play a larger role (Costa, Cohen, and Schaeffer, 2007; IAEA, 2006)	generation of nuclear energy systems that are competitively priced and reliable while addressing safety, waste, and proliferation issues. ▪ Brazil participates in the International Project on Innovative Nuclear Reactors and Fuel Cycles, INPRO (IEA, 2008)
Hydropower (especially small hydropower)	*High* (McKinsey, 2009; La Rovere et al, 2006)	*Low* (McKinsey, 2009; La Rovere et al, 2006)	▪ Can conflict with other beneficial uses of water, particularly in Brazil's Southeast region (IAEA, 2006) ▪ Can conflict with country's policy of increasing energy security, as recent studies have shown possible negative impacts of global climate change on hydroelectricity generation in some parts of the country (de Lucena et al. 2009)	▪ Current efforts to foster public/private investment partnerships for new hydro (La Rovere et al, 2007) ▪ Government proposal to conduct preinvestment studies of hydropower and make them available to investors, for the purpose of increasing share of hydropower in its long-term energy supply contracts (de la Torre et al, 2009) ▪ Existing incentives for small-scale hydro producers (FRB, 2004) ▪ World Bank proposal to streamline environmental permitting for hydro projects (de la Torre et al, 2009)	▪ Existing efforts to liberalize the power market tend to favor power plants with short payback periods, incenting natural gas thermal plants over hydro (La Rovere et al, 2006; Schaeffer and Szklo, 2001) ▪ Difficulty in obtaining environmental permits, especially given most remaining potential lies in the Amazon (de la Torre et al, 2009; La Rovere et al, 2007; La Rovere et al, 2006) ▪ Past resettlement of people for larger hydro plants has lingering social impacts (IAEA, 2006), organized as National Movement of those Affected by Dams (Costa, Cohen, and Schaeffer, 2007)	▪ Carbon finance: 75 hydroelectricity projects in the Clean Development Mechanism (CDM) pipeline as of November 2008
Sugar-cane bagasse	*High* (La Rovere et al, 2006)	*Medium* (La Rovere et al, 2006)	▪ Biomass-fired electricity may adversely impact local air quality (Schaeffer and Szklo, 2001).	▪ Existing goal of alternative-energy program PROINFA to increase bagasse and straw co-generation (FRB, 2007) ▪ Existing efficiency	▪ Initial PROINFA incentives did not encourage electricity production from biomass (La Rovere et al, 2007) ▪ Insufficient regulatory and incentive framework	▪ Global Environment Facility – funded projects, including Sugarcane Renewable Electricity (SUCRE) and Advanced Technology Cogeneration Project for the Costa Pinto Sugar Refinery

Option	Mitigation Potential in 2030[51]	Relative Cost	Overlapping Policy Objectives	Proposed or Adopted Policies	Key Barriers	International Support Mechanisms
				requirements for co-generation facilities (FRB, 2004) ▪ Proposal for utility reform to integrate combined heat and power into grid (Geller et al, 2004)	(de Gouvello, 2007) ▪ Lagging national attention on co-generation (IAEA, 2006) ▪ Limited awareness and technology availability (IAEA, 2006) ▪ Subsidized fuel prices in industrial sector (IAEA, 2006)	
Other renewables	*High* for wind power (La Rovere et al, 2006)	*Medium* (Wetzelaer et al, 2007) to *High* (La Rovere et al, 2006) for wind power	▪ Can support goal to diversify electricity supply mix (FRB, 2007) ▪ Can support existing rural electrification efforts, e.g. Light for All and Light in the Countryside (FRB, 2007; FRB, 2004) ▪ Supports economic development (La Rovere et al, 2006)	▪ Proposal to extend existing incentives for small-scale hydro to other renewables (FRB, 2004; Geller et al, 2004) ▪ Existing goal for 10% renewables by 2022 set forth in the 2004 Program to Foster Alternative Sources of Electrical Energy, PROINFA (FRB, 2007; CCAP, 2007) ▪ Recent auctions for new, alternative energy supply, with large focus on wind and sugar cane bagasse (EPE, 2008; FRB, 2007; CCAP, 2007) ▪ Proposal to implement a Renewable Portfolio Standard (IAEA, 2006) ▪ Proposal to develop and stimulate adoption of new bioenergy sources for electricity generation (IAEA, 2006)	▪ Insufficient regulatory and incentive framework (de Gouvello, 2007) ▪ High cost of photovoltaic cells and solar thermal systems (FRB, 2007) ▪ Lagging development of hydrolysis for ethanol production for bio-electricity (La Rovere et al, 2006) ▪ Lagging development of solar technology in Brazil makes country dependent on international markets (IAEA, 2006) ▪ Significant lack of data on potential for wind, solar, and biomass (IAEA, 2006) ▪ Limited in-country capacity for producing wind turbines (La Rovere et al, 2006)	▪ Carbon finance: 117 renewable energy projects in the Clean Development Mechanism (CDM) pipeline as of November 2008 ▪ Global Environment Facility, GEF, which has funded a solar thermal study in Brazil (FRB, 2004)
TRANSPORTATION						
Vehicle Efficiency	*High* (McKinsey, 2009 ; La Rovere et al,	*Low* for most technologies (McKinsey, 2009; La	▪ Financial savings and reduced local air pollution (de la Torre et al, 2009)	▪ Light-duty vehicle efficiency labeling program due to start in April 2009 (CONPET,		

Option	Mitigation Potential in 2030[51]	Relative Cost	Overlapping Policy Objectives	Proposed or Adopted Policies	Key Barriers	International Support Mechanisms
	2006)	Rovere et al, 2006) but ranging to the high end of *Medium* for plug-in hybrids		2008; La Rovere et al, 2007; La Rovere et al, 2006; FRB, 2004) ▪ Existing Motor Vehicle Air Pollution Control Program, Proconve, including efficiency standards for heavy-duty vehicles (FRB, 2007; FRB, 2004) ▪ Existing tax incentives for smaller engines (FRB, 2004; Chandler et al, 2002) ▪ Existing programs to promote fuel saving in bus and freight fleets (FRB, 2007; FRB, 2004)		
Fuel Switching – Ethanol & Biodiesel	*High* (McKinsey, 2009 ; La Rovere et al, 2006)	▪ *Medium* for light-duty fleet (La Rovere et al, 2006) ▪ *High* for heavy-duty fleet, based on high cost of biodiesel (La Rovere et al, 2006)	▪ Supports job creation and wages in the country's agricultural industry and help reduce regional inequality (FRB, 2007; Costa, Cohen, and Schaeffer, 2007; IAEA, 2006; FRB, 2004) ▪ Can support objectives for cleaner air and water relative to petroleum fuels (FRB, 2004; La Rovere et al, 2006; La Rovere et al, 2007) ▪ Supports strategic objective to diversify into non-petroleum energy (FRB, 2004) ▪ Can conflict with goals to reduce deforestation if biodiesel is to come from soy (Schaeffer and Rodrigues, 2005)	▪ Existing requirement for 20-25% ethanol in gasoline as part of Proalcool (La Rovere et al, 2006; FRB, 2004) ▪ Existing National Program for Biodiesel Production and Use (PNPB) that includes family farm incentives (FRB, 2007) ▪ Existing tax incentives for flex-fuel light duty vehicles running on any combination of gasoline and ethanol (Szklo, Schaeffer, and Delgado, 2007) ▪ Existing 3% biodiesel blend requirement (Schaeffer, 2008), with proposal to increase blend to 5% after 2012 (FRB, 2007) ▪ Existing government-sponsored R&D for	▪ High cost of biodiesel production (La Rovere et al, 2007; La Rovere et al, 2006); Schaeffer and Rodrigues, 2005) ▪ Complicated operational and farming logistics for biodiesel (La Rovere et al, 2007) ▪ Potential competition with food production and forestry (Rathmann, Szklo, and Schaeffer, 2009; McKinsey, 2009; La Rovere et al, 2007; Schaeffer and Rodrigues, 2005) ▪ Difficult agricultural working conditions (Costa, Cohen, and Schaeffer, 2007; IAEA, 2006) ▪ Trade barriers and high subsidies in other countries limit growth of Brazil's biofuel industry	▪ Existing World-Bank funded study on biodiesel

Option	Mitigation Potential in 2030[51]	Relative Cost	Overlapping Policy Objectives	Proposed or Adopted Policies	Key Barriers	International Support Mechanisms
			and feedstocks can compete with edible oils (McKinsey, 2009)	biodiesel development (FRB, 2004) ▪ Existing trend towards more sustainable sugar cane farming techniques (IAEA, 2006)	and also limit global greenhouse gas mitigation opportunities (da la Torre et al, 2009)	
Fuel Switching – natural gas	Not quantified by studies reviewed	Not quantified by studies reviewed		▪ Existing efforts under CONPET to encourage natural gas in urban and public transport (FRB, 2007)	▪ Likely preferential use of limited natural gas supplies for industry and power generation, not transport (La Rovere et al, 2006; Geller et al, 2004)	
Reductions in VMT	Not quantified by studies reviewed	*Medium* for public transit improvements (Borba, 2008)		▪ Proposed expansion of Sao Paulo and Rio de Janeiro subways (La Rovere et al, 2006) ▪ Proposed expansion and increased efficiency of freight railway network (La Rovere et al, 2006; Geller et al, 2004) ▪ Proposed improvements in land use planning and mode-shifting policies (IAEA, 2006)		▪ Existing Global Environment Facility-funded projects,: *Transport And Air Quality Improvement Program For São Paulo* and *Hydrogen Fuel Cell Buses for Urban Transport*
BUILDINGS & APPLIANCES						
Residential & Commercial, including fuel-switching from fuelwood	▪ *High* for residential (McKinsey, 2009; Schaeffer et al, 2009) ▪ *Low* (LaRovere et al, 2006) to *Medium* (McKinsey, 2009) for commercial	*Low* (McKinsey, 2009; FRB, 2007 and Schaeffer et al, 2009)	▪ Supports economic development (La Rovere et al, 2007) ▪ Can support efforts for increased socio-economic equality and energy access (IAEA, 2006) ▪ Helps to postpone the building of expensive new power plants (Schaeffer et al, 2009, in press)	▪ Existing National Energy Conservation Program, PROCEL (FRB, 2007; FRB, 2004) ▪ Existing law requires public utilities to invest 1% of net operating income in energy efficiency measures (FRB, 2007) and proposal to expand this law (Geller et al, 2004) ▪ Existing labeling of energy efficient appliances (FRB, 2007;	▪ Conflict between economically efficient energy pricing and goal of increased energy access, especially for low-income populations (IAEA, 2006) ▪ Lack of energy codes for new commercial buildings (IAEA, 2006)	▪ Carbon finance: one residential energy efficiency project in the Clean Development Mechanism (CDM) pipeline as of November 2008 ▪ Existing World-Bank-funded study on energy efficiency in Brazil ▪ Global Environment Facility-funded project, Market Transformation for Energy Efficiency in Buildings

Option	Mitigation Potential in 2030[51]	Relative Cost	Overlapping Policy Objectives	Proposed or Adopted Policies	Key Barriers	International Support Mechanisms
				FRB, 2004) and proposal to expand and more fully implement this law (IAEA, 2006; Geller et al, 2004) ▪ Existing maximum energy consumption standards for electrical machines and motors manufactured in Brazil (La Rovere et al, 2007) ▪ Existing Brazilian Energy Efficiency Information Center (FRB, 2007) ▪ Proposed market reform to encourage natural gas and LPG distribution and use (IAEA, 2006) ▪ Proposal to create a new national energy efficiency agency (IAEA, 2006) ▪ Proposal to adopt energy codes for new commercial buildings (IAEA, 2006; Geller et al, 2004) ▪ Proposal to create a financing mechanism for energy service companies (IAEA, 2006)		
INDUSTRY						
Cement	*High* (McKinsey, 2009; La Rovere et al, 2006)	*Low* for efficiency improvements and fuel switching (McKinsey, 2009; La Rovere et al, 2006) and *High* for CCS			▪ Limited data to assess industrial efficiency opportunities (La Rovere et al, 2007)	▪ Carbon finance: one cement-focused project in the Clean Development Mechanism (CDM) pipeline as of November 2008

Option	Mitigation Potential in 2030[51]	Relative Cost	Overlapping Policy Objectives	Proposed or Adopted Policies	Key Barriers	International Support Mechanisms
Iron/Steel, both efficiency improvements and decreased use of coal in favor of renewable charcoal	*High* (McKinsey, 2009; La Rovere et al, 2006)	*Low* (efficiency of new plants, use of sustainable charcoal) to *Medium* (efficiency retrofits) to *High* (CCS) (McKinsey, 2009)	▪ Use of charcoal can conflict with desire to protect native forests unless charcoal is produced renewably from planted forests (McKinsey, 2009; IAEA, 2006)	▪ Existing efforts to decrease use of coal in favor of renewable charcoal as a reducing agent in steel production (FRB, 2007; Costa, Cohen, and Schaeffer, 2007; IAEA, 2006)	▪ Poor working conditions and reliance on child labor in the charcoal industry (Costa et al, 2007; IAEA, 2006) ▪ Limited data to assess industrial efficiency opportunities (La Rovere et al, 2007)	▪ Carbon finance: 12 industrial energy efficiency projects in the Clean Development Mechanism (CDM) pipeline as of November 2008
Oil Refining Sector – various improvements	*Medium* (Schaeffer, personal communi-cation, 2008) to *High* (McKinsey, 2009)	*Low* at high oil prices; *High* at low oil prices (Schaeffer, 2008; Szklo and Schaeffer, 2007)		▪ Existing efforts to integrate co-generation into Petrobras industrial facilities (FRB, 2004) ▪ On-going efforts to modernize refinery facilities, including the Zero Burn-Off Plan (La Rovere et al, 2006; IAEA, 2006) ▪ Existing research and pilot projects on CCS by Petrobras (Schaeffer, 2008) ▪ Existing study into gas-to-liquids as an alternative to gas flaring (Branco, Szklo, and Schaeffer, in preparation)	▪ Little research on effect of potential carbon prices on oil production (de Gouvello, 2007) ▪ Subsidized fuel prices in industrial sector (IAEA, 2006)	▪ Carbon finance: 12 industrial energy efficiency projects in the Clean Development Mechanism (CDM) pipeline as of November 2008
Pulp and Paper	▪ *Medium* for pulp & paper (La Rovere et al, 2006)	*Limited data to assess* (La Rovere et al, 2006)			▪ Switch from fuel oil to natural gas depends on new natural gas supply and infrastructure (La Rovere et al, 2006) ▪ Limited data to assess industrial efficiency opportunities (La Rovere et al, 2007)	

Promising Opportunities

Several studies and institutions, including many of those discussed above, have proposed policy directions for Brazil based on assessment of mitigation potential, Brazil's development goals and social needs, and other factors. Table 14, below, highlights leading greenhouse gas mitigation policies as identified in three of these studies.

Table 14. Top Greenhouse Gas Mitigation Options for Brazil as Identified in Leading Studies

Sector	**Brazil National Plan on Climate Change** (FRB, 2008)[52]	**Centro Clima** (La Rovere et al, 2006)[53]	**McKinsey** (2009)	**Geller et al** (2004)[54]	Other Ideas
Electricity Generation	▪ Reduce "non-technical" losses ▪ Increase hydroelectricity ▪ Increase wind energy ▪ Increase solar PV ▪ Increase co-generation from sugar cane bagasse	▪ Increase small hydroelectricity ▪ Increase wind power ▪ Increase use of sugar cane bagasse in electricity co-generation	▪ Increase small hydro-electricity	▪ Adopt minimum efficiency standards for new thermal power plants ▪ Stimulate grid-connected wind power ▪ Stimulate renewable energy use off-grid	
Transport	▪ Encourage ethanol production ▪ Deploy biodiesel blending standards ▪ Stimulate international ethanol market	▪ Efficiency gains in light duty vehicles ▪ Further implementation of flex fuel in light duty vehicles ▪ Increase biodiesel in heavy vehicles	▪ Increase vehicle efficiency ▪ Expand use of sugarcane and switchgrass ethanol	▪ Adopt minimum efficiency or emissions standards for new vehicles ▪ Expand ethanol ▪ Improve efficiency of freight transport	▪ Improve public transit (Borba, 2008)
Buildings & Appliances	▪ Implement *National Policy for Energy Efficiency* ▪ Implement refrigerator replacement and solar hot water heating	▪ Switch residents from wood and businesses from fuel oil to LPG and natural gas	▪ Improved lighting and water heating efficiency and improved thermal insulation and airflow in buildings	▪ Adopt minimum efficiency standards for appliances, motors, and lighting products ▪ Expand utility investments in end-use energy efficiency ▪ Adopt energy codes for new commercial buildings ▪ Expand use of combined heat and power systems fueled by natural gas	

[52] Brazil's 2008 *National Plan on Climate Change* did not specify particular medium-term actions; therefore, all energy-sector actions listed in the plan's *Executive Summary* are listed here.

[53] La Rovere et al (2006) did not make explicit recommendations. The options listed in this table are those included in the study's "advanced options" scenario and which each represent (with the exception of the buildings & appliances options) at least 1% of the country's projected 2030 energy-related greenhouse gas emissions.

[54] Geller et al (2004) focused on near-term options – all of which are included. The Geller study was funded by a grant from the U.S. EPA's Office of Air and Radiation.

Sector	**Brazil National Plan on Climate Change** (FRB, 2008)[52]	**Centro Clima** (La Rovere et al, 2006)[53]	**McKinsey** (2009)	**Geller et al** (2004)[54]	**Other Ideas**
Industry	▪ Increased use of sustainable charcoal in iron/steel sector	▪ Increased use of sustainable charcoal in iron/steel sector ▪ Increase content of cementious materials and thermal efficiency gains in the cement industry	▪ Increased efficiency, use of sustainable charcoal, and CCS in iron/steel sector ▪ Increased use of natural gas, sugar cane bagasse, process improvements, and CCS in chemical/ refinery sector ▪ Clinker substitution and CCS in cement industry	▪ Adopt industrial energy intensity reduction targets	▪ Implement CCS, reductions in gas flaring, and other improve-ments at refining facilities (Schaeffer, 2008; Branco, Szklo, and Schaeffer, in prep.)

Conclusions

Much of the discussion regarding Brazil's contribution to climate change focuses on the country's forestry sector and practices in the Amazon. Indeed, much of Brazil's potential to mitigate greenhouse gas emissions lies in the forestry and land use sectors (McKinsey, 2009; de la Torre et al, 2009). Nonetheless, the country remains a large energy consumer, ranking ninth among all countries[55]. Although its primary source of electricity has been carbon-neutral hydropower, the use of greenhouse-gas-intensive fossil fuels to generate electricity has been increasing steadily. Several relatively low-cost options exist to mitigate large quantities of energy-related emissions in Brazil.

Within the country, the federal government, the Centro Clima at the Federal University of Rio de Janeiro, other universities such as the University of Sao Paulo, and industry have all played leading roles in energy-sector climate mitigation research. Researchers at these institutions have examined the potential from individual technologies and policies and collaborated with international organizations (for example, de Gouvello, 2007; La Rovere et al, 2007; La Rovere eta al, 2006; Geller et al, 2004; Chandler et al, 2002). Current collaborations include work by the Federal University of Rio de Janeiro on a "Low Carbon Country Case Study" with the World Bank, a study not published or available in time for this review.

Studies reviewed for this paper suggest that a number of policy options are available that could each reduce Brazil's greenhouse gas emissions by at least 1% at relatively low cost. These include vehicle efficiency standards, increased penetration of hydropower in Brazil's electricity sector, increased energy efficiency (and fuel switching) in residential buildings and appliances, and energy improvements in Brazil's iron and steel and petrochemicals industries. These and other policies are summarized in Table 13, along with research on ongoing efforts (and remaining barriers) to their full implementation.

Many of these policies are also likely to receive support from the government of Brazil. In late 2008 the country released a *National Plan on Climate Change*. The plan lays out an ambitious agenda, stating,

[55] U.S. Energy Information Administration. "International Total Primary Energy Consumption and Energy Intensity." http://www.eia.doe.gov/emeu/international/energyconsumption.html. Accessed February 26, 2009

"the potential of this Plan to the reduction of emissions of greenhouse gases is one of the largest – if not the largest – among all nations." Although the plan offers relatively little quantification of its intended actions, Brazil does state support for many of the same high-potential actions identified by other researchers, as discussed above.

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Chapter 6. Mexico

Mexico has long been active in international climate change discussions and is the only developing country to have submitted three national communications under the United Nations Framework Convention on Climate Change. In 2007, the country released its *National Climate Change Strategy.* In 2008, the country released an initial review draft of its *Special Program on Climate Change*, intended to implement the national strategy, and announced a goal of reducing emissions 50% by 2050. The country is presently engaged in efforts with the World Bank and other partners to outline how it could meet its 50% reduction goal, including implementation of a domestic emissions trading system. Mexico has also recently proposed a new large scale World Climate Change Fund under the UNFCCC to target mitigation, adaptation, and technology.[56]

The following table displays several economic and climate indicators for Mexico relative to the U.S. and to other countries included in this study.

Table 15: Mexico Development Indicators Relative to Other Countries
(Source: World Bank's World Development Indicators, 2009)

	China	India	Brazil	Mexico	South Korea	South Africa	U.S.
Population, millions (2007)	1,320	1,120	192	105	48	48	302
GNI[57] Per Capita, PPP (2007)	$5,420	$2,740	$9,270	$13,910	$24,840	$9,450	$45,840
GDP Growth, Annual (2007)	13.0%	9.1%	5.4%	3.2%	5.0%	5.1%	2.0%
Energy use per capita, kg oil equivalent (2006)	1,433	510	1,184	1,702	4,483	2,739	7,768
CO_2 emissions per capita (2005)	4.3	1.3	1.7	4.1	9.4	8.7	19.5

Although Mexico is a significant actor in the world economy, and it has made climate change a significant priority, the country is rarely singled out in global mitigation studies (unlike China, India, or Brazil, for example); instead, Mexico is often grouped with other Latin American countries (e.g., as in IEA, 2008, UNFCCC, 2007). Although fewer global studies exist in comparison with the preceding country chapters, the release of several new studies in the first half of 2009 provides considerable new insights into potential mitigation pathways in Mexico through 2030.

Baseline Emissions Forecast

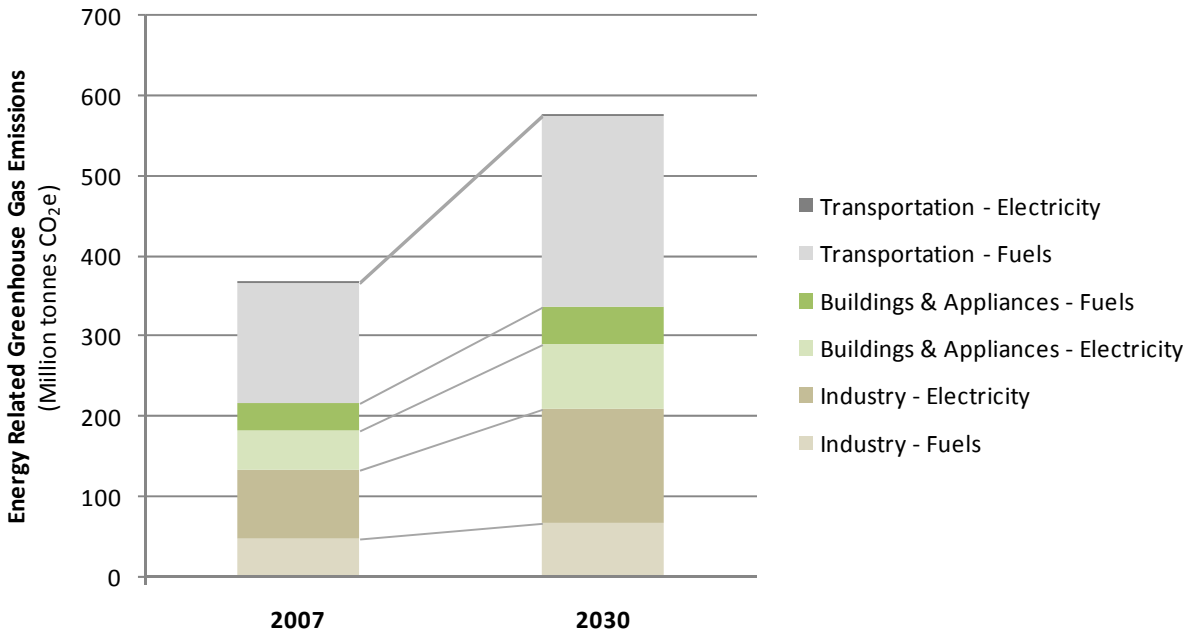
Figure 8 below, displays the estimated baseline emissions for Mexico between now and 2030.[58]

[56] FCCC/AWGLCA/2008/MISC.2, http://unfccc.int/resource/docs/2008/awglca3/eng/misc02.pdf

[57] GNI is Gross National Income and is reported here using the purchasing power parity (PPP) method of converting to international dollars.

[58] For details on SEI's LEAP model and projection methodology, please see the appendix.

Figure 11. Projected Baseline Energy-sector Greenhouse Gas Emissions in Mexico in 2030



Mitigation Potential

Compared the quantity of research on China, India, and Brazil, relatively few international studies have quantified greenhouse gas mitigation potential in Mexico. However, the country itself has been active in reporting on its activities, emissions, and future intentions, and recent attention by President Calderon to the issue of climate change has helped generate new interest and research, with several new studies released in late 2008 and early 2009. Studies that provide particularly useful data for this study include the following:

- **Mexico's *Special Program on Climate Change*** (CICC, 2009), a revised public review draft of which was released in March 2009, begins charting out the actions and policies needed to reduce Mexico's emissions by 50% from 2002 levels by 2050, in accordance with President Calderon's ambitious emission-reduction goals.
- **McKinsey and Centro Mario Molina's** preliminary *Low-Carbon Growth: A Potential Path for Mexico* (CMM and McKinsey, 2008) sets forth an ambitious scenario of 50% reduction in greenhouse gas emissions relative to business-as-usual by 2030.
- **United Nations Framework Convention on Climate Change** (2007). This study, *Investment and Financial Flows to Address Climate Change*, quantifies emission reduction potential in industry and building efficiency in Mexico through 2030, based on modeling work by IEA, as part of its assessment of investment and financial flows needed to address climate change.

In addition to these sources listed above, our team also reviewed Mexico's *Third National Communication* (CICC, 2006a), which focused primarily on documenting recent or planned near-term opportunities of energy efficiency, and Mexico's *National Strategy on Climate Change* (CICC, 2007), which does not provide sufficient basis for mitigation estimates to 2030, per the focus of this report. We also reviewed documents by the Pew Center on Global Climate Change (Chandler et al, 2002), the Center for Clean Air Policy (CCAP, 2007), the International Energy Agency (IEA, 2008), and several presentations and white papers produced by academic researchers in Mexico. In general, these studies either referenced

estimates from Mexico's *National Communication*, as discussed above, or else did not include quantitative estimates suitable for this study. Several of the sources were consulted, however, to help assess current actions and potential barriers to implementation.

Based on review of the studies above, we assembled estimates of the medium-term mitigation potential for the following options in Mexico, as listed in Table 16, below.

Table 16. Estimated Mitigation Potential in Mexico in 2030, $MtCO_2e$/year

Sector/Option	Government of Mexico (CICC, 2009)[59]	Centro Mario Molina & McKinsey (2008)	UNFCCC (2007)
ELECTRICITY	95	140	
CCS	95	8	
Fuel Switching		21	
Nuclear Power		12	
Small Hydroelectricity		15	
Renewables		20 (onshore wind) 9 (offshore wind) 20 (solar CSP) 8 (solar PV) 10 (geothermal)	
Transmission & Distribution Efficiency		15	
TRANSPORTATION	45	76	
Vehicle Efficiency	45	38	
Fuel Switching - Biofuels		15	
Reduction in VMT		23	
BUILDINGs & APPLIANCES	5	35	3
Residential & Commercial	5	35	3
INDUSTRY	21	77	13
Refining	18	37	13
Other	3	40	

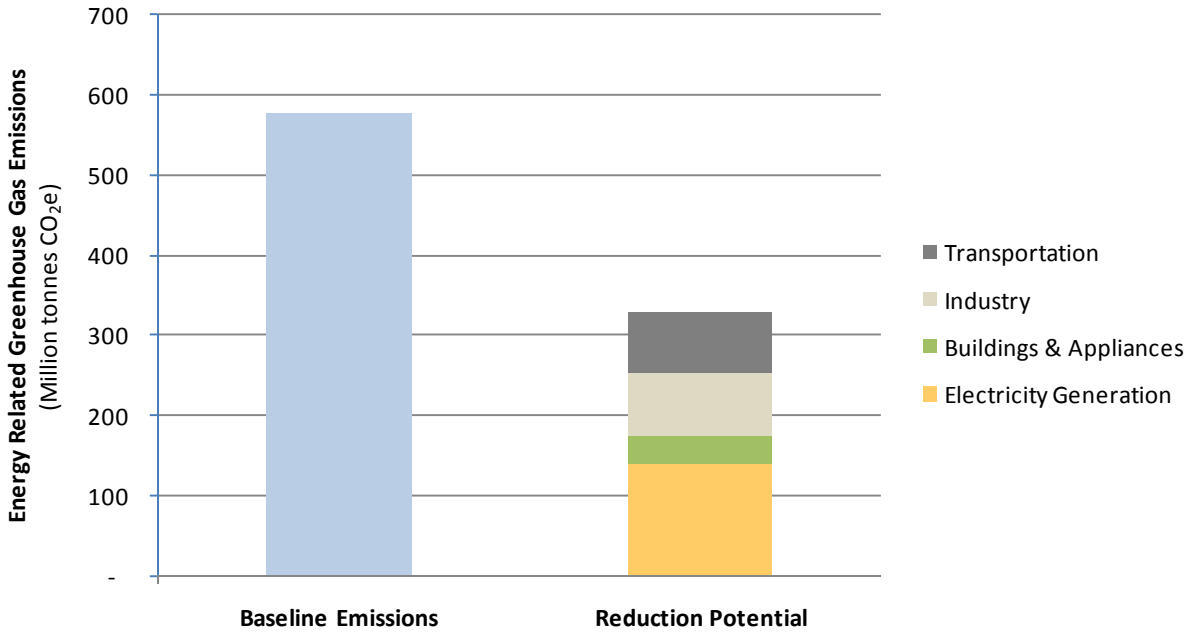
As evidenced by the relative scarcity of medium-term mitigation estimates for Mexico, much opportunity still exists to quantify potential greenhouse gas mitigation scenarios for the country. The Mexican government is presently engaged in such an effort, driven in part by President Calderon's stated intention to reduce greenhouse gas emissions 50% below 2002 levels in 2050, a reduction goal that implies an emissions target of less than 325 MtCO2e in 2050, more than 100 MtCO2e less than the ambitious mitigation scenario presented by Centro Mario Molina and McKinsey and Company in their preliminary report *Low Carbon Growth: A Potential Path for Mexico* (CMM and McKinsey, 2008).

Figure 12, below, displays a composite 2030 mitigation scenario based on estimates from the Mexican government and the UNFCCC. Note that we combine aspects of these two scenarios for illustration purposes, but further work would be needed to determine how the two studies compare in terms of underlying assumptions and potential for double-counting between sectors (such as buildings and appliances and electricity generation), as well as between the baseline assumptions of those studies and

[59] Estimates calculated by SEI based on Figure 1.5 in CICC (2009).

the SEI-produced baseline displayed in the chart. Nevertheless, the chart clearly indicates the relative scale of existing mitigation potential estimates relative to Mexico's projected 2030 energy-related emissions.

Figure 12. Energy-related Greenhouse Gas Emissions in Mexico in 2030 – Baseline Emissions and Reduction Potential
(Baseline from SEI analysis; reduction potential from CMM and McKinsey, 2008; see text for caveats regarding comparison of figures)



Assessment of Options

The options in Table 16 reflect estimates of the achievable greenhouse gas reductions for energy-related options in Mexico. The success of efforts to implement these options will depend on numerous factors, including cost-effectiveness, extent of overlap with social or economic development objectives, extent of existing country experience with similar measures or policies, and potentially international support mechanisms, among other factors.

We conducted a review of the available literature, as well as interviews with other researchers focused on Mexico, to summarize and assess the potential barriers and opportunities for each option. Table 17, below, provides results of this research, and is followed by a summary of high priority opportunities for involvement.

Table 17. Assessment of Mitigation Options in Mexico

Option	Mitigation Potential in 2030[60]	Relative Cost	Overlapping Policy Objectives	Proposed or Adopted Policies	Key Barriers	International Support Mechanisms
ELECTRICITY						
Power Plant Efficiency	*Medium* (CMM and McKinsey, 2008)	*High* for some technologies in some studies (CICC, 2006b), *Low* for others (Wetzelaer et al, 2007)	▪ Can support economic development and energy security (CMM and McKinsey, 2008)	▪ Proposed legal reform to enable greater private sector participation in energy production and distribution (Pew, 2002; CICC, 2007; Tudela, 2003) ▪ Proposed integration of the Federal Electricity Commission (CFE) and Central Light and Power (LFC) into voluntary, then capped GHG accounting and reporting systems (CICC, 2008; CICC, 2007) ▪ Proposal to increase efficiency of fuel-oil-fired plants by 2% (CICC, 2007) ▪ Proposal for the state Federal Electricity Commission (CFE) to join the voluntary Mexican GHG accounting program and develop more CDM-eligible projects (CICC, 2008)	▪ Budgetary hardships and monopoly state of the Federal Electricity Commision (CFE) limits investment in efficiency (Tudela, 2003) ▪ High investment costs (Garibaldi, 2007)	▪ International Energy Agency's Implementing Agreement on Clean Coal Science, of which Mexico's Instituto de Investigaciones Electricas is a member ▪ U.S. *Climate Change Development Policy Loan* , $501 million ▪ Carbon finance: 4 power plant efficiency projects in the Clean Development Mechanism (CDM) pipeline as of November 2008
Carbon Capture & Storage	*High* (CMM and McKinsey, 2008)	*High* (CMM and McKinsey, 2008)		▪ Proposed research into carbon capture and geological storage (CICC, 2009; CICC,2007)	▪ Concerns over permanence, legal framework, technological and commercial immaturity of technology (CMM and McKinsey, 2008) ▪ Low cost-effectiveness (CICC, 2006b)	▪ Mexico is a member of the Carbon Sequestration Leadership Forum

[60] Options characterized as *High* have the potential to reduce Mexico's energy-related greenhouse gas emissions by at least 1% of Mexico's 2030 energy-related emissions, or about 6 $MtCO_2e$. Options characterized as *Medium* have the potential to reduce 2030 emissions by 0.1%, or about 0.6 $MtCO_2e$.

Option	Mitigation Potential in 2030[60]	Relative Cost	Overlapping Policy Objectives	Proposed or Adopted Policies	Key Barriers	International Support Mechanisms
Fuel Switching – Oil or Coal to Natural Gas	*High* (CMM and McKinsey, 2008; CICC, 2007)	*Low* (CMM and McKinsey, 2008; CICC, 2006b)	▪ Can support economic development and energy security (CMM and McKinsey, 2008) ▪ Improve local air quality (CMM and McKinsey, 2008)	▪ On-going phase-out of old and inefficient plants in favor of high-efficiency natural gas-fired power plants (CICC, 2009; de la Torre et al, 2009) ▪ Proposal to install a gasification terminal for imported liquefied natural gas on the Pacific Coast (CICC, 2009; CICC, 2008; CICC, 2007) ▪ Proposal to phase out and reorient fuel oil production incentives and convert fuel oil-fired thermoelectric plants to combined cycle (CICC, 2007)	▪ Limited availability of natural gas in Mexico (CICC, 2006b) ▪ Price speculation and the possible dependence upon foreign sources for natural gas (CICC, 2006b) ▪ Budgetary hardships and monopoly state of the Federal Electricity Commision (CFE) limits investment in fuel-switching (Tudela, 2003)	▪ Carbon finance: the Clean Development Mechanism (CDM) supports fossil-fuel-switching projects, but Mexico doesn't have any such projects in the CDM pipeline as of November 2008
Nuclear Power	*High* (CMM and McKinsey, 2008; CICC, 2006a)	*Medium* but with high uncertainty (CMM and McKinsey, 2008)		▪ Proposal to investigate feasibility of expanding nuclear power capacity in accordance with international safety standards (CICC, 2009; CICC, 2008) ▪ Proposal to strengthen national policy and legal framework concerning nuclear safety (CICC, 2008)	▪ Strong public resistance (CICC, 2008; Chandler et al, 2002; Tudela, 2003) ▪ Concerns around waste disposal, security, weapons proliferation, safety, and other environmental impacts, as well as high capital costs and bottlenecks in equipment and expertise (CMM and McKinsey, 2008)	

Option	Mitigation Potential in 2030[60]	Relative Cost	Overlapping Policy Objectives	Proposed or Adopted Policies	Key Barriers	International Support Mechanisms
Small Hydropower	*High* (CMM and McKinsey, 2008)	▪ *Low* (CMM and McKinsey, 2008) to *Medium* (CICC, 2006b) for small hydro ▪ *High* for large hydropower (CICC, 2006b)	▪ Can support economic development and energy security (CMM and McKinsey, 2008)	▪ Many of the proposed or adopted policies under *Renewables*, below, apply to hydropower	▪ Environmental and social impacts, including ineligibility of hydroelectric project bond funding via CDM market due to potential environmental damage and social impact (CICC, 2006b) ▪ Current regulation limits hydroelectricity capacity (CMM and McKinsey, 2008) ▪ Bottlenecks with equipment supply may limit rapid scale-up (CMM and McKinsey, 2008) ▪ Need for assessment of the impacts of climate change on hydroelectricity generation (CICC, 2007)	▪ Carbon finance: 4 hydroelectricity projects in the Clean Development Mechanism (CDM) pipeline as of November 2008

Option	Mitigation Potential in 2030[60]	Relative Cost	Overlapping Policy Objectives	Proposed or Adopted Policies	Key Barriers	International Support Mechanisms
Renewables	*High* (CICC, 2006a)	▪ *Low* for wind power (CICC, 2006b; Wetzelaer et al, 2007)) ▪ *High* for solar power (CICC, 2006b)	▪ Supporting objective to electrify rural areas ▪ Can support economic development (e.g., export of solar power technology or electricity) and energy security (CMM and McKinsey, 2008)	▪ Goal to increase private sector participation in renewable energy supply, including price incentives (CICC, 2009) ▪ Proposal to develop and implement a National Program for Renewable Energy, including financial incentives, research and development, and international cooperation (CICC, 2008) ▪ Staged phase-in of national emissions trading scheme (CICC, 2009; CICC, 2008; CICC, 2007) ▪ Proposal to extend renewables goals (currently 8%) in the 2005 Law for the Use of Renewable Energy (LAFRE) (CICC, 2007) ▪ Existing tax incentives for purchase of renewable systems (CCAP, 2007; Ovalle, 2005) ▪ Proposal to install 7,000 MW of new renewable capacity (CICC, 2007) ▪ Proposed reform of the Mexican Federal Electricity Commission's interconnection contract to facilitate tie-in of renewables (CICC, 2006b) ▪ Proposal to consider externalities in project appraisal (CICC, 2008)	▪ Legal framework restricts purchase of energy from private parties to surplus energy (CICC, 2006b) ▪ Intermittency constraints, especially for wind power (CMM and McKinsey, 2008) ▪ High capital costs (CMM and McKinsey, 2008) ▪ Bottlenecks with equipment supply may limit rapid scale-up (CMM and McKinsey, 2008) ▪ National Utility is bound to a "least cost" principle (CICC, 2006; Ovalle Araize, 2005) ▪ Belief that Mexico has large undiscovered oil and gas reserves (Ovalle Araiza, 2005)	▪ Carbon finance: 39 renewable energy projects in the Clean Development Mechanism (CDM) pipeline as of November 2008 ▪ Existing World Bank/Global Environment Facility funding for large-scale renewable energy projects, including a large-scale wind power plant and Hybrid Solar Thermal Power Plant (Ovalle Araiza, 2005; World Bank 2008; GEF, 2009) ▪ Existing GEF funding for Action Plan for Removing Barriers to the Full-scale Implementation of Wind Power, Grid-connected Photovoltaic Project, and other renewables
Transmission and Distribution	*High* (CMM and McKinsey, 2008; CICC, 2007)	*Low* (CICC, 2006b)		▪ Proposal to increase efficiency of transmission and distribution lines by 2% (CICC, 2007) ▪ Proposed legal reform to enable greater private sector participation in energy production and distribution (Chandler et al, 2002; CICC, 2007)	▪ A "smart grid" would require technology transfer from other nations, new technical capacities, significant capital investment, and consumer education campaign (CMM and McKinsey, 2008)	

Option	Mitigation Potential in 2030[60]	Relative Cost	Overlapping Policy Objectives	Proposed or Adopted Policies	Key Barriers	International Support Mechanisms
TRANSPORTATION						
Vehicle Efficiency	*High* (CMM and McKinsey, 2008; CICC, 2006a)	*Low* (CMM and McKinsey, 2008 ; de la Torre et al, 2009)	▪ Supporting benefits of large improvements in local air quality (de la Torre et al, 2009)	▪ Proposal to adopt new vehicle efficiency standards in 2010 (CICC, 2009; CICC, 2007; CICC, 2006a) ▪ Proposed financial incentives for renewal of vehicle fleet in favor of more efficient vehicles (CICC, 2009; CICC, 2007; CICC, 2006b) ▪ Proposed inspection and monitoring program for existing vehicles at the U.S. border and in major cities (Johnson, 2009) ▪ Proposal to replace older freight trucks and diesel buses (CICC, 2006b; CICC, 2007) ▪ Proposal to design and implement a new program for efficiency in the shipping industry (CICC, 2009; CICC, 2008) ▪ Proposal to promote and conduct research on airline industry efficiency (CICC, 2008)	▪ Higher vehicle costs (CMM and McKinsey, 2008)	▪ Partnership with World Resources Institute and U.S. EPA to pilot diesel bus retrofit program in Mexico City ▪ On-going Low Carbon Country Case Study with the World Bank focused on this and other transportation options
Fuel Switching - biofuels	*High* (CMM and McKinsey, 2008; CICC, 2006a) but only for sugarcane-based ethanol (Johnson, 2009)	*Medium* (CMM and McKinsey, 2008)	▪ Potential for conflict with competing goals of low-cost food (de la Torre et al, 2009)	▪ Proposal to develop a national biofuels strategy with sustainability criteria for assessing biofuels (CICC, 2009) ▪ Proposal to conduct R&D on production, use, and potential markets of biofuels in Mexico (CICC, 2008)	▪ Competition for land with food crops (CMM and McKinsey, 2008), as well as potential for increased emissions due to clearing land for biofuel crops (de la Torre et al, 2009) ▪ Political challenges associated with importing biofuels rather than growing them domestically (CMM and McKinsey, 2008) ▪ Need for assessment of technical, economic and environmental attributes of biofuels production and use (CICC, 2007)	

Option	Mitigation Potential in 2030[60]	Relative Cost	Overlapping Policy Objectives	Proposed or Adopted Policies	Key Barriers	International Support Mechanisms
Reductions in vehicle miles traveled (VMT)	*High* (CMM and McKinsey, 2008 ; de la Torre et al, 2009)	▪ *Low* for increased and more efficient bus transport (CMM and McKinsey, 2008 ; de la Torre et al, 2009) ▪ *High* for increased public electric rail (CMM and McKinsey, 2008)	▪ Supports objective for improved air quality and can offer time savings (de la Torre et al, 2009) ▪ May conflict with national plan to expand and modernize the federal road network (CICC, 2008)	▪ Proposal to develop sustainable public transport in cities with at least 100,000 residents (CICC, 2009) ▪ Proposed regulatory reform to clarify rail rights (CICC, 2008) ▪ Proposal to expand Metro and implement light rail in suburbs of major metropolitan areas (CICC, 2009; CICC, 2008) ▪ Proposal to research, identify, and implement urban planning guidelines to reduce transportation emissions (CICC, 2008) ▪ Proposal to build select new road sections to reduce (presumably) VMT (CICC, 2009) ▪ Ongoing expansion of bus rapid transit in more than a dozen cities (CCAP, 2007) ▪ Proposal to increase freight rail coverage and connectivity (CICC, 2009; CICC, 2008; CICC, 2007)	▪ Consumer preferences for cars, as influenced by frequency, perceived network density, and cost per trip of public transit options (CMM and McKinsey, 2008) ▪ Complex and lengthy planning processes, high infrastructure cost for electric rail (CMM and McKinsey, 2008)	▪ Existing international partnerships to launch Bus Rapid Transit in Mexico City, involving World Bank, World Resources Institute, GEF, others (World Bank, 2008)
BUILDINGS & APPLIANCES						
Residential and Commercial	*Medium* (UNFCCC, 2007) to *High* (CMM and McKinsey, 2008)	*Low* (de la Torre et al, 2009; Wetzelaer et al, 2007)		▪ Existing efficiency standards of the National Commission on Efficient Use of Energy (CONUEE, formerly CONAE, which is focused on appliances) and the Trust Fund for Energy Savings (FIDE) (CICC, 2008; CICC, 2007; CICC, 2006a) ▪ Proposed development of new energy efficiency standards for equipment and home/office consumption (CICC, 2008; CICC, 2007) ▪ Proposal to expand capacity of energy efficiency programs of FIDE, including funding for residential appliance and efficiency upgrades (CICC, 2009; CICC, 2008) ▪ Proposal to develop an energy efficiency program for new residential construction, including financing and technical assistance (CICC, 2009) ▪ Proposal to promote solar hot water heaters and more efficient wood stoves (CICC, 2009) ▪ Proposal to investigate energy codes for new buildings (CICC, 2008)	▪ High capital costs and long payback periods in many cases (CMM and McKinsey, 2008) ▪ "Principal-agent" problem where beneficiary of investments cannot implement them (CMM and McKinsey, 2008) ▪ Limited homeowner awareness and financial incentives (CMM and McKinsey, 2008) ▪ Poor track record of building standard enforcement (CMM and McKinsey, 2008)	▪ World Bank funds helped create CONAE, the predecessor to CONUEE (Tudela, 2003) ▪ Carbon finance: the Clean Development Mechanism (CDM) supports residential and commercial energy efficiency projects, but Mexico doesn't have any such projects in the CDM pipeline as of November 2008

Option	Mitigation Potential in 2030[60]	Relative Cost	Overlapping Policy Objectives	Proposed or Adopted Policies	Key Barriers	International Support Mechanisms
INDUSTRY						
Combined Heat and Power (cement, steel, sugar) and other efficiency measures	*High* (CMM and McKinsey, 2008; CICC, 2007)	*Low* (de la Torre et al,2009; CICC, 2006b)		▪ Proposal to conduct a national cogeneration potential study (CICC, 2009) ▪ Proposed reform of the Mexican Federal Electricity Commission's interconnection contract to facilitate tie-in of renewables (CICC, 2008; CICC, 2007; CICC, 2006b) ▪ Proposed regulatory reform to allow sale of electricity between private parties (CICC, 2006b) ▪ Proposal to "develop the CHP Potential of the national cement, steel, and sugar industries, among others" (CICC, 2007) ▪ Staged phase-in of national emissions trading scheme to other sectors and links to CDM (CICC, 2009), beginning with the establishment of a voluntary carbon market in Mexico (CICC, 2009; CICC, 2008) ▪ Proposal to develop funding or other financial incentives for industrial energy efficiency in partnership with private financing (CICC, 2009; CICC, 2008) ▪ Proposal to offer technical assistance to industry (CICC, 2008)	▪ Legal framework limits private sector involvement in power generation, including combined heat & power	▪ Carbon finance: five industrial energy efficiency projects in the Clean Development Mechanism (CDM) pipeline as of November 2008

Option	Mitigation Potential in 2030[60]	Relative Cost	Overlapping Policy Objectives	Proposed or Adopted Policies	Key Barriers	International Support Mechanisms
Oil and gas refining, including at PEMEX	*High* (CMM and McKinsey, 2008)	*Medium* (CMM and McKinsey, 2008; CICC, 2006b) although varies considerably by option		▪ Existing and on-going tax relief, reform and emissions trading within PEMEX, the state-owned oil company that monopolizes crude oil and gas extraction, to enable efficiency (CICC, 2009; CICC, 2007; Chandler et al, 2002) ▪ Proposed installation of combined heat and power plants and other technologies in PEMEX facilities (CIC, 2009; CICC, 2008; CICC, 2007) ▪ Consolidate PEMEX's existing virtual GHG trading scheme, implement caps, and begin integrating with existing voluntary programs and other sectors as part of a staged phase-in of national emissions trading scheme (CICC, 2009; CICC, 2007)		▪ Environmental Defense Fund (EDF) was active in helping PEMEX to establish its internal emissions trading system (Tudela, 2003). ▪ World Bank planning support for co-generation at PEMEX in 2009 (World Bank, 2008) ▪ Carbon finance: five industrial energy efficiency projects in the Clean Development Mechanism (CDM) pipeline as of November 2008

Promising Opportunities

The Mexican government – with support from its own researchers as well as outside institutions such as the Centro Mario Molina, McKinsey, and the World Bank, has been active in assessing and proposing potential policy directions for mitigating greenhouse gas emissions. Table 18, below, highlights greenhouse gas mitigation policies as identified in recent studies, including the government's draft *Special Program on Climate Change*.

Table 18. Top Greenhouse Gas Mitigation Options for Mexico as Identified in Leading Studies

Sector	Mexico's ***Special Program on Climate Change*** (2009)[61]	**Centro Mario Molina and McKinsey** (2009)[62]	**World Bank** (de la Torre et al, 2009)[63]
Electricity Generation	▪ Pursue renewable: wind, solar, small hydro, and geothermal power ▪ Pursue nuclear power	▪ Minimum requirements for renewable, particularly wind, solar, and small hydro power ▪ Continue shift from oil to natural gas ▪ Deploy CCS as available ▪ Improve power transmission efficiency ▪ Consider nuclear power in long term	▪ Deploy Mexico's significant wind and solar resources
Transportation	▪ Improve public transportation, including bus rapid transit ▪ Establish performance standards for light-duty vehicles ▪ Promote second-generation biofuels	▪ Set tight fuel efficiency standards for all new vehicles ▪ Develop and use second-generation biofuels ▪ Increase use and efficiency of public transport	▪ "Top policy priority is...incentives for more efficient cars and reduced car use." ▪ Integrated strategies that span transportation modes and reduce urban sprawl ▪ Optimization of freight traffic through better logistics and improvements in fuel efficiency
Buildings & Appliances	▪ Residential and commercial energy efficiency measures	▪ Mandate energy efficiency standards for new construction ▪ Introduce more-efficient lighting and appliances	▪ Implement new standards for residential and commercial lighting
Industry	▪ Combined heat and power in industrial, oil, and gas sectors	▪ Implement combined heat and power and CCS (as applicable) in oil and gas, iron and steel, and petrochemical industries ▪ Reduce gas flaring	▪ Pursue combined heat and power in the steel and cement industries

[61] Options listed in this table are those cited in PECC (2009) as having high impact (defined in that study as greater than 3 MtCO2e/year) for the period 2008-2030. Other options were also listed by PECC (2009) as priorities that had low cost but lower than 3 MtCO2e/yr potential (e.g., improvements in transmission and distribution of electricity) and are not included in Table 18.

[62] Options listed here are those featured in the CMM and McKinsey (2009) executive summary.

[63] Note that the World Bank's *Low-Carbon, High Growth* Latin American (de la Torre et al, 2009) report did not devote a section to specific strategies for Mexico. While we expect the World Bank to release its Mexico-specific Low Carbon Country Case Study in June, 2009 (but not in time to be reviewed for this report), the preliminary recommendations listed here are those included in the *Low-Carbon, High Growth* report with specific reference to Mexico.

Conclusions

In December 2008, Mexico's government announced plans to reduce economy-wide emissions by 50% below 2002 levels by 2050 by creating a cross-sector cap-and-trade program by 2012. This bold goal represents a strong departure from previous intentions (as documented in its *National Strategy on Climate Change*) which focused primarily on incremental improvements in efficiency. By contrast, efforts to meet a goal of reducing emissions by 50% would require a major restructuring of Mexico's energy supply and ambitious efforts in the industry, buildings, and transportation sectors well beyond the modest mitigation potentials previously envisioned by the country, as well as new efforts in the agriculture and forestry sectors. The country is presently developing the details of how it plans to achieve this ambitious goal and Mexican president Felipe Calderon is expected to release the new plan in 2009. A national cap-and-trade program is expected, as well as expansion of renewable energy generation and increased switching from coal to natural-gas-fired power plants (Holly, 2008).

For Mexico to meet this ambitious target, international assistance will be critical, including financing assistance. The options presented and assessed above provide a summary of the types of measures needed if Mexico is to attain its target. Although further details and communication from the Mexican government (and partners such as the World Bank) in 2009 will help clarify Mexico's path, the suite of options presented above is likely to remain relatively stable and provide a starting point for discussions concerning international involvement.

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Chapter 7. South Africa

The South African government has produced several energy and climate assessments and is one of only a handful of developing countries to have released climate action plans. Its *Vision, Strategic Direction and Framework for Climate Policy* document (2008) has gathered considerable attention as a model for developing country engagement. South Africa has also been prominent in promoting the concept of so-called sustainable development policies and measures that would address multiple objectives, and possibly be supported through international finance and registered with the UNFCCC. The country has an active research community working on the intersection of energy, climate, and development issues, including the University of Capetown's Energy Research Center, among other institutions.

The following table displays several economic and climate indicators for South Africa relative to the U.S. and to other countries included in this study. [64]

Table 19: South Africa Development Indicators Relative to Other Countries
(Source: World Bank's World Development Indicators, 2009)

	China	India	Brazil	Mexico	South Korea	South Africa	U.S.
Population, millions (2007)	1,320	1,120	192	105	48	48	302
GNI[65] Per Capita, PPP (2007)	$5,420	$2,740	$9,270	$13,910	$24,840	$9,450	$45,840
GDP Growth, Annual (2007)	13.0%	9.1%	5.4%	3.2%	5.0%	5.1%	2.0%
Energy use per capita, kg oil equivalent (2006)	1,433	510	1,184	1,702	4,483	2,739	7,768
CO_2 emissions per capita (2005)	4.3	1.3	1.7	4.1	9.4	8.7	19.5

Note that of the six countries included in this study, South Africa has the highest per-capita energy use and emissions, explained by its highly developed urban areas and heavy reliance on coal.

Baseline Emissions Forecast

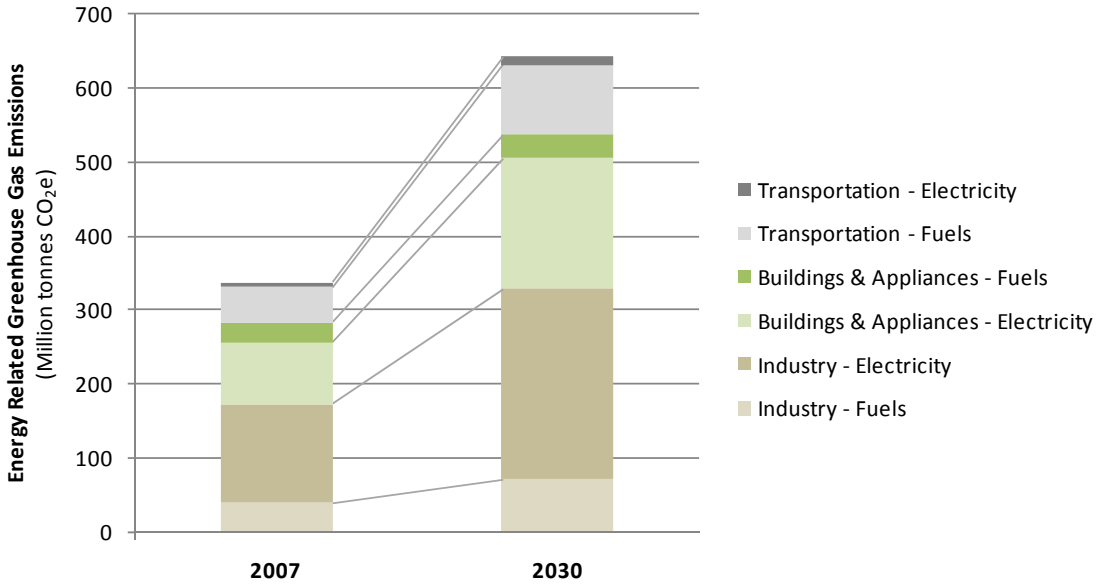
Figure 8 below, displays the estimated baseline emissions for South Africa between now and 2030.[66]

[64] Note that in 2004 (the latest year for which comparable, international metrics are available).

[65] GNI is Gross National Income and is reported here using the purchasing power parity (PPP) method of converting to international dollars.

[66] For details of SEI's LEAP model and projection methodology, please see the appendix.

Figure 13. Projected Baseline Energy-sector Greenhouse Gas Emissions in South Africa in 2030



Mitigation Potential

Relatively few international studies have quantified greenhouse gas mitigation potential in South Africa, but the South African government and the country's research community have been active producers of rigorous research and projections. In particular, the following two studies include estimates of greenhouse gas mitigation in the country:

- **Energy Research Centre's *Long-Term Mitigation Scenarios*** (2007) reports. In 2007, the University of Capetown's Energy Research Study released the leading study on medium and long-term mitigation in the country. The study builds on the study's ongoing research that has produced several papers relative to this study, including the 2006 *Energy Policies for Sustainable Development in South Africa: Options for the Future.*

- **South Africa's *First National Communication*** (2000). South Africa's *First National Communication* included assessment of alternative mitigation scenarios through 2030, including graphical display of mitigation potential. Although the presentation of numerical results is limited and the research is many years old, this study can still be used as a point of comparison with the ERC work described above.

In addition to these sources listed above, our team also reviewed documents by the United Nations Framework Convention on Climate Change (UNFCCC, 2007), the International Energy Agency (IEA, 2008), several other reports by the South African government (including its *White Paper on Renewable Energy,* 2003, its *National Climate Change Response Strategy*, 2004, and its *Vision, Strategic Direction and Framework for Climate Policy* document, 2008), among other publications. Although these studies provided few quantitative mitigation estimates, several of the sources did help assess current actions and potential barriers to implementation.

Based on review of the studies above (primarily the Energy Research Centre's *Long-Term Mitigation Scenarios* reports), we assembled estimates of the medium-term mitigation potential for the following options in South Africa, as listed in Table 20, below.

Table 20. Estimated Mitigation Potential in South Africa in 2030, $MtCO_2e$/year

Sector/Option	Energy Research Centre (ERC, 2007)[67]	South Africa's First National Communication (RoSA, 2000)[68]
ELECTRICITY	150	70
Power Plant Efficiency	3	
Carbon Capture & Storage (CCS)	9	
Fuel Switching – Coal to Natural Gas		10
Nuclear Power	70	30
Renewables	54	30
TRANSPORTATION	50	28
Vehicle Efficiency	14	12
Fuel Switching (biofuels)	14	16
Fuel Switching (electric)	13	
Reductions in Vehicle Miles Travelled (VMT)	9	
BUILDINGS & APPLIANCES	22	26
Residential	12	23
Commercial	10	3
INDUSTRY	123	
Industrial efficiency	100	
CCS in synfuels sector	23	

Note that despite the side-by-side inclusion of mitigation potential estimates from the Energy Research Centre (2007) and South Africa's First National Communication (2000) in Table 20, the findings are not necessarily directly comparable, as the two studies did not assume the same level of overall ambition with respect to emission reduction targets. As discussed in the *Methodology* chapter, estimates of mitigation potential also depend on numerous other underlying assumptions that are not always transparent, let alone consistent. Regardless, the mitigation potential estimates from the two studies help inform the types of activities likely to play a significant role in reducing South Africa's greenhouse gas emissions over the coming decades.

Figure 14, below, displays results from the only study that included mitigation estimates for all four of the energy-related sectors addressed in this report, the ERC's *Long-Term Mitigation Scenarios*. Note that the total energy-related mitigation potential suggested by this study is nearly 350 $MtCO_2e$ including all the options above. If additional, financial mechanisms such as an escalating carbon tax are also included,

[67] ERC's Long-Term Mitigation Scenario Technical Report includes cumulative figures for 2003 through 2050. The figures listed in this table are estimated for the year 2030 based on figures included in the Technical Report and are relative to ERC's "Growth Without Constraints" scenario. Where multiple scenarios are included in the source document, we have listed the "Extended" option. Note that the figures within each sector are assumed to be additive (since ERC uses them to build a cost curve) except for Energy Supply, for which the total is approximated from Figure 39 of the ERC report for combined implementation of renewable and nuclear and is greater than the sum of the individual options, presumably due to reinforcements between the two options when implemented together.

[68] All figures taken from South Africa's First National Communication (RoSA, 2000) are approximations as read from charts in the document.

then ERC estimates suggest that the potential in 2030 could be over 500 $MtCO_2e$, an ambitious figure in line with the 500 $MtCO_2e$ potential in 2030 suggested in McKinsey's recent *Pathways to a Low-Carbon Economy: Version 2 of the Global Greenhouse Gas Abatement Curve* (McKinsey, 2009).

Figure 14, below, shows estimates of mitigation potential over time, through 2030, for the mitigations options discussed above in Table 20.

Figure 14. Energy-sector Mitigation Potential for South Africa in 2030
(ERC, 2007)

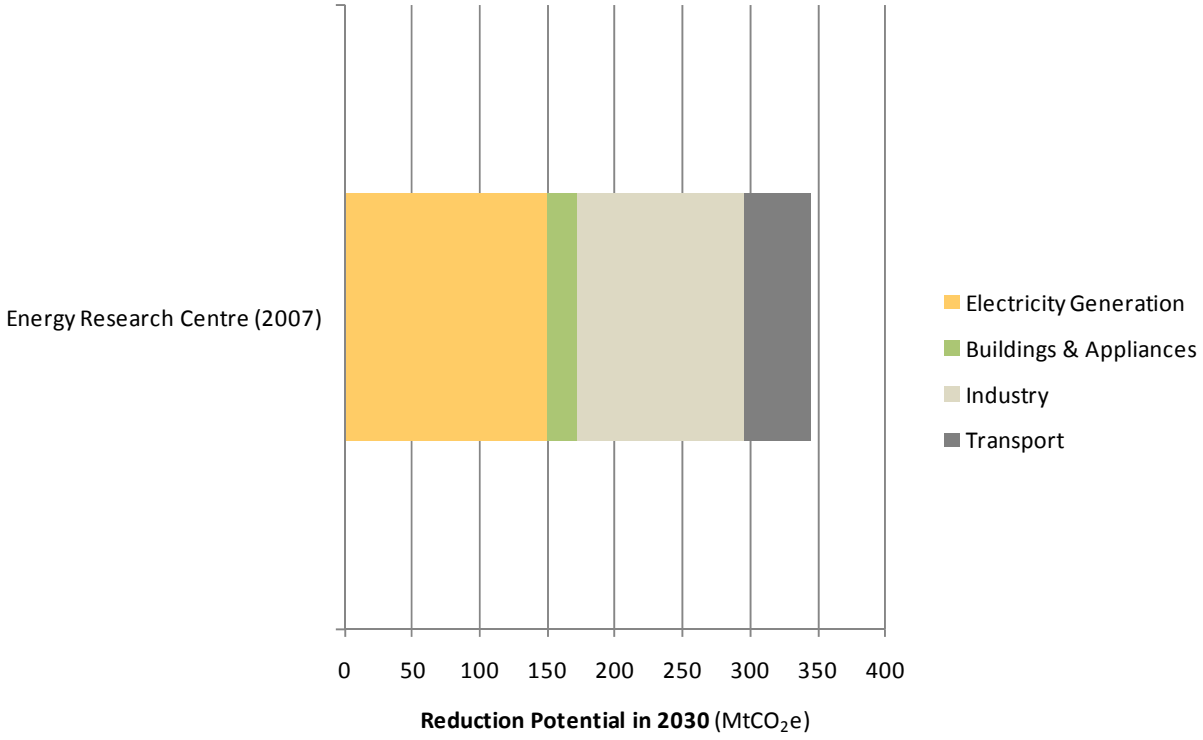
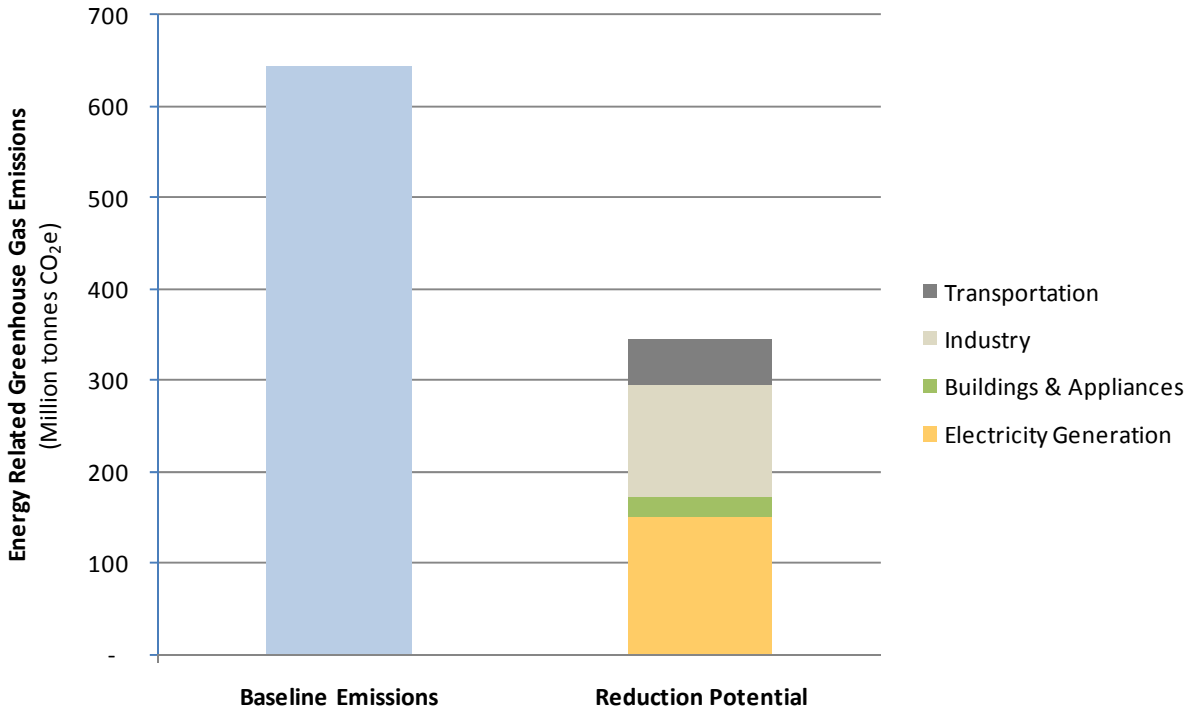


Figure 15, below, displays the mitigation scenario estimates derived from the *Long-Term Mitigation Scenarios* report (ERC, 2007) in the context of SEI's projected energy-sector baseline emissions. Note that no attempt was made to reconcile possible differences in ERC's baseline from our projected baseline – differences that would potentially alter the magnitude of the emission reductions shown. Nevertheless, the figure does display the general scale of emission reductions identified by ERC relative to SEI's projected future energy-sector emissions in South Africa.

Figure 15. Energy-related Greenhouse Gas Emissions in South Africa in 2030 – Baseline Emissions and Reduction Potential
(Baseline from SEI analysis; mitigation scenario from ERC, 2007; see text for caveats regarding comparison of figures)



Assessment of Options

The options in Table 20 reflect estimates of the achievable greenhouse gas reductions for energy-related options in South Africa. The success of efforts to implement these options will depend on numerous factors, including cost-effectiveness, extent of overlap with social or economic development objectives, extent of existing country experience with similar measures or policies, and potentially international support mechanisms, among other factors.

Our team conducted a review of the available literature, as well as interviews with other researchers focused on South Africa, to summarize and assess the potential barriers and opportunities for each option. Table 21, below, provides results of this research, and is followed by our team's assessment of high priority opportunities for involvement.

Table 21. Assessment of Mitigation Options in South Africa

Option	Mitigation Potential in 2030[69]	Relative Cost[70]	Overlapping Policy Objectives	Proposed or Adopted Policies	Key Barriers	International Support Mechanisms
ELECTRICITY						
Power Plant Efficiency	*Medium* (ERC, 2007)	*Low* (ERC, 2007)	▪ Supports South Africa's goal to use locally available resources, i.e. coal, and rely on coal as the primary energy source for decades to come (RoSA, 2004)	▪ Proposal to consider including externalities in coal pricing, including a carbon tax (RoSA, 2008; RoSA, 2003; Winkler et al, 2007) ▪ Proposal to introduce more stringent thermal power-plant efficiency standards (RoSA, 2008) ▪ Existing R&D on coal efficiency technologies (RoSA, 2004)	▪ Abundant South African coal reserves (RoSA, 2004; Winkler et al, 2007) ▪ Plans to continue reliance on conventional coal technologies (Winkler et al, 2007) ▪ High up-front costs for more-efficient coal technologies (Winkler et al, 2007)	▪ International Energy Agency's Implementing Agreement on Clean Coal Science, of which South Africa's government is a member ▪ Carbon finance: one power plant efficiency project in the Clean Development Mechanism (CDM) pipeline as of November 2008 ▪ Partnership between ESKOM and the World Bank to assess lower-carbon coal technologies (World Bank, 2007)
Carbon Capture & Storage (CCS)	*High* (ERC, 2007)	*Medium* to *High* depending on discount rate assumptions (ERC, 2007)	▪ Supports South Africa's goal to use locally available resources, i.e. coal and rely on coal as the primary energy source for decades to come (RoSA, 2004)		▪ Technology developments requiring up to two decades (UNFCCC, 2007)	▪ South Africa is a member of the Carbon Sequestration Leadership Forum ▪ South Africa is applying for membership in the IEA's Greenhouse Gas R&D Program (Surridge, 2007) ▪ U.S.-led FutureGen project that includes BHPBilliton and Xstrata Coal, both with activities in South Africa

[69] Options labeled *High* have the potential to reduce 7 million metric tons of CO2 in 2030 (approximately 1% of South Africa's projected 2030 emissions). Options labeled *Medium* have the potential to reduce at least 0.7 million metric tons of CO2 in 2030 (approximately 0.1% of projected 2030 emissions). Any option with less potential is labeled as *Low*.

[70] Most cost estimates are taken from ERC (2007), which used a 10% discount rate in its summary assessment of mitigation costs. To the extent this discount rate is different than those used in other studies, estimates of cost may not be comparable. For example, ERC (2007) also reports some results for a 3% discount rate, under which the costs of certain options (e.g., CCS) would be much higher.

Option	Mitigation Potential in 2030[69]	Relative Cost[70]	Overlapping Policy Objectives	Proposed or Adopted Policies	Key Barriers	International Support Mechanisms
Fuel Switching	*Medium* (RoSA, 2000)	*Medium* (Wetzelaer et al, 2007)	▪ Supports national development objective to diversify energy sources (Winkler et al, 2007; Chandler et al, 2002) ▪ Conflicts with goal for domestic economic and technological growth (RoSA, 2000)	▪ Proposal to explore additional imports of natural gas from Namibia and West Coast (RoSA, 2004; Winkler et al, 2007) ▪ Existing national plans to build two natural-gas fired plants and increase relative share of natural gas in electricity generation (Winkler et al, 2007) ▪ Existing exploration off South Africa's coast (Winkler et al, 2007) ▪ Proposal to remove subsidies for synthetic fuels, lift international embargos (Chandler et al, 2002)	▪ Costs and other uses (e.g., chemical production by SASOL) are likely to limit use of natural gas for electricity (Winkler et al, 2007) ▪ Very limited domestic natural gas reserves relative to coal (RoSA, 2003)	▪ Carbon finance: four fuel-switching projects in the Clean Development Mechanism (CDM) pipeline as of November 2008
Nuclear Power	*High* (ERC, 2007)	*Low* to *Medium* depending on discount rate assumptions (ERC, 2007) although costs are uncertain and have led to ESKOM suspending planned nuclear expansion (Wang, 2009)	▪ Supports national development objective to diversify energy sources (Winkler et al, 2007; Chandler et al, 2002) ▪ May conflict with goal of energy security, given need to import feedstock (Winkler et al, 2007)	▪ Stated government intentions to develop all energy sources, including nuclear (Winkler et al, 2007) but recent suspension of ESKOM plans to build second nuclear power plant (Fakir, 2009; Wang, 2009) ▪ On-going research by Eskom into Pebble Bed Modular Reactors (Winkler et al, 2007) ▪ Over 20 new nuclear power reactors have been proposed, although few of them have yet been planned (IEA, 2008)	▪ High up-front investment costs needed (Winkler et al, 2007; Fakir, 2009; Wang, 2009) ▪ Concerns about disposal of spent nuclear fuel (RoSA, 2000)	▪ South Africa is part of the Generation IV International Forum (IEA, 2008), which aims to develop a future generation of nuclear energy systems that are competitively priced and reliable while addressing safety, waste, and proliferation issues. ▪ South Africa participates in the International Project on Innovative Nuclear Reactors and Fuel Cycles, INPRO (IEA, 2008)

Option	Mitigation Potential in 2030[69]	Relative Cost[70]	Overlapping Policy Objectives	Proposed or Adopted Policies	Key Barriers	International Support Mechanisms
Hydropower	*High* for imported hydropower (RoSA, 2000)	*Low* for imported hydropower (Winkler et al, 2007)	▪ Supports national development objective to diversify energy sources (Winkler et al, 2007; Chandler et al, 2002) ▪ Supports regional economic development (RoSA, 2004)	▪ Proposal to explore increasing imports of hydropower from neighboring countries in the Southern African Power Pool (RoSA, 2004; Winkler et al, 2007; Chandler et al, 2002) ▪ Feed-in tariffs and power purchase agreements announced in March 2009 for small hydro power (NERSA, 2009)	▪ Uncertain political stability in the Democratic Republic of the Congo, the largest potential source of imported hydro (Winkler et al, 2007) ▪ Need to strengthen interconnection between national grids and the Southern African Power Pool for imported hydro (Winkler et al, 2007) ▪ Few sites available for large hydro in South Africa (Winkler et al, 2007) ▪ Stringent environmental measures for any hydro in South Africa (Winkler et al, 2007)	▪ Existing Southern African Power Pool and its regional coordination center (ERC, 2006) ▪ Existing New Partnership for Africa's Development (NEPAD) has a major focus on regional cooperation on energy development (Winkler et al, 2007) ▪ Carbon finance: two hydro projects in the Clean Development Mechanism (CDM) pipeline as of November 2008

Option	Mitigation Potential in 2030[69]	Relative Cost[70]	Overlapping Policy Objectives	Proposed or Adopted Policies	Key Barriers	International Support Mechanisms
Renewables	*High* (ERC, 2007)	*Low* to *Medium*, depending on degree of technology learning assumed (ERC, 2007)	▪ Can support country's objective of 100% access to electricity (RoSA, 2003; Winkler et al., 2007; Chandler et al, 2002) ▪ Can support economic development if local manufacturing of renewables technologies (RoSA, 2003b; ERC, 2006) ▪ Switch to renewable can support country's objective of preserving woodlands, currently a major source of rural energy (RoSA, 2003)	▪ Feed-in tariffs and power purchase agreements announced in March 2009 for wind, landfill gas, and concentrated solar power (NERSA, 2009) ▪ Proposal to enact ambitious national targets for renewables (RoSA, 2008) ▪ Proposal to consider a Renewable Energy Portfolio Standard (RoSA, 2003; Winkler et al, 2007) ▪ In-process development of a Tradeable Renewable Energy Certificate System (RoSA, 2008) ▪ Existing subsidies available through the Renewable Energy Fund Subsidy Office (Warburton, 2007; Winkler et al, 2007) ▪ Existing target for 4% of electricity demand met by renewables by 2013 (RoSA, 2003) ▪ Proposal to increase access to international CDM funding (RoSA 2003, 2004) ▪ Proposal to establish and clarify residential solar access rights (RoSA, 2003) ▪ Proposal to develop and launch public education and outreach campaign around renewables (RoSA, 2003) ▪ Proposal to direct Central Energy Fund resources to renewables (RoSA, 2003)	▪ Lack of progress towards targets and legislative needs (Winkler et al, 2007; Warburton et al, 2007) ▪ High capital costs relative to status quo of coal (RoSA, 2003; Winkler et al, 2007; EDRC, 2003) ▪ Low cost of coal (ERC, 2006) ▪ Limited consumer awareness of benefits and opportunities (RoSA, 2003; EDRC, 2003) ▪ Lack of economic or regulatory infrastructure for renewables (RoSA, 2003) ▪ Existing policy of discriminatory access to national electricity grid (RoSA, 2003) ▪ Limited financial lending resources (EDRC, 2003) ▪ Intermittent nature of many renewables (ERC, 2006) ▪ Concern over visual and noise pollution of wind turbines (RoSA, 2000)	▪ Carbon finance: six renewable energy projects in the Clean Development Mechanism (CDM) pipeline as of November 2008 ▪ New Southern African Trade Protocol free trade area (RoSA, 2003) ▪ Global Environment Facility (GEF) and World Bank – funded project on South Africa Renewable Energy Market Transformation and GEF-funded project on South Africa Wind Energy Programme

Option	Mitigation Potential in 2030[69]	Relative Cost[70]	Overlapping Policy Objectives	Proposed or Adopted Policies	Key Barriers	International Support Mechanisms
Improved Energy Governance and Market Reform	Not quantified by studies reviewed	Not quantified by studies reviewed	▪ Could support economic development if efficiency gains are realized in part by removing trade barriers and increasing private sector involvement (Chandler et al, 2002)	▪ Feed-in tariffs and power purchase agreements announced in March 2009 for wind, landfill gas, and concentrated solar power (NERSA, 2009) ▪ Proposal to develop legal and regulatory framework for integrating independent power producers (RoSA, 2003) ▪ Proposal to increase private sector involvement (applies broadly across energy options) (Chandler et al, 2002) ▪ Proposal to use "full cost accounting" frameworks for electricity planning and pricing when and if adopted by developed nations (RoSA, 2005; RoSA, 2004; RoSA, 2003b; Winkler et al, 2007) ▪ Proposal to include GHGs under Existing 2004 Air Quality Act (RoSA, 2004; Winkler et al, 2007) ▪ Proposal to remove trade barriers (Winkler et al, 2007)	▪ Lack of progress on legislative needs (Warburton et al, 2007) ▪ Current national policy of discriminant access to the national electricity grid (RoSA, 2003)	
TRANSPORTATION						
Vehicle Efficiency	*High* (ERC, 2007)	*Low* for efficiency standards (ERC, 2007)	▪ Supports goal of decreased local air pollution (RoSA, 2000)	▪ Proposal to put in place more ambitious national targets for transportation emissions (RoSA, 2008) ▪ Current consideration of vehicle efficiency standards by Department of Environmental Affairs and Tourism (ERC, 2006)	▪ Increased up-front cost to the consumer (RoSA, 2000) ▪ Lack of public emphasis on fuel efficiency (Ratcliffe, 2008)	

Option	Mitigation Potential in 2030[69]	Relative Cost[70]	Overlapping Policy Objectives	Proposed or Adopted Policies	Key Barriers	International Support Mechanisms
Fuel Switching	▪ *Medium* for biofuels or *High* with biofuels subsidy (ERC, 2007) ▪ *High* for electric vehicles (ERC, 2007)	▪ *High* for biofuels (ERC, 2007) ▪ *High* for electric vehicles (ERC, 2007)	▪ Potential to support black economic empowerment through bio-fuel farmer co-ops (RoSA, 2003)	▪ Proposal to integrate LPG, CNG, electric, bio-fuels into existing transportation infrastructure and regulatory framework (RoSA, 2004; RoSA, 2003) ▪ Existing targets for renewable energy: equivalent of 10,000 Gwh from electricity, biofuels, solar hot water heaters by 2013 (RoSA, 2003) ▪ Existing biodiesel and bio-ethanol subsidies available through the Renewable Energy Finance and Subsidy Office (Winkler et al, 2007) ▪ Bio-fuels strategy currently before the South African government (Surridge, 2007)	▪ High cost of electric vehicles and biofuels (ERC, 2007) ▪ Potential concern over competition for land to produce biofuels, as well as other resource concerns, as noted in other country chapters of this report	
Reductions in VMT	*High* (ERC, 2007)	*Low* (ERC, 2007)	▪ Can support existing goal of increasing transit service (RoSA, 2004) ▪ May increase energy security through decreased use of fossil fuels (Ratcliffe, 2008)	▪ Proposal to expand and improve public transit (RoSA, 2004) ▪ Proposal to advance non-motorized transit through planning, infrastructure, and promotion (RoSA, 2004) ▪ Existing National Department of Transport study on sustainable transport with focus on mode-shifting (Ratcliffe, 2008)	▪ High capital investment costs of public transit systems (Ratcliffe, 2008) ▪ Lack of a safe and efficient public transit system (World Bank, 2007)	▪ GEF-funded project, Sustainable Public Transport and Sport: A 2010 Opportunity

Option	Mitigation Potential in 2030[69]	Relative Cost[70]	Overlapping Policy Objectives	Proposed or Adopted Policies	Key Barriers	International Support Mechanisms
BUILDING EFFICIENCY						
Residential Efficiency and Fuel-Switching	*High* (ERC, 2007)	*Low* (ERC, 2007)	▪ Can help advance social equity (RoSA, 2005; RoSA, 2003) ▪ Can support increased improved air quality (RoSA, 2005; RoSA, 2003) ▪ Can support country's objective of preserving woodlands, currently a major source of rural energy (RoSA, 2003) ▪ Can enhance energy security and economic development (RoSA, 2005), although could also decrease demand for domestic coal (RoSA, 2000)	▪ Existing national goal of 12% energy efficiency and emissions reduction improvement against baseline by 2014 (Winkler et al, 2007) ▪ Proposed mandatory energy efficiency targets, including stringent building standards (RoSA, 2008) ▪ Proposed residential energy efficiency codes for housing (RoSA, 2005; RoSA, 2004; RoSA, 2003; ERC, 2006; Winkler et al, 2007) ▪ Proposal to develop energy efficiency appliance standards (RoSA, 2005; RoSA, 2003; ERC, 2006) ▪ Proposal to offer financial incentives for energy efficiency (RoSA, 2004; Winkler et al, 2007) ▪ On-going establishment of "Energy Centres" to dispense clean fuels in low-income areas and public education campaign termed "Basa Njengo Magogo" (ERC, 2006) ▪ Proposal to encourage CDM funding (RoSA, 2005)	▪ No clear government agency responsibility for energy efficiency (Winkler et al, 2007; EDRC, 2003) ▪ Low cost of coal (ERC, 2006) ▪ Lack of public awareness and technical proficiency (ERC, 2006; EDRC, 2003; RoSA, 2000) ▪ High cost of technologies, including appliances (ERC, 2006; EDRC, 2003; RoSA, 2000) ▪ Other, more pressing needs for government financial resources (RoSA, 2005) ▪ Lack of building codes (RoSA, 2000) ▪ Pressure to build houses as quickly and cheaply as possible (RoSA, 2000)	▪ Carbon finance: one residential energy efficiency project in the Clean Development Mechanism (CDM) pipeline as of November 2008 ▪ Existing partnership with the International Institute for Energy Conservation ▪ Existing Global Environment Facility funding for Solar Water Heaters (SWHs) for Low-income Housing in Peri-Urban Areas project ▪ Current efforts by the World Bank to assist ESKOM with development of CFL, solar hot water heating, and demand-side management program and projects (World Bank, 2007)

Option	Mitigation Potential in 2030[69]	Relative Cost[70]	Overlapping Policy Objectives	Proposed or Adopted Policies	Key Barriers	International Support Mechanisms
Commercial Energy Efficiency	*High* (ERC, 2007)	*Low* (ERC, 2007)		▪ Proposal for increased national focus on demand-side management (RoSA, 2008; Winkler et al, 2007; RoSA, 2004) ▪ Proposal to offer financial incentives for energy efficiency (RoSA, 2004; Winkler et al, 2007)	▪ Lack of awareness and technical proficiency among building owners (ERC, 2006; EDRC, 2003) ▪ Split incentives between building owners and tenants (ERC, 2006) ▪ No clear government agency responsibility for energy efficiency (Winkler et al, 2007; EDRC, 2003) ▪ High up-front costs and interest rates (EDRC, 2003)	▪ Current World Bank effort to help scale up commercial lending for energy efficiency, including a plan to engage energy service companies, or ESCOs (World Bank, 2007)
INDUSTRY						
Industrial energy efficiency	*High* (ERC, 2007)	*Low* (ERC, 2007)		▪ Proposal to increase demand-side management (e.g., peak shaving), waste avoidance, and efficiency measures in industry (RoSA, 2008; RoSA, 2004) ▪ Existing trend towards use of fly ash and other by-products in cement (RoSA, 2004) ▪ Proposal to phase out existing wet-process clinker kilns (RoSA, 2004) ▪ Proposal to implement process and/or boiler improvements and co-generation in steel and paper industries (RoSA, 2004) ▪ Proposal to increase recycled content in aluminum and paper industries (RoSA, 2004)	▪ No established network for communicating best practices for industry (ERC, 2006; EDRC, 2003) ▪ No clear government agency responsibility for energy efficiency (Winkler et al, 2007; EDRC, 2003) ▪ High up-front costs and interest rates for investments in efficiency (EDRC, 2003)	Carbon finance: one industrial end-use efficiency project and one co-generation project in the Clean Development Mechanism (CDM) pipeline as of November 2008

Option	Mitigation Potential in 2030[69]	Relative Cost[70]	Overlapping Policy Objectives	Proposed or Adopted Policies	Key Barriers	International Support Mechanisms
Synthetic Fuel Industry				▪ Proposal to consider switching from coal to natural gas for primary energy needs (RoSA, 2004)	▪ No legally binding air pollution regulations (RoSA, 2006)	

Promising Opportunities

The South African government – with significant technical support from the Energy Research Centre (ERC), has taken a leading and assertive role in assessing medium and long-term actions to mitigate greenhouse gas emissions from South Africa. Table 14, below, highlights leading greenhouse gas mitigation policies as identified in ERC's *Long-Term Mitigation Scenarios (LTMS): Technical Report* as well as initial indication of priorities of the Republic's Cabinet based on the LTMS work and process.

Table 22. Top Greenhouse Gas Mitigation Options for South Africa as Identified in Leading Studies

Sector	Republic of South Africa (RoSA, 2008)[71]	Energy Research Centre (ERC, 2007)[72]
Electricity Generation	▪ Put in place more ambitious national targets and research and development for renewable energy and introduce renewable feed-in tarriffs ▪ Introduce more stringent thermal efficiency and emissions standards from coal-fired power plants	▪ Transition to zero-carbon electricity by mid-century via a significant shift to renewable and nuclear, including a subsidy for renewable electricity ▪ Add carbon capture and storage to remaining coal-fired plants (2% of output share)
Transportation	▪ Put in place more ambitious national targets and research and development for transportation emissions, including stringent and escalating fuel efficiency standards, facilitating passenger modal shifts towards public transport and the aggressive promotion of hybrids and electric vehicles	▪ Introduce electric vehicles powered by a renewable and nuclear electricity grid (or, vehicle efficiency standards) ▪ Introduce a biofuels subsidy to extend biofuels use ▪ Implement passenger modal shifts (reduction in VMT)
Buildings & Appliances	▪ Set ambitious and mandatory energy efficiency targets by sector and continuously update these standards to reflect increasingly ambitious national targets ▪ Adopt more stringent building standards	▪ Implement residential and commercial efficiency measures ▪ Implement subsidy for solar hot water heaters
Industry	▪ Set ambitious and mandatory energy efficiency targets by sector and continuously update these standards to reflect increasingly ambitious national targets ▪ Make current energy efficiency and demand-side management activities mandatory and continuously renewed and amended to reflect more ambitious national targets	▪ Implement industrial energy efficiency measures
Other or economy-wide policies	▪ Study an escalating carbon tax ▪ Implement education & outreach	▪ Implement an escalating carbon tax

[71] RoSA (2008) is based on the Long-Term Mitigation Scenarios review process as interpreted and prioritized by the Cabinet.

[72] Policies and actions listed in this table re those in ERC's "Scale Up" and "Use the Market" scenarios.

Conclusions

Since 2007, the Republic of South Africa has been engaged in a path-breaking effort to identify a low-carbon growth trajectory for the country. The government plans to spend much of 2009 developing its sector-focused policies and negotiating positions in preparation for Copenhagen in December and to update and finalize its climate change response strategy by the end of 2010 (RoSA, 2008).[73]

Based on review of the Energy Research Centre's work as well as qualitative studies by other researchers, we have summarized several promising mitigation options, as well as barriers to their implementation, above. The country faces many challenges in transitioning to a lower-carbon electricity system – chief of which may be cost. For example, although the government has a stated its intention to further develop nuclear energy as a low-carbon fuel source, high costs contributed to Eskom's recent cancellation of a planned nuclear facility. On the other hand, the government's assertive new renewable energy feed-in tariff is looking promising as a means of incenting new renewable energy investment (Fakir, 2009). Clearly, numerous opportunities exist for international support, from funding and technology assistance to renewable energy policy and building code development.

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[73] Among other partners, the World Bank is offering assistance through its Low Carbon Country Case Studies program.

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Chapter 8. South Korea

In 2008, South Korea released its *Comprehensive Plan for Combating Climate Change* (Republic of Korea, 2008a). The Plan sets forth a vision of "low carbon, green growth" including an objective to develop its climate industry as a new economic driving force. The country is currently developing both its Third National Communication and a long-term mitigation assessment, developed in partnership with the Korea Environment Institute and the Korea Energy Economics Institute (Kim, 2009; Jick Yoo, 2008; Republic of Korea, 2008) and is expected to announce emission reductions targets by the end of 2009 (Herskovitz, 2009).

The following table displays several economic and climate indicators for South Korea relative to the U.S. and to other countries included in this study.

Table 23: South Korea Development Indicators Relative to Other Countries
(Source: World Bank's World Development Indicators, 2009)

	China	India	Brazil	Mexico	South Korea	South Africa	U.S.
Population, millions (2007)	1,320	1,120	192	105	48	48	302
GNI[74] Per Capita, PPP (2007)	$5,420	$2,740	$9,270	$13,910	$24,840	$9,450	$45,840
GDP Growth, Annual (2007)	13.0%	9.1%	5.4%	3.2%	5.0%	5.1%	2.0%
Energy use per capita, kg oil equivalent (2006)	1,433	510	1,184	1,702	4,483	2,739	7,768
CO_2 emissions per capita (2005)	4.3	1.3	1.7	4.1	9.4	8.7	19.5

Among the six countries included in this study, South Korea has the highest per-capita income and high emissions per capita, based on a vibrant economy with strong electronics, vehicle, and other manufacturing sectors.

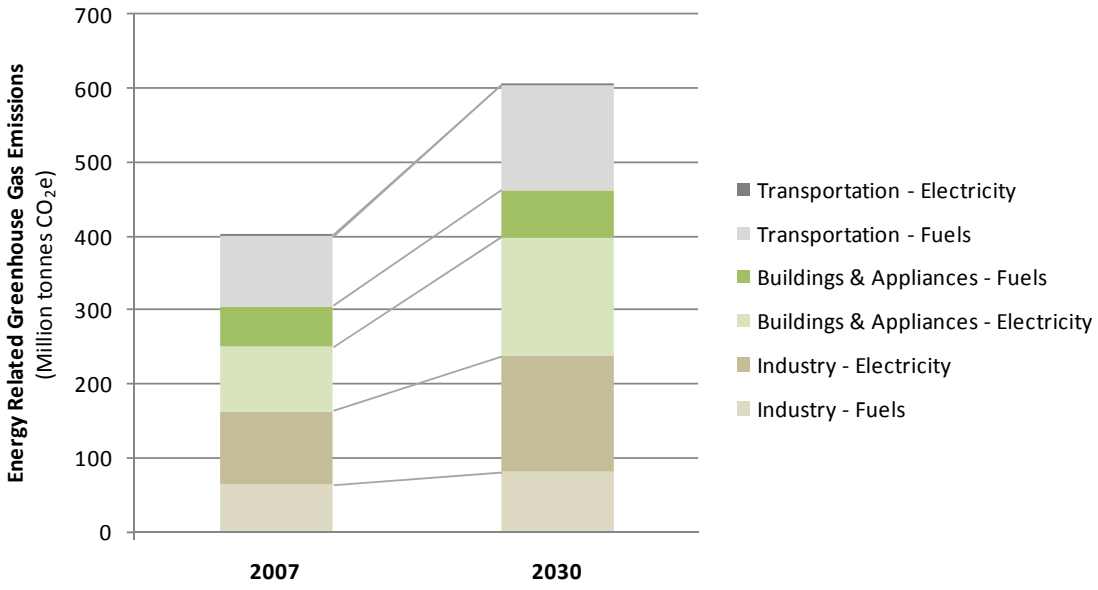
Baseline Emissions Forecast

Figure 8 below, displays the projected baseline emissions for South Korea between now and 2030.[75]

[74] GNI is Gross National Income and is reported here using the purchasing power parity (PPP) method of converting to international dollars.

[75] For details on SEI's LEAP model and projection methodology, please see the appendix.

Figure 16. Projected Baseline Energy-sector Greenhouse Gas Emissions in South Korea in 2030



Mitigation Potential

Few international studies have quantified greenhouse gas mitigation potential in South Korea. The most comprehensive previous study was the Asian Development Bank's 1998 *Asia Least-Cost Greenhouse Gas Abatement Strategy: Republic of Korea.* While some studies have included estimates for Korea (e.g., UNFCCC, 2007), others either do not include South Korea or include the country as part of a broader region (e.g., as in McKinsey, 2009, Wetzelaer et al, 2007). The South Korean government and its research community are currently creating a long-term mitigation potential assessment, which is expected to be released in 2009.

Table 24. Estimated Mitigation Potential in South Korea, $MtCO_2e$/year

Sector/Option	**UNFCCC** (2007) Estimates for 2030	**Asia Development Bank** (1998) Estimates for 2020[76]
ELECTRICITY		*95*
TRANSPORTATION		*22*
BUILDINGS & APPLIANCES	*11*	*21*
INDUSTRY	*37*	*1*

As evidenced by the scarcity of mitigation potential estimates for South Korea, much analytical work remains to be completed. The government's current long-term mitigation scenarios effort is expected to significantly fill this gap, but the work is yet to be made public. In the absence of such mitigation potential estimates, we rely on the limited estimates available from the UNFCCC and the much older work of the Asia Development Bank's Asia Least-cost Greenhouse Gas Abatement Strategy for Korea (ADB, 1998). Note that the Asia-Development Bank's work may not be as dated as the decade-old report may otherwise suggest, as many of the policies suggested in that report have yet to be implemented and are currently being recommended by the Republic of Korea in its current *Comprehensive Plan* (for a comparison of major recommendations in the two reports, see Table 26).

Figure 17, below, displays the mitigation potential estimates from the Asia Development Bank's 1998 report.

[76] The figures presented for the Asia Development Bank's assessment are the sector-wide mitigation potentials from the report's "Abatement Scenario 2" which, by design, focused less on industrial measures. Several individual industrial measures are assessed in the report but are not included in ADB's Abatement Scenario 2.

Figure 17. Energy-sector Mitigation Potential Estimates for South Korea in 2020
(Asia Development Bank, 1998)

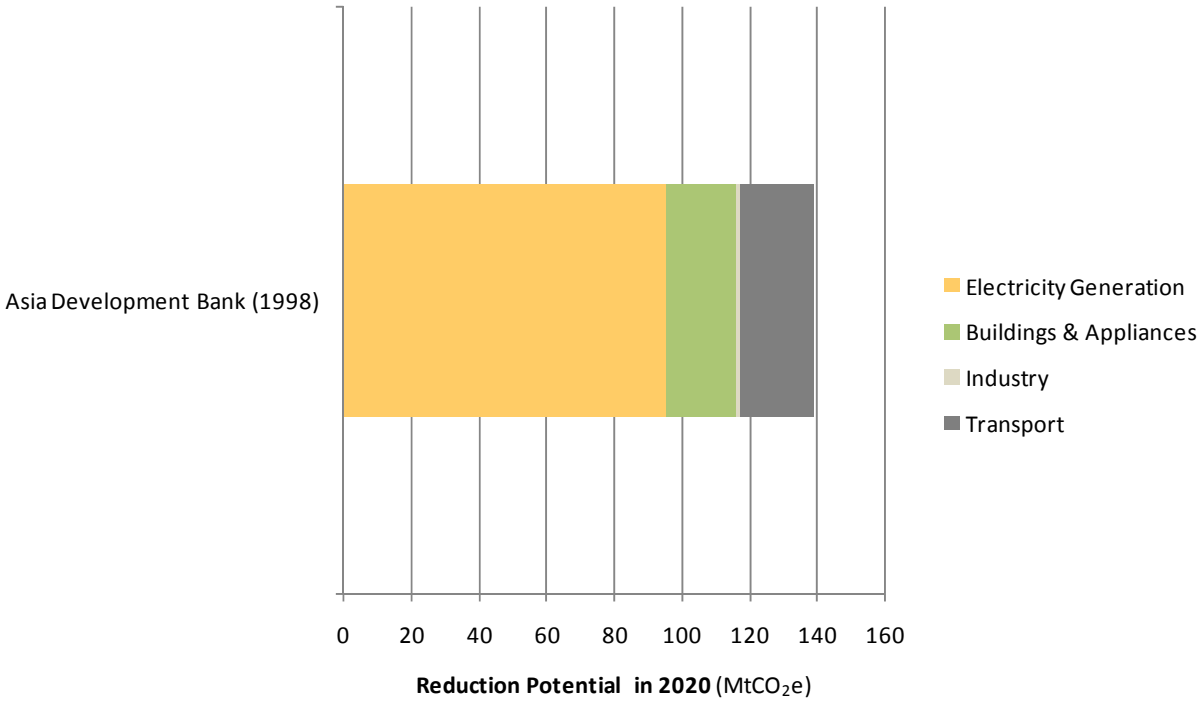
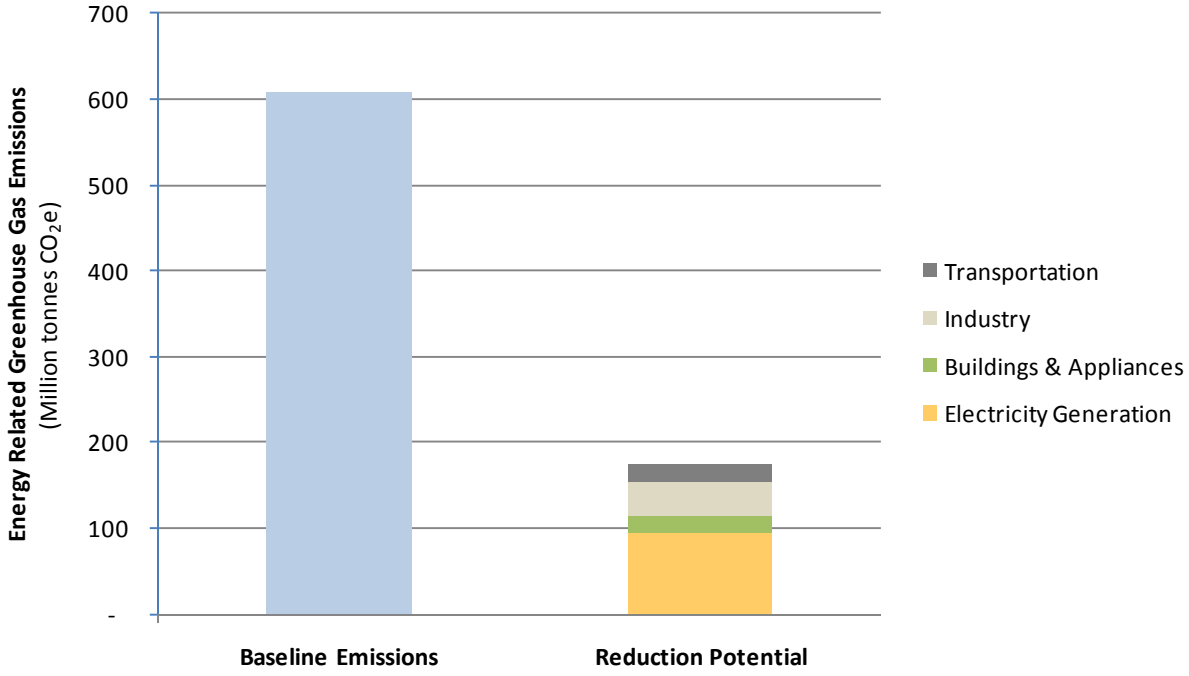


Figure 18, below, displays the mitigation scenario estimates derived from the Asia Development Bank's (ADB, 1998) and United Nations (UNFCCC, 2007) studies in the context of projected energy-sector baseline emissions. Note that no attempt was made to reconcile differences in the the study baselines from our projected baseline – differences that would potentially alter the magnitude of the emission reductions shown. Nevertheless, the figure does display the general scale of emission reductions identified by the studies relative to SEI's projected future energy-sector emissions in South Korea. Note that new analysis released by the Republic of Korea later in 2009 is expected to offer much needed new insights into mitigation potential of the country and its economic sectors, likely rendering as obsolete the ADB's work, which is already a decade old.

Figure 18. Energy-related Greenhouse Gas Emissions in South Korea in 2030 – Baseline Emissions and Reduction Potential
(Baseline from SEI analysis; mitigation scenario from ADB, 1998 and UNFCCC, 2007[77])



Assessment of Options

While Table 24 displayed coarse estimates of mitigation potential by sector, it did not, due to limitations in the underlying studies, present estimates for individual technologies or policies. Nevertheless, Korea's existing *Comprehensive Plan* and other studies do discuss – in general terms – the opportunities and challenges inherent in specific alternative approaches. The success of efforts to implement these options will depend on numerous factors, including cost-effectiveness, extent of overlap with social or economic development objectives, extent of existing country experience with similar measures or policies, and potentially international support mechanisms, among other factors.

We conducted a review of the available literature to summarize and assess the potential barriers and opportunities for several options within each sector. Table 13, below, provides results of this research, and is followed by a summary of high priority opportunities for involvement, given the limited research available concerning the country.

[77] Note that ADB's (1998) mitigation potential estimate is for 2020 as is applied here for the transportation, buildings, and electricity generation sectors. Given the fact that many of the actions suggested in ADB's report to mitigate greenhouse gas emissions have yet to be realized and lack of other suitable estimates, we include ADB's 2020 estimate as a reasonable order-of-magnitude estimate for 2030 and look to Korea's upcoming long-term mitigation assessment to provide further updated estimates. The industry sector estimate included in this figure is from UNFCCC (2007).

Table 25. Assessment of Mitigation Options in South Korea

Option	Mitigation Potential in 2030[78]	Relative Cost	Overlapping Policy Objectives	Proposed or Adopted Policies	Key Barriers	International Support Mechanisms
ELECTRICITY						
Power Plant Efficiency	*High* (Oh et al, 1999; ADB, 1998)		▪ Supports reduction in "conventional "air pollution (ADB, 1998)	▪ Recent break-up and partial privatization of Korea Electric Power Corporation (KEPCO), which may encourage efficiency (Von Hippel and Hayes, 2008)	▪ Slow penetration of key technologies in Korea (Oh et al, 1999; ADB, 1998) ▪ High capital cost (ADB, 1998)	▪ Carbon finance: one power plant efficiency projects in CDM pipeline as of November 2008
Carbon Capture & Storage (CCS)				▪ Proposal for government R&D and international cooperation on CCS (Republic of Korea, 2008b; Yoo, 2008)		▪ Korea is part of the FutureGen International Partnership focused on developing and building a zero-emissions coal-fired power plant
Fuel Switching			▪ Relative to coal, natural gas supports objective for cleaner air (Oh et al, 1999)	▪ Proposed international diplomacy and infrastructure development to support increased role of natural gas and nuclear power (Republic of Korea, 2008b) ▪ Proposal to develop natural gas pipeline with Russia (Lee, 2007) ▪ Proposed price reform and market restructuring to favor natural gas (Republic of Korea, 2008b; ADB, 1998)	▪ No or limited natural gas reserves in Korea and no (as of yet) international pipeline (Von Hippel and Hayes, 2008; Lee, 2007; Oh et al, 1999; ADB, 1998) ▪ Geopolitical concerns of crossing North Korea to construct natural gas pipeline (Oh et al, 1999)	▪ Carbon finance: 3 fossil fuel switching projects in CDM pipeline as of November 2008
Nuclear Power	*High* (Oh et al, 1999)	*Low* (IEA, 2008)	▪ Supports national energy security objectives (Republic of Korea, 2008b)	▪ Proposal by Korean government to increase role of nuclear energy (Republic of Korea, 2008b; Yoo, 2008) and develop a nuclear waste management strategy (Republic of Korea, 2008b) ▪ Proposed international diplomacy and infrastructure development to support	▪ Difficulty with nuclear waste disposal and publicly acceptable sites for new reactors (Oh et al, 1999) ▪ Limited social acceptance of nuclear (Republic of Korea, 2008b)	▪ The Republic of Korea participates in the International Project on Innovative Nuclear Reactors and Fuel Cycles, INPRO (IEA, 2008) ▪ Korea is a member of the Generation IV International Forum and has signed the Framework Agreement for International Collaboration on Research and Development of Generation IV

[78] Options labeled *High* have the potential to reduce 6 million metric tons of CO2 in 2030 (approximately 1% of South Korea's projected 2030 emissions). Options labeled *Medium* have the potential to reduce at least 0.6 million metric tons of CO2 in 2030 (approximately 0.1% of projected 2030 emissions). Any option with less potential is labeled as *Low*.

Option	Mitigation Potential in 2030[78]	Relative Cost	Overlapping Policy Objectives	Proposed or Adopted Policies	Key Barriers	International Support Mechanisms
				increased role of nuclear power (Republic of Korea, 2008b) ▪ Seven new nuclear power plants in planning stage (IEA, 2008) ▪ Proposed government R&D for next-generation nuclear (Republic of Korea, 2008a) ▪ Proposal to increase export of Korean nuclear technology (Republic of Korea, 2008a)		Nuclear Energy Systems. ▪ Korea is a member of the International Project on Innovative Nuclear Reactors and Fuel Cycles
Hydropower	*Low* (Oh et al, 1999)				▪ Limited hydropower resources that are nearly exploited to full potential (Oh et al, 1999)	▪ Carbon finance: 14 hydro projects in CDM pipeline as of November 2008
Renewables			▪ Can support national energy security objectives (Republic of Korea, 2008b)	▪ Proposal to increase share of renewable from 2% of portfolio in 2006 to 11% in 2030, including a renewable portfolio standard (Republic of Korea, 2008a; Republic of Korea, 2008b) ▪ Proposed government R&D for wind and tidal power (Republic of Korea, 2008a) ▪ Proposed focus on wind, solar PV, and hydrogen/fuel cell technology (Yoo, 2008) ▪ Existing feed-in tariffs for solar PV, wind, small-scale hydro and landfill gas and proposal to expand (Yoo, 2008; Asia-Pacific Partnership, 2007) ▪ Existing program of renewable energy grants to local autonomies (Asia-Pacific Partnership, 2007)	▪ Cap and feed-in tariffs (Asia-Pacific Partnership, 2007) ▪ Power fluctuations as renewable and distributed generation represents increasing share, suggesting need for energy storage or other grid stabilization technologies (Asia-Pacific Partnership, 2007)	▪ Korea is chair of the Renewable Energy and Distributed Generation Task Force of the Asia-Pacific Partnership on Clean Development and Climate (Asia-Pacific Partnership, 2009) ▪ Carbon finance: 14 renewable energy projects in CDM pipeline as of November 2008 ▪ Korea is a member of the IEA's Photovoltaic Power Systems Programme (IEA, 2008)
Other				▪ Proposal to implement real-time electricity pricing (Republic of Korea, 2008b)		

Option	Mitigation Potential in 2030[78]	Relative Cost	Overlapping Policy Objectives	Proposed or Adopted Policies	Key Barriers	International Support Mechanisms
TRANSPORTATION						
Vehicle Efficiency		*Medium* (ADB, 1998)	▪ Supports reduction in "conventional "air pollution (ADB, 1998)	▪ Proposed government R&D for transportation efficiency technologies (Republic of South Korea, 2008) ▪ Proposal to increase efficiency of new vehicles by 30% by 2013 (Republic of South Korea, 2008) including corporate average fuel efficiency standards (Yoo, 2008) ▪ Proposed subsidies for hybrid vehicle purchases and other incentives for sub-compact cars (Yoo, 2008)	▪ Expected high growth rate in transportation energy consumption (Yoo, 2008)	
Fuel Switching		*High* (ADB, 1998)	▪ Switch from diesel to CNG Supports reduction in "conventional "air pollution (Oh and Jung, 2005; ADB, 1998)	▪ Proposal to increase biodiesel in fuel mix to 3.0% in 2012 (Yoo, 2008) ▪ Proposal to offer incentives for CNG and LNG vehicles (Yoo, 2008)	▪ Lack of alternative fuel infrastructure (ADB, 1998) ▪ High price of alternative fuel vehicles (ADB, 1998) ▪ Lagging technology development for electric vehiciles (ADB, 1998)	
Reductions in VMT				▪ Proposal to extend Bus Rapid Transit (Yoo, 2008) ▪ Plan to support local land use planning and mode-shifting efforts (Republic of Korea, 2008b)		
BUILDINGS & APPLIANCES						
Residential and Commercial	*High* (UNFCCC, 2007)	*Low* (ADB, 1998)		▪ Proposed government R&D for building efficiency technologies, including LEDs, cost-share of commercial building energy audits, energy efficiency rating system for buildings, minimum efficiency standards for lighting		▪ Korea is chair of the Buildings and Appliances Task Force of the Asia-Pacific Partnership on Clean Development and Climate (Asia-Pacific Partnership, 2009)

Option	Mitigation Potential in 2030[78]	Relative Cost	Overlapping Policy Objectives	Proposed or Adopted Policies	Key Barriers	International Support Mechanisms
				and appliances, mandatory efficiency technology in public buildings (Republic of Korea, 2008a; Yoo, 2008) ▪ Proposed shift to natural gas for building energy (Yoo, 2008) ▪ Existing insulation requirements in new buildings under "certain criteria" since 2002 (Oh and Jung, 2005) ▪ Existing "Green Building Certificate" program for new buildings since 2002 (Oh and Jung, 2005) ▪ Existing Certificate for Energy Efficiency program since 2001 (Oh and Jung, 2005) ▪ Existing energy efficiency rating program for home appliances since 1002 (Oh and Jung, 2005)		
INDUSTRY						
Industrial energy efficiency	*High* (UNFCCC, 2007)	*Low* (ADB, 1998)		▪ Proposal to develop financial incentives linked to existing national GHG emissions registry (Republic of Korea, 2008a) ▪ Proposal to make existing voluntary agreements with industry mandatory (Republic of Korea, 2008a; Yoo, 2008) ▪ Proposal to reduce industrial energy intensity by 46% by 2030 (Lee, 2008) ▪ Proposed carbon tax (ADB, 1998)	▪ Low fuel prices provide little inherent incentive for many efficiency improvements (ADB, 1998)	▪ Carbon finance: one project in industrial end-use energy efficiency and one in industrial co-generation as of November 2008

Promising Opportunities

In 2008, the Republic of Korea released its *Comprehensive Plan on Combating Climate Change.* Although the Korean government has increasingly signaled its intentions to release more specific policies and analysis in 2009, the *Comprehensive Plan* remains the most recent and thorough documentation (though lacking in quantitative estimates) of promising options in the country. Table 26, below, summarizes these policy options and includes top recommendations from the Asia Development Bank's 1998 *Asia Least-cost Greenhouse Gas Abatement Strategy* for South Korea because it is interesting to note that, even though the study is a decade old, many of the recommended policies remain to be implemented and are again recommended by Korea's current *Comprehensive Plan*.

Table 26. Top Greenhouse Gas Mitigation Options for South Korea as Identified in Leading Studies

Sector	Republic of Korea's ***Comprehensive Plan for Combating Climate Change*** (2008a)	**Asia-Development Bank** (1998)
Electricity Generation	▪ Government R&D for next-generation nuclear plants, transmission and distribution efficiency, wind and tidal power ▪ Increase share of renewable energy from 2% of portfolio in 2006 to 11% in 2030 and 20% in 2050, including implementation of a renewable portfolio standard	▪ Increased implementation of coal-based power plant efficiency technologies, including PFBC and IGCC
Transportation	▪ Government R&D for transportation efficiency technologies ▪ Increase energy efficiency of new vehicles by 30% by 2013	▪ Expand infrastructure and vehicle purchase incentives for electric, CNG, and LPG vehicles ▪ R&D support for more-efficient vehicles
Buildings & Appliances	▪ Government R&D for building efficiency technologies, including LEDs ▪ Implement "one million green homes" project that include small-scale solar and wind power generation capacity ▪ Require renewable energy installation in renovated buildings and school facilities ▪ Government cost-sharing of commercial energy audits via ESCOs ▪ Implement minimum energy efficiency standards for lighting ▪ Introduce energy efficiency rating system	▪ Standards and incentives for efficient lighting ▪ Activation of energy-saving design standards in building codes ▪ Promote awareness and conduct R & D for improved building boiler technologies ▪ Financial incentives and education for residential condensing gas boilers ▪ R&D support for solar hot water heaters and required installation in public buildings ▪ Introduce appliance energy labeling ▪ Promotion of energy service companies (ESCOs)
Industry	▪ Require large energy-intensive industries (e.g., steel and petrochemicals) to undergo energy review ▪ Expanding minimum energy efficiency standards ▪ Develop negotiated agreements with industry ▪ Develop financial incentives, including links to the Korea Certified Emission Reduction scheme	▪ Financial support for replacement of industrial furnaces, boilers, and kilns with more efficient models ▪ Implement a carbon tax ▪ Minimum efficiency standards for electric motors ▪ Technical assistance to small manufacturers for the installation of more efficient motors
Other or economy-wide policies	▪ Promote "green culture" and "less carbon" lifestyles ▪ Consider national cap-and-trade program	▪ Implement a carbon tax

Note that Korea's 2003 *Second National Communication* also included a catalog of existing and intended policies, but it is not included in the table above because its policy discussions are similar to (and assumed to be superseded by) the 2008 *Comprehensive Plan*.

Conclusions

In 2008 and early 2009, the Republic of Korea has made increasingly ambitious announcements regarding its climate policy and goals. Building on its 2008 *Comprehensive Plan on Combating Climate Change,* the government plans to announce a national goal in 2009, including sector mitigation targets (Republic of Korea, 2008a). Although considered a developing country by the international climate negotiations to date (and therefore not bound to an emissions reduction target), the country has discussed publicly its intention to serve as a potential liason between developing and "industrialized" countries by announcing a national GHG reduction target and (possibly) a cap-and-trade program later this year (Herskovitz, 2009).

Until the country releases the details of its long-term mitigation potential assessment and associated policy details, further efforts to identify promising opportunities are limited, especially considering the scant details included in other published work to date. Nevertheless, the research and findings documented above suggest significant greenhouse gas mitigation potential in Korea's energy sector, with several options available at low cost and with high ancillary benefits for the country. Korea's 2009 work to advance details of its plans will clarify potential priority areas for international involvement; based on research conducted for this project, it appears opportunities to partner with the Republic of Korea on deployment of renewable energy, investment and research needs, and efficiency technologies in all industries and building sectors will remain high.

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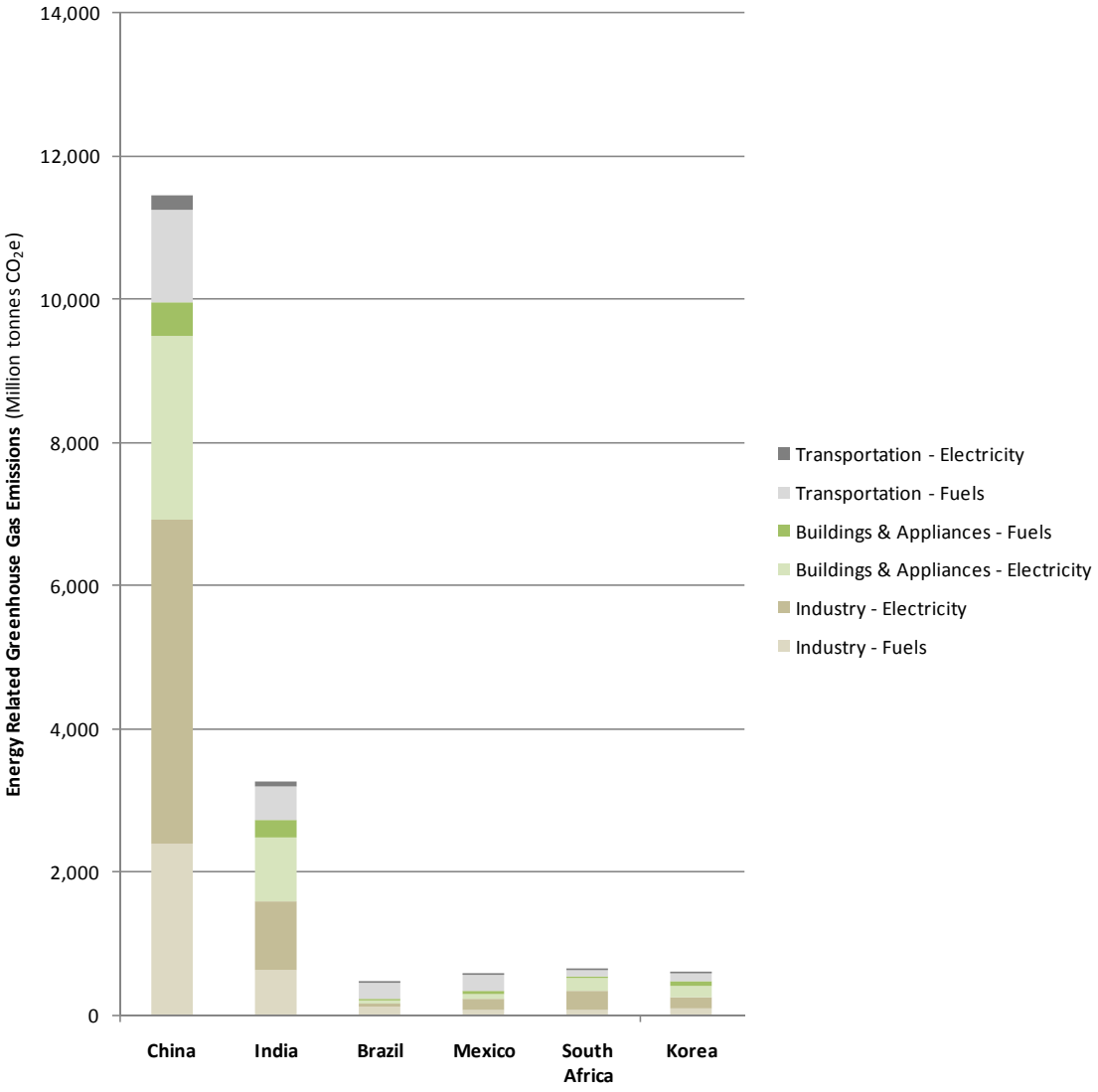
Chapter 9.
Cross-Cutting Opportunities

This report has provided a summary of existing literature concerning greenhouse gas mitigation opportunities in six developing countries over the next two decades. In addition, we have provided a set of baseline emission scenarios for the countries against which mitigation potential estimates can be assessed. While our methodology for the baseline emission scenarios across the six countries is consistent, the variability in approaches to assessing mitigation potential in the studies reviewed varies widely. This variability is observed both within a country (where estimates of GHG mitigation potential may vary by an order of magnitude) as well as between countries, for which meaningful comparisons can be particularly problematic. Sources of the variability include differing projections of future economic activity, stringency of future greenhouse gas policies assumed (if any), assumptions regarding financial discount rates, availability of technology and degree of technology learning over time, and many other assumptions.

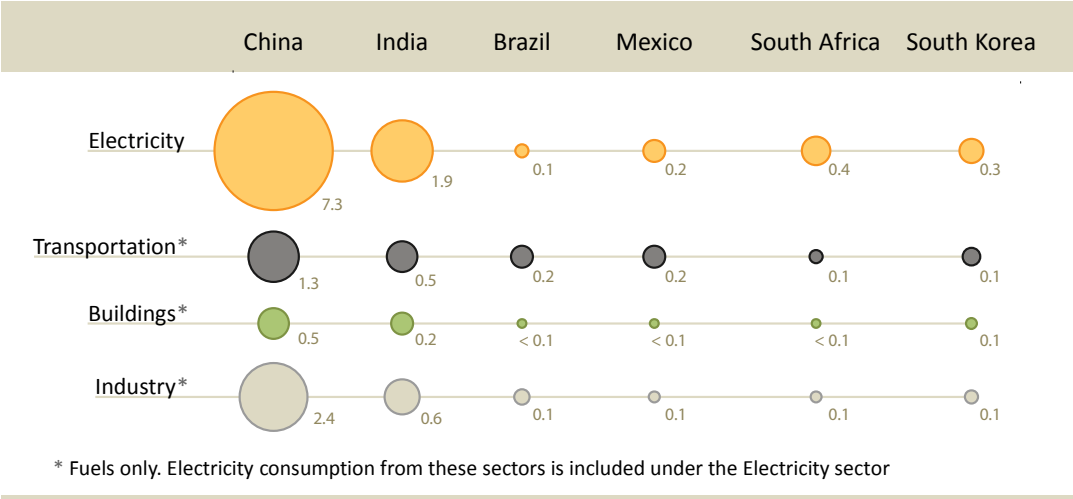
Several studies (e.g., UNFCCC, 2007; IEA, 2008; McKinsey & Company, 2009) have assessed and compared mitigation potential across countries, and these studies help provide valuable starting points for efforts to identify priorities for international involvement. We have included quantitative mitigation potential estimates and qualitative assessments from these studies, as well as country-specific studies, for each country throughout this report. Given the variability in methodologies and policy ambition between studies, however, detailed quantitative comparisons of specific mitigation options or figures between countries is fraught with uncertainty. Furthermore, even within a country, choices regarding relative policy emphasis between studies may mask the true, underlying potential of some options. For example, Tsinghua University (2006) advanced a mitigation scenario of China's energy future that depended largely on nuclear and hydropower. Yet China's energy future could instead plausibly rely much more heavily on wind and solar energy, as suggested by McKinsey and Company (2009). Rather than include a cross-country comparison of options across countries that attempts the challenging task of identifying and accounting for such biases, we instead present, below, a quantitative comparison of the baseline emissions in each country and a qualitative assessment of likely potential, by sector. For details on specific options or analyst estimates, we refer readers to the individual chapters.

Figure 19. Projected Baseline Energy-sector Greenhouse Gas Emissions in Six Countries in 2030



Similar to the greenhouse gas projections presented above, Figure 20, below, presents relative baseline emissions in each of the six countries within four (condensed) sectors. Assuming that the overall suite of mitigation options is similar in each of the countries, the relative size of the circles can serve as an indication of the relative mitigation potential across sectors and countries. Clearly, projected baseline emissions in China and India dwarf emissions in the other countries, but note that gains within certain sectors in each of the countries would contribute significantly to global greenhouse gas mitigation. Furthermore, even where the contribution to global mitigation potential is small, actions to reduce emissions may bring other benefits to the country, extend naturally from similar efforts in other countries (or from other sectors within the same country), or potentially offer leveraged benefit for global greenhouse gas reductions. For example, although vehicle emissions in South Korea are expected to comprise less than 1% of the six countries' baseline greenhouse gas emissions in 2030, the country's growing presence in the global automobile market suggests that efforts to increase efficiency of vehicles made within the country could bring both significant economic benefits as well as contribute to global reduction of greenhouse gases

Figure 20. Projected 2030 Baseline Greenhouse Gas Emissions by Sector and Country
(Gigatons CO_2e; Energy-related sectors only; Projected emissions proportional to area of circle)



The following table identifies options within each sector and country that showed particular potential in the studies reviewed. While the options included in this table are by no means exhaustive, they are intended to represent options that each have the potential to reduce greenhouse gas emissions by at least 1% of each country's projected 2030 baseline emissions.[79] Most of the options listed have also received a critical level of support (or expressed interest) from leading policy studies (including government-issued plans), although not all options are universally supported.

[79] In general, options included have the potential to reduce greenhouse gas emissions by at least 1% of that country's projected 2030 baseline emissions, but with two broad exceptions. The first is the "Buildings & Appliances" category, for which the potential to reduce sector-wide emissions is estimated by the studies reviewed to be least 1% for all countries, and for which leading options under discussion in the country are listed regardless of whether they individually would meet the 1% threshold or not. This varying standard for Building and Appliances was used because many studies did not quantify reductions associated with individual options in this sector. The second exception is for South Korea, for which insufficient information exists to apply this 1% threshold, so the options listed for this country are those included in its *Comprehensive Plan for Combating Climate Change* (Republic of Korea, 2008a).

Table 27: High Potential Mitigation Options by Sector and Country
(as identified in available mitigation studies)

	China	India	Brazil	Mexico	South Africa	South Korea
Electricity Production	▪ Nuclear power ▪ Renewables ▪ Coal-fired power plant efficiency ▪ CCS	▪ Nuclear and renewable electricity ▪ Coal-fired power plant efficiency ▪ CCS ▪ Reduce trans-mission losses	▪ Wind power, small hydro, and sugar cane bagasse co-generation	▪ Renewables (especially wind and solar) ▪ Reduced trans-mission losses ▪ Fossil-fuel-fired power plant efficiency ▪ Switching to natural gas from fuel oil ▪ Nuclear ▪ CCS	▪ Renewables ▪ Coal-fired power plant efficiency ▪ CCS	▪ Nuclear ▪ Coal-fired power plant efficiency ▪ Renewables (wind, tidal, solar) ▪ Transmission and distribution efficiency
Transportation	▪ Vehicle efficiency standards ▪ Electric vehicles	▪ Vehicle efficiency standards ▪ Biofuels ▪ Enhanced public transport and urban planning	▪ Vehicle efficiency standards ▪ Ethanol from sugar cane	▪ Vehicle efficiency standards ▪ Second-generation biofuels ▪ Mode-shifting ▪ Optimized freight traffic	▪ Vehicle efficiency standards (including electric vehicles) ▪ Biofuels ▪ Mode-shifting	▪ Vehicle efficiency standards ▪ Government R&D for efficient vehicles
Buildings	▪ Building codes and enforcement ▪ Appliance efficiency and labeling standards	▪ Extension of existing building codes ▪ Retrofits of existing buildings via ESCOs	▪ Adoption of building energy codes ▪ Appliance efficiency standards ▪ Fuel switching from wood and oil to LPG and natural gas	▪ New standards for lighting efficiency ▪ Expansion of existing energy efficiency programs, possibly to include building codes	▪ More-stringent building standards and mandatory efficiency targets (including use of solar hot water heaters)	▪ Energy efficiency standards (lighting) & ratings (appliances) ▪ Government R&D for efficiency technologies and cost-sharing for ESCOs
Industry	▪ Agreements, standards, and incentives for efficiency in iron/steel, cement, and chemical industries	▪ Tradable energy certificates and other incentives ▪ Energy efficiency in cement, iron/steel industries	▪ Use of sustain-able charcoal in iron/ steel industry ▪ Process and efficiency gains and CCS in cement industry	▪ Combined heat & power in steel, cement, sugar, and oil industries	▪ Stringent, mandatory energy efficiency activities and targets	▪ Industry-specific agreements, standards, and required audits
Other				▪ Proposed national cap-and-trade	▪ Study of escalating carbon tax	▪ National cap-and-trade under consideration

Other options not included in this table (whether or not discussed within each country's chapter) may also prove to be cost-effective means of reducing emissions.

Appendix. Baseline Scenario Methodology

SEI's LEAP software system was used as the organizing framework to develop business-as-usual, "baseline" projections of the energy systems of each of six developing countries out to 2030 along with their resulting GHG emissions.

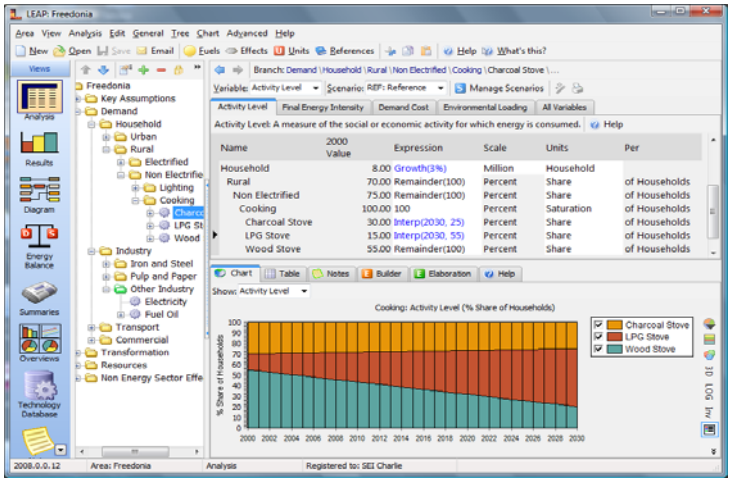


Figure 21: SEI's LEAP Modeling Software

The six countries studied were Brazil, China, India, Mexico, South Korea and South Africa. LEAP was used to construct the **baseline scenarios** included in this report. The baseline scenarios examined likely future trends in energy consumption, production and GHG emissions in the absence of specific new policies to mitigate climate change. This scenario was developed in a relatively simple top down manner and was calibrated to match the emissions trends foreseen in the IEA's latest World Energy Outlook 2008 report.

Historical Accounts

The two scenarios were based on historical accounts of the evolution of each country's energy sector from 1971 to the study base year in 2006. These historical accounts were based on standard data sources, primarily including:

- Energy consumption and production data by sector and by fuel from the IEA's World Energy Balances for non OECD Countries, 2008 . This source provides data on total energy consumption by major sector (households, industry, transport, services, agriculture, non-energy) by major fuel categories in Thousands of Tonnes of Oil Equivalent (TOE) for 1971 to 2006 for all major non OECD countries. In the case of transport, consumption is also broken down by major mode (road, rail, air, water, pipelines) and in the case of industry it is broken down by major manufacturing sector (iron and steel, chemicals and petrochemicals, non ferrous metals, non metallic minerals, transport equipment, machinery, food and tobacco, pulp and paper, wood and wood products, textiles and leather and other manufacturing). In terms of production, the IEA provides information on the consumption and production of energy in major transformation sectors including transmission and distribution, electric generation, oil refining, etc. sufficient to reproduce the energy balances of each country in each year from 1971 to 2006.

- GDP and sectoral value added for services, agriculture, industry and manufacturing in purchasing power parity (PPP) terms from the World Bank World Development Indicators, 2008

- Population data and future population growth estimates from the UN Population projections medium variant, 2006 Revision

- Value added shares for individual manufacturing sectors (iron and steel, chemicals and petrochemicals, non ferrous metals, non metallic minerals, transport equipment, machinery, food and tobacco, pulp and paper, wood and wood products, textiles and leather and other manufacturing) derived from the UNIDO INDSTAT database using 3 digit Rev3 ISIC Codes, with the exception of China which was based on 3 digit Rev2 ISIC Codes.

- Tier 1 emission factors from the IPCC
- Non energy sector emissions from the CAIT database developed by WRI (http://cait.wri.org), although non-energy emissions are not presented in this report.

These data were organized within LEAP to provide a complete historical picture of energy consumption and production trends and their associated GHG emissions.

In terms of energy consumption, a hierarchical data structure was constructed in LEAP to contain energy consumption data by major sector (buildings, industry, transport, agriculture, non energy use and non specified energy use). Transport and industry were further divided into their modes and subsectors (see Figure 22 right).

The same tree structure was utilized across all six countries so that different data could be entered for each country whilst results could be examined in a consistent and comparable format.

Within each of these categories, total historical energy consumption data were entered for each major fuel for every year from 1971 to 2006, and for each fuel standard static IPCC tier 1 GHG emission factors were specified in order to calculate an estimate of emissions for the following pollutants: carbon dioxide (CO2), carbon monoxide (CO), methane (CH4). Note that given the constraints of this project, the same standard tier 1 emission factors had to be used across all countries. Better dynamic emission factors in the form of country and technology specific information would likely yield a better overall estimate of emissions.

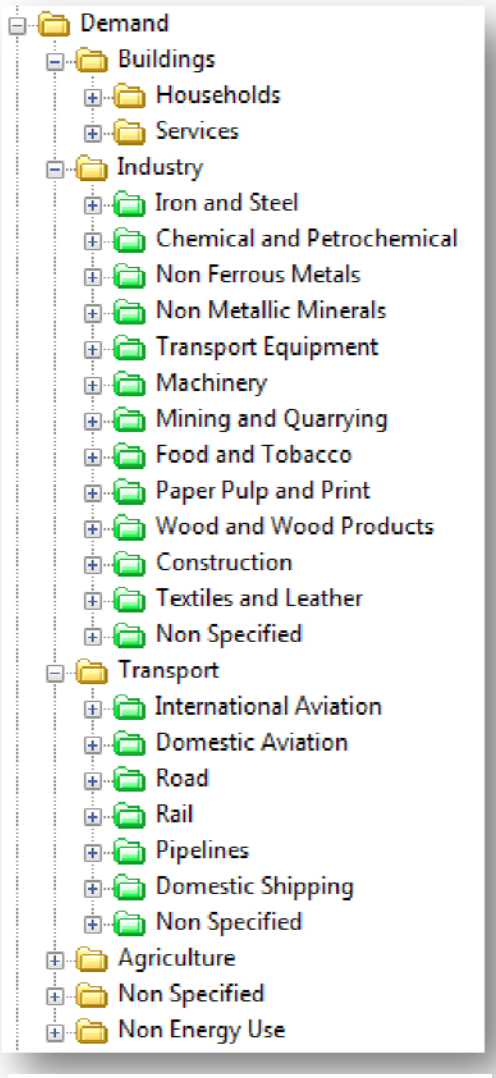


Figure 22: Energy Consumption Structure in LEAP

In terms of energy Transformation, the IEA energy statistics were used to derive a comprehensive historical picture from 1971 to 2006 of energy conversion and transportation in each of the six countries being studied. The IEA data were used to derive historical efficiencies and feedstock fuel shares for each of the following major transformation sectors: transmission and distribution, own use, electric generation, heat production, CHP production, gas works, oil refining and coal liquefaction. In addition, data was specified on energy imports and exports by year for each country. This information when entered into LEAP and combined with the energy demand data described above (as well as historical information from the IEA on stock changes and statistical differences) was sufficient to allow LEAP to be used to calculate the historical energy balances for 1971-2006 for each of the six countries. As with our energy demand analysis, we specified IPCC tier 1 GHG emission factors for each relevant feedstock fuel in order to calculate an estimate of emissions for the following pollutants: carbon dioxide (CO2), carbon monoxide (CO), methane (CH4).

The final step in the historical analysis was to develop estimates of the historical trends in energy intensities and sectoral fuel shares within each major sector. While not required to estimate historical

energy consumption and emissions trends, these trends were later used to help create our baseline projections of energy consumption.

Historical intensities were calculated as follows. In the household sector intensities were calculated per person for the sector as a whole as total energy consumption in TOE divided by the population. In the services and agriculture sector energy intensities were calculated by dividing the total energy consumption by the economic value added in those sectors. Value added in each year was calculated as the GDP in PPP terms divided by the share of value added in each of those two sectors taken from the World Bank World Development indicators database, thus yielding energy intensities in units of TOE per dollar of value added. For each industrial sector, total industrial value added was first divided into manufacturing vs. non manufacturing value added using data from the World Bank World Development indicators database. Manufacturing value added was then further allocated down to industrial subsectors using annual data from the UNIDO INDSTAT database. For the transport, non energy use and non specified sectors, energy intensities were simply calculated in terms of energy consumption per dollar of GDP PPP (TOE/$). These calculated historical energy intensities were later used to help inform the trends developed in the Baseline scenario.

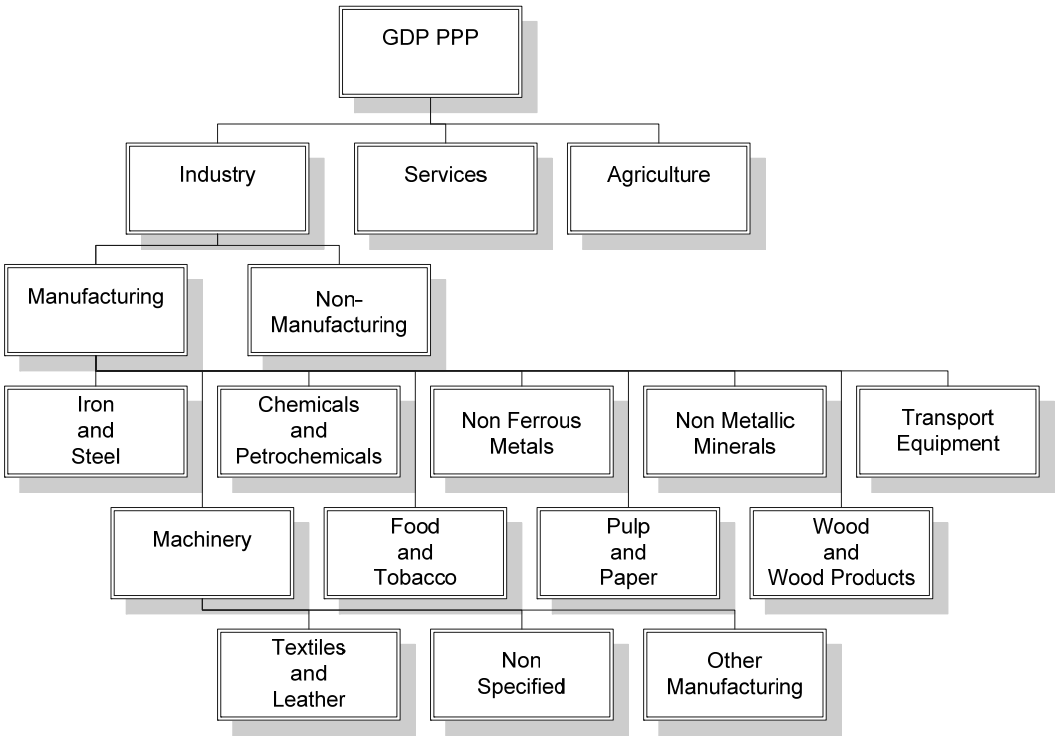


Figure 23: Allocation of GDP to Value Added for Calculation of Energy Intensities

Figure 23 illustrates how GDP values were allocated down to value added in different sectors and subsectors. This allocation approach was important for deriving forward looking scenarios because it allowed future demand forecasts to be derived from overall GDP forecasts combined with assumptions about potential future shifts in the structure of production between industry services and agriculture, and between heavy and lighter industries.

Finally, our historical data set also included information on non energy sector GHG sources from industrial processes, land use change and forestry, agriculture, waste and other sectors. Historical data for these emissions was taken from the CAIT database developed by WRI (which in turn references various other data sources and studies). When reviewing non energy sector GHG emissions it is important to note that these sources of data are not as comprehensive or as well monitored as the IEA's annual energy sector data. For example they are generally available as rough estimates and for only a small number of years for most countries. Thus, they should be considered as being as reliable as the

energy sector emissions. Due to the constraints of this project, we did not consider projections of future sources and sinks for non energy sector GHGs.

The Baseline Scenario

Our baseline scenarios were developed to roughly match the regional projections of the IEA's World Energy Outlook 2008 (WEO2008). Unfortunately, WEO2008 does not include detailed results for all of the countries in this study (in fact it only includes detailed results for China and India). Thus our scenarios are only approximately calibrated to the regional results in WEO2008.

We developed our baseline scenarios as follows.

First within each country projections of population growth from the UN Population projections medium variant, 2006 Revision were combined with future income growth rates for each country taken from the IEA's WEO2008 scenario for the period 2007-2030. Shares of value added among services, industry and agriculture were assumed to stay unchanged from 2007-2030 as were the shares of value added among each industrial subsector. Thus value added in each sector was projected to 2030.

Within each sector fuel shares were extrapolated to 2030 by visually inspecting past trends to extrapolate shares for 2030 whilst bearing in mind saturation effects and the availability of different types of fuels in each country.

In the household sector energy intensities were assumed to increase as a function of the projected increases in income levels in each country. A simple convergence algorithm was developed based on the assumption that energy intensities will converge toward a fraction of current OECD intensities as incomes in each country approach current OECD incomes levels. It was assumed that intensities approach only about 80% of current OECD levels to account for likely future efficiency improvements in the household sector.

In all other sector, energy intensities per dollar of output are expected to decline. Declines in energy intensity were set so that overall energy consumption in each sector of each country in 2030 roughly matched the projections of the IEA WEO 2008 reference scenario. These declines assume a continuation of the declines that have been seen in recent decades in most large non OECD countries albeit at a slower rate than in the past. It is also worth noting that these intensities are declining, in most sectors of these 6 countries intensities remain well above those seen in the OECD (with some notable exceptions such as Korea).

In the Transformation sector, a similar trend extrapolation of conversion efficiencies and feedstock fuel shares was conducted for the electric generation and transmission and distribution sectors. The efficiencies and structures of other sectors were assumed to remain largely unchanged.