# Planning for Higher Oil Prices:
## *Power Sector Impact in Latin America and the Caribbean*

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# Foreword

The past decade has witnessed a rising trend in oil prices. Between 2002 and 2008, prices increased more than fivefold, peaking at prices in real terms not seen since the oil crisis of the 1970s. The spillover effect on the economy has affected consumers, producers, and fiscal balances. Following the 2008 financial crisis, the price of oil fell sharply, bottoming at US$50 a barrel in early 2009, before resuming its upward climb, reaching $109 a barrel in 2011. Nowadays prices are less volatile, yet they remain high and could continue rising if global economic activity fully recovers and demand outpaces supply.

For countries with a large share of oil-based generation, the power sector—a critical channel through which fluctuating fuel prices affect numerous segments of the economy—is especially vulnerable to higher oil prices. Considering the possibility for higher prices in the future, it is vital that energy planners in Latin America and the Caribbean (LAC) understand how higher oil prices in the years ahead could impact their plans for additional capacity generation.

This study analyzes the potential short- and long-term impacts of high oil prices on the power sector in the LAC region. The findings show that changes in the cost of power generation resulting from higher oil prices could have a significant financial impact on economies of the region. The effect would be particularly substantial in net oil importing countries. In the oil price scenarios evaluated, the generation matrix readjusts considerably at $150 per barrel if oil prices make other technologies more competitive with fuel oil or diesel.

Given the large potential impact of higher oil prices on the power sector and broader economy, especially in oil importing nations, it would be prudent for energy planners in the LAC region to take steps now to reduce future risks. The results documented in this report suggest that LAC energy planners should diversify their power generation portfolio, increasing generation from both renewable and non-renewable sources, and promote energy efficiency options to reduce longer-term demand for oil-based generation.

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# Abbreviations and Acronyms

| | |
|---|---|
| AR | Autoregression |
| CCGT | Combined-Cycle Gas Turbine |
| ECLAC | UN Economic Commission for Latin America and the Caribbean (CEPAL, *Comisión Económica para América Latina y el Caribe*) |
| EIA | U.S. Energy Information Administration |
| ETOAG | Energy Technology Assessment Guide (now known as META) |
| FOB | Free On Board |
| GHG | Greenhouse Gas |
| HFO | Heavy Fuel Oil |
| IEA | International Energy Agency |
| IPP | Independent Power Producer |
| LAC | Latin America and the Caribbean |
| LCSSD | Sustainable Development Department for Latin America and the Caribbean Region |
| LNG | Liquefied Natural Gas |
| META | Model for Electricity Technology Assessments (formerly ETOAG) |
| MSW | Municipal Solid Waste |
| OECD | Organisation for Economic Co-operation and Development |
| OLADE | Latin American Energy Organization (*Organización Latinoamericana de Energía*) |
| OPEC | Organization of the Petroleum Exporting Countries |
| VAR | Vector Autoregression |
| WDI | World Development Indicators |
| WTI | West Texas Intermediate |

## Units of Measure

| | |
|---|---|
| Btu | British Thermal Unit |
| $gCO_2$ | Grams of Carbon Dioxide |
| GW | Gigawatt |
| GWh | Gigawatt Hour |
| kg | Kilogram |
| kW | Kilowatt |
| kWh | Kilowatt Hour |
| mmcf | Million Cubic Feet |
| MW | Megawatt |
| MWh | Megawatt Hour |
| TWh | Terawatt Hour |

# Executive Summary

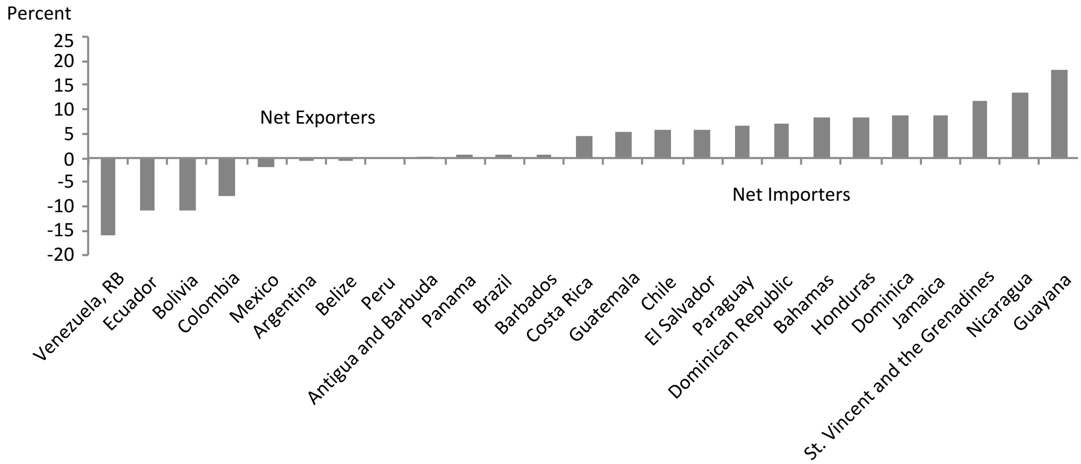
***As a result of high oil prices, countries in Latin America and the Caribbean (LAC) could face significant headwinds along their growth and development path.*** Higher oil prices affect a wide range of variables—from economic growth and production costs and inflation to trade balance, exchange rates, and competitive advantage. In turn, households pay more for electricity, heating, and transport services; firms face higher costs for providing goods and services; and governments often confront the challenges of larger subsidies, more complex macroeconomic management, and possible backtracking on poverty reduction programs. Given the regressive effects of energy shocks on society, it is vital that LAC energy planners understand how higher oil prices in the future could impact their plans for additional capacity generation in the coming years.

***This study aims to evaluate the impact of higher oil prices—those above US$100 per barrel—on the cost of generating electricity in countries of the LAC region in order to better inform energy policy planning.***[1] The study's main objectives are to (i) analyze the economic effects of higher oil prices on LAC countries, particularly oil importing nations; (ii) assess the short-term impact on electricity generation costs based on the composition of generation matrices across countries in the region; and (iii) quantify the long-term impact on electricity costs if countries modify the composition of their generation matrices in response to higher oil prices. The purpose is not to forecast specific oil prices or predict high prices in the future; rather, the intent is to select a sufficiently high potential oil price to delimit a framework for evaluating its impact on relevant macroeconomic variables and the LAC power sector.

***Countries in the LAC region exhibit a wide range of differences in their net oil trade position relative to gross domestic product (GDP).*** At one end of the spectrum, Venezuela, RB has net fuel exports equivalent to 16 percent of GDP. At the opposite end, Guyana's net fuel imports equal about 18 percent of GDP. Between are such countries as Belize and Peru, which exhibit more balanced fuel imports and exports. Countries that are net oil importers are more vulnerable to higher oil prices, while net exporters are more likely to benefit (Figure ES.1).

***Oil shock–driven economic downturns would create greater risk exposure for oil importing nations, which could trigger a balance-of-payments problem;***

**Figure ES.1 Net Fuel Imports Relative to GDP in Selected LAC Countries, 2010**




*Sources:* World Bank 2011; authors' calculations.
*Note:* 2009 figures are used for Honduras.

***conversely, oil exporters would see faster growth and improved current accounts.*** Importers would experience higher inflation.[2] The World Bank (2006) suggests that every 25 percent rise in the price of West Texas Intermediate (WTI) would mean a 1 percentage point increase in net oil importers' subsidy outlay relative to government expenditure. This study's estimates suggest that the average effect of an oil price doubling from US$100 to $200 per barrel on GDP growth would be approximately +0.67 percentage points for oil exporters and −0.33 percentage points for oil importers. The regressive effects on society would be borne mainly by lower-income residents since their household expenditures represent a larger proportion of income. Given that the LAC region is highly unequal, greater wealth and income disparities could occur.

***The power sector's vulnerability to higher oil prices is particularly acute, suggesting its significance as a channel through which fluctuating fuel prices affect the greater national economy.*** For example, in oil importing countries of the Caribbean that rely heavily on fossil fuels for power generation, a US$50 increase in the price of oil could raise electricity prices by about 5¢ per kWh on average—assuming the entire price increase is passed through to consumers—representing a 10 percent increase in electricity costs. Many governments across the LAC region have attempted to insulate their populations from costly oil by subsidizing fuel oil, gas, and electricity prices, with negative effects on the fiscal budget. Even such oil exporting countries as Mexico and Venezuela, RB could face mounting budgetary pressures if fuel and electricity pricing structures are not aligned to pass through international price increases to the domestic market.

***Higher oil prices create statistically significant, opposite effects on GDP growth and the current account in net oil importing and exporting nations.*** To predict the potential economic effects of a continued upward trend in oil prices for the LAC region, this study conducted a sensitivity analysis for net oil importing and exporting countries, using three oil price scenarios. US$100 per barrel was taken as the initial price, with the three scenarios corresponding to $125, $150, and $200 a barrel. Results indicate that a 25 percent price increase would accelerate GDP growth by 0.17 percentage points in net oil exporting nations and decrease it by 0.08 percentage points in net oil importing countries. The current account balance would improve by 1.35 percentage points for net exporters and would worsen by 1.44 percentage points for net importers. A 50 percent price increase would increase GDP growth by 0.34 percentage points for oil exporters and decrease it by 0.17 percentage points for net importers. For oil exporters, the current account balance would grow by about 2.7 percentage points relative to GDP and would decrease by 2.9 percentage points for oil importers. Finally, a price doubling would increase oil exporters' economic growth by 0.67 percentage points and reduce it by 0.33 percentage points for oil importers. The current account balance of oil exporters would grow by about 5.4 percentage points relative to GDP and would decrease by 5.7 percentage points for oil importers.

***Simulation results suggest that higher oil prices would lead to higher inflation and require larger subsidy outlays, depending on the pricing policy mechanism in place, particularly in net oil importing countries.*** For example, a 50 percent price increase could cause inflation to rise by up to 1.64 percentage points in oil importing countries over the course of a year based on annual impact estimates. A price doubling to US$200 per barrel could increase subsidies as a fraction of government expenditure by up to 3.3 percentage points. For all three simulations, a pass-through of the entire price increase would lead net oil importers to switch to alternative generation sources, based on the historical aggregate share of oil in power generation. The share of non-oil power generation could increase by 3.6 percentage points.

***In the short term, higher oil prices would make power-sector producers more vulnerable since there would be little flexibility to adjust the electricity generation mix.*** The countries most affected would be those that rely heavily on oil-fired power generation; that is, most Caribbean countries, with Jamaica, Haiti, Nicaragua, and the Dominican Republic exhibiting the largest increases in electricity production costs. A second larger group, with lower levels of oil-based thermal generation in its energy mix, would still face significant cost increases. This group comprises Argentina, Bolivia, Ecuador, Mexico, Trinidad and Tobago, and Uruguay, along with four countries in Central America (El Salvador, Guatemala, Honduras, and Panama). A third group, which generates a larger share of its electricity from hydropower resources, would be less affected. This group consists of Brazil, Chile, Colombia, Costa Rica, Paraguay, Peru, Uruguay, and Venezuela, RB.

***The short-term impact on electricity generation costs could increase the region's electricity tariff by 8 percent on average.*** For any particular country, the impact would depend on the share of oil in its generation matrix, the cost of generation as a share of total electricity production cost, and the pricing policies and pass-through mechanisms in place. For example, in countries with a high share of oil-based generation with pass-through mechanisms in place, a US$50 price increase (i.e., from $100 to $150 per barrel) would raise the electricity tariff by up to 21 percent. In countries with a low share of oil-based generation with large subsidies in place for household consumers, a full pass-through could raise the electricity tariff by up to 84 percent.

***Changes in the cost of power generation resulting from higher oil prices could have a significant financial impact on economies of the LAC region.*** The effect would be particularly substantial in net oil importing countries. For the Dominican Republic, Honduras, and Nicaragua, the increase in electricity cost resulting from a US$50 per barrel price hike would amount to more than 1 percent of GDP per year and nearly 3 percent a year in the case of Jamaica. The magnitude of these increases relative to these countries' economies underscores the need to diversify their energy matrices to reduce their vulnerability to oil price fluctuations.

***To determine how the LAC region could meet the added incremental growth in electricity demand required by 2030 with oil at US$150 a barrel, two scenarios were developed.*** Taking 2009 as the baseline year, Scenario 1 assumes that natural gas and oil prices will move in tandem, while Scenario 2 assumes that the price of natural gas will decouple from that of oil, remaining low despite higher oil prices. In both scenarios, the generation matrix is readjusted considerably if oil prices make other technologies more competitive with fuel oil or diesel. Substitution with renewable energy sources is considered to the level that is technically possible, prioritizing the use of cheaper technologies; and non-renewable sources are used to generate excess demand in the same proportion as that of the 2009 electricity matrix.

***Under Scenario 1, assuming pass-through, a US$50 oil price increase would lower the share of electricity generation from fuel oil and diesel by 10 percent, resulting mainly from the expanded use of natural gas.*** The average cost of electricity generation with fuel oil would grow by 6¢ per kWh (from 15 to 21¢), while the cost of diesel-powered generation would rise by about 8¢ per kWh (from 19 to nearly 27¢). The price of natural gas would rise moderately along with oil prices, while coal prices would remain fairly constant. The share of natural gas in total generation would increase by 6 percent.

***With oil at US$150 a barrel, hydropower, along with natural gas, would dominate the region's generation mix.*** Hydropower will increase in absolute terms, although the percentage of hydro generation could decrease in relative terms by 4 percent (from 59 to 55 percent). Over the next 20 years, an additional 642,449 GWh could be required—95 percent more than what the region currently produces—meaning that current hydro generation would need to nearly double.

***In addition, a window of opportunity would open for generating more electricity from other renewable sources.*** Wind energy generation, currently concentrated in Brazil and Mexico, would be developed considerably in Argentina, Chile, the Dominican Republic, and Haiti. In Brazil, generation from biomass would increase nearly fivefold by 2030, raising the overall average for the LAC region. Geothermal generation, previously limited to Costa Rica, El Salvador, Mexico, and Nicaragua, would be developed substantially in Chile, where it could reach up to nearly 6 percent of the national generation mix by 2030.

***Under Scenario 1, fuel oil and diesel could be substituted with cheaper generation sources in most countries.*** With oil priced at US$150 per barrel, it would make sense for many countries to diversify away from traditional thermal generation. Haiti, for example, could switch from oil-fired generation to a mix of hydro, natural gas, and wind by 2030 and thus reduce emissions. Bolivia, Colombia, Ecuador, Honduras, Peru, and Venezuela, RB could generate all of their required electricity using only hydro and natural gas. However, fossil-fuel use would persist in Caribbean countries, which have limited options to diversify their generation sources.

***With oil priced at US$150 per barrel, electricity prices would be high enough to promote diversification away from oil-based generation.*** As a result of higher oil and gas prices, the cost of electricity generation in 2030 could be 10¢ per kWh higher than in 2009, when the average oil and gas prices were $62 per barrel and $3.67 per mmcf, respectively. In such countries as Bolivia, Brazil, and Peru, greater use of natural gas would suffice to increase the total cost. Caribbean countries would face higher generation costs due to limited options for substitution in their generation matrices. However, Ecuador and countries in Central America (i.e., El Salvador, Guatemala, Honduras, Nicaragua, and Panama) would see their costs reduced considerably as a result of switching from diesel to hydro generation.

***Under Scenario 2, which assumes natural gas prices remain constant, a total substitution of fuel oil and diesel with natural gas and wind could occur.*** Compared to Scenario 1, natural gas would comprise 4 percent more of the generation mix (29 percent versus 25 percent), while wind would account for 1 percent more (2 versus 1 percent).[3] In Argentina alone, wind would account for 4 percent more of generation than in Scenario 1 (7 percent versus 3 percent) due to the complete substitution of oil. Conversely, biomass and hydropower would comprise 2 percent and 1 percent less, respectively. Hydro would account for a smaller share of generation in Chile, Costa Rica, El Salvador, Guatemala, Nicaragua, Panama, Uruguay, and Venezuela, RB. Finally, nuclear and geothermal shares would remain constant, at 4 percent and 1 percent, respectively. By 2030, the regional cost of electricity generation (US¢ per kilowatt hour) would decrease slightly from 2009 levels.

***Results of this study's simulations suggest the dominance of both hydropower and natural gas in the LAC region's total electricity generation mix.*** The potential for hydropower generation would be considerable, given its price competitiveness with other available renewable sources to meet the region's expected demand growth by 2030. If natural gas prices were to remain constant, the region could achieve a total substitution of fuel oil and diesel generation by 2030, resulting mainly from the expanded use of natural gas, as well as wind energy, particularly in Argentina.[4] In turn, the region could reduce its vulnerability to future oil price increases and the average cost of generation per kilowatt hour, with countries in Central America experiencing the largest cost savings.[5]

***By 2030, the replacement of oil in the LAC region's generation mix could reduce greenhouse gas (GHG) emissions by 18 percent or 23 percent, respectively, under Scenarios 1 and 2 (compared to 2009 levels).*** Central America and the Caribbean—subregions historically more vulnerable to higher oil prices because of their heavy reliance on oil-fired generation—would stand to benefit the most. If natural gas prices rise, Central America could cut its GHG emissions by two-thirds or by half if gas prices decouple from oil. In either case, the Caribbean could see a 30 percent reduction in GHG emissions.

***The key challenge for energy planners is managing future electricity demand in a way that maintains sufficient economic growth without compromising the public budget.*** Meeting this goal requires making difficult decisions on multiple fronts, including how to diversify the power generation portfolio, enhance energy efficiency, increase generation from renewable sources, and shift peak load through demand-side management. This study illustrates the significant potential for both renewable and non-renewable energy sources, particularly natural gas, to comprise a larger share of electricity generation. Though future correlations between oil and natural gas prices are unclear, the current pattern introduced by the shale gas revolution in the U.S. suggests the advisability of diversifying from oil to natural gas–based generation. For countries heavily dependent on oil-based imports, the benefits of such diversification could include increased competitiveness and less risk exposure to oil price volatility.

***The large impacts of higher oil prices on the economy and power sector, especially in oil importing nations, suggest the need for LAC energy planners to take steps now to reduce future risk.*** The results of this study's analysis suggest that considerable investment will be required; however, the potential gains are many, including lower electricity prices for consumers (and potentially lower subsidies) and significant reductions in GHG emissions. Making the needed changes in the energy matrix to meet these optimistic goals will require an enabling policy environment with institutional and regulatory flexibility. The challenge is great; yet the cost of not planning how to reduce the risk of higher oil prices in the future could be considerable.

## Notes

1. The recent upward trend in oil prices suggests that sustained higher prices above US$100 per barrel are plausible in the foreseeable future. In the 2001–06 period, the price of oil rose from US$30 to nearly $70 a barrel and nearly doubled again by 2008, setting a new monthly record high of $133 per barrel. The price fell sharply during the ensuing financial crisis, bottoming at $50 a barrel in early 2009, and subsequently resumed its upward price climb, reaching $109 a barrel in 2011.

2. The extent of import- and export-dominant countries is changing. Most oil exporters, including Argentina, Ecuador, Mexico, and Venezuela, RB, have decreased their position as global suppliers, while Colombia has more than doubled its exports with respect to local consumption. In the case of oil importers, Chile, Honduras, and Panama have increased their external supplies more than other oil-importing countries.
3. The use of natural gas increases only 4 percentage points because it is substituting for hydro and biomass generation. Due to high oil prices (US$150 per barrel), most oil-based electricity generation under Scenario 1 was already substituted by hydro and gas.
4. The only exception would be Jamaica, which would rely on oil generation in both scenarios owing to its limited renewable energy potential.
5. By 2030, Nicaragua, Honduras, and Guatemala could see reductions of about 35, 33, and 30 percent, respectively, compared with 2009 levels.

CHAPTER 1

# Introduction

Oil prices are pivotal in deciding how to meet future energy needs. They establish the basis for comparing the costs and benefits of alternative fossil fuels and renewable energy sources, thus determining the future energy matrix. They also play an important role in infrastructure planning, which is based on least-cost considerations. Current and future fuel prices are usually included as a factor of uncertainty in assumptions relied on by decision-making models for planning the expansion of power-system capacity.

Higher oil prices raise the overall cost of electricity, having a greater effect in countries where oil comprises a larger share of the power generation matrix. In deciding about future generation investment, higher oil prices make renewable energy more attractive on the basis of cost benefit analysis. A scenario with higher oil prices has important implications for diverting from oil-based technologies to renewables, as well as gas, coal, and nuclear alternatives.

Today oil is constrained by supply shortages, paired with a substantial boost in demand, resulting from higher energy requirements in China, India, and other developing countries and regions. By 2030, energy demand in Latin America and the Caribbean (LAC) is expected to double from 2008 levels (Yépez-García, Johnson, and Andrés 2011). This expected demand growth presents a serious challenge for the region's energy sector. A key issue is deciding on the most appropriate mix of fuels for power generation, given the various prices of energy sources and technologies, as well as availability of renewable energy.

## 1.1 Study Purpose

This study's broad aim is to evaluate the impact of higher oil prices on the cost of generating electricity in countries of the LAC region so that better-informed energy policy planners can buffer future adverse effects. The study defines high oil prices as those above US$100 per barrel. This price is considered a reasonable starting point for discussion given the recent range in oil prices, which averaged $95 a barrel in 2011. A price of $150 per barrel is defined as considerably high yet plausible given historical and current price levels, available forecasts, and other potential price drivers.

The study's specific objectives are to (i) analyze the economic effects of higher oil prices on LAC countries, particularly oil importers; (ii) assess the short-term impact on electricity generation costs based on the composition of generation matrices across countries of the region; and (iii) quantify the long-term impact on electricity costs if countries modify the composition of their generation matrices in response to higher oil prices. A key question is what would happen to natural gas prices if oil prices scaled up above US$100 per barrel. In this context, the decoupling of natural gas prices from the price of oil would have an important effect on generation costs. Although it is difficult to assess the future price correlations between oil and gas in North and South America, it is worthwhile to make some assumptions about them and evaluate their impact on planning decisions for electricity generation in the years ahead.

The purpose of this evaluation is not to forecast specific oil prices or predict high prices in the future; rather, the intent is to select a sufficiently high potential price to delimit the framework for evaluating its impact on relevant macroeconomic variables and the LAC energy sector. Presenting the possibility of such a scenario can raise awareness among energy planners, institutions, government officials, and other decision makers to stimulate deeper analysis and discussions and thus better inform the energy-policy planning process.

## 1.2 Structure of This Report

This report is organized as follows. Chapter 2 presents the framework for analyzing the impact of higher oil prices, including an overview of recent price trends, major drivers of oil and gas prices, and a medium-term scenario under which higher prices might occur. Chapter 3 analyzes the impact of higher oil prices on LAC countries. It assesses country risk exposure; offers a regionwide statistical analysis, showing the recent impact of higher prices on macroeconomic and power-sector indicators; and provides three price scenarios to assess the potential impact of higher oil prices on those variables. Chapter 4 focuses on the short-term impact of higher oil prices on the electricity sector and the potential impact on the cost of generation, depending on the planning decisions made for future electricity generation. It reviews recent vulnerability in electricity generation costs, estimates the short- and long-term effects of a US$50 price increase on LAC countries, and provides two high oil price scenarios for meeting additional incremental electricity demand to 2030, with implications for reducing greenhouse gas emissions. Finally, Chapter 5 offers policy makers recommendations on the relevance of considering the potential impact of higher oil prices on countries' fiscal and trade balances, the cost of electricity to final consumers, and the impact that such cost might have on the competitiveness of their productive sector.

CHAPTER 2

# High Oil Price Scenario

*Framework for Analysis*

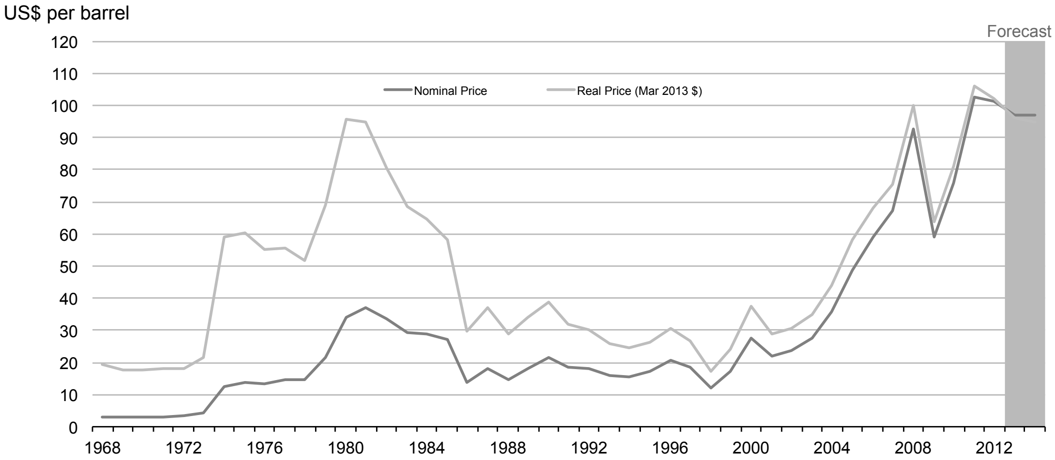
Today the limits of oil supplies are being pushed to meet current and prospective energy demand requirements, particularly in fast-growing developing countries, placing added pressure on oil prices. Substantial increases in incremental supply, combined with the unlikelihood of economic slowing in developing countries, suggest continued market tightness,[1] making sustained high oil prices above US$100 per barrel quite plausible in the foreseeable future. How would such a scenario affect the economies of the LAC region, particularly the energy sector? Both macroeconomic and microeconomic disruptions would be likely, with diverse effects on households, utilities, firms, and governments across the region. For oil-importing nations characterized by a large share of fossil fuels in their energy matrix, macroeconomic stability could be severely affected.

This chapter begins with a brief overview of recent trends in oil prices and current price levels. It then describes five major factors that influence oil and gas prices. Finally, using the data contained in the available oil price forecasts, it considers the circumstances under which a high oil price scenario might occur over the medium term.

## 2.1 Oil Price Trends

Over the past decade, oil prices have generally trended upward, characterized by periods of significant price volatility (Figure 2.1). Over a five-year period (2001–06), the price more than doubled, rising from US$30 to nearly $70 per barrel. The price peak of 2006 was eclipsed two years later by a new average monthly high of $133 per barrel. During the ensuing financial crisis, oil prices declined sharply, bottoming at $50 a barrel in February 2009. Subsequently, as economic conditions began to improve and the Organization of the Petroleum Exporting Countries (OPEC) agreed to cut production,[2] oil resumed its upward price climb, reaching $89 per barrel by December 2010. Early the next year, arguably as a result of increased geopolitical risk, the price rose further to

**Figure 2.1 Annual Price Estimates for Imported Crude Oil, 1969–2013**




*Source:* EIA 2013a.

$109 per barrel and remained above $100 a barrel through mid-2011. For 2011 overall, West Texas Intermediate (WTI) averaged $95 a barrel, oscillating between $85 and $109 a barrel.[3]

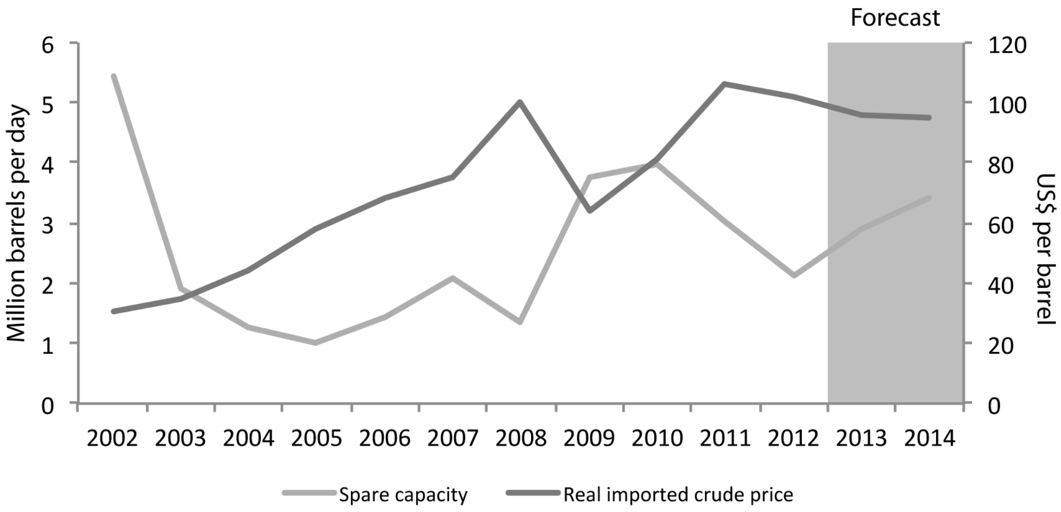
In real terms, the high price levels witnessed during 2007–08 are of the same magnitude as those registered during the 1970s, which resulted from the 1973 oil embargo and Iranian conflict (Kesicki 2010) (Figure 2.1). Various studies argue that the 2007–08 price behavior was fueled, in part, by higher demand originating in such developing countries as China. Kaufmann (2011) establishes that the price increase was driven by both market fundamentals that considered supply-demand factors, as well as speculation. Another potential supply-side driver of higher prices, highlighted in the literature, was the stalled production growth of non-OPEC oil in mid-2000s, combined with OPEC's decreased spare capacity (Figure 2.2).

Given these historical price trends, what is the possibility of a future scenario featuring sustained oil prices above US$100 per barrel? Answering this question requires a better understanding of the key factors that influence oil price behavior, which is the topic of the next section.

## 2.2 Key Drivers of Oil Prices

Attempting to understand the factors that drive oil price behavior is an enormous challenge, particularly since the literature is replete with analyses of influencing factors. That said, the most widely accepted market and speculative factors that interact to drive the behavior of oil pricing and volatility are (i) oil supply, (ii) oil demand, (iii) market tightness, (iv) financial markets, and (v) external events.

**Figure 2.2 Oil Price and OPEC Spare Capacity, 2002–14**




*Source:* EIA 2013a.

### *2.2.1 Oil Supply*

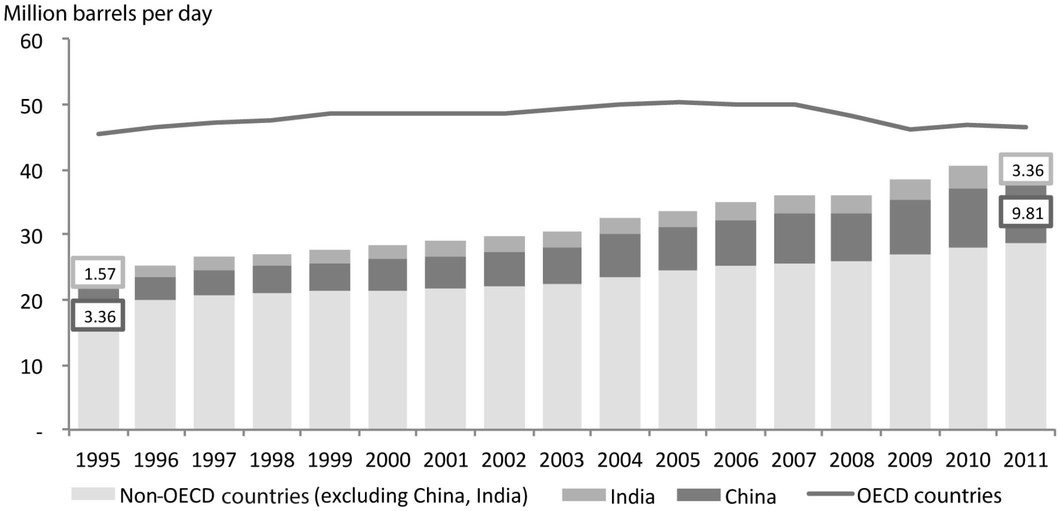
According to the U.S. Energy Information Administration (EIA), nearly two-fifths of the world's crude oil supply is currently provided by OPEC member countries, with an annual daily output of about 34 million barrels.

The large volume traded by OPEC member countries on the international markets correlates with the organization's power to influence market prices. The literature discusses target-pricing methods that OPEC used in the early 2000s, before abandoning them in late 2003 (OECD 2004). These included a price-band mechanism, whereby it would push to increase or decrease production if the price of oil had reached a certain limit over a number of consecutive days (Horn 2004). Non-OPEC countries account for the remaining three-fifths of world oil production, with a daily output of nearly 50 million barrels. Because these countries do not operate under production agreements, they are free to decide when and how much to produce. This increases the likelihood that they operate under a market mentality that responds to market prices, rather than attempting to influence them.

### *2.2.2 Oil Demand*

In the simplest terms, a country's demand for oil and oil products is based on the intensity of its economy. An economy's size and growth rate correlate with the amount of oil needed to support the energy requirements of its region. Demand for oil can also be categorized by whether a country is a member of the Organization for Economic Co-operation and Development (OECD). According to the EIA, in 2010, OECD member countries demanded about 53 percent of world oil production (46 million barrels a day), of which the U.S.

**Figure 2.3 Oil Consumption in Non-OECD Countries, 1995–2011**




*Source:* Authors, with EIA data.

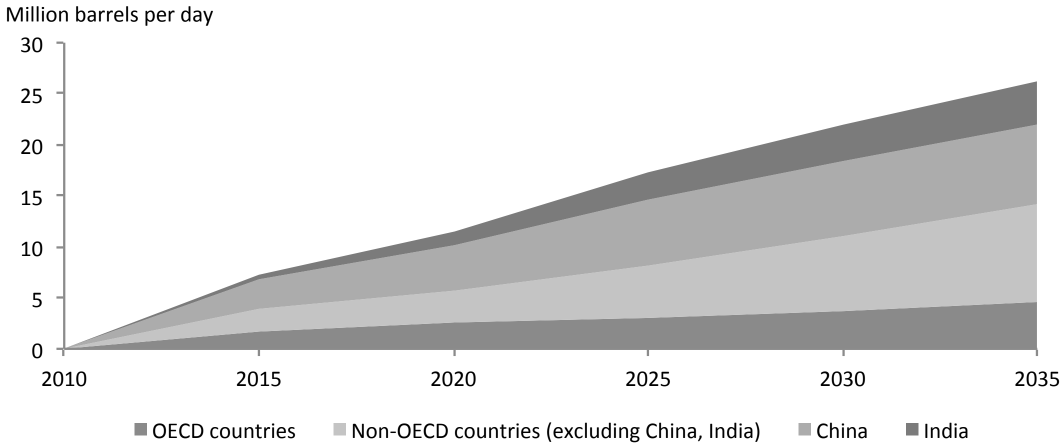
accounted for about two-fifths (19 million barrels a day). Non-OECD countries accounted for the remaining 47 percent. From 1995 to 2010, consumption in non-OECD countries grew by 18 percent, with China and India comprising a significant proportion of that growth. Over the 15-year period, China's oil demand nearly tripled, while India's almost doubled (Figure 2.3).

Global demand for oil and the resulting oil prices can be greatly influenced by current and expected future economic growth. In addition, energy intensity defines demand for oil to support growth. Such sectors as manufacturing have a higher energy intensity compared to service or agricultural sectors. For countries that rely heavily on manufacturing to support economic growth, the greater energy intensity per unit of GDP generated may require larger volumes of oil and other fossil fuels. In many countries, oil and oil products are vital to supporting the economy, especially the transport sector, and generating the power needed by productive sectors. Such rapidly growing economies as China and India suggest the need to allocate large amounts of oil to support this development (Figure 2.4).[4]

### *2.2.3 Market Tightness*

In addition to production, such market variables as inventories and reserves stored as inventories play a role in determining the mechanism by which demand for oil is satisfied. These variables may be used at various points in time to match available supply with current and expected future demand. Because resources must be transported and processed, it takes time for supply to reach the final market; for this reason, inventories are often used as a buffer to sat-

**Figure 2.4 Expected Incremental Growth in Oil Demand, 2010–35**




*Source:* Authors, with EIA data.
*Note:* Annual increments with respect to 2010 demand.

isfy immediate demand. In this context, market analysts use oil inventories as an indicator to evaluate market tightness.

How inventories are interpreted must occur in the context of a particular setting with clear assumptions—this can be difficult since the analysis can support different conclusions. For example, from the perspective of the physical market,[5] inventories can be used to satisfy current demand; however, they can also be analyzed in the context of future price expectations. An increase in inventories can further increase prices if the market considers that growing demand is the driving force behind the accumulation of precautionary stocks. In the context of sustained economic growth, this can lead to a reinforcing circle of increasing prices. Conversely, if the market perceives that larger stocks are the result of a supply glut, prices will face downward pressure. Although it can be difficult to generalize how the variation in inventories can affect prices (and vice versa), it is undeniable that the market will jointly adjust price expectations and inventory levels.

Another influencing factor is the logistical imbalance between global oil supply and local demand. While global supply may suffice to satisfy global demand, local processing capacity and availability may present a constraint, given the various types of oil. Regional imbalances between availability of a certain grade of oil and refinery infrastructure may put pressure on the price of that grade. Such a mismatch occurred in the U.S. in 2004; the heavy grade of oil high in sulfur that was available on the market was of little use to industry, which demanded a light, non-sulfur crude to maximize gasoline production for the season (OECD 2004).

Refinery utilization rates are used to measure the balance between local capacity and the amount of oil that refiners decide to run. Their decision can be affected by crude oil availability, infrastructure constraints, prevailing prices for both feedstock and refined products, and even temporary disruptions related to weather or geopolitical events. Crude may be available in various grades (e.g., heavy or light) and qualities (e.g., sweet or sour [indicative of sulfur content]). However, refineries are designed to operate more efficiently for certain oil types. Light crude is generally of better quality since processing it requires less capital-intensive infrastructure and yields greater volumes of highly-valued products, including gasoline. Much of the world's current oil refinery capacity is designed to process light sweet crude, which is queued first for production, while heavy crude is frequently processed in the margin (McKinsey Global Institute 2011).

The distance between oil production fields and refineries means that transport via pipelines or tankers is often necessary. But limited availability of transport capacity can hinder achieving a balance between global supply and local demand. For example, transport constraints for oil and oil products can drive up oil tanker rates, with the increased cost transferred directly to the price of crude.

#### *2.2.4 Financial Markets*

Financial markets are one of the main arenas in which the expectation of continued market tightness occurs. Market participants can buy and sell physical quantities of oil, as well as trade contracts for its future delivery. Private companies and oil-producing countries seek to co-locate their physical production of oil, while buyers seek to acquire those physical quantities to run their businesses (e.g., airlines or refineries). Additionally, market agents seek to profit from oil transactions, speculating on commodity prices, risk, and instruments for current or future transactions. According to the International Monetary Fund (IMF), the expectation of continued market tightness, along with market fundamentals (i.e., supply-demand interaction), was the primary driver of crude oil prices during 2003–05 (IMF 2005).

#### *2.2.5 External Events*

Geopolitical and weather-related events also influence the price of oil and oil products. Such events may disrupt the physical production and flow of products to markets or simply increase uncertainty about future supply and demand, modifying the supply-demand balance and driving up prices and volatility.

### 2.3 Creating a Medium-term Scenario for Analysis

Taking the WTI range of US$80–109 per barrel as the starting point,[6] how high could the price of oil rise over the next decade if the above-described drivers of oil pricing were to coincide to further tighten the market? Given the main factors that drive oil prices, along with the forecasts of industry experts, a price range of $100–150 per barrel would be plausible under a certain set of circumstances. To analyze the impact on the LAC region, we construct a framework using $100 and $150 per barrel. For purposes of comparison, the subsection below summarizes available oil price forecasts.

### *2.3.1 Oil Price Forecasts*

For the reference scenario—business as usual with current trends—the average WTI spot price climbs from US$88 to $161 over a 25-year period (2015–40) (Table 2.1).

The EIA reference case assumes that current practices, policies, and trends continue over the medium term. For example, it assumes continuous, robust economic growth in non-OECD countries, including Brazil, China, and India. For the same 25-year period, the EIA presents a high oil price scenario, with an average price of US$181 per barrel; by 2040, the price of crude would be expected to reach $235 a barrel. This scenario assumes higher annual GDP growth in non-OECD countries than in the reference case. Considering this forecast, the $100–150 price range selected for our analysis is quite reasonable.

### *2.3.2 Oil and Gas Price Correlations*

Oil and natural gas are the two most important hydrocarbon fuels in the energy matrix of most countries. Given that their price evolution is critical for energy-sector planners and investors, one must consider the price of gas in order to better grasp the implications of high oil prices.

Much research has focused on analyzing gas price behavior in relation to the price of oil. For example, Hartley, Medlock, and Rosthal (2008) conclude that an indirect price relationship results from market competition between natural gas and residual fuel oil. Brown and Yucel (2007) also discuss this concept, explaining that industry and electric power generators can switch between natural gas and residual fuel oil, depending on which is less expensive. Based on their regression analysis, these authors' study indicates that the prices are correlated; using data from 1994–2006, they show that a 150 percent increase in the price of oil means a 162 percent increase in the price of natural gas. However, they also argue that short-term price correlations may be unimportant given the more immediate factors of seasonality, extreme weather conditions, and resource disruptions, which may distort the supply-demand balance.

**Table 2.1 Projected WTI Spot Price, 2010–40**

| *Scenario Type* | *2010* | *2011* | *2015* | *2020* | *2025* | *2030* | *2035* | *2040* |
|---|---|---|---|---|---|---|---|---|
| High oil price | 81 | 95 | 126 | 153 | 171 | 190 | 211 | 235 |
| High economic growth | 81 | 95 | 89 | 105 | 118 | 132 | 148 | 167 |
| Reference | 81 | 95 | 88 | 104 | 115 | 128 | 143 | 161 |

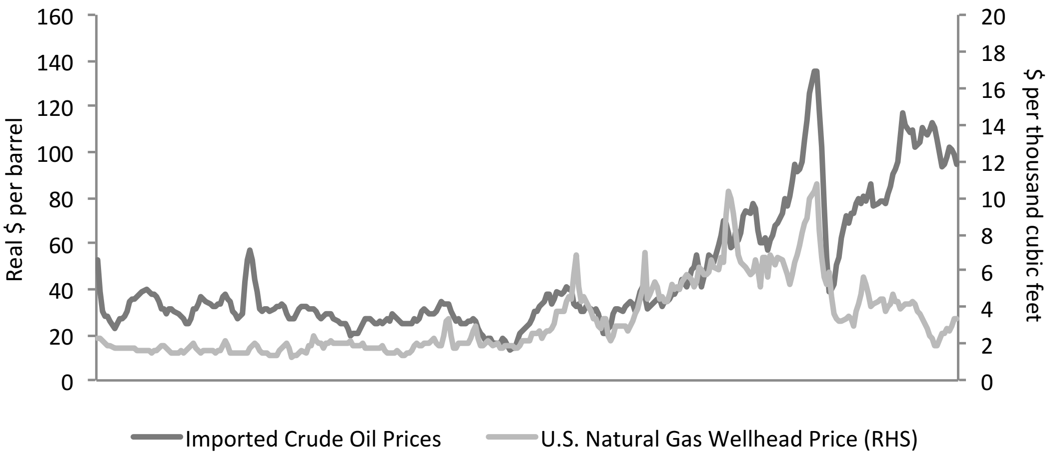
*Source:* EIA 2013b.
*Note:* Projected prices are presented in 2011 US$ per barrel.

Some argue that oil and gas prices in North America, which usually moved in tandem prior to 2008, have begun to diverge (e.g., De Bock and Gijon 2011). The increasing decoupling of crude oil and gas prices in the North American market has intensified discussion on this topic (Figure 2.5). The IMF (2005) argues that this decoupling behavior coincides with increased non-conventional gas production in the U.S., especially shale gas, whose excess supply has fueled speculation on the possibility of the U.S. becoming a gas exporter.

It must be stressed that gas market analysis, like that of the oil market, is highly complex, considering how many diverse factors may affect its behavior. For example, the above-mentioned analyses refer only to the North American market.[7] However, gas is traded on three major markets—North America, Europe, and Asia—each of which behaves distinctly (MIT 2011). For example, the European market is based on "long-term contracts with price terms based on a mix of competing fuels," such as fuel oil, while the Asian market relies on natural gas prices, which are the result of a benchmark with oil prices.

In this context, the relationship between oil and gas prices is unique for each of the three markets. Supply-demand market fundamentals are arguably an important factor in understanding the basics of gas pricing. As the International Energy Agency (IEA) notes, Henry Hub gas prices have been low as a result of abundant supply in North America, while in Europe, prices have risen as a result of constrained global gas markets (IEA 2011). The study indicates that supply is ample for meeting the 15 percent global demand growth expected over the 2010–2016 period, which is mainly from non-OECD producing countries.

**Figure 2.5 Wellhead Natural Gas and WTI Price Movement, 1986–2012**




*Source:* Authors, with EIA data.
*Note:* A simple regression analysis between oil and gas prices shows the following $R^2$ coefficients: $R^2 = .11$ (Jan. 2006–Feb. 2012); $R^2 = .37$ (Jan. 1997–Feb. 2012); $R^2 = .55$ (Jan. 1986–Feb. 2012).

The Henry Hub gas index is a good indicator of the opportunity cost of natural gas in North America; however, it is not the best reference for Central and South America. Although this index is the price indicator for the world's deepest and most dynamic natural gas market, global natural-gas markets are not yet fully integrated, meaning that prices for natural gas differ across regions. In the case of North and South America, natural gas prices are not highly correlated, and do not share similar patterns in oil-price comparisons.

### *2.3.3 Natural Gas Prices in South America*

In the largest gas-producing countries of South America, natural-gas wellhead prices are not highly correlated with Henry Hub prices;[8] while the correlations between natural gas prices and the WTI oil price are significantly higher, averaging 0.83 (excluding Venezuela, RB). Henry Hub and WTI prices have a smaller correlation of 0.61 (Table 2.2).

Over the 2000–10 period, natural gas prices rose more significantly in Brazil than in Argentina, where authorities regulated prices. In addition, coal prices in Brazil and Colombia, although representing different markets, exhibited a similar overall trend (Figure 2.6).

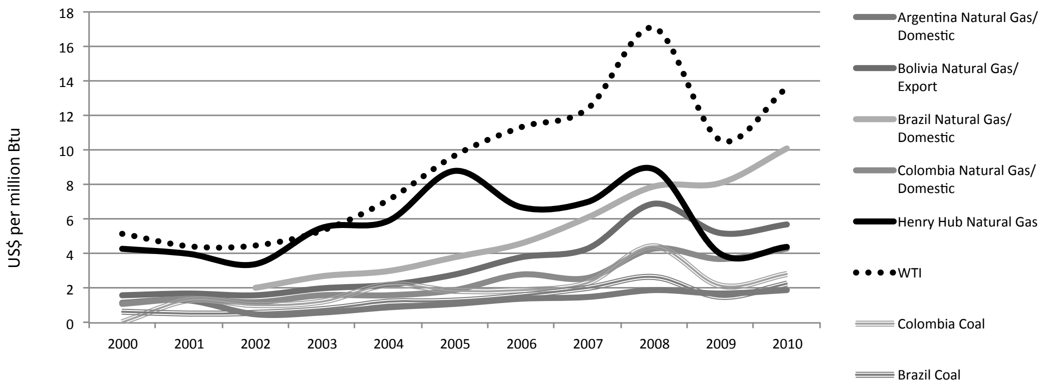
Barriers to the development of alternative technologies, such as hydropower or oil products, are likely to favor natural gas. Such a scenario would be magnified if gas prices were to remain low or if resource availability proved vast. The EIA projects that gas prices will not return to the higher pre-2008 recession levels; gas will be available, and production will increase (EIA 2012). In its reference case scenario, the EIA wellhead price reaches nearly US$6 per million Btu, not exceeding $5 per million Btu until 2023. It expects that shale gas will be the largest contributor to growth. With low prices, development of the already proven gas technology would likely soar. However, a low-price scenario based on excess supply of shale gas could only be achieved if the potential environmental, social, and health risks associated with its extraction technology were settled.[9]

**Table 2.2 Natural Gas and Oil Price Correlations, Annual Averages for 2000–10**

| *Natural Gas Producer (Market)* | *Henry Hub Price* | *WTI Oil* |
|---|---|---|
| Argentina (domestic) | 0.24 | 0.82 |
| Bolivia (export) | 0.40 | 0.95 |
| Brazil (domestic) | 0.01 | 0.83 |
| Chile (import) | 0.02 | 0.74 |
| Colombia (domestic) | 0.29 | 0.91 |
| Henry Hub | 1.00 | 0.61 |

*Sources:* Kozulj 2012; www.ciflorestas.com.br; www.energy.gov.

**Figure 2.6 Annual Price Estimates of Wellhead Natural Gas, Oil, and Coal, 2000–10**




*Sources:* Kozulj (2012); www.ciflorestas.com.br; www.energy.gov.

### *2.3.4 Coal Pricing Behavior*

Coal, a readily available fossil fuel, continues to be used worldwide to power the energy sector. The price of coal, like that of gas, is a key variable in determining the fuel's competitiveness and the effects of higher oil prices on fuel substitution. The EIA projects a reference case scenario in which coal prices remain fairly constant until 2035, with an average price of US$2.51 per million Btu (EIA 2012). It also provides a high price scenario of $4.08 per million Btu, 65 percent higher than in the reference case. These prices reflect differences in level of demand since many power operators can switch between coal and gas, evaluating their choices based on the prices of gas, coal, and carbon (Alberola, Chevallier, and Cheze 2008).

The literature indicates that coal may play an important role in the future energy matrix, given its low required capital costs and global distribution of resource availability (MIT 2007). Various studies concur that supply will be sufficient to satisfy increasing demand; the McKinsey Global Institute (2009), for example, does not view coal supplies as a constraint to demand growth and foresees a relatively balanced supply-demand path overall, despite the potential for temporary imbalances. At the same time, there is concern that growing demand for coal, particularly in China, could outstrip supply, and that usable coal resources may be overestimated, which could drive up prices (Heinberg and Fridley 2010).

The literature indicates that the pricing behavior of coal, like that of oil and gas, depends on market fundamentals, especially resource availability, and speculation of future demand. Given that the literature contains no references to price interactions with oil, it appears that a high oil price scenario does not affect the price of coal. MIT (2007) indicates the importance of China's future fuel decisions, suggesting that whatever fuel the country chooses to rely on to

**Table 2.3 Coal Pricing Correlation in Brazil and Colombia, Annual Averages, 2000–10**

| *Coal Producing Country* | *Brazil, Coal* | *Colombia, Coal* | *Brazil, Natural Gas* | *Colombia, Natural Gas* | *Henry Hub* | *WTI Oil* |
|---|---|---|---|---|---|---|
| Brazil | 1.0 | 0.91 | 0.84 | 0.90 | 0.56 | 0.99 |
| Colombia | 0.91 | 1.0 | 0.70 | 0.82 | 0.55 | 0.90 |

*Sources:* Kozulj 2012; www.ciflorestas.com.br; www.energy.gov.

meet its large expected energy demand will modify the market, reiterating the importance of supply-demand considerations as drivers of price. The study concludes that continued high oil and gas prices make a coal-intensive scenario for the country's power generation more plausible.

In the coal-producing countries of Brazil and Colombia, coal and natural gas prices are strongly correlated. However, coal prices appear to move in accordance with the WTI oil price rather than the Henry Hub natural gas price (Table 2.3). Regressing coal prices on WTI oil prices reveals a link between them. Regressing Colombian coal prices on WTI oil prices gives an $R^2$ of 0.9, while regressing Brazilian coal prices on WTI oil prices gives an $R^2$ of 0.99. Coal and natural gas prices are also highly correlated for both countries. In short, these prices are correlated in South America, but not in North America.

## 2.4 Concluding Remarks

Considering the major factors that interact to affect oil price behavior, a scenario with prices above US$100 per barrel is certainly plausible given that the reference scenarios cited in the literature forecast an average price range of $100–130 per barrel over the 2015–35 period, with the expected range for crude oil at $110–144 a barrel by 2035. In the high oil price scenarios cited, oil averages $192 a barrel over the 20-year period. Presumably, a high oil price scenario would mean that the energy sector—traditionally, it has planned new generation capacity based on a least-cost approach, using a country's available resources—would require an entirely new configuration. Before exploring such configurations in the context of the LAC region's electricity sector, the next chapter considers how higher oil prices are likely to affect macroeconomic and power-sector indicators for countries in the region.

Some assumptions are made to estimate the impact of higher oil prices. The estimated cost impact is an indicator of the extent to which the economy and power sector might be affected by higher oil prices in the short and long term. Another element to consider is the interaction among oil, gas, and coal prices. As previously discussed, oil, gas, and coal prices are highly correlated in South America (i.e., Colombia and Brazil) but not in North America, where natural gas and oil prices have decoupled over the past three years, owing mainly to the added shale-gas supply.

## Notes

1. Although the use of horizontal drilling in conjunction with hydraulic fracturing has expanded the ability of non-OPEC producers to recover oil, particularly in North America, its impact on the overall balance of oil remains limited. According to the EIA, production of oil sands/bitumen/shale oil in 2011 was only 2.9 percent of the world's total liquids production (2.6 million of barrels per day).
2. OPEC Production Allocations (http://www.opec.org).
3. WTI, also known as Texas light sweet, is a grade of crude oil used as a benchmark in oil pricing. The grade is described as light because of its relatively low density, and sweet because of its low sulfur content.
4. A nation's energy intensity is defined as the units of energy required per unit of economic output (GDP). A country's energy intensity is influenced by a range of factors, including (i) whether it is an energy exporter or importer, (ii) its economy's mix of industries and the degree to which they depend on energy as an input, (iii) economic growth rate and stage of development, (iv) degree of energy efficiency, and (v) geography.
5. The physical market refers to a commodity market where purchasers buy the commodities, as opposed to the futures market, where they buy and sell the right to purchase commodities at a future date.
6. As previously mentioned, the price of WTI averaged US$80 per barrel over the past five years and fluctuated between $80 and $109 a barrel in 2011 and 2012.
7. In North America, oil and gas prices were highly correlated until 2008, when prices decoupled; however, in the case of South America, prices remain correlated and there is no evidence of future decoupling.
8. The correlation between Bolivia's quarterly export prices and Henry Hub, calculated for 2007–12, was −0.45.
9. Hydrological fracturing or *fracking* is a nascent technology based on injecting high-pressure water with additives to increase rock fissures to permit gas to escape. Studies on the method's potential risks are still in the verification stages. The media and scientific articles have highlighted the method's potential risks to ecosystems (e.g., toxicity to water beds resulting from leakage of additives) and public health (e.g., given that heavy metals, hydrocarbons, and radioactive materials are extracted from the shale) (Howarth, Ingraffea, and Engelder 2011). An added concern is that methane, a potent greenhouse gas, may escape into the atmosphere during the mining process.

CHAPTER 3

# Impact in LAC Countries

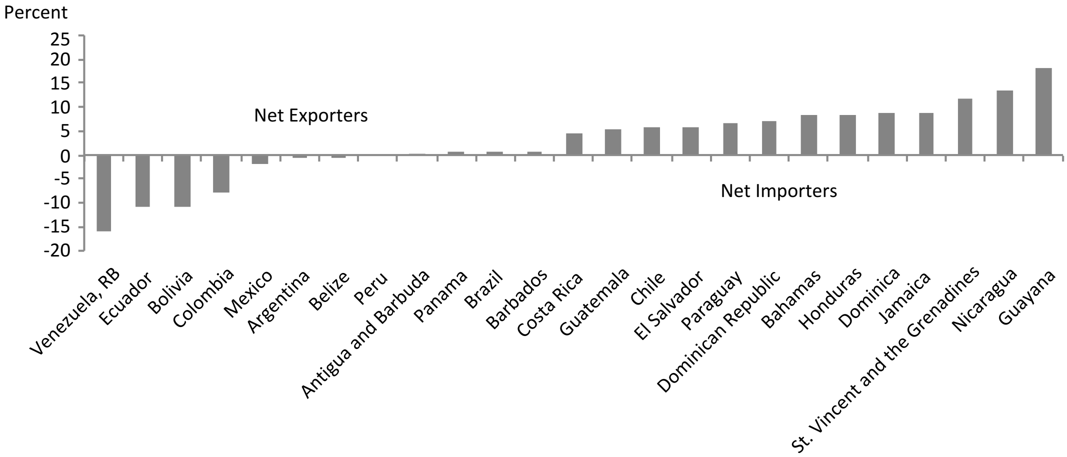
Higher oil prices may top the list of economic shocks in terms of their ripple effect across economic activities and agents. At the household level, higher oil prices mean paying more for electricity, heating, and transport services. Firms face higher costs for providing goods and services; while governments are likely to confront the challenges of larger subsidies, more complex macroeconomic management, and possible backtracking on poverty reduction programs. In short, higher oil prices mean that countries face significant headwinds along their growth and development path (Appendix A).

This chapter analyzes the impact of higher oil prices on Latin America and the Caribbean (LAC). It begins by assessing the unique oil export and import status of countries in the LAC region, including their dependence on oil as a primary energy source, particularly for power generation, to determine their risk exposure to higher oil prices. A regionwide statistical analysis follows, showing the impact of higher oil prices on key macroeconomic and power-sector indicators over the past 25 years. Finally, three price scenarios are used to assess the potential effects of sustained high oil prices on those variables.

## 3.1 Vulnerability and Economic Exposure

Higher oil prices are interlinked with a country's trade balance and energy resources, implying a transfer of wealth from oil importing to oil exporting nations (IMF 2000b). In the LAC region, countries exhibit a wide range of differences in their net oil trade position relative to GDP. At one end of the spectrum, Venezuela, RB has net fuel exports equivalent to 16 percent of GDP. At the opposite end, Guyana's net fuel imports total about 18 percent of GDP. Between are such countries as Belize and Peru, which exhibit more balanced fuel imports and exports. Countries that are net oil importers are more vulnerable to higher oil prices, while net exporters are more likely to benefit (Figure 3.1).

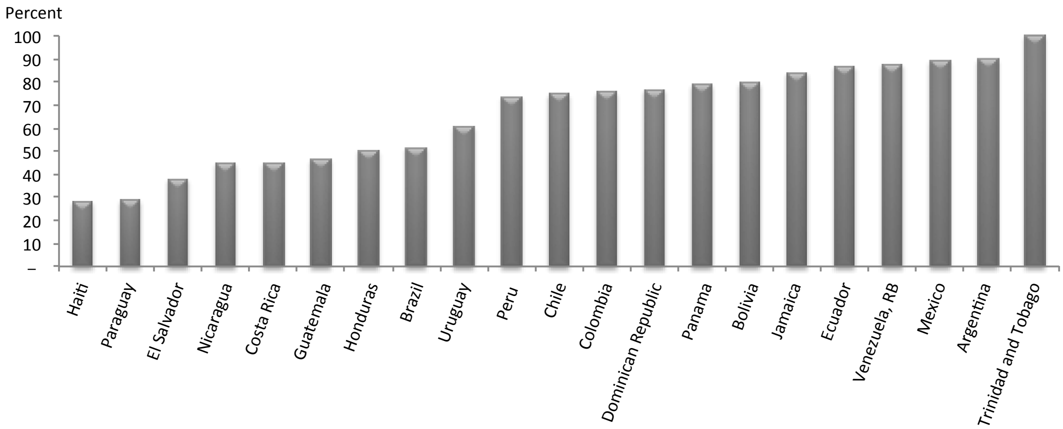
**Figure 3.1 Net Fuel Imports Relative to GDP in Selected LAC Countries, 2010**




*Sources:* World Bank 2011; authors' calculations.
*Note:* 2009 figures are used for Honduras.

Countries in the LAC region vary widely in their relative dependence on oil as a primary energy source (Figure 3.2). Fossil fuels account for nearly 99 percent of energy consumption in Trinidad and Tobago, compared to less than 30 percent in Haiti and Paraguay. At least 70 percent of energy demand for the Dominican Republic, Jamaica, Panama, and Mexico is supplied by fossil fuels; while Southern Cone countries (i.e., Peru, Chile, Colombia, Venezuela, RB, Bolivia, Ecuador, and Argentina) use large amounts to produce their energy requirements. In all but six countries, fossil fuels comprise at least half of energy consumption.

**Figure 3.2 Share of Fossil Fuels in Total Energy Consumption in LAC Countries, 2009**



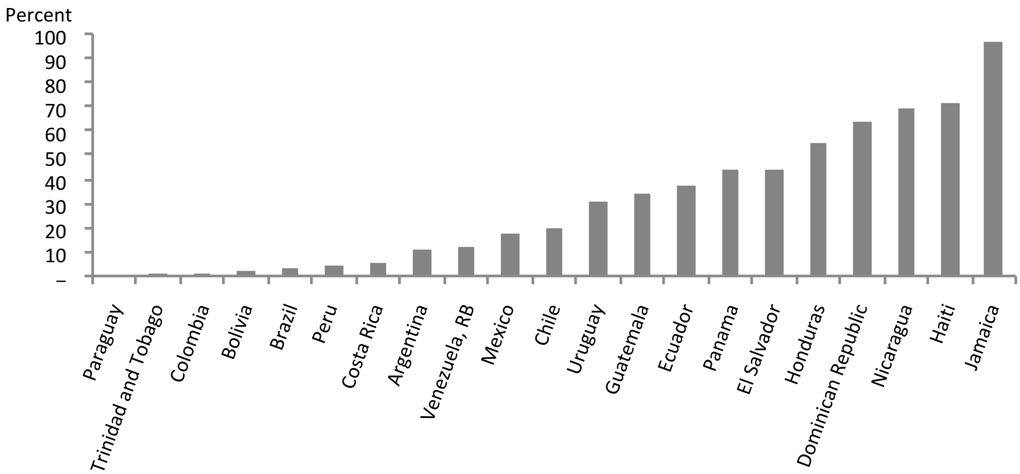

*Sources:* World Bank 2011; authors' calculations.

The power sector exhibits a more specific measure of vulnerability, suggesting its significance as a channel through which higher oil prices can affect countries. The region's greatest risk is found in Central America and the Caribbean (Figure 3.3).

Analyzing the LAC region's evolution over the past 20 years (1990–2009) in terms of its energy imports, energy efficiency, and energy consumption reveals several trends (Figure 3.4). Overall the region has become more efficient in terms of energy use as a function of GDP; however, Bolivia, El Salvador, Guatemala, Haiti, and Trinidad and Tobago have all increased their energy use in terms of kilograms of oil equivalent by nearly 43 percent. In terms of per capita energy consumption, Argentina, Chile, Costa Rica and Trinidad and Tobago exhibit increases. With respect to the import-export trend, most oil exporting countries, including Argentina, Ecuador, Mexico, and Venezuela, RB, have decreased their position as global suppliers; while Colombia has more than doubled its exports for local consumption. In the case of oil importers, Chile, Honduras, and Panama have increased their external supply proportionately more than have other countries in the region.

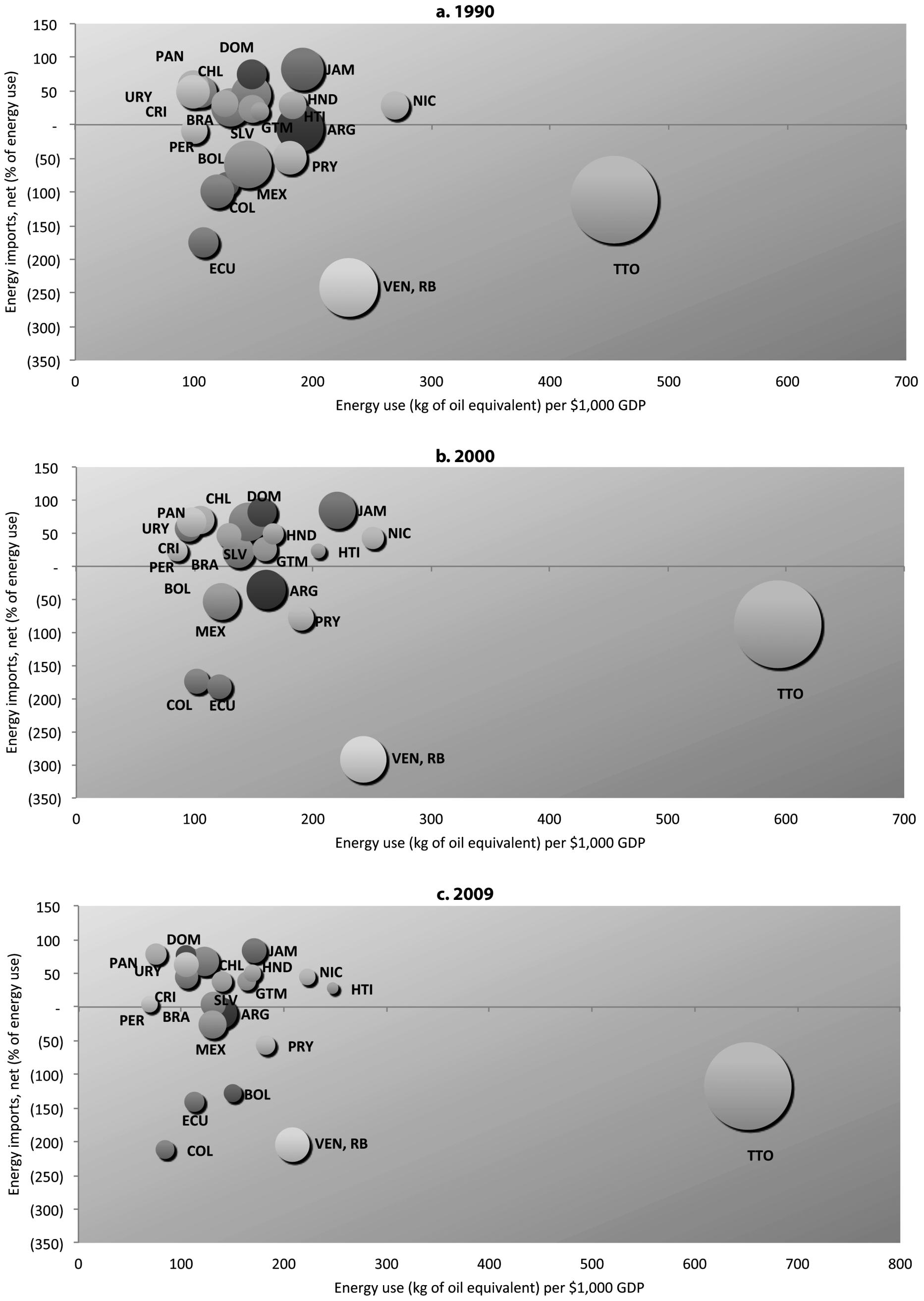
Consumer subsidies represent net expenditures for oil importing countries; thus, this study presents energy consumption subsidies as a price gap between final consumers and reference prices. Since public information is unavailable on the real recovery cost for each country, the term *subsidy* is used when domestic retail prices remain below the international price. Under such circumstances, oil exporters can consider the subsidy an opportunity cost of the pricing policy. This cost can be re-qualified as a comparative advantage in the allocation of natural resources, suggesting it should first be captured by a pricing policy (Box 3.1).

**Figure 3.3 Oil as a Share of Total Power Generation, 2009**




*Source:* World Bank 2011.

**Figure 3.4 Evolution of Energy Imports, Efficiency, and Consumption in LAC Countries, 1990–2009**




*Sources:* World Bank 2011; authors' calculations.

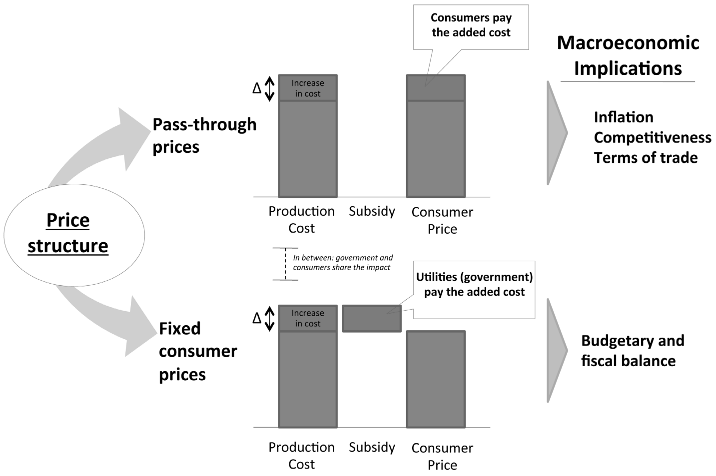
*Note:* Countries are placed in the energy imports and efficiency space, with bubble sizes representing the kilograms of oil equivalent per capita. Net energy imports are shown as a percentage of total energy use (e.g., Venezuela, RB exports twice the amount of energy that it uses in a given year, while Brazil and Peru may be considered balanced).

ARG = Argentina, BOL = Bolivia, BRA = Brazil, CHL = Chile, COL = Colombia, CRI = Costa Rica, DOM = Dominican Republic, ECU = Ecuador, GTM = Guatemala, HND = Honduras, HTI = Haiti, JAM = Jamaica, MEX = Mexico, NIC = Nicaragua, PAN = Panama, PRY = Paraguay, PER = Peru, SLV = San Salvador, TTO = Trinidad and Tobago, URY = Uruguay, VEN, RB = Venezuela, RB.

**Box 3.1 Higher Electricity Prices: Who Bears the Risk Burden?**

In Latin America and the Caribbean, countries with a large proportion of liquid fuel–based generation face high risks from oil price volatility. The impact on households, utility companies, and governments depends on the energy market structure, relationship between private- and public-sector stakeholders, and electricity tariff policy. At one extreme, tariffs may be set to allow utilities to pass through the change in fuel costs to end-user consumers, who bear the total risk burden, as illustrated below. In this case, a price-elasticity impact on demand is likely, especially among the poor, leading to demand for energy conservation and reduced electricity consumption. At the other extreme, end-user tariffs remain fixed as the fuel cost varies, with the utility—and the government, as last resort—bearing the full risk. In this case, the utility does not recover its costs, and price signals to consumers are inefficient, leading to overconsumption of electricity.

**Distribution of Higher Energy Costs**




Oftentimes, the government will step in to ensure that the utility remains solvent and operational, which may crowd out resources that could otherwise be directed to social needs and other productive uses. Most governments operate somewhere along the continuum between these extremes, using subsidies and other smoothing mechanisms to shield consumers and businesses from price volatility and keep prices affordable for the poor. However, these mechanisms represent increased government outlays. In periods of high oil prices, increased subsidy expenditure can deteriorate the fiscal balance and increase public debt. Striking the right balance between the two extremes so that risk is distributed equitably and efficiently is a challenge for many countries.

*Source:* Authors.

The LAC region is quite diverse in its natural resource endowments, energy use, and risk exposure. While general conclusions can be drawn along the lines of oil importers and exporters, the magnitude and channels through which oil prices affect economies must be viewed in the context of each country's unique features, including its institutional arrangements, electricity pricing policies, and power-sector structure.

When prices fail to cover generation costs, utilities often sacrifice asset maintenance, resulting in lower-quality power supplies or chronic power disruptions owing to a lack of generation reserve margin or network constraints. Financially strained, state-owned utilities are poorly positioned to finance investments, in which case the government or private sector must step in. But governments have limited resources, and the private sector is unlikely to find such investments attractive if power tariffs do not reflect true costs or if there are concerns about the government's ability to sustain funding of subsidies to independent power producers or guarantee payments by the state-owned utility.

Reforming inefficient energy subsidies entails a delicate balancing act for policy makers, who must weigh fiscal and environmental concerns, on the one hand, against consumer affordability concerns on the other. Subsidies have a fiscal impact that makes governments financially vulnerable. They also have important environmental implications as they promote higher energy consumption and waste. Politicians must handle the balance between the financial and environmental impact of subsidies and political pressure to keep consumer prices low. Once a government adopts energy subsidies, it is difficult to roll them back. While gradual approaches to reform have a greater chance of success, they are beset by challenges. For example, they allow opponents of reform (e.g., those who stand to lose rents, desire to curb inflation, or are concerned about business competitiveness) to mobilize resources.

Politicians may use subsidies to deliver rents to favored constituencies, meaning that their political fortunes are tied to maintaining the status quo, despite the financial costs and impact on the fiscal balance. In addition, the short-term political cycle in many countries can work against subsidy reform, discouraging long-term planning and investment, which could tilt the energy balance toward a more sustainable price regime. Furthermore, if consumers (whether household, industrial, or commercial), producers, and government fail to perceive the crisis—instead believing in the sustainability of the status quo (e.g., large subsidies, poor financial status of the utility, and unreliable power supply)—major change is unlikely to occur. Moreover, high oil prices are often viewed as temporary, which works against efforts to implement significant changes concerning long-term investments in energy and transport infrastructure.

## 3.2 Impact on Macroeconomic and Power-Sector Indicators

This section quantifies the average effect of oil price changes on the economy, government indicators, and such structural aspects as share of oil-fired power generation. The variables covered are taken from the World Bank's World

Development Indicators database (World Bank 2011). The data set spans the 1986–2011 period as most of the analysis, except for share of oil-fired power generation, which extends through 2009. The sample combines oil price changes, measured as the annual percentage change in average WTI prices.[1] While data availability varies by country, the data set spans all LAC countries, except for Cuba. Based on a panel of LAC countries, regression results are presented for each variable. An auto-regressive model, AR(1), was fitted to the data with current real GDP growth and oil price changes as exogenous variables, except in the model for GDP growth, which by construction can only be a function of its lagged value and oil price changes.

This initial approach provides an overview of the effects of higher oil prices in a way that is economical, symmetric, and easily managed, allowing for the separation of net importers and net exporters as distinct units of analysis. The findings reveal most of the expected effects of oil prices on macro indicators, as well as the differential impact between net importers and exporters in such areas as the current account and output growth.

Once such symmetric treatment is made, the analysis is carried a step further to study the impact of higher oil prices on GDP growth, the current account, and inflation, based on standard models on the determinants of these variables found in the literature. Following diverse studies, explanatory variables (e.g., real exchange rate, demographic trends, capital formation, and institutional development) are added. In the case of GDP growth, World Bank (2006) methodology is used to determine country-specific effects, which are then aggregated across the region and by the respective countries' oil trade balances.

Table 3.1 presents the results from the symmetric treatment across variables. To account for potential wealth transfer from oil importers to exporters and inherent differences across these subgroups, separate analyses were conducted for net oil importing and exporting countries.[2]

When statistically significant, the effects of oil prices are as expected. In the case of net oil importers, higher oil prices are associated with higher inflation, deterioration of the current account, increased subsidies relative to government expenditure, decreased oil-fired power generation, and negative growth. By contrast, for net oil exporters, higher oil prices lead to an improved current account and faster growth and exhibit no statistically significant effect on the other variables. In short, net oil importers, unlike net exporters, are adversely affected in many dimensions. These findings are consistent with those in the literature on oil price effects and previous World Bank studies.

The regression estimates from this exercise can be used to predict the impact of persistently higher oil prices. The predictions presented below are based on the specific point estimates from the regressions, which themselves are comparable with the literature (Box A.1).

Before proceeding with the simulation, the econometric specifications and estimation technique for measuring the impact of higher oil prices on GDP growth, the current account, and inflation are refined. The general conclusions

**Table 3.1 Effects of Oil Prices on the Economy**

| *Variable* | *GDP Growth* | *Current Account* | *Inflation* | *Oil-Fired Generation* | *Subsidies* |
|---|---|---|---|---|---|
| *Net Importers* | | | | | |
| GDP growth (t − 1) | 0.361***<br>(0.05) | | | | |
| Current account (t − 1) | | 0.755***<br>(0.05) | | | |
| Inflation (t − 1) | | | 0.711***<br>(0.06) | | |
| Generation (t − 1) | | | | 0.978***<br>(0.01) | |
| Subsidies (t − 1) | | | | | 0.925***<br>(0.02) |
| Oil price change (t) | −0.020***<br>(0.01) | −0.021**<br>(0.01) | 0.039***<br>(0.01) | −0.036**<br>(0.02) | 0.033**<br>(0.01) |
| GDP growth (t) | | -0.119<br>(0.07) | -0.176***<br>(0.07) | 0.230**<br>(0.11) | 0.152*<br>(0.09) |
| Constant | 0.023***<br>(0.00) | -0.013**<br>(0.01) | 0.022***<br>(0.00) | 0.010*<br>(0.01) | 0.021***<br>(0.01) |
| $R^2$ | 0.141 | 0.595 | 0.562 | 0.941 | 0.925 |
| N | 593 | 593 | 469 | 317 | 187 |
| *Net Exporters* | | | | | |
| GDP growth (t − 1) | 0.256***<br>(0.11) | | | | |
| Current account (t − 1) | | 0.784***<br>(0.09) | | | |
| Inflation (t − 1) | | | 0.815***<br>(0.06) | | |
| Generation (t − 1) | | | | 0.948***<br>(0.03) | |
| Subsidies (t − 1) | | | | | 0.737***<br>(0.23) |
| Oil price change (t) | 0.028*<br>(0.02) | 0.092***<br>(0.01) | 0.030<br>(0.02) | -0.013<br>(0.01) | 0.033<br>(0.06) |
| GDP growth (t) | | -0.212*<br>(0.11) | -0.379**<br>(0.18) | 0.079<br>(0.06) | 0.013<br>(0.26) |
| Constant | 0.023***<br>(0.01) | 0.000<br>(0.01) | 0.027**<br>(0.01) | 0.003<br>(0.00) | 0.118<br>(0.10) |
| $R^2$ | 0.093 | 0.641 | 0.723 | 0.963 | 0.714 |
| N | 165 | 172 | 136 | 163 | 33 |

*Source:* Authors' calculations.
*Note:* * = $p < 0.1$, ** = $p < 0.05$, *** = $p < 0.01$; parentheses indicate robust standard errors.

hold, but since the scenarios use the point estimates, it is important to reduce potential omitted variable biases. Furthermore, in the case of GDP growth, using variations in the countries' terms-of-trade and respective oil balances allows for teasing out the country-specific impacts of oil prices.

Using an alternative methodology, the World Bank (2006) shows that higher oil prices may impact countries' economic growth and that the effects for oil importing and exporting countries may differ. In the LAC region, the long-term growth effects for oil exporters could be up to +0.14 percent per year, while the rate for oil importers could be −0.1 percent a year (Box 3.2 table).[3] This methodology is used in the analysis that follows.

Using a fixed-effects, panel-based estimation with terms-of-trade shocks rather than oil price changes, along with other commonly used determinants of GDP growth (e.g., capital formation, openness to trade, and financial depth), the growth impact of higher oil prices can be deduced for each country.

Following World Bank (2006) methodology, the terms-of-trade coefficient estimate in this sample is 0.035.[4] This, in turn, can be used to calculate the impact of higher oil prices based on a country's oil trade balance and openness to trade. For example, for a given oil price change $\varepsilon$, the corresponding change in the economy's growth rate is expressed as follows:

$$dy_i = \beta_{TOT} * X_i * ((1+(s_{Xi}* \varepsilon))/(1+(s_{Mi}* \varepsilon)) - 1),$$

where $Xi$ represents the openness of country $i$ relative to the average for the LAC region, and $s_{Xi}$ and $s_{Mi}$ stand for oil exports and imports as respective shares of total exports and imports for country $i$.

By way of example, a doubling of oil prices would imply a decrease in GDP growth of 0.33 percentage points for net importers of oil and an increase of 0.67 percentage points for net exporters. Based on the sample, Venezuela, RB, would stand to gain the most, while Guyana would experience the largest reduction in output growth (Figure 3.5).

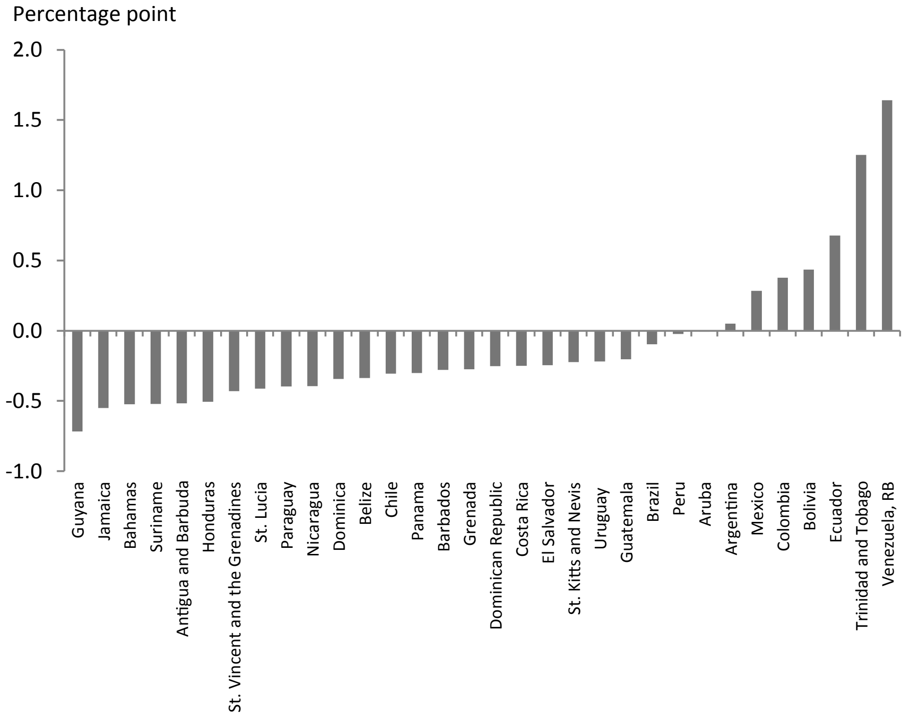
For analysis of the current account, the study follows the literature (Calderon, Chong, and Loayza 2002; Morsy 2009), including a broader set of regressors, including the real exchange rate, demographic changes, and the country's oil balance. This alternative panel-based specification clusters fixed

**Table 3.2 Effects of Oil Prices on GDP Growth**

| *Variable* | *Terms of Trade* | *Capital Formation* | *Private Credit* | *Trade Openness* | *Inflation* |
|---|---|---|---|---|---|
| Coefficient estimate | 0.035** | 0.142*** | 0.056 | 0.009 | −0.005** |
| | (0.014) | (0.020) | (0.041) | (0.008) | (0.01) |
| $R^2$ | 0.38 | | | | |
| N | 431 | | | | |

*Source:* Authors' calculations.
*Note:* * = $p < 0.1$, ** = $p < 0.05$, *** = $p < 0.01$; parentheses indicate robust standard errors. Intercept and dummy-year regressors are omitted.

**Figure 3.5 Change in GDP Growth from Higher Oil Prices**




*Source:* Authors' calculations.

effects and observations by year to reduce the bias of the commonality of oil shocks across countries. It supports the above findings, highlighting the asymmetry between net oil importers and exporters. Table 3.3 presents the point estimates for oil prices used in the scenario simulations that follow.

The last macroeconomic variable to analyze is inflation. Following recent studies that focus on the relationship between oil prices and inflation, such

**Table 3.3 Effects of Oil Prices on the Current Account**

| *Variable* | *GDP Growth* | *Oil Balance* | *Oil Price* | *Oil Price (importers dummy)* | *Population Growth* | *Real Exchange Rate* |
|---|---|---|---|---|---|---|
| Coefficient estimate | −0.216*** | 0.031 | 0.054*** | −0.057*** | 0.149 | 0.000 |
| | (0.060) | (0.021) | (0.021) | (0.022) | (0.134) | (0.001) |
| $R^2$ | 0.29 | | | | | |
| N | 504 | | | | | |

*Source:* Authors' calculations.
*Note:* * = $p < 0.1$, ** = $p < 0.05$, *** = $p < 0.01$; parentheses indicate robust standard errors. Intercept regressors are omitted.

**Table 3.4 Effects of Oil Prices on Inflation**

| *Variable* | *Inflation (lag)* | *GDP Growth* | *Oil Prices* | *Institutions* | *Energy Intensity* |
|---|---|---|---|---|---|
| *Net Importers* | | | | | |
| Coefficient estimate | 0.402*** | -0.034 | 0.033*** | 0.004 | 0.001*** |
| | (0.128) | (0.088) | (0.011) | (0.006) | (0.000) |
| $R^2$ | 0.74 | | | | |
| N | 156 | | | | |
| *Net Exporters* | | | | | |
| Coefficient estimate | 0.443*** | -0.741*** | 0.029 | -0.016 | 0.000 |
| | (0.170) | (0.182) | (0.024) | (0.013) | (0.000) |
| $R^2$ | 0.9 | | | | |
| N | 86 | | | | |

*Source:* Authors' calculations.
*Note:* * = $p < 0.1$, ** = $p < 0.05$, *** = $p < 0.01$; parentheses indicate robust standard errors. Intercept regressors are omitted.

as Gelos and Ustyugova (2012), the coefficient estimate for the impact of oil in both net oil importing and exporting countries controls for the level of energy intensity in the economy, as well as institutional development; for the latter, a proxy estimate from the Rule of Law index, Worldwide Aggregate Governance Indicators, is used. Table 3.4 presents the fixed-effects panel results. As expected, higher oil prices would have an inflationary effect on net-importing countries.

### *3.2.1 Potential Economic Effects: Three Oil Price Scenarios*

To predict the potential economic effects of a continued upward oil-price trend in the LAC region, a sensitivity analysis was performed for net oil importers and exporters, using three price scenarios (i.e., 25, 50, and 100 percent increase in the price of WTI). The analysis was based on the assumption of a representative country in the LAC region, where the predictions are average effects for importing and exporting countries in the sample. That is, based on the sample estimates, we ask what the effect of a given percentage increase in oil prices would be. The three price scenarios were fed into the model's parameter estimates to assess the change in each of the variables, all other factors being equal. Thus, the model output corresponds to the percentage change in each variable for a given change in oil price.[5]

It is important to note that the analysis assumes a linear effect of oil prices on the corresponding variables. At higher oil prices, the effect can weaken as agents adjust their behavior. For this reason, extrapolations to longer-term horizons should be done with care since fuel demand is more inelastic in the short run. The prediction applies to a two-year time horizon at most.[6]

Assuming a current price of approximately US$100 per barrel of WTI, the three scenarios correspond to the equivalent of $125, $150, and $200 a barrel. The variables for which the two subgroups demonstrate the greatest difference in impact from higher oil prices are GDP growth and the current account. For example, a 25 percent oil price increase would accelerate economic growth by 0.17 percentage points in net exporting countries and reduce GDP growth by −0.08 percentage points in net importing countries, all other factors being equal. The current account balance would rise by 1.35 percentage points in net exporting countries and worsen by 1.44 percentage points in net importing countries (Figure 3.6).

Inflation would adversely affect net oil importing countries. Simulation results suggest that a 50 percent oil price increase could raise inflation by up to 1.64 percentage points for net importers. While higher oil prices would have no statistically significant effects on subsidies or share of oil-fired power generation in net exporting countries, oil importers would be affected. For example, a price doubling to US$200 per barrel would increase subsidies as a fraction of government expenditure by up to 3.3 percentage points, while the share of oil-fired power generation would fall by 3.6 percentage points. As noted above, many countries have a high share of oil-based power generation, making substitution more difficult.

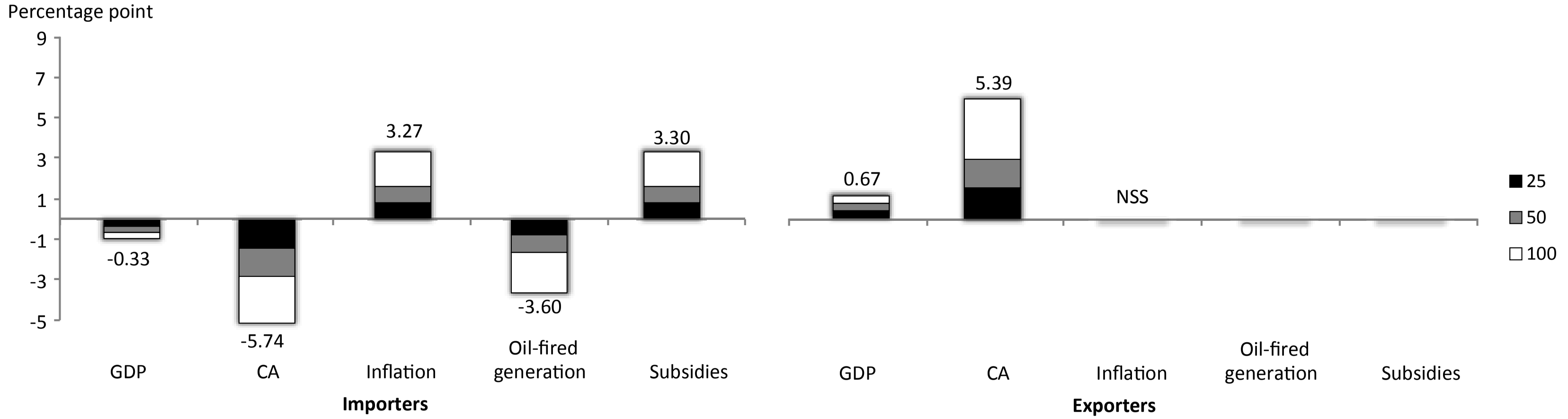
### 3.2.2 GDP Growth and Current Account

Higher oil prices create statistically significant, opposite effects for GDP growth and the current account, depending on a country's oil balance. In oil exporting countries, higher oil prices stimulate growth. However, in oil importing countries GDP growth turns negative. Based on the growth regression, a 100 percent increase or price doubling slows growth by 0.33 percentage points in oil importing countries and accelerates it by 0.67 percentage points in oil exporting countries, all else being equal (Figure 3.7).

In the case of the current account, a 1 percentage point rise in oil prices increases the current account relative to GDP by approximately 0.054 percentage points in oil exporting countries, while reducing it by 0.057 percentage points in oil importing countries (Figure 3.8).

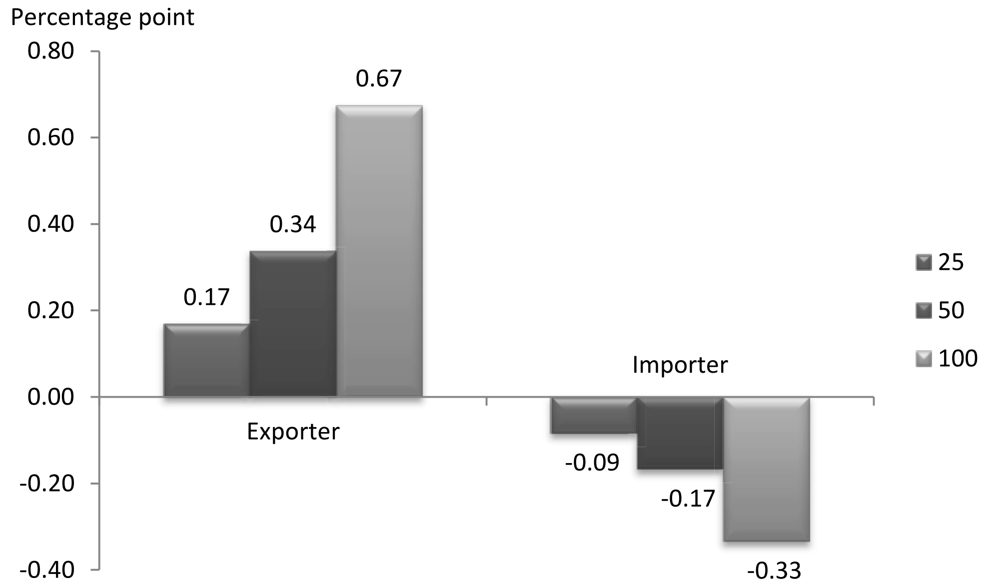
With a 50 percent price increase, corresponding to US$150 per barrel, the current account would increase by approximately 2.7 percentage points relative to GDP in oil exporting countries and decrease by 2.87 percentage points in net importing countries. While this opposite impact reflects an improving international asset position for oil exporters and a worsening situation for oil importers, the effects of foreign exchange must also be considered. Foreign currency inflows can appreciate the currency and hamper the country's international competitiveness, and in extreme cases, result in Dutch disease–like effects. At the same time, greater demand for foreign currency in net importing countries could depreciate the local currency, leading to higher import costs and inflation, as previously discussed.

**Figure 3.6 Summary of Three Oil Price Scenarios**



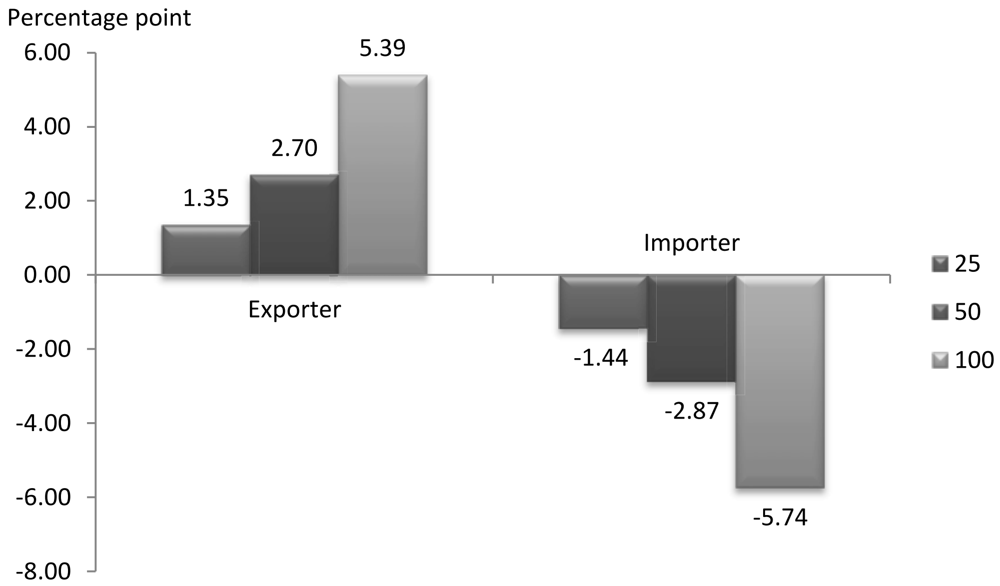

*Source:* Authors' calculations.
*Note:* CA = current account; NSS = not statistically significant

**Figure 3.7 Effect on GDP Growth by Oil Price Scenario**




*Source:* Authors' calculations.

**Figure 3.8 Effect on Current Account-to-GDP Ratio, by Oil Price Scenario**




*Source:* Authors' calculations.

### 3.2.3 Inflation

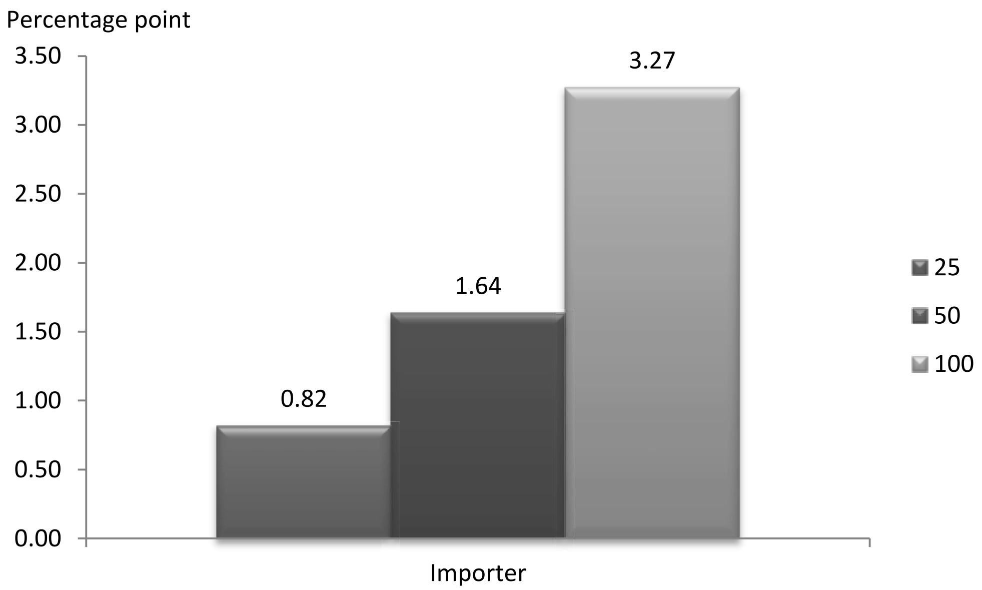
For both net oil importers and exporters, the spillover effect of higher oil prices can result in a supply shock, which can lead to inflation. As the above discussion suggests, this type of effect may be stronger for oil importers. The three price scenarios indicate that, for these countries, a 1 percentage point increase in oil prices raises inflation by 0.033; with a 100 percent price increase, it could reach 3.27 percentage points (Figure 3.9).

### 3.2.4 Subsidies

Given the regressive effects of energy shocks on society, governments often insulate the population from costly oil by subsidizing fuel oil, gas, and electricity prices; however, this approach carries a negative fiscal effect, which is statistically significant only for net oil importers. In this case, a 10 percent increase in oil prices results in a 0.3 percentage point increase in the ratio of subsidies to government expenses (Figure 3.10).

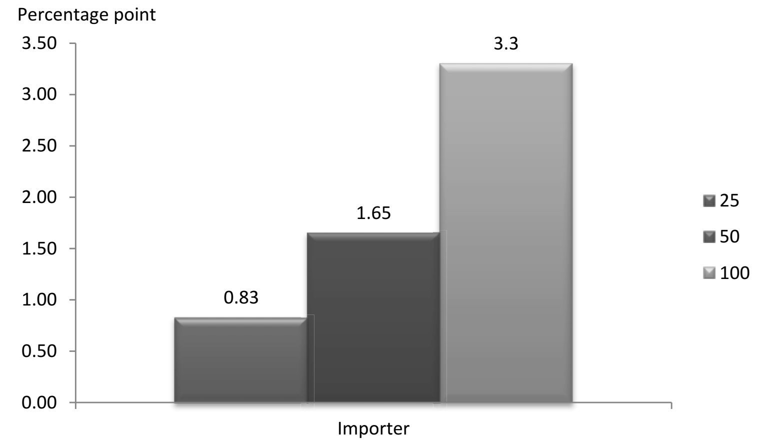
As Figure 3.10 shows, a 25 percent increase in oil prices would increase the share of subsidies in government expenditure by close to 0.83 percentage points, while a price doubling would increase it by approximately 3 percentage points.

**Figure 3.9 Effect on Inflation by Oil Price Scenario**




*Source:* Authors' calculations.

**Figure 3.10 Effect on Subsidies (as share of Government Expenditure) in Net Importing Countries, by Oil Price Scenario**



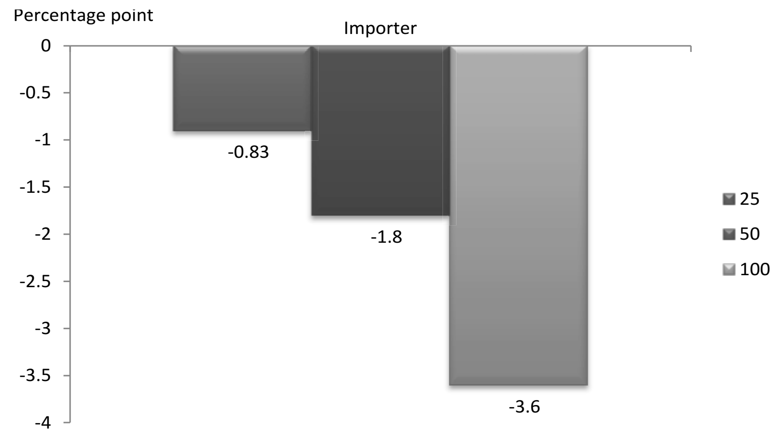

*Source:* Authors' calculations.

### *3.2.5 Oil-Fired Power Generation*

Finally, the effect on the share of oil-fired power generation was analyzed for the three scenarios. In all three simulations, higher oil prices led net importers to switch to alternative generation sources.

Figure 3.11 is based on the finding that a 1 percent increase in oil prices decreases the share of oil-fired generation by 0.036 percentage points. Thus, a 100 percent increase in oil prices would lead to an increase of 3.6 percentage points in the share of non-oil power generation. An indirect effect from such a shift in generation would be a decrease in greenhouse gas (GHG) emissions, granted that the shift is not to coal-based technologies.

**Figure 3.11 Effect on Oil Fired Generation in Net Importing Countries, by Oil Price Scenario**

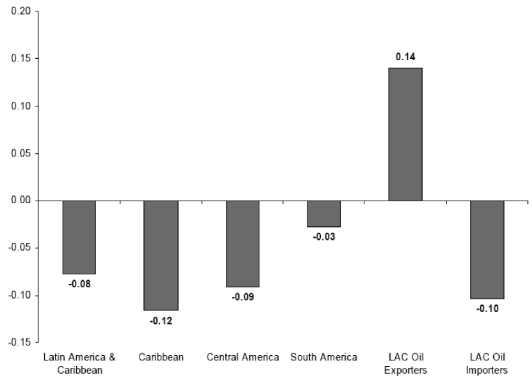



*Source:* Authors' calculations.

**Box 3.2 Assessing the Impact of Higher Oil Prices in Latin America and the Caribbean**

The World Bank (2006) estimates that a 16 percent annual increase in oil prices over a five-year period would increase growth for oil exporters in the LAC region by 0.14 percentage points per year and decrease it by 0.10 percentage points for the region's oil importers. As illustrated below, the Caribbean and Central America would suffer the greatest losses, at 0.12 and 0.09 percentage points, respectively. For some countries, the macroeconomic effect is unclear; for example, an oil exporter may use windfall oil profits to subsidize fuel prices or reduce fiscal deficit; but such cases are the exception.

**Growth Effect Comparisons from Higher Oil Prices**




**Macroeconomic Effects of Higher Oil Prices in Selected Countries**

| *Country* | *CPI Pass-Through* | *Fiscal Balance* | *Interest Rate* | *External Account* |
|---|---|---|---|---|
| Argentina | None | – | None | + |
| Brazil | Limited | + | None | + |
| Colombia | None | + | None | + |
| Dominican Republic | Significant | – | Significant | – |
| Ecuador | None | + | n.a. | + |
| El Salvador | Limited | – | n.a. | – |
| Guyana | Limited | – | Modest | – |
| Honduras | Significant | – | None | – |
| Mexico | None | + | None | + |
| Venezuela, RB | None | + | None | + |

*Note:* n.a. = not available.

*box continues next page*

**Box 3.2 Assessing the Impact of Higher Oil Prices in Latin America and the Caribbean**
*(continued)*

As the table suggests, for individual countries, the pass-through of fuel prices into inflation is limited, as is the response of monetary policy; these phenomena can be explained, in part, by the perception of monetary authorities that oil price shocks are temporary. However, countries in Central America and the Caribbean, which are notably net oil importers, experience a deterioration of their fiscal balance because of larger subsidies or lower tax receipts due to an economic slowdown. In addition, these countries' external and fiscal effects are symmetric, as higher oil prices translate into higher energy import bills.

*Source:* World Bank 2006.

### *3.2.6 Asymmetry between Importers and Exporters*

A corollary from the analysis is the asymmetry in incentives and budgetary constraints between oil importing and exporting countries. The negative growth effect, worsening of international balances, and rise in subsidy expenditures require swifter adjustment in oil importing countries. Together with the buildup in inflation, the required policy mix for such countries is more challenging. By contrast, in oil exporting countries, the windfall from higher oil revenues may dampen the perceived need for more efficient resource allocation and government responsiveness. This duality suggests that oil importing countries ought to receive technical aid in handling such episodes, while oil exporters should be monitored to avoid complacency stemming from higher international energy prices. Such concerns extend to such structural issues as share of oil-fired power generation, where institutional and regulatory flexibility must accompany an enabling environment in which changes to the energy matrix are made.

## 3.3 Concluding Remarks

The general consensus across the oil price literature is that higher oil prices would likely influence a wide array of economic variables, including economic growth, production costs and inflation, trade balance, exchange rates, and competitive advantage. For the LAC region, the impact of higher oil prices would vary according to the net trade balance of hydrocarbons, whether countries are net oil importers or exporters, and the share of oil-fired power in their electricity generation matrices. Economic downturns could create greater risk exposure for net oil importers, which could trigger a balance-of-payments problem; while net oil exporters would see faster growth and improvements in their current account. In addition, oil importers would experience higher inflation. For every 25 percent rise in WTI price, net oil importers would witness a 0.83 percentage point increase in subsidy outlay relative to government expenditure. Estimate-based simulations suggest that the average effect of an oil price doubling on the current account relative to GDP would be approximately +5.4 percentage points in oil exporting countries and −5.7 percentage points in oil importing countries. Evidence also suggests that a continued oil price increase would make net importers more responsive to reducing oil-fired power generation.

Pass-through mechanisms would have an inflationary impact and consumption effects, while subsidies would have a fiscal impact and limited or no inflationary effect; partial subsidies would have both inflationary and fiscal effects. For countries that pass through the costs of higher oil prices, demand for fuel would decrease, leading to efforts at energy conservation and providing the right economic incentives to switch to alternative generation sources. At the same time, households would be directly affected. As documented by Bacon (2005), higher energy prices are regressive as lower income groups experience greater household expenditure and a higher cost of living. Given that LAC is a highly unequal region, wealth and income disparities would likely increase. Thus, in the interim, there would likely be a need to protect the poor from such adverse impacts.

For countries that do not pass through the costs of higher oil prices, the incentive to switch to alternative generation sources would be limited or nonexistent. At the same time, households would be affected indirectly since higher oil prices would mean less government resources available to spend on social programs. In these countries, governments might be interested in reducing subsidies if their fiscal situation became untenable as a result of the oil import bill and the attendant subsidy. The financial and physical performance of the power sector would likely be affected, which, in turn, could further impact the government's finances. The next chapter considers how higher oil prices could impact the LAC region's power sector.

## Notes

1. To avoid potential spurious relations associated with trending variables, percentage changes in oil prices and inflation rates, rather than non-stationary real oil prices, were used.
2. For both subgroups, a VAR model was estimated for robustness. Constrained by a diagonal variance-covariance matrix, the VAR model yielded estimates that implied the same effect of oil prices on the selected variables as the AR(1). Since the VAR limits the data set to the available number of observations with all variables per year, preference was given to the AR model, whose results are presented.
3. Box 3.2 summarizes previous World Bank findings that echo this chapter's aggregate findings, particularly in terms of the growth effects of higher oil proces. The study's country-specific results further reveal the asymmetries between net oil importers and exporters in terms of inflation, fiscal balance, interest rates, and external accounts.

4. In World Bank (2006) the corresponding estimate is 0.038.
5. Even though such price increases consider sample forecasts, the models are estimated with exogenous percentage changes in oil prices in the set of regressors.
6. This section's estimates are based on regionally pooled data and thus reflect average effects. Individual country responses were beyond the scope of the study.

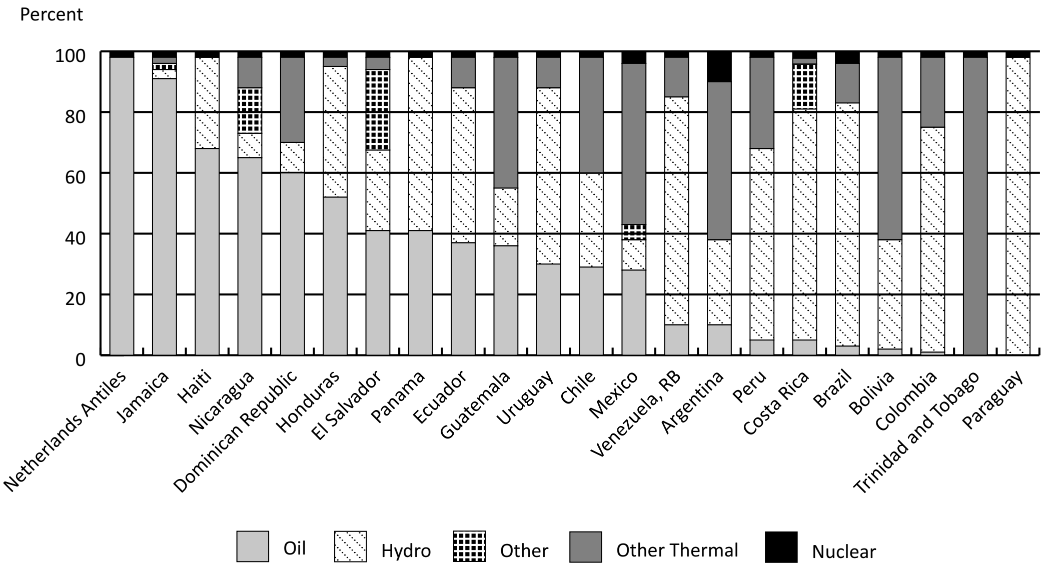
CHAPTER 4

# Impact on the LAC Power Sector

Oil prices are an important driver of electricity costs. The impact varies by country, primarily as a function of the share and efficiency of oil-based thermal generation (as distinct from coal or natural gas) in the respective countries' electricity generation mix. The relative weight of oil-based thermal generation varies widely across the LAC region, ranging from nearly 100 percent in certain Caribbean countries to less than 2 percent for some countries in South America (Figure 4.1).

This chapter analyzes the impact of higher oil prices on the electricity sector in the LAC region, beginning with increased generation costs resulting from the recent spike in oil prices, which have averaged nearly US$100 per barrel a year. Next, it estimates the short-term impact of an additional $50 per barrel increase in terms of production costs, tariffs, and several other measures, followed by a long-term analysis that considers regional demand by 2030, price

**Figure 4.1 Electricity Generation by Plant Type, 2009**




*Sources:* IEA 2012; OLADE 2012.

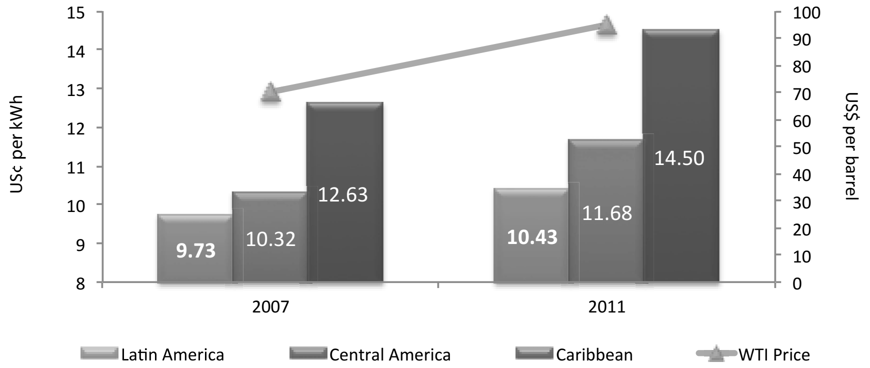
elasticity, and countries that could reduce consumption. Two scenarios are offered to assess the potential generation matrices that could be developed by 2030 to minimize countries' current exposure to oil and their potential impact on generation costs and GHG emissions (Appendix E).

## 4.1 Recent Vulnerability in Generation Costs

Between 2007 and 2011, oil prices in the LAC region rose an average of US$23 per barrel (from $72 to $95 a barrel, on average), causing the cost of electricity generation to rise 0.7 US¢ per kWh on average. The most vulnerable subregions were Central America and the Caribbean, owing to their greater reliance on oil-based power generation (Figure 4.2).

Countries in the Caribbean and Central America with a high proportion of oil in their primary energy mix are especially vulnerable to higher and more volatile oil prices. Because these countries are net importers of crude oil and oil products, they are more vulnerable to external price shocks. While Haiti and other smaller oil importers in the Caribbean have utilized regional agreements to reduce their vulnerability (Box 4.1), these short-term solutions avert the longer-term issue of exposure to high oil prices for electricity generation. Such countries as the Dominican Republic now face financial struggle as a result of having a large share of oil in their generation mix (Box 4.2).

**Figure 4.2 Growth in Average Electricity Cost, 2007–11**




*Source:* Authors.

### Box 4.1 Fuel Price Vulnerability in Haiti

In Haiti, imported oil products represent about 18 percent of GDP, and more than 80 percent of the power sector's operating capacity is thermal (diesel and fuel oil), much of it consisting of older, inefficient plants operated by local Independent Power Producers (IPPs). The Haitian government intervenes heavily in the fuels sector, with purchasing centralized under the Ministry of Planning and electricity prices regulated without pass-through.

Under the Petrocaribe agreement, the Haitian government purchases subsidized oil products from Venezuela's national oil company. Haiti pays only 30–60 percent of the FOB price of the cargo within 90 days, while the remainder is a debt paid over a 25-year period at a 1 percent interest rate with a 2-year grace period. When international oil prices rise, the share paid within 90 days is reduced to the lower end of the range. The agreement partially mitigates Haiti's exposure to higher oil prices. But since there is no pass-through, EDH (*Electricité d'Haiti*), the country's public utility, bears the burden of oil price increases directly. Given that EDH operates at a loss, the burden eventually shifts to the national budget, from which large and recurrent transfers must be made to keep EDH operational.

These budget transfers reflect poor sector governance at both the utility and government levels. Electricity consumers not served by EDH are directly affected since they must use individual gensets. The poor suffer even more since they must rely on kerosene or candles for basic lighting. Schools not connected to the grid may be unable to cover their fuel costs to operate gensets, and even gas stations may close before nightfall to reduce variable costs.

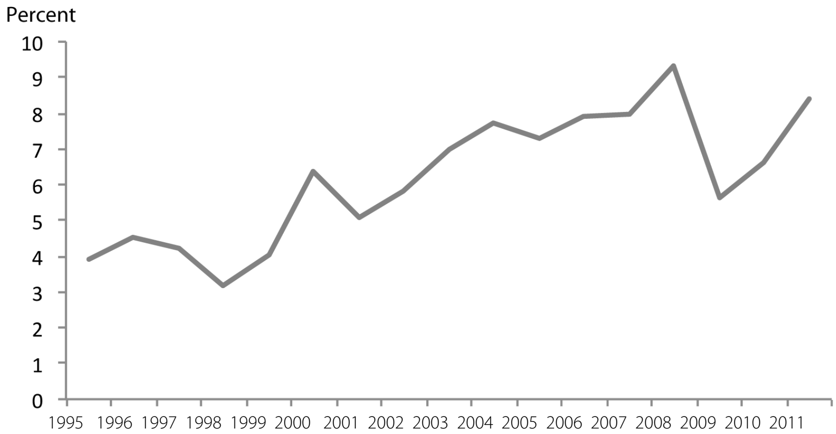
Breaking this vicious circle of increasing oil dependency and vulnerability to international fuel prices requires (i) reducing the pressure of suppressed demand by implementing aggressive measures to lower fuel consumption and losses and (ii) diversifying the energy matrix.

*Source:* "Fuels Price Vulnerability in Haiti," World Bank, April 7, 2011.

**Box 4.2 Oil Price Vulnerability in the Dominican Republic**

The Dominican Republic is especially vulnerable to higher oil prices. Two-fifths of the country's total power generation is from oil—all of which is imported—followed by natural gas and coal. Owing to higher oil prices, net oil imports as a percentage of GDP have been ticking upwards in recent years, spiking to 9 percent in 2008, as illustrated below. Although oil prices declined sharply in 2009 due to the financial crisis, they have since resumed their upward climb, remaining above US$80 per barrel every month since October 2010. The country now faces mounting fiscal pressure and must adopt urgent measures to manage its oil price vulnerability.

**Oil Imports as a Percent of Gross Domestic Product, 1995–2011**




*Sources:* IMF 2011; EIA 2012.

## 4.2 Estimating the Impact of a US$50 Price Increase

To better understand how oil price increases affect the power sector in various countries of the LAC region and thus its vulnerability to oil prices, we evaluated the impact of a US$50 per barrel increase over both the short and longer term (Appendix B). In economics, the short term can be defined as that period in which the quantity of at least one input is fixed, while those of the other inputs can vary; by contrast, the long term is that period during which the quantities of all inputs can vary. Over the short term, no changes in generation technologies are made, suggesting that producers would have limited flexibility adjusting their short-term generation mix, making them more vulnerable to sudden increases in variable costs. For example, despite rapidly increasing oil prices, hydropower generation facilities could not be built on short notice to achieve maximum substitution; however, plans could be put in place to ensure that all future hydro plants considered optimal could be built over the ensuing 20 years.

### 4.2.1 Short-Term Price Effects

***Electricity Production Costs***

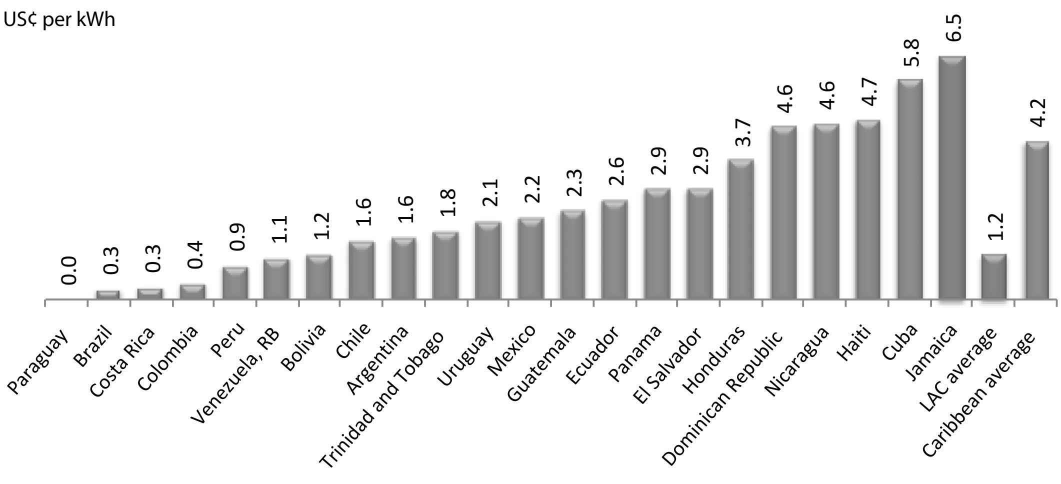
In the LAC region, a US$50 per barrel increase in the price of oil raises electricity cost by an average of 1.2¢ per kWh (from 14.7 to 15.9¢ per kWh). The group most heavily reliant on oil-fired electricity generation includes most countries in the Caribbean subregion, with Jamaica, Haiti, Nicaragua, and the Dominican Republic exhibiting the largest cost increases. A second larger group—Argentina, Bolivia, Ecuador, Mexico, Trinidad and Tobago, Uruguay, and four countries in Central America (El Salvador, Guatemala, Honduras, and Panama)—has lower levels of oil-based thermal generation in its energy mix but faces significant cost increases (from 11.7 to 13.9¢ per kWh). Finally, a third group—Brazil, Chile, Colombia, Costa Rica, Paraguay, Peru, Uruguay, and Venezuela, RB—is less affected because it generates a large share of electricity from hydropower resources. Figure 4.3 shows the cumulative variation in the cost of electricity production that could accrue from an additional $50 per barrel price increase, starting from 2011 prices.[1]

The LAC region could experience an average increase of 1.2¢ per kWh; however, countries in the first group—Dominican Republic, Haiti, Jamaica, and Nicaragua—could witness an increase of more than 4¢ per kWh. Because of its larger share of thermal generation, Jamaica could exhibit the most dramatic increase, at more than 6¢ per kWh, about 2¢ higher than the average increase for countries in the Caribbean subregion (4.2¢ per kWh).

***Electricity Tariffs***

For all countries in the LAC region that pass through oil price increases to electricity consumers, the impact of a US$50 per barrel price increase (i.e.,

**Figure 4.3 Impact of Added US$50 per Barrel Increase on Average Electricity Production Cost**




*Source:* Authors.

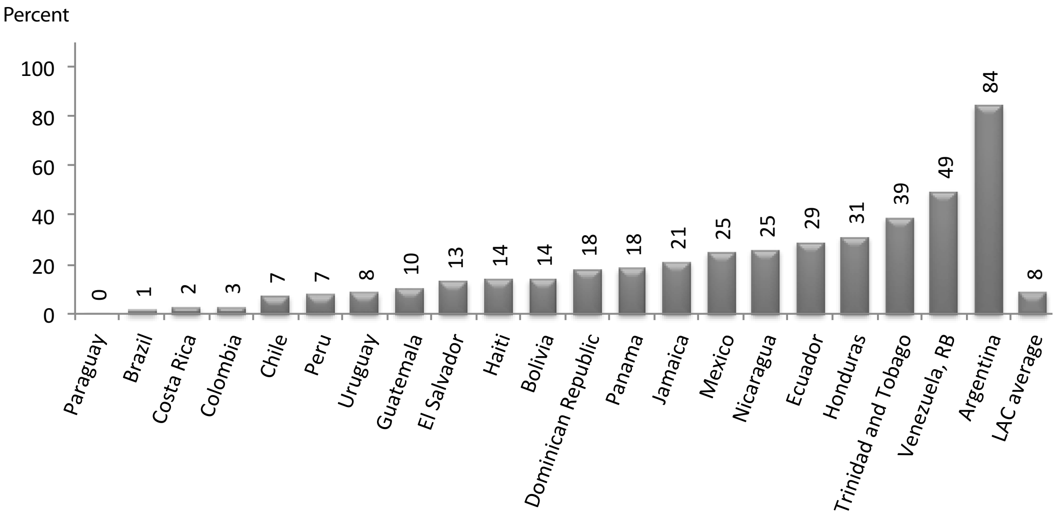
$100 to $150) on generation costs could raise electricity tariffs by 8 percent on average (Figure 4.4).[2]

The impact of the oil price increase on tariffs is a function of several factors: (i) share of oil in electricity generation mix, (ii) share of generation cost in total cost of electricity production, and (iii) pricing policies and pass-through mechanisms in place (i.e., the cost-recovery tariff structure through which the oil price variation translates into an actual tariff adjustment). For example, in Jamaica, which has a pass-through system, a US$50 per barrel price increase would be expected to raise the electricity tariff by 21 percent. If pass-through mechanisms were applied in such countries as Argentina, Honduras, and Mexico, which typically do not pass through the cost of oil price variations to residential users, the tariff increase could be substantially higher.

### *Aggregate Generation Costs Relative to GDP*

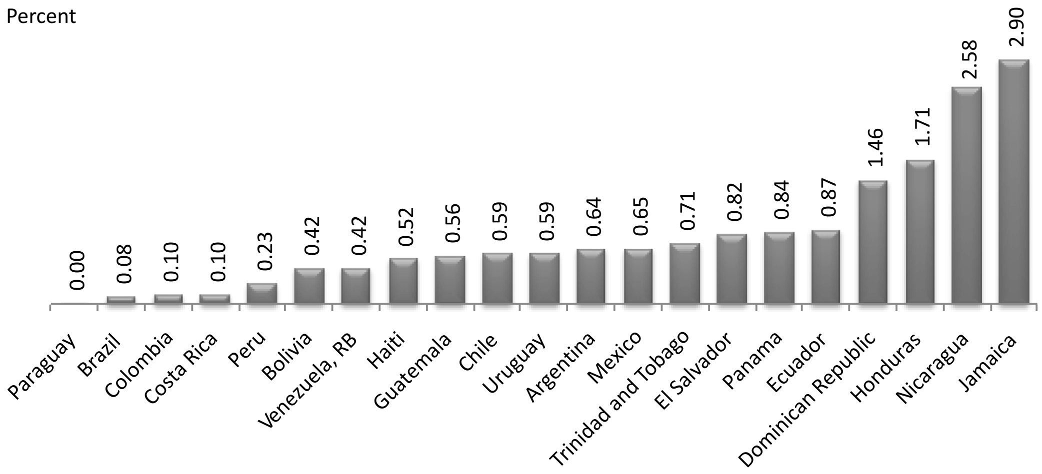
Changes in the cost of power generation resulting from higher oil prices have a significant financial impact on the LAC region's economies (Figure 4.5). The effect is particularly substantial for Jamaica, Nicaragua, the Dominican Republic, and Honduras, where the respective electricity cost increases from a US$50 per barrel price hike amount to more than 1 percent of GDP per year—nearly 3 percent in the case of Jamaica.[3] The magnitude of these increases relative to these countries' economies underscores their need to diversify their energy matrices and reduce their vulnerability to oil price fluctuations.

**Figure 4.4 Impact of Oil Price Increase as Percentage of Electricity Tariff, 2010**




*Source:* Authors, with OLADE data.
*Note:* This increase in the electricity tariff is the ratio between a country's average generation cost increase and the average electricity tariff in 2010.

**Figure 4.5 Impact of Oil Prices on Electricity Costs as Percent of GDP, 2010**




*Source:* Authors.

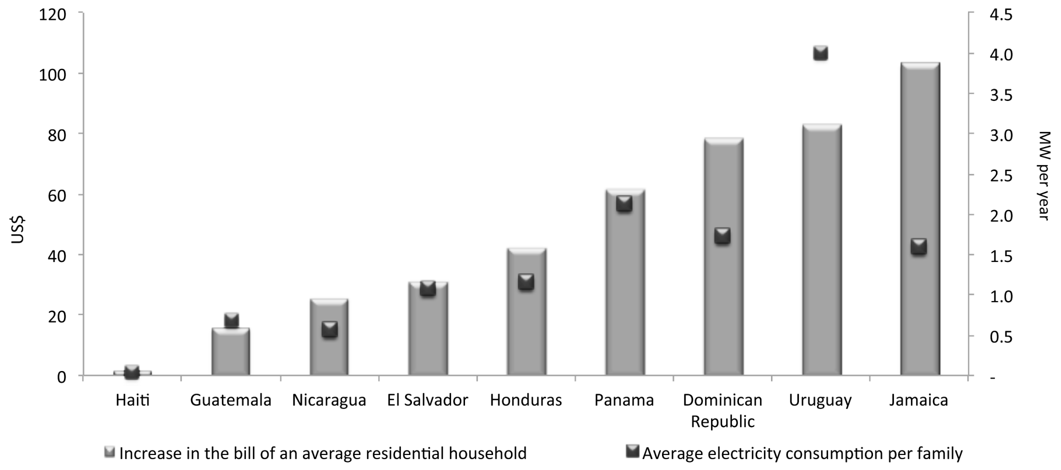
### *Cost Sharing Among Consumers, the Utility, and Government*

In a market with pass-through tariffs, consumers bear the bulk of the oil price impact. However, in most countries of the LAC region, consumers have been shielded to varying degrees by tariffs with embedded generalized subsidies (i.e., those that extend beyond the poor). The size of these subsidies relative to production cost increases determines how the increased cost is distributed among consumers, the utility, and government. Full coverage of rising costs by tariffs is rare, and many governments transfer funds to their utilities to cover a portion of the difference between production costs and revenue. But these transfers are often insufficient, resulting in a worsening financial position for the utility.

### *Household Electricity Expenditure*

The impact of higher oil prices on households depends on electricity pricing policies and the share of oil-fired plants in domestic generation, along with household electricity consumption. For example, in Jamaica—where price increases are passed through to consumers and 96 percent of the country's electricity is generated from oil—a US$50 per barrel increase in oil prices will increase the average household consumer's electricity bill by US$103 per year (with average consumption factored at 1.6 MWh per year). Figure 4.6 shows the potential increases in the average household electricity bill for the subset of LAC countries where at least 30 percent of electricity is from oil-fired generation. After Jamaica, the highest potential increases are observed in Uruguay, the Dominican Republic, Panama, and Honduras.

**Figure 4.6 Impact of Oil Prices on Household Electricity Cost**




*Source:* Authors, with OLADE and ECLAC data.

One may apply this same method to such countries as Argentina and Mexico, where the share of oil-fired power generation is limited to 10 and 18 percent, respectively. Since these countries typically do not pass through increased costs to consumers, the oil price increase would not affect the average household consumer's monthly electricity bill; rather, it would cost the respective utilities US$52 and $38 more to produce the monthly amount consumed by an average household.[4]

The foregoing analysis shows that changes in the cost of oil have had variable impacts on the LAC region's electricity sector. The 2007–08 upsurge in prices drove up the cost of power production significantly for most countries. The notable exceptions—Brazil, Chile, Colombia, Paraguay, and Trinidad and Tobago—are countries that rely heavily on hydropower and natural gas for generation. The recent downturn in oil prices points to an environment in which heavy volatility presents important challenges for power-sector planners, who need to better understand and quantify the interplay of oil and other factors of power-sector production.

### 4.2.2 Long-Term Price Effects

Given the potential for oil price variation, it is also important to identify the long-term responsiveness of both consumers and producers to higher oil prices. That is, for different sets of oil prices, by what amount would consumers reduce their daily electricity consumption and to what extent would producers diversify their generation matrix to include more efficient technologies.

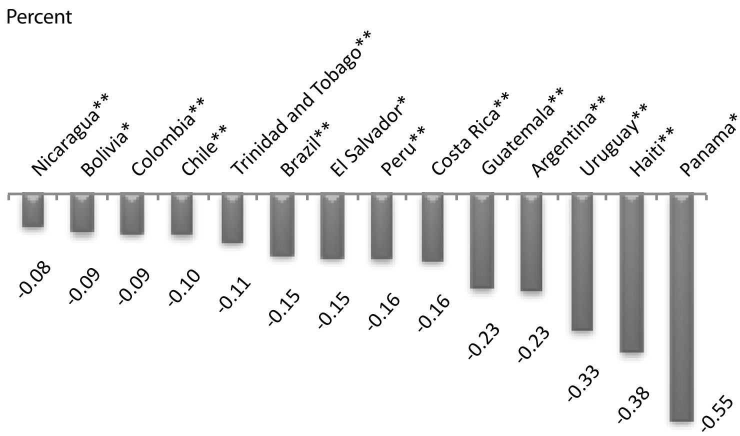
***Price Elasticity of Electricity Demand***

A simple logarithmic regression was used to identify the effect that electricity prices, WTI prices, and GDP have had on power demand in countries of the LAC region from 1986 to 2010. For the countries with available data and significant price coefficients, the models showed a good data fit. In these countries, a 1 percent increase in the price of electricity decreased demand by –0.20 percent on average. From the sample, the largest declines were observed in Panama, Haiti, and Uruguay, where demand showed higher price elasticity than in other countries of the region (Figure 4.7).

***Predicted Demand Growth***

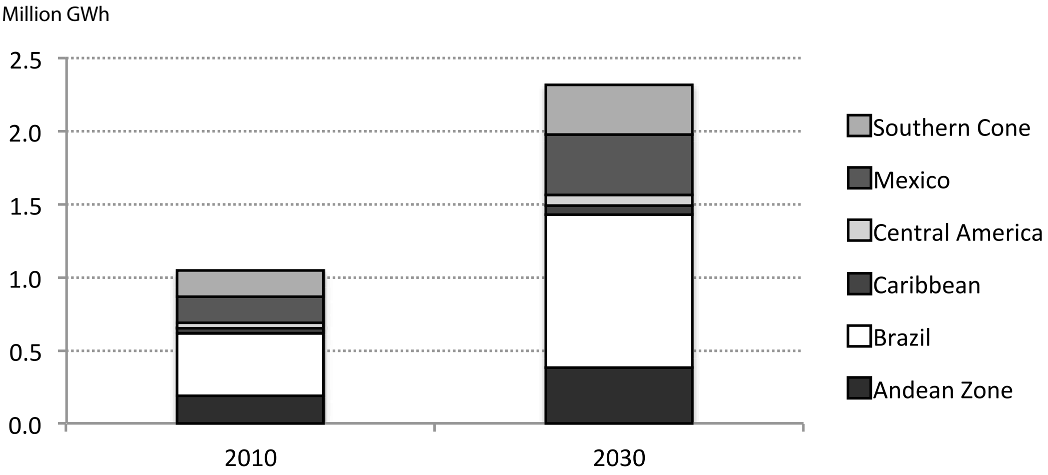
To forecast electricity demand to 2030, a log-linear model was developed using the previous elasticity, GDP country estimates (IMF 2011), and WTI prices.[5] The model results indicated that the LAC electricity sector would experience substantial growth over the next 20 years. Regional electricity demand growth is expected to average 4.1 percent annually, with Brazil and Central America outpacing the average by 0.4 percent. The growth path would be concentrated in the second half of the period analyzed (2015–30), at 78 percent, with a 22 percent increase in the initial years (2008–15), with the share of each subregion roughly the same throughout the 2008–30 timeframe. Mexico and the Andean Zone would grow at a similar pace, at 3.9 percent and 3.8 percent, respectively, while demand growth in the Southern Cone and the Caribbean subregions would be slightly more moderate, at 3.6 percent (Figure 4.8).

**Figure 4.7 Price Elasticity of Electricity Demand**




*Source:* Authors, with OLADE and ECLAC data.
*Note:* * and ** denote significant levels of 10 percent and 5 percent, respectively.

**Figure 4.8 Electricity Demand by Subregion, 2010 and 2030**




*Source:* Authors' calculations.

## 4.3 Meeting Added Incremental Demand to 2030: Two Scenarios

To decide how the LAC region will satisfy this additional electricity demand with crude oil at US$150 per barrel, two scenarios were developed, taking 2009 as the starting point. In Scenario 1, price increases in natural gas and oil move in tandem, following the market trend prior to 2008. Thus, a $50 per barrel increase in the price of oil would correspond to a price increase of $3.20 per mmcf of natural gas. Scenario 2 assumes that natural gas prices decouple from oil prices due to increased non-conventional gas production in the U.S., in which case natural gas prices remain constant despite oil price increases for the entire region.[6]

### *4.3.1 Renewable Energy Potential*

Although the future technology mix is not expected to change significantly past 2009, the matrix is readjusted considerably in both scenarios if oil prices make other technologies more competitive with fuel oil or diesel generation. The LAC region's remaining potential for renewable energy–based generation is large (Appendix C).[7] But owing to its variability, renewable energy could not fully replace fossil fuels to cover all additional demand; thus, substitution with renewable sources is considered to the level technically feasible (Box 4.3). This study assumes that non-renewable sources would be needed to generate excess demand in the same proportion as in the 2009 electricity matrix.

In many countries, the remaining potential of renewables is larger than current electricity generation. In 2009, Costa Rica, Colombia, Ecuador, Guatemala, and Honduras could have at least doubled their hydro-based electricity generation; while such countries as Antigua and Barbuda, Argentina, Haiti, and Nicaragua were similarly positioned in terms of wind energy. Conversely, such

**Box 4.3 Technical Constraints to Large-Scale Penetration of Renewables**

The availability of renewable energy in the LAC region varies widely by country. For example, renewable sources are abundant in Argentina, Bolivia, Brazil, Colombia, Costa Rica, Surinam, and Venezuela. However, potential is limited in countries of the Caribbean and Central America (except for Costa Rica) (Appendix C).

Reducing oil consumption by diversifying from oil-fired power generation can fundamentally manage the impact of high and volatile oil prices on the power sector. But developing alternative energy sources to achieve a diversified generation matrix requires time, which is a challenge for many developing countries that struggle to provide sufficient capacity. Even in countries with a large renewable-energy potential, full use of these sources may be limited by technical, economic, and environmental constraints.

Wind and solar PV energy sources have an intermittent production profile, meaning that electricity generation is inconsistent within a 24-hour period or from day to day. In addition, predicting future output is error-prone. At higher levels of renewable penetration, energy systems might require complementary peaking plants that could ramp up (e.g., when wind production falls) and down quickly to match demand and supply. In addition, demand-response or market mechanisms could be utilized to match demand to renewable energy variability. Technological advances may make renewable-energy storage systems cost-effective, which could help smooth out generation. While natural gas and hydro are suitable for peaking power, it would be inefficient to use coal, which is not designed to ramp up and down quickly.

Barring cost-competitive, renewable-energy innovations that could overcome technical limitations, base-load generation sources (i.e., coal, hydro, and nuclear) will be required in all of the region's energy systems in the years ahead—except for Paraguay, where hydro is expected to meet 100 percent of electricity demand. Countries seeking to achieve high levels of renewable-energy penetration from intermittent sources will need to adopt a generation mix that combines low-cost, base-load power sources with flexible, peaking-power sources to match their load profile.

*Sources:* Channell, Lam, and Pourreza 2012; authors.

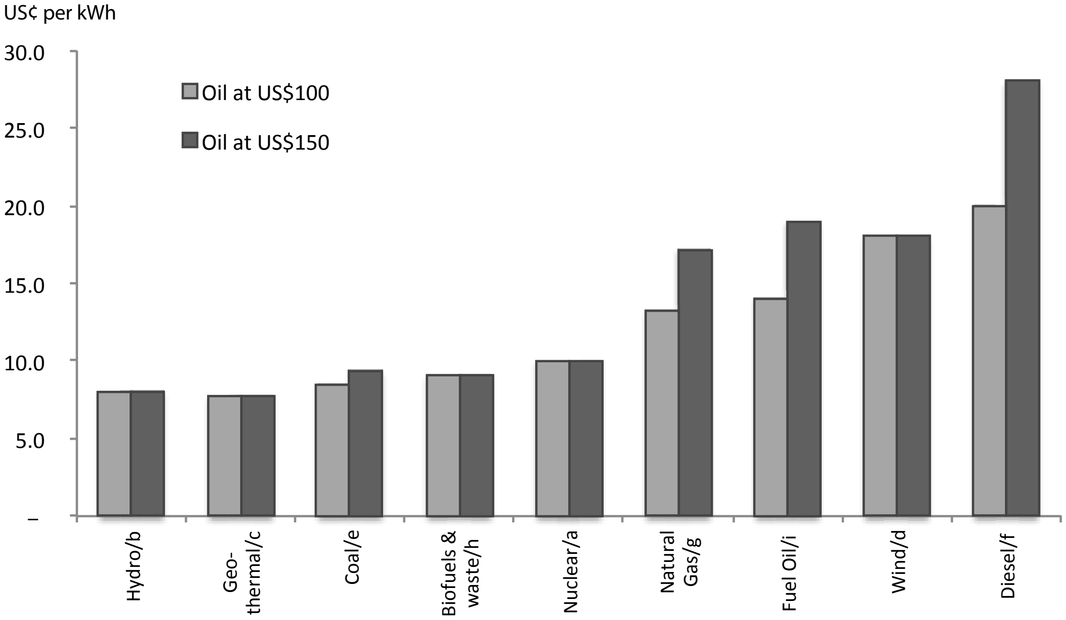
countries as Jamaica, Mexico, Paraguay, and Trinidad and Tobago have limited remaining hydro potential, suggesting the emerging strategic importance of solar energy over the next two decades.

### *4.3.2 Filling the Demand Gap*

In deciding how to bridge the gap between expected electricity demand growth and the generation potential of renewable energy, it is important to determine which available technologies are cheapest. In this study, costs of the various technologies were estimated based on ESMAP's Model for Electricity Technology Assessments (META), first at an oil price of US$100 per barrel and then at prevailing market prices of $150 per barrel (Appendix D).[8] One should note that these costs do not incorporate those associated with program implementation, especially considering externalities. For simplification, this study assumes that the technology used (not specific project conditions) is the only source of difference between projects. Based on this assumption, all hydro projects have the same average cost per kilowatt hour and are cheaper than geothermal, which might not always hold true in reality.

It should be noted that oil at US$100 per barrel is already less competitive than coal, natural gas, and nearly all renewable technologies, assuming that the cost is passed through. If the costs presented reflected market conditions to some extent (Figure 4.9), countries around the globe would already be moving away from oil to maximize their use of renewables, coal, and natural gas. Hydro projects in particular could cover all electricity consumption in such countries

**Figure 4.9 Average Cost of Fuels per Kilowatt Hour Generated, Scenario 1**




*Source:* Authors, using META.
a. Cost with a dual-unit nuclear plant at 85 percent load factor.
b. Average cost of medium and large hydro plants at 55 percent load factor.
c. Average of small, medium, and large geothermal plants at 80 percent load factor.
d. Average of on- and off-shore wind plants at 25 percent load factor.
e. Average of medium and large steam plants at 75 percent load factor.
f. Average of a combined-cycle diesel engine and large gas turbine at 75 percent load factor.
g. Average of medium and large steam, combined-cycle, diesel and gas turbine plants with natural gas at 75 percent load factor.
h. Biomass steam plant at 75 percent load factor.
i. Average of large steam and diesel engines at 75 percent load factor.

as Brazil, Colombia, Ecuador, Guatemala, Panama, Peru, and Venezuela, RB. That these countries have not yet begun to shift toward hydro generation under prevailing oil price conditions demonstrates how available renewable potential can be limited by various other issues, including environmental concerns, operational complexity, lack of operational flexibility and regulatory and financial constraints.[9]

Given that renewable-energy sources alone cannot provide all of the needed expansion in electricity supply at an acceptable cost, expanding conventional thermal-generation technologies using non-oil fossil fuels appears inevitable in Central America and the Caribbean. A conventional diversification strategy is to shift to coal in electricity markets above a certain size. Determining the competitiveness of natural gas versus coal requires more assumptions about logistics and transport costs for units of a similar size. Coal may have some cost advantages on a fuel-to-fuel basis; but those advantages are unclear when transport costs and availability are taken into account. Coal-fired systems have a larger impact on GHG emissions, which raises the cost of coal versus cleaner options. New clean-coal technology can reduce carbon dioxide ($CO_2$) emissions per kilowatt hour; however, emissions remain significantly higher than for natural gas. Also, such coal plants are likely to have higher capital costs than more basic designs considered in the past. In short, owing to logistics and availability costs, coal may not be cheaper than natural gas from a cost perspective, even without considering the impact on GHG emissions.

While Colombia possesses the region's largest coal deposits, this source accounted for only 7 percent of the electricity generated in 2009. High international prices and the strategic location of Colombian coal production results in more than 90 percent of steam coal being exported, with only about 30 percent of remaining production used for electricity generation. This situation is intensified by the development and competitive price of hydroelectric generation, which represents more than 40 percent of the generation matrix.

Another example of low coal use is Brazil, where poor-quality coal hinders development of the sector. The country has few operational coal plants, most of which are located in the South. Currently, only three small coal plants are included in the Growth Acceleration Plan or PAC (*Plano de Aceleração do Crescimento*), although 360 electricity generation projects are included in the National Plan.

Taking 2009 as the baseline year, this study acknowledges current restrictions (i.e., countries do not necessarily use all of their hydro potential despite it being the cheapest available technology). The two scenarios presented below assume that substitution using renewable sources will be made whenever possible, prioritizing the use of cheaper technologies up to the technically feasible amount. These exercises consider the technical constraints of generation using variable renewable energy, such as wind and solar PV.

### 4.3.3 Scenario 1

Scenario 1 considers shares of fuels and technologies for electricity generation by 2030, as projected by Yépez-García, Johnson, and Andrés (2011), using the SUPER (*Sistema Unificado de Planificación Eléctrica Regional*) model to calculate the generation mix and investment requirements to meet demand.[10] This scenario reflects the power-expansion plans currently available in LAC countries with respect to the 2009 generation matrix, taken as the baseline for the region going forward.

A US$50 increase in the price of oil would raise the average cost of electricity generation from fuel oil–based technology by 6¢ per kWh (from 15 to 21¢ per kWh). The cost of diesel technology would rise by about 8¢ per kWh (from 19 to nearly 27¢ per kWh) (Figure 4.9). Despite the magnitude of this increase, it can be considered negligible for this exercise since diesel was already the most expensive technology in the analysis, making all other technologies preferable. Under the assumptions of this scenario, wind technology could become more competitive than diesel, further opening a window of opportunity for increasing the use of renewables. Along with higher oil prices, natural gas prices are assumed to increase moderately while coal prices remain fairly constant; both of these generation technologies remain more competitive than fuel oil and diesel.

As a result of price increases for both natural gas and oil, countries will try to optimize their generation matrix by substituting both technologies with available renewables. In this exercise, oil substitution with renewable energy was evaluated at the limit technically possible, with hydro found to be the cheapest among the renewable technologies.[11]

Results of our analysis show that the total LAC generation mix is expected to remain dominated by hydroelectricity and natural gas, with less dependence on oil. While hydro generation would decrease in percentage, an additional 642,449 GWh would be required over the next 20 years for it to remain the region's main supplier of electricity; this is equivalent to nearly doubling current hydro generation, considering that an extra 95 percent of what the region currently produces would be needed.

The main change estimated by the model is a decrease of about 10 percent in the share of fuel oil and diesel generation, which would occur mainly as a result of expanded generation of natural gas, whose respective share in the total generation mix would increase by 6 percent. Generation from wind, biomass, and geothermal would increase both in absolute numbers and as a percentage for the region. Wind energy generation, currently concentrated in Brazil and, to a lesser extent, in Mexico, would be developed considerably in Argentina, Chile, the Dominican Republic, and Haiti. In Brazil, generation from biomass would increase fivefold by 2030 (compared to the 2009 baseline), increasing the overall average for the LAC region.

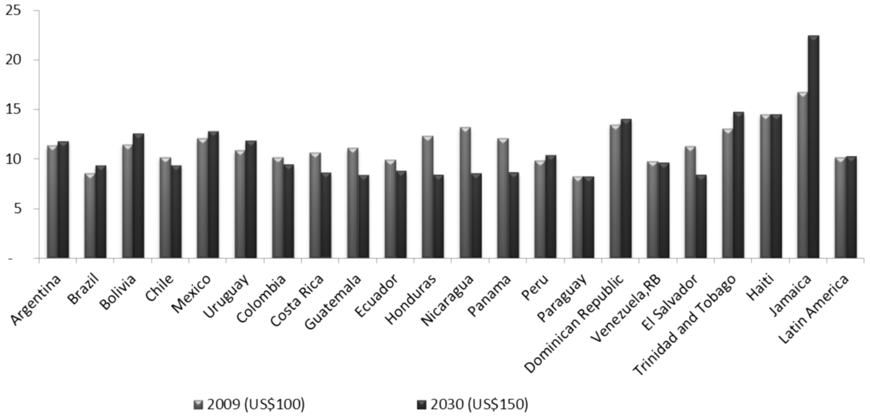
Geothermal generation, which was limited to Costa Rica, El Salvador, Mexico, and Nicaragua in 2009, suggests positive scenarios for development, particularly in Chile, where it could reach nearly 6 percent of national electricity generation.[12] While nuclear generation presents an expansion equivalent to three times current levels in absolute terms, its use is limited to countries where it is currently included in the generation matrix (i.e., Argentina, Brazil, and Mexico).

The modeling exercise reveals that fuel oil and diesel could be substituted with cheaper sources of generation for most of the LAC region (except for Argentina and Jamaica). Haiti, where 96 percent of current electricity generation is oil-fired, could switch to a mix of hydro, natural gas, and wind, thereby reducing emissions and maintaining the same cost by 2030. Such countries as Bolivia, Colombia, Ecuador, Honduras, Peru, and Venezuela, RB could generate most of their required electricity using only hydro and natural gas. Finally, for countries in the Caribbean subregion, fossil fuels would persist, accounting for more than 90 percent of electricity generation (Appendix E).

Analyzing the cost impact of a new generation matrix by country shows that regional cost would remain similar, increasing from 10.17¢ per kWh in 2009 to 10.27¢ per kWh by 2030 (Figure 4.10). Despite the reduction in oil consumption, the price increases would be moderately due to greater use of natural gas, which is a more expensive resource under this scenario. In such countries as Bolivia, Brazil, and Peru, greater use of natural gas for generation would be enough to increase the total cost. This can be explained by the assumption that an increase in natural gas prices by 2030, coupled with oil at US$150 per barrel, could make this generation technology nearly as expensive as fuel oil in 2009, at $100 a barrel; of course, the result would differ if natural gas prices were decoupled from oil prices.

**Figure 4.10 Cost of Electricity Generation, Scenario 1**

US¢ per kWh (2009)




*Source:* Authors, with data from the LCSSD simulator model.

Countries in the Caribbean subregion would face a greater increase in electricity costs due to limited substitution options in their generation matrices. Conversely, in countries of Central America (i.e., El Salvador, Guatemala, Honduras, Nicaragua, and Panama) and in Ecuador, costs would be reduced considerably as a result of switching from diesel to hydro generation.

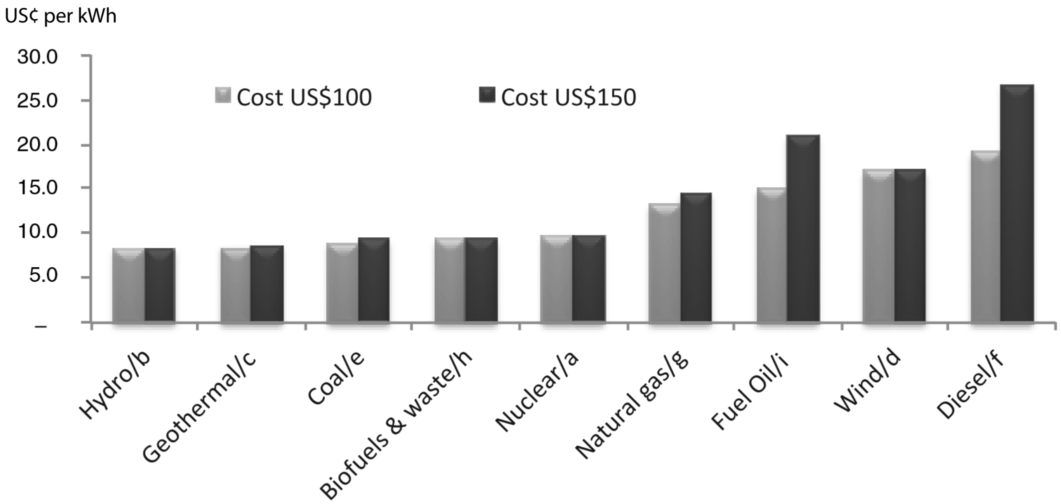
### *4.3.4 Scenario 2*

In contrast to Scenario 1, Scenario 2 assumes that natural gas prices decouple from those of oil and thus do not experience the same increase (Figure 4.11). As mentioned previously, sustained low gas prices would be feasible under circumstances of increased gas production and availability, with shale gas being the largest contributor to growth, as summarized by the EIA (2012).

With a greater expected share of natural gas, owing to its cost remaining constant, as well as hydro, only oil substitution would be necessary. As in Scenario 1, oil at US$100 per barrel remains less competitive than coal, natural gas, and nearly all renewable technologies, with the exception of wind.

The main change estimated by the model with respect to the 2009 baseline case is the total substitution of fuel oil and diesel generation, which would occur as a result of expansion mainly from natural gas and wind. Despite

**Figure 4.11 Average Cost of Fuels per Kilowatt Hour Generated, Scenario 2**




*Source:* Authors, using META.
a. Cost with a dual-unit nuclear plant at 85 percent load factor.
b. Average cost of medium and large hydro plants at 55 percent load factor.
c. Average of small, medium, and large geothermal plants at 80 percent load factor.
d. Average of on- and off-shore wind plants at 25 percent load factor.
e. Average of medium and large steam plants at 75 percent load factor.
f. Average of a combined-cycle diesel engine and large gas turbine at 75 percent load factor.
g. Average of medium and large steam, combined-cycle, diesel and gas turbine plants with natural gas at 75 percent load factor.
h. Biomass steam plant at 75 percent load factor.
i. Average of large steam and diesel engines at 75 percent load factor.

**Table 4.1 Proportion of Generation by Plant Type, 2009 and 2030**

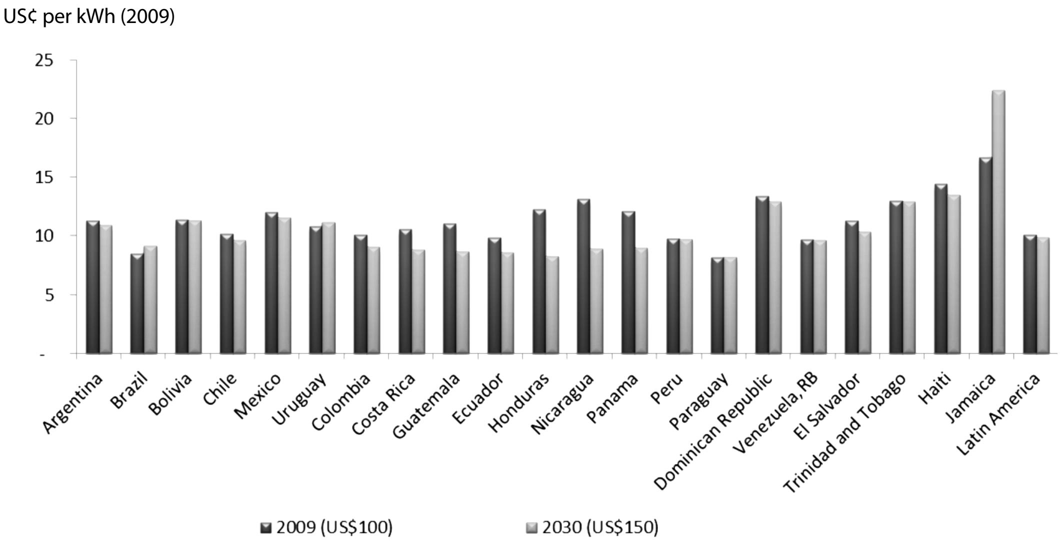
| *Case* | *Oil* | *Gas/coal* | *Hydro* | *Nuclear* | *Geothermal* | *Biomass* | *Wind* |
|---|---|---|---|---|---|---|---|
| 2009, Baseline | 10.83 | 26.01 | 58.89 | 2.73 | 0.96 | 0.45 | 0.13 |
| 2030, Scenario 1 | 0.53 | 32.44 | 55.50 | 4.33 | 0.98 | 4.73 | 1.50 |
| 2030, Scenario 2 | 0.22 | 35.85 | 54.23 | 4.33 | 0.68 | 2.89 | 1.81 |

*Source:* Authors.
*Note:* The use of natural gas increases only 4 percentage points form Scenario 1 to Scenario 2 because it substitutes for hydro and biomass generation. Due to high oil prices (US$150 per barrel), most oil-based electricity generation in Scenario 1 has already been substituted by hydro and gas, and opportunities for more substitution are more limited.

hydro generation dropping to 54 percent of the regional matrix, additional generation capacity of nearly 90 GW—equivalent to 90 percent of current hydro generation—would be required over the next 20 years for it to remain the region's main supplier of electricity. Compared with results in Scenario 1, hydro and biomass would comprise a smaller share of generation, compensated by greater use of wind and natural gas. Nuclear and geothermal would remain at 4 percent and 1 percent, respectively. In Table 4.1, the two scenarios for 2030 are compared with the 2009 baseline case.

The generation mix in Scenario 2 differs from Scenario 1, owing mainly to the larger share of wind generation in Argentina (from 3 to 7 percent) due to complete substitution of oil (Appendix E). Also, there is a smaller share of hydro generation in Chile, Costa Rica, El Salvador, Guatemala, Nicaragua, Panama, Uruguay, and Venezuela, RB. Analyzing the cost impact of a new generation matrix by country shows that regional cost would remain similar, decreasing only slightly (from 10.17¢ per kWh in 2009 to 10.02¢ per kWh by 2030) (Figure 4.12).

**Figure 4.12 Cost of Electricity Generation under Scenario 2**




*Source:* Authors, with data from the LCSSD simulator model.

**Figure 4.13 Reduction in $CO_2$ Emissions for the LAC Region**

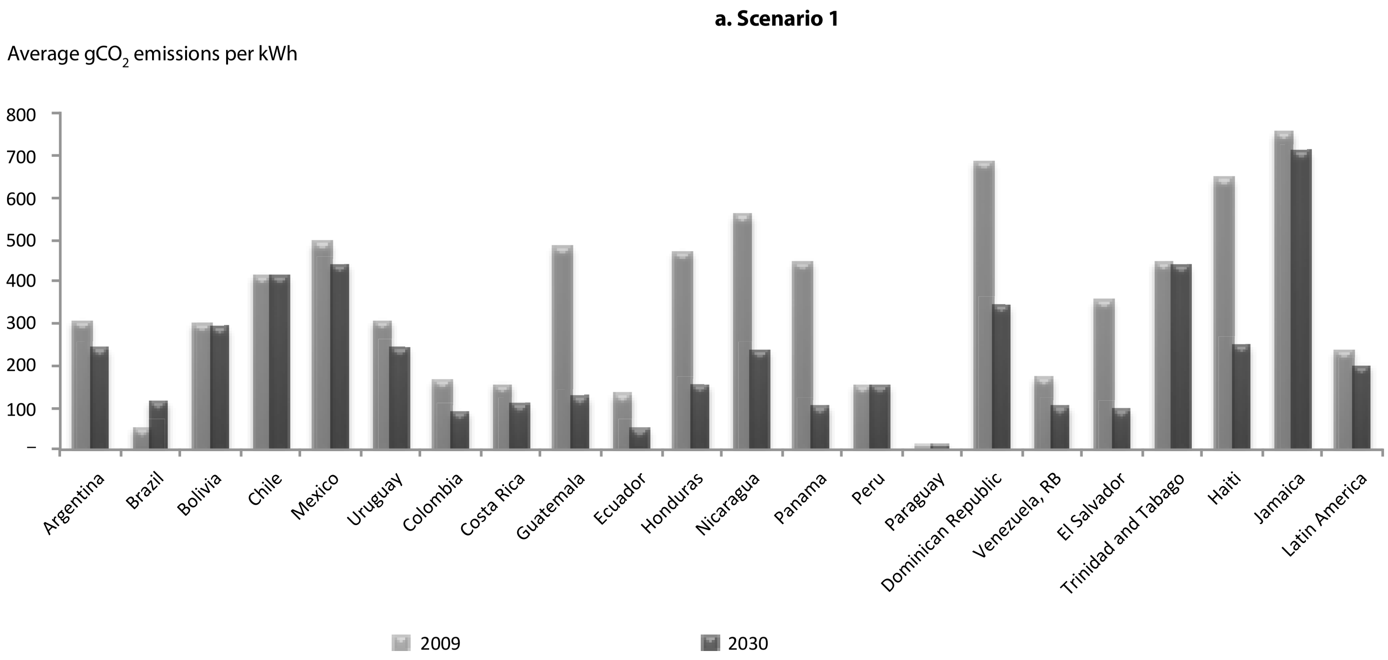
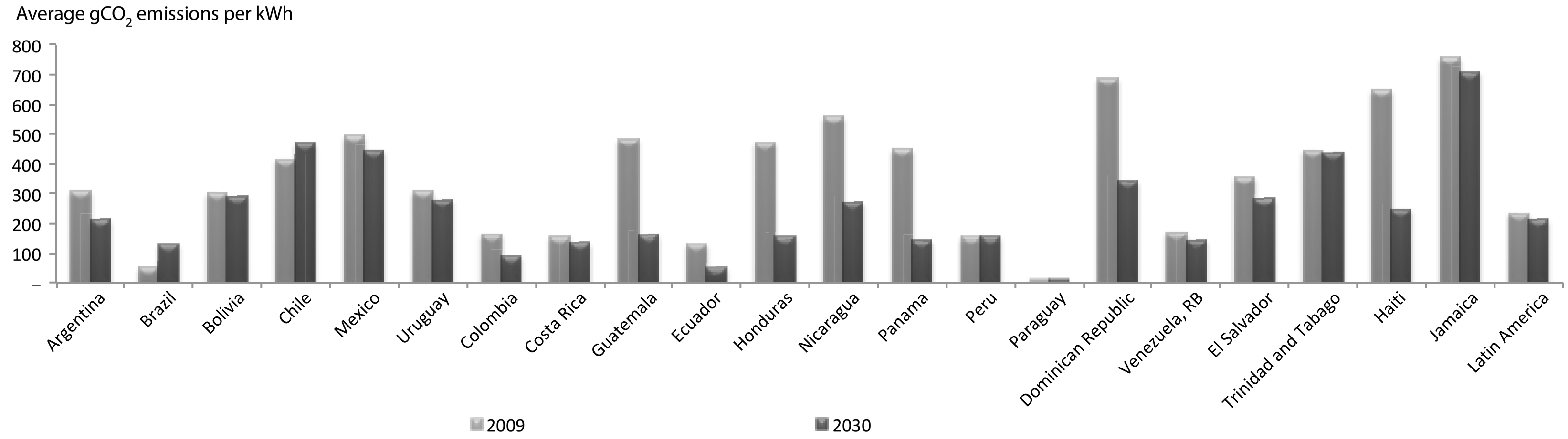


**Figure 4.13 Reduction in $CO_2$ Emissions for the LAC Region** *(continued)*

**b. Scenario 2**




*Source:* Authors.
*Note:* Average emissions per kilowatt hour per type of technology taken from the LCSSD simulator model.

## 4.4 Greenhouse Gas Emissions

By 2030, greenhouse gas (GHG) emissions would be reduced considerably under both scenarios.[13] The largest reductions would accrue under Scenario 1, in which case most countries and the LAC region would use less fuel oil and diesel overall and more hydropower and natural gas. Reduction in $CO_2$ emissions would be particularly evident in countries of Central America and Haiti (Figure 4.13a). However, Brazil and Chile would have higher average emission rates by 2030 due to the larger share of natural gas and the smaller share of hydro in their generation matrices, compared to the 2009 baseline.

The $CO_2$ emission reductions in Scenario 2, although considerable for both the LAC region overall and most countries, are less than in Scenario 1 owing to the larger share of natural gas and smaller share of hydro in the regional generation matrix. Brazil and Chile display slight increases in GHG emissions, while the largest decreases are found in countries of Central America, the Dominican Republic, and Haiti (Figure 4.13b). These results are particularly relevant since LAC countries have assumed voluntary commitments to reduce GHG emissions, including the setting up of market mechanisms (i.e., cap and trade and nationally appropriate mitigation actions), which would mainly impact energy-related industries over the next two decades.

## 4.5 Concluding Remarks

Results of the simulations presented in this chapter suggest the dominance of both hydropower and natural gas in the LAC region's total electricity generation mix (Appendix F). The potential for hydro generation would be considerable, given its price competitiveness with other available renewable sources to meet the region's expected demand growth by 2030. Obviously, rising natural gas prices would limit the amount of oil substitution that could be made. However, if natural gas prices were to remain constant, the region could achieve a total substitution of fuel oil and diesel generation by 2030, resulting mainly from the expanded use of natural gas, as well as wind energy, particularly in Argentina. In turn, the region could reduce its vulnerability to future oil price increases and the average cost of generation per kilowatt hour, with countries in Central America experiencing the largest cost savings.

By 2030, the LAC region's replacement of oil in its generation matrix could reduce regional GHG emissions by 18 or 23 percent, respectively, compared with 2009 levels. Central America and the Caribbean—subregions historically more vulnerable to higher oil prices because of their heavy reliance on oil-fired generation—would stand to benefit the most. If natural gas prices rise, Central America could cut its GHG emissions by two-thirds or by half if gas prices decouple from oil; while the Caribbean could see 30 percent emission reductions in either case.

## Notes

1. This exercise assumes that the price of oil increases from US$100 to $150 per barrel and that the price of natural gas follows the historical correlation with the price of oil. It also assumes a simple average between oil-powered plants that use heavy fuel oil (lower bound) versus diesel (upper bound).
2. This increase in the electricity tariff is the ratio between a country's average generation cost increase and the average electricity tariff in 2010.
3. This section measures the output cost on these two higher-impact countries (Dominican Republic and Honduras), while the analysis in Chapter 3 estimates the average impact on the growth rate of the economy.
4. Under a variety of simplifying assumptions.
5. The demand model used energy statistics from the OLADE database.
6. This scenario presumes that natural gas prices decouple from oil prices as a result of the shale gas impact and a reduction in LNG transport costs.
7. In the LAC region, energy endowments vary tremendously by country in terms of scale of potential relative to current electricity output and mix of available resources.
8. The META, initially referred to as the Energy Technology Assessment Guide (ETOAG) model, was developed by Chubu Electric Power Corporation, Inc. and Economic Consulting Associates for the World Bank's Energy Sector Management Assistance Program (ESMAP) in May 2012.
9. Costs could vary greatly by country and between locations within the same country; to simplify the analysis, it was assumed that renewable energy costs were the same across the entire region.
10. Developed by OLADE, the SUPER model aims at prioritizing, scaling, and selecting electricity projects to meet projected demand.
11. In considering renewable energy or increasing its share, it is important to keep in mind the limits of its operational flexibility and the other investments required for its optimal use (e.g., modernization of transmission systems for handling increased variability, and, in some cases, additional backup generation, particularly for wind and solar).
12. As noted above, renewable energy is subject to specific constraints (e.g., feedstock for biomass and upfront costs and exploration risks for geothermal).
13. With the caveat that the potential environmental and health risks associated with shale-gas extraction technology are settled, as mentioned in Chapter 2.

CHAPTER 5

# Conclusion

Energy planners in Latin America and the Caribbean (LAC) face the daunting task of deciding how to meet expected growth in electricity demand in the coming decades. The key challenge is managing additional incremental demand in a way that maintains sufficient economic growth without compromising the public budget. Presumably, a high oil price scenario could require an entire reconfiguration of the energy sector. There is ample room in the region's current energy matrix to diversify from traditional oil-based electricity generation to alternative renewable and non-renewable generation sources. Diversification would reduce oil dependence, in turn, mitigating the power sector's vulnerability to higher oil prices in the future.

The large impacts of higher oil prices on the economy and power sector, particularly in oil importing countries, as evidenced by this study, suggest the need for LAC energy planners to take steps now to reduce future risk. This will require decision-making on multiple fronts, including how to diversify the power generation portfolio, enhance energy efficiency, increase generation from renewable sources, and shift peak load through demand-side management. This study's comparison of generation plans for additional capacity in higher oil price scenarios, which variously impact the price of electricity and greenhouse gas (GHG) emissions, can help planners identify the best options to meet and manage future demand.

The potential impact of high oil prices on macroeconomic variables and electricity costs is large enough to merit serious reflection on how the future generation matrix might be reconfigured to reduce the share of oil-based generation to the extent technically feasible, particularly in Central America and the Caribbean, where the power sector is fueled heavily by oil-based imports. Although future correlations between oil and natural gas prices are unclear, the current pattern introduced by the shale gas revolution in the U.S. suggests the advisability of diversifying from oil to natural gas–based generation. This option could be especially interesting for Central American countries as trading of liquefied natural gas (LNG) accelerates across the region and prices decline as a result of applying new technologies that reduce the cost of liquefying, transporting, and re-gasifying natural gas.

The results of this study's analysis suggest that large investments will be required; however, the potential gains are many. As previously discussed, these include lower electricity prices for consumers (and potentially lower subsidies) and significant reductions in GHG emissions, particularly in subregions that currently rely heavily on oil-fired generation. The LAC region has significant potential for expanding generation from renewable sources, including hydropower, biomass, and wind, despite the limited flexibility of these options to match demand profiles relative to fossil fuels. The analysis illustrates the potential of renewable energy to comprise a greater share of power generation and thus reduce medium- and long-term vulnerability to high and volatile oil prices.

Increasing the share of renewable-energy sources, along with a larger share of non-oil fossil-fuel alternatives, particularly natural gas, can yield energy-security, economic, and environmental benefits, particularly in Central America and the Caribbean, where the cost of heavy oil dependence could mean reduced competitiveness and greater risk exposure to oil price volatility. Energy-sector authorities in Central America have already expressed interest in natural gas as a way to meet the population's energy needs, and some private investors have proposed electricity generation projects based on natural gas. Making the needed changes in the energy matrix to meet these optimistic goals will require an enabling policy environment with institutional and regulatory flexibility. Though the challenge is great, the cost of not planning how to reduce the risk of higher oil prices in the future could be considerable.

**APPENDIX A**

# Economic Effects of High Oil Prices

The general impact of oil prices has been extensively studied. The vast amount of literature on this topic reflects the wide range and scope of the approaches used (Box A.1). The general consensus is that oil prices and the economy are related; however, there are divergent opinions regarding the magnitude of the relationship and the channels affected (Rasmussen and Roitman 2011). Some of the affected economic variables may include the economic growth rate, cost of producing goods and services, balance of payments, and inflation. According to Roubini and Setser (2004), the magnitude of the relationship and the variables affected may depend on such factors as the percentage increase in oil prices and its persistence, the dependency of the economy on oil and energy, and the policy response of fiscal authorities. Other variables that may influence how a country responds to high oil prices include its energy intensity, extent of a diversified energy matrix, and level of dependence on energy imports.

Over the past decade, oil prices have risen steadily. Following a decade of high and volatile oil prices after the 1973 oil crisis, prices in the 1980s and 1990s were volatile, yet they exhibited no specific trend. Since 2002, however, oil prices have increased dramatically. In July 2008, the monthly average price for imported crude oil peaked at US$136 per barrel (real March 2013 dollars). The average price over the 2000–12 period was $64 per barrel, compared to $29 a barrel during 1986–99. In 2011, the highest annual average price was reached, at $106.05 a barrel; this price rise was also linked to higher volatility, adding uncertainty to an already elevated price environment (Figure A.1).[1]

Higher oil prices affect countries in multiple dimensions, having both short- and longer-term economy-wide implications for government and private-sector performance, as well as a society's overall well-being. The sections below describe an array of variables affected by high oil prices, ranging from economic growth and exchange rates, trade balance, and the cost of production and inflation, to unemployment, fiscal balance, competitiveness, and social concerns.

**Box A.1 Spanning the Literature on the Impact of High Oil Prices**

Literature on the impact of high oil prices encompasses many fields, from finance and development to macroeconomics and microeconomics. On the finance front, Sauter and Awerbuch (2003) survey literature on the effect of higher and volatile oil prices on growth and stock-market performance. In the development arena, Villafuerte and Lopez-Murphy (2010) offer a survey of recent literature on the so-called "resource curse" of resource-rich countries that tend to be poor.

The macroeconomics literature focuses more on the inflationary and growth effects of rising oil prices. Blanchard and Gali (2007) explore why the effects of recent oil price increases in industrialized economies have been milder than in the 1970s; their findings point to better energy efficiency and monetary policy, more flexible labor markets, and lack of concurrent adverse shocks. Hunt, Isard, and Laxton (2002) explore the mechanisms through which higher oil prices can pass through to core inflation in industrialized economies. For net exporting nations, Lizardo and Mollick (2010) note that higher oil prices can lead to currency appreciation and loss of competitiveness; higher inflation can also reduce net importers' competitiveness.

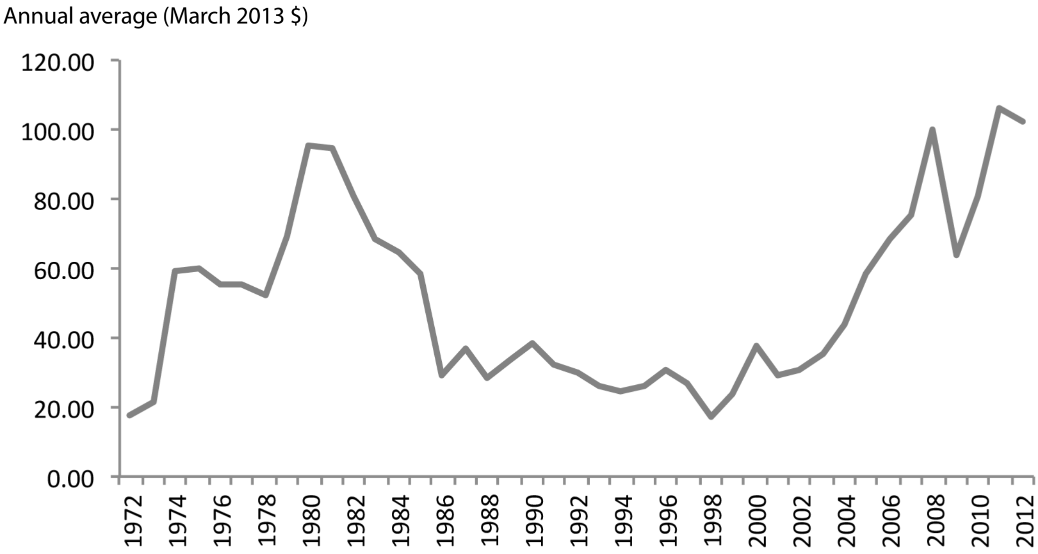
Cologni and Manera (2008) document how resource reallocation toward less energy-intensive industries can trigger temporary increases in labor-market unemployment. Industry-level studies provide a cross-sectional view of the impact of oil prices on various sectors. Fukunaga, Hirakata, and Sudo (2010) find that, for the U.S. and Japan, oil shocks reduce the supply of oil-intensive industries (e.g., petroleum refining, chemicals, and paper) and reduce demand in the auto and other industries.

Policy research seeks to quantify the macroeconomic effects of oil prices on alternative measures of vulnerability. Yépez-García and Dana (2012) focus on higher prices and oil price volatility, providing an overview of the channels through which oil prices affect a country's economy and strategies to mitigate a country's vulnerability to such factors. Bacon and Kojima (2008) present a decomposition of vulnerability based on price, import dependence, oil share, energy intensity, and real exchange rate effects. In a subsequent study, Kojima (2009) analyzes the policy response to rising oil prices in 49 developing countries, along with the consequences of alternative market interventions. The U.S. Energy Information Administration's survey estimates on the effects of oil prices on GDP growth and inflation show that the average effect across studies for a 33 percent increase in oil prices can be up to −0.5 percentage points for GDP growth and 0.4 percentage points for inflation (EIA 2006).

## A.1 Economic Growth Rates

The World Bank (2006) shows that higher oil prices may impact countries' economic growth and that the effects for oil importing and exporting countries may differ. The World Bank study estimates suggest that the effects may be moderate. For the LAC region, for example, the long-term growth effects for

**Figure A.1 Real Annual Average Imported Crude Price, 1972–2012**




*Source:* EIA 2013a.

oil exporting countries could be up to 0.14 percent per year, while the rate for the region's oil importing countries could be −0.1 percent per year.[2]

The magnitude of the impact of high oil prices may depend on the extent to which a country relies on oil and oil products to fuel its economy and how heavily it depends on oil imports to satisfy domestic energy needs. Another important factor that can determine the size of the impact is the energy intensity of a country's industrial sectors (e.g., manufacturing, textiles, chemical industries, wood and wood products, and metal products). Economies based on less oil-intensive industries, such as those in the Euro area, are expected to experience more limited, indirect effects. Rasmussen and Roitman (2011) provide a quantitative measure of the magnitude of the possible impacts of high oil pricing, explaining that a 25 percent price increase may cause the typical oil importer, where net oil imports have averaged 3–4 percent of GDP, to experience a cumulative output loss of about 0.3 percent of GDP over 2–3 years; their result matches the conclusion of the World Bank (2006). Furthermore, they indicate that, in countries where oil imports exceed 5 percent of GDP, the output loss increases to about 1 percent.

## A.2 Trade Balance

A recent study supported by the International Monetary Fund (IMF) indicates that, in a high oil price scenario, higher income transfers flow from oil importing countries to oil producers (IMF 2000a). High oil prices directly affect the trade balance of countries that must import oil for domestic consumption. In net oil importing countries, the value of exports decreases relative to that of imports, meaning that such countries must export a larger quantity of goods to cover the amount of oil imported, all other factors being equal; otherwise, they must borrow from abroad or deplete their foreign exchange reserves, which can develop into a balance-of-payments crisis, putting pressure on the value of their currency.

The study further indicates that these concerns are magnified in emerging economies with high debt levels, large trade deficits, or difficulty tapping into capital markets. Such countries adjust by spending less, which negatively affects real economic activity. The study estimates that these effects would be larger in heavily indebted, poor countries. Lacking economic diversification, such countries run large trade deficits, which, in turn, increase their dependence on consumption and capital goods from abroad. In addition, they are often on the margins of international capital markets.

## A.3 Cost of Production and Inflation

The IMF study analysis shows how higher oil prices can affect the global economy through the rise in the cost of producing goods and services (IMF 2000a). The classic example of how higher energy costs are transmitted to the price of a consumption good is often referenced in the case of food products: Higher energy prices contribute to rising food prices because energy—especially oil products, such as gasoline and diesel—accounts for more than one-third of the costs of grain production and transport (OECD 2011). Through this transfer mechanism, an increase in the price of energy is passed on to the final consumer, thus affecting inflation. Higher energy prices can make production more costly and profitability more difficult. Maintaining a constant profit margin, before and after the energy price increase, depends on the degree to which the rise in production cost would be transferred to the consumer.

The way in which the oil price increase is transferred to consumers also determines the magnitude of the effect. The IMF-supported study states that the impact of high oil prices on inflation depends on "the pass-through to domestic prices and whether countries allow the oil price increase to feed through into administered energy prices" (IMF 2000a). In this context, the World Bank–supported study argues that the pass-through from oil prices to inflation levels is significant in only two LAC countries (Dominican Republic and Honduras) and limited in three (Brazil, El Salvador, and Guyana) (World Bank 2006). The study also finds that such countries as Argentina, Bolivia, Mexico, and Venezuela, RB show no significant pass-through from oil prices to domestic gasoline prices and no pass-through from oil to consumer price index (CPI) prices.

A recent study supported by the Organisation for Economic Co-operation and Development (OECD) also serves to illustrate the magnitude of inflationary effects driven by high oil prices (OECD 2011). The study indicates that, in OECD member countries,[3] an increase of US$10 in the price of oil could raise inflation by roughly two-tenths of a percentage point in the first year after the oil price increase and by another one-tenth in the second year. This analysis exemplifies the concept that an increase in oil prices is transferred to higher inflation and that the impact continues in subsequent years.

## A.4 Unemployment

Cologni and Manera (2008) state that, after an increase in energy prices, "industries would tend to move from energy-intensive sectors to energy-efficient ones." The industry readjustment would take time to finalize, suggesting that unemployment could increase, at least until wages and prices adjusted to new equilibrium levels. In such cases as Greece, there is a specific country econometric analysis indicating that "oil prices have an immediate negative effect on industrial production and employment" (Papapetrou 2001).

## A.5 Fiscal Balance

The increase in oil prices would make oil products and the energy sources used as production inputs more expensive, translating into higher production costs; the extent of the pass-through to market prices and tariffs would have important implications for the fiscal balance. For oil importing countries in which the government plays an important role in setting the prices of oil products and electricity, a high oil price scenario may call for larger subsidies. Yépez-García, Johnson, and Andrés (2011) argue that the need for larger subsidies may lead to a fiscal imbalance, whereby government income is used to maintaining artificially low price levels. As a result, consumers do not receive the signals to use energy more efficiently and push for optimal levels of consumption and technological advancement.

For tariffs that fully reflect the increase in production costs, a tax would generate revenue increases greater than required for fiscal policy considerations (IMF 2000a). In this situation, the taxes would need to readjust to the fiscal policy requirements, imposing the minimum additional burden on consumers. Overall, taxes and subsidies on gasoline, oil products, and electricity would need to readjust to reflect the new macroeconomic situation of a high oil price scenario.

## A.6 Competitiveness

The European Central Bank reported that appreciation in the exchange rate would be expected to hurt a country's external competitiveness (ECB 2004). Chen and Chen (2007), Lizardo and Mollick (2010), and other studies argue that high oil prices would factor in the behavior of oil exporters and importers. In the high oil price scenario, a weaker exchange rate might hinder a country's potential to compete for resources in the international market.

In addition, a rise in the cost of production and inflation could deteriorate a country's competitiveness. Sustained high oil prices would likely worsen a country's comparative advantage in energy-intensive sectors, especially if the energy mix is undiversified. In net oil importing countries, the effect is direct as costs rise (Yépez García, Johnson, and Andrés 2011). In a broader sense, high oil prices are a common shock to such countries; however, idiosyncratic structural differences, energy intensities, and inefficiencies can amplify the impact on competitiveness, all other factors being equal.

## A.7 Other Social Impacts

Increasing the price of oil and oil products disproportionately affects poor households, for whom fossil fuel–based services, along with food and transport, comprise a large portion of their income. Rural communities without access to grid-powered electricity or renewable-energy sources, such as photovoltaic (PV) systems, often rely on kerosene lanterns for household lighting and small diesel-powered motors for on-farm agricultural production. As indicated by the African Development Bank and African Union, increasing the price of oil-based fuels, which sustain the lives of many rural households, would likely "exacerbate the incidence and depth of poverty and distort income distribution structures" (AfDB and AU 2009).

## Notes

1. Yépez-García and Dana (2012) provide discussion and documentation of higher oil price volatility.
2. In the study, these figures correspond to the associated response from a 16 percent annual increase in oil prices, based on an average price of US$34 per barrel of oil.
3. Chile and Mexico are the only two OECD member countries located in the LAC region.

APPENDIX B

# Key Indicators of Oil Price Impacts

**Table B.1 Impact of US$50 per Barrel Oil Price Increase on Electricity Production Costs**

| *Country* | *Scenario 1 US¢/kWh* | *Scenario 2 US¢/kWh* | *Average US¢/kWh* |
|---|---|---|---|
| Paraguay | 0.00 | 0.00 | 0.00 |
| Brazil | 0.25 | 0.30 | 0.27 |
| Costa Rica | 0.29 | 0.36 | 0.32 |
| Colombia | 0.41 | 0.42 | 0.41 |
| Peru | 0.85 | 0.94 | 0.89 |
| Venezuela, RB | 1.00 | 1.20 | 1.10 |
| Bolivia | 1.17 | 1.20 | 1.19 |
| Chile | 1.40 | 1.72 | 1.56 |
| Argentina | 1.54 | 1.71 | 1.63 |
| Trinidad and Tobago | 1.80 | 1.81 | 1.81 |
| Uruguay | 1.83 | 2.33 | 2.08 |
| Mexico | 2.03 | 2.31 | 2.17 |
| Guatemala | 2.07 | 2.62 | 2.35 |
| Ecuador | 2.34 | 2.94 | 2.64 |
| Panama | 2.57 | 3.27 | 2.92 |
| El Salvador | 2.58 | 3.28 | 2.93 |
| Honduras | 3.24 | 4.11 | 3.68 |
| Dominican Republic | 4.05 | 5.07 | 4.56 |
| Nicaragua | 4.09 | 5.20 | 4.64 |
| Haiti | 4.18 | 5.31 | 4.75 |
| Cuba | 5.13 | 6.45 | 5.79 |
| Jamaica | 5.69 | 7.23 | 6.46 |
| LAC average | 1.08 | 1.26 | 1.17 |

*Sources:* IEA 2009; authors' calculations.
*Note:* All oil-powered plants use heavy fuel oil (lower bound) in Scenario 1 and diesel (upper bound) in Scenario 2.

**Table B.2 Impact of US$50 per Barrel Oil Price Increase on Electricity Costs, Expressed in Terms of Tariff**

| *Country* | *Average Electricity Costs US¢/kWh* | *Average Residential Tariff US¢/kWh* | *Cost Increase as Share of Tariff %* |
|---|---|---|---|
| Paraguay | 0.00 | 7.23 | 0 |
| Brazil | 0.27 | 23.64 | 1 |
| Costa Rica | 0.32 | 13.21 | 2 |
| Colombia | 0.41 | 16.40 | 3 |
| Chile | 1.56 | 22.94 | 7 |
| Peru | 0.89 | 12.21 | 7 |
| Uruguay | 2.08 | 25.88 | 8 |
| Guatemala | 2.35 | 23.53 | 10 |
| El Salvador | 2.93 | 23.05 | 13 |
| Haiti | 4.75 | 35.00 | 14 |
| Bolivia | 1.19 | 8.63 | 14 |
| Dominican Republic | 4.56 | 25.60 | 18 |
| Panama | 2.92 | 16.21 | 18 |
| Jamaica | 6.46 | 31.21 | 21 |
| Mexico | 2.17 | 8.87 | 25 |
| Nicaragua | 4.64 | 18.21 | 25 |
| Ecuador | 2.64 | 9.21 | 29 |
| Honduras | 3.68 | 11.90 | 31 |
| Trinidad and Tobago | 1.81 | 4.69 | 39 |
| Venezuela, RB | 1.10 | 2.24 | 49 |
| Argentina | 1.63 | 1.94 | 84 |
| LAC average | 1.08 | 1.26 | 1.17 |

*Source:* Authors.

**Table B.3 Impact of Oil Prices on Electricity Cost as Percent of GDP**

| *Country* | *Electricity Generated (2009)* | *Increased Amount Millions of US$* | *GDP (2009)* Millions of US$* | *Increase as Share of GDP %* |
|---|---|---|---|---|
| Paraguay | 54,960 | -- | 14,216 | 0.0 |
| Brazil | 466,470 | 1,260 | 1,600,841 | 0.1 |
| Colombia | 57,270 | 237 | 234,182 | 0.1 |
| Costa Rica | 9,290 | 30 | 29,241 | 0.1 |
| Peru | 32,930 | 294 | 126,924 | 0.2 |
| Bolivia | 6,120 | 73 | 17,464 | 0.4 |
| Venezuela, RB | 123,450 | 1,363 | 325,678 | 0.4 |
| Haiti | 720 | 34 | 6,552 | 0.5 |
| Guatemala | 9,040 | 212 | 37,683 | 0.6 |
| Chile | 60,720 | 944 | 161,079 | 0.6 |
| Uruguay | 8,860 | 184 | 31,322 | 0.6 |
| Argentina | 122,350 | 1,992 | 310,351 | 0.6 |
| Mexico | 261,020 | 5,676 | 879,158 | 0.6 |
| Trinidad and Tobago | 7,740 | 140 | 19,623 | 0.7 |
| El Salvador | 5,790 | 170 | 20,661 | 0.8 |
| Panama | 6,950 | 203 | 24,059 | 0.8 |
| Ecuador | 17,230 | 455 | 52,022 | 0.9 |
| Dominican Republic | 14,980 | 683 | 46,714 | 1.5 |
| Honduras | 6,580 | 242 | 14,126 | 1.7 |
| Nicaragua | 3,450 | 160 | 6,214 | 2.6 |
| Jamaica | 5,530 | 357 | 12,313 | 2.9 |

*Source:* Authors.
*IMF figure.

**Table B.4 Estimated Elasticity on Electricity Demand, 1986–2010**

| *Country* | *Electricity* | *Price* | *WTI*[a] | *Price* | *GDP*[b] | *Price* | $R^2$ |
|---|---|---|---|---|---|---|---|
| Antigua and Barbuda | nd | | 0.04 | ** | 0.33 | ** | 0.985 |
| Argentina | −0.23 | ** | 0.02 | ns | 0.90 | ** | 0.966 |
| The Bahamas | nd | | 0.10 | ** | 0.99 | ** | 0.985 |
| Barbados | −0.01 | ns | −0.02 | ns | 1.85 | ** | 0.940 |
| Belize | nd | | 0.10 | ns | 0.92 | ** | 0.926 |
| Bolivia | −0.09 | * | −0.04 | ns | 1.49 | ** | 0.996 |
| Brazil | −0.15 | ** | 0.04 | ns | 1.36 | ** | 0.982 |
| Chile | −0.10 | ** | 0.06 | * | 1.11 | ** | 0.998 |
| Colombia | −0.09 | ** | −0.05 | ** | 0.99 | ** | 0.977 |
| Costa Rica | −0.16 | ** | −0.02 | ns | 1.04 | ** | 0.997 |
| Dominica | nd | | 0.14 | ns | 1.34 | ** | 0.934 |
| Dominican Republic | 0.23 | ns | −0.19 | * | 0.94 | ** | 0.972 |
| Ecuador | −0.01 | ns | −0.09 | ** | 1.53 | ** | 0.979 |
| El Salvador | −0.15 | * | −0.09 | ** | 1.58 | ** | 0.975 |
| Grenada | −0.49 | ns | −0.08 | ns | 1.99 | ** | 0.958 |
| Guatemala | −0.23 | ** | −0.03 | ns | 1.78 | ** | 0.997 |
| Guyana | 0.11 | ns | −0.50 | ** | 1.12 | ** | 0.830 |
| Haiti | −0.38 | ** | 0.05 | ns | 3.81 | ** | 0.734 |
| Honduras | 0.09 | ns | −0.21 | ** | 1.83 | ** | 0.983 |
| Jamaica | 0.29 | ns | −0.79 | ** | 8.43 | ** | 0.942 |
| Mexico | 0.02 | ns | −0.03 | * | 1.22 | ** | 0.994 |
| Nicaragua | −0.08 | ** | 0.15 | ** | 1.21 | ** | 0.980 |
| Panama | −0.55 | * | 0.08 | ns | 0.97 | ** | 0.979 |
| Paraguay | 0.05 | ns | 0.05 | ns | 1.74 | ** | 0.968 |
| Peru | −0.16 | ** | 0.12 | ** | 0.95 | ** | 0.966 |
| Suriname | 0.01 | ns | 0.00 | ns | 0.30 | ** | 0.721 |
| Trinidad and Tobago | −0.11 | ** | 0.03 | ns | 0.70 | ** | 0.985 |
| Uruguay | −0.33 | ** | 0.06 | ns | 1.15 | ** | 0.966 |
| Venezuela, RB | 0.00 | ns | −0.01 | ns | 1.32 | ** | 0.963 |

*Source:* Authors.
*Note:* nd = no data, ns = not significant, * and ** denote significance at 10 percent and 5 percent, respectively; electricity consumption in billion kWh.
a. WTI Cushing, OK WTI spot price FOB, constant prices, expressed in national currency units per barrel.
b. GDP in constant prices, expressed in billions of national currency units; base year is country-specific.

**APPENDIX C**

# Potential of Renewable Energy Resources for Electricity Generation in Latin America

by Alan Douglas Poole

Latin America and the Caribbean (LAC) has a large remaining potential for supplying electricity using renewable energy sources. However, natural resource endowments vary tremendously by country in terms of scale of potential relative to current electricity output and mix of available resources. Table C.1 summarizes the results of country-level quantitative estimates made for hydropower, biomass (i.e., sugarcane), geothermal, and wind resources, comparing the estimated effective potential of each resource with total generation in 2009. Data sources vary widely by country and resource in terms of the type of estimated potential and level of detail in the underlying analysis. An attempt is made here to estimate the potentials on a roughly comparable basis; that is, an approximation of the "effective" potential that may actually be constructed.

The results are necessarily quite preliminary. The estimates contain many uncertainties, and the picture that emerges can only approximate the total potential of renewable sources. However, an effort has been made to synthesize widely disparate data in roughly comparable terms. Given the state of current information, this is the most that can be accomplished. To our knowledge, this is the first published attempt to systematically quantify the remaining potential of renewable energy sources in a comparable way.

In various countries, the remaining potential of the quantified renewable is substantially larger than current electricity generation. In other countries, the potential is large, exceeding 50 percent of generation. In still others, including many Caribbean countries and Mexico, the remaining potential is rather small (Table C.1, shaded cells). In such countries, the emerging potential for solar energy generation will be of strategic importance in the coming two decades. It is hoped that the quality of this analysis will be improved further as countries

**Table C.1 Comparison of Potential Renewable Sources for Electricity Generation, 2009**

| | | *Remaining Effective Potential, Share 2009 Total Generation* | | | | | |
|---|---|---|---|---|---|---|---|
| *Country* | *Total Generation (2009)* | Hydro % | Non-hydro % | Sugar-cane[a] % | Geo-thermal % | Wind % | Total Renewables % |
| Antigua and Barbuda | 0.1 | 0 | 251 | 0 | 0 | 251 | 251 |
| Argentina | 121.9 | 10 | 354 | 2 | 0 | 353[b] | 364 |
| Barbados | 1.0 | 0 | 6 | 4 | 0 | 2 | 6 |
| Belize | 0.2 | 0 | 44 | 44 | 0 | 0 | 44 |
| Bolivia | 6.1 | 1998 | 9 | 9 | 0 | 0 | 2007 |
| Brazil | 466.5 | 59 | 32 | 12 | 0 | 20[c] | 91 |
| Chile | 60.7 | 49 | 15 | 0 | 11 | 4 | 65 |
| Colombia | 57.3 | 256 | 20 | 6 | 0 | 14 | 276 |
| Costa Rica | 9.3 | 212 | 15 | 4 | 5 | 6 | 226 |
| Cuba | 17.7 | 2 | 57 | 6 | 0 | 51 | 59 |
| Dominica | 0.1 | 0 | 564 | 0 | 564 | 0 | 564 |
| Dominican Republic | 15.0 | 7 | 53 | 3 | 0 | 49 | 60 |
| Ecuador | 17.2 | 212 | 17 | 3 | 14 | 0 | 229 |
| El Salvador | 5.8 | 115 | 86 | 6 | 19 | 60 | 200 |
| Grenada | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 |
| Guatemala | 9.0 | 215 | 84 | 12 | 40 | 29 | 297 |
| Guyana | 0.8 | 789 | 35 | 35 | 0 | 0 | 824 |
| Haiti | 0.5 | 0 | 1279 | 22 | 0 | 1257 | 1279 |
| Honduras | 6.6 | 233 | 72 | 8 | 8 | 55 | 304 |
| Jamaica | 5.5 | 0 | 4 | 3 | 0 | 1 | 4 |
| Mexico | 261.0 | 9 | 10 | 1 | 1 | 8 | 20 |
| Nicaragua | 3.5 | 157 | 370 | 7 | 147 | 215 | 526 |
| Panama | 6.9 | 145 | 44 | 2 | 3 | 38 | 189 |
| Paraguay | 55.0 | 1 | 1 | 1 | 0 | 0 | 2 |
| Peru | 35.4 | 312 | 47 | 2 | 0 | 46 | 360 |
| Saint Kitts and Nevis | 0.1 | 0 | 1147 | 8 | 1132 | 7 | 1147 |
| Saint Lucia | 0.3 | 0 | 60 | 0 | 37 | 23 | 60 |
| Saint Vincent and the Grenadines | 0.1 | 0 | 4 | 2 | 0 | 3 | 4 |
| Suriname | 1.6 | 384 | 1 | 1 | 0 | 0 | 384 |
| Trinidad and Tobago | 7.7 | 0 | 2 | 0 | 0 | 1 | 2 |
| Uruguay | 8.9 | 0 | 49 | 0 | 0 | 49 | 49 |
| Venezuela, RB | 123.4 | 49 | 8 | 1 | 0 | 7 | 57 |
| Total LAC | 1,305 | 69 | 56 | 6 | 2 | 48 | 125 |

a. Value for effective potential is based on the average of low and medium scenarios for sugarcane.
b. Effective wind potential for Argentina is based on 10 percent of the technical potential of the resource above 7.5 miles per second; elsewhere, 25 percent is assumed for cases where calculations are based on the technical potential.
c. Brazil's effective wind potential is taken as the average of the low and high estimates.

deepen their inventory work and international efforts, supported by greater resources, are made to consolidate detailed national inventory work at the regional and subregional levels.

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**APPENDIX D**

# Levelized Cost of Generation

The Model for Electricity Technology Assessments (META model), developed by the Energy Sector Management Assistance Program (ESMAP), is an interactive tool that permits the comparative evaluation of performance and cost estimates for a range of electricity generation and delivery technologies, using project-specific requirements.[1] The META model calculates, among other things, generation unit cost estimates for an extensive list of generation technologies, including fossil-fuel and renewable options. One of its outputs is the levelized or discounted cost of power generation, which includes capital cost with finance charges, fixed and variable O&M costs, fuel cost, and external costs. The levelized cost of generation, which quantifies the unitary cost of electricity (US$ per kWh) for a specific technology, is a useful tool for analyzing the potential impacts of sustained high oil prices on electricity generation in Latin America and the Caribbean (LAC).

The model provides a comparative assessment of the 2010 economic costs in real U.S. dollars for a wide range of generation options. It uses recent cost data compiled from several published sources with default inputs for three representative countries (India, Romania, and the United States) as proxies for developing, middle-income, and developed countries, respectively.

To analyze the effect of oil prices on the unit cost of electricity generation for the LAC region, 21 generation technologies were selected from the META model. Data for the U.S.,[2] with financial cost of capital at 8 percent, an average construction time,[3] and a discount rate of 6 percent were used in the analysis. The model used fuel prices estimated as a function of a range of oil prices from US$50 to $150 per barrel instead of default values (Box D.1).

To simplify the analysis, several assumptions were used in the exercise. For generation cost of renewable energy sources, general assumptions were used to estimate the order-of-magnitude impact from higher oil prices. While a more detailed analysis using local conditions would have been preferable, it was beyond the scope of the exercise. However, the approach used is in keeping with the aim of the exercise, which is to reveal the order of magnitude of the impact of high oil prices on the power sector. Table D.1 includes selected

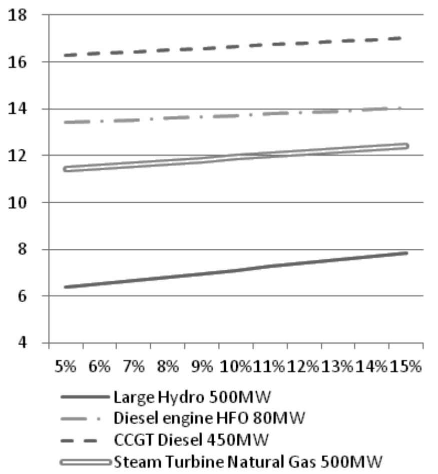
### Box D.1 Sensitivity Analysis of Cost of Capital and Discount Rate

The model we used to calculate levelized costs of electricity generation assumes a financial cost of capital of 8 percent and a discount rate of 6 percent. To test the model's sensitivity to these parameters, we assessed the costs of selected energy generation technologies vis-à-vis a range of possible values for the cost of capital and discount rate, from 5 to 15 percent, keeping all else constant. The levelized cost is linear with respect to these two parameters.

The discount rate and the cost of capital have a relatively larger effect on technologies that have higher costs at the beginning and lower costs in later years, such as hydropower generation. Changing the discount rate from 5 percent to 15 percent would increase the levelized kilowatt hour cost of hydropower generation by 5¢ (from 6¢ to 11¢). Comparing steam turbines fueled by natural gas or a diesel engine, a higher discount rate would slightly reduce the difference between their levelized costs. Moreover, according to the model, changes in the cost of capital produce smaller effects on the levelized costs than changes in the discount rate, as illustrated below. In short, the simulated scenarios would only affect the magnitude of the cost, but would not affect the relative position of the total levelized cost between renewable and non-renewable technologies.

**Cost of Capital**

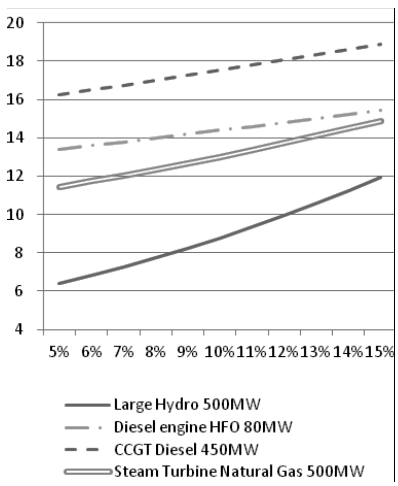
Levelized cost (US¢ per kWh)




*Note:* Cost of capital for the public sector is considered as 4.5 percentage points smaller than for the private sector, with no risk premium and guarantee costs. Oil prices are fixed at US$100 per barrel. The results represent an average of public- and private-sector costs. Load factors are the same as those used for other estimations in this study.

**Discount Rate**

Levelized cost (US¢ per kWh)




*Note:* Oil prices are fixed at US$100 per barrel and cost of capital at 8 percent for the private sector. The results represent an average of public- and private-sector costs. Load factors are the same as those used for other estimations in this study.

**Table D.1 Selected Scenario Assumptions**

| *Variable* | *Scenario 1* | *Scenario 2* |
|---|---|---|
| Energy price | | |
| Oil (US$/bbl) | 150.0 | 150.0 |
| Natural gas (US$/mmcf) | 8.8 | 3.8 |
| Fuel oil (US$/bbl) | 127.5 | 127.5 |
| Diesel (US$/bbl) | 182.4 | 182.4 |
| Coal (US$/metric ton) | 133 | 133 |
| Discount rate (%) | 6 | 6 |
| Lifespan of equipment (years) | 30 | 30 |
| Capacity factor (%) | | |
| Wind | 25 | 25 |
| Geothermal | 80 | 80 |
| Fuel Oil | 75 | 75 |
| Diesel | 75 | 75 |
| Gas | 75 | 75 |
| Coal | 75 | 75 |

*Source:* Authors.

assumptions considered in the analysis. In addition, some sensitivity analysis is presented to illustrate how the levelized cost of electricity could change when modifications to key variables (e.g., discount rate, cost of capital, oil price, and capacity factor) are introduced.

## D.1 Capacity Factors

Before estimating the levelized cost of generation for different fuel prices, it is necessary to determine the optimal performance for the selected technologies; therefore, the levelized cost of generation for each technology was first estimated as a function of the operational range of capacity factors.

Below we present a series of simulations using the META model, comparing the generation cost of various technologies. These exercises aim to determine the oil price at which thermal-based technologies become more expensive than renewable-energy ones. The break-even price depends not only on oil price but also on capacity factor, unit size and number of units in the facility, location, financial cost during project development, and decreasing cost of renewable technologies (e.g., due to innovation). In this exercise, we present simulations as a function of capacity factors first and then as a function of oil prices.

It must be noted that price alone cannot be the only consideration for planning the generation mix, which must include both base-load and peaking power sources. An electricity system needs to optimize the combination of both power types to ensure efficient resource allocation and use.

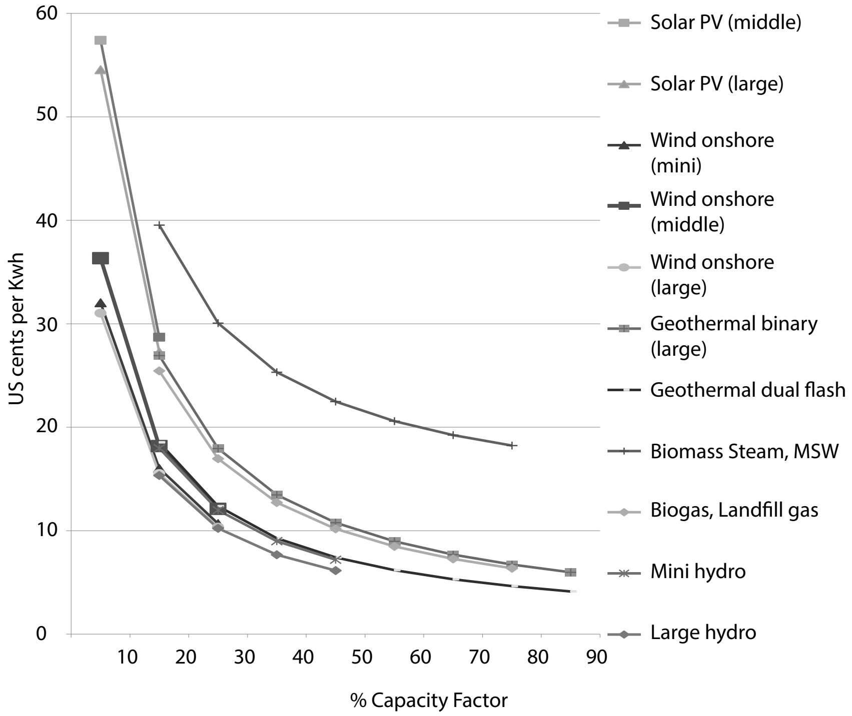
As expected, all 21 combinations of electricity generation technologies analyzed have decreasing levelized generating cost as the capacity factor increases. The optimal operation of all technologies is at their highest capacity factor. Among the renewable technologies, solar PV has the highest cost per kilowatt hour, followed by biomass steam municipal solid waste (MSW). The renewable technology with the lowest unit cost is geothermal dual flash; large hydro plants have the second lowest, followed by wind and biogas plants (Figure D.1).

In the analysis of gas, oil, and diesel generating alternatives, the most competitive options are the gas technologies, especially combined-cycle generating plants. The most expensive generating technology in this group is the diesel-powered plant (Figure D.2).

All of the five coal generating units analyzed show similar decreasing unit costs with respect to increasing load factor (Figure D.3). Coal-Circulating-Fluidized Bed (CFB) plants have low unit capital cost because there is no need for desulfurization or de-nitrification equipment; thus, they exhibit the lowest estimated levelized generating cost.

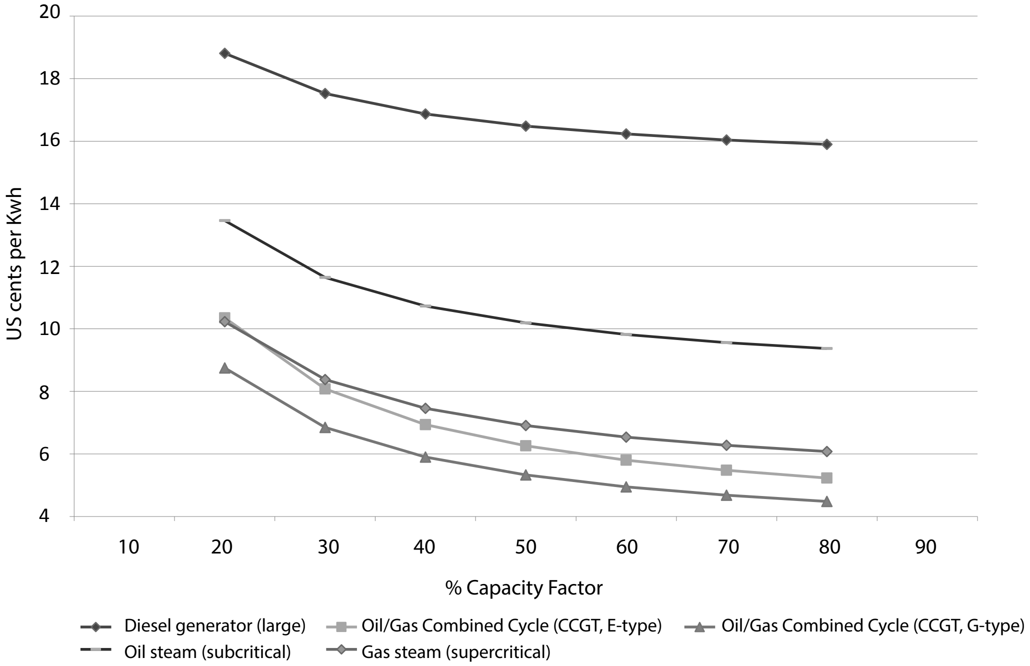
Among all fossil-fuel power plants, the 800 MW gas plant (oil/gas CCGT) has the lowest levelized generation cost, followed by the 300 MW coal CFB and the 450 MW gas (oil/gas CCGT) plants.

**Figure D.1 Decreasing Levelized Generating Cost of Renewable Technologies**



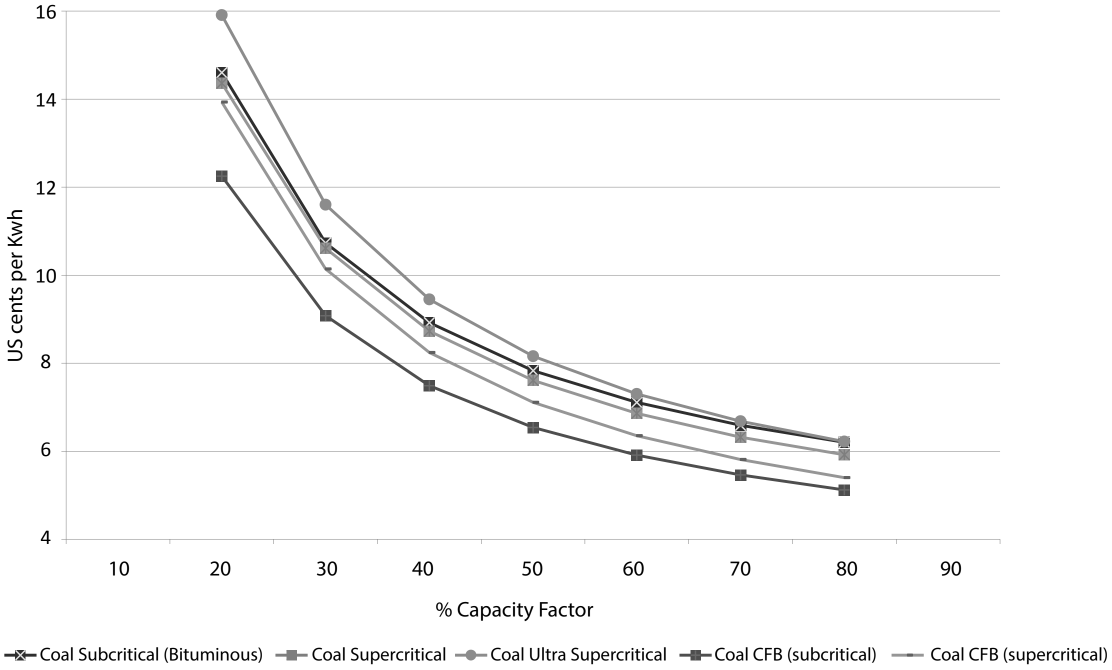

*Source:* Authors.

**Figure D.2 Decreasing Levelized Generating Costs of Gas, Oil, and Diesel Units**




*Source:* Authors.

**Figure D.3 Decreasing Levelized Generating Cost of Coal Units**




*Source:* Authors.

## D.2 Price of Crude Oil

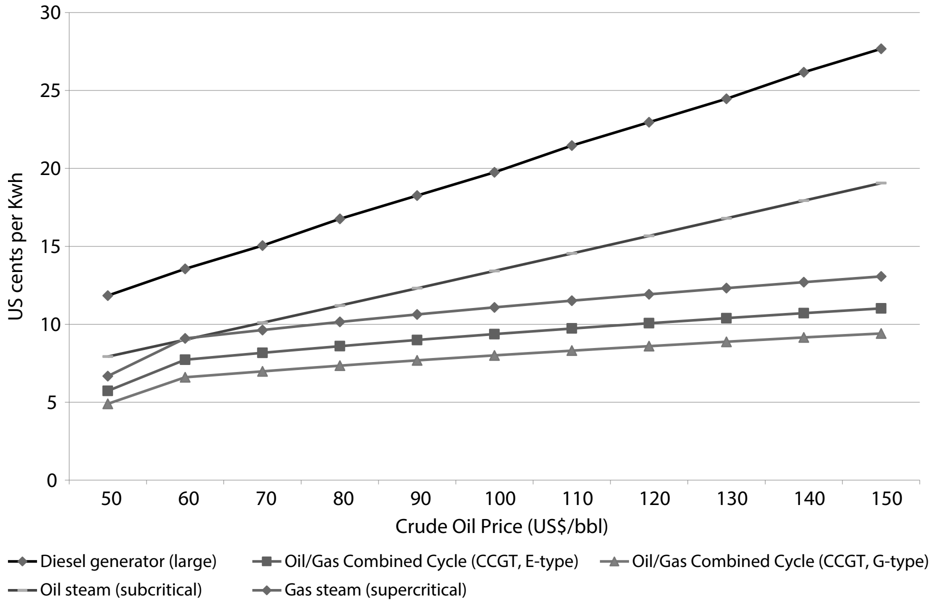
In the sensitivity analysis of levelized cost with respect to the price of crude oil, all generation plants were considered at their highest operational capacity factor. The estimated levelized cost for all fossil-fuel power plants (i.e., coal, natural gas, diesel, and oil) are directly affected by increases in the price of crude oil. Among this group, generation units that use gas show less steep increases in cost with respect to changes in the price of crude than generation units that use diesel and oil (Figure D.4). Coal generation has similar increasing unit cost trends with respect to changes in the price of crude oil (Figure D.5).

The estimated levelized cost of renewable generation plants is not affected by changes in the price of crude oil. At a low crude oil price, some fossil-fuel generation plants are more competitive than renewable ones. However, this advantage changes as the price of crude oil rises. At low prices of crude, fossil-fuel generation is more competitive than wind generation. However, when the price of crude rises above US$90 per barrel, the 500 MW gas steam plant becomes more expensive to operate than the lowest-cost wind plant. Once crude rises to $130 per barrel, the gas steam plant is more expensive than any of the three wind plants considered here (Figure D.6).

A close look at coal plants versus the lowest-cost renewable generating plants shows that, at low crude oil prices, the levelized costs of coal plants are even lower than those of renewable resource plants. But as the price of crude oil rises above US$110 per barrel, the geothermal binary plant becomes more competitive than two of the coal plants. At $120 per barrel, the large hydro plant becomes more competitive than the coal subcritical plant (Figure D.7).

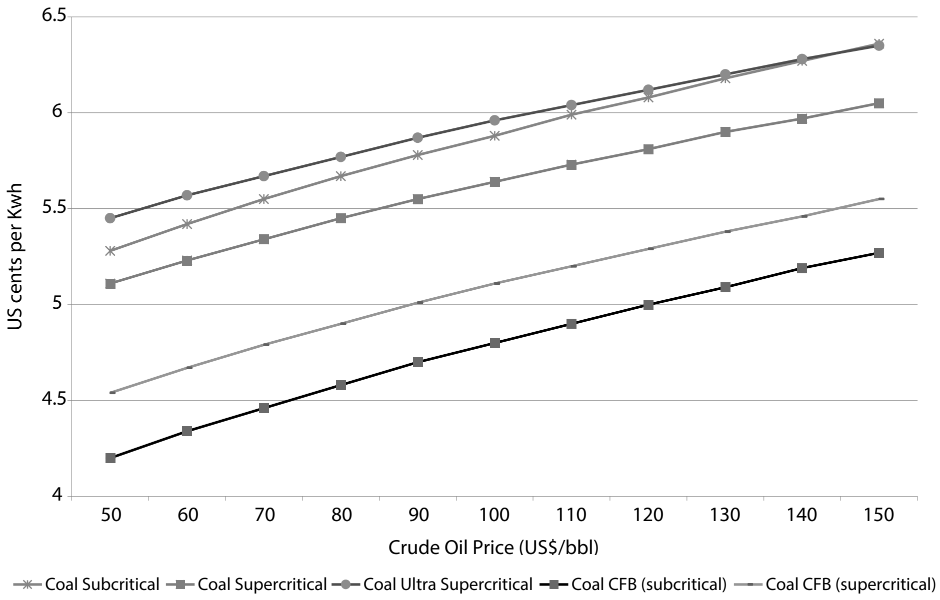
Biomass steam MSW, a renewable plant with a high generation cost, becomes more competitive with diesel and oil plants (which exhibit some of the highest levelized cost of generation) once the price of cruel oil rises above US$90 per barrel. Hydro is more competitive than gas at crude oil prices above $60 per barrel. Finally, wind has a lower levelized cost than gas steam generation at crude oil prices above $90 per barrel (Figure D.8).

**Figure D.4 Levelized Cost of Gas, Oil, and Diesel Plants Relative to Rising Price of Crude Oil**



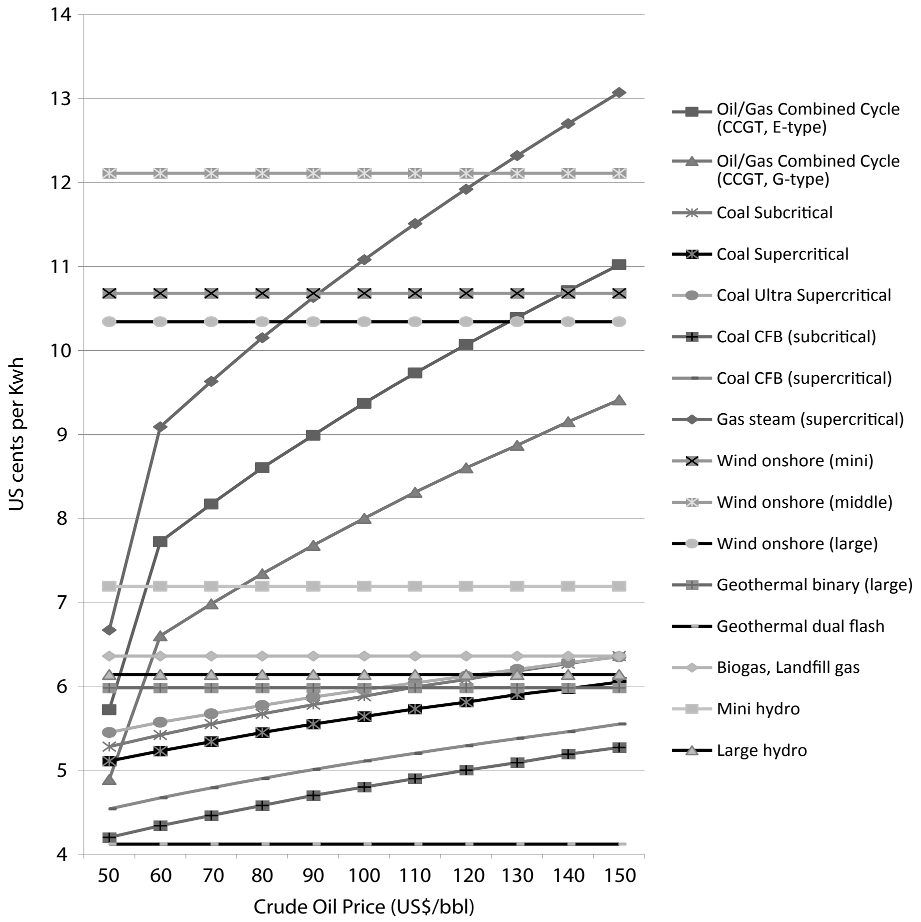

*Source:* Authors

**Figure D.5 Levelized Cost of Coal Generating Units Relative to Rising Price of Crude Oil**



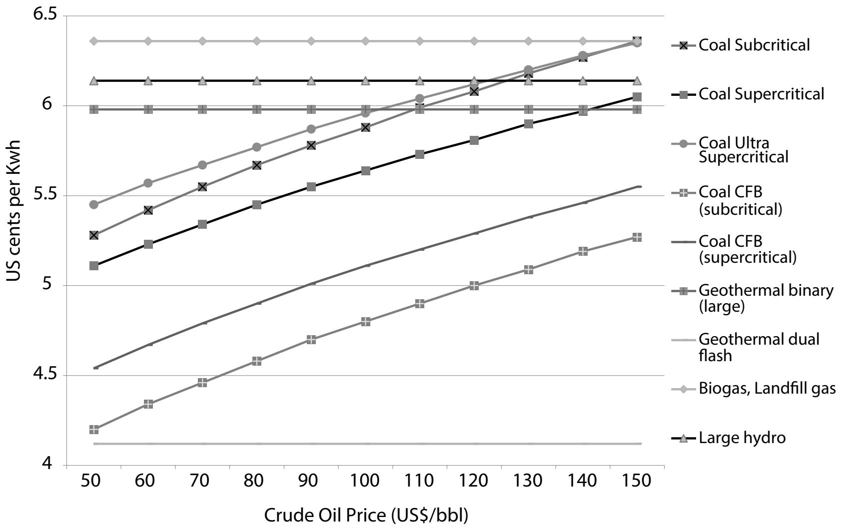

*Source:* Authors

**Figure D.6 Comparing the Levelized Generation Cost of Fossil Fuels and Renewables as Price of Crude Oil Rises**



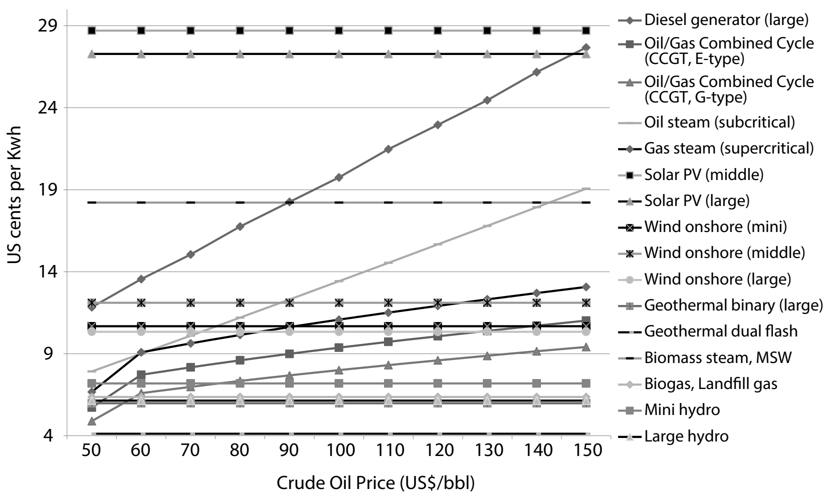

*Source:* Authors
*Note:* Solar generation plants, which have the highest unit cost of generation, are not included in this comparison.

**Figure D.7 Competitiveness of Lowest-Cost Renewable Generating Plants with Coal**




*Source:* Authors

**Figure D.8 Competitiveness of Renewable Generating Plants with Gas, Oil, and Diesel**




*Source:* Authors

## Notes

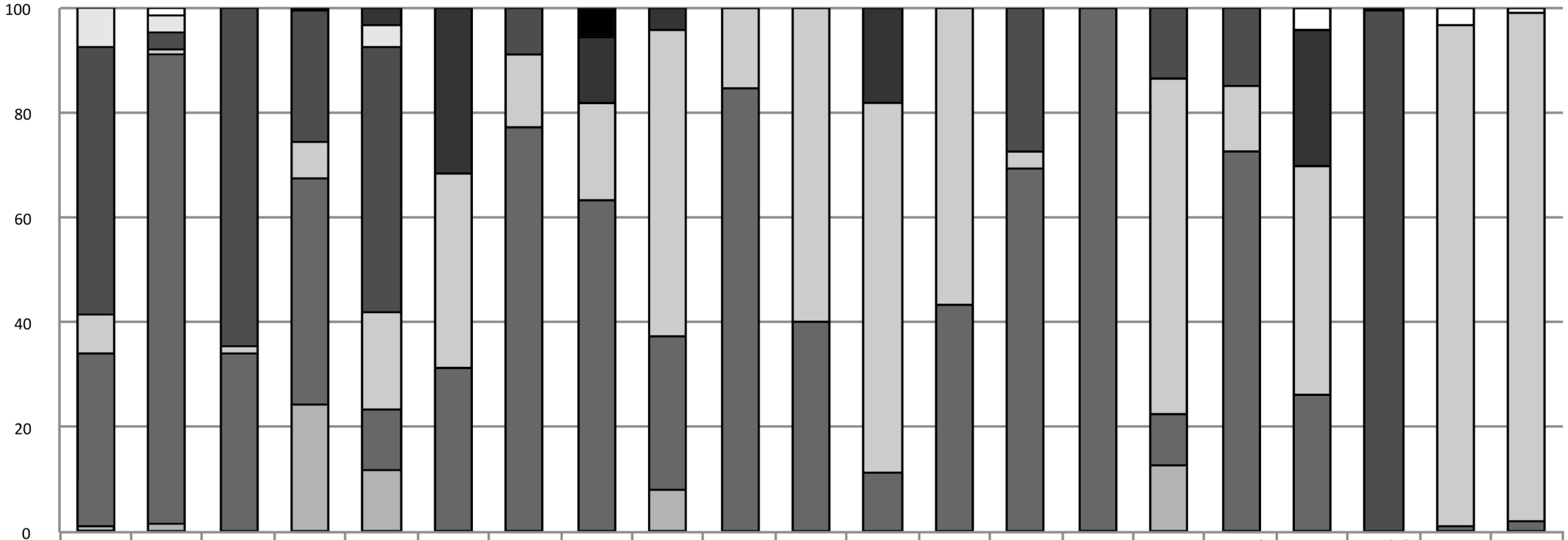
1. The ETOAG model was developed by Chubu Electric Power Corporation, Inc. and Economic Consulting Associates for ESMAP in May 2012.
2. Although most countries in the LAC region fit as a group of developing countries, U.S. cost data is more representative than that of India for these countries.
3. For example, construction time has been estimated as one year for wind plants, four years for coal plants, and five years for large hydro plants.
4. The sensitivity analysis considers an oil price of US$100 per barrel.

**APPENDIX E**

# Generation Matrix by Country

Tables E.1–E.3 show the electricity generation matrices for 21 countries in Latin America and the Caribbean by plant type. Table E.1 provides the 2009 baseline case, while Tables E.2 and E.3 provide Scenarios 1 and 2, respectively, for 2030. The generation sources include wind, biomass, geothermal, nuclear, natural gas, oil, hydropower, and coal.

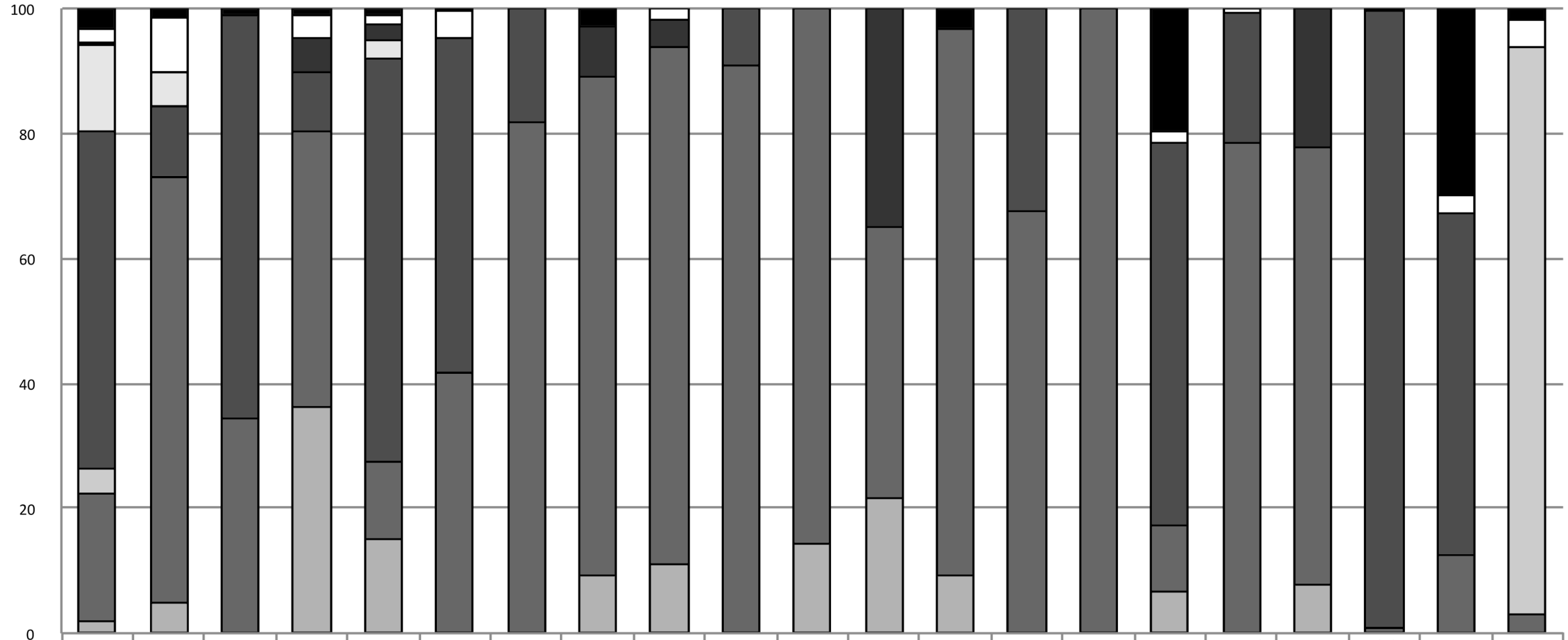
**Table E.1 Generation by Plant Type, 2009**




| | Argentina | Brazil | Bolivia | Chile | Mexico | Uruguay | Colombia | Costa Rica | Guatemala | Ecuador | Honduras | Nicaragua | Panama | Peru | Paraguay | Dominican Republic | Venezuela, RB | El Salvador | Trinidad and Tobago | Haiti | Jamaica |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wind | 0% | 0% | 0% | 1% | 0% | 0% | 0% | 5% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Bio | 0% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 4% | 0% | 3% | 1% |
| Geo | 0% | 0% | 0% | 0% | 3% | 31% | 0% | 13% | 4% | 0% | 0% | 18% | 0% | 0% | 0% | 0% | 0% | 26% | 0% | 0% | 0% |
| Nuclear | 7% | 3% | 0% | 0% | 4% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Gas | 51% | 3% | 64% | 25% | 51% | 0% | 9% | 0% | 0% | 0% | 0% | 0% | 0% | 28% | 0% | 13% | 15% | 0% | 99% | 0% | 0% |
| Oil | 8% | 1% | 1% | 7% | 18% | 37% | 14% | 18% | 59% | 15% | 60% | 71% | 57% | 3% | 0% | 64% | 13% | 44% | 0% | 96% | 97% |
| Hydro | 33% | 89% | 34% | 43% | 12% | 31% | 77% | 64% | 29% | 85% | 40% | 11% | 43% | 69% | 100% | 10% | 73% | 26% | 0% | 1% | 2% |
| Coal | 1% | 2% | 0% | 24% | 12% | 0% | 0% | 0% | 8% | 0% | 0% | 0% | 0% | 0% | 0% | 13% | 0% | 0% | 0% | 0% | 0% |

*Source:* Authors.

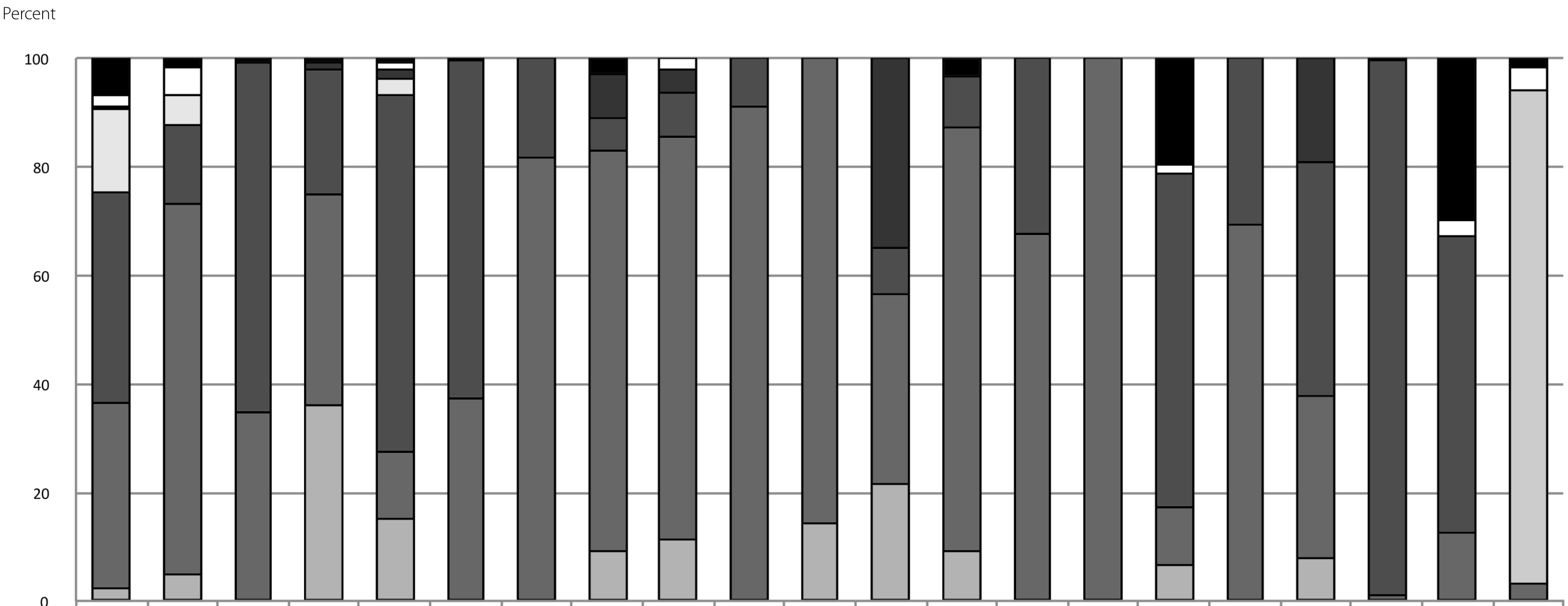
**Table E.2 Generation by Plant Type in 2030, Scenario 1**




| | Argentina | Brazil | Bolivia | Chile | Mexico | Uruguay | Colombia | Costa Rica | Guatemala | Ecuador | Honduras | Nicaragua | Panama | Peru | Paraguay | Dominican Republic | Venezuela, RB | El Salvador | Trinidad and Tobago | Haiti | Jamaica |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wind | 3% | 2% | 1% | 1% | 1% | 0% | 0% | 3% | 0% | 0% | 0% | 0% | 3% | 0% | 0% | 20% | 0% | 0% | 0% | 30% | 2% |
| Bio | 3% | 9% | 0% | 4% | 2% | 4% | 0% | 0% | 2% | 0% | 0% | 0% | 0% | 0% | 0% | 2% | 1% | 0% | 0% | 3% | 4% |
| Geo | 0% | 0% | 0% | 6% | 2% | 0% | 0% | 8% | 4% | 0% | 0% | 35% | 0% | 0% | 0% | 0% | 0% | 22% | 0% | 0% | 0% |
| Nuclear | 14% | 6% | 0% | 0% | 3% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Gas | 54% | 11% | 64% | 9% | 64% | 54% | 18% | 0% | 0% | 9% | 0% | 0% | 0% | 33% | 0% | 61% | 21% | 0% | 99% | 55% | 0% |
| Oil | 4% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 91% |
| Hydro | 20% | 68% | 35% | 44% | 13% | 42% | 82% | 80% | 83% | 91% | 86% | 43% | 88% | 67% | 100% | 11% | 79% | 70% | 1% | 12% | 3% |
| Coal | 2% | 5% | 0% | 36% | 15% | 0% | 0% | 9% | 11% | 0% | 14% | 22% | 9% | 0% | 0% | 7% | 0% | 8% | 0% | 0% | 0% |

*Source:* Authors.

**Table E.3 Generation by Plant Type in 2030, Scenario 2**




| | Argentina | Brazil | Bolivia | Chile | Mexico | Uruguay | Colombia | Costa Rica | Guatemala | Ecuador | Honduras | Nicaragua | Panama | Peru | Paraguay | Dominican Republic | Venezuela, RB | El Salvador | Trinidad and Tobago | Haiti | Jamaica |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wind | 7% | 2% | 1% | 1% | 1% | 0% | 0% | 3% | 0% | 0% | 0% | 0% | 3% | 0% | 0% | 20% | 0% | 0% | 0% | 30% | 2% |
| Bio | 3% | 6% | 0% | 0% | 1% | 0% | 0% | 0% | 2% | 0% | 0% | 0% | 0% | 0% | 0% | 2% | 0% | 0% | 0% | 3% | 4% |
| Geo | 0% | 0% | 0% | 1% | 2% | 0% | 0% | 8% | 4% | 0% | 0% | 35% | 0% | 0% | 0% | 0% | 0% | 19% | 0% | 0% | 0% |
| Nuclear | 16% | 6% | 0% | 0% | 3% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Gas | 39% | 15% | 64% | 23% | 65% | 62% | 18% | 6% | 8% | 9% | 0% | 8% | 10% | 33% | 0% | 61% | 31% | 43% | 99% | 55% | 0% |
| Oil | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 91% |
| Hydro | 34% | 68% | 35% | 39% | 13% | 37% | 82% | 74% | 74% | 91% | 86% | 35% | 78% | 67% | 100% | 11% | 69% | 30% | 1% | 12% | 3% |
| Coal | 2% | 5% | 0% | 36% | 15% | 0% | 0% | 9% | 11% | 0% | 14% | 22% | 9% | 0% | 0% | 7% | 0% | 8% | 0% | 0% | 0% |

*Source:* Authors.

APPENDIX F

# Meeting the Balance of Electricity Supply and Demand in Latin America and the Caribbean: *Report Summary*

by Rigoberto Ariel Yépez-García, Todd M. Johnson, and Luis Alberto Andrés

The objective of this report is to provide an assessment of the electric power sector in Latin America and the Caribbean (LAC) to 2030. The report relies on the most recent and consistent regional data set from the Latin American Energy Organization (OLADE) and uses a common modeling framework to examine possible future trends in electricity supply. The report also examines a range of options and the policies needed to meet the future electricity supply challenges in the region. Among these options are the expanded use of hydropower, natural gas, and non-hydro renewable energy resources; increased regional electricity trade; and efficiency improvements on both supply and demand sides.

Since the 1970s, the LAC power sector has experienced steady growth. Regional electricity production grew at an average rate of 5.9 percent per year between 1970 and 2005, compared with the worldwide average of 4.3 percent over the same period.

Six countries account for 84 percent of total electricity production in the LAC region. Brazil is the largest electricity producer (36 percent), followed by Mexico (21 percent), Argentina (9 percent), República Bolivariana de Venezuela (9 percent), Colombia (5 percent), and Chile (4 percent). Paraguay is a significant producer (5 percent) through its share of production from the gigantic Itaipu hydrostation; however, the majority of the electricity produced by Paraguay is sold to Brazil.

There are large disparities in electricity access rates both between and within countries. Despite the overall impression of affluence generated by the average growth rates for electricity production and consumption, countries in the LAC region face significant supply-demand imbalances (especially during dry years), and there are large differences in connection rates and affordability.

Hydroelectricity has been the dominant source of electricity for the region, but its share has been declining. Historically, hydropower has provided the largest share of electricity in the LAC region, with Brazil, the largest producer, generating about 87 percent of its electricity from hydro in 2005. For the region as a whole, hydro provided 59 percent of electricity supply (2005), the highest share from hydroelectricity in any region of the world. Nonetheless, hydropower's share has been declining in recent years (from 66 percent in 1995), and there are indications that the downward trend will continue.

A significant trend in the LAC power sector over the past 15 years has been growth in the use of natural gas, which accounted for 10 percent of generation capacity in 1995, rising to 19 percent in 2005. Over the same period, natural gas capacity rose from 15 to 38 percent in Mexico and from 19 to 33 percent in the Southern Cone.

While petroleum use has declined overall, it remains significant for some subregions and countries. The use of petroleum products (mainly fuel oil and diesel) for power generation has been significant in the Caribbean and Central America, accounting for 75 percent and 40 percent, respectively (2005). In Mexico, petroleum products account for 31 percent of power generation (2005), down from 58 percent two decades earlier. For the region as a whole, however, the share of oil-fired generation has declined 6 percent (1985–2005), accounting for only 14 percent in 2005. Dealing with unpredictable oil-price fluctuations and the associated effect on balance of payments remains a central concern for countries with a high share of oil in their electricity and overall energy-supply mixes.

Coal and other energy sources account for a small share of power generation in the LAC region. Coal use accounted for about 6 percent of power production in 2005, up from about 4 percent in 1985.

The regulatory framework for the LAC region's power sector has experienced dramatic changes since the 1990s, with the creation of independent regulatory agencies, the unbundling and privatization of large state-owned companies, and the implementation of competitive market-oriented frameworks in various countries. However, the state remains an important power-sector player throughout the region through the ownership of companies involved in generation, transmission, and distribution.

## F.1 Baseline Electricity Supply Scenario

Modeling of electricity supply to 2030 was undertaken for the LAC region. To illustrate the implications of current trends in electricity development for countries, subregions, and the overall region, scenarios to 2030 were developed using a simple electricity demand function and a detailed energy-supply planning model:

- **Demand function.** Electricity demand for each country was estimated using GDP forecasts from the International Monetary Fund to 2014 (IMF 2009). For the period 2015–30, a common set of economic assumptions was used, based on an average GDP growth rate of 3 percent per year.
- **Supply model.** An electricity supply scenario—intended to reflect the LAC region's current power-sector expansion plans—was created to illustrate regional supply trends. Using OLADE's SUPER (*Sistema Unificado de Planificación Eléctrica Regional*) model and consistent country-level data, the authors created an electricity supply scenario that relies on the latest power-sector plans of individual countries and that satisfies the demand-function estimates.
- **ICEPAC (Illustrative Country Expansion Plans Adjusted and Constrained) scenario.** Using the demand estimates and the SUPER supply model, the authors created a baseline scenario for the next two decades. The "illustrative" scenario is based on Country Expansion Plans to 2030, where available, which are then "adjusted" to account for missing data and extrapolate country expansion plans (most of which are available to 2018 or 2020), and then "constrained" so as not to exceed energy resource potential (such as domestic hydroelectric resources), using a database of international technology supply costs that places a cost-minimizing constraint on the electricity supply model. From the ICEPAC scenario, it is possible to observe what would happen to the scale and structure of electricity supply, the financing that would be needed for new investment, and future $CO_2$ emissions from the power sector.

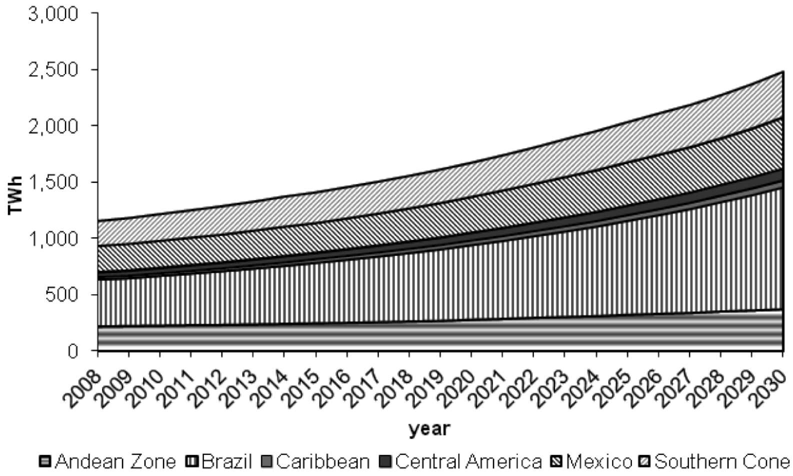
Key results of the electricity modeling exercise, reflecting current country expansion plans, are as follows:

- At a modest rate of economic growth, the region's demand for electricity would reach nearly 2,500 terawatt hours (TWh) by 2030, up from about 1,150 TWh in 2008 (Figure F.1 and Table F.1). In Brazil, demand would more than double to about 1,090 TWh. A total of 239 gigawatts (GW) of new generation capacity would be needed to match demand, with Brazil adding about 97 GW, the Southern Cone 45 GW, Mexico 44 GW, the Andean Zone 30 GW, Central America 15 GW, and the Caribbean 7 GW.
  - Hydropower and natural gas would provide the majority of additional power capacity. Although the share of hydropower would continue to decline, the combined share of hydropower and natural gas would be higher. Petroleum use would continue to decline, while nuclear use would increase slightly (concentrated in Argentina), as would non-hydro renewables.
  - Despite hydropower's declining share, many subregions and countries are planning to substantially increase their absolute capacity of hydropower

over the coming decades. These include the Andean Zone, Brazil, Central America, and the Southern Cone. The aggregate increase in hydroelectric capacity by 2030 would total about 85 GW under the ICEPAC scenario.
- In Mexico, natural gas is estimated to be the most important fuel for new power generation (51 percent of new capacity), followed by coal (23 percent), hydroelectricity (14 percent), diesel (8 percent), wind (3 percent), and nuclear energy (1 percent).
- The high degree of fuel and generation technology diversity in the Southern Cone would become even more dynamic over the period, with the subregion adding sizeable generating capacity for hydropower, natural gas, coal, and nuclear energy in Argentina.
- In Central America, hydroelectricity would be the largest source of new capacity (45 percent), while fuel oil, coal, and natural gas would together account for about 45 percent of additional capacity.
- In the Caribbean, the generation mix would continue to depend largely on fossil fuels, with natural gas accounting for 43 percent of the additional capacity and coal 23 percent.

- Investment in new generation capacity under the ICEPAC scenarios is estimated at about US$430 billion between 2008 and 2030. Investments by subregion and country are as follows: Brazil, $182 billion; Southern Cone, $78 billion; Mexico, $78 billion; Andean Zone, $58 billion; Central America, $25 billion; and Caribbean, $9 billion.
- $CO_2$ emissions from electricity generation in the LAC region would more than double between 2008 and 2030 as a result of a decline in hydroelectricity and an increase in fossil fuel–based generation.

**Figure F.1 Regional Electricity Demand Scenario, 2008–30**




*Source:* Authors, based on optimization model.

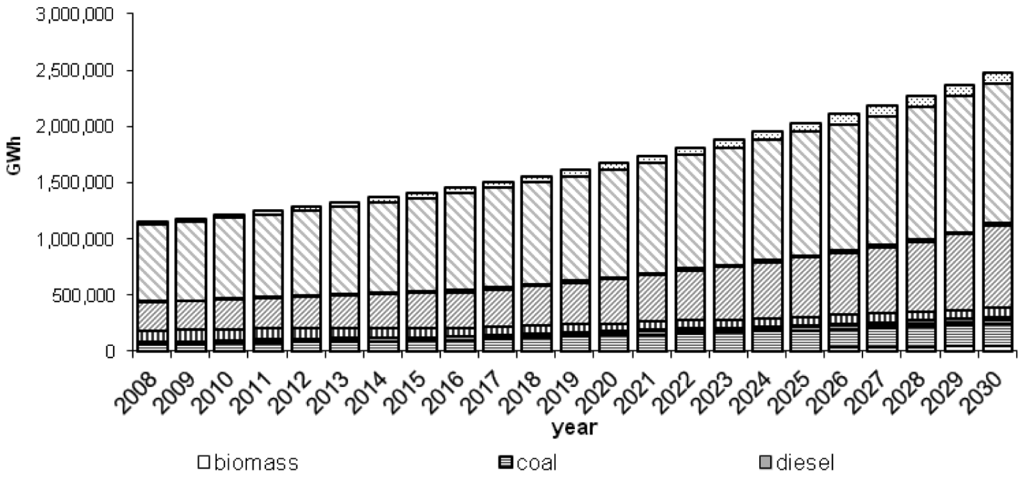
**Table F.1 Growth in Regional Electricity Demand**

| *Subregion or Country* | *Average Annual Growth (%)* |
|---|---|
| Andean Zone | 2.8 |
| Brazil | 4.7 |
| Caribbean | 3.2 |
| Central America | 5.3 |
| Mexico | 3.4 |
| Southern Cone | 2.8 |
| Average | 3.7 |

*Source:* Authors.

The modeling exercise demonstrates that, with modest economic growth, the region will require a large expansion in power generating capacity, mainly fueled by hydropower and natural gas (Figure F.2 and Table F.2). These are the two least-cost sources of new power capacity and will contribute to both local and global environmental sustainability. To meet the optimistic goals for hydropower and natural gas—which are not explained in the modeling analysis—many LAC countries will need to reform their respective regulatory, contracting, and licensing processes. Various other options for helping to meet the region's electric power needs do not feature prominently in most national electricity expansion plans and thus are not captured in the modeling analysis. These include expansion of non-hydro renewable sources, greater regional electricity trade, and enhanced energy efficiency.

**Figure F.2 LAC Electricity Generation by Technology, ICEPAC Scenario, 2008–30**




*Source:* Authors, based on optimization model.

**Table F.2 LAC Electricity Generation Mix in the ICEPAC Scenario, 2008 and 2030**

| *Energy Source* | *2008 Mix (%)* | *2030 Mix (%)* |
|---|---|---|
| Biomass | 0.5 | 2.0 |
| Coal | 4.6 | 7.9 |
| Diesel | 2.3 | 1.2 |
| Wind | 0.1 | 1.3 |
| Fuel oil | 8.4 | 3.3 |
| Natural gas | 22.0 | 29.4 |
| Geothermal | 1.0 | 0.8 |
| Hydropower | 58.6 | 50.0 |
| Nuclear | 2.8 | 4.2 |

*Source:* Authors.

## F.2 Summary and Conclusions

Under modest GDP growth assumptions, electricity demand in the LAC region would more than double by 2030. Under current expansion plans, the region would need to add more than 239 GW of new power generating capacity to meet demand. A higher rate of economic growth or a higher demand for electricity would require even more new capacity. Under any economic scenario, it will be challenging for the region to meet future electricity demand by relying on current plans for power-sector expansion.

Under the baseline scenario, the vast majority of the increase in generating capacity between now and 2030 would be met by hydropower (36 percent) and natural gas (35 percent). The baseline scenario represents a best case because many of the country expansion plans for hydropower and natural gas are already quite optimistic. Under the baseline, an estimated 85 GW of new hydro capacity would be required, compared with only 76 GW built in the region over the past 20 years. In addition, in some countries, many of the best sites—in terms of construction costs and low environmental and social impacts—have already been developed. The relatively long payback periods, high capital costs, and environmental and social risks have reduced private-sector involvement in hydroelectric plants and thus reduced the scale and pace of hydro development.

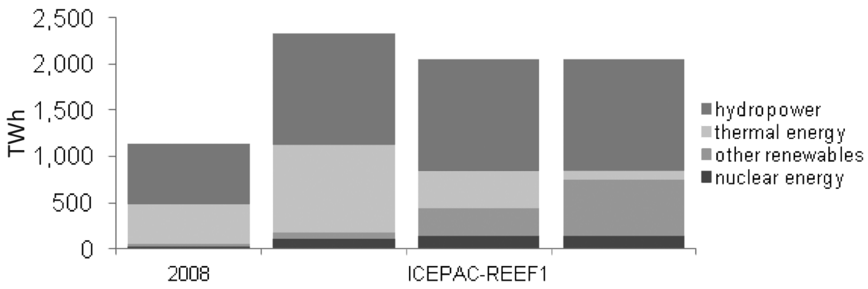
Natural gas is one of the LAC region's best alternatives both economically and environmentally for new power-generating capacity. Under the baseline, gas-fired capacity would grow from 60 GW to more than 144 GW by 2030. Many countries in the region have been expanding the use of natural gas for power generation using efficient combined-cycle technology. However, in some countries, low preferential gas prices and low electricity tariffs have resulted in the inefficient use of natural gas, including open-cycle plants, as well as reduced incentives for producing and distributing gas for power generation.

The analysis suggests that meeting the LAC region's electricity demand can be achieved not only by building new generating capacity but also by relying on an increased supply of non-hydro renewables, expanding electricity trade, and making use of supply- and demand-side energy efficiency to reduce overall demand.

- **Expanded use of non-hydro renewables.** There is significant potential for expanding the use of non-hydro renewables in the LAC region, including extensive wind resources from Mexico to Argentina, geothermal resources along the tectonically active Pacific rim and in the Caribbean, and biomass resources (e.g., sugarcane bagasse) throughout the region. These energy resources can help diversify the region's overall electricity supply mix; in many instances, non-hydro renewable technologies are becoming cost-competitive with conventional power technologies.
- **Increased electricity trade.** Trade could provide significant new capacity by enlarging the region's electricity market and lowering overall supply costs in the process. Increased trade could also help the region make use of its hydroelectric and other energy resources by linking energy supplies to a larger market, thus justifying some larger-scale projects and attracting regional investment.
- **Improved energy efficiency.** Energy efficiency is the most cost-effective way to meet future energy demand, with significant potential on both the supply and demand sides. Many investments (e.g., reducing transmission and distribution losses and tapping the enormous amount of cogeneration potential in industry) quickly pay for themselves. The potential for improving the efficiency of energy use is even greater on the consumption side, ranging from residential and commercial lighting to broadly-used electrical appliances (e.g., refrigerators and air conditioners) and industrial motors and pumps. Recent studies in Brazil and Mexico confirm the extent of the energy efficiency potential that could be tapped at low cost.

The aggregate effect of these alternatives—in terms of lowering the requirements for new generation capacity, much of it thermal—could be large (Figure F.3).

**Figure F.3 LAC Electricity Supply Mix, Various ICEPAC Scenarios**




*Source:* Authors, based on optimization mode.
*Note:* ICEPAC = Illustrative Country Expansion Plans Adjusted and Constrained; REEF = Renewable Energy and Energy Efficiency alternative scenarios.

The analysis suggests that an aggressive program to expand non-hydro renewables could provide 15–30 percent of total electricity supply by 2030. In addition, increased trade could lower electricity costs by allowing the development of larger-scale and, in some cases, regional projects including more renewables and could reduce investments in reserve capacity. Finally, the region's overall electricity demand could be lowered by at least 10–15 percent through limited supply- and demand-side energy-efficiency measures at a fraction of the cost of constructing new power-generating capacity.

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