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Study on the Development of the Renewable Energy Market in Latin America and the Caribbean

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STUDY ON THE DEVELOPMENT OF THE RENEWABLE ENERGY MARKET IN LATIN AMERICA AND THE CARIBBEAN UNDER THE IDB CLIMATE CHANGE EVALUATION

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Introduction

The region of Latin America and the Caribbean is already a global low-carbon leader in terms of power generation from hydrological and biomass resources, and it recently has made great strides in developing its other renewable energy sources. Declining costs, maturing technologies, and vast untapped potentials for renewables offer an unprecedented opportunity for further development of the renewable energy market in the region. Continuing to invest in renewables will provide Latin America and the Caribbean with the opportunity to address key economic, social, and environmental challenges in the energy sector. These include:

- **Achieving universal access to electricity**

  Approximately 34 million people in Latin America and the Caribbean still lack access to electricity. Renewable energy has the ability to provide reliable, affordable, and sustainable modern energy services to those who currently lack them. Increasing electricity access through decentralized micro-grid solutions—thereby avoiding economically prohibitive grid expansion to remote locations—will advance economic productivity, social opportunity, gender equality, and a host of other developmental priorities at a fraction of the cost of fossil fuels over the long term.

- **Meeting future electricity demand**

  To meet rapidly growing electricity demand, Latin America and the Caribbean will need to double its installed power capacity by 2030. A self-sufficient, domestic renewable energy supply can increase energy security, eliminate the need for expensive fuel imports, and reduce the burden on national budgets. It can also result in substantial economic and societal benefits such as increasing competitiveness, job creation, and balance of payments, apart from its local and global environmental benefits.

- **Transforming the electricity system**

  In most parts of Latin America and the Caribbean, the grid infrastructure is outdated and in need of significant modernization and expansion. This creates a unique opportunity to build a 21st-century electricity system through integrated, system-wide national and regional energy planning that can support growing shares of renewable energy, increase energy efficiency, and provide reliable service at the least cost in the long term. This development must be based on thorough analysis of the technical and socioeconomic potentials of the full spectrum of renewable technologies and result in a coherent policy consisting of ambitious goals and concrete support mechanisms, supported by effective governance and administrative structures and processes.

- **Mitigating and adapting to climate change**

  Climate change is already having, and will continue to have, profound impacts on the regional economy, ecosystems, and human well-being in Latin America and the Caribbean. Climate change and the power sector are closely related given that the power sector is an important source of greenhouse gas emissions and that the sector itself is vulnerable to the impacts of climate change. In addition to contributing to climate change mitigation, renewable energy can help make the region's energy systems more reliable and resilient in the face of a changing climate.

Renewables are increasingly the most economic option for new generation capacity, especially for countries that depend on fuel oil for power generation, such as many in Central America and the Caribbean. Resource advantages give the region the potential to match or even undercut the lowest costs achieved in other parts of the world. Low-cost financing and the scaling up of local industries are important keys to realizing that potential.

Effective policies and measures can greatly improve the investment environment for domestic and international, as well as public and private, actors—particularly given a market that is distorted due to both direct and indirect subsidies for fossil fuels. Considering the longevity of current investments in power system infrastructure, it is imperative that policymakers carry out integrated resource plans that seek to lower overall electricity system costs in the long term by taking advantage of synergies among different renewable sources, energy efficiency, and smart grid technologies.

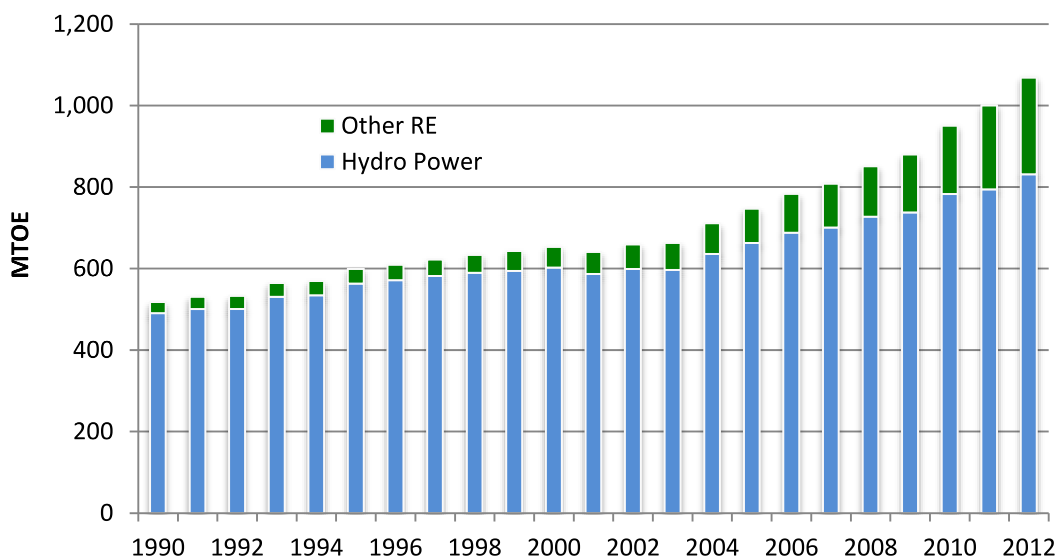
This report begins with an overview of the status of renewable energy technologies for power generation and their global markets (Chapter 1). It then provides an overview of the power sector in Latin America and the Caribbean and of regional renewable energy development to date (Chapter 2). This is followed by an assessment of the current barriers to the continued development of renewable energy in the region, along with best practices for addressing them (Chapter 3). The report then analyzes the impacts of climate change in the region and suggests adaptation strategies for the power sector (Chapter 4). Finally, the report ends with recommendations to any Multilateral Development Bank, including the Inter-American Development Bank, on how they can best position and strengthen their role as a driving force behind the development of a future energy system powered by a large share of renewables in Latin America and the Caribbean.

1 Renewable Energy for Power Generation: Global Trends

As a major source of greenhouse gas emissions, the energy sector is a critical component of low-carbon development strategies being designed and adopted worldwide. These efforts seek to maximize the cross-sectoral impacts of renewable energy development, such as economic and social development, energy security, energy access, and reduced negative impacts on human and environmental health.

Electricity markets around the world have experienced rapid and dynamic change over the past five years. Propelled by USD 1.1 trillion of investment since 2009—the vast majority of it from the private sector—renewable power generation has grown at double-digit rates and accounted for more than 40% of the new generating capacity added in 2012.[1] (See Figures 1.1 and 1.2.) It can now be said with confidence that new renewable energy technologies (in addition to long-established hydropower) have entered mainstream energy markets and are in many cases economically competitive with fossil fuels—sometimes by wide margins.

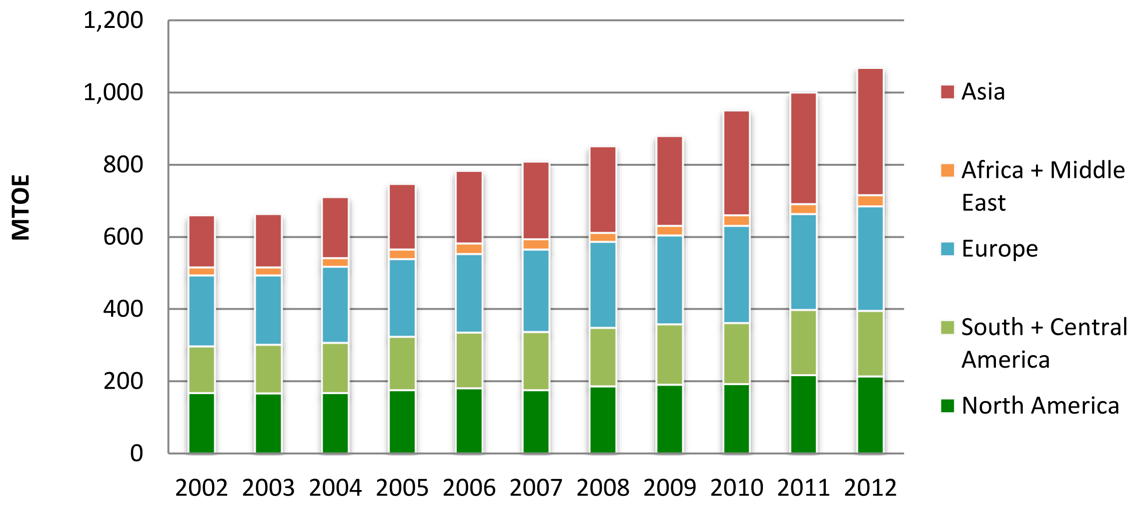
FIGURE 1.1 World Primary Energy from Renewable Sources, 1990–2012



Source: BP

The global emergence of renewable energy is far from uniform, however. A handful of countries and regions—including China, Europe, and North America—dominate both the manufacturing and use of these technologies. The commercial maturity and economic competitiveness of individual renewable technologies is also uneven, with most of the recent growth occurring in wind, solar, and biomass power. Geothermal, small hydropower, and marine technologies continue to advance, but their markets remain tiny and are confined mainly to geographic or resource conditions that are only rarely present.

FIGURE 1.2 Total Primary Energy from Renewable Sources, by Region, 2002–2012



Source: BP

Wind, solar, and biomass resources are found in abundance and in varying combinations in most parts of the world. Moreover, many of the technologies to tap these resources are now widely available on the world market. Where the right market conditions and policy frameworks are in place, new power sources and industries can be established in just a few years. This chapter provides an overview of the status of renewable energy technologies for power generation and their global markets.

1.1 Status of Renewable Energy Technologies

Most renewable power technologies are based on principles of mechanical, electrical, and chemical engineering that were understood many decades ago and are already being deployed widely in other industries. For example, modern wind turbines draw on aviation design and materials, whereas biomass combustion employs some of the same processes as coal-fired power plants. The newest renewable technology in wide use today is the solar photovoltaic (PV) cell, a semiconductor material invented in the 1950s and related closely to the now-ubiquitous silicon chip.

Despite the surprisingly "conventional" nature of most renewable power technologies, turning them into commercially reliable and economically competitive electricity generators has been a difficult and time-consuming process. Virtually all of these devices were already at the prototype stage or beyond as early as the 1970s, but efforts to commercialize them rapidly in response to rising oil prices were stymied by technical and reliability problems, high costs, and a lack of solid policy frameworks to support their development.

Wind power is the most widely deployed new renewable technology in use today, with 318 gigawatts (GW) of capacity connected to the world's power grids as of the end of 2013.[2] Although the industry has experimented with a range of technologies over the past three decades, the sector is dominated today by a single design: three carbon fiber blades set atop a 50–100 meter steel tower that generates between 500 kilowatts (kW) and 5 megawatts (MW) of electricity. Individual turbines generally sell for USD 1,400 per kW.[3] Turbines as small as

1 kW and below are also available, mainly for distributed and off-grid applications, but their cost of generation is two to four times as high as for large turbines, and their contribution to global power supplies is minimal.[4]

The cost of grid-scale wind turbines has fallen steadily since these were introduced in the 1980s, as a result of small, cumulative improvements in components ranging from generators and transmissions to electronic controls. The largest factor in falling costs, however, has been the 40-fold increase in average turbine size, from less than 50 kW to nearly 2 MW.[5] In addition, developers now place turbines higher to harness stronger winds, and operate them with higher capacity factors. Developing new wind farms typically takes 1–3 years (compared to 5–10 years for large coal and hydro plants), and individual turbines can be installed in a matter of days. However, installation of the largest turbines is sometimes constrained by the availability of transport infrastructure to move the massive equipment to the deployment site.

Solar power has experienced the most rapid technology advances and cost reductions of any renewable technology in use today. Although the basic design of the semiconductor-based PV cells that dominate the market has changed only modestly since the 1970s, cumulative advances in cell and module efficiency and the scaling up and automation of manufacturing have brought down module costs. Average PV module prices have fallen by nearly 75% in the past three years.[6] These factors, combined with heightened global competition, have lowered prices from USD 4,000 per kW to well under USD 1,000 per kW just since 2009.[7] Although invented in the United States, solar modules have become a global commodity, with manufacturing now centered in China and other Asian countries, and the ability to ship modules virtually anywhere in the world.

Unlike any other electricity technology, solar PV can be deployed economically at virtually any scale, from small cells that power individual light bulbs to square kilometers of panels that can produce as much electricity as a large coal-fired power plant. Another solar technology that is available for large-scale power generation (although only in high-insolation desert conditions) is concentrated solar thermal power (CSP), which collects solar heat and uses it to produce steam and drive a turbine. CSP plants are often equipped with the ability to store heat, which allows them to meet power needs several hours after sunset. Although CSP was deemed less expensive than PV electricity as recently as five years ago, CSP cost reductions have not kept up with sharply falling PV prices, and generation costs are now more than twice as high.[8]

Biomass—including urban and agricultural wastes, forest products, and dedicated energy crops—is a solid fuel that, most simply, can be used to fuel a power generator in the same way as coal. Direct combustion of biomass for power generation has been used for decades and is common in parts of Europe and North America. Biomass also can be converted to a premium fuel such as methane (biogas) or ethanol, or it can be gasified and used to run a generator. These technologies are in limited use today but continue to advance. The plethora of devices, scales, and feedstock options, however, has impeded industry standardization and mass production, keeping growth modest compared with solar and wind.

Hydropower is a fully mature renewable energy technology that continues to be deployed in many developing countries. In addition to large hydro plants, small hydropower (less than 10 MW in size) is a popular option, particularly in areas where electricity from the main grid is unavailable. An estimated 75 GW of small hydro capacity is now in use—a third or more of it in China, which has prioritized its development.[9]

Geothermal electricity has been used since the 1970s and is deployed in locations where geothermally heated water is found near the Earth's surface. The hot, pressurized water can be converted directly to steam to spin a turbine, or it can be used to heat a secondary fluid that drives the turbine. These resources are found in few locations, however, and just over 10 GW of generating capacity is now in operation worldwide.[10] New installations in 2013 were just 1% of the capacity installed in both the wind and solar industries.[11] New technologies that can harness the virtually unlimited geothermal heat found deeper in the Earth's crust have been under development for many years, but they have been slowed by technical hurdles and high costs. High exploration and drilling expenses have limited industry investment, and the opportunity for large-scale manufacturing is minimal.

A range of marine resources is being developed to supply renewable electricity as well. Tides, waves, currents, and tropical heat differentials (known as ocean thermal energy conversion, or OTEC) all represent enormous resources, but they are technologically challenging and expensive and provide only tiny amounts of electricity today. With the exception of tidal power in a few select locations, none of these technologies is likely to be widely available commercially for at least a decade, and potentially much longer.

1.2 Renewable Energy Global Markets

Global markets for renewable energy have been on the rise for decades, but in the past five years accelerated double-digit growth has brought them into the mainstream of electricity production. Large hydropower, which has been in use for more than a century, continues to dominate renewable power supplies globally (see Table 1.1), with much of the growth in Asia and Africa, where most of the potential remains untapped.[12] Small hydro is a growing portion of the hydropower market, but its growth remains modest.

TABLE 1.1 Global Electricity Generating Capacity of Selected Renewable Energy Sources, 2013

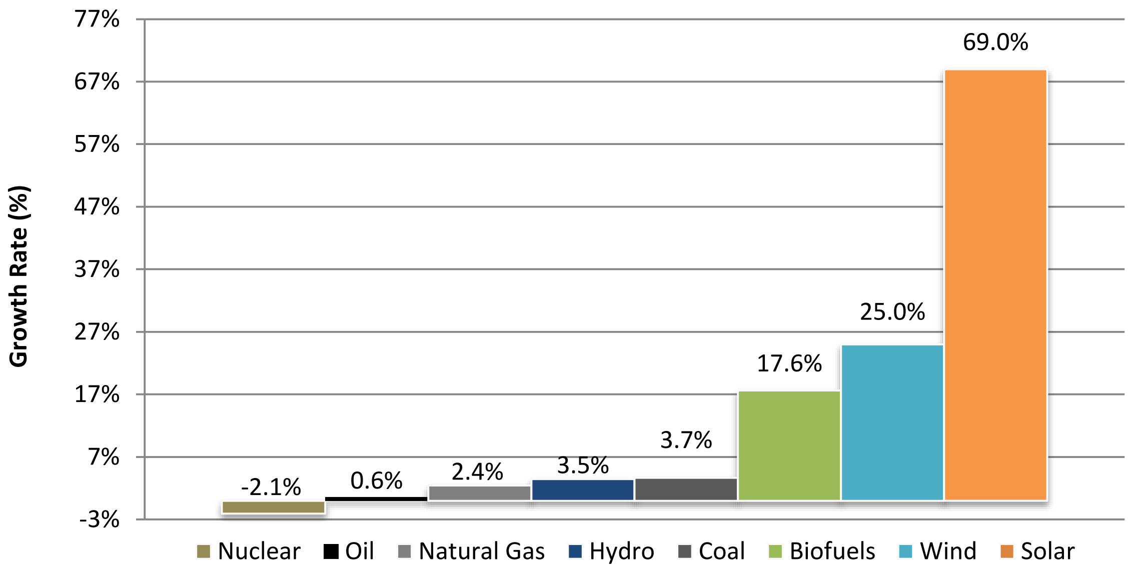
	Generating Capacity
	gigawatts
Hydropower	1,000
Wind power	318
Solar PV power	139
Biomass power	88
Geothermal power	12
CSP	3.4

Source: See Endnote 12 for this chapter.

After hydro, wind is the largest producer of renewable power at 318 GW, followed by solar PV (139 GW), biomass (88 GW), geothermal (12 GW), and CSP (3.4 GW).[13] By comparison, the total current generating capacity of the entire Latin America region is roughly 300 GW.[14] In 2013, renewable energy provided roughly 22.1% of the world's electricity (5.7% if hydro is excluded).[15] Measured by annual growth rates over the past five years, the prominence of renewable energy sources is striking: solar has grown at 69% annually, wind at 25%, and biomass at 12% (see Figure 1.3); in contrast, all of the fossil fuels are growing at less than 4% annually.[16] The new renewable energy technologies (excluding large hydro) combined contributed 44% of the generating capacity added in 2013.[17]

Most of the growth in renewables has occurred in a small number of countries, including China, Denmark, Germany, and the United States. Growth within the United States has been uneven, however, with a handful of states dominating the market. This concentration of renewable energy deployment is almost entirely a consequence of policy differences, pointing to the large untapped potential to take technologies and policy ideas that are already proven and to adopt them quickly in other parts of the world.

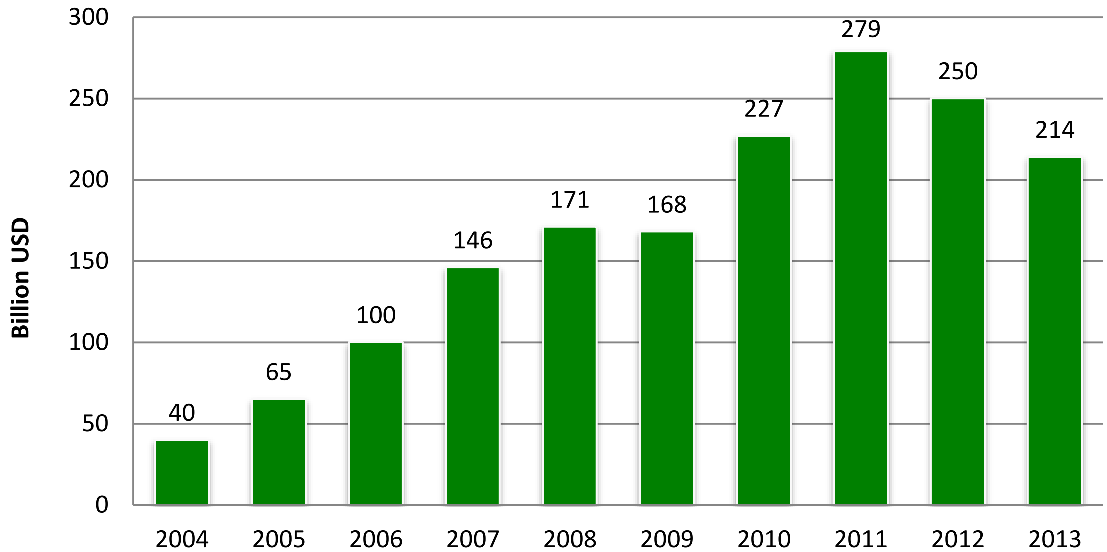
FIGURE 1.3 Global Growth in Energy, by Source, 2007–2012



Source: BP

Global investment in renewable energy (including biofuels) reached USD 254 billion in 2013 (see Figure 1.4), making renewables one of the largest and most dynamic segments of the electricity industry.[18] The USD 15 billion invested in renewable energy in Latin America and the Caribbean in 2012 was just 6% of the world total, with Brazil alone accounting for more than a third of the regional share.[19] As other regions have demonstrated, such investment could be increased rapidly with more-supportive policy frameworks in place.

FIGURE 1.4 Global Investment in Renewable Energy, 2004–2013



Source: BNEF

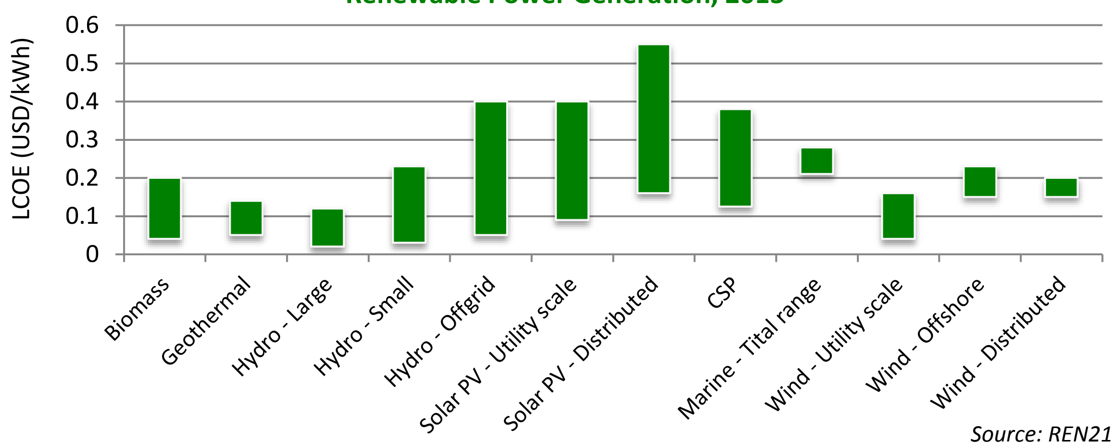
Renewable power has become an engine of employment in the countries where it has grown the fastest. The renewables sector is more jobs intensive than most of the energy industry, and the positions created require moderate-to-high skill levels and also pay relatively well. Of the estimated 6.5 million renewable energy jobs reached in 2013 (including fuels and heat as well as electricity), most were in solar, bioenergy, and wind.[20] The majority of the jobs were found in China, Brazil, the United States, India, Germany, Spain, and Bangladesh.[21]

As renewable power markets have grown, the scale of individual installations has varied enormously. Wind power, for example, began with a decentralized model in Denmark and Germany, with thousands of individual turbines installed on farms—many of them owned by individual farmers or cooperatives. In the United States and China, however, wind power has been dominated by large wind farms, often with hundreds of turbines clustered in particularly windy locations (with generating capacities as high as 300 MW). The larger wind farms are generally less expensive, but they are limited by the availability of transmission lines and the cost of building new ones.

Biomass power plants tend to be of intermediate scale (rarely more than 50 MW), limited by the availability of nearby biomass and the cost of transporting it long distances. Solar power, which has emerged as a significant electricity option only in the past few years, is being installed at virtually every scale possible, from large desert-based power plants to small residential rooftops. Small, "distributed" applications of less than 5 MW are rapidly gaining market share due to the limited economies of scale and to the fact that sufficient sunlight is available in urban areas where most power is consumed. Germany alone now has over 1 million individual generators connected to its electricity grid. In northern Europe, such systems are often owned by local farmers and their cooperatives, whereas in the United States, specialized firms are now building solar installations on commercial and residential rooftops, with the building owner paying for the electricity only as it is generated.

Generating electricity from renewable resources is now economical in many circumstances, with costs varying widely depending on the local resources, the capabilities of local industry, and the cost of capital. These variables must be evaluated locally to determine the true economics. Generally, if resources are abundant, biomass, geothermal, and hydropower have the lowest electricity cost, followed by onshore wind, solar PV, and CSP. However, besides being constrained by their resource availability, geothermal and hydropower projects have long lead times, which limit their rate of growth. For wind and solar, their larger resource, wider geographic distribution, and targeted policy support in key markets have led to widespread development and to increased convergence of the levelized cost of electricity (LCOE) of different renewables.[22] (See Figure 1.5.)

FIGURE 1.5 Global Levelized Cost of Energy Ranges for Renewable Power Generation, 2013



Source: REN21

Hydropower is currently the most reliable and cost-effective renewable power generation technology. Because it is a mature technology, further cost reductions in the future are unlikely. Costs depend heavily on the cost of civil works, civil engineering design, and other factors pertaining to the site and the scale of development of the country.

Biomass costs rely heavily on feedstock prices, and data on prices vary widely between countries. Because data are lacking on price trends of feedstock, comparisons of price trends are difficult.

The installed costs of geothermal power plants have risen due to increases in drilling costs (similar to the oil and gas sectors) and to a rise in commodity prices. Cost reductions are also heavily dependent on resource availability and siting of power plants, so it is unclear whether there will be significant reductions in the future.[23]

Total installed costs of wind power are again declining after reaching their peak in 2009. The rise in wind power costs was due to higher costs for materials for wind turbines, which constitute the largest cost component. New cost reductions have resulted from a global overcapacity of wind turbine manufacturers and increased competition from Chinese manufacturers. The difference between U.S. and Chinese turbine prices still remains large, making further price reductions likely in the future.[24]

The continued growth of solar PV installed capacity combined with a high learning curve and overcapacity in the manufacturing base has resulted in significant price decreases globally. Although PV module price reductions are expected to slow, balance-of-system (BoS) costs are likely to have a larger impact on future PV prices.

Parabolic trough collection has been the most dominant and reliable CSP technology to date, used in 80% of CSP power plants; capital costs for CSP power plants therefore are much higher in comparison to other technologies. However, opportunities for reducing capital costs exist: for example, doubling the plant size from 50 MW to 100 MW can cut costs by 12%.[25]

It is important to note that a static analysis of costs by technology may not lead to the most appropriate choice of energy mix or least-cost energy system in the long term. A dynamic system analysis is required to identify the right combination of renewable energy sources that can unlock the synergies among them and provide flexibility to the power system. This analysis can provide policymakers with the information needed to support the development of the least-cost solution from a systems perspective.[26]

Table 1.2 summarizes the status of renewable energy technologies, including their costs and technical and operational considerations.[27]

TABLE 1.2 Status of Renewable Energy Technologies: Characteristics and Costs

Technology	Market Niches	System Characteristics	Capital Cost (USD/kW)	LCOE* (USD/kWh)	Technology and Operational Considerations
Biomass	Utility-scale (Direct combustion, co-firing with coal, MSW**)	Plant size: 1–200 MW Capacity factor: 50–90%	800–4,500 Co-fire: 200–800	0.04–0.20 Co-fire: 0.04–0.12	Many technologies are well established, although gasification and pyrolysis are less mature. Biomass is low cost where long-term, sustainable supply of low-cost feedstock is available. Feedstock costs vary by type, location, and preparation required. Generally, landfill gas and biogas are cheapest, then forest and agricultural residue, followed by energy crops. Small-scale gasifiers are more competitive than diesel for off-grid applications.
	Industrial co-generation or self-generation	Plant size: 1–20 MW Capacity factor: Co-fire: 50–90% Gasification: 40–80% Anaerobic digestion: 50–90%	Co-fire: 200–800 Gasification: 2,050–5,500 Anaerobic digestion: (biogas) 500–6,500 (landfill gas) 1,900–2,200	Co-fire: 0.04–0.12 Gasification: 0.06–0.24 Anaerobic digestion: (biogas) 0.06–0.19 (landfill gas) 0.04–0.07	
	Off-grid	Plant size: <1 MW	500–6,500	0.06–0.24	
Geothermal	Utility-scale	Plant size: 1–100 MW Capacity factor: 60–90%	Condensing flash: 1,900-3,800 Binary: 2,250–5,500	Condensing flash: 0.05-0.13 Binary: 0.07–0.14	A mature technology that offers low-cost baseload power. Good resources are found only in a few locations. The exploration process is expensive and time consuming. Enhanced geothermal technology is not deployed extensively yet, and costs are unclear.
Hydropower	Utility-scale	Plant size: 1–18,000+ MW Capacity factor: 30–60%	Large hydro: 750–2,500 Small hydro: 750–4,000	Large hydro: 0.02–0.12 Small hydro: 0.03–0.23	A mature technology that offers low-cost baseload power. Large hydro projects have long lead times and environmental concerns. Reservoirs can help with grid stability and act as storage for renewable integration. Small hydro does not have the same economies of scale yet remains a very competitive option for rural electrification.
	Off-grid	Plant size: 0.1–1,000 kW	1,175–6,000	0.05–0.40	
Solar PV	Distributed (Rooftop)	Peak capacity: 3–500 kW Capacity factor: 10–25%	2,150–7,000	0.16–0.55	A mature, proven technology that has achieved grid parity in many markets. Capacity factors vary with resource available. Distributed systems have higher LCOEs but are competitive with residential electricity tariffs in some markets. PV with storage is a cheaper option than diesel for off-grid electricity. It can be combined with wind or back-up power (e.g., biomass or diesel generator) for increased reliability.
	Utility-scale	Peak capacity: 2.5–250 MW Capacity factor: 10–25%	1,200–1,950	0.09–0.40	
	Off-grid	Peak capacity: 10–200 W Capacity factor: 10–25%		0.20–0.45	

Technology	Market Niches	System Characteristics	Capital Cost (USD/kW)	LCOE* (USD/kWh)	Technology and Operational Considerations
CSP	Utility-scale	Plant size: 10–250 MW Capacity factor: 20–40% 35–75% (with storage)	3,100–7,300 With storage: 7,100–9,800	0.19–0.38 With storage: 0.12–0.37	Commercial deployment is still in its infancy. Capital costs are high, especially when storage is added. However, generation costs with storage may be lower given increased electricity production. CSP also adds flexibility to the grid. Greater operational experience, economies of scale, learning curves, etc. may lower costs in the future.
Marine	Utility-scale	Tidal range: Plant size: <1 MW to >250 MW Capacity factor: 23–29%	Tidal range: 5,290–5,870	Tidal range: 0.21–0.28	Of the five technologies under development (tidal power, tidal currents, wave power, temperature gradients, and salinity gradients), none has been widely deployed yet. Yet great potential exists and numerous demonstration projects have been or soon will be deployed.
Wind	Utility-scale onshore	Turbine size: 1.5–3.5 MW Capacity factor: 25–40%	925–1,950	0.04–0.16	Onshore wind LCOE is competitive with fossil fuels. Operational costs of offshore wind are high due to difficulties of the offshore environment. Higher capital costs of offshore wind are somewhat offset by higher generating capacities achieved. Off-grid wind turbines can be coupled with diesel generators, batteries, or other distributed sources for higher reliability.
	Utility-scale offshore	Turbine size: 1.5–7.5 MW Capacity factor: 35–45%	4,500–5,500	0.15–0.23	
	Off-grid	Turbine size: <100 kW Capacity factor: varies	1,900–6,040	0.15–0.20	

* *LCOE = Levelized Cost of Electricity*
** *MSW = Municipal Solid Waste*
Source: See Endnote 27 for this chapter.

1.3 Grid Integration of Renewable Energy

Integrating renewable power presents challenges for those who manage electricity systems, but these challenges are generally modest and can be addressed gradually over time. The electricity grid can handle low levels of renewables (up to 15% of capacity) without additional investments. As renewable energy penetration increases, smart grid technologies such as demand response, demand automation, advanced metering infrastructure, and weather forecasting can enable the cost-effective integration of renewable energy. Once renewable energy capacity reaches high levels (30–50% depending on the flexibility of the power system), smart grid technologies and other investments become crucial for reliable grid operation.[28] Necessary investments include the expansion of transmission capacity and an increase in system flexibility on both the supply and demand sides.

Geothermal and biomass power plants operate much like conventional power plants, usually providing steady "baseload" electricity and being capable of being turned on and off as needed. However, both solar and wind power—the two fastest-growing new power sources—are variable in nature (the sun does not always shine and the wind does not always blow), and they therefore place unique demands on electricity systems. Although this limitation may appear daunting, electric utilities have successfully developed a range of responses that are most effective and economical when deployed as part of overall systems planning.

Some of these strategies require minimal investment and should be adopted before more-expensive strategies are undertaken. In many instances, utility engineers have been surprised to discover that existing power systems are more resilient and adaptable than expected. Less-robust electricity systems with fewer connections to other grids present more challenges, but these are hardly insurmountable. While the challenges of increasing wind and solar generation are dependent on the nature of the renewable supply and electricity demand, as well as on the flexibility of the power system, studies on the experiences of power systems around the world have provided best practices that can be applied elsewhere.

Denmark, Ireland, Germany, Portugal, Spain, Sweden, and the United Kingdom all have had renewable energy exceed 5–10% of annual generation without technical issues.[29] This is possible as long as local concentrations of variable renewable energy generation are avoided, renewable energy plants contribute to stabilizing the grid when needed, and short-term forecasting is used effectively.[30] The capacity of the current grid to deal with variability in electricity demand and the possibility of outages can be used to handle the variability and uncertainty of wind and/or solar power generation at these levels.

Integrating large shares of wind and/or solar power requires more significant investments, and a system-wide transformation is recommended to minimize total system costs.[31] When renewable energy is deployed, it should take into account the long-term development of the whole system, including future transmission infrastructure plans and synergies with other energy sources. In addition, wind and solar systems can be operated in a way that provides short-term grid stability and when needed can be curtailed to avoid moments of extreme variability.[32] System and market operations can be improved through the adoption of short-term power markets (such as nodal pricing in the Electric Reliability Council of Texas (ERCOT) or power delivery contracts in Germany), system service markets that value flexibility, renewable energy production forecasts, and cooperation with nearby service areas.[33]

In systems with high growth in demand that require significant investments in the short term, such as those of emerging economies in Latin America, deployment of high levels of wind and solar power can be carried out in line with grid expansions, thereby avoiding putting existing generators under economic stress. However, these systems usually do not enjoy the flexibility provided by a larger existing asset base, so long-term investment plans that consider additional system flexibility are important.

The growing importance of solar and wind power is propelling a growing interest in energy storage technologies that can help address the variability challenge. With the exception of pumped hydropower, which is used for storage in some regions, storing electricity has tended to be too expensive for widespread use. However, recent advances in a range of battery technologies have convinced many experts that storage will soon be affordable, with much of it likely to be located close to customers. The batteries in growing fleets of plug-in hybrid-electric vehicles may provide a portion of this storage.

1.4 Environmental Impacts and Sustainable Development

All energy technologies have impacts on the environment, and the ability to mitigate many of those impacts is one of the main advantages of renewable energy. Fossil fuel-fired power plants are a major contributor to local air pollution and are responsible for an estimated 7 million premature deaths each year.[34] They are also the largest single source of greenhouse gas emissions, which are projected to grow rapidly in coming decades, with all of that growth centered in developing countries. By contrast, most renewable technologies produce negligible emissions, which are offset quickly via reduced fossil fuel pollution over their operating lives. Their consumption of water, another limited resource, also tends to be much lower.[35]

Renewable energy sources do have some unique environmental impacts, but these are largely local and can be integrated via careful planning and the application of proven mitigation strategies. Government regulation is generally needed to ensure that companies do not take shortcuts in order to lower costs. Wind power, for example, can put birds at risk of striking the turbine blades, which is minimized via careful siting and the installation of devices that warn birds about the turbines. Large solar installations can be hazardous to some land animals, requiring environmental impact assessments to determine the potential project impacts.

Both geothermal power and solar cell production can release toxic chemicals with potential health effects. China, for example, has reported instances of solar manufacturers dumping dangerous chemicals into nearby waterways, provoking a crackdown by local authorities.[36] To avoid this, the chemicals must be contained and then either recycled, destroyed, or safely sequestered.

Biomass power can threaten soil health and biodiversity, depending on the feedstock used and how it is harvested. When using forestry or agricultural waste, sufficient crop residues should be left behind to improve carbon storage, maintain nutrient levels, and prevent erosion. Energy crops present higher land-use impacts, but using sustainable agriculture practices can improve efficiency of land use and soil health.[37] Hydropower is also often limited by environmental factors: for example, large dams have flooded vast swaths of land, destroying biodiversity and requiring the relocation of millions of people. Most hydro development in industrial countries has been stopped, and in developing countries, long and bitter struggles have emerged over many hydro projects. In most cases, small hydropower stations do not require large impoundments, limiting their environmental impact.

Renewable power technologies can be used for sustainable development as well, to provide electricity to some of the 1.3 billion people who currently lack such access.[38] This is one of the three goals of the United Nations' Sustainable Energy for All (SE4ALL) initiative, which is aimed at ending energy poverty by 2030.[39] Many of the people without access to electricity live in areas that are too remote or inaccessible to be reached by traditional electricity grids. Although diesel generators have provided power in some areas, renewables offer a more economical alternative in many cases. In some locations, such as parts of Africa and South Asia, small solar panels are sufficient to run lights and power mobile phones, producing enough power to make meaningful improvements in people's lives.

In recent years, attention has turned to the development of "micro-grids" to provide electricity in islands or remote regions where grid extension is possible. Small hydropower has been used in this way for decades, but most of the power for existing micro-grids comes from diesel generators, which typically cost several times as much as grid electricity. Thousands of these micro-grids could be made more affordable by replacing diesel generators with a combination of renewable technologies, with the mix varying depending on resource availability. In such a configuration, the diesel units would be retained mainly for backup power, saving fuel and reducing the overall cost of electricity. In other areas, new micro-grids can be built from scratch. In both cases, modern electronic controls facilitate the use of multiple power sources, ensuring increased reliability and cost savings compared with the systems in place today.

The last decade has seen dramatic growth in renewable energy markets, the proliferation of support policies, and significant cost reductions in renewable technologies across the world. Already, investments in renewable energy are shifting to new markets in Asia, Latin America, the Middle East, and Africa. Still, significant opportunities for future development in these markets remain and are expected to attract further investment.

2 Renewable Energy in Latin America and the Caribbean

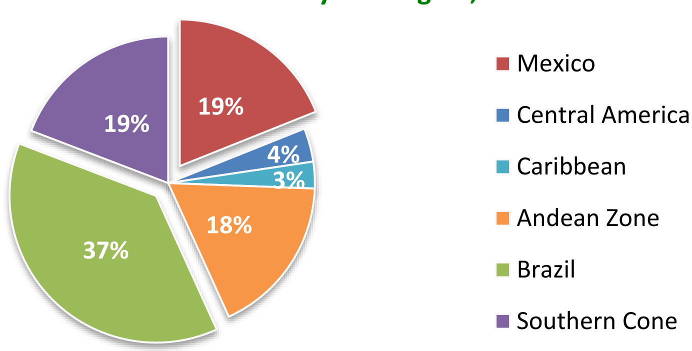
Latin America and the Caribbean is a very diverse region, with economies of varying sizes. The two largest economies, Brazil and Mexico, drive many of the regional trends, masking some of the developments in the power sector that require individual analysis. This chapter provides an overview of the power sector in Latin America and the Caribbean and of the development of renewable energy in the region to date.

The chapter orders the 26 borrowing members of the Inter-American Development Bank geographically, from north to south, into: Mexico, Central America (Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama), the Caribbean (Bahamas, Barbados, Dominican Republic, Guyana, Haiti, Jamaica, Suriname, and Trinidad and Tobago), the Andean Zone (Bolivia, Colombia, Ecuador, Peru, and Venezuela), Brazil, and the Southern Cone (Argentina, Chile, Paraguay, and Uruguay). Unless otherwise specified, the data presented here include only the 26 countries in the region.

2.1 Introduction to the Electricity Sector in the Region

Brazil accounts for the majority of the installed power capacity in Latin America and the Caribbean (37%), while Mexico, the Andean Zone, and the Southern Cone each represent about a fifth, and Central America and the Caribbean represent 4% and 3%, respectively.[1] (See Figure 2.1.)

FIGURE 2.1 Share of Installed Power Capacity in IDB Member Countries, by Sub-region, 2013

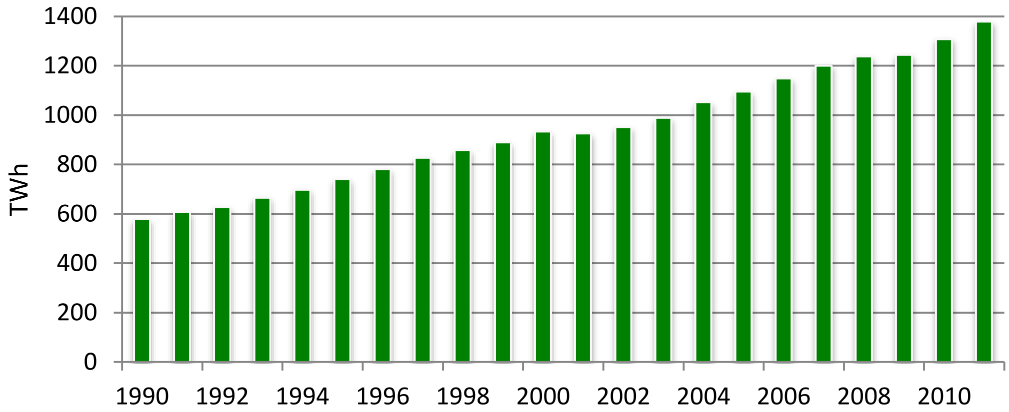


** Note: Share is out of total installed power capacity of 327 GW in 26 IDB countries.*

Source: MIF and BNEF

It is well known that electricity production and consumption are correlated positively with economic growth. Over the last 20 years, average economic and electricity growth in Latin America and the Caribbean have exceeded the global average. Electricity production has more than doubled, from 609 Terawatt-hours (TWh) in 1991 to 1,379 TWh in 2011, representing average growth of 4.4% per year.[2] (See Figure 2.2.) This sustained growth trajectory coincided with the economic recovery of the 1990s.[3] Even during the recent global recession, the region enjoyed strong economic growth—averaging 3.8% annually over the last decade—a level that is expected to continue into the foreseeable future.[4]

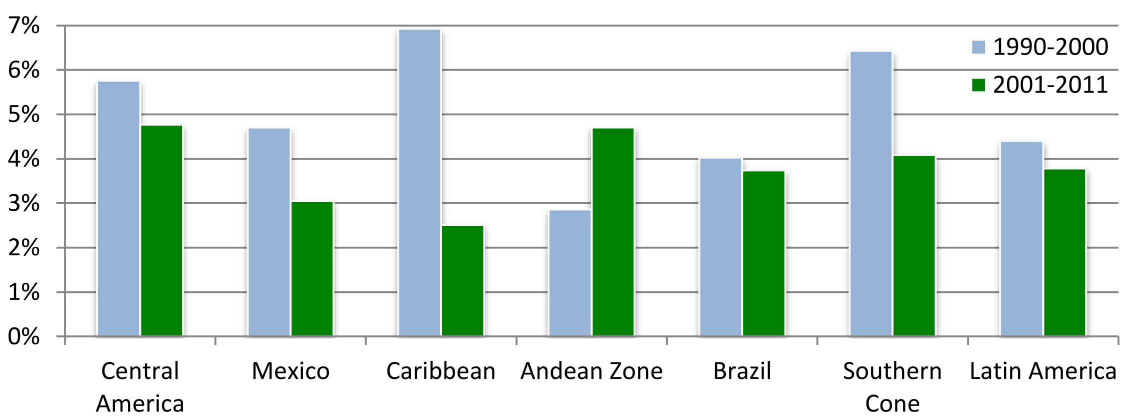
FIGURE 2.2 Electricity Production in IDB Member Countries, 1990–2011



Source: U.S. EIA

In the 1970s, Brazil had the highest growth in electricity consumption in the region, averaging 12%, but this rate has decreased significantly in the last two decades. Mexico has followed a similar trend. Meanwhile, Central America, the Caribbean, the Andean Zone, and the Southern Cone experienced a sharp increase in electricity consumption in the 1990s, which has continued for the Andean Zone in the last decade. The Caribbean saw the largest change in electricity consumption growth in the last two decades.[5] (See Figure 2.3.)

FIGURE 2.3 Growth in Electricity Consumption in IDB Member Countries, by Sub-region, 1990–2000 and 2001–2011

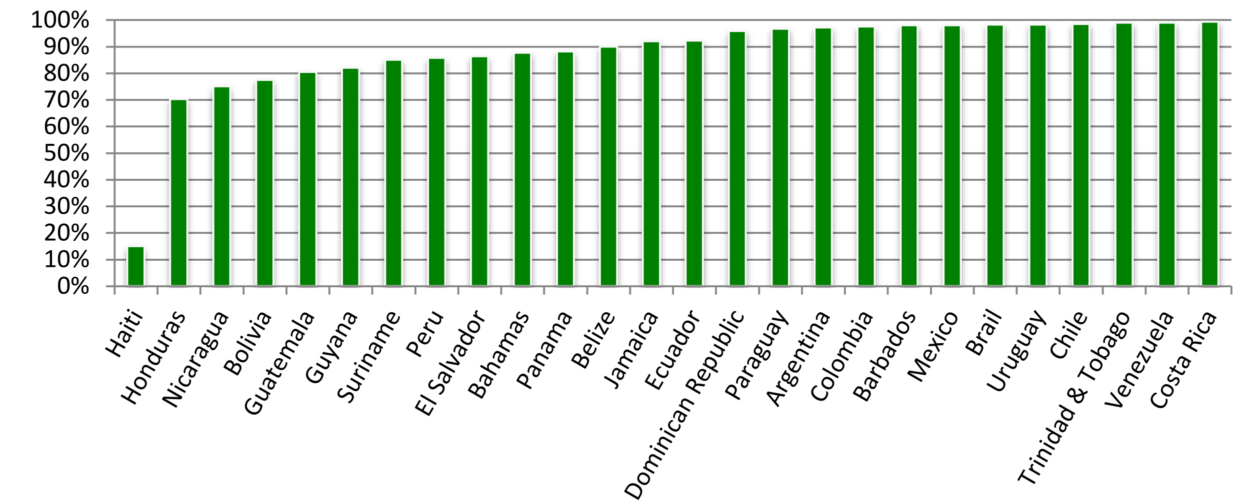


Source: U.S. EIA

Generally, as economies grow, there is a positive correlation between growth in GDP per capita and growth in power consumption per capita. This trend is more noticeable in developing economies, such as those of Latin America and the Caribbean, than in developed nations, due in part to lower levels of energy efficiency, growing use of electric appliances, and increases in electricity access. The population of Latin America and the Caribbean is forecast to grow by 0.85% annually over the next 20 years, while the economies of the region are expected to expand by 3% a year on average.[6] Meeting this growing demand will require nearly doubling the region's combined electricity generation capacity from 1,379 TWh in 2011 to 2,500 TWh in 2030.[7]

This immense growth in energy consumption is tied to increased access to electricity in the region. In 1970, only half of Latin America and the Caribbean's 275 million people had access to electricity.[8] By 2013, the region, with a population of 590 million people, boasted an 88% electrification rate, and 17 of the 26 countries had electrification rates at or above the average.[9] An estimated 34 million people in the region still lack access to electricity, over 8 million of whom live in Haiti.[10] (See Figure 2.4.)

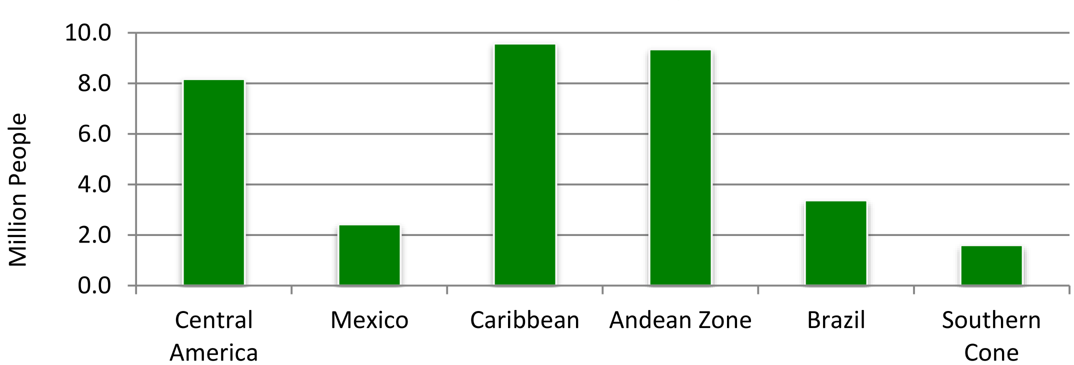
FIGURE 2.4 Electricity Access in IDB Member Countries, 2012



Source: MIF and BNEF

On a sub-regional basis, Brazil, Mexico, and the Southern Cone have close-to-universal electricity access. However, the size of Brazil and Mexico's populations is reflected in the amount of people without access in each country: 3.4 million and 2.4 million, respectively.[11] In the Andean Zone, Bolivia and Peru are the outliers with access rates of 78% and 86%, and 2.3 million and 4.3 million people without electricity, respectively.[12] Central America as a whole has the highest number of countries at or below the regional average, including Honduras, Nicaragua, Guatemala, El Salvador, and Panama, which together are home to just over 8 million people without access.[13] The largest outlier in the Caribbean and in the region as a whole is Haiti, with only 15% electricity coverage and 8.6 million people without access.[14] (See Figure 2.5.)

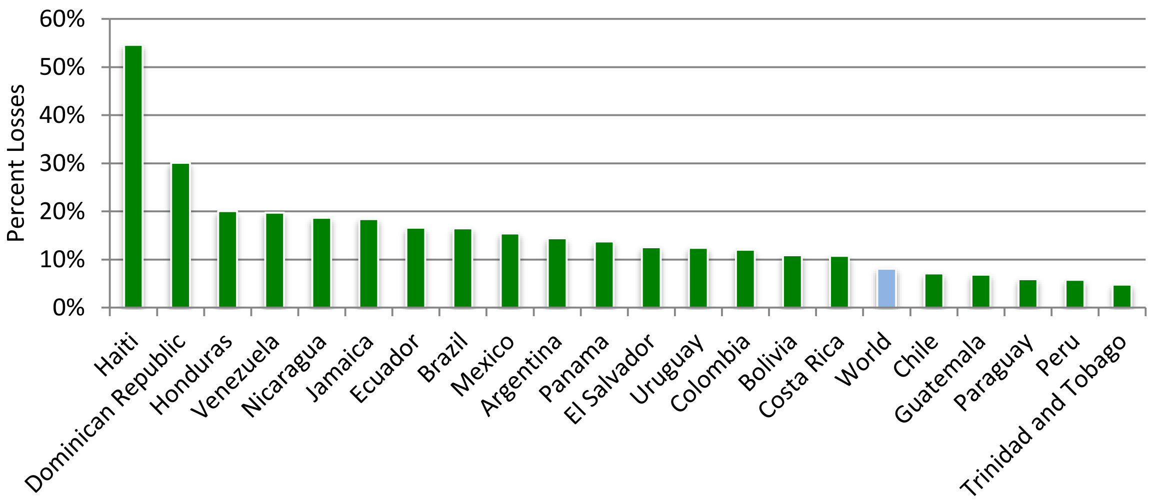
FIGURE 2.5 Population Without Access to Electricity in IDB Member Countries, by Sub-region, 2012



Source: MIF and BNEF

Access to electricity is not the only challenge, however, as the region faces serious grid reliability and stability challenges, which translate to significant economic losses to the system. On average, system losses, which include losses during transmission between sources of supply and points of distribution and during the distribution to consumers, reached 15% of total power output, or 1,379 TWh, in 2011—almost twice the world average. [15] (See Figure 2.6.) As with electricity access, power losses vary significantly by country, yet improving transmission and distribution systems as a region could contribute to meeting the growing energy demand.

FIGURE 2.6 Electric Power Transmission and Distribution Losses in IDB Member Countries, 2011

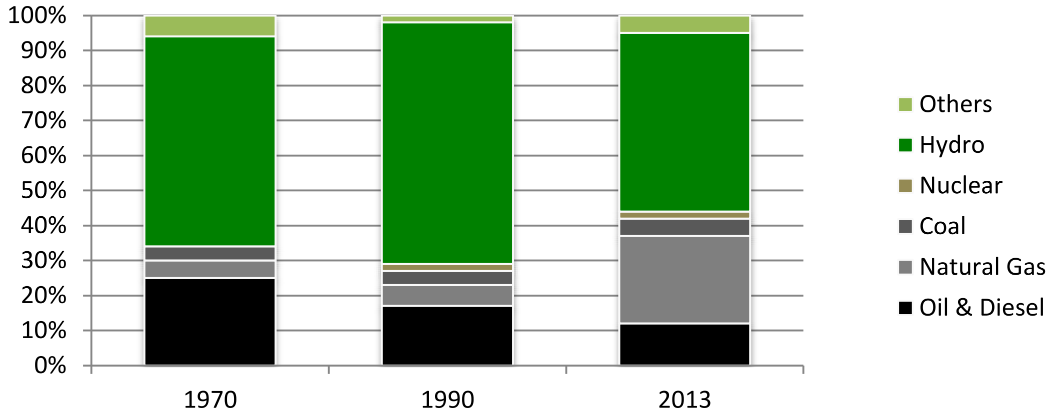


Source: World Bank

Currently, electricity and heat generation is the largest global contributor to greenhouse gas emissions; as a region, however, Latin America and the Caribbean has the world's greenest electricity mix (in terms of carbon intensity).[16] This is due primarily to its large hydropower development, which has been the biggest source of electricity generation since the 1970s and currently makes up 51% (small and large hydro) of total installed generating capacity.[17] However, the share of electricity from hydro has been declining over the last decade, a trend that is expected to continue with the development of natural gas and renewable resources. Overall, the role of fossil fuels in the region has changed over time, with fuel oil being replaced slowly by natural gas, while coal use remains consistently low.[18] (See Figure 2.7.)

This trend is especially true for Mexico, Brazil, and the Southern Cone (Chile and Argentina), although Brazil remains heavily dominated by hydro. Nevertheless, oil use for power generation in the Caribbean and Central America continues to be significant. While the Caribbean's electricity mix has remained relatively stable over the past three decades, Central America's mix has changed with the introduction of coal in Costa Rica and the recent development of renewables throughout the sub-region. The Andean Zone has experienced little change in its electricity mix, with a slight decrease in natural gas and oil, accompanied by an increase in hydropower.[19]

FIGURE 2.7 Electricity Generation by Source in IDB Member Countries, 1970, 1990, and 2013

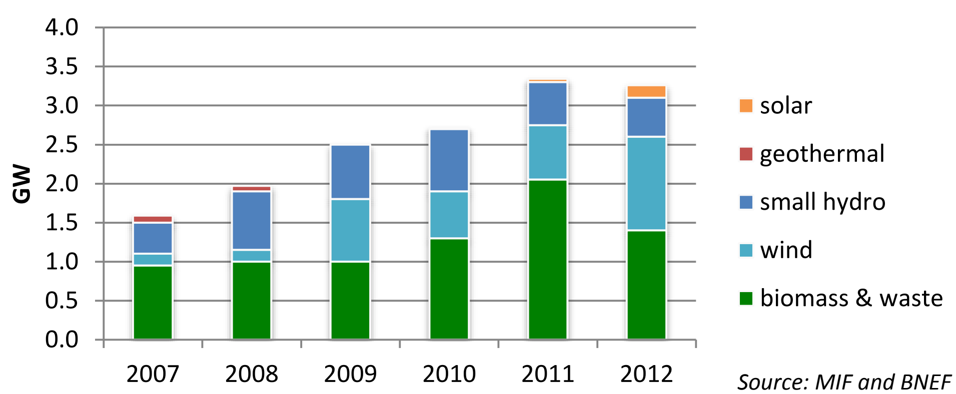


Source: Tissot, OLADE

** Figure includes data for Cuba and Grenada but does not include the Bahamas.*

Although renewables other than large hydro currently comprise only 9% of total installed power capacity (4% biomass and waste, 3% geothermal, and 2% wind), they have begun to grow rapidly in recent years. Between 2006 and 2012, installed renewable capacity more than doubled from 11.3 GW to 26.6 GW.[20] Biomass and waste make up the majority of this growth (largely in Brazil), but there has also been significant development of small hydro and wind. Falling costs of solar are making this resource more attractive as well.[21] (See Figure 2.8.)

FIGURE 2.8 Net Renewable Capacity Additions by Source in IDB Member Countries, 2007–2012



Source: MIF and BNEF

In global terms, Latin America and the Caribbean has the most extensive and diverse supply of renewable energy resources of any region, but this potential has only begun to be tapped.[22] (See Table 2.1.) Even excluding hydropower, which is not yet fully exploited, the region could produce an estimated more than 78,000 TWh of electricity from renewable energy sources.[23] This is enough capacity, combined with hydropower, to meet the region's current (1,400 TWh) and future (2,500 TWh) electricity needs many times over.

TABLE 2.1 Renewable Energy Potential in IDB Member Countries

Country	Hydro Potential	Wind Potential	Solar Potential	Geothermal Potential	Biomass and Waste Potential
Argentina	HIGH	HIGH	HIGH	HIGH	HIGH
Bahamas	UNKNOWN	MEDIUM	HIGH	UNKNOWN	MEDIUM
Barbados	LOW	HIGH	HIGH	UNKNOWN	LOW
Belize	MEDIUM	HIGH	HIGH	UNKNOWN	UNKNOWN
Bolivia	HIGH	HIGH	HIGH	HIGH	MEDIUM
Brazil	HIGH	HIGH	HIGH	MEDIUM	HIGH
Chile	HIGH	HIGH	HIGH	HIGH	HIGH
Colombia	HIGH	HIGH	HIGH	HIGH	LOW
Costa Rica	HIGH	HIGH	HIGH	HIGH	HIGH
Dominican Republic	HIGH	MEDIUM	HIGH	UNKNOWN	LOW
Ecuador	HIGH	UNKNOWN	HIGH	HIGH	UNKNOWN
El Salvador	HIGH	HIGH	HIGH	HIGH	UNKNOWN
Guatemala	HIGH	HIGH	HIGH	HIGH	HIGH
Guyana	HIGH	MEDIUM	HIGH	UNKNOWN	LOW
Haiti	HIGH	HIGH	HIGH	UNKNOWN	LOW
Honduras	HIGH	HIGH	HIGH	HIGH	HIGH
Jamaica	LOW	MEDIUM	HIGH	HIGH	LOW
Mexico	HIGH	HIGH	HIGH	HIGH	HIGH
Nicaragua	HIGH	HIGH	HIGH	HIGH	HIGH
Panama	HIGH	HIGH	HIGH	UNKNOWN	UNKNOWN
Paraguay	HIGH	HIGH	HIGH	UNKNOWN	MEDIUM
Peru	HIGH	HIGH	HIGH	HIGH	MEDIUM
Suriname	HIGH	LOW	HIGH	UNKNOWN	LOW
Trinidad and Tobago	LOW	LOW	HIGH	UNKNOWN	LOW
Uruguay	HIGH	HIGH	HIGH	UNKNOWN	MEDIUM
Venezuela	HIGH	HIGH	HIGH	LOW	HIGH

Source: See Endnote 21 for this chapter.

2.2 Renewable Energy Development by Sub-region

2.2.1 Mexico

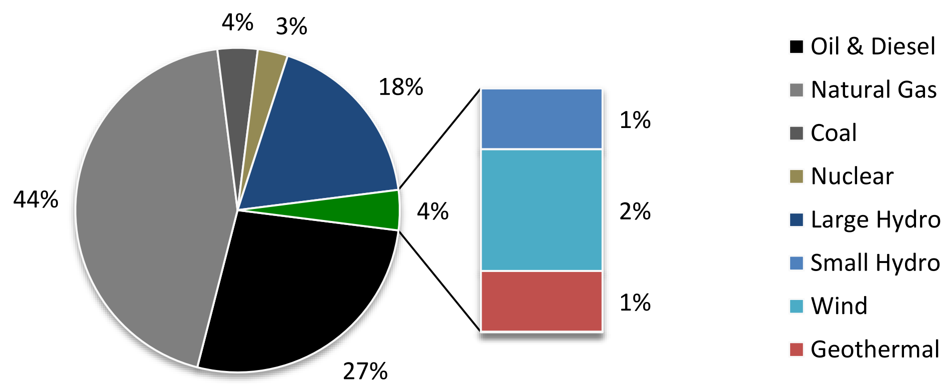
TABLE 2.2 Key Sub-regional Statistics: Mexico

Country	Population (2012)	GDP per Capita (2013)	Ease of Doing Business (2013)	Electricity Access Rate (2012)	CO_2 Emissions Electricity & Heat Prod. (2011)	Avg. Retail Electricity Tariff (2012)	Net Electricity Imports (2011)	Oil or Natural Gas Producer
	millions	USD	out of 189	%	million tons	USD/kWh	TWh	
Mexico	120.8	14,555	53	98	133.1	0.14	-0.6	Both

Source: See Endnote 24 for this chapter.

Mexico is the second largest country in Latin America and the Caribbean after Brazil in terms of population and the size of its economy. It has an installed capacity of 62 GW, which is comparable to that of the Southern Cone as a whole.[25] In 2013, Mexico generated 258 TWh of electricity, mostly from thermal power plants.[26] Mexico is the largest oil and natural gas producer in the region, but it is also a net importer of refined fuels, mainly from the United States. Fittingly, the majority of its electricity is generated from natural gas, with a significant portion generated from oil and diesel.[27] (See Figure 2.9.) It is one of only three countries in the region with nuclear energy plants, along with Brazil and Argentina.

FIGURE 2.9 Installed Power Capacity in Mexico, by Source, 2012
Total Capacity: 62 GW



Source: MIF and BNEF

Mexico has the highest carbon dioxide (CO_2) emissions from electricity and heat production in the region and released a total of 133 million metric tons of CO_2 in 2011, or 1.1 million tons per capita.[28] Mexico's total emissions are more than twice those of the region's next largest emitter, Argentina. Yet Mexico has established a voluntary target for reducing emissions 30% by 2020 under the United Nations Framework Convention on Climate Change (UNFCCC).

Mexico has a renewable energy share of 22%, with large hydro being its largest source of renewables. The country is also fourth in the world in geothermal production, and, more recently, it has begun developing other renewable energy resources, mainly wind. Mexico currently has 1,992 MW of wind capacity installed, most of which was added in the last three years, and it is expecting to add another 4.7 GW of wind power with its latest energy auction. Although solar has not been developed on a utility scale yet, an estimated 75–100 MW of PV is in operation, a figure that is expected to increase to 240 MW by the end of 2014.[29]

CFE, a state-owned, vertically integrated utility, controls three-quarters of Mexico's generating capacity and has a monopoly on electricity transmission and distribution. Although the average electricity retail tariff is not the highest in the region, commercial and high-consuming residential customers pay tariffs that are twice as high. Since 1992, Mexico has allowed private participation in generation for certain categories of power generation: self-supply, cogeneration, independent power producers (IPPs), small production (under 30 MW), and import/export. As of June 2013, a total of 1.5 GW of installed capacity came from private generators, the majority of which was wind power (89%). There was also some hydropower (8%), biogas (3%), and solar PV (1%). Of these, the majority was produced under self-supply, but wind power was also produced under IPP and small production permits.

In December 2013, Mexico passed a landmark energy reform for hydrocarbons and electricity. Secondary legislation is still under way, and the details are not established yet. However, it seems that the reform will result in a more open electricity sector through the creation of an electricity market that will be operated separately from the CFE. All generation will be open to private participation, and the operator will grant impartial access to the grid to generators. These changes will provide greater transparency to the market and should result in growth in renewable energy investments in the near future.

2.2.2 Central America

TABLE 2.3 Key Sub-regional Statistics: Central America

Country	Population (2012)	GDP per Capita (2013)	Ease of Doing Business (2013)	Electricity Access Rate (2012)	CO_2 Emissions Electricity & Heat Prod. (2011)	Avg. Retail Electricity Tariff (2012)	Net Electricity Imports (2011)	Oil or Natural Gas Producer
	millions	USD	out of 189	%	million tons	USD/kWh	TWh	
Belize	0.3	9,528	106	90	0.5[1]	0.21	0.2	Oil
Costa Rica	4.8	12,237	102	99	0.6	0.15	0.0	No
El Salvador	6.3	7,352	118	86	1.4	0.21	0.2	No
Guatemala	15.1	5,218	79	81	2.3	0.23	0.3	Oil
Honduras	7.9	4,763	127	70	2.6	0.13	-0.2	No
Nicaragua	6.0	4,456	124	75	1.8	0.25	0.0	No
Panama	3.8	15,017	55	88	2.8	0.15	0.1	Oil

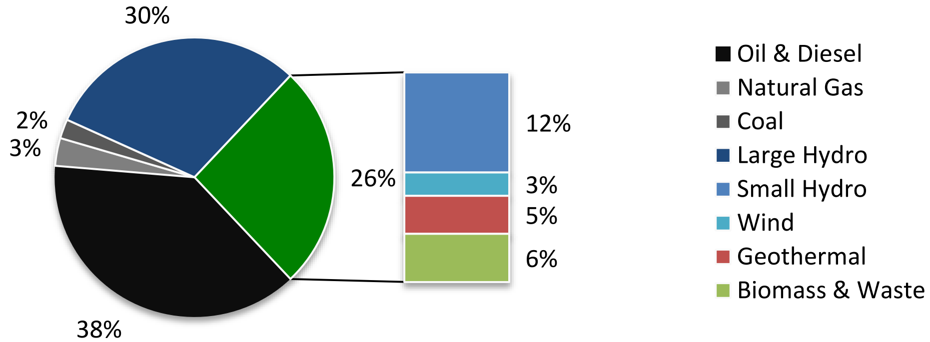
Source: See Endnote 30 for this chapter.

Central America is home to seven countries of varying sizes, including the smallest economy in Latin America and the Caribbean, Belize. The sub-region has a total installed generation capacity of 12 GW. Guatemala and Costa Rica have the largest capacity with approximately 3 GW each, followed by Honduras and Panama with just over 2 GW each, El Salvador and Nicaragua with 1 GW each, and Belize with 0.1 GW.[31] (See Figure 2.10.) As a whole, they generated 43 TWh in 2011. Historically, Central America has been powered mostly by hydropower, but in the mid-1990s hydro's share dropped as it began to be replaced by oil. In the mid-2000s, increasing shares of renewables, such as wind in Costa Rica, Honduras, and Nicaragua, and biomass in Belize decreased somewhat the sub-region's dependence on oil.

[1] CO_2 emissions value for Belize represents total energy consumption. An estimate of emissions for electricity and heat production was not found.

FIGURE 2.10 Installed Power Capacity in Central America, by Source, 2012

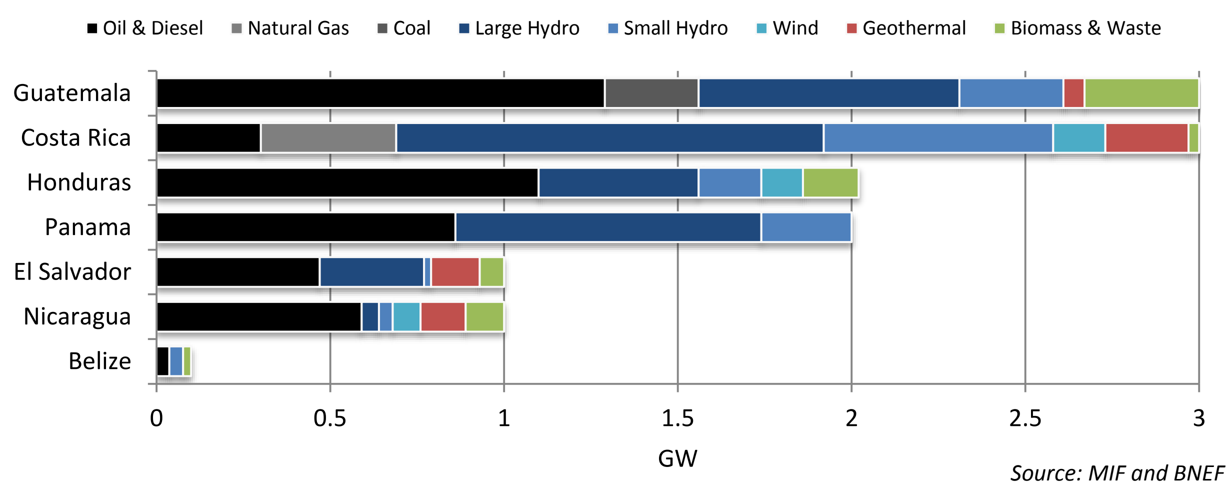
Total Capacity: 12 GW



Source: MIF and BNEF

Today, the electricity mix is split mostly between hydropower (30% large hydro plus 12% small hydro) and oil and diesel (38%).[32] (See Figure 2.11.) However, concerns about the environment and energy security have prompted the region to develop other renewable resources. While hydropower is a source of renewable energy, the development of large hydro dams through flooding can result in high levels of greenhouse gas emissions. In addition, large hydropower development can have adverse local social and environmental impacts such as changes in water quality and flow patterns, fish migration and biodiversity, and population displacement.[33] Panama, Costa Rica, and Belize have higher hydropower capacity than that of fossil fuels. El Salvador, Guatemala, and Honduras depend on hydropower to a lesser extent. Nicaragua is the only country in Central America without significant amounts of hydropower.

FIGURE 2.11 Installed Power Capacity in Central America, by Country and Source, 2012



Source: MIF and BNEF

The region's dependence on hydropower has led to concerns about energy security, especially given recent extreme dry events that have resulted in electricity shortages. In response, the Central American countries commissioned the creation of a regional grid (SIEPAC) that would enable international power exchanges. They also established a regional electricity market and a regulatory commission. To reinforce this interconnection and to enable access to North American and South American markets, a Mexico-Guatemala interconnection was completed and a Colombia-Panama interconnection is under construction.

The biggest challenge facing SIEPAC has been the creation of the regulatory framework for trade, given the region's different power market structures. Central America experienced a wave of market liberalization reforms in the 1990s. El Salvador, Guatemala, Nicaragua, and Panama liberalized their entire electricity markets, unbundled their vertically integrated utilities, and opened segments of generation, transmission, and distribution to private competition. Honduras unsuccessfully attempted to follow suit, so its state-owned utility still operates as a single buyer. Costa Rica preserved its vertically integrated utility, which is state owned and operates as a single buyer as well. In both countries, additional generation is purchased from IPPs. Belize's primary utility, nationalized in 2011, has an effective monopoly on generation, transmission, and distribution.

As a sub-region, Central America has the largest share of renewables (56%) and the most diverse mix of renewable generation with biomass, geothermal, wind, and hydro. Costa Rica, El Salvador, Honduras, and Nicaragua have developed some of their geothermal resources. Costa Rica, Honduras, and Nicaragua have about 350 MW in wind farms, and Panama has 158 MW of wind energy in the pipeline. Given its high share of renewables, Central America is a relatively small source of CO_2 emissions, releasing 12.0 million tons from electricity and heat production in 2011. Yet emissions vary by country. Panama, Honduras, and Guatemala are the highest CO_2 emitters in Central America given their relative size and high use of oil, as well as Guatemala's use of coal.[34] Belize and Panama's per capita CO_2 emissions exceed the regional average.

Electricity access is a major challenge for Central America. An estimated 8 million people still do not have access to electricity throughout the region, with the highest numbers in Guatemala, Honduras, and Nicaragua.[35] The majority of these people live far from urban centers and electrical grids. Because expanding the grid for long distances is economically prohibitive, distributed generation is the most affordable option, especially given the region's rich renewable resources.

2.2.3 The Caribbean

TABLE 2.4 Key Sub-regional Statistics: Caribbean IDB Member Countries

Country	Population (2012)	GDP per Capita (2013)	Ease of Doing Business (2013)	Electricity Access Rate (2012)	CO_2 Emissions Electricity & Heat Prod. (2011)	Avg. Retail Electricity Tariff (2012)	Net Electricity Imports (2011)	Oil or Natural Gas Producer
	millions	USD	out of 189	%	million tons	USD/kWh	TWh	
Bahamas	0.4	29,842	84	88	4.7*	0.23	0.0	No
Barbados	0.3	25,069	91	98	1.4[2]	0.09	0.0	Gas
Dominican Republic	10.3	9,604	117	96	9.6	0.22	0.0	No
Guyana	0.8	7,795	115	82	1.7[2]	0.30	0.0	No
Haiti	10.2	1,268	177	15	0.3	0.28	0.0	No
Jamaica	2.7	9,292	94	98	3.2	0.41	0.0	No
Suriname	0.5	12,271	161	85	2.3[2]	0.05	0.0	Oil
Trinidad and Tobago	1.3	19,964	66	99	4.5	0.06	0.0	Both

** CO_2 emissions value for Bahamas, Barbados, Guyana, and Suriname represents total energy consumption. An estimate of emissions for electricity and heat production was not found.*
Source: See Endnote 36 for this chapter.

The Caribbean is the sub-region with the largest economic disparity in Latin America and the Caribbean. It includes the Bahamas, Barbados, and Trinidad and Tobago, the three countries with the highest per capita GDP in the region, as well as Haiti, the poorest country in the region, which has been plagued by political violence and a devastating 2010 earthquake from which it has not fully recovered. The Caribbean has a total installed electricity capacity of 20 GW, a third of which is located in Trinidad and Tobago and the Dominican Republic.[37] In 2011, the Caribbean generated 32 TWh, the least in the region.[38]

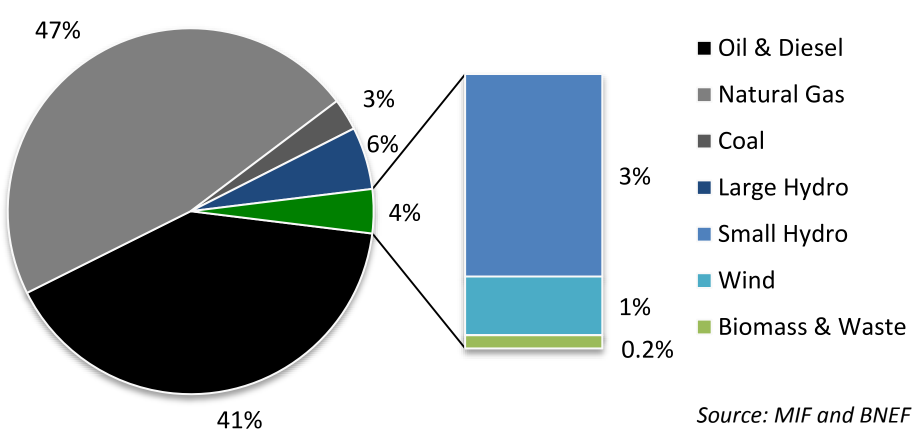
Electricity access in the Caribbean ranges widely. Haiti has the lowest electrification rate in the region and the largest number of people without access to electricity—over 8 million.[39] Distributed generation is the most favorable way to increase electricity access in Haiti and in many of the other countries in the sub-region given their geographies. The Caribbean is rich in solar resources, and falling prices make solar PV an ideal choice to address this challenge. Some countries in the sub-region have good wind, biomass, and small hydropower resources, providing more alternatives.

Nevertheless, Caribbean countries are dominated mainly by oil and diesel power generation. Because most of these countries do not have local oil or natural gas resources and are too small to burn coal cost effectively, they are subject to oil and diesel imports with volatile prices that result in high electricity tariffs. Jamaica is a prime example, with average retail tariffs in 2006 much higher than elsewhere in Latin America and the Caribbean. This characteristic makes renewable energy especially attractive in the sub-region, yet such development is limited due to fossil fuel subsidies with high fiscal costs and to a lack of economies of scale. Meanwhile, some Caribbean nations—including Trinidad and Tobago, Barbados, and Suriname—have abundant fossil fuel resources that have suppressed the development of renewable energy and have kept electricity tariffs low.

Hydropower is the main renewable resource in the Caribbean and accounts for just over 0.8 MW of the sub-region's installed capacity of 20 GW.[40] (See Figure 2.12) Half of Suriname's installed capacity is large hydro; Haiti has 23% renewables, all from small hydro; the Dominican Republic has 19% renewable energy capacity, of which 11% is large hydro and 7% small hydro; and Jamaica has 2% small hydro.[41] (See Figure 2.13.) Jamaica and the Dominican Republic have also developed their wind resources, with 50 MW and 30 MW, respectively.[42] Guyana is the only country in the sub-region to have developed its biomass resources, at 0.02 GW.

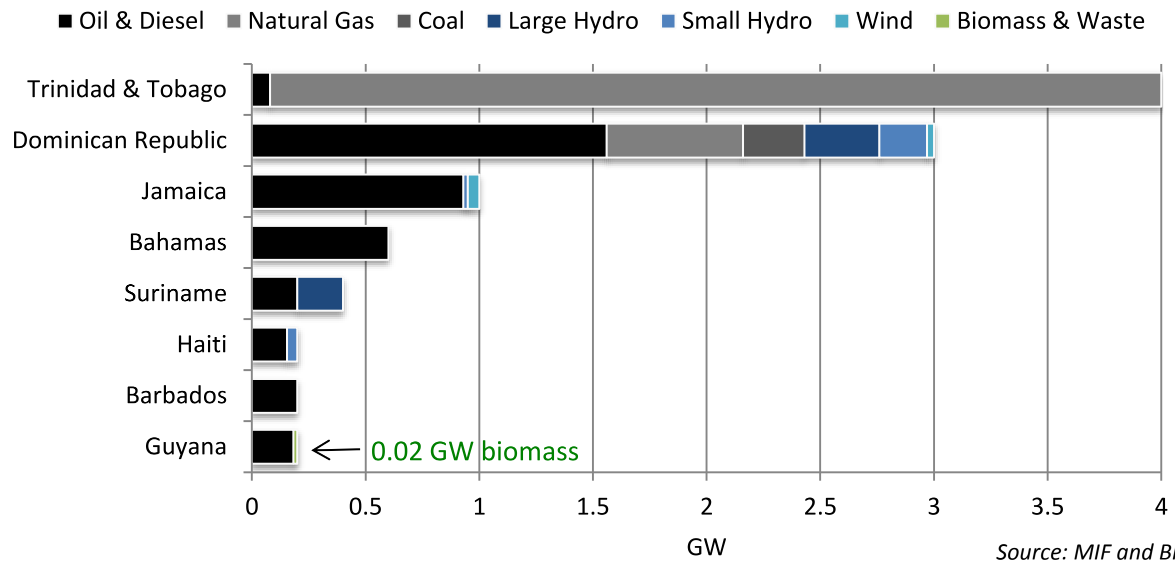
FIGURE 2.12 Installed Power Capacity in the Caribbean IDB Member Countries, by Source, 2012

Total Capacity: 20 GW



Source: MIF and BNEF

FIGURE 2.13 Installed Power Capacity in the Caribbean IDB Member Countries, by Source, 2012



Source: MIF and BNEF

The size of these countries makes their contributions to overall CO_2 emissions in Latin America and the Caribbean relatively minimal; however, given their low shares of renewables, their emissions per capita are the highest in the region. In 2011, the Caribbean released 28 million tons of CO_2 from electricity and heat production, over a third of which the Dominican Republic emitted from its diverse mix of imported fossil fuels.[43] The country's lack of domestic fossil fuel resources makes the development of renewable energy especially advantageous and its potential for greenhouse gas mitigation high. The situation is similar for the Bahamas, which has the highest CO_2 emissions per capita from electricity and heat production in all of Latin America and the Caribbean. Unsurprisingly, Trinidad and Tobago is another high emitter given its relative installed capacity and local oil and gas resources.

2.2.4 Andean Zone

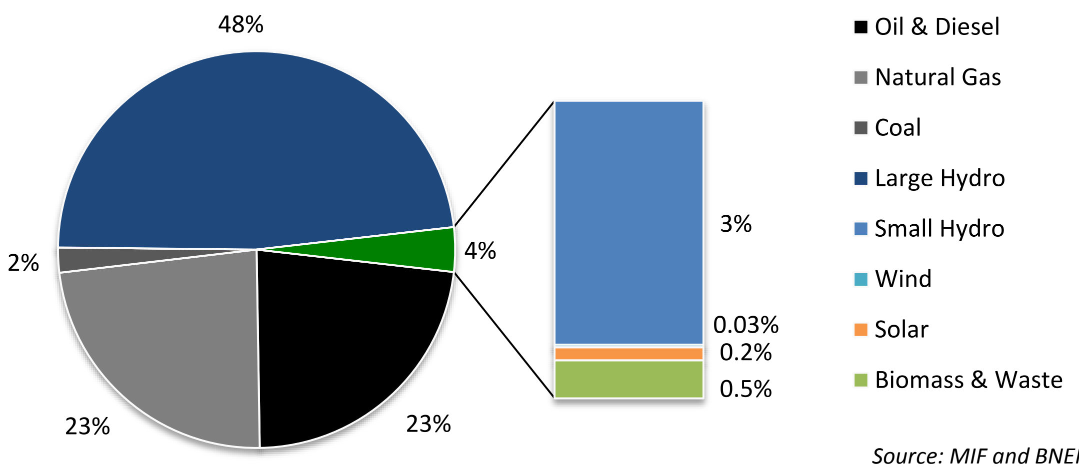
TABLE 2.5 Key Sub-regional Statistics: The Andean Zone

Country	Population (2012)	GDP per Capita (2013)	Ease of Doing Business (2013)	Electricity Access Rate (2012)	CO_2 Emissions Electricity & Heat Prod. (2011)	Avg. Retail Electricity Tariff (2012)	Net Electricity Imports (2011)	Oil or Natural Gas Producer
	millions	USD	out of 189	%	million tons	USD/kWh	TWh	
Bolivia	10.5	5,259	162	78	3.1	0.08	0.0	Both
Colombia	47.7	10,544	43	98	6.7	0.17	-1.5	Both
Ecuador	15.5	9,889	135	92	7.0	0.08	1.3	Both
Peru	30.0	10,894	42	86	11.7	0.10	0.0	Both
Venezuela	30.0	13,417	181	99	28.6	0.03	0.0	Both

Source: See Endnote 44 for this chapter.

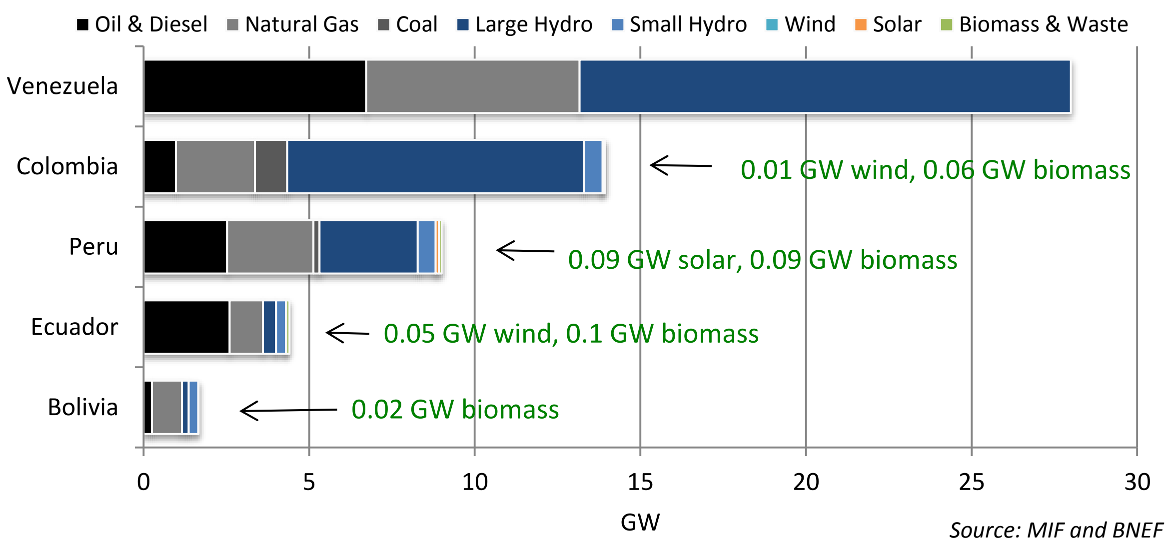
The Andean Zone, formed by Bolivia, Colombia, Ecuador, Peru, and Venezuela, all located in the northwest of South America, is composed of major oil and natural gas producers, a factor that has shaped its electricity mix. The Andean Zone has an installed capacity of 58 GW (slightly smaller than Mexico or the Southern Cone), of which approximately half is large hydropower, one-quarter oil and diesel, and one-quarter natural gas.[45] (See Figure 2.14.) There is 2% installed coal capacity (in Colombia and Peru), and only 4% of renewables other than large hydro.[46] (See Figure 2.15.) This consists mostly of small hydro (3%), but there is some biomass capacity (263 MW), solar capacity in Peru (90 MW), and wind capacity in Colombia (14 MW) and Ecuador (19 MW).[47] Venezuela is the only country in the Andean Zone with no renewable development outside of large hydro.

FIGURE 2.14 Installed Power Capacity in the Andean Zone, by Source, 2012
Total Capacity: 58 GW



Source: MIF and BNEF

FIGURE 2.15 Installed Power Capacity in the Andean Zone, by Country and Source, 2012



Source: MIF and BNEF

In the early 1990s, the Andean Zone followed the global trend of power market liberalization pioneered by neighboring Chile and emulated globally from the United Kingdom and parts of the United States and Australia. Recently, however, many countries in the Andean region including Bolivia, Venezuela, and Ecuador have implemented reforms championing a reversal to more regulation and further state control of the energy sector. After the California power crisis of the early 2000s, many markets around the world (and particularly in the United States) that were experimenting with power market liberalization opted to go back to deregulation. However, the trend in the Andean region reflects a broader nationalistic trend rather than structural problems with power market liberalization and deregulation reforms.

Colombia and Peru still have liberalized power markets with significant private participation and unbundled electricity generation, transmission, and distribution; however, Bolivia, Ecuador, and Venezuela have shifted relatively recently toward resource nationalization. In Colombia, electricity is centrally dispatched by a system operator based on day-ahead bids made by generators. In Peru, electricity is commercialized by public and private utilities, as well as by some generation companies directly. Since 2006, Bolivia has nationalized the energy sector, along with mining and telecommunications, with the goal of offering "equitable" service. In 2012, two private distribution companies were expropriated. In 2007, Ecuador created new centralized national energy companies to consolidate electricity distribution. Centralized, state-owned companies have controlled the electricity market in Venezuela since 2007.

Together, the Andean Zone countries emitted 57.1 million tons of CO_2 in 2011 from electricity and heat production, more than Brazil but less than Mexico and the Southern Cone.[48] This is due primarily to the sub-region's high fossil fuel consumption levels. The largest emitter in the Andean Zone is Venezuela (the fifth largest emitter in Latin America and the Caribbean after Mexico, Argentina, Brazil, and Chile), which released over half of that total (29 million tons of CO_2). Peru was the next largest emitter, releasing 12 million tons of CO_2 in 2011.

The Andean Zone faces challenging circumstances for renewable energy development given its rich fossil fuel resources and low (mostly subsidized) electricity tariffs. However, the shifting attitudes toward resource nationalization and the priority for energy security may incentivize some of these countries to develop their renewable sources. In addition, the Andean Zone includes two countries with below-average electricity rates, Bolivia and Peru, and is home to over 9 million inhabitants without electricity access. Bolivia and Peru have already started providing rural electrification through PV systems, and demand for small-scale renewable projects should increase.

2.2.5 Brazil

TABLE 2.6 Key Sub-regional Statistics: Brazil

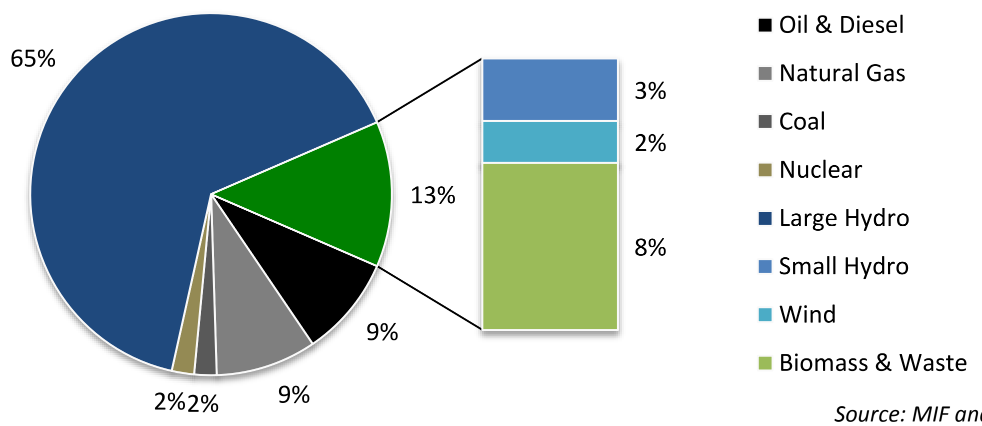
Country	Population (2012)	GDP per Capita (2013)	Ease of Doing Business (2013)	Electricity Access Rate (2012)	CO_2 Emissions Electricity & Heat Prod. (2011)	Avg. Retail Electricity Tariff (2012)	Net Electricity Imports (2011)	Oil or Natural Gas Producer
	millions	USD	out of 189	%	million tons	USD/kWh	TWh	
Brazil	198.7	12,061	116	98	36.1	0.15	35.9	Both

Source: See Endnote 49 for this chapter.

Brazil is the largest economy in Latin America and the Caribbean and has an installed capacity of 123 GW, approximately twice the capacity of the region's next largest economy, Mexico. Its power generation is dominated by large hydropower, which at 80 GW represents 65% of total generating capacity.[50] (See Figure

2.16.) However, concerns about dry seasons that have led to energy shortages are pushing Brazil to move away from hydro. Only 20% of power capacity comes from fossil fuel sources, mainly fuel oil, natural gas, and coal. Nevertheless, the share of natural gas is expected to increase. Brazil currently has two nuclear plants, with a third under construction. In all of Latin America and the Caribbean, Brazil has had by far the largest levels of clean energy investment, most of which has gone to wind. However, the largest contributor to renewable power capacity at the moment continues to be biomass and waste.

FIGURE 2.16 Installed Power Capacity in Brazil, by Source, 2012
Total Capacity: 123 GW



Source: MIF and BNEF

Brazil produced 36 million tons of CO_2 from electricity and heat production in 2011, or 0.2 million tons per capita.[51] Even with its large share of hydropower and other renewables, it is the third largest emitter in the region. Future development of domestic natural gas and oil reserves could lead to much higher emissions.

Brazil underwent a series of electricity reforms in the 1990s and 2000s, prior to which the government controlled most of the power sector, as in the rest of Latin America and the Caribbean. In the first reform, the sector was liberalized and some state-owned utilities were privatized, except for transmission. The second reform happened as a result of the energy crisis of 2002 and resulted in the *modelo novo* or New Power Sector Model. This model is one with an independent system operator in a deregulated wholesale market. However, prices in the regulated market are set by market forces, not by the government, via competitive auctions. There is also a functioning energy trading system. While Eletrobras, the largest utility in Brazil, controls most of electricity generation via its subsidiaries, as well as all of transmission, it is not a purely state-owned company. Eletrobras is majority owned by the government but is a publicly traded company. Distribution has a relatively high level of private participation (64%).

In terms of renewable energy development, Brazil has led the region by example. While local content restrictions on certain energy equipment have impeded even greater development, they have also led to the development of local value chains in all of the country's renewable technologies. With the falling prices of renewables, the next challenge for Brazil will be to accurately value renewable energy for its electricity generation, especially considering further development of domestic natural gas resources.

2.2.6 Southern Cone

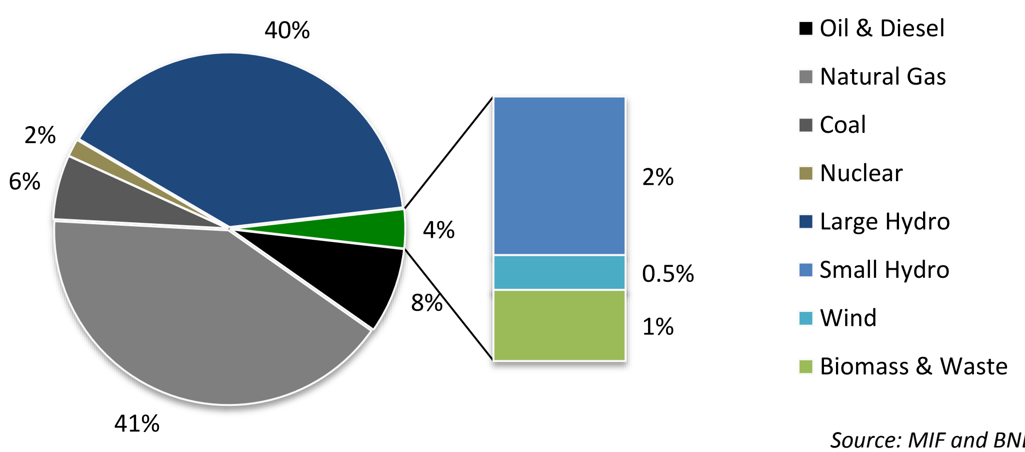
TABLE 2.7 Key Sub-regional Statistics: Southern Cone

Country	Population (2012)	GDP per capita (2013)	Ease of Doing Business (2013)	Electricity Access Rate (2012)	CO_2 Emissions Electricity & Heat Prod. (2011)	Avg. Retail Electricity Tariff (2012)	Net Electricity Imports (2011)	Oil or Natural Gas Producer
	millions	USD	out of 189	%	million tons	USD/kWh	TWh	
Argentina	41.1	18,086	126	97	50.6	0.07	9.7	Both
Chile	17.5	18,351	34	99	29.0	0.20	0.7	Both
Paraguay	3.8	6,838	109	97	0.0	0.07	-46.1	Oil
Uruguay	3.4	15,846	88	98	2.0	0.26	0.5	Oil

Source: See Endnote 52 for this chapter.

The Southern Cone has an installed power capacity of 63 GW, over half of which belongs to Argentina, the largest economy in this sub-region and the third largest in Latin America and the Caribbean after Brazil and Mexico. The electricity mix in the Southern Cone is dominated by natural gas and large hydropower, which account for 41% and 40% of generation, respectively.[53] (See Figure 2.17.)

FIGURE 2.17 Installed Power Capacity in the Southern Cone, by Source, 2012
Total Capacity: 63 GW

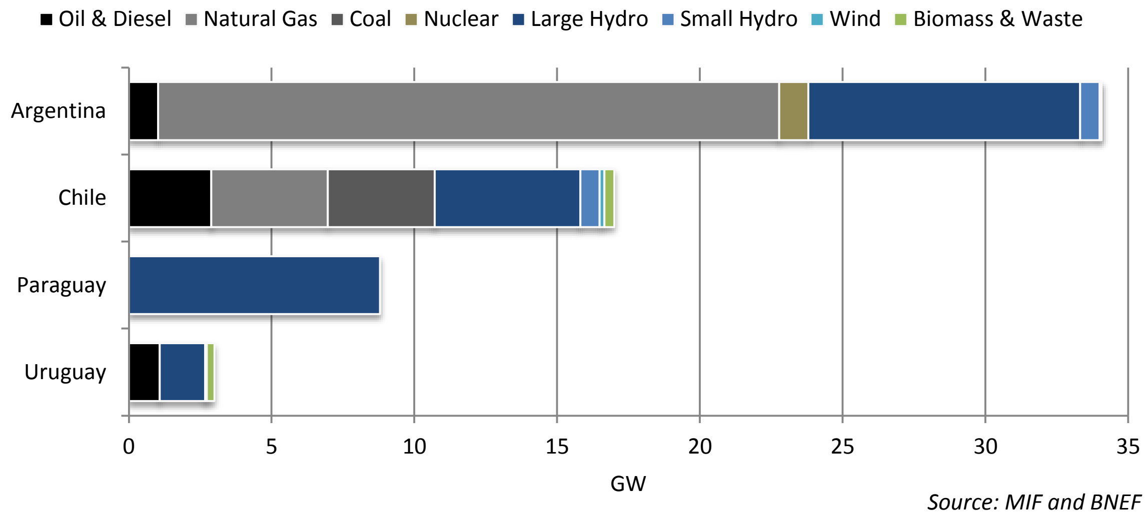


Source: MIF and BNEF

The average is slightly skewed, however: Argentina is South America's largest natural gas producer, and Paraguay effectively is powered solely by hydropower.[54] (See Figure 2.18.) Argentina is also one of the only nuclear energy producers in Latin America and the Caribbean besides Brazil and Mexico.

Chile has the most diversified electricity mix in this sub-region: in addition to natural gas and hydropower, it relies on fuel oil, coal, small hydro, wind, and biomass. Uruguay's wind and biomass make it the second "greenest" electricity producer in the region after Paraguay.

FIGURE 2.18 Installed Power Capacity in the Southern Cone, by Country and Source, 2012



Source: MIF and BNEF

Even with its high share of renewables, the Southern Cone is a large emitter of CO_2. In 2011, the sub-region produced 82 million tons of CO_2 emissions from electricity and heat production.[55] Argentina alone produced 51 million tons—or 62% of that total—making it the second largest emitter in all of Latin America and the Caribbean, after Mexico. Chile produced 29 million tons—comparable to Venezuela, a similar-sized economy but with almost twice the population. However, Chile is looking to cut its emissions from power generation and has established a voluntary target for a 20% reduction from 2007 levels by 2020 under the UNFCCC.

In 1982, Chile became the first country to deregulate and privatize electricity and served as an example for the world. Since then, all generation, transmission, and distribution in the country has been privatized. In Argentina, the electricity sector is liberalized, and generation, transmission, and distribution are open to the private sector. However, competition is more prevalent in generation than in the other two sectors due to more stringent regulation. Uruguay's transmission and distribution sectors are public, and there is very little private participation in generation (6% of installed capacity). Paraguay, meanwhile, has a public, vertically integrated monopoly on the whole sector. It is also one of the sub-region's largest electricity net exporters.

In the Southern Cone, Chile leads in the development of renewable energy, with more than 10.1 GW in the pipeline. It has strong renewable potentials, high energy demand growth, high electricity prices, and a liberalized power market. However, its power system is supported by four separate systems (SING, SIC, Aysen, and Magalhanes), and connecting energy demand to where renewable supply is high is a critical challenge to furthering Chile's development of renewables. Uruguay is expected to dramatically increase its renewable capacity through the new development of its wind sector. Argentina has renewable energy promotional policies in place, but its high cost of debt, low availability of local and foreign capital, perceived political risk, and high electricity prices have limited renewables growth.

In contrast, Paraguay has had little new renewable energy development. It already generates more electricity than it consumes, all from hydropower and at very low cost, and its growth in energy demand is relatively low. However, the economy suffers from regular power outages and high system losses. In addition to investments in its transmission system, Paraguay could benefit from distributed sources of energy for greater supply reliability.

2.3 Renewable Energy Policy Landscape and Trends

2.3.1 Renewable electricity targets

To date, 10 countries in Latin America and the Caribbean have set official targets for increased deployment of renewable energy technologies.[56] (See Table 2.8.) These take several forms: In Argentina, Barbados, and Peru, renewable energy targets are based on the share of consumption; In Chile, the Dominican Republic, and Mexico, they are based on the share of generation; and in Jamaica, Nicaragua, and Uruguay, they are based on the share of capacity installed. The ambitiousness of these goals varies widely, reflecting national disparities in resource availability, the current status of renewable technologies and investment, and political willingness. For example, while Jamaica aims to achieve 20% renewable capacity by 2030, Nicaragua has committed to reaching 94% by the same year.

TABLE 2.8 Renewable Electricity Targets in Selected IDB Member Countries

Country	Renewable Electricity Target
Argentina	8% of consumption by 2016
Barbados	29% of consumption by 2029
Chile	10% of generation by 2024
Colombia	3.5% of on-grid and 20% of off-grid generation by 2015
Dominican Republic	10% of generation by 2015; 20% by 2025
Jamaica	20% of capacity by 2030
Mexico	35% of generation by 2024
Nicaragua	94% of capacity by 2017
Peru	5% of consumption by 2013
Uruguay	15% of capacity by 2015

Source: See Endnote 56 for this chapter.

2.3.2 Renewable energy tenders or auctions

Renewable energy tenders or auctions are procurement mechanisms by which public actors solicit bids to supply a given amount of renewable energy capacity. To date, 9 of the 26 countries in the region have implemented auctions for renewable energy technologies.[57]

Brazil integrated auctions into its regulatory framework in 2004 and has used them since, offering long-term, 20-year contracts ahead of delivery for the regulated market. The original motivation behind the introduction of auctions was price disclosure and efficiency in the procurement process. The Brazilian auctions take two forms: regular, annual auctions exclusive to new energy; and “reserve energy” auctions. The former is technology neutral, offering standardized long-term energy contracts, organized in a central procurement by the government to achieve economies of scale and paid for by regulated consumers.

Reserve energy auctions contract supplementary energy to increase supply security. The government defines the volumes to contract and can select the technologies that will participate. All consumers pay for the energy.[58] Since 2005, 25 auctions—of which 9 were exclusive to renewable energy—have resulted in 62 GW of new capacity being contracted for future delivery, of which 60% was renewable (40% conventional hydro and 20% other renewables). In December 2012, auctions resulted in contracts for 574 MW, nearly half of which was allocated toward wind projects at a record low average tariff of USD 42 per megawatt-hour (MWh). It is expected that Brazil will hold a solar-specific auction in 2014.

Peru held technology-specific auctions for small hydro, solar, wind, biomass, and geothermal in 2009/2010, 2011, and 2013. These auctions offered 20-year power purchase agreements (PPAs), with an expectation to yield an annual 12% rate of return based on a ceiling price determined by OSINERGMIN, the Peruvian electricity regulator.[59] The Peruvian auctions have been largely successful: they have been the only auctions in the region to successfully auction solar contracts, and they brought down the prices of other renewable technologies between 2010 and 2011, decreasing prices for small hydro by 11%, wind by 14%, and solar PV by 46%. In the third auction, in 2013, the bids were slightly short of their 1,300 GWh per year target (by less than 25 GWh per year) but still managed to award 19 small hydro projects.

Other countries implementing auctions include Argentina, Costa Rica, Guatemala, Honduras, Panama, and Uruguay.[60] (See Table 2.9.) Jamaica held an auction for 115 MW of renewable energy in mid-2013, for which results have not been publicly announced.

TABLE 2.9 Renewable Energy Contracted Under Auctions in IDB Member Countries, 2007–2013

Country	Biomass	Wind	Solar PV	Small Hydro	Geothermal	Contract Duration
	megawatts					years
Argentina	110	760	20	10	—	n.a.
Brazil	—	289	—	—	—	20
Costa Rica	—	100	—	138	—	n.a
Guatemala	16	110	55	221	—	15
Honduras	33	—	—	257	35	20-30
Panama	—	158	—	—	—	n.a.
Peru	29	144	84	184	—	20
Uruguay	—	630	—	—	—	20

Source: See Endnote 60 for this chapter.

2.3.3 Regulatory policies

Feed-in tariffs

Feed-in tariffs (FiTs) set a fixed price at which renewable power can be sold and fed into the grid, guaranteed over a certain period. Although their design varies according to the context in which they are implemented, FiT policies aim to incentivize renewable generators by providing market certainty and stability. Use of FiT mechanisms in Latin America and the Caribbean has been less widespread than in other regions, in part because most governments already subsidize electricity for low-income consumers and face other development issues. The costs of implementing FiTs would therefore further burden national budgets.

The recent challenges surrounding FiTs in Europe have also meant that countries in Latin America and the Caribbean are careful to avoid the mistakes of early adopters in Europe who had to revise tariffs to account for changes in the market. When designing a FiT, it is important to account for the reduction in costs over time of renewable energy technologies by using a so-called degression policy. After a major review of its FiT in 2000, Germany introduced a degression policy to balance the effectiveness of the program and the rising costs of electricity for ratepayers.

Nevertheless, several countries in the region have moved forward with the FiT model. Argentina and the Dominican Republic approved legislation for FiTs in 2006 and 2007, respectively; however, these have yet to be implemented. Honduras and Panama offer a 10% and 5% price premium, respectively, for renewable electricity generators that sell to the main utility. Uruguay has offered contracts with private investors for electricity from biomass. Nicaragua implemented a FiT for all renewable energy sources of 5.5–6.5 U.S. cents/kWh. Brazil's PROINFA (Programme of Incentives for Alternative Energy Sources, which ended in 2011) and Ecuador's FiT program (ended in 2012) guaranteed above-average market prices to 3.3 GW and 645 MW of projects, respectively.

The model implemented by PROINFA in Brazil differed somewhat from traditional FiT policies seen in Europe. The mechanism set the target of contracting 3.3 GW of renewable generation capacity by 2009, equally from wind, biomass, and small hydro. Although new projects could no longer qualify for PROINFA after December 2006, implementation was postponed until 2012. Installed capacity reached 2,888 MW with 132 projects (60 projects and 1,157 MW of small-hydro; 51 projects and 1,182 MW of wind; and 21 projects and 550 MW of biomass). The costs of the scheme are levied from customers on electricity bills. The program set competitive tariff rates in 2010, with wind at USD 150/MWh, small hydro at USD 96/MWh, and biomass at USD 70/MWh.[61]

Quota obligations

Quota obligations require certain actors to meet a minimum target for renewable energy. Chile is the only country in the region that uses a utility quota obligation. The law mandates that electric utilities with more than 200 MW of operational capacity generate 20% of electricity from renewable sources by 2025. This was implemented after reforming Law No. 20.257 of March 2008, which mandated utilities to generate at least 10% of their electricity from renewable sources by 2024. The new target of 20% by 2025 will be valid for contracts established from July 2013 onward.

Other quota obligations in the region concern biodiesel and ethanol blending mandates for conventional diesel and gasoline respectively, which are not discussed here since they relate to transportation and not electricity.

Net metering

Net metering policies allow utility customers to install their own renewable systems and to feed the electricity they produce back into the grid, thereby reducing their electricity bills. In Latin America and the Caribbean, eight countries have adopted net metering policies, although the specifics vary by country.

Barbados adopted the Renewable Energy Rider program, where customers may generate renewable electricity up to a maximum of 1.5 times their monthly energy consumption and sell the excess to the national utility for an assured 10 years of access.[62] Brazil implemented a program for small-scale power generation of 1 MW or less for retail electricity customers, allowing them to install self-generation facilities interconnected with the utility grid, to deliver surplus generation, and to obtain compensation in the form a subsequent billing credit.[63] Chile approved net billing legislation for renewables up to 100 kW.[64] In Costa Rica, the ICE net-metering pilot program allows individual consumers to connect systems up to the size of their annual electricity consumption with 15-year contracts.[65]

Elsewhere in the region, the Dominican Republic implemented net metering regulation in 2011 and launched a pilot project the same year. Since then, residential and commercial projects account for over 6 MW in solar PV capacity.[66] Jamaica established a pilot net metering program beginning in May 2012 for an initial two years, offering net billing at the retail rate to connected customers.[67] Mexico implemented its net metering program as early as 2007, resulting in 1,700 connected users up to the end of 2012, of which 1,640 were small scale (up to 30 kWh) and the remaining 60 were medium scale (up to 500 kWh).[68] Uruguay's net metering program was introduced in 2010 and connects 24 customers with 140 kW of renewable capacity to the grid.[69]

2.3.4 *Fiscal incentives*

Fiscal incentives of various forms represent the most commonly applied mechanism to support renewable energy deployment in the region; they are currently being used by 14 of the 26 countries in this study.[70] (See Table 2.10.) The most prevalent fiscal incentives are tax relief for renewable energy generators and import duty exemptions for renewable energy equipment. Argentina and Mexico implemented accelerated depreciation, while the Dominican Republic, El Salvador, Guatemala, Honduras, and Nicaragua implemented income tax reductions for renewable energy generation projects.[71]

TABLE 2.10 Fiscal Incentives for Renewable Energy in IDB Member Countries

Country	Accelerated Depreciation	Tax Relief	Income Tax	Import Duty	Tax Rebate	Other
Argentina	**Yes**	No	No	No	**Yes**	No
Bahamas	No	No	No	No	No	No
Barbados	No	No	No	No	No	No
Belize	No	No	No	No	No	No
Bolivia	No	No	No	No	No	No
Brazil	No	**Yes**	No	**Yes**	**Yes**	No
Chile	No	No	No	No	No	**Yes**
Colombia	No	**Yes**	No	No	No	No
Costa Rica	No	**Yes**	No	No	No	No
Dominican Republic	No	**Yes**	**Yes**	**Yes**	No	No
Ecuador	No	**Yes**	No	No	No	No
El Salvador	No	No	**Yes**	**Yes**	No	No
Guatemala	No	**Yes**	**Yes**	**Yes**	No	No
Guyana	No	No	No	No	No	No
Haiti	No	No	No	No	No	No
Honduras	No	**Yes**	**Yes**	**Yes**	No	No
Jamaica	No	No	No	No	No	No
Mexico	**Yes**	No	No	No	No	No
Nicaragua	No	No	**Yes**	**Yes**	No	**Yes**
Panama	No	**Yes**	No	**Yes**	No	**Yes**
Paraguay	No	No	No	No	No	No
Peru	No	No	No	No	No	No
Suriname	No	No	No	No	No	No
Trinidad and Tobago	No	No	No	No	No	No
Uruguay	No	**Yes**	No	No	No	No
Venezuela	No	No	No	No	No	No

Source: See Endnote 70 for this chapter.

2.3.5 Public funds for renewable energy projects

Several countries in Latin America and the Caribbean have established mechanisms to funnel public funds to support renewable energy projects. In Brazil, BNDES FINEM created a credit line for such projects in March 2004, providing low interest rates for loans financing up to 80% of total project costs, amortized over 16 years. The credit line offers a grace period of six months after the commissioning date. Final interest can vary in the range of 7.0–12.5% per year. In 2012, BNDES launched a new credit line under Brazil's National Climate Change Fund; part of the Fund comes from Brazil's oil exploration revenues. Offering rates begin at 2.5% per year, depending on the sub-programs, and USD 160 million is earmarked for the reimbursable portion that is managed by BNDES.[72]

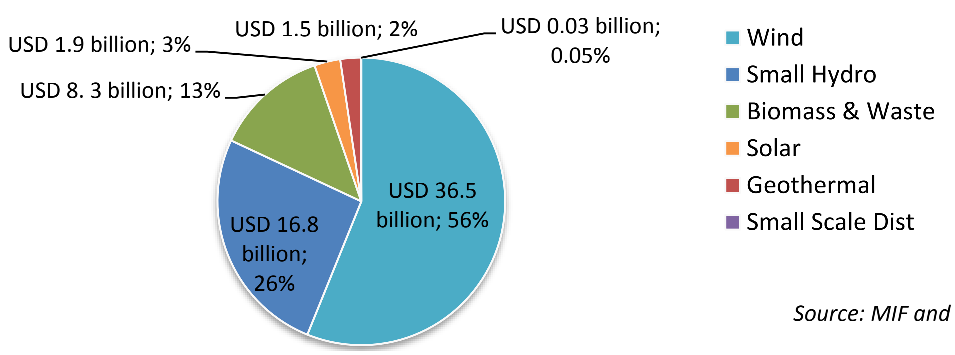
In Mexico, two separate funds aim to support renewable energy technologies. Managed by the Ministry of Energy (SENER) and the National Council on Science and Technology (CONACYT), the Mexico Sustainable Energy Fund receives 20% of the revenue raised by an annual tax of 0.65% on Petroleos Mexicanos (PEMEX), Mexico's state-owned oil company for oil and natural gas extraction. CONACYT organizes projects established by the Fund and holds periodic tenders to choose the institutions that develop the fund's research and technology projects. Projects can only be developed by Mexican research and academic institutions.[73]

Similarly, the Mexico Energy Transition and Sustainable Use of Energy Fund, with an annual budget of MXN 3 billion (USD 250 million in 2009), aims to encourage renewable energy and clean technology development by promoting initiatives that favor the transition to sustainable use of energy, energy efficiency, and clean energy technologies. The fund will be managed by a technical committee which will be chaired by a representative of SENER and 11 other members from different ministries and energy-related agencies. The committee is charged with setting the strategies and regulations of the fund's activities.

2.4 Renewable Energy Investment Flows and Market Trends

Investment in renewable energy in Latin America and the Caribbean has grown considerably since 2006, although it was constrained by the global economic recession of 2008 and a slowing economy in 2012. Cumulative investment in renewable energy for power generation totaled some USD 65 billion between 2006 and 2012, with wind energy attracting over half of this total.[74] (See Figure 2.19.) Small hydro and biomass have attracted significant shares as well, but solar appears to be poised for future growth given recent investment commitments in Peru, Mexico, Chile, Costa Rica, and Ecuador.

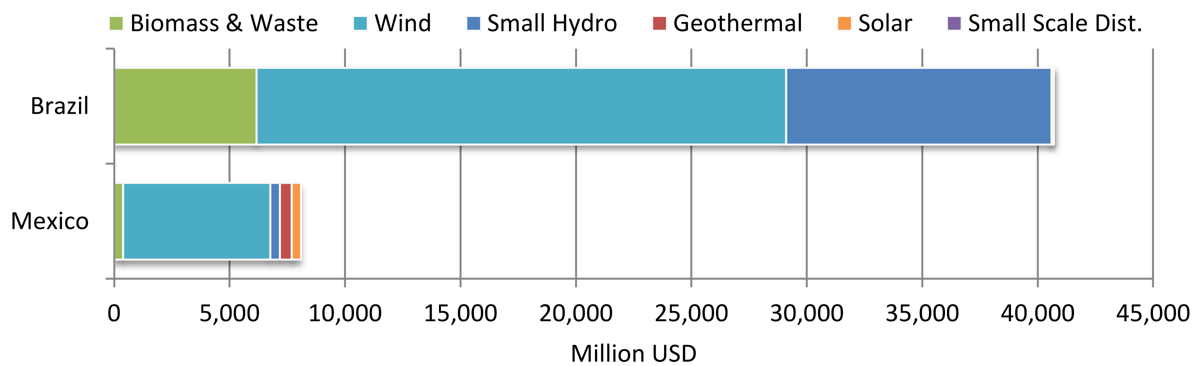
FIGURE 2.19 Cumulative Renewable Energy Investment in IDB Member Countries, by Technology, 2006–2012 Total: USD 65 Billion



Source: MIF and BNEF

Regionally, Brazil has attracted more investment in renewable energy than any other country or sub-region in Latin America and the Caribbean, with over USD 40 billion in cumulative investment between 2006 and 2012.[75] (See Figure 2.20.) As the largest regional economy and supported by a comprehensive policy framework, it is easily the most attractive market for renewable energy development. Wind has attracted over half of Brazil's renewable energy investment since 2006, primarily through asset finance. Small hydro and biomass have been funded steadily over this period as well.

FIGURE 2.20 Cumulative Renewable Energy Investments in Brazil (USD 41 Billion) and Mexico (USD 8 Billion), by Technology, 2006–2012



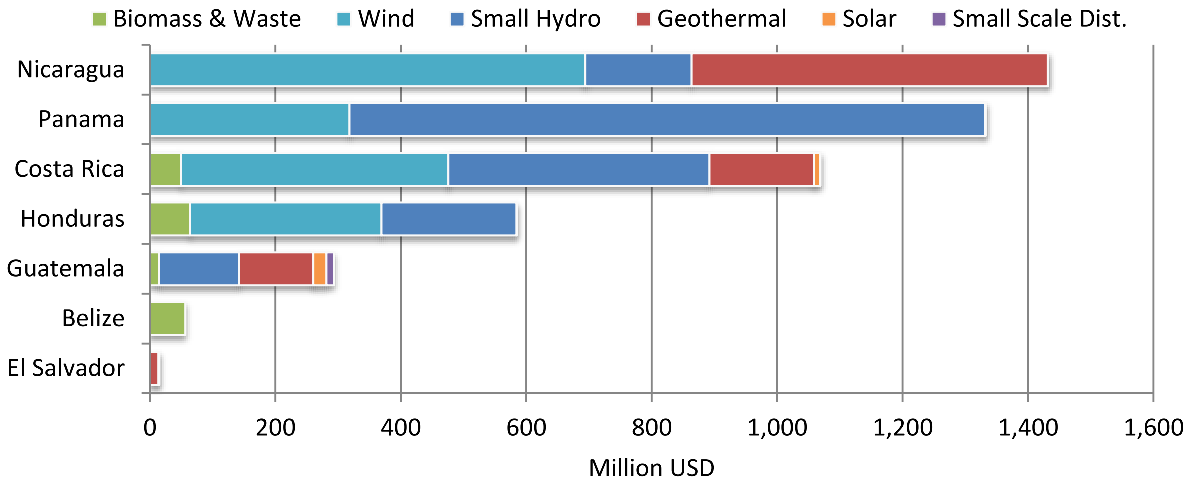
Source: MIF and BNEF

Since 2012, however, the share of renewable investments in countries other than Brazil—particularly Mexico, Chile, Peru, and Nicaragua—has been growing. Mexico has attracted over USD 8 billion in renewable energy investment since 2006, receiving USD 2.9 billion in 2012 alone.[76] Although almost 80% of this investment was in wind power, all other renewables have received funding as well, and trends indicate that solar will continue to attract growing investment.

On a GDP basis, Central America—in particular Nicaragua and Panama—has seen some of the largest renewable energy investment in the region.[77] (See Figure 2.21.) Nicaragua has attracted over USD 1.4 billion since 2006, which represents 5.4% of its GDP in 2013. The country has been able to overcome its poor overall investment climate through ambitious targets, transparent policies, and micro-financing to develop its abundant wind and geothermal resources.

Panama, with a significantly higher GDP than Nicaragua, has attracted over USD 1.3 billion since 2006, or 2.3% of its GDP in 2013. All of this investment has gone to small hydro and wind, although the expected combined capacity of over 300 MW of wind has yet to come on line. Costa Rica has attracted over USD 1 billion in investment, distributed unevenly among the past seven years. This funding has led primarily to geothermal, wind, and small hydro development, as well as to a utility-scale solar PV plant that received USD 10 million in support in 2012.

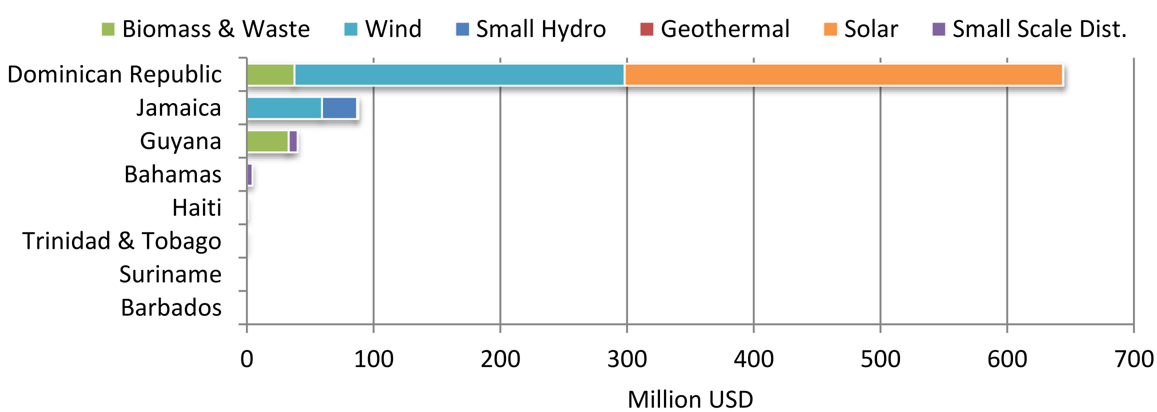
FIGURE 2.21 Cumulative Renewable Energy Investment in Central America, by Technology, 2006–2012
Total Investment: USD 4.8 Billion



Source: MIF and BNEF

The Caribbean has attracted very little investment for renewable energy. Cumulatively, it has received USD 0.8 billion since 2006, the vast majority of which was directed to the Dominican Republic.[78] (See Figure 2.22.) While the Dominican Republic has a relatively low share of renewables in its electricity mix, its policies and incentives are attracting greater amounts of financing, as evidenced by the USD 248 million committed to a 52 MW expansion of a wind farm and a new 30 MW solar PV plant in 2012. Outside of the Dominican Republic, there has been no significant and recent investment in renewable energy in the sub-region. In 2010, Jamaica received some investment for wind and small hydro, and Guyana for biomass.

FIGURE 2.22 Cumulative Renewable Energy Investment in Caribbean IDB Countries, by Technology, 2006–2012
Total Investment: USD 0.8 Billion

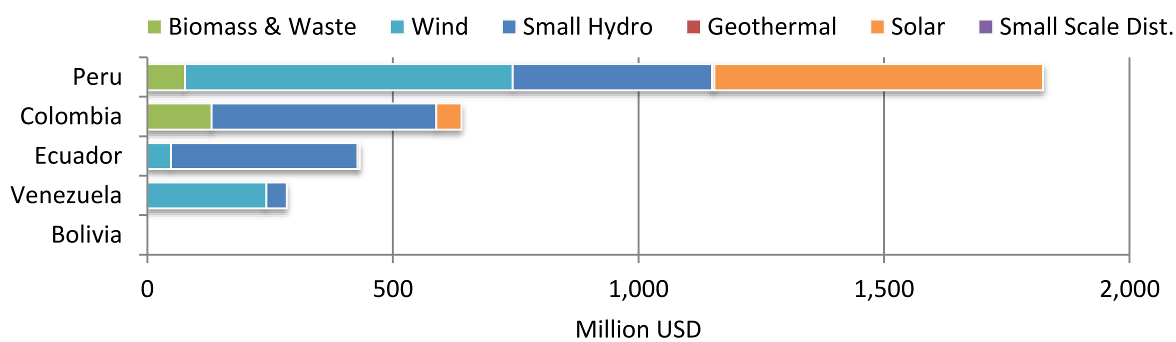


Source: MIF and BNEF

The Andean Zone attracted USD 3.2 billion in investment for renewable energy, over half of which was received by Peru, the country that has attracted the most investment for solar in all of Latin America and the Caribbean.[79] (See Figure 2.23.) Peru's renewable energy investment has grown astonishingly fast, especially in 2012 when it attracted over USD 1 billion for wind (USD 667 million), solar (USD 468 million), and small hydro (USD 94 million). After Peru, Colombia has the highest cumulative investment in the sub-region, but as the fifth largest economy in Latin America and the Caribbean, this level of investment falls short, especially considering that Colombia attracted none in 2012. Most of Colombia's cumulative investment has been directed to small hydro (USD 457 million) as well as some biomass (USD 131 million) and solar (USD 52 million). Ecuador, a much smaller economy, has attracted over USD 400 million since 2006, largely for small hydro (USD 380 million).

FIGURE 2.23 Cumulative Renewable Energy Investment in the Andean Zone, by Technology, 2006–2012

Total Investment: USD 3.2 Billion

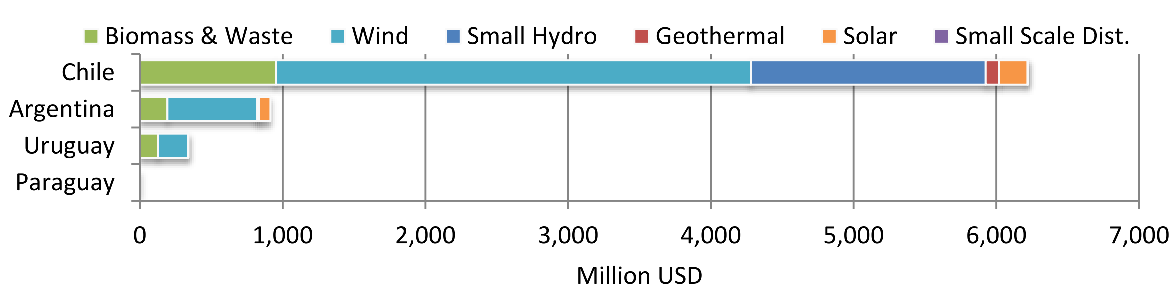


Source: MIF and BNEF

The Southern Cone has one clear outlier: of the USD 7.5 billion in cumulative investments in the sub-region, more than USD 6 billion went to Chile.[80] (See Figure 2.24.) Chile's renewable energy investments have been growing consistently since 2006; in 2012 alone, over USD 2 billion was invested in wind energy. Besides wind, small hydro has received constant funding (USD 1.6 billion), and solar finally attracted investment in 2012 (USD 203 million). As the third largest economy in the region, Argentina has not attracted significant renewable energy investment; however, the investment it has received has grown constantly since 2006, and has supported wind, biomass, and solar development. Despite its size, Uruguay has been able to attract USD 393 million by becoming a dynamic wind market, which has received more than half of that investment.

FIGURE 2.24 Cumulative Renewable Energy Investment in the Southern Cone, by Technology, 2006–2012

Total Investment: USD 7.5 Billion



Source: MIF and BNEF

2.5 Outlook for Medium-Term Expansion of Renewable Energy in the Region

The falling prices of renewables, their abundance, and their complementarity with the hydro-dependent electricity mix in many Latin American countries mean that the development of renewable energy is a sure way to meet growing regional energy demand and to provide energy security at a competitive cost. Already, declining costs of wind and solar have made those technologies cost competitive in several markets in the region, especially those that depend on imported fossil fuels for power or that have high electricity tariffs.

Additional policy support, such as the use of energy auctions, has led to growth in renewable energy capacity in Brazil, Uruguay, and Peru, with a number of countries following suit including Argentina, Costa Rica, the Dominican Republic, Guatemala, Jamaica, and Panama. Although wind and small hydropower have received the largest share of investments to date, solar energy is poised for growth, with Chile, Mexico, and Peru are pioneering that market. There are enormous opportunities for future renewable energy development in the region, including options that are rapidly expanding beyond Brazil, historically the largest player in the market. Domestic and international investors will be increasingly willing to harvest these opportunities if the remaining technical, market, finance, and social barriers can be removed.

3 Barriers to the Advancement of Renewable Energy in Latin America and the Caribbean, and Opportunities to Overcome Them

With the tremendous rise in renewable energy investment in the region, Latin America and the Caribbean is now a global leader in the growth of renewable energy. Still, some countries lag far behind others, and the region as a whole remains far from using its full renewable energy potential to supply affordable, reliable, and sustainable energy for all. Renewable energy deployment in the region faces a multitude of cross-cutting barriers, including a lack of public awareness of its benefits and technological feasibility; vested interests in the status quo; inaccessibility of data; fossil fuel subsidies; a lack of capital; unavailability of appropriate loan products; volatile legal systems; and a lack of long-term policy frameworks as well as concrete support policies and mechanisms. However, diverse mechanisms exist to overcome these barriers that have proven their effectiveness in the region and beyond.

This chapter defines and analyzes some of the main barriers to renewable energy investment and deployment in the region. It appraises the importance of specific barriers and provides opportunities to overcome them, drawing on practical examples from the region where possible.

3.1 The Importance of Policies and Measures in Overcoming Barriers

Renewable energy deployment is often hampered by unfavorable regulatory environments and a lack of long-term political frameworks. Energy markets, including those for renewables, are affected heavily by policy support mechanisms; thus, a lack of regulation and political incentives is in itself the most important barrier to the advancement of renewable energy development and deployment. Chapter 2 explored the cumulative investment flows in renewable energy throughout Latin America and the Caribbean. Those countries that have little-to-no investment are also the ones that have not implemented effective renewable energy policies—or any at all.

A consistent and credible long-term energy policy—containing both targets and concrete policies—is a significant signal for private investors. As discussed in Chapter 2, countries in the region have already adopted a wide mix of policies and targets tailored to unique domestic conditions; however, less than half of the 26 countries examined have announced concrete renewable energy targets.

Renewable energy policies have proven most effective in attracting investment if they target existing resource potentials and technological challenges; address one or more market and financial barriers; and plausibly create clear social and economic benefits. Policies need to fit with the overall regulatory environment and have to be implemented rigorously. Their implementation needs to be fair, transparent, accountable, and reasonable. And their impacts need to be regularly monitored and reported on.

Successful examples of how well-designed policies can attract investment in renewable energy include PROINFA in Brazil, Chile's energy market liberalization, Nicaragua's tax exemptions for renewable energy equipment, Uruguay's tendering system, Peru's utility regulation prioritizing the dispatch of renewable energy sources, and Mexico's target of a 35% renewable energy share in overall power production by 2024 (as well as its active support for IPPs).[1]

The majority of mechanisms target the regulatory, economic, and financial needs of renewable energy projects. Each also has its own potential benefits and drawbacks. Addressing resource and technology as well as social and human resource barriers requires capacity building, awareness raising, and the creation of supporting institutions such as national or regional knowledge centers.

A policy or measure does not operate in a vacuum; it must be an integral part of a country's overall energy and procurement policies and its broader development agenda. Integrated energy planning needs to consider the interplay of different energy technologies in the production, transmission, distribution, consumption, and storage of electricity. It must also consider the social and economic impacts of different energy pathways. Such planning should form the basis of any energy policymaking that targets an improved environment for investments, be they public or private, domestic or international.

There is growing experience regarding the effectiveness of individual policies and mechanisms as well as the effectiveness of broader low-emissions development strategies within the region and beyond. These lessons learned should guide future policymaking elsewhere. Future successes and failures of leading countries advancing to new stages in their energy transitions, with further increasing renewable shares, should be documented so that they can serve as models for others.

3.2 Technological Barriers

Uncertainties regarding renewable energy resource potentials and the technical feasibility of their deployment can hinder the deployment of renewable energy. Specific challenges may apply with regard to electricity transmission in on- or off-grid settings. The perception of many technical risks is sometimes outdated, and integrated energy planning can help to address many remaining technological challenges where they still occur.

3.2.1 Lack of available data and information

Latin America and the Caribbean boasts among the highest renewable energy resource potentials in the world. Although mapping of this potential has been carried out in most of the 26 IDB countries, an overview of existing and publicly available resource assessments across the region that includes all technologies is still missing.

Governments, often supported by international organizations, nongovernmental organizations, and private consultants, have laid important groundwork by providing national, sub-national, and "zonal" resource assessments. The Solar and Wind Energy Resource Assessment (SWERA), for example, provides resource maps for Central America overall as well as country-wide assessments for El Salvador, Honduras, Guatemala, and Nicaragua. Specific terrain features, land-use exclusions, and accessibility to the existing transmission grid in more detailed, publicly available assessments are required for final comprehensive decisions.[2] If public, these data can be used for political deliberations, public consultations, and as a first reference for investors, project developers, and other stakeholders. Additional site-specific assessments that are necessary for the development of individual projects can be left largely to industry.

Governments play an important role in coordinating available energy data, addressing remaining information barriers, and changing social paradigms. Chile's National Energy Commission (CNE) serves as an example of a national energy intelligence unit. It has been set up as an international capacity building effort through the support of the IDB, the U.S. government's National Renewable Energy Laboratory (NREL), and others. CNE is a central authority on renewable energy—gathering and disseminating knowledge, inputs, and policy advice to local and national governments, industry, and potential investors. With a memorandum of cooperation signed in 2009, its long-term goal is to serve as a source of information for investors and policymakers in the region, researching, developing, and promoting non-conventional renewable energy projects.[3]

3.2.2 Transmission and distribution challenges

Infrastructure challenges can present major concerns for developing any energy project, whether conventional or renewable. Perceived or real, they are often cited as particularly acute for renewable energy deployment, increasing the risk and cost associated with renewable investments and, in extreme cases, preventing a prospective project from being pursued. The deployment of renewables often means that existing grid networks must be extended or upgraded to account for new factors such as suitable project siting in resource-rich zones and the need to manage intermittent generation.[4]

Intermittent energy sources such as wind and solar cause power-quality challenges in terms of voltage fluctuation, reactive power compensation, harmonic distortion, energy storage, load demand management, and synchronization. Technical solutions for each challenge are available today, ranging from differences in the construction of wind turbines to improved planning and management of load demand.[5]

A variety of methods can be employed to integrate renewable energy into the grid. Identifying complementary renewable energy from different sources or geographic areas that are strongest at different times of the day can help smooth the intermittency and variability of power production from renewables. System operators need to improve forecasting, modeling, and monitoring of the flow of power into the grid, either via daily or preferably hourly forecasts. Long-term forecasting based on historical data of seasonal and diurnal resource availability is an important part of energy planning and policymaking. The more accurate the forecasts, the less variability will negatively affect the system.

Forecasting also has effects on pricing of electricity and on the openness of markets. Seasonal variation is useful for power-system planning and scheduling long-term maintenance, whereas daily variation is important for determining when peak production can meet peak electricity demand.[6] Energy storage capacity equally needs to be aligned with the overall power supply and demand cycle, allowing for smoothing of the variability.

Micro-grids and off-grid distributed generation do not face siting issues with the grid, offering solutions for expanding access to electricity, especially in remote rural areas. Employing anchor-client business models—such as integration with mobile phone towers—can offer synergies between industries and guarantee a market for electricity. However, they may present their own challenges. If such systems are deployed in remote locations, economies of scale and high transportation costs may become a barrier. Training for maintenance and service of these systems is paramount to their continued operation. Rural electrification programs can provide the support and resources needed to ensure their success.

3.2.3 The need for integrated resource planning

Stakeholder consultations among IPPs, the electricity utility, the government, and local populations need to be held to synchronize the siting of new power plants and the expansion of transmission and distribution networks. Integrated resource planning is built on principles of comprehensive and holistic analysis.[7] It provides an opportunity for electric system planners to address complex issues through a range of feasible supply-side and demand-side options and assesses them against a common set of planning objectives and criteria. At the same time, it provides a chance for interested parties both inside and outside the planning region to review, understand, and provide input to planning decisions.

Although technical solutions have been developed to manage the intermittency of renewable energy sources, addressing this challenge effectively may require additional, and sometimes substantial, investments. On the other hand, significant investments in modernizing the grid and extending transmission and distribution to meet existing and future demand growth is necessary in all countries of the region. It is important that investments reflect the technical requirements of a modern electricity system, including supply- and demand-side management.

3.3 Market Barriers

Potential market barriers to renewable energy deployment encompass limitations in the power market due to insufficient grid access for IPPs and economies of scale, high transaction costs and counterparty risks, as well as market distortions through fossil fuel subsidies.

3.3.1 Restricted grid and power market access

Countries in Latin America and the Caribbean vary widely in their openness to the private sector and independent power producers (see Chapter 2), ranging from fully liberalized markets to vertically integrated monopolies; however, access has been continuously improved since the 1990s. The majority of Caribbean islands are characterized by vertically integrated monopolies, with most allowing competition or at least offering contracts for electricity purchasing from IPPs. Great progress has been made in Central and South America through the implementation of wholesale power markets, where generators, distributors, marketers, and large consumers trade electricity via spot transactions and long-term contracts.

Brazil successfully established a legal framework and institutional structure for open access, including a strong regulatory agency and an independent system operator. In the power wholesale market, independent energy traders contribute to liquidity through bilateral contracts and the Electricity Trading Chamber. The Brazilian market, however, does not deliver real-time or day-ahead prices. Plants are dispatched on merit-order protocols of the system operator, ONS, which are based on ensuring energy security, rather than on location-specific costs of moving energy across the grid. Market participants that offer demand-responsive or distributed electricity are therefore often left out of the market.[8]

Even a fully liberalized market by itself cannot guarantee the introduction of renewable energy generators; grid parity with fossil fuel-based generation provided through incentives or the removal of support for fossil fuels must be established, and regulation needs to be effective. Private sector participation also does not relate directly to the scope for competition in all cases. Ecuador adopted a fully competitive wholesale power market but failed to attract much private participation; meanwhile, the smaller island states have high private sector participation with minimal competition.[9]

Mexico underperformed in renewable energy deployment for a long period even after allowing private sector participation in 1992 (as described in Chapter 2). By 2008, the state-run utility CFE still owned 80.3% of Mexican power generation, of which 80% was based on fossil fuels, with hydro (11%), nuclear (4.5%), and geothermal (3%) accounting for the remainder.[10] Further incentives for renewable energy in terms of security of accessing the grid were required.

Following the implementation of energy reforms in 2013, private generators in Mexico will be allowed to sell power into wholesale electricity markets with greater legal certainty and on equal footing with CFE.[11] Furthermore, the creation of the National Energy Control and Power Market Center (*Centro Nacional de Control de Energía y Mercado Eléctrico*) will allow CFE and the private sector to coordinate financing, operation, and maintenance of the transmission and distribution network, guaranteeing non-discriminatory and open access.[12] Although liberalized markets such as Chile's are highly attractive to investors, Mexico presents an interesting example of achieving high levels of investment even with a vertically integrated monopoly utility. High insolation, high domestic commercial power prices, and proximity to the U.S. market for exports all contribute to Mexico's renewable energy expansion despite reduced access to the grid. (See Chapter 2.)

The difficulty of ascertaining who is responsible for transmission investments required to connect new generation has had a negative impact on the renewable energy sector overall. It was estimated that by 2013, Brazil would have as much as 1.3 GW of idle wind power capacity due to the lack of grid infrastructure.[13] Recognizing the difficulty in allocating costs for grid connection, the Brazilian Ministry of Mines and Energy published new rules for auctions in April 2013. Developers are now required to connect to the grid at their own expense. Projects will be allowed to compete in auctions only if they can connect to existing or already committed future substations and grid lines.[14]

Peru adopted a different approach, passing legislation in 2006 to ensure future energy supply by reorganizing the system operator (COES) to be more inclusive and by improving the planning and pricing policy for generation and transmission. Peru formulized centralized and binding transmission planning for COES, requiring it to identify system expansion needs and in the process resolve cost allocation disputes between transmission investors and the general public.[15] The legislative package passed in 2006 also introduced a set of measures to overcome market and finance barriers that are discussed in the following sub-sections.

3.3.2 Lack of economies of scale

The size of the overall power market and the size of individual projects, particularly distributed power projects, are key hindrances to achieving economies of scale. Most of the Caribbean islands—and select countries in the broader Latin America and the Caribbean region—have low-demand markets, rising transaction costs, and lower investor confidence or attractiveness. Individual distributed renewable energy projects do not compare to large hydro or fossil fuel-based power plants in terms of generation capacity, necessitating new business models and bundling to achieve comparable structures for investment.

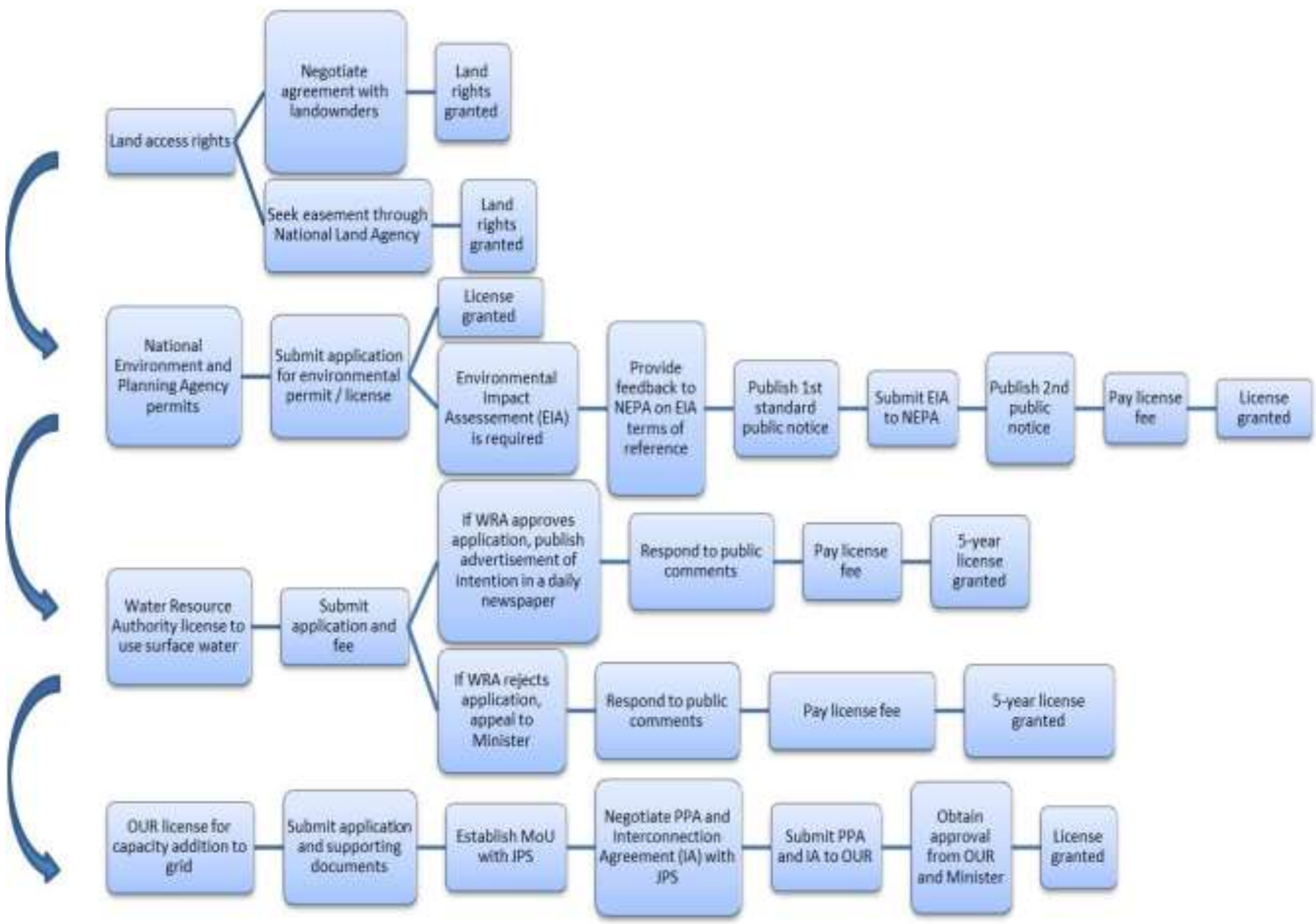
The establishment of regional power markets through interconnection in Central America or among Caribbean islands could increase the size of the electricity market, providing the necessary economies of scale for investment and easing the integration of variable generation sources. Access to larger markets may be necessary for the full exploitation of certain technologies, such as geothermal in the Caribbean. Likewise, interconnection in Central American countries would allow for increased flexibility and greater incentives for investment.

Individual projects, whether distributed or grid connected, can be bundled into project portfolios to increase investment interest. Brazil achieved such a bundling by centralizing the procurement process in one government agency overseeing capacity auctions, which allowed project developers to determine how best to provide the contracted capacity. On an international level, the International Finance Corporation (IFC) issued a USD 1 billion green bond in 2013 allowing individual projects to be pooled, reducing the cost of debt and increasing the competitiveness of small-scale renewable energy projects.[16] By bundling the projects and securitizing them in this form, investors can in turn buy and bundle these projects into larger offerings, allowing larger funds to participate.

3.3.3 High transaction costs

Labor-intensive, complex processes and long time frames for obtaining licenses and permits increase transaction costs for renewable energy deployment. Procedures related to energy, environment, mining, conservation, gas, electricity, and land use can all have an impact on deployment. Due to the breadth of jurisdictions, often several ministries are involved in licensing and permitting for renewables. (See Figure 3.1 for an example from Jamaica.) The lack of a central authority on renewable energy further presents a hurdle to formulating concise and encompassing policies.

FIGURE 3.1 Permitting Process for Small Hydro Capacity (100 kW to 25 MW) in Jamaica



An analysis of permitting procedures in the 26 IDB countries via the World Bank's Doing Business Index reveals lengthy procedures prevalent in the majority of countries. The average time required for construction permits is 233 days, at an average cost of 153% of per capita income.[17] As the index does not account for environmental permits or take into account the special requirements of renewable energy projects, the average amount of days and cost requirements for permitting are most certainly higher.

In Mexico, projects are required to obtain soil use and construction permits granted by the municipal government, a generation permit issued by the *Comisión Reguladora de Energía*, an interconnection agreement with CFE, and an environmental permit issued by the *Secretaría del Medio Ambiente y Recursos Naturales*. Furthermore, the *Instituto Nacional de Antropología e Historia* can determine the issuance of construction permits or delay the execution of the project, should archaeological sites be found.[18]

The establishment of a central authority on renewable energy to provide input and information to industry and government and aid in the streamlining of the permitting process is crucial for mitigating the impact of transaction costs. A "one-stop-shop" solution could provide the necessary transparency and efficiency to lower transaction costs. This is especially necessary when dealing with small-scale generation. Guatemala, for example, established requirements for net metering in its Law 171-2008, and its utility, Empresa Electrica de Guatemala, S.A., reduced the application process to a single form, resulting in an average 18 days between application and authorization for distributed generation at a household level.[19]

3.3.4 Counterparty risk

Uncertainty surrounding contracts between IPPs and utilities for power offtake and their enforcement can hinder renewable energy deployment as well. Mexico faced self-supply difficulties before 2006, as the utility offered only short-term contracts for purchasing excess supply.[20] Following the recent reforms, private power generators will be allowed to enter into electricity offtake agreements with traders and qualified customers.[21]

A lack of enforcement of contracts due to poor rule of law or missing sovereign guarantees increases the risk for IPPs and investors. The establishment of power purchase agreements can provide the necessary security, but clear regulation of the utility and IPPs, as well as standardized power purchase contracts, need to be implemented to alleviate counterparty risk to a reasonable degree. On the government's side, entering into long-term PPAs with decreasing technology prices could lead to higher expenditures for the government. Furthermore, the prices of the various technologies differ considerably depending on their market readiness.

Renewable assets, however, do not face the risk of price fluctuations due to changes in commodity prices, as occurs with natural gas, for example. To further mitigate risk, the use of auctions can provide a preliminary price signal for determining PPAs (or FiTs) for each technology. Throughout Latin America and the Caribbean, countries have been implementing auctions to achieve just such a price discovery. (See Chapter 2).

Governments can face the same risk when pricing feed-in-tariffs. In its Renewable Energy Sources Act (*Eneuerbare Energien Gesetz*), Germany adjusted FiT levels first every four years until 2009. Following the rapid expansion of solar PV installations, exceeding target volumes significantly, the country revised the Renewable Energy Sources Act in 2009 with an automatic adjustment mechanism dependent on ongoing deployment volumes to better reflect PV system price reductions.[22] In 2012, with the volume of PV installations continuously outstripping targets, the German Environment Ministry announced that solar PV FiTs would be revised on a monthly or at a minimum quarterly basis in the future.[23]

3.3.5 Fossil fuel subsidies

In addition to not taking into account the social benefits of renewable energy, the power market remains heavily distorted on a pure cost basis in favor of fossil fuels due to subsidies prevalent in many Latin American and Caribbean countries.[24] Although well-targeted subsidies can be beneficial to low-income communities—enabling greater access to electricity—widespread fossil fuel subsidies pose high economic burdens on many economies and make them more susceptible to external shocks, hampering their sustainable development. The Organisation for Economic Co-operation and Development (OECD) and International Energy Agency (IEA) estimate that at the national level, Mexico and Venezuela are among the top 12 countries with the highest fossil fuel subsidies in the world, spending USD 24 million and USD 16 million, respectively, in 2011.[25]

Fossil fuel subsidies entail both consumption and production subsidies. The International Monetary Fund (IMF) calculated the post-tax subsidy for countries in Latin America and the Caribbean.[26] (See Table 3.1.) The group's methodology adjusts the benchmark price or international price of petroleum products for efficient taxation and subtracts the price paid by consumers. This approach has a number of caveats due to lack of reporting on subsidies and insufficient data on international prices of petroleum products. Thus, the amount of subsidies shown here are likely to underestimate subsidy levels.

TABLE 3.1 Post-Tax Fossil Fuel Subsidy as Share of GDP in IDB Member Countries

Country	Post-Tax Subsidy as Share of GDP
Argentina	0.31
Bahamas, The	1.40
Barbados	0.42
Belize	0.00
Bolivia	4.88
Brazil	0.06
Chile	2.36
Colombia	0.00
Costa Rica	0.30
Dominican Republic	0.03
Ecuador	9.70
El Salvador	0.75
Guatemala	0.72
Guyana	1.00
Haiti	N/A
Honduras	0.43
Jamaica	0.41
Mexico	1.98
Nicaragua	0.01
Panama	2.20
Paraguay	0.00
Peru	0.22
Suriname	0.00
Trinidad and Tobago	5.78
Uruguay	0.00
Venezuela	8.11

Source: See Endnote 26 for this chapter.

According to the IMF, the Latin America and Caribbean region makes up approximately 7.5% of global fossil fuel subsidies of USD 1.9 trillion.[27] Chile is heavily dependent on fossil fuel imports and was vulnerable to external shocks when oil prices were volatile. Through a series of reforms, the country eventually introduced a tax adjustment mechanism in 2011 to smooth transmission of international prices to domestic prices and to reduce the burden on its budget.[28] In Ecuador and Venezuela, fossil fuel subsidies exceed 8% of GDP, and the resulting low electricity prices largely crowd out potential renewable energy deployment.

Phasing out subsidies would raise energy prices in the short term, offering higher incentives for renewable energy deployment, but it would also increase production costs for other industries. However, such a phaseout would also free up money from national budgets that can be used to implement economy-boosting policies. In the long term, it would also decrease inequality, as current subsidies disproportionately benefit the rich.[29]

3.3.6 The need to create open, fair, and competitive electricity markets

Although power markets have significantly opened up to private sector participation, renewable energy deployment is hampered by issues of economies of scale, high transaction costs, counterparty risks, and market distortions in the form of fossil fuel subsidies.

Addressing economies of scale requires the adaptation of financial mechanisms and business models, but this challenge can also be alleviated through regional cooperation and integration of power markets. High transaction costs can be avoided by streamlining the permitting processes and implementing one-stop-shop solutions. Improving the enforcement of contracts is central to attracting higher investment to a country. Experiences with PPAs and standardized rules for contracting with IPPs have shown that such measures can improve the credibility of the market for investors.

Despite direct and indirect subsidies that artificially lower the costs of fossil fuel-based generation, renewable energy technologies are already cost competitive with conventional fossil power generation in regions that have high electricity costs and abundant resources. In 2013, retail consumers in 10 Latin America and the Caribbean countries paid on average USD 0.28 per kWh or more and residential consumers paid USD 0.20 per kWh or more, compared to the costs of solar and wind, which reached USD 0.10 per kWh and USD 0.05–0.09 per kWh, respectively.[30]

In other markets, if market distortions from fossil fuel subsidies were phased out, renewable energy deployment could prove to be the more cost-effective solution, reducing the need for financial support mechanisms. Moreover, implementing a carbon tax could provide price signals to balance the impacts caused by fossil fuel use, not only leveling the playing field for renewable energy sources in all countries, but making renewables more cost effective than fossil fuel-based generation.[31]

3.4 Finance Sector Barriers

Within the financial sector, risks for renewable energy deployment arise from myriad sources. From an international perspective, macroeconomic risks related to political instability, currency, and overall credit worthiness may lower investor confidence in the country itself, as with any other investment. On a national level, the market capitalization of many countries is low, compounded by the lack of adequate financial products in the form of special credit lines or grants. Many domestic financial sectors are also underdeveloped, lacking the capacity and/or willingness to provide credit for renewable energy projects.

3.4.1 Currency risks

Unfavorable currency exchange movements due to the macroeconomic instability of a country can increase the risk for renewable energy deployment. Currency devaluation can lead to a disparity wherein the project fails to collect enough revenue (in the local currency) to meet its scheduled debt payment, which is typically made in a different currency (such as USD), increasing the chance of default.[32] Heavily Indebted Poor Countries (HIPCs)[1] are reluctant to commit to long-term hard currency liabilities, as their debt would increase significantly should their own currency devalue.

Countries in Latin America and the Caribbean have taken different approaches to mitigating currency risk. Ecuador, Honduras, and Nicaragua pay their feed-in tariffs in hard currency, for example, whereas Argentina maintains its FiT in local currency.[33] Countries with financial mechanisms in local currency face increased difficulties in financing a project through development loans as these are usually denominated in USD. Additionally, since many of these countries do not have a developed clean energy value chain, most of the equipment needs to be imported and thus paid in dollars. These difficulties can make projects unviable in many markets.

For international investors, currency fluctuations can increase the depreciation risk of investments. When sourcing international funds, developing countries face higher foreign exchange risks, and the private sector is reluctant to provide mechanisms to hedge this risk for less-frequently traded currencies. The public sector could fill the gap of hedging of less-commonly traded currencies by establishing currency funds supplemented by private sector capital. The Currency Exchange Fund, provided by the Dutch Ministry of Foreign Affairs with investors including the African Development Bank, European Bank for Reconstruction and Development, United Nations Environment Programme, and German Bank KfW, offers those investing in developing markets the opportunity to hedge their local currency risk with swap products. Another method is to offer guarantees for bond issues to finance renewable energy projects, as provided by the ADB.[34]

3.4.2 Inadequacy of financial products

Financing renewable energy projects faces many challenges. These projects often have a payback period exceeding seven years, yet debt financing is often not available for longer than 5–6 years, and equity finance is rare due to high equity requirements (on average 40%).[35] Additionally, there are few private and public financial products that correctly assess and address inherent risk, which prohibits competitive interest rates.

Of the 26 IDB countries, policy frameworks in only 3 utilize equity financing through national funds (Brazil and Dominican Republic) or grants (Mexico). Policies that establish debt financing are wholly absent in the region, except for a special credit line that BNDES in Brazil offers for renewable energy projects (see Section 3.2).[36] The **c**redit line offers low-interest-rate financing for up to 80% of a project's total costs for amortization in 16 years**.** In conjunction with auctions, this credit line has led Brazil to become a leader in renewable energy investment.

In the Dominican Republic's banking sector, only one of the five major domestic commercial banks, Bank BHD, provides a credit line for clean energy. The longest available repayment period that the commercial banks are able to offer is 5–7 years. The IFC and BHD are currently developing a new credit line for "clean" products, such as renewable energy. The credit line would offer low-interest (around 5.5%) medium-term loans (repayment

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[1] Of the 26 IDB countries, Haiti, Honduras, and Nicaragua are considered HIPCs by the World Bank.

within five years with a one-year grace period) for small- to medium-sized project developers, covering up to 70–80% of the project's investment costs.

BHD would be responsible for most aspects of the lending process, including marketing, appraisal, and credit approval. BHD would also provide technical expertise (resource assessment, feasibility studies, etc.) and business assistance to developers through the project preparation process. BHD has already started lending to fuel-switching projects, but not yet to renewable energy.[37] The IFC/BHD credit line helps build the BHD's experience in financing renewable energy and effectively addresses the main barriers that private investors and commercial financiers face in funding renewable energy projects.

3.4.3 Underdeveloped financial sectors

The lack of adequate products to finance projects is due mostly to the lack of capacity or experience with renewable energy lending in financial institutions. Local lenders across Latin America and the Caribbean often have limited experience with renewable energy and are hesitant to offer project loans. Capacity building is challenged by a lack of information, risk assessment skills, and track record for renewable energy projects within the investor community; a lack of network effects (investors, investment opportunities) found in established markets; and a lack of familiarity with and skills related to project-finance structures.

It is indicative that countries with higher investment in renewable energy generally are home to more financial institutions and "green" microfinance Institutions than countries with lower investment.[38] Countries showing a higher penetration of financial institutions for renewables also are those that have provided public financial products. Within the last six years, sustainability themes have gained increased importance in the financial sector in Latin America and the Caribbean. Studies of 85 financial institutions within the region show that 53% offer products for financing renewable energy.[39]

The major obstacle for integrating sustainability policies into the operations of financial institutions remains the lack of comprehension of the risks and opportunities of renewable energy and the lack of capacity to address these with the right financial products. The financial sector requires the expertise to assess and manage the risks, and to adequately design products to reflect the needs and specific pay-off times of the various technologies. To address this, the public sector or development banks can offer guarantees in the form of loans or regular auditing to prove the efficacy of renewable energy projects even at the small and medium scale.

In Jamaica, the capacity and willingness of commercial banks to engage in renewable energy lending has increased significantly in recent years. The Development Bank of Jamaica (DBJ) manages several credit lines aimed at increasing the capacity of private banks for energy efficiency and renewable energy projects. These credit lines are aimed at small- and medium-scale investments, as opposed to the conventional asset finance of large-scale investments. These loans cover up to 90% of project costs, with costs for audits built into the loan. DBJ equally offers a partial loan guarantee program to accept renewable energy equipment as collateral for loans, which can enable larger-scale project financing.[40] Similarly, the Central American Bank for Economic Integration (CABEI) and BAC-San José signed a technical cooperation agreement within the framework of CABEI's Green MSME Initiative to create a green credit product to support renewable energy and energy efficiency investments.[41]

Stakeholder dialogues incorporating industry, the banking sector, and the government can alleviate suspicion toward renewable energy projects and their perceived higher risks. DBJ Greenbiz, launched in Jamaica in June 2012, demonstrates the benefits of energy efficiency measures for small and medium-sized enterprises, and trains Certified Energy Auditors and Managers to enable effective use of the Fund established by the IDB and DBJ. The initiative doubled the uptake of Energy Fund loans from between JMD 300–400 million between 2008 and early 2012 to JMD 600 million by November 2012.[42] Under the 4E project, INCAE in collaboration with Germany's Gesellschaft für Internationale Zusammenarbeit (GIZ) created a stakeholder dialogue by bringing together financial institutions and project developers through a learning course on financing renewable energy projects.[43]

3.4.4 The need for financial sector development

Because renewable energy is a relatively new market player compared to fossil fuel technologies, financial institutions have yet to fully adapt to its unique financing requirements. While currency risks are tied to the general macroeconomic stability of a country, the lack of financial products and capacity requirements are easier to address. Financial policies such as FiTs and net metering have created markets for renewable energy in those countries that have adopted them. The private sector is expanding its portfolio of financial products to support these markets and to create new business opportunities, yet many financial institutions lack the necessary technical know-how and familiarity with the specifics of renewable technologies. Capacity building and training in project financing and risk assessment can reduce adversity to renewable energy and have positive spillover effects to other clean energy projects.

3.5 Social Barriers

Potential social barriers to renewable energy advancement include a lack of awareness of the opportunities of their deployment on behalf of the wider public and/or key stakeholders. Three prominent examples are general unacceptance of the feasibility and/or the economics of renewable energy; vested interests in the status quo/business as usual; and not-in-my-backyard (NIMBY) resistance at the project level.

3.5.1 Lack of public acceptance

Despite the fact that renewable energy sources have matured technologically and have become price-competitive with or even significantly cheaper than conventional alternatives in many geographical settings, there remains resistance due to a lack of understanding of the costs and opportunities of renewables when compared to fossil fuel-based or nuclear power generation.

One 2011 analysis explored the impacts of wind power plants on local rural development and the growing opposition movement in Ceara, Brazil. Based on 129 qualitative interviews with local stakeholders, the wind projects created few local benefits and many negative impacts. Although regional benefits included job creation and mitigated pollution, local-level consequences included blocked access to fishing areas and damage to homes during the construction phase. As a result, opposition movements from academics and NGOs spread to towns where wind power projects were merely proposed.[44]

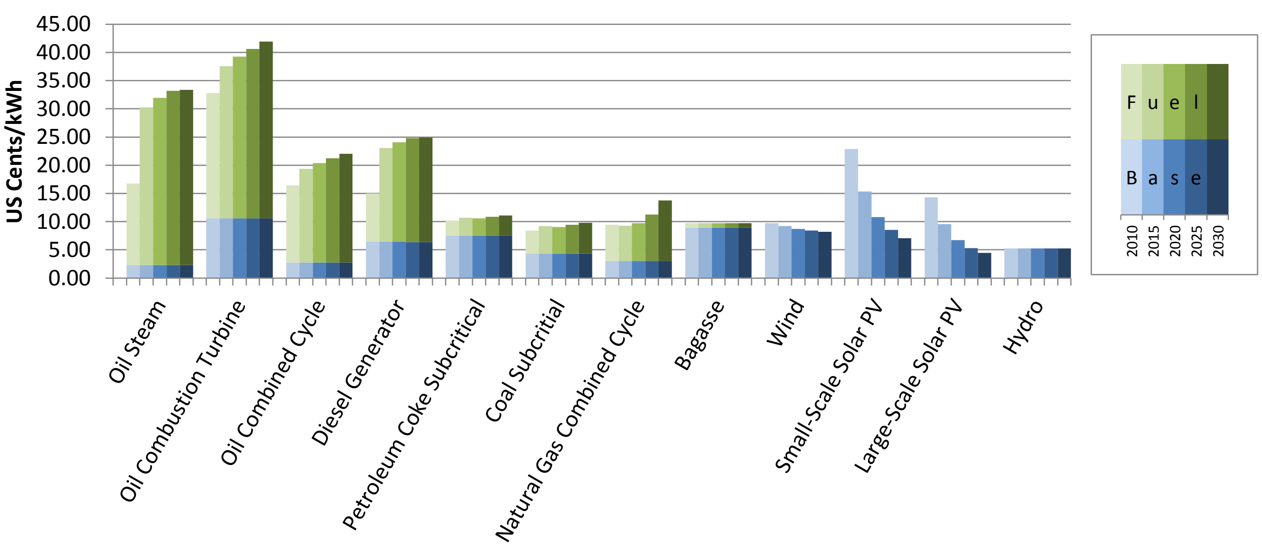
Engaging the community and local government in all stages of development projects is essential to ensure transparency and higher accountability, and to reduce negative impacts on the environment and society. Honduras is a positive example of this, having recently released a guide on best practices in small hydropower development to meet the exigencies of its Law for the Promotion of Renewable Energy Generation (Decreto 70-2007).[45]

3.5.2 Vested interest in business as usual

With fossil fuels still comprising 78% of power generation worldwide, vested interests in maintaining this system are both present and strong throughout the world.[46] Within Latin America and the Caribbean, supplier countries such as Venezuela and Trinidad and Tobago see little incentive to abandon fossil fuels, as these fuels can supply secure energy at home for decades to come and their export brings significant income. Yet even in countries that are net importers of fossil fuels (i.e., the vast majority of countries in the region), interest in the status quo often remains high, whether on behalf of governments that collect taxes on imports and electricity sales, or companies and individuals that profit from the import, distribution, and burning of fossil fuels.

Within Latin America and the Caribbean, the cost benefits of renewables are becoming increasingly clear. Although the base costs of renewables may exceed those of fossil fuels in certain markets, renewables may still be more cost effective because they do not require expenditure on fuels. This cost advantage increases over the life cycle of the installation, as the case of Jamaica clearly indicates.[47] (See Figure 3.2.) Nevertheless, the long-term cost effectiveness of renewable energy versus fossil fuels does not feature prominently in public discussions, leading to continued misperception of renewables as overly expensive.

FIGURE 3.2 Levelized Cost of Energy Projection for Jamaica, 2010–2030



Source: Worldwatch Institute

3.5.3 Not In my backyard

Infrastructure projects around the world often face a not-in-my-backyard (NIMBY) mentality. These concerns are often well founded, based on environmental and/or economic impacts. Landowner considerations and zoning issues, including the use of both public and private land, are important to address. In the Dominican Republic, the Juancho Los Cocos wind farm was sited in the region of Pedernales—instead of in Puerto Plata, which had more attractive wind capacity potential—because of the possible negative impact on tourism that an offshore wind power plant could have had. As a result, opposition from the hotel industry was avoided.[48]

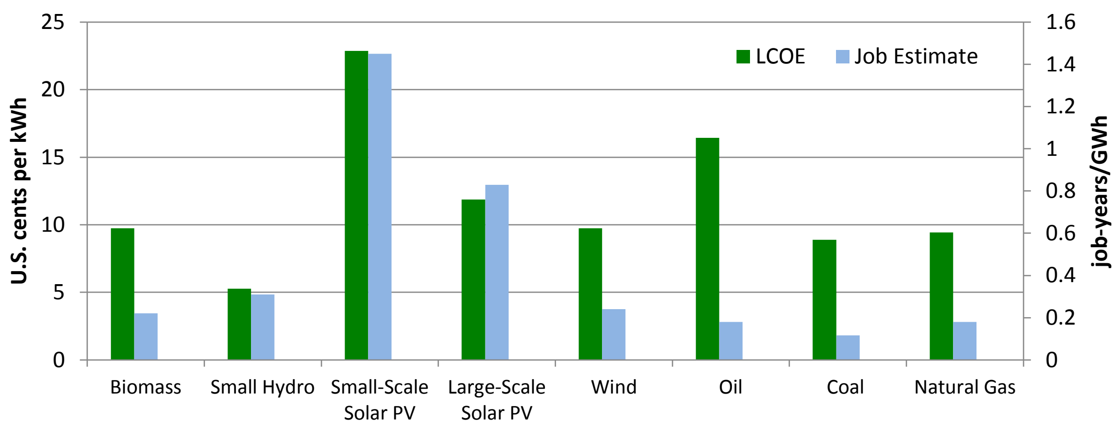
Stakeholder dialogues and proactive outreach campaigns are necessary to ensure that negative project impacts are minimized, thereby reducing resistance to renewables. This can be achieved by including community and industry stakeholders in the decision-making process. In August 2011, Chile enacted a law stipulating the requirement of an annual stakeholder dialogue. After initially reporting on a project's plans, policies, programs, actions, and implementation via a website, a stakeholder dialogue now provides room for the expression of public opinions, questions, and criticisms for 15 consecutive days.[49]

3.5.4 The need for up-to-date, fully inclusive data gathering and communication

Despite rapidly evolving technology costs that have seen renewable energy technologies approach or reach grid parity in many regions of the world, the perception persists that renewables are not cost competitive with traditional fossil fuel-based power generation. Moreover, cost comparisons typically do not take into account the additional societal benefits of renewable energy.

Vergara et al. show that quantification of these societal benefits in terms of avoided climate change damage costs and economic benefits (through balance of payments and net job creation) is often sufficient to justify the wholesale entry of renewable energy technologies.[50] Avoided climate change damages are estimated at USD 0.14 per kWh when taking into account avoided financial costs of emissions. Avoided costs of climate change adaptation are estimated at USD 0.215 per kWh, and avoided costs of air pollution control measures are estimated at USD 0.12 per kWh.[51] In Jamaica, such levelized cost of energy *plus* (LCOE+) assessments have led governments to commit to creating successful awareness programs and stakeholder dialogues.[52] (See Figure 3.3.)

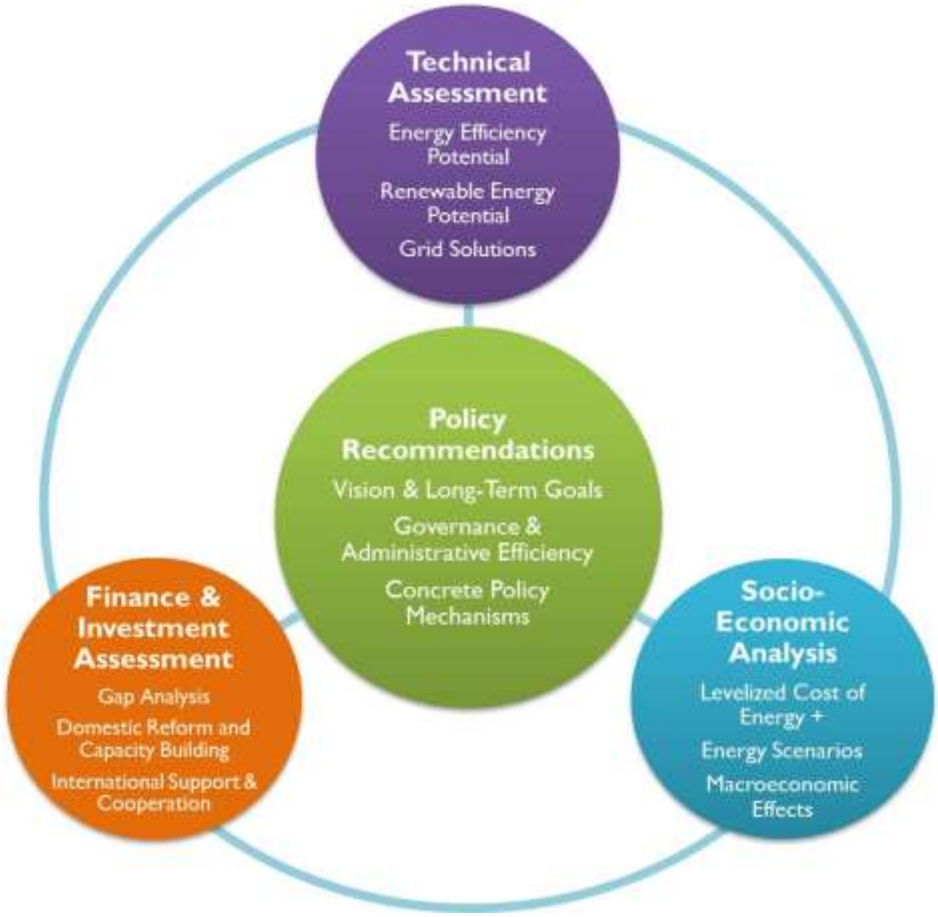
FIGURE 3.3 Levelized Cost of Energy and Job Creation Estimates for Jamaica, by Power Source



Source: Worldwatch Institute

This chapter has described the main barriers to renewable energy deployment in the 26 IDB member countries. Communicating the nature and cause of these barriers and methods to overcome them is imperative to developing a sustainable energy plan. Such integrated energy planning furthermore requires detailed roadmaps for renewable energy deployment through technical, socio-economic, and financial assessments. (See Figure 3.4 for Worldwatch's methodology.) These assessments are essential to developing long-term goals, implementing concrete policy mechanisms, and enhancing governance as well as administrative efficiency.

FIGURE 3.4 Worldwatch Methodology for Sustainable Energy Roadmap Development



Only through the collaborative effort of governments, the private sector, and civil society can effective policies and market solutions be implemented to scale up renewable energy deployment in the face of competition from well-established conventional energy sources.[53] The promising examples of successful policies described in this chapter should serve as a guide for future efforts to advance and accelerate the sustainable energy transition in other countries in Latin America and the Caribbean.

4 Vulnerability to Climate Change, and Adaptation Strategies in the Power Sector in Latin America and the Caribbean

Already today, the impacts of climate change worldwide have demonstrated how vulnerable natural and human systems are, highlighting the need for adequate adaptation strategies. In Latin America and the Caribbean, climate change will continue to affect precipitation levels and air and water temperatures, as well as result in sea-level rise, ocean acidification, and an increase in extreme weather events. These changes will have profound effects across economic sectors, including the power sector, with impacts ranging from changes in resource endowments, infrastructure, and transportation of fuels, to changes in energy demand levels.

Latin America and the Caribbean's dependence on hydropower makes its power sector especially susceptible to changes in water availability. The region already has experienced large economic losses from reduced generation. Although the impacts of climate change on hydropower have been studied—resulting in some adaptation measures—the impacts on other sources of energy, as well as on power infrastructure and energy demand, have not been assessed in depth. Assessing the risks of climate change impacts and developing corresponding adaptation strategies are crucial to protecting energy investments and ensuring a resilient and reliable power supply. This chapter analyzes the impacts of climate change in the region as well as adaptation strategies for the power sector.

4.1 Climate Change Impacts in the Region

According to the Intergovernmental Panel on Climate Change's (IPCC) latest report on climate change impacts, vulnerability, and adaptation, published in March 2014, the effects of climate change are now being felt "on all continents and across oceans," and the magnitude and extent of these impacts is increasingly certain as compared with the IPCC's previous assessment from 2007.[1] Furthermore, the impacts of recent extreme weather events have shown how vulnerable both natural and human systems are, highlighting inadequate levels of adaptation globally.

Climatic changes observed in Latin America and the Caribbean include changes in precipitation (such as increases in annual rainfall in southeastern South America and decreases in Central America, central-southern Chile, and the Caribbean), as well as temperature alterations (warming in Central America, South America, and the Caribbean, and cooling off the Chilean coast).[2]

Climate scenarios indicate further changes in precipitation patterns (ranging from -22% to +7% for Central America, -22% in northeast Brazil, -10% to -1% in the Caribbean, and +25% in southeastern South America by 2100), as well as additional air and ocean warming (ranging from +1.6 to +4.0 degrees Celsius (°C) in Central America, +1.7 to +6.7 °C in South America, and +1.2 to 1.9 °C in the Caribbean).[3] Other expected impacts include sea-level rise (0.5–0.6 meters for the Caribbean), ocean acidification, an increase in frequency of weather and climate extremes, and an increase in frequency and intensity of hurricanes in the Caribbean Basin.[4]

These changes suggest profound impacts on the region's economy, ecosystems, biodiversity, and human well-being. Alarming ice and glacial retreat in the Andes is affecting seasonal timing and volume of stream flows. In addition to glacial retreat, decreasing rainfall and increases in temperature and evapotranspiration will exacerbate water scarcity, which in turn will affect water supply for cities, hydropower generation, and agriculture. Although increasing rainfall in southeastern South America could lead to sustained or increased agricultural productivity, decreasing rainfall and warmer climates in Mexico, Central America, northeast Brazil, and parts of the Andean region could lead to a decrease in productivity, threatening food security. Land-use change, warming temperatures, and changing precipitation patterns will also lead to significant biodiversity loss, some of which will likely be irreversible.

Thermal stress and ocean acidification will continue to result in coral bleaching events and threaten the viability and productivity of reef systems, affecting the livelihoods of coastal communities. In addition, rising sea levels pose a risk of flooding and direct exposure to climatic events for coastal countries in the region, where some 460 million people live within 200 kilometers of the coast.[5] Sea-level rise will affect mangrove ecosystems, threatening the environmental services they provide and damaging fisheries in the region. Beach erosion and sea-water intrusion in many coastal countries could affect water quality and availability.

Vulnerability to extreme weather and climate events is high throughout the region. Higher frequency and/or intensity of extreme weather and climate events could lead to significant economic costs and affect the health and survival of thousands in the region. Climate change can also affect the frequency of disease outbreaks that are influenced by climate-related drivers—such as respiratory and cardiovascular diseases, malaria, dengue fever, yellow fever, leishmaniasis, cholera, and other diarrheal diseases.[6]

4.2 Power Sector Vulnerability to Climate Change Impacts, and Adaptation Measures

The link between the power sector and climate change has traditionally been addressed from the perspective of mitigation, given that the power sector is an important source of greenhouse gas emissions. But it is increasingly clear that the sector itself is vulnerable to the impacts of climate change.

Not only does climate change affect energy supply and demand levels, but it can have an impact on the entire energy supply chain through resource endowment, infrastructure, and transportation of fuels, as well as indirectly through related sectors such as water and agriculture. Given the longevity of energy investments, it is necessary to assess the impacts that climate change may have on existing energy infrastructure, to evaluate the technical and economic viability of future energy investments, and to identify possible adaptation strategies.

In general, the power sector can be made more robust and reliable to withstand the impacts of climate change or other non-climate risks through improvements in weather and storm forecasting capabilities, higher structural and design standards, decentralized energy generation, energy storage, flood control, and coastal defenses. Power sector planning should consider the different timelines of climate change impacts and ensure that investments are confined to locations that are less exposed to climate vulnerabilities when possible.

4.2.1 Power generation

Table 4.1 summarizes the vulnerability of power generation sources, transmission and distribution systems, and energy demand to climate change impacts in Latin America and the Caribbean, based on studies from the World Bank (2011), Asian Development Bank (2012), and U.S. Department of Energy (2013).[7] Several regional studies by the United Nations Economic Commission for Latin America and the Caribbean (ECLAC) and the Organization of American States (OAS) were also consulted.[8] Possible adaptation measures for power generation sources, transmission and distribution systems, and energy demand are also summarized briefly.[9]

TABLE 4.1 Power Generation Vulnerabilities to Climate Change and Adaptation Measures by Technology

Energy Source	Resource Risks	Infrastructure Risks	Adaptation Measures
Hydropower	• Constraints on water resource possible from glacial retreat, decreasing rainfall, increasing temperatures, and evapotranspiration. • Increased water scarcity and competition for water resources can increase pressure on resource availability. • Changes in water resources affect ability of power plant to buffer seasonal variations in rainfall.		• Estimate climate variations and their impact on hydrological resources over lifetime of plant. • Develop adaptive management operating rules and carry out modifications, including: choosing turbines more suited to expected flow rates; modifying canals or tunnels for expected changes in water flows; restoring and better managing upstream land to reduce floods, erosion, silting, and landslides; building higher dams or small dams upstream for increased flows; and augmenting water storage reservoirs for decreased flows.
Thermal power (coal, natural gas, fuel oil)	• Increases in temperature can reduce overall efficiency. • Higher temperatures and decreasing precipitation result in decreased water availability, yet significant water required for fuel processing, cooling, and power production.	• Sea-level rise and extreme weather events could damage infrastructure and disrupt fuel supplies of fuel (e.g., in 2006, Hurricane Katrina in the U.S. state of Louisiana caused U.S. fuel prices to rise by 38%).	• Decrease amount of water used through more water-efficient cooling facilities, with water recovery from condensers and heat exchangers, secondary or wastewater usage, dry cooling, and reduction of evaporative losses.
Biomass	• Increases in temperature reduce overall efficiency. • Higher temperatures and decreasing precipitation result in decreased water availability, yet significant water required for fuel processing, cooling, and power production. • Feedstock may be affected by changes in temperature and precipitation (in a positive or negative way) as well as by severe weather events (droughts, floods, fires)	• Sea-level rise and extreme weather events could damage infrastructure and disrupt fuel supplies.	• Crops selected for biomass power generation should be robust and have high tolerance for high temperatures and water stress. • Other irrigation sources can be considered such as rainwater harvesting, desalinated water, and recycled water. • Irrigation systems can be improved to deliver water to crops more efficiently (e.g., drip irrigation).
Nuclear	• Thermal efficiency can decrease by over 2% during droughts or heat waves due to higher water temperatures. • Heat waves may cause nuclear power plants to reduce output or shut down due to limitations on water abstractions and discharge, as occurred in France in 2003. • Higher temperatures and decreasing precipitation result in decreased water availability, given significant amount required for cooling.	• For power plants situated near the ocean, sea-level rise, flooding, and other extreme events could significantly affect this infrastructure, resulting in major safety issues, as seen in Japan during the 2012 Fukushima accident.	• Decrease amount of water used through more water-efficient cooling facilities. • Given increased safety risks of nuclear power, extreme weather events are of particular concern and require more stringent safety investments and the creation of long-term strategies to respond to these events.

Energy Source	Resource Risks	Infrastructure Risks	Adaptation Measures
Geothermal	• Temperature increases may negligibly affect operating efficiency. • Limited effects from changes in water availability, since it utilizes less water than other sources.		• If water availability is an issue, air cooling can be used or other water sources can be considered, as suggested for other technologies.
Wind	• Changes in frequency distribution, average speed, and timing of winds can affect turbine performance and power output. • Climate change could increase the variability of atmospheric pressure, ambient temperature, humidity, and air density or decrease their predictability, affecting power output	• Ice buildup and very strong wind gusts pose a risk to foundations, towers, and other components.	• Turbines should be built to withstand higher wind speeds and wind gusts. • Building wind turbines on higher towers to reach higher wind speeds can improve power output. • The effects of temperature extremes should be considered when choosing construction materials.
Solar PV and CSP	• Efficiency and power output of solar PV panels decreases with increased temperature and cloud cover. • Higher precipitation and wind speeds can cool and clear debris off panels. • CSP requires cooling water, so it may be affected by decreases in water availability and precipitation levels.	• Extreme weather events can damage solar cells and mounting structures	• In locations where temperature increases might be expected, PV materials that are more heat resistant should be used. • Passive cooling can be used by designing systems with targeted airflow to cool modules. • Appropriate tilt angles and micro inverters can increase power output of the whole system. • Distributed systems can improve grid stability and decrease impact of cloud cover. • Systems should be installed where there is lower probability of dust and grit. • Materials and system design should include surfaces that are self-cleaning or easy to clean. • Structures should be designed to withstand strong winds and flooding, especially the more fragile CSP systems

Source: See Endnote 9 for this chapter.

4.2.2 Electricity transmission and distribution

Transmission and distribution networks tend to be capital-intensive investments with very long lifetimes (30–50 years). Without reliable transmission and distribution systems, lowering the vulnerabilities of power generation plants would be ineffective. Not only is it important to maintain the right operational conditions to limit power losses and ensure safe operations, but load demand also must be managed to operate within capacity constraints. Extreme weather and climate events can have significant impacts on transmission and distribution infrastructure, affecting the reliability of the whole system.

A rise in temperatures can limit the power rating of overhead lines, underground cables, and transformers, increasing power losses. It can also cause sag of overhead lines, reducing their integrity. Droughts can cause dust build-up on conductors. Strong winds can damage distribution systems directly or through tree damage. Extreme weather events such as flooding, wind storms, and hurricanes can affect transmission and distribution infrastructure, especially equipment located at ground level or near coasts.

Because transmission and distribution systems need to match electricity supply and demand, load management and grid control is critical, especially with the addition of distributed generation and renewable energy. For this reason, accurate forecasting and understanding of climate change impacts on both energy supply and demand is critical for transmission and distribution system operation and future system planning.

Transmission and distribution systems will need to adapt to climate change impacts by becoming more resilient to potential damage, in order to continue operating or to resume operation rapidly if outages do occur. Construction of transmission and distribution infrastructure should have higher design standards that incorporate stronger structures, avoid trees or other elements that could affect transmission lines, utilize underground distribution systems, incorporate cooling measures where temperature increases or extremes are expected, and protect systems against lightning.

Flexibility should be increased in transmission and distribution networks to reroute electricity during interruptions as well as to handle high capacities and intermittent resources. Distributed energy generation is one way to increase grid flexibility. Transmission and distribution systems can be upgraded with smart grids and smart meters that manage demand and supply better and improve grid reliability. In addition, more resilient information and communications technology (ICT) components can be used that withstand higher temperatures and humidity. Finally, masts, antennae, switch boxes, aerials, overhead wires, and cables should be protected from precipitation, wind, unstable ground conditions (flooding, subsidence), and changes in humidity.

4.2.3 Energy demand

Climate change will affect energy demand levels, with rising temperatures leading to larger cooling loads during the spring and summer. Higher temperatures in the winter could lead to fewer heating needs in certain locations as well. Larger energy demand could affect building design, cooling and heating systems, and transmission and distribution grids, with temporal shifts in energy demand and higher energy peaks. For a region with high population and economic growth, climate change could add another reason for increasing the energy supply to meet demand.

In addition to increasing generation capacity to meet increased demand as a result of climate change, efficiency of energy supply and end-use efficiency should be improved, such as through minimum energy performance standards for power plants, buildings, and appliances, as well as legislation to incentivize efficiency improvements.

4.4 Adaptation Developments in the Region to Date

Because Latin America and the Caribbean depends on hydropower for 50% of its electricity, water availability is a major concern. Several studies have been undertaken on the impact of climate change in relevant water basins, including two IDB technical notes on hydroelectric systems in Central America and the tropical Andes and a forthcoming in-depth analysis of climate change impacts on hydroelectric plants in the seven Central American countries.[10]

The latest IPCC report discusses some of those impacts. A 20% reduction in runoff is projected for Central America's Lempa River basin, which could continue to limit hydropower production in the region, with a potential reduction in capacity of 33–53% by 2070–2099.[11] Studies for the Sinu-Caribe basin in Colombia also project a reduction in capacity of up to 35% due to higher levels of evaporation, even with increases in rainfall.[12] Chile, Argentina, and Brazil are expected to suffer capacity reductions as well.[13] In contrast, higher levels of precipitation in Ecuador's Paute River basin are projected to increase hydropower generation capacity there.[14]

Latin America has already experienced decreases in hydropower due to extreme droughts, such as the one in Costa Rica in 2001, which reduced generation by 165 GWh, causing losses of USD 8.8 million.[15] In addition, glacial melt could cost Peru's electricity sector between USD 212 million and USD 1.5 billion.[16]

ECLAC, in collaboration with sub-regional organizations, carried out a series of analyses of the economic impacts of climate change in Latin America and the Caribbean, including studies covering the whole region (2009), Central America (2010), and the Caribbean (2011).[17] These analyses summarize the expected impacts of climate change according to IPCC scenarios, estimate the economic impacts of these changes on different sectors (agriculture, human health, biodiversity, water resources, etc.), and provide general recommendations for mitigation and adaptation responses, although they do not address the energy sector specifically.

The OAS carried out a study of the impacts of climate change in the Caribbean (2008), as did ECLAC for the Caribbean (2013) and Central America (2011).[18] These studies are limited to impacts on the energy sector; one study estimates the economic costs of these impacts and possible mitigation options, but none offers adaptation measures or strategies. The Central America study concludes that the hydro sector will suffer the largest impact, with costs ranging from USD 319 million to USD 68 billion, or even triple this range, depending on the scenario used.[19] The study stresses that these results should not be viewed as negative for the future viability of hydro projects, but rather as a recommendation to prioritize integrated watershed and hydrologic resource management to face expected climate change risks.

Climate change is a critical factor in every country's energy sector and the sustainability of its investments. Thus, identifying, evaluating, and managing risks and opportunities related to climate change constitutes an effective strategy to address the economic risk from an objective standpoint. Private companies are becoming increasingly aware of this: for example, EDP in Brazil developed *ClimaGrid,* a real-time forecasting system that the company aims to integrate with the day-to-day operation of its power plants.

Increasingly, the topic of vulnerability to climate change and the need to adapt to its effects is receiving greater attention at the regional level as well as at the national level in some countries in Latin America and the Caribbean. However, this attention must be translated into concrete action in one of the most vulnerable economic sectors. The region continues to lack in-depth assessments of the impacts of climate change on non-hydro energy sources, vulnerability studies at a national level, and the development of adaptation strategies. One successful adaptation strategy is the "sustainable water resource management of the La Plata basin in relation to climate change impacts" program, carried out by the governments of Argentina, Bolivia, Brazil, Paraguay, and Uruguay in 2006, which resulted in the formation of an intergovernmental committee that manages the La Plata basin.[20]

The development of adaptation measures such as these is needed throughout the region and should be an integral part of future energy sector planning. With the expected rapid expansion of the energy sector in Latin America and the Caribbean by 2030, the impacts of and adaptation to climate change must be assessed thoroughly to ensure that the region can develop in a way that guarantees energy security, reliability, and resiliency.

5 How Multilateral Development Banks Can Support Renewable Energy Development in Latin America and the Caribbean

As renewable energy technologies have reached technological maturity and become cost competitive with conventional energy sources in many markets around the world, their deployment has expanded rapidly (Chapter 1). This report presents key trends in the generation and use of renewable power in Latin America and the Caribbean and demonstrates the enormous regional diversity in energy resources, power sector structures, investment drivers, and policy frameworks (Chapter 2). These trends reflect the varying extent to which barriers still exist, as well as the extent to which countries have been able to mitigate them through technical, financial, and policy support measures (Chapter 3). Assessing the power sector's vulnerability to climate change and developing sector-specific adaptation strategies will be a key challenge moving forward (Chapter 4).

Renewable energy development is essential in addressing the region's key energy challenges: providing universal access to energy, meeting future energy demand, transforming the electricity system, and mitigating and adapting to climate change. This chapter identifies four key ways that Multilateral Development Banks (MDBs) can support that development, by: 1) building enabling infrastructure for the grid of the future, 2) securing private sector investment, 3) engaging in policy design and development, and 4) helping to establish supply chains for current and future technologies.

5.1 Building Enabling Infrastructure for the Grid of the Future

- *MDBs can be pivotal in helping governments address important infrastructure and technical barriers to building a smart, low-carbon, and low-cost energy system.*

Latin America and the Caribbean's electricity demand is forecasted to double by 2030 and to triple by 2050.[1] Vast investments in the physical infrastructure of the electricity system are necessary to ensure that the electricity supply can meet this challenge. The longevity of energy infrastructure means that investments made today will have long-term systemic impacts.

Rather than locking in socially, economically, and environmentally unsustainable conventional power assets and infrastructure, the region can leapfrog into a grid of the future. Unlike most developed countries, which are plagued by heavily engrained carbon-based infrastructure and will require significant transformation of their current electric power systems, the region has the opportunity to design a system that is highly flexible, reliable, cost effective, and resilient, and that can accommodate high levels of renewable energy.

- *MDBs can assist governments in carrying out critical infrastructural investments, as well as aid in capacity building of system operators throughout the region.*

Significant investments in transmission and distribution networks are required to upgrade and increase the performance of the current electric grid through more-efficient transformers and the construction of higher-voltage lines. Enhancing the reliability of the grid will also necessitate investment in technologies that can detect and isolate system faults, as well as provide linkages to relay power transmission in the event that flow is interrupted. Balancing electricity loads with supply will require accurate forecasting and dispatch techniques for system operators. Additional investments will be needed to connect new electricity generation sources to load centers.

- *MDBs can support countries in coordinating infrastructure expansion with the establishment of smart grids, weather forecasting, and energy efficiency technologies.*

Integrating variable renewable energy into the grid will require additional flexibility. As experiences in Europe have shown, today's electric grids are capable of integrating a higher-than-expected penetration of renewable energy in the short term. Increasing capacity additions in solar and wind will, however, necessitate both supply- and demand-side efficiency mechanisms.

Smart grid technologies such as demand-response, demand-automation, advanced metering infrastructure, and energy storage, along with market models that provide real-time price signals, are essential in supporting the integration of variable renewable energy sources. Countries should be supported in developing and encouraging investment in companies working in those sectors, building technical capacity, sharing knowledge on best practices, and ensuring that the most effective investments are undertaken before more-expensive transformation strategies are required.

- *MDBs can assist governments in carrying out feasibility and environmental impact studies of potential large-scale renewable energy generation sites and in planning for their integration to the grid.*

Higher energy efficiency, weather forecasting, and smart grid technologies can add significant flexibility to the grid. However, further expansion of variable renewable energy resources can create both costs (such as additional capacity needed to meet peak demand, and additional transmission investments needed to connect high renewable sources to demand centers) and benefits (such as reduced capacity needs from resources that match peak loads or are near demand centers, and improved system operations). These costs and benefits should be assessed carefully to reduce long-term supply costs and enhance the reliability of the system. Renewable baseload power capacity, such as hydropower and geothermal energy, as well as distributed generation, can provide additional grid integration support for high levels of variable renewable energy.

- *MDBs can provide technical and policy assessments for the most cost-effective regional integration strategies and aid countries in harmonizing national-level energy plans and regulations.*

Latin America and the Caribbean's diversity in renewable resource potential provides significant opportunities for regional integration. Regional integration can provide a hedging mechanism for the variability inherent in solar and wind power generation, as well as the increasing variability of hydropower due to climate change, thus increasing the reliability of the electricity system. The impacts of climate change on the energy sector, from fuel supply to power generation and energy demand, are affecting and will continue to affect the reliability and cost of energy supply. These impacts should be assessed comprehensively to determine appropriate adaptation strategies to be included in national energy plans.

To decrease long-term costs and improve the reliability of the electricity system, national energy plans addressing power generation variability and climate change impacts should be harmonized regionally. Technical and policy assessments can help determine the most cost-effective and socioeconomically beneficial path to regional integration. They are also an important first step to an integrated regional power market.

5.2 Securing Private Sector Investment

- *MDBs can assist governments in lowering market and financial barriers that prevent the private sector from investing in small-, mid-, and large-scale renewable energy, energy efficiency, and smart grid projects.*

Liberalization and deregulation have meant that governments and utilities are no longer the only players in the power market. The private sector is investing heavily in renewable energy in markets where renewables are competitive with fossil fuels and where the right price signals exist. The continued liberalization and deregulation of electricity markets in countries throughout the region will create opportunities for new actors, business models, and market niches.

Private sector investment in renewable energy projects requires clear policy and regulation that can provide long-term stability to investments. Developing countries face additional financial challenges due to unstable political regimes, volatile local currencies, and/or lack of infrastructure. These risks can be mitigated through clear, long-term supporting policy frameworks, as well as through a variety of financial support mechanisms.

- *MDBs can help leverage private sector investment through risk mitigation of renewable energy projects.*

Because of the unique financial requirements of renewable energy projects, appropriate financial products that address the risks and opportunities of renewable energy need to be made available. MDBs have already provided significant technical assistance and loan guarantees for private sector investment in renewable energy projects. While continuing to do so, MDBs can also develop new financial products that can help mitigate risk and attract more private investment.

The lack of local currency-based financing continues to be one of the principle hurdles for financing in the region. MDBs can make local currency loans available in certain countries to help investors mitigate currency risk. Alternatively, MDBs can provide credit guarantees, risk guarantees, and hedging products. In addition, blended investments that match different risk appetites can demonstrate project viability to the markets, build a track record of successful projects, and catalyze private sector investment. Banks, pension funds, private equity, and venture capital funds all have their own risk-reward profiles, which when combined can help bridge the gap in funding for renewable energy projects.

Project bonds can be used to raise debt for renewable energy projects, but they currently have high requirements to receive investment grade. MDBs can catalyze the use of project bonds through pilot programs that invest in bonds from international development finance institutions (such as the World Bank) so as to dictate the conditions for future renewable energy investments to happen.

Renewable energy projects can be hampered by the credit-worthiness of offtakers. Standardization of renewable energy project development and finance components can also de-risk investments. These include standardization of off-taker guarantees, financial instruments, PPAs, and project evaluation tools. The MDB's regional presence could be beneficial in launching this process.

- *MDBs can aid small-scale projects in meeting equity requirements and help build the capacity of local financial institutions, increasing their familiarity with renewable energy projects and lowering perceived risks.*

Investments lacking economies of scale can be made more attractive by bundling projects and facilitating access to international finance, for example from green funds and international climate mechanisms. Assembling investment portfolios of similar projects diversifies investment and mitigates risk. Offering governmental or multilateral securities for such portfolios will attract investors.

Facilitating green microfinance will be essential to enable the financing of rural power projects that can provide electricity access to the 34 million people who continue to lack such access in Latin America and the Caribbean. Lessons learned in countries with a high penetration of microfinance institutions should be applied to countries with limited microfinance capacity.

Lenders and investors need to understand the market differences of small renewable energy projects and to increase their familiarity with them in order to avoid overestimation of risks and high costs of capital. MDBs can support local microfinance institutions with credit lines and technical assistance through capacity building and knowledge products. Additional technical capacity can be built through the creation and expansion of networks of regional financial institutions (CABEI, CDB, CAF, BNDES, FONPLATA, etc.) and local microfinance institutions.

- *In markets with limited private sector involvement, MBDs can stimulate engagement by providing support for public-private partnership (PPP) projects.*

The private sector's technical, project management, and communications expertise can be aligned with governments' ability to streamline the regulatory process and lower investment barriers, as well as to back up and secure private capital. PPPs are used to varying degrees in the region, but they tend to be concentrated in mature markets. Wider use of PPPs is hampered by a lack of knowledge and awareness of their benefits and by difficulties in bringing PPPs to market.

In an advisory role to governments, MDBs can support the creation of PPPs by helping them structure, execute, and manage PPPs, facilitate PPPs through pilot projects, and replicate successful pilot projects. This in turn would enhance the capacity of governments to execute more PPPs. The IDB, for instance, is already promoting the use of PPPs in the region through the Multilateral Investment Fund's "Building PPPs for Development Program," which is creating pilot projects, providing technical assistance, evaluating the environment of PPP investment, and organizing events to enable collaboration between private and public actors.[2] The program, co-financed by the GEF and approved in 2012, is already resulting in financing for renewable energy and energy efficiency and in private sector interest. Continued engagement in these types of programs and increased familiarity with projects developed through PPPs could facilitate investment in new, smaller, and less mature markets.

5.3 Engaging in Energy Policy Design and Development

- *MDBs can continue to play an important role in assisting governments through capacity building, institutional development, and policy design.*

Today, there exists a large toolbox of policies and measures that have proven effective in supporting renewable energy deployment and broader human development. Countries that have become leaders in the transition to sustainable energy systems have improved the investment environment for domestic renewable energy sources by creating stable decision frameworks that include a long-term vision of change, ambitious

targets, concrete support policies and mechanisms, as well as clear, transparent, and cost-effective administrative processes.
Designing a framework capable of harvesting the full benefits of deploying renewable energy for a given nation or region requires reliable technical, socio-economic, financial, and political analysis. This analysis must take into account the country-specific technical potentials and challenges, costs and benefits of different energy pathways, and details of the local investment and legislative environment. Goals need to be integrated with the larger development agenda and mainstreamed with other sectoral policies. There is no one-size-fits-all policy framework to promote clean energy. Policies need to be specifically designed and tailored to the circumstances in each country.

- *MDBs, with its extensive knowledge of the region, are ideally positioned to support national governments in developing sustainable energy plans that are suitable to their needs and goals.*

To be effective, national energy strategies should incorporate sustainable energy transition pathways that are simultaneously achievable and bold. Governments should ensure that strategies are consistent and inclusive on different levels of planning. They should monitor progress, report regularly where they stand toward reaching the set goals, and re-evaluate as necessary. They need to assess the effectiveness of individual policies and measures, including those of counter-productive instruments such as fossil fuel subsidies. Based on this analysis, transparent policy adjustments can be developed.

MDBs can support governments at every step along the way to smart policymaking—from initial resource assessments and technical feasibility studies to their integration in socio-economic models of alternative energy pathways; from financial needs assessment, to the development of comprehensive energy planning, to advice on the design of concrete support mechanisms.

Both large-scale and distributed solutions need to be weighed as to their role in expanding energy access and satisfying future energy demand. Furthermore, the impacts of climate change on the power sector and corresponding national and regional adaptation measures should be integrated into energy planning. The IDB's development expertise can ensure that the full impact of renewable energy is taken into account, from energy security to balance of payments and avoided costs, from job creation to cross sectoral and international competitiveness, from local air pollution to climate change and the health effects of both.

In addition, the integration of renewable energy sources and the implementation of supply- and demand-side management technologies require an appropriate electricity market design that creates incentives and compensates providers justly for facilitating grid stability and reliability. MDBs can encourage the advancement of further power liberalization and policies that enable short-term power markets and system service markets to favor economically efficient solutions through accurate price signals. From the outset, the policymaking process should incorporate stakeholder engagement mechanisms in order to forge alliances with key societal groups and the private sector, as well as to avoid misconceptions and problems that fuel social disengagement or disillusionment with renewable energy.

5.4 Helping to Establish Supply Chains for Current and Emerging Technologies

- *MDBs can support the growth of local supply chains for clean energy technologies through capacity building and technical cooperation, as well as through financing of pilot projects, local businesses, and emerging clean energy technologies.*

Latin America and the Caribbean's abundant renewable energy potentials; its social, economic, and security incentives to transition to more sustainable energy systems; and its human resources eager to become involved in 21st-century technological solutions, provide the region with a competitive advantage in the development of clean energy value chains for renewable energy technologies. Establishing a dynamic renewables industry can attract capital and sustain the development of low-carbon energy systems. This could include education and training; research and development; manufacturing and construction; project development and implementation; operation and maintenance; and financial, legal, and marketing services.

Latin America and the Caribbean as a region already has complete clean energy value chains for biofuels, biomass, waste, and hydropower. Solar, wind, and geothermal also have near-complete value chains, except for silicon production, bearing manufacturing for wind equipment, and geothermal operation and maintenance service providers. Argentina, Brazil, Chile, and Mexico have the most complete clean energy value chains in the region. For smaller economies, it is practical to focus on the creation of regional markets. For example, Barbados's enormous experience with solar water heating could spread through the region if CARICOM, possibly supported by the IDB, promotes its success model and helps it expand to markets in neighboring islands. This could also serve as a first step toward a Caribbean solar manufacturing industry.

The region has some of the largest potentials in the world for emerging renewable energy technologies, including CSP and marine energy. For instance, the Atacama Desert in Chile has among the highest solar radiation concentration in the world. This potential is starting to be explored with the development of the first CSP plant in Latin America.[3] Off the Chilean coast lies vast unexplored marine power potential, with an estimated generation capacity of 100–200 GW. The IDB, for instance, is helping Chile tap some of that potential through a technical cooperation grant for the development of two marine energy pilot projects.[4]

Latin America and the Caribbean has the opportunity to become a test bed for innovation for current and future renewable power generation technologies, as well as for smart grid and storage technologies. Continuing the development and deployment of renewables in the region would lead to the creation of thousands of jobs. MDBs should continue to support pilot projects as well as the regional implementation and scale-up of proven technologies. They should help establish financing programs to support the growth of local supply chains for renewable energy technologies through business incubators. Finally, it can be instrumental in building technical capacity by fostering cooperation among technical leaders from both within and outside the region.

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