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Energy Markets in Latin America

Emerging Disruptions and the Next Frontier

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ESMAP
Energy Sector Management Assistance Program

Energy Markets in Latin America

Emerging Disruptions and the Next Frontier

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Attribution: Elizondo-Azuela, Gabriela, Antonio A Barbalho, Luiz Maurer, Susana Moreira, Catiana Garcia- Kilroy, Christophe de Gouvello, Juan Benavidez, David Reinstein, and Jiemei Liu. 2017. "Energy Markets in Latin America and the Caribbean: Emerging Disruptions and the Next frontier", World Bank, Washington, DC.

Design and layout by blossoming.it.

Acknowledgments

This report is the result of a joint initiative of the Latin America and Caribbean Region Vice-Presidency and the Energy and Extractives Global Practice (LCR Energy).

The report was produced by a core team of World Bank staff and external experts led by Gabriela Elizondo Azuela. The work was conducted under the oversight and guidance of Antonio Barbalho, Practice Manager (GEE04).

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Additional research and/or background papers were commissioned from the Swedish Royal Institute of Technology (Oliver Broad, Mark Howells, and Gustavo de Moura), ENERDATA (Cyril Cassisa, Sylvain Cail), Adam Brown (Energy Scenarios and Investment), Beatriz Arizu (Electricity Markets), Raul Garcia, Pablo Givogri (Gas Markets), Juan Benavides (Political Economy of Disruption), Tito Yepez (Country Investment Scenarios), and Santiago Enriquez (Environmental Aspects of Energy Infrastructure).

The report considered the results of a client survey focused on identifying priorities in the energy sector developed by Monitor Deloitte.

The team is grateful for guidance provided by Jorge Familiar Calderon, Vice President of the Latin America and Caribbean Region, Karin Erika Kemper, Senior Regional Adviser, Marianne Fay, Chief Economist, as well as comments and helpful suggestions from Vivien Foster, Salvador Rivera, Waleed Saleh I. Alsuraih, Pedro Sanchez, Pedro Antman, Horacio Terraza, Jaime Millan, Ashish Khanna, Demetrios Papathanasiou, Patricio de Vivies, Carlos Alberto Lopez, Heinz Rudolph, Philippe Neves, Luciana Guimaraes, Javier Bolzico, Daniel Bond, Jose Luis Guasch, Fernanda Nunez, Gonzalo Martinez, Carlos Senon, and Roberto Luis Estevez Magnasco.

John Burgess edited the report, and Steven Kennedy the executive summary and overview.
Design and layout by blossoming.it.
The report has been co-financed with ESMAP resources.

The findings, interpretations, and conclusions expressed in this document are those of the authors and do not necessarily reflect the views of the Executive Directors of the World Bank, the governments they represent, or the counterparts consulted or engaged with during the informality study process. Any factual errors are the responsibility of the team.

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Abbreviations

AMI	Advanced Metering Infrastructure
BOO	Build, Operate and Own
BOOT	Build, Operate, Own and Transfer
CAGR	Compounded Annual Growth Rate
CNG	Compressed Natural Gas
COP21	21st Conference of the Parties
DER	Distributed Energy Resources
DFI	Development Finance Institution
DSM	Demand Side Management
EMEs	Emerging Market Economies
ENSO	El Niño Southern Oscillation
FSRU	Floating Storage and Regasification Units
GHG	Greenhouse Gas
GNI	Gross National Income
GOT	Grid of Things
ICT	Information and Communication Technologies
IEA	International Energy Agency
INDC	(Intended) Nationally Determined Contribution
IOT	Internet of Things
LAC	Latin America and the Caribbean
LNG	Liquefied Natural gas
MER	Mercado Eléctrico Regional
MERCOSUR	Mercado Común del Sur
NCRE	Non-Conventional Renewable Energy
NDC	Nationally Determined Contribution
NG	Natural Gas
NPS	New Policies Scenario
OECS	Organization of Eastern Caribbean States
PPA	Power Purchase Agreement
PPP	Purchasing Power Parity
PPPs	Public Private Partnerships
PSP	Private Sector Participation
R&D	Research and Development
VRE	Variable Renewable Energy
RISE	Regulatory Indicators for Sustainable Energy Sustainable Energy
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SIEPAC	Sistema de Interconexión Eléctrica de los Países de América Central
SINEA	Andean Electrical Interconnection System
TFEC	Total Final Energy Consumption
TPES	Total Primary Energy Supply
VRE	Variable Renewable Energy
WBG	World Bank Group
WEC	World Energy Council

Introduction

Change is afoot in the global energy system

Efficient energy services are essential for economic growth, competitiveness and human development. Globally, energy markets are undergoing a transformation: fossil fuel prices are responding to new and unpredictable dynamics, and new energy and ICT technologies are emerging and disrupting traditional market architectures. These are pushing a paradigm shift, at a time when rapid urbanization and climate change pose critical and uncharted challenges of multidimensional complexity. At the same time, public budgetary resources for infrastructure development are scarce, and mobilization of private finance requires acceptable risk-return profiles and the availability of long- term finance.

The international community has recently established climate stabilization targets and Sustainable Development Goals (SDGs) to ensure global economic growth consistent with crucial human and planetary needs.

At the Conference of the Parties (COP21) held in Paris in December 2015, 196 countries—including 27 in the Latin America and Caribbean (LAC) region—gathered to discuss and ratify an agreement to limit global warming to less than 2°C by 2100, and make best efforts to limit it to 1.5°C. Progress towards this ambitious goal depends on the successful implementation of the national climate pledges submitted by almost 200 countries in the run-up to COP21 and afterward—the Nationally Determined Contributions, or NDCs.

In parallel, public and private actors have renewed their global commitments to increase investments and research and development to boost carbon pricing and end wasteful energy subsidies.

The 2030 Development Agenda for Sustainable Development adopted in September 2015 by the 193 countries of the United Nations General Assembly establishes sustainable energy as number seven of its 17 Sustainable Development Goals (SDG7). It seeks to ensure access to affordable, reliable, sustainable, and modern energy for all. It includes three targets to be achieved by 2030: universal access to energy, a substantial increase of the share of renewable energy in the global energy mix, and a doubling of the global rate of improvement in energy efficiency.

The ambitions of the Paris Agreement and the 2030 Development Agenda are high, but grounded in technical and economic feasibility. It is widely recognized that the challenge lies more in the capacity of institutions to deliver the policies and regulations necessary to drive a transformation and mobilize private sector investment. While much of the finance will have to come from the private sector, public finance—both national budgets and concessional transfers—will have a crucial role to play in helping set economies on the right path.

So in this increasingly complex and rapidly changing context, how are LAC energy markets progressing? How will emerging disruptions and game changers influence the evolution and transformation of energy markets in LAC? How ready are existing markets and institutions to actively move toward the next frontiers of efficiency? What is needed to break through to the modern, efficient, secure, and sustainable energy systems needed to support the regional economy in the coming years? What investment will be needed and how is LAC poised to attract private finance?

This report explores these questions and offers insights into paths and actions needed to approach the next efficiency frontier. The report focuses on electricity and gas markets.

The analysis acknowledges the varying conditions and challenges of different countries in the region. Intraregional variation is addressed through analysis of country groupings and selection of appropriate comparators, benchmarks, and best practice frontiers.

Key Messages

The report analyzes the progress and challenges of the electricity and gas sectors in Latin America and the Caribbean, and examines how emerging disruptions and game changers could shape their future evolution. The 5 key messages of the report are the following:

1

The convergence of multiple trends is disrupting the status quo and evolution of energy markets globally and in LAC.

These include new dynamics in global energy and fossil fuel markets, high urbanization rates, climate change, disruptive technologies, and increased financial constraints. Emerging technologies in particular—renewables, storage, smart grids, digital solutions, and small LNG among them—are transforming energy systems not only because they are increasingly cheap, but because they will unleash new and vibrant energy markets on the consumer side.

The region already has the cleanest energy matrix in the world due to a gradual substitution of oil for natural gas, and high use of hydropower and biofuels. But it is only starting to develop non-conventional renewables despite abundant indigenous resources and has lagged other regions in improving energy efficiency and rationalizing energy consumption. A key challenge in the region is that rainfall variability and Niño events are increasingly impacting hydropower output.

2

LAC could and should take advantage of emerging innovations to approach higher efficiency frontiers.

On the whole, the region has made great strides in developing sophisticated electricity markets and gaining increased access to natural gas via LNG trade and indigenous resources. Different groups of countries (sometimes with overlapping members) face different challenges, but adopting emerging innovations is key to the future development of efficient energy services in all of them. This path would deliver climate co-benefits such as emissions reductions and enhanced resilience to climatic shocks and would reduce the social and environmental constraints that often accompany development of large infrastructure.

3

Embracing the clean energy and digital revolution makes economic sense for LAC.

Demand for energy in LAC is projected to continue to grow at high rates. The region would need an estimated US$ 1.3 trillion dollars between now and 2030 to develop its electricity and natural gas infrastructure under a business-as-usual path. However, current investment flows fall short of these needs. Investment requirements could fall considerably under a development path that emphasizes efficient use of existing infrastructure, grid-connected renewables and a menu of demand-side solutions.

4

Policy makers and regulators need to create the market architecture and incentives necessary to develop demand-side and distributed resources.

This will require planning that considers the full menu of supply- and demand-side resources as well as proactive regulation that creates the pricing and incentives necessary to develop them. Markets will need to increase electricity trade in existing cross-border interconnections and consider further integration where politically feasible. City governments could play a key role in making the energy infrastructure "smarter" and growing the clean energy economy via new incentives and investment. All these steps would require strong institutional capacity and agility.

5

Creating new asset classes will require financial ingenuity.

Mobilization of debt and institutional investor resources will only happen after affordable risk management instruments and innovative products are in place.

1

SECTION 1

Current Energy Landscape

Section 1 looks at regional energy trends and examines how LAC's energy markets have progressed over the last few decades, considering differences among countries and intraregional patterns.

In **Chapter 1**, the analysis focuses on how primary energy and consumption have evolved, LAC's resource endowments and energy security, and the fiscal and economic impact of energy. **Chapters 2 and 3** examine the evolution and main challenges of the electricity and gas sectors as well as how markets have developed and performed. **Chapters 4 and 5** then look at issues of sustainable energy, including renewable energy, energy efficiency, and energy access, and discuss how close LAC is to achieving the energy sustainable development goal (SDG7). **Chapter 5** delves into the issue of energy poverty.

The section thus provides an analysis of the trends and status quo, and identifies the main regional challenges and opportunities in energy infrastructure development. Across indicators, the analysis establishes a stance among international best practice and efficiency frontiers.

Key Messages

The key messages emerging from Section 1 are the following:

1

THE REGION'S ENERGY MATRIX IS ONE OF THE CLEANEST IN THE WORLD.

Notably due to a gradual substitution of oil for natural gas, and high use of hydropower and biofuels. Yet, the region still relies heavily on fossil fuels (73% of primary energy supply, with 33% of fuel oil, 35% of natural gas, and 5% of coal). A key challenge in the region is that rainfall variability and Niño events are increasingly impacting hydropower output. Promisingly, LAC is rapidly introducing non-conventional renewable energy.

2

LAC'S ENERGY INTENSITY IS BELOW THE GLOBAL AVERAGE, BUT RATES OF IMPROVEMENT ARE BELOW THOSE OF DEVELOPED ECONOMIES.

Indeed, a decomposition analysis shows that expansive untapped opportunities remain for energy efficiency improvements in the region. With continuous economic growth and increased energy demand, attention to demand side management and energy efficiency is critical.

3

ENERGY POVERTY IS STILL A CRITICAL PROBLEM.

Despite the incredible progress in the energy access agenda, inequality of access is still common among rural and low income population (18.5 million people in LAC remain without access to electricity, and 84 million people without access to modern non-solid fuels). Exposure to indoor pollution continues to be a critical problem among the poor.

4

THE REGION HAS DEVELOPED CONSIDERABLE EXPERIENCE WITH THE DESIGN AND OPERATION OF ELECTRICITY AND GAS MARKETS, ALTHOUGH PERFORMANCE HAS VARIED.

Electricity and gas markets in LAC have evolved in different, if not contrasting ways. Electricity markets are widespread in the region (except for only a few countries) with varied structures and levels of competition, and many of them are extremely sophisticated. Natural gas markets as such, where competition exists in one or more segments of the supply chain, have been difficult to establish; and the few that have thrived are considered incomplete. Access to natural gas has increased via LNG trade.

CHAPTER 1

Energy and the Economy

Decoupling of GDP growth from energy consumption is accelerating in LAC

At the individual country level, the strength of the energy-economy linkage depends on the level of development, the structure of the economy, and degree of access to energy services. Overall, shifts from economic structure have been small.

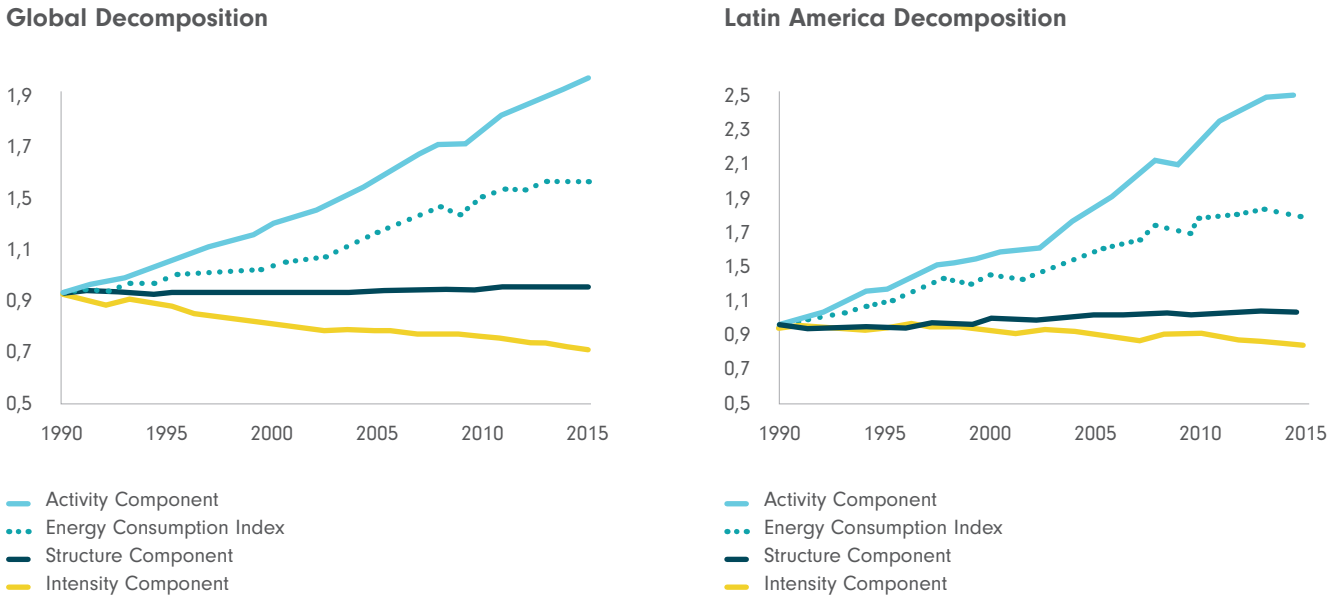
At the global level, reductions in energy intensity have provided the main offset to rising energy consumption and economic output (see Figure 1.1). Many countries, including high-income and industrializing ones such as China, have shown it is possible to achieve decoupling by reducing energy intensity.

Decomposition analysis makes it possible to assign values for energy intensity (that is, avoided energy consumption) to regions and countries. Most recently, East Asia (notably China) and North America have been the main contributors to reductions in energy intensity globally. Latin America and the Caribbean (LAC) has delivered a comparatively minor impact in terms of total volume saved, although many countries of the region have achieved savings at the level of those of developed economies when measured as a percent of total final consumption (World Bank and International Energy Agency (IEA) 2015, see Figure 1.2).

As a whole, LAC has an energy intensity level of 4 MJ (megajoules) per $2011, PPP. This is well below the global average of 5.5 MJ and comparable to Europe's 4.6 MJ. The region's relatively low intensity is due to factors including relatively high electricity prices, a modest share of energy-intensive activities in the economy, low per capita incomes, and moderate climate.

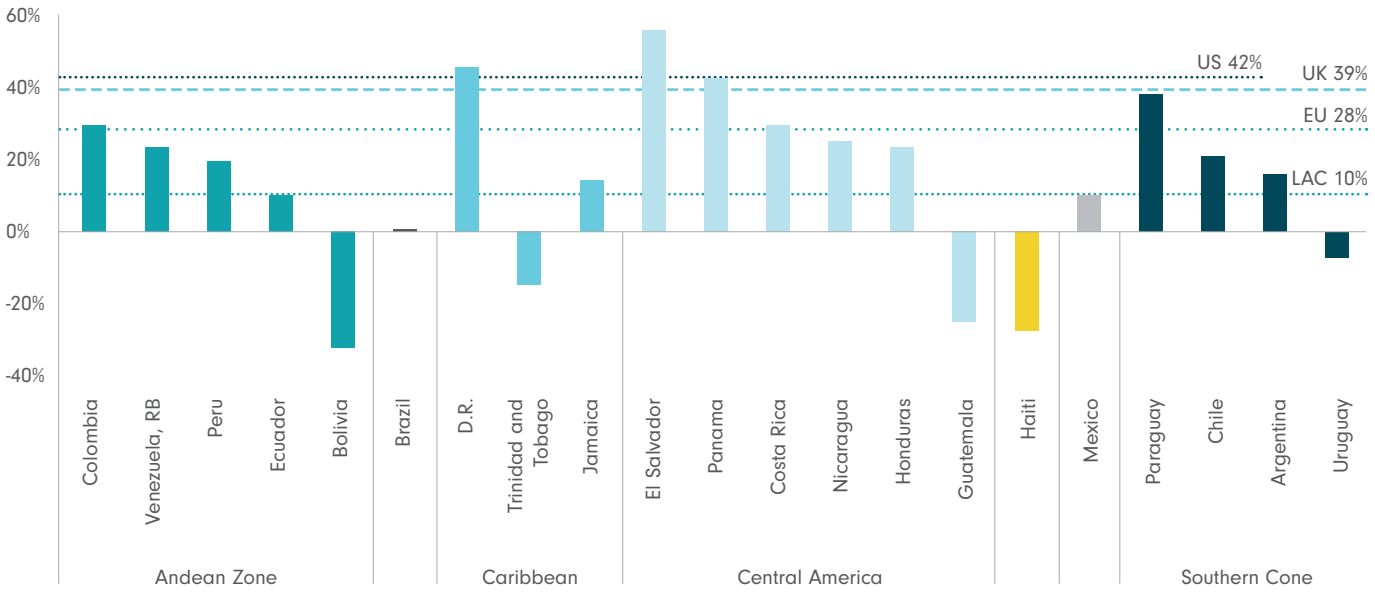
The regional picture is not reflected in some LAC countries, such as Trinidad & Tobago (19.8 MJ/$2011, PPP), Haiti (9.9), Guyana (6.6), Honduras (6.6), República Bolivariana Venezuela (henceforth referred to as Venezuela) (5.5) and Bolivia (5.2), which are all still highly energy intensive. Indeed, decomposition analysis shows that a broad scope remains for energy efficiency improvements in the LAC region. While energy demand is for now low compared to other regions, continuing economic growth is likely to push up demand. For example, in the IEA's New Policies Scenario (NPS), primary energy demand in the region grows at a compounded annual growth rate (CAGR) of 1.5 percent between 2012 and 2040, 0.5 percentage points above the rate expected for global primary energy demand growth.[1]

FIGURE 1.1 Decomposition of Trends in Final Energy Consumption: Contributions of Activity, Structure and Intensity Components (1990-2015) *(Index, 1990=1)*



Sources: Prepared by authors based on data from the IEA Energy Statistics and Balances (database) 2017 and UN Energy Statistics (database).

FIGURE 1.1 Energy Savings Relative to Total Final Energy Consumption (average 2004-2014) *(Percent)*



Sources: Prepared by authors based on data from World Bank and IEA 2017.

Note: Ratio of cumulative avoided energy demand due to energy intensity improvements 2004-2014, to cumulative total final energy consumption 2004-2014.

The region is endowed with abundant energy resources

Overall, LAC is an energy-rich region with large oil and gas deposits, concentrated mainly in Venezuela, which has the largest reserves of crude oil and the eighth-highest gas reserves outside the Middle East. Coal resources are found mainly in Colombia and Brazil, although these reserves are not as large in global terms. The region has substantial untapped proven gas reserves (8 trillion cubic meters—4.1 percent of the world's total and technically recoverable resources of 190.8 tcm). More than 70 percent of LAC's total proven natural gas reserves in 2014 are in Venezuela (Table 1.1).

Hydro and non-hydro renewable energy resources in LAC are also substantial (see Figure 1.3). Recent assessments show that the region could produce over 93 PWh of electricity from solar, wind, marine, geothermal, and biomass energy, which is well above foreseeable demand and enough to power the entire region in the next century (Vergara et al. 2015).[2] Only 25 percent of the available hydro resource has so far been exploited.

TABLE 1.1 Proved Hydrocarbon Reserves as of 2014 *(Trillion cubic feet, TCF)*

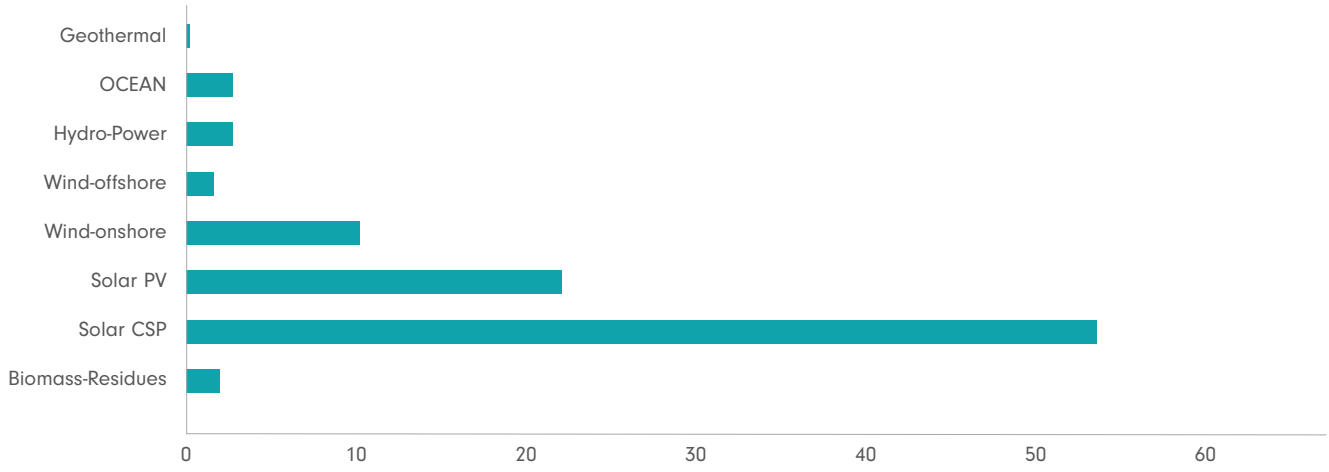
NATURAL GAS			CRUDE OIL			COAL (TOAL RECOVERABLE)		
LAC Ranking	Global Ranking	TCF*	LAC Ranking	Global Ranking	Billion Barrel	LAC Ranking	Global Ranking	Million Short Tons
Venezuela	8	197	Venezuela	1	298	Colombia	13	7,436
Mexico	32	17	Brazil	14	15	Brazil	14	7,308
Brazil	33	16	Mexico	17	9.1	Mexico	25	1,335
Peru	34	15	Ecuador	19	8.9	Argentina	32	606
Trinidad and Tobago	36	12	Colombia	33	2.4	Venezuela	36	528
Argentina	37	11	Argentina	34	2.3	Chile	53	171
Bolivia	39	10	Peru	41	0.7	Peru	65	49
Colombia	45	6	Trinidad and Tobago	42	0.2	Ecuador	68	26
Chile	51	3	Bolivia	55	0.2	Suriname	71	13
Cuba	57	3	Chile	61	0.2	Bolivia	81	1

Source: IEA 2015.

Notably, Chile's Atacama desert—the driest non-polar desert of the world—has the potential to become a regional hub for solar power, in view of its large area and very high solar irradiance.[3]

Argentina, Bolivia and Brazil also hold 54% of world's lithium resources (area known as the "lithium triangle"), a coveted commodity used to produce lithium-ion batteries (necessary in the manufacturing of electric cars, electric grids, wind turbines and solar photovoltaic). Chile in particular has dominated the lithium markets for decades as the Atacama salt flat has the largest and highest quality proven reserves of the world (Economist, 2017).

FIGURE 1.3 Estimated Resource Endowment from Renewables in Latin America *(Petawatt-hour (PWh)/year)*



Source: Ecofys 2009.

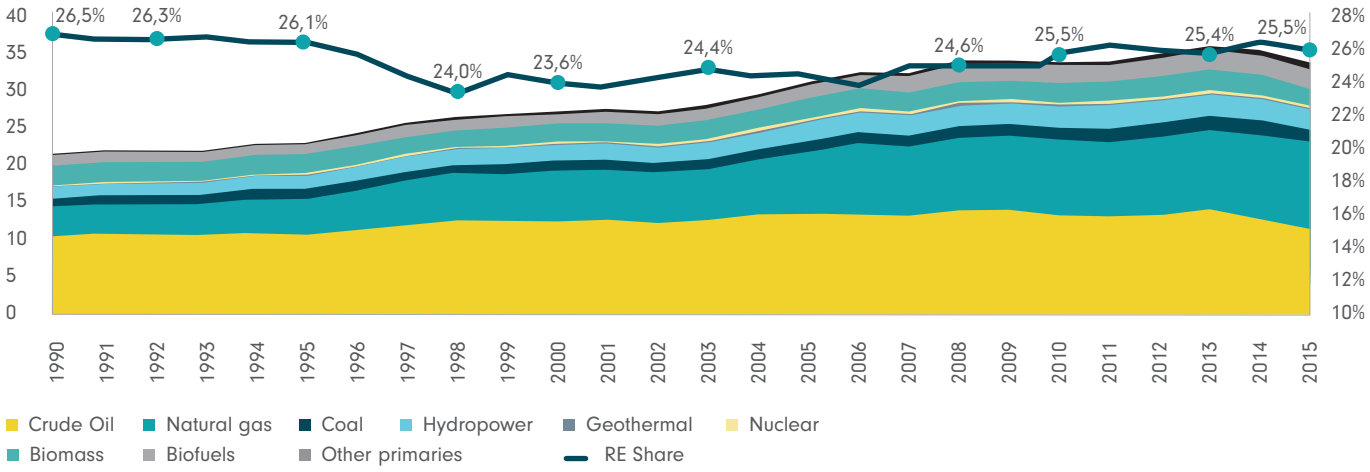
Note: Solar is in practice a limitless resource. However, in this study, the potential solar resource was bounded base on limited space availability (assuming 269 million hectares for Mexico and Central America and 1,761 for South America) with an average land use factor of 0.6, average solar irradiation of 152.4 to 175.9 W/m2, 25% conversion of efficiency, and a performance factor of 90%.

LAC still relies heavily on fossil fuels, although it has steadily decarbonized

Primary energy supply in the LAC region is predominantly reliant on fossil fuels, at 72 percent in 2014 (Latin American Energy Organization Energy-Economic Information System (OLADE-SIER)). The rest is hydropower (8.1 percent), solid biomass (7.6 percent), nuclear (1 percent), geothermal (0.6 percent), and other (3 percent, including wind, solar, and modern biomass).

Changes in total primary energy supply (TPES) and total final energy consumption (TFEC) show three important regional energy trends in the 1990-2014 period: (1) an increase in the share of fossil fuels accompanied by a gradual decarbonization (mainly due to a shift from oil to gas), (2) a decline in the use of solid biomass for cooking and heating, most probably because of increased access to modern non-solid fuels, and (3) a decrease in the share of renewable energy (Figure 1.4).[4]

FIGURE 1.4 Total Primary Energy Supply (1990-2015) *(Millions of terajoules (TJ), left axis; percent, right axis)*



Source: Prepared by authors based on data from OLADE-SIER (database).

On the demand side, compared to many other regions, LAC uses a high level of renewable resources—25.5 percent of its primary energy. But it still relies heavily on oil and gas, importing 35 percent of its oil and 43 percent of its gas.[5] The use of coal is comparatively limited. During the economic slow-down of recent years, the growth rate of TPES gradually declined from a CAGR of 3.5 percent over the 1990-2000 period to 2.5 percent between 2008 and 2012, before increasing again slightly in 2013-2014.

The overall share of modern renewable energy in TFEC has also been declining in the region, from 32.3 percent in 1990 to 27.3 percent in 2014.[6] To some extent this is because the weather impacts of the El Niño Southern Oscillation (ENSO)[7] constrained hydropower production while overall energy demand continued to increase. It is important to note that the region has been a leader in the production and use of biofuels, led by the Brazilian biofuel industry. Despite the rise in the share of fossil fuels in energy supply, carbon emissions from energy use have gradually declined because of a steady shift from oil to natural gas.

At the regional level, the transport and industrial sectors were the primary energy consumers in 2014, consuming 36 and 31 percent respectively of TFEC. The residential sector accounted for 16 percent.[8]

The share of hydropower in electricity production has gradually declined

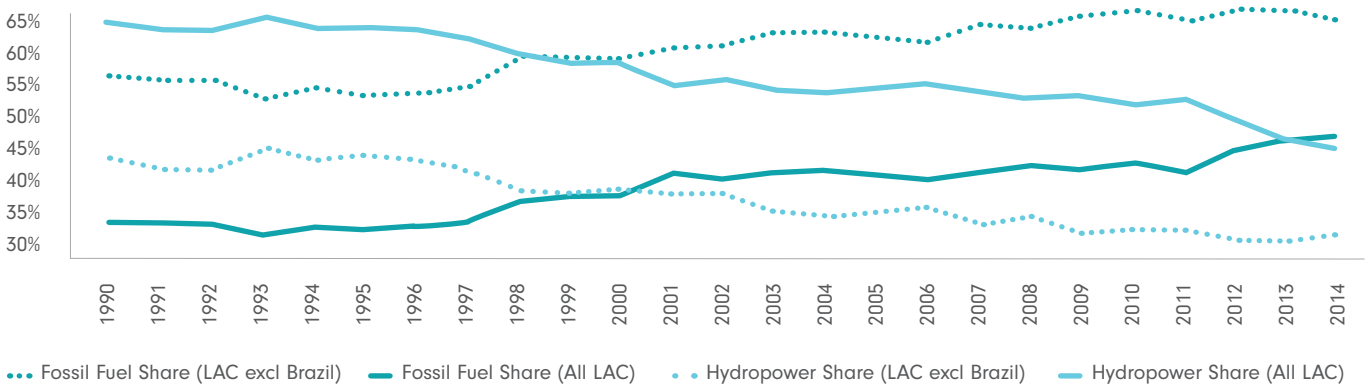
During the 1990-2010 period, electricity demand in LAC rose more rapidly than the global average (at an average annual rate of 5.3 percent compared to a global average of 3 percent). The recent economic stagnation in the region has reduced electricity demand growth rate substantially (the rate was 2.7 percent in 2014).

Hydro supplied 58 percent of the total regional electricity supply in 2013 (1,183 TWh) and accounted for 54 percent of total installed generation capacity (146 GW of the total 270

GW). The region includes many of the countries in the world that have the highest share of hydropower in electricity supply: Uruguay, Colombia, Costa Rica, Ecuador, Brazil, Peru, Panama, and Paraguay.

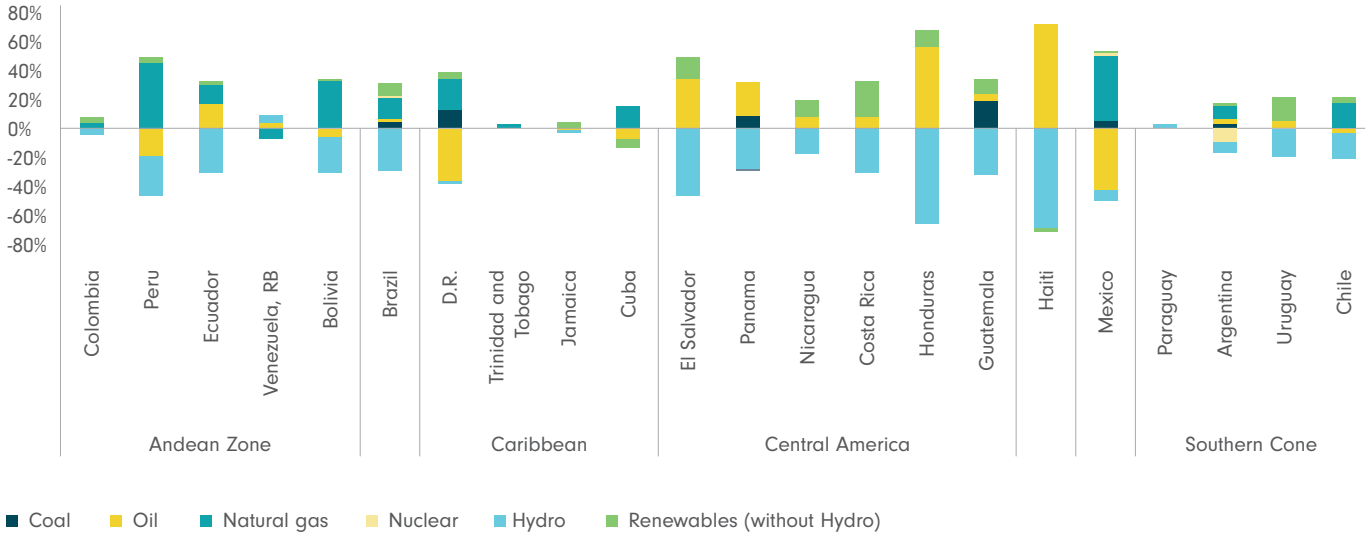
Hydropower's share of generation in LAC, however, has declined consistently since 1990 (see Figure 1.5). To some extent, this is due to increased use of natural gas for generation, but also playing a role are changing hydrological patterns, transmission and distribution constraints—limited capacity and congestion—and difficulty of obtaining environmental licenses.[9] Bolivia, Ecuador, Peru, Central American countries, Haiti, Uruguay, and Chile all reduced their share of hydropower generation between 1990 and 2014 (Figure 1.6).

FIGURE 1.5 Composition of Hydropower and Fossil Fuel Based Generation in LAC (with and without Brazil) (1990-2014) *(Percent)*



Source: Prepared by authors based on data from IEA Energy Statistics and Balances (database) 2017.

FIGURE 1.6 Change in Fuel Source for Generation (1990-2014) *(Percent)*



Source: Prepared by authors based on data from IEA Energy Statistics and Balances (database) 2017.

Natural gas consumption accounted for 24 percent of primary energy consumption in 2014 in LAC but there is strong variation at the country level (OLADE-SIER). Natural gas accounts for 68 percent of energy consumption in Trinidad and Tobago and 53 percent in Argentina—both are natural gas producers—but comparatively less in Brazil (12 percent), Chile (12 percent), and Ecuador (8 percent). Overall, the use of natural gas in LAC's power mix has expanded 2.5 times since 1990.

Energy security in the LAC region varies significantly by country

The World Energy Council's energy security dimension of its Trilemma Index provides a good proxy for a comparative analysis within the region.[10] Some LAC countries, including Venezuela, Colombia, Uruguay, Chile, and Argentina are ranked among the top 44 globally. However, other countries in the region have very low rankings, including Jamaica, Dominican Republic, Honduras, Guatemala, and Panama (Figure 1.7).[11] Overall, Caribbean and Central American countries have lower scores in the World Energy Council's (WEC) energy security indicator than the LAC average. And the Southern Cone and Andean economies—except for Bolivia and Paraguay—are doing better on this front.

When ranked by a simpler indicator, TPES's fuel diversity index, Ecuador, Trinidad and Tobago, and Jamaica have very low fuel diversity (or a high concentration of a particular fuel).

Diversity of electricity supply is a particularly significant element of energy security for the region. Given climatic variability's impact on rainfall in LAC and the heavy dependence of some countries on hydropower, diversification is of increasing importance (see Figure 1.8). At the same time, many of the smaller countries still rely heavily on oil-based generation. While physical constraints on oil availability are unlikely, and global oil prices remain at low levels, such countries are susceptible to the economic consequences of fluctuating oil prices.

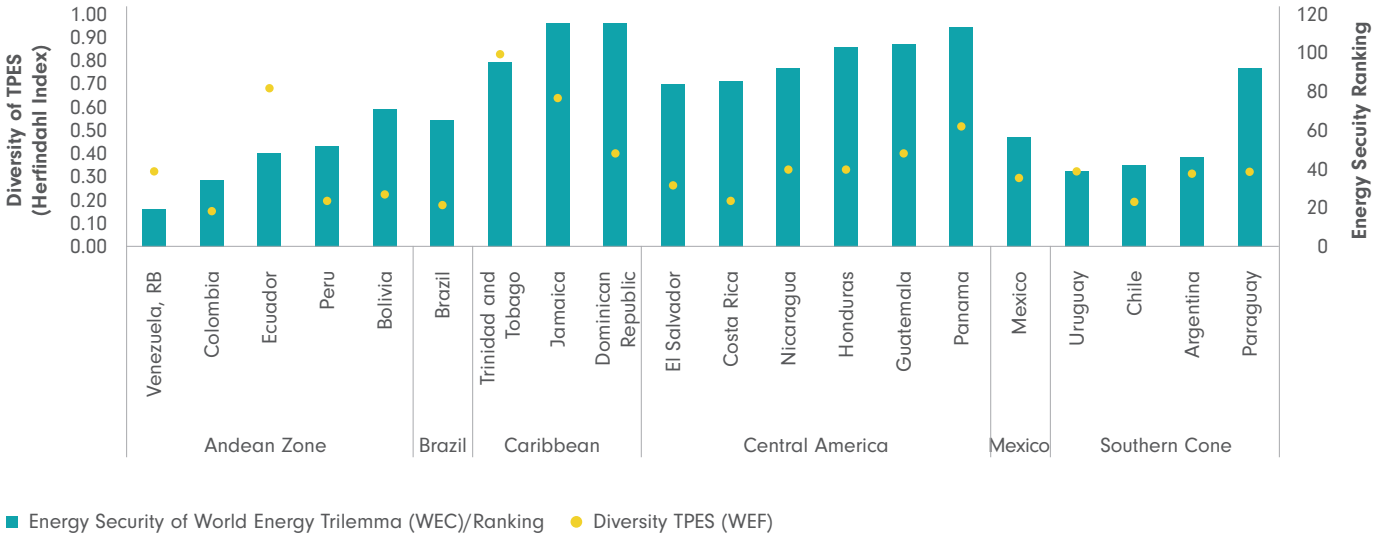
Providing access to a more secure and diverse electricity supply is therefore a priority. This can be achieved by improving the efficiency of production, transmission, and distribution, improving end use efficiency, and implementing demand-side management. In addition, security can be improved by investing in alternative electricity supply options including gas and diverse forms of renewable energy, and by improving regional interconnections. Several countries are making strides in this direction. For example, Brazil has stimulated increased levels of gas, wind, and solar generation in recent years to meet rising demand without increasing hydropower dependence.

The regional trend toward decarbonization, which has meant in practice a substitution of natural gas for oil, has been constrained by the capacity of natural gas infrastructure within the region. This has led to increased importing of LNG. Thus, increased use of natural gas has not necessarily improved energy independence even though the region has significant natural gas reserves of its own (see Chapter 3).

Matrix 1.1 shows a benchmarking of various indicators associated with energy security and resilience for different LAC groups, peers and comparators.[12] Mexico and Brazil are

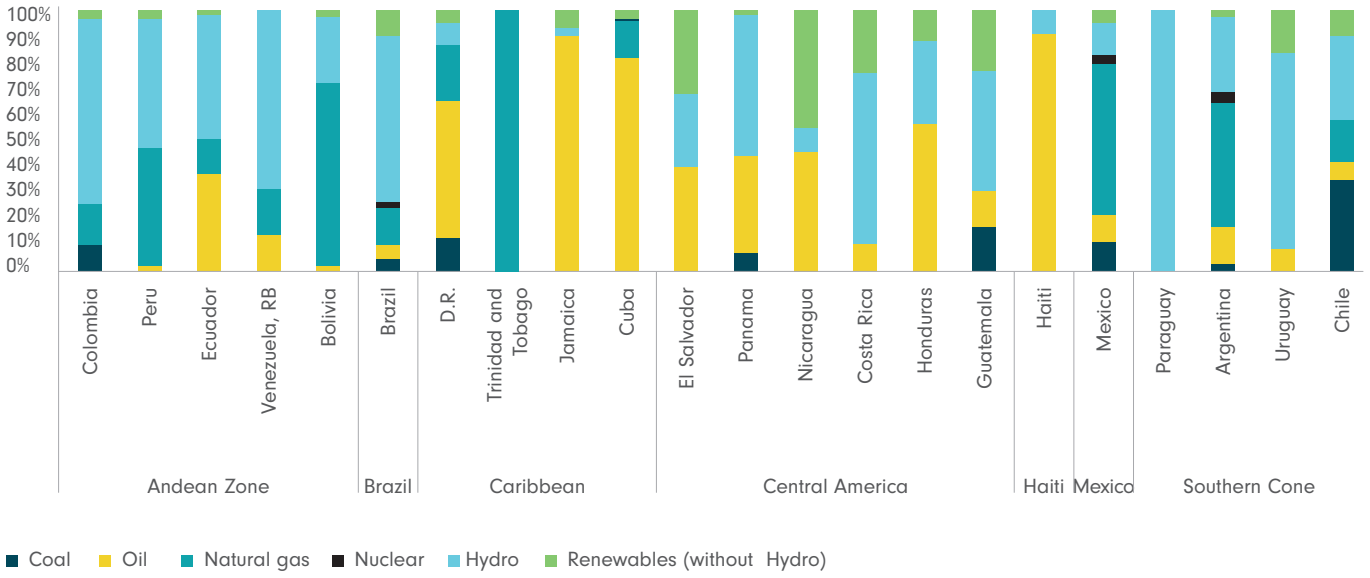
compared to the East Asia and Pacific "tigers" (China, South Korea, and Singapore), showing that the tigers countries have higher aggregated energy intensity (aligned to their economic growth), lower fossil fuel energy depletion indexes, but similar WEC energy security index levels.

FIGURE 1.7 Energy Security and TPES Diversity (2015) *(Indexes)*



Sources: World Economic Forum (WEF) and Accenture 2016; World Energy Council (WEC) and Oliver Wyman 2016; and IEA Energy Statistics and Balances (database) 2017.

FIGURE 1.8 Electricity Output by Source *(Percent)*



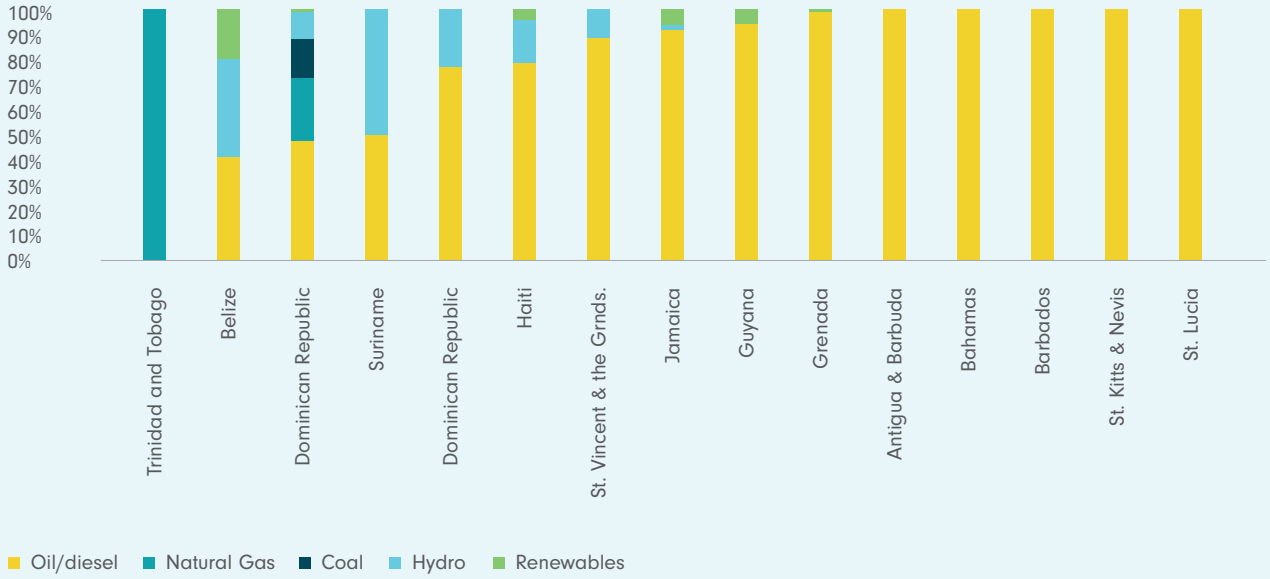
Source: Prepared by authors based on data from IEA Energy Statistics and Balances (database) 2016.

BOX 1.1 Oil Dependence in the Caribbean

Oil provides for more than 90 percent of primary energy needs in the Caribbean, making the region highly vulnerable to price fluctuations. With the exception of Trinidad and Tobago, the Caribbean region imports most of the petroleum products - diesel and heavy fuel oil – needed for electricity generation and transportation. The Caribbean is endowed with abundant renewable energy resources (geothermal, solar, wind, biomass, and marine) and have increased access to LNG, but it is yet to fully diversify its electricity generation matrix.

Dominican Republic and Jamaica are now starting to deploy solar and wind based generation, and geothermal solutions are being prepared in five countries (Dominica, Grenada, St. Kitts and Nevis, St. Vincent and the Grenadines, and St. Lucia). Figure below shows composition of electricity output in Caribbean countries.

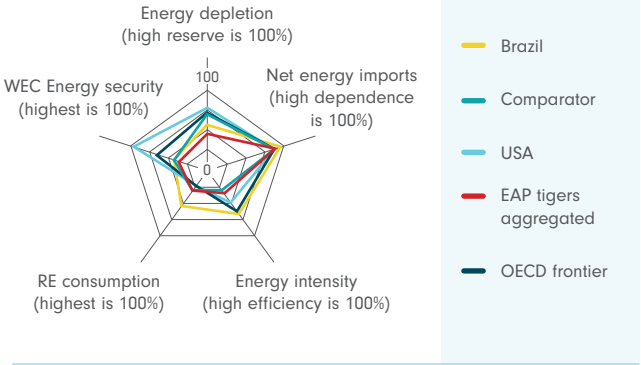
Electricity Sources in the Caribbean, 2012



Source: Prepared by authors based on data from World Bank World Development Indicators (WDI) (database); and Multilateral Investment Fund and Bloomberg New Energy Finance, 2012.

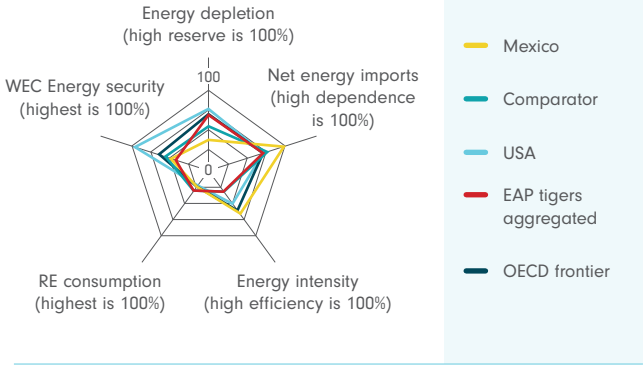
MATRIX 1.1 Measures of Energy Security: LAC Groups, Peers, and Best Practice Frontier

Brazil



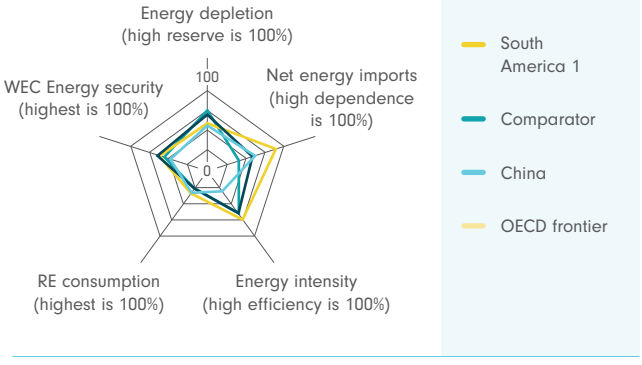
1. Comparators: China, Turkey, Thailand.
2. EAP tiger countries: China, Korea, Singapore
3. OECD frontier: Australia, Canada, Chile, France, Italy, Korea, Rep., Mexico, Poland, Portugal, Turkey, United Kingdom.

Mexico



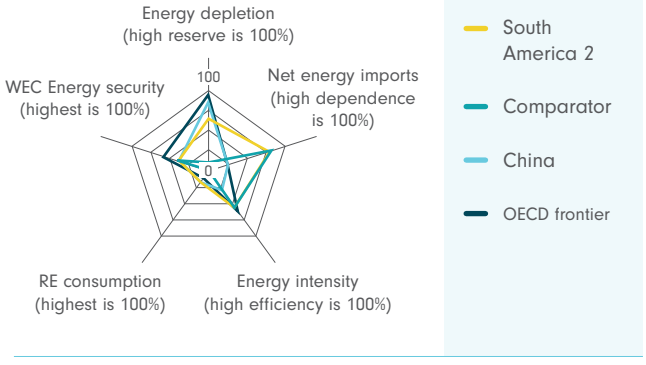
1. Comparators: China, Malaysia, Poland.
2. EAP tiger countries: China, Korea, Singapore.
3. OECD frontier: Australia, Canada, Chile, France, Italy, Korea, Rep., Mexico, Poland, Portugal, Turkey, United Kingdom.

South America 1



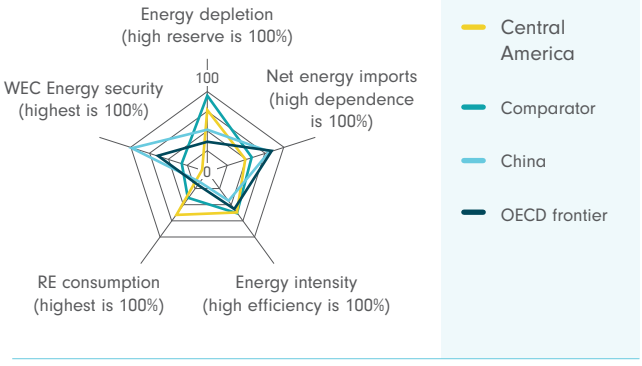
1. Countries in South America 1: Uruguay, Peru, Colombia, Chile, Argentina.
2. Comparators: Hungary, Turkey, Poland, Croatia, Bulgaria.
3. OECD frontier: Australia, Canada, Chile, France, Italy, Korea, Rep., Mexico, Poland, Portugal, Turkey, United Kingdom.

South America 2



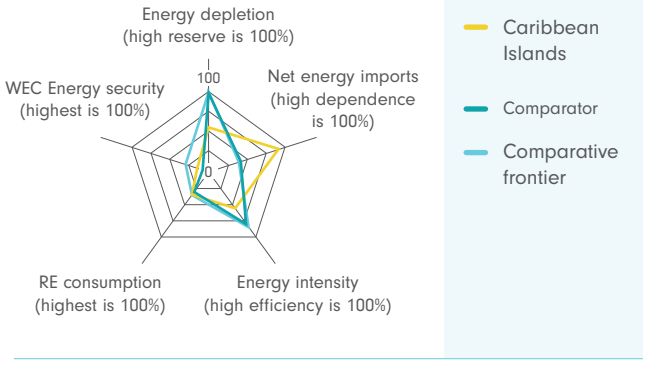
1. Countries in South America 2: Venezuela, Paraguay, Ecuador, Bolivia.
2. Comparators: Algeria, Azerbaijan, Iraq, Uzbekistan.
3. OECD frontier: Australia, Canada, Chile, France, Italy, Korea, Rep., Mexico, Poland, Portugal, Turkey, United Kingdom.

Central America



1. Central America: Panama, Nicaragua, Honduras, Guatemala, Costa Rica
2. Comparators: Bulgaria, Sri Lanka, Armenia.
3. OECD frontier: Australia, Canada, Chile, France, Italy, Korea, Rep., Mexico, Poland, Portugal, Turkey, United Kingdom.

Caribbean



1. Caribbean small states: Includes only Jamaica and Dominican Republic.
2. Comparators: Mauritius, Maldives, Tonga, Seychelles, Samoa.
3. Comparative frontier: Greece, Cyprus, Malta.

1. Energy security dimension of the World Energy Council's (WEC) Trilemma Index.
2. Energy depletion reflects domestic energy resource reserve. Energy depletion (% of GNI) is ratio of the value of the stock of energy resources to the remaining reserve lifetime (capped at 25 years). It covers coal, crude oil, and natural gas.
3. Energy independence is based on net energy imports data, estimated as energy use minus production, both measured in oil equivalents. A negative value indicates that the country is a net exporter.
4. Energy intensity level of primary energy is the ratio between energy supply and gross domestic product measured at purchasing power parity. Energy intensity level reflect the efficiency of energy use.
Source: World Bank WDI (database); WEC 2016.

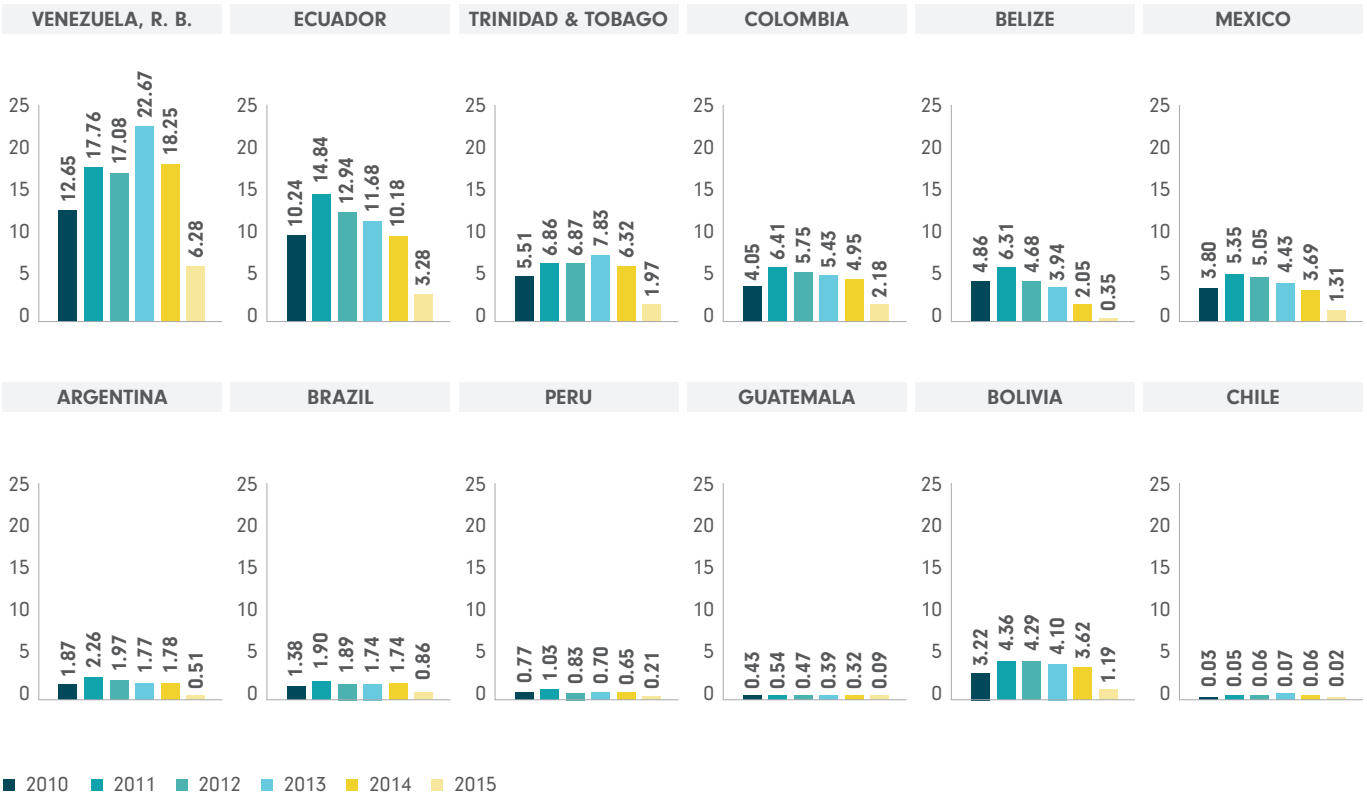
Changes in international oil prices have major—but varying—impact on LAC economies

The plunge in world oil prices—from $105 per barrel in mid-2014 to current levels of $25-40—has had important fiscal implications for net oil importers and exporters in LAC (Figure 1.9).

The impact on net oil exporters in LAC (Bolivia, Colombia, Ecuador, Mexico, Trinidad and Tobago, and Venezuela) is negative. In most of these countries, oil operators and dominant state-oil companies provide significant fiscal revenues through royalties, profits, income taxes, and dividends. Ecuador, Mexico, and Trinidad and Tobago have already begun to curb spending to offset the decline in hydrocarbon-related revenues. It is in Venezuela—where oil rents dominate the economy—that low oil prices have had the most dramatic impact.

Most net oil-importing economies in LAC, on the other hand, are benefiting to some extent from the reduction in oil prices. Though proceeds from taxes on oil imports have declined, the cost of fossil fuel subsidies has fallen.

FIGURE 1.9 Oil Rent in LAC *(Percent of GDP)*

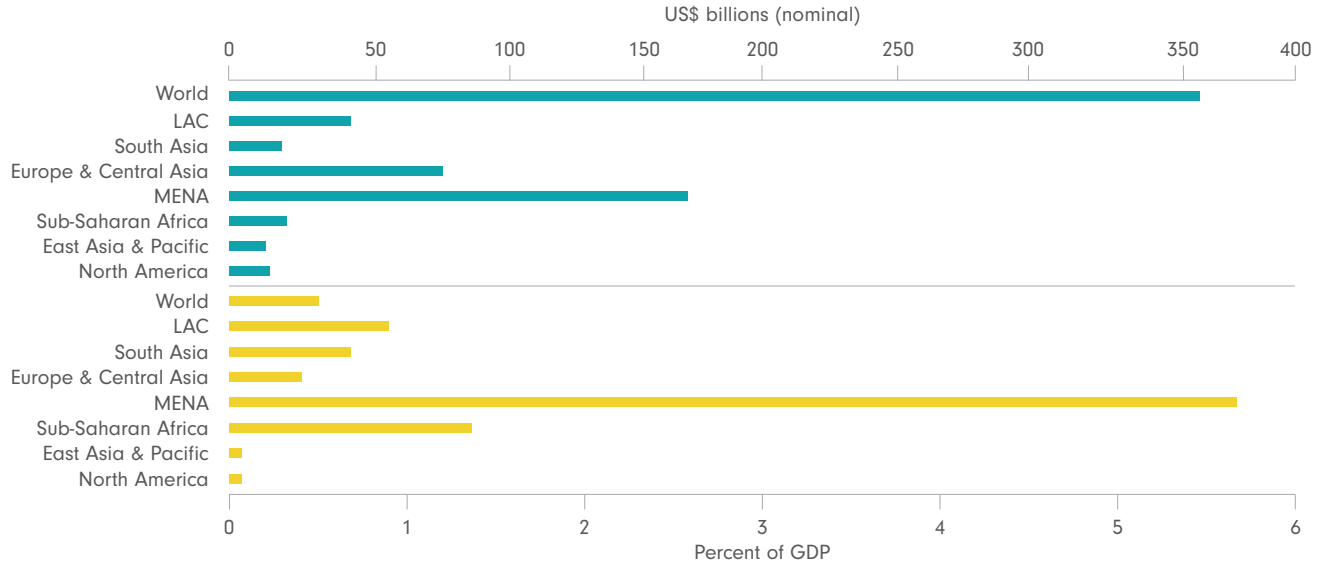


Source: World Bank WDI (database).

Energy subsidies are high and well above the global average

Energy subsidies in LAC are estimated at about 0.68 percent of GDP, which is almost 14 times higher than in advanced economies and emerging Europe (Figure 1.10).

FIGURE 1.10 Energy Subsidies by Region (2016) *(USD Billions nominal and Percent of GDP)*



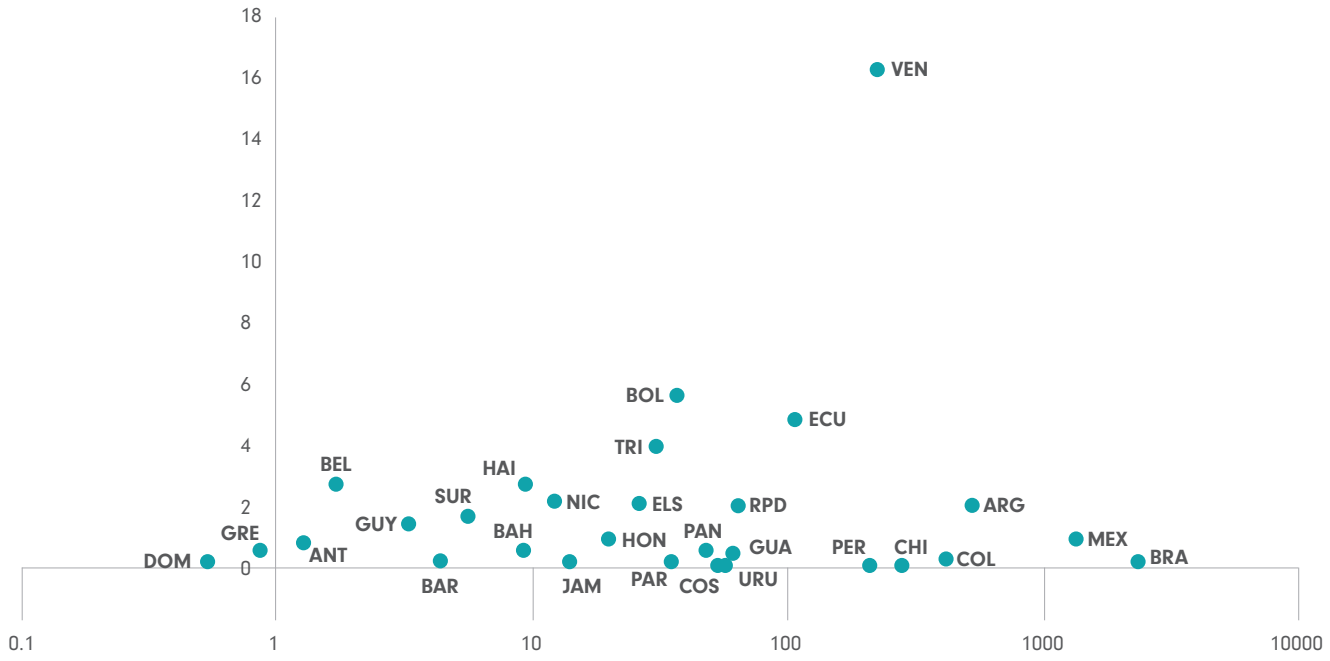
Source: Prepared by authors based on data from Coady et al. 2015.

The countries with the highest fiscal impact of subsidies, ranging from 2 to 16 percent of GDP, are in Central America (Belize, Nicaragua, and El Salvador), the Caribbean (Trinidad and Tobago and Haiti), and the Andes (Venezuela, Bolivia, and Ecuador). See Figure 1.11.

Governments in LAC generally do not have a unique price-setting process for all hydrocarbon products. Instead, they set the price for some products while maintaining a market-based price for others. And even in cases where there is a uniform pricing strategy, governments may also influence final prices via the tax structure (Beylis and Cunha forthcoming 2017).

Various governments in LAC have policy tools intended to stabilize or smooth domestic fuel prices. Colombia and Peru have price stabilization funds for fuels. Mexico instead uses an excise tax to smooth out the trajectory of domestic fuel prices and avoid the volatility of international oil prices. Not all price stabilization funds have worked, however. During the 2000s, for example, funds established in Colombia and Peru did not achieve the intended self-financing, leading the government to consistently grant exceptional loans over the years.

FIGURE 1.11 Energy Pre-Tax Subsidies by Country vs GDP (2015) *(Percent of GDP, vertical axis; Nominal GDP log USD Billions, horizontal axis)*



Source: Coady et al. 2015.

Some countries have devoted large fiscal support to keeping energy prices low. Subsidies to gasoline and diesel are generally delivered through interventions in the price-setting process, while subsidies for LPG and kerosene (generally used for cooking or lighting) are delivered both through government intervention in the price formation and through differential taxation rates. The fiscal costs of underpricing electricity are more modest than with fuels and most of the subsidies are directed towards the residential sector.

Despite the diverse range of pricing policies in the region, final post-tax electricity prices are relatively high in LAC. The electricity sector has also been subject to other types of government intervention in the region.

Most electricity tariffs are composed of a fixed charge, which covers the remuneration for distributors and transmission network operators, and a variable charge that depends on the amount of energy consumed and the costs of generation. Price intervention by governments has focused on this last component, to avoid passing increased generation costs through to consumers. High oil prices in the past had a significant impact on generation costs—especially for countries relying heavily on fossil fuel-based thermal generation—and governments have intervened with different policy tools.

Governments in LAC have adopted different approaches for the pricing of electricity—particularly for residential consumers. Most countries have Increasing Block Tariff (IBT) structures—also called progressive tariffs, tiered-rates or inverted block rates—which provides lower-cost electricity to consumers with low levels of consumption while charging higher

prices to higher-volume consumers. Some countries have combined the IBT structure with a volume-differentiated tariff structure in which the unit price of electricity increases with the level of consumption.

Overall, the challenge of reducing the fiscal impact of energy subsidies lies in the capacity of the government to introduce transparency and competition and design smart subsidies, learning from the regional and international experience.

A few countries in LAC have made substantial progress in reducing or eliminating subsidies. Uruguay, Peru, Costa Rica, Mexico, and Chile are all examples (Box 1.2 describes progress in Mexico).

BOX 1.2 Mexico: Impact of Phasing Out Fuel Subsidies

Some countries are acting to reform large and inefficient energy subsidies. Mexico has made significant progress. At the end of the 2000s, its electricity, diesel, gasoline, and liquefied petroleum gas subsidies represented 1.8 percent of the country's GDP (on average Mex$200.4 billion per year). 63 percent of the subsidies went to electricity and 31 percent to gasoline and diesel. Fuel subsidies were regressive: the richest 20 percent of Mexico's citizens—the ones who own most of the cars and electrical equipment— received 59 percent of the subsidy, while the poorest 20 percent got only 3 percent. Overall, fuel subsidies encouraged consumers to use more fuels than they would if market prices prevailed.

A World Bank study conducted in 2013 found that removing energy subsidies would increase GDP 1.5 percent by 2030 even if the funds were not reallocated to more productive use. The analysis found that cutting fuel subsidies would reduce fossil fuel consumption, leading to significant reduction of greenhouse gas emissions, air pollution, and overexploitation of aquifers.

The government of Mexico phased out fossil fuel subsidies from 2013 to 2015. An ex-post analysis estimates that this action reduced gasoline consumption by 11 billion liters and kept 26 million tons of CO2 out of the atmosphere. However, the damage caused by fossil fuel use remains significant and includes pollution, congestion, and road accidents. Taxing fossil fuels is helping to reduce such effects.

Source: Sanchez-Triana Forthcoming.

The private sector has played a key role in energy infrastructure investment

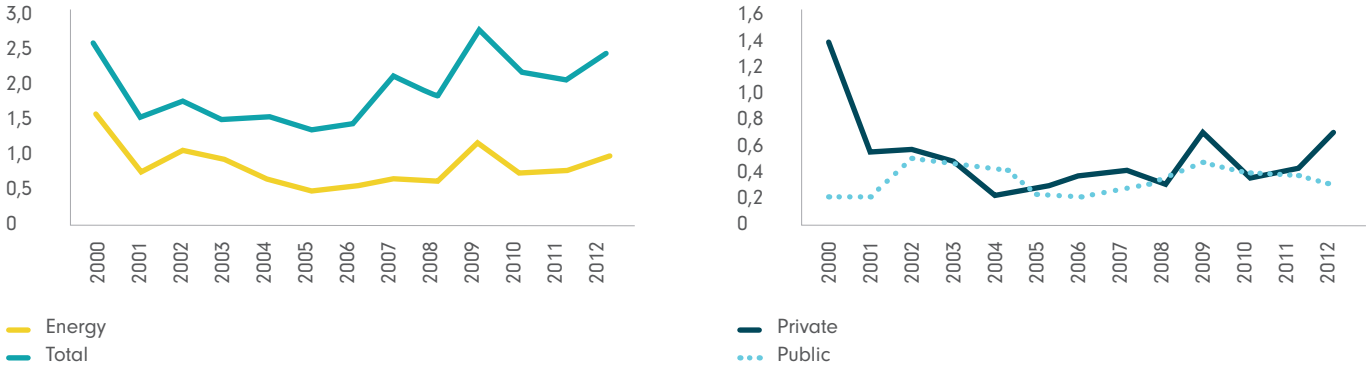
Public investment in energy infrastructure has remained in the range of 0.2-0.5 percent of GDP over the last few years. Private investment, however, has followed a more cyclical pattern that responds to external shocks but also to domestic events in the large economies of the region (Figure 1.12).

Concerning government finances, the LAC region has a large aggregated fiscal deficit, the result of rising interest rates, currency depreciations, and lower prices for oil and other commodities. Brazil, Colombia, Mexico, Colombia, Ecuador, Venezuela, and

Trinidad and Tobago have suffered a contraction of their fiscal space in recent years. A few countries in Central America and the Caribbean have managed to improve their fiscal balances recently, but they remain vulnerable to external shocks.

The fiscal deficit undermines government capacity to invest in energy infrastructure (Box 1.3). Thus, private investment will continue to be key to energy infrastructure growth. Public spending will need to be increasingly efficient, used, for instance, to mobilize private investment, and targeted at the appropriate segments and projects not only for new infrastructure but also to improve performance of existing assets.

FIGURE 1.12 Public and Private Investment in Electricity and Gas Infrastructure (2000-2012) *(Percent of GDP)*



Source: Infralatam (database).

Note: Infralatam includes electricity (generation, transmission, and distribution) and natural gas (transmission and distribution).

BOX 1.3 A tight fiscal stance limits expenditures in infrastructure

The evolution of the public sector's budget constraint—which plays a big role in shaping fiscal space—matters for the level of infrastructure investment. Public investments in infrastructure in Latin America respond to lagged changes in public savings. However, this response is asymmetric, being stronger in good times, when lagged public savings rise, than in bad times, when lagged public savings fall (Serebrisky et al. 2015).

Many countries in Latin America are now facing persistent and often sizable fiscal deficits, which are bound to impact their ability to undertake much-needed public investments in infrastructure even with the asymmetry discussed above. But the overall fiscal picture is not uniform across the region.

A highly heterogeneous fiscal space picture has emerged in the region, largely driven by trade structure (De la Torre et al. 2016). Two broad groups have been identified: South America, dominated by net commodity exporters, which are generally following China's ups and downs, and the Mexico-Central America-Caribbean (MCC) group, where net commodity importers prevail, and which is generally following the U.S. cycle. Fiscal balances have deteriorated markedly in most of South America, but not so much for the average MCC country.

Source: Fay et al. 2017.

Notes

1. The New Policies Scenario (NPS) of the World Energy Outlook broadly serves as the IEA's baseline scenario. It takes account of broad policy commitments and plans that have been announced by countries, including national pledges to reduce greenhouse gas emissions as well as plans to phase out fossil fuel subsidies, even if the measures to implement these commitments have yet to be identified or announced.

2. Global power demand is estimated in 19.7 PWh (IEA 2015).

3. Assuming an average efficiency of 15 percent in solar technology and use of 4 percent of the Atacama area, solar power could deliver a volume of energy equivalent to what could be generated using all oil reserves in Saudi Arabia with current thermal technologies (WRI, 2017).

4. The decarbonization trend has been less pronounced in TFEC. Oil remains the dominant source of LAC's total final energy consumption, accounting for 52.6 percent of the total at the regional level (see Annex I).

5. Figures 1a and 1b in the Annex provide a more detailed breakdown of energy supply and use.

6. Modern renewable energy in this report excludes traditional uses of solid biomass.

7. ENSO is an irregularly periodical variation in winds and sea surface temperatures over the tropical eastern Pacific Ocean, affecting much of the tropics and subtropics. The warming phase is known as El Niño and the cooling phase as La Niña.

8. Annex I provides a detailed analysis of regional energy production and consumption, TPES, TFEC, and electricity.

9. Many studies describe the discretionary nature and procedural complexity of environmental and social permitting in the region, notably for hydropower developments. Projects that require the flooding of large areas may lead to significant impacts on biodiversity and affect the livelihoods of indigenous communities. There has been intense opposition to large hydropower developments from environmentalists and indigenous organizations in many LAC countries (projects installed in Xingu River in Belo Monte, Brazil, Alto Maipo in Chile, EL Quimbo in Colombia, Barro Blanco in Panama, Cahabón River in Guatemala, and Agua Zarca, Honduras are a few examples).

   The fact that many projects obtain the necessary environmental and social licenses, but nevertheless remain a source of conflict and are often halted by judicial processes, poses serious questions about the effectiveness and legitimacy of such licenses. These problems also extent to run-of-river developments and other energy infrastructure projects, although the magnitude of social and environmental impacts vary depending on the characteristics of the project and its location.

   The adequate planning and preparation of a large hydroelectric plants requires complex environmental impact assessments and long periods of consultation to comply with national legal frameworks and Convention 169 of the International Labor Organization (ILO) on indigenous people's rights.

10. In WEC's index, energy security is scored with six indicators: (1) Ratio of total energy production to consumption, (2) Diversity of electricity generation, (3) Distribution losses as a percentage of generation, (4) Five-year CAGR of the ratio of TPEC to GDP, (5) Days of oil and oil product stocks and (6) Net fuel imports as a percentage of GDP (for importers) or fuel exports as a percentage of GDP (for exporters).

11. Not all countries are ranked, including Antigua and Barbuda, Belize, Dominica, Grenada, Guyana, Haiti, Puerto Rico, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, and Suriname.

12. Peers and comparators were selected based on similarity in economic and poverty indicators.

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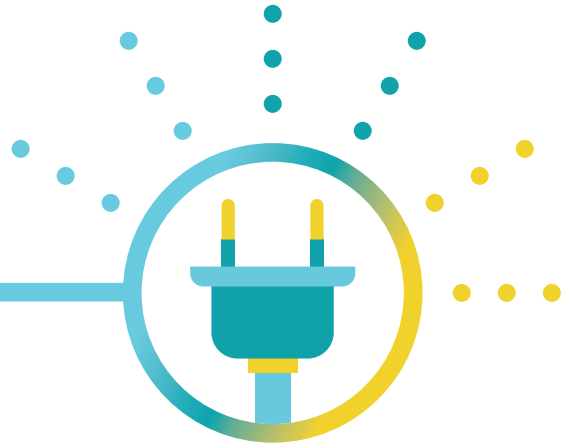
CHAPTER 2

Electricity Markets



Many countries in LAC have developed sophisticated electricity markets

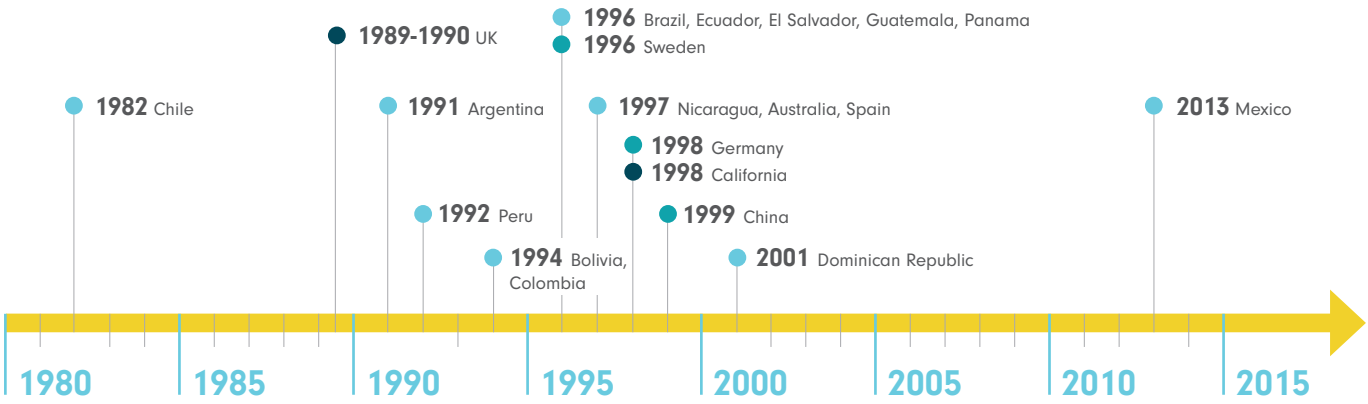
From the early 1980s, many countries of the LAC region—Chile in 1982 followed by Argentina in 1991—began pioneering different models of power sector reform (Figure 2.1). The main objectives initially were to improve service quality, strengthen security of supply, and reduce public debt. To those ends, governments rewrote the regulations for network services, fostered market competition, and allowed private-sector participation. The reforms served to transfer risks, rights, and obligations to power companies and avoid the creation of public sector liabilities.

Other countries in the region chose not to go for comprehensive reform and instead maintained their state-owned monopolies. These included Mexico, Uruguay, Costa Rica, Honduras, Paraguay, and most Caribbean island states. Yet even in these countries, the monopolies were not left untouched. Mexico, Costa Rica, Honduras, and Uruguay promoted competition in generation though introduction of independent power production (IPP). Mexico made perhaps the most progress with this strategy, although in 2013 it too introduced a full energy sector reform, including both hydrocarbons and electricity.

Countries that did opt for comprehensive reform proceeded in different ways and at different times, as shown in Figure 2.1 and Map 2.1, but there were recurring structural changes: vertical unbundling of generation, transmission, and distribution; horizontal unbundling of the generation and distribution business (functional or accounting separation); establishment of wholesale electricity markets; introduction of quality of service regulations and performance-based multi-year tariff regimes; and segmentation of regulated and non-regulated markets, giving large consumers freedom to choose suppliers at negotiated prices. In most countries, reform combined privatization of existing assets with introduction of new greenfield projects. The new markets introduced organizations that included independent regulators and specialized system and market operators.

Due to the region's high reliance on hydroelectric generation, reforms in many countries preserved the concept of least-cost and security-constrained dispatch (based on hydrothermal optimization and in some cases value of water). Except for Colombia, all countries adopted a cost-based bid approach to price energy in the short-term market.

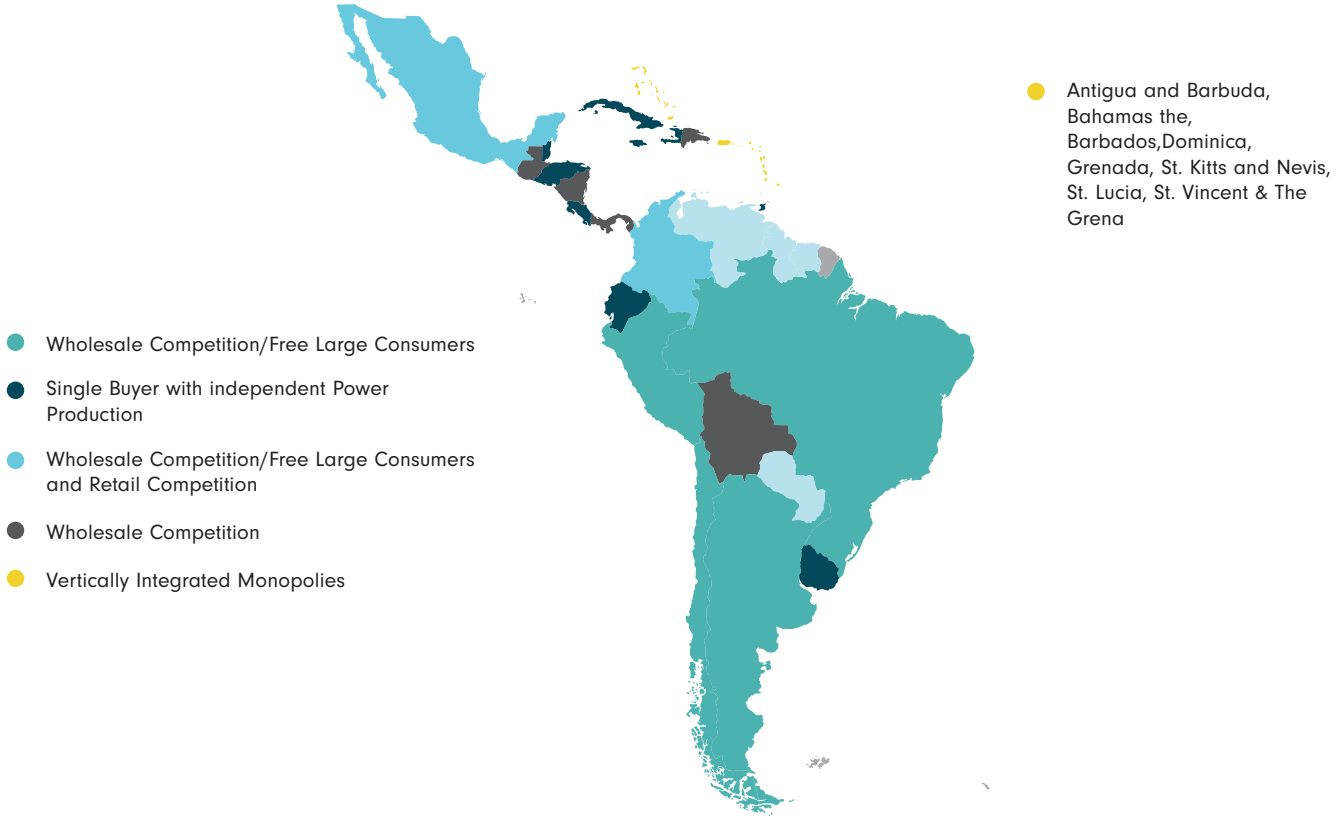
FIGURE 2.1 Timeline of Power Sector Reforms



Source: Prepared by authors.

Notes: Countries in blue introduced reforms structurally similar to those in LAC. Countries in green introduced reforms for different reasons of in structurally different ways as LAC countries, e.g.: triggered by EU Directives.

MAP 2.1 Type of Market Structure



Source: Prepared by authors.

BOX 2.1 Waves of Adjustments to Power Sector Reforms in LAC

Initial Reforms (early 1980s to early 2000s)

- Restructuring: vertical and horizontal unbundling, divesting, and privatization
- Institutional reorganization: independent regulators and system operators, administrators
- Liberalization (wholesale markets): spot and contract markets ("competition in the market")
- Regulated capacity payments to ensure supply adequacy

In this initial stage, the reforms sought to promote competition in generation and attract private capital for capacity expansion. There were initial attempts to create competitive spot markets, but vesting contracts were soon allowed between generators and distributors to hedge against spot price volatility. Yet, prices and market signals did not create the conditions for new investments in capital-intensive generation projects, resulting in low reserve margins and periods of rationing in some countries. This indicated lack of formal instruments to guide market-based system expansion in systems with high demand growth rates. In addition, incentives to extend service to poor or rural areas were weak.

Wave 1 (early 2000s-onwards)

- Reintroduction of indicative expansion plans, in some cases with the intention to guide procurement of new infrastructure
- Launching of tenders or auctions to award long-term contracts and ensure timely investment in new generation capacity ("competition for the market"). Resulting prices served as a basis for the pass-through of power purchase costs by distribution companies to regulated consumers. In some systems, auctions focused on strategic projects such as large hydrothermal plants and cold reserve.
- Market-based mechanisms introduced to ensure security and affordability of supply: capacity adequacy requirements (forward markets), auctioning of firm energy (reliability charge), and replacing of the traditional capacity payments (Colombia is an example)
- Governments return to planning and extension of energy access in low income and rural areas.

Wave 2 (2009-2010 onwards)

- Introduction of policy and regulatory measures to scale up renewable energy and energy efficiency, including distributed generation and demand-side management
- Increased use of auctions to scale up renewable energy capacity, in part to comply with international commitments, but mainly as a diversification (security of supply) strategy
- Consideration of new market design features to increase competition, such as intraday and locational pricing
- New strategies to strengthen power systems' resilience to more frequent and intense climate events

Source: Prepared by authors.

The relatively small size and lack of interconnection among island nations of the Caribbean has led to the dominance of vertical monopolies (generation, transmission and distribution). However, there are varying degrees of state versus private ownership throughout the region. And, increasingly, there is a move toward opening these markets to at least limited competition in the power generation (Table 2a in Annex I gives additional information on the ownership status of utilities in the Caribbean.

Today the region has impressive experience in electricity reform

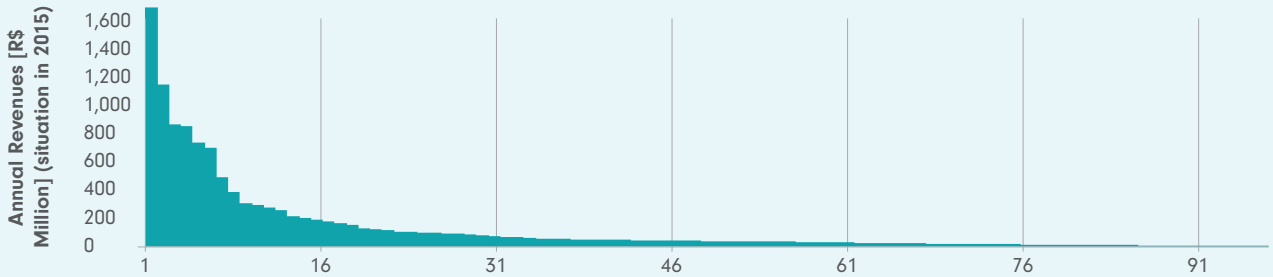
Thirty years into the process, the LAC region has built a wealth of experience in the design and operation of efficient electricity markets, either through regulation or competition. Highlights include:

- Chile pioneered the concept and design of the world's first power sector reform, introducing a competitive market in generation in the early 1980s.
- Argentina carried out a successful "big-bang" reform in the power, gas, and oil sectors. It increased competition, improved production, enhanced quality of service, and attracted new players.
- Colombia refined its regulatory framework to pioneer the auctioning of reliability options, with a goal of ensuring sufficient firm obligations to supply demand under stress conditions, such as the frequent dry spells caused by El Niño.
- Argentina, Brazil, and Peru introduced competitive tenders or auctions for concessions (a kind of Build, Operate and Own (BOO) or Build, Operate, Own and Transfer (BOOT) scheme) to ensure the timely addition of transmission capacity (Box 3.2). This lowered tariffs and raised the number of transmission owners, including private ones.
- Peru, Brazil, Uruguay, Chile, Panama, El Salvador, Guatemala, and more recently Mexico and Argentina launched auctions to scale up non-conventional renewable energy. All auctions have attracted great interest from new investors and delivered extremely competitive prices (Box 3.3).

BOX 2.2 Increased Competition and Private Capital Participation Through Concessions for Transmission Expansion: The Case of Brazil

Brazil has developed considerable experience with auctions for transmission concessions. In the 2000-2013 period, Brazil extended its transmission infrastructure by 50,000 kilometers through concessions that today deliver almost $3 billion in annual revenues. The country now has about 90 transmission concessionaires, with notable participation by private players. The auctions have been increasingly competitive, resulting in reduced prices and controlled revenues.

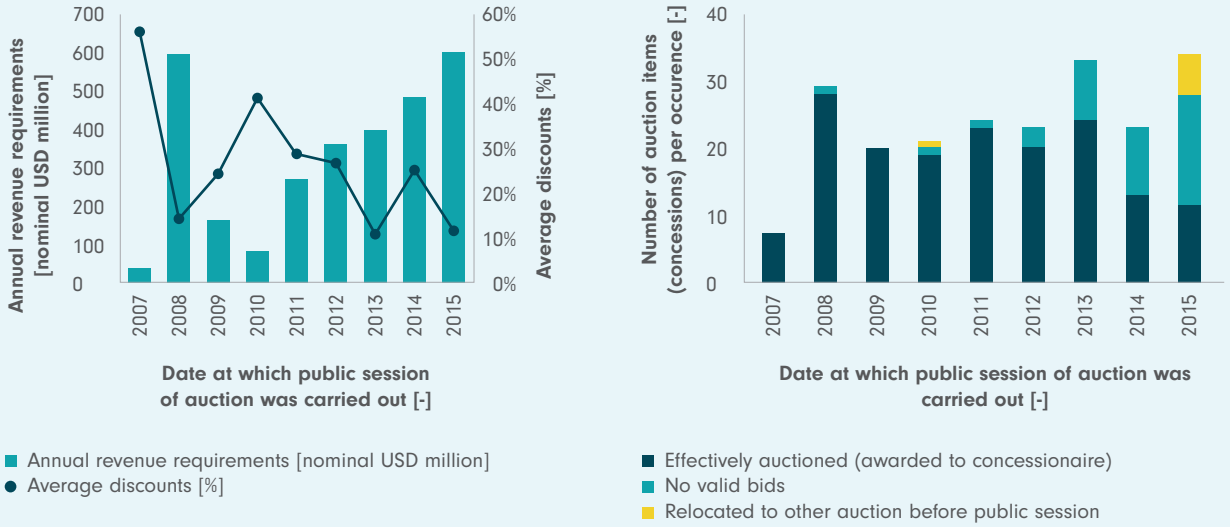
Annual Regulated Revenues (R$ Million)



Source: Prepared by authors based on data from World Bank World Development Indicators (WDI) (database); and Multilateral Investment Fund and Bloomberg New Energy Finance, 2012.

The auction design has been gradually adjusted to discourage delays in construction and underbuilding (for instance, by raising execution completion bonds from 5 percent of capital expenditure in 2000 to 10 percent in 2015). Brazil has learned many lessons in the process, most notably the challenges of properly allocating the risk of delays in environmental licensing and the acquisition of land-use rights.

Brazilian Transmission Auction Results (left) and Concessions Granted per Auction (right) (2007-2015)



Source: De Sa Ferreira et al. 2016.

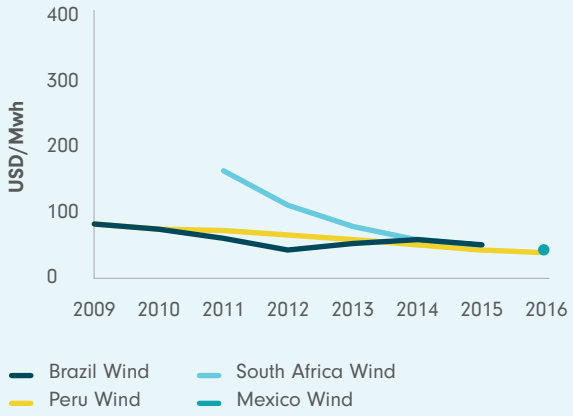
BOX 2.3 Experience with Renewable Energy Auctions in LAC

Latin America has been a pioneer in deploying renewable source-based generation capacity through auctions, increasing transparency and fostering competition.

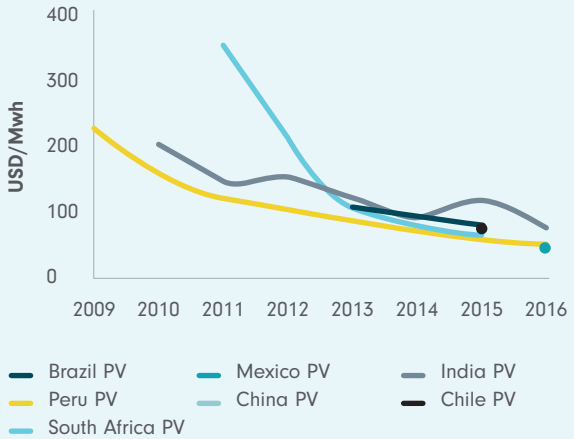
Auctions' ability to deliver renewable capacity at competitive prices has been demonstrated in Brazil and Peru and more recently in Mexico and Chile. Recent LAC auctions achieved several record-breaking low costs for solar PV developments.

Evolution of Renewable Energy Auctions *(USD/MWh)*

Evolution of onshore wind auctions



Evolution of solar PV auctions



Source: Prepared by authors based on Bloomberg New Energy Finance (database).

The path of reform has rarely been smooth, however. Over the long course of electricity reform, politics and financial/economic crises often led countries to backtrack.

- In Argentina, the original reform in 1992 created a wholesale market and retail competition for large consumers. With the economic and financial crises of 2001—including a significant currency devaluation—the government declared a state of emergency and introduced transitional arrangements in the market without altering the main legal framework. These measures included government taking over purchase of fuel oil for generation; providing subsidies for the difference between fuel oil and spot electricity prices, which were estimated as a function of natural gas price; setting regulated electricity tariffs below market prices; and reintroducing centralized planning and public investment for new generation and transmission capacity.

- In Bolivia, the reform of 1994 created a wholesale market and competition for large consumers. In 2009, amendments to the constitution introduced new legal provisions for the electricity sector, and in 2010 a new Electricity Law was enacted, reversing most of the original reforms. Going forward, the government would fund newest investment. A new constitution principle "socialized" the electricity sector to establish lower tariffs that did not cover the costs of electricity supply.

- In Ecuador, the reform of 1996 established a wholesale market. In 2008, due to poor technical and financial performance of distribution companies, privatization was deemed to have failed. New generation investments were delayed and the crisis led to full reversal of electricity sector reform. In 2009, the government reintegrated generation, transmission, and distribution activities, with the state-owned power utility absorbing 10 existing companies. As in Bolivia, tariffs were no longer cost-reflective, with government partially absorbing the cost of service.

- In Venezuela, the government nationalized *Electricidad de Caracas* in 2007. That cancelled a proposed reform that would have unbundled the sector, created a dedicated transmission company with a system operator, set efficient tariffs, and established a competitive market.

- In Dominican Republic, a restructuring and privatization of the electric sector failed to achieve its goals due to multiple factors. Commercial and technical losses were rampant, aggravated by low collection rates. This resulted in the financial breakdown of the distribution sector, which in turn had no resources to pay for energy delivered by independent generators. Without timely payments, generators were not able to pay for fuel, and the financial crisis morphed into a supply crisis. Blackouts became widespread. The country nationalized the distribution system but no significant improvements resulted.

Retail competition and financial hedge are still very limited

The operation of liberalized electricity markets in LAC delivered important lessons of experience. One was the realization that in systems with high rates of demand growth, wholesale markets could not deliver the level of investment required to develop new infrastructure and maintain minimum reserve margins. In Brazil, Peru, Colombia, and Chile, competition "in the market" was substituted for competition "for the market" via auctions for the development of new generation and transmission capacity. The award of power purchase agreements (PPAs) to service captive demand unlocked new investment. This adjustment has limited the scope and depth of retail competition in most LAC electricity markets.

Retail competition is allowed in most countries, but the number of customers switching suppliers is still small. In Brazil, despite high voltage or load threshold levels, most eligible customers have opted to switch to retail competition (Box 2.4). About one-third of the total market (in gigawatt hours) operates on a non-franchised basis, and traders and marketers play an important role. Retail competition via distributed generation "behind the meter" (such as rooftop PV) is allowed in some countries through such arrangements as net-metering, but capacity thresholds are low and participation is still quite modest.[1]

Electricity markets continue to evolve. Colombia, Nicaragua, and Panama have implemented centralized economic dispatch based on price (as opposed to cost) bids. Still, most countries could further enhance some aspects of market design through introduction of nodal pricing and active participation of the demand side in day-ahead and real-time markets. Most LAC countries don't allow demand-side participation and even in those that do, it is seldom utilized.

Financial contracts are sometimes mandated, to hedge against spot price volatility. At the same time, the market for financial derivatives is virtually non-existent in most LAC countries. Except for Mexico, financial transmission rights are not allowed, though they are necessary for markets to move towards a more granular locational pricing framework.

Compared to more advanced power markets, the region still lacks the elements necessary to promote vibrant competition on the demand side (see Matrix 2.1). For

example, Texas and California have centralized economic dispatch based on price bids, intraday markets, nodal pricing, retail competition, and intense demand-side participation. To increase the overall economic efficiency of electricity services, LAC power markets need to foster more competition and improve sector performance, but also to introduce rules that fully unlock the huge market of demand-side resources, including clean energy in distributed business models.

BOX 2.4 Brazil: Retail Competition and Impact on Tariffs

As part of the power sector reform carried out in many LAC countries in the late 1990's, competition was introduced in generation and retail activities. In generation, new independent power producers were allowed to compete on a level playing field with integrated utilities to provide bulk energy – in some cases via auctions. In retail, some customers were allowed to procure energy from alternative suppliers (but still use the grid services from the incumbent distribution utility).

The so called "free-customers" were given the option to self-generate and/or establish bilaterally negotiated contracts with power plants or independent marketers (or traders), therefore benefitting from retail competition. In many developed countries, this prerogative has been given to all customers, but typically only larger ones – or the ones where energy is an important cost element – have opted in and shifted suppliers.

In Latin America, the definition of "free-customer" varies on a case by case basis. One country where retail competition has been relatively vibrant is in Brazil. The definition of "free customer" is the one with a peak load above 3 MW (or 500 kW if the energy is sourced from renewable sources). A large portion of large customers have exercised the option to be served by an alternative supplier, in particular large industrial companies. The "free market" currently represents about 30% of the total energy consumed in the country, and this number could grow to 40% in the short term if the threshold is further reduced.

There are about 70 independent marketers in Brazil offering different types of products and services to suit their customer needs. The main advantage for those customers is the possibility of obtaining energy at more convenient prices and conditions. Under those circumstances, the regulated tariff, which is normally taken into account in many studies on industrial competitiveness no longer applies those customers. The exact terms and conditions in the free market are not known, since those bilateral contracts are confidential. However, it is possible to estimate that free customers benefit from an energy 15 to 20% cheaper than regulated tariffs.

A similar phenomenon will likely be observed in the years to come with the scaling up of distributed generation. Many customers, including high-income residential and commercial ones, which normally cross-subsidize other customer categories, will have incentives to install their own solar PV rooftop panels, therefore reducing dramatically their consumption or even exporting surpluses to the grid. The actual cost of energy to those customers will no longer be the regulated tariffs, but the capital costs to install (or lease) the PV rooftop facility. Dramatic drops in the price of technology is one of the factors that will lead to more retail competition, even for small customers. As a result, utilities will have to review their policies on cross-subsidies and will have to ascertain that fixed costs are properly recovered from a declining customer based. Those regulatory issues are in state of flux, even among developed countries.

Source: Prepared by authors based on Bloomberg New Energy Finance (database).

MATRIX 2.1 Features of Electricity Market Design in Selected LAC Countries

	TRADITIONAL			EMERGING				APPROACHING			FRONTIER	
	NIC	SALV	PAN	PER	CHI	ARG	GUA	BRA	CO	MX	California	Texas
MARKET COMPETITION												
Centralized economic dispatch via price bids									x		**x**	**x**
Demand side bidding allowed	x		x						x		**x**	**x**
PRICING IN TIME												
Intraday Markets											**x**	**x**
LOCATIONAL PRICING												
One single pool price	x	x	x						x			
Zonal pricing								x				
Nodal pricing				x	x	x	x			x(2)	**x**	**x**
CUSTOMER CHOICE												
Medium/high (voltage or load) thresholds	x	x	x	x	x	x	x	x	x	x	**x**	
Low (voltage or load) Thresholds			x			x	x		x	x(2)		
Full retail competition (open to all customers, including residential)												**x**
Active non-franchised market (1)								x				**x**
Participation of independent traders/marketers/retailers)		x				x	x	x	x	x(2)	**x**	**x**
Emerging competition via self-generation (e.g. PV rooftop)										x	**x**	**x**
HEDGING PRICE VOLATILITY												
Competition for Transmission Concessions or BOT/BOOT Contracts				x	x	x	x	x	x			
Organized market of financial derivatices									x		**x**	**x**
Financial Transmission Rights (FTRs)										x(2)	**x**	**x**
Competition for Long-term Energy Contracts for franchised market	x	x	x	x	x	x	x	x		x(2)	**x**	**x**

(1) High rates of opting out for eligible customers
(2) Included in the current market reform, under implementation

Source: Prepared by authors.

Economically efficient regulation is a recurrent challenge

Improving regulation to adapt to new market dynamics and emerging disruptions such as increased climate-related events and oil-price volatility is a recurrent challenge in LAC. In some countries, external pressures like these have tested the effectiveness of existing market mechanisms, notably in hydro-based systems that have endured prolonged droughts.

In Brazil in 2013 and 2014, all available thermal capacity (about 14 GW) came on line to counter lower hydropower generation, but the country took no measures to promote consumer participation and lower demand, resulting in higher costs to the system (about $25 billion just in revenue shortfall, which the customer base is now absorbing). Colombia offered a contrast during its El Niño drought of September 2015 to March 2016 (Box 2.5). There, use of demand-side management significantly lowered financial impact on the system and customers.

BOX 2.5 Adjusting Regulation to Ensure Adequacy and Reliability: The Case of Colombia

About two thirds of Colombia's installed capacity and generation is hydro-based and thus highly vulnerable to weather and variability of water supplies, notably those related to El Niño. To ensure the availability of firm energy, the government introduced a capacity payment mechanism to allocate firm energy obligations via a descending auction.

The mechanism consists of a fixed payment to generators (set by the auction) that covers a level of fixed costs, providing comfort to debt investors. When plants are called upon to provide supplementary power in shortage situations, they receive payments for energy delivered based on the spot price caped by the "scarcity price". The scarcity price formula is a function of fuel oil price (i.e.; defined as the escalated variable cost of the most expensive thermal unit operating in 2006).

Recently, the country endured a prolonged and intense drought, which lowered reservoir levels, resulting in high spot prices. The length of the drought provided a real-world test of the effectiveness of the reliability payment and the ability of generators to deliver on their firm energy commitments.

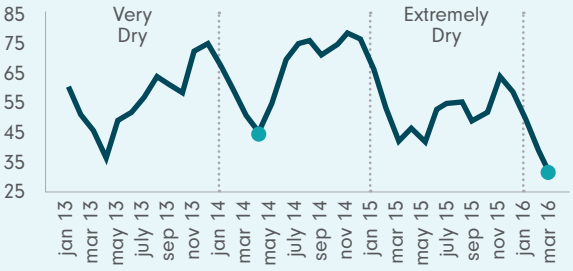
In March 2016, the aggregate hydro reservoir reserve fell to a record 30 percent. The spot price exhibited spikes of $370/MWh (November 2015) and $270/MWh (March 2016), while the scarcity price, which acts as strike price for the energy obligations options, remained at $100/MWh. That was lower than the variable cost of most of the thermal plants that were called to provide power to fulfill their firm energy obligations during this period.

The mismatch between the actual thermal generation costs and the strike prices became a financial burden for thermal generators that had been awarded firm energy obligations. For example, the Termo Candelaria power plant faced significant financial losses, forcing the government to undertake the administration of the plant during the critical El Niño period.

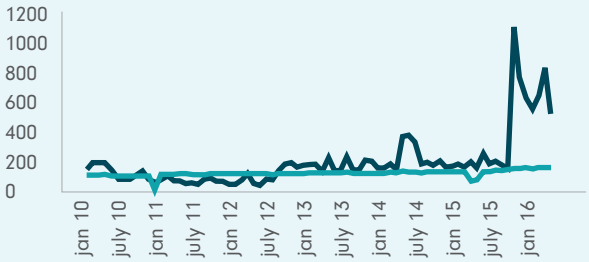
To avoid the risk of rotating load shedding, the government introduced an emergency plan for demand side management targeting savings of 5 percent of energy consumption. The plan was quite successful in ameliorating the shock. In retrospect, the reliability payment did help deliver the necessary energy during the crisis. But the payments to generators had a high price tag—about $5 billion.

Recent assessments have identified key factors affecting the performance of the electricity market in Colombia. They include (1) limited availability of natural gas and high prices, (2) misalignment between reliability payments and actual costs of thermal generators, (3) high degree of market concentration, and (4) a thin long-term contract market.

Hydro Reservoir Reserve (2013-2016) ***Percent***



Spot Price and Average Contract Price (2010-2016) ***CP$/KWh***



Source: Prepared by authors.

Despite reforms, electricity prices in LAC are high compared to other regions

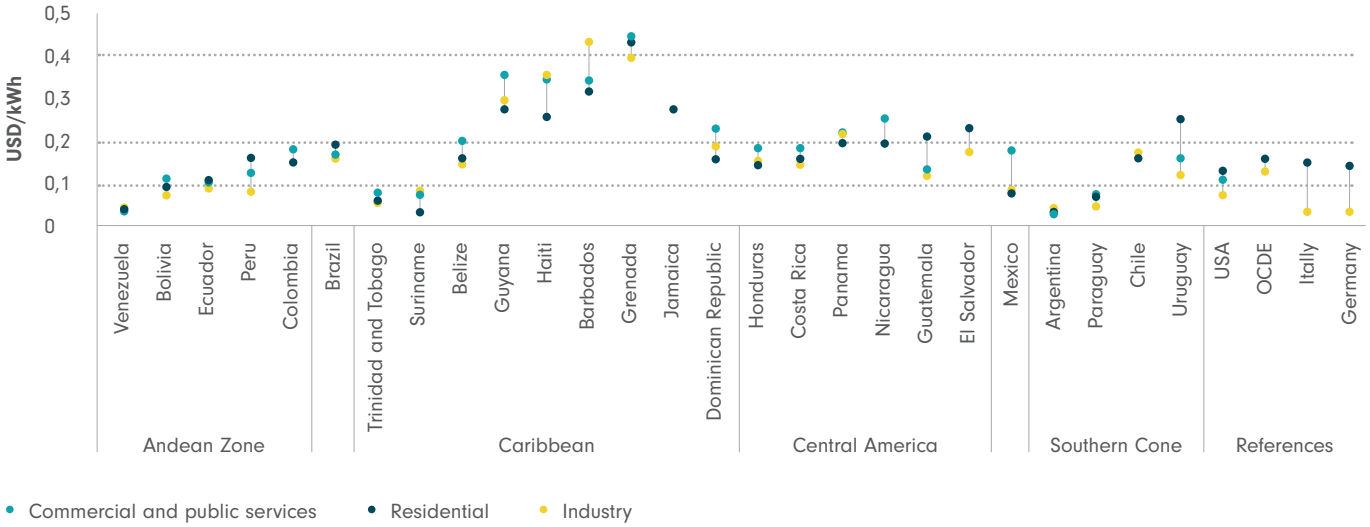
Energy market structures and pricing policies differ across LAC countries and the resulting prices tend to be high by world standards. Figure 3.2 compares electricity tariffs for the residential, industry, commercial, and public services sectors for selected countries and international benchmarks.[2]

Tariffs are high in Central America and the Caribbean, where there is significant dependence on imported fuel oil and diesel, and lack of diversity in the energy matrix. Many other factors affect marginal cost and tariff schedules, including high transmission and distribution losses.

In addition to high operational costs, elevated tariffs in some countries are the result of high fixed costs (such as high cost of capital, expensive new infrastructure, and heavy depreciation schedules imposed on tariffs).

In Uruguay, for instance, a predominantly hydro-based electricity system (74% of installed capacity), tariffs are relatively high due to a combination of factors: i) system relies on one large hydroelectric plant with a relatively small reservoir (so there is abundant capacity, but generally low energy output; even in seasons with average hydropower production and high wind generation, the system needs to use expensive fuel oil/diesel based generation to close the supply-demand gap), ii) the system has introduced a large amount of wind capacity, and generation is paid on a "take-or-pay" basis, iii) transmission and distribution losses are in the order of 17%, iv) regional interconnections are underutilized (notably with Brazil, and exchanges are moderate with Argentina), and v) public utility has to transfer minimum dividends to the Government (which has a large fiscal deficit).

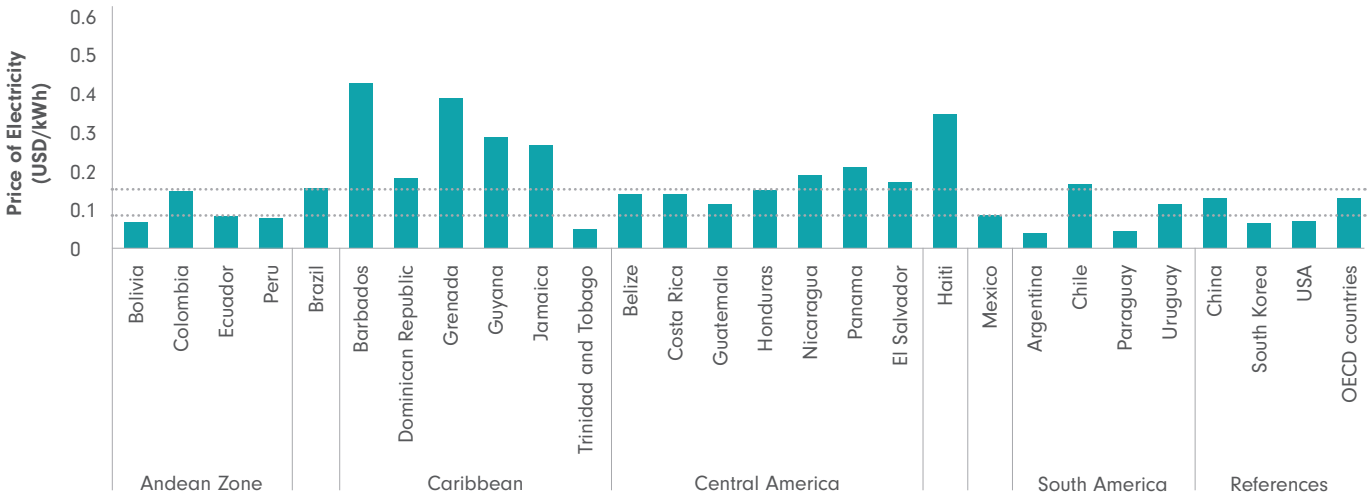
FIGURE 2.2 Electricity Tariffs in Selected LAC Countries (2015) *(USD/kWh)*



Source: Prepared by authors based on data from Latin American Energy Organization Energy-Economic Information System (OLADE-SIER); IEA Electricity Supply (database); utility data.

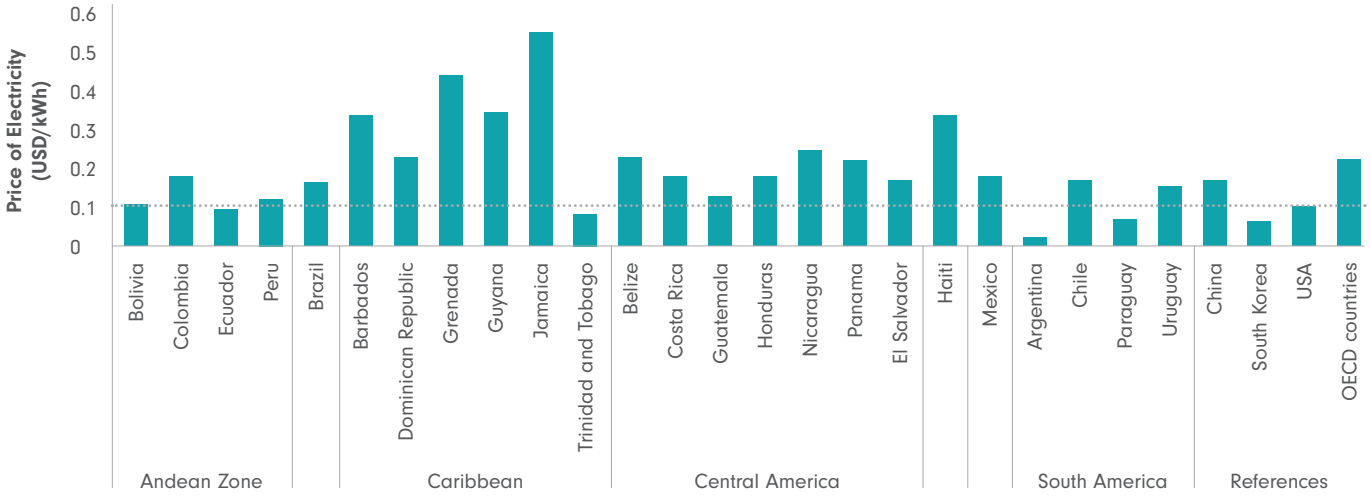
Overall, electricity prices are high when compared to international peers (see Figures 2.2 to 2.5). Many countries in LAC have residential tariffs above OECD averages, and tariffs for industrial and commercial consumers are also among the highest in the world. Average prices for commercial enterprises in LAC are 50 percent higher than the averages for East Asia and Europe and twice the average for the United States.

FIGURE 2.3 Electricity Price Industrial Consumers *(USD/kWh)*



Source: World Bank WDI (database).

FIGURE 2.4 Average Electricity Price Commercial Consumers *(USD/kWh)*



Source: Prepared by authors based on data from World Bank 2016.

Note: The price of electricity is derived from the monthly consumption of a hypothetical commercial warehouse.

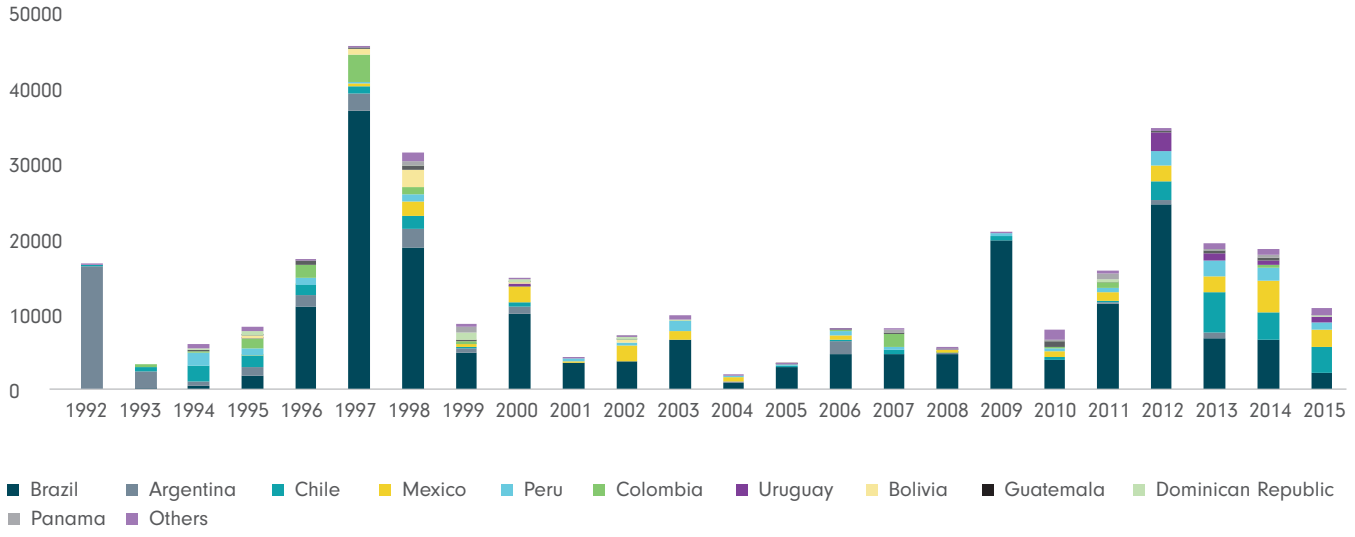
Many countries in LAC subsidize electricity rates in some way. Some limit subsidies to lifeline rates while others apply them to broader groups of customers.

Electricity subsidies represented 5.4% of GDP in Venezuela in 2016, 5% of GDP Argentina (2016), 2.8% in Mexico (2013, in recent publications reported as 0.8%), 1.84% of GDP in Brazil (2016), and 1.26% of DGP in Dominican Republic (2015) (Beylis and Cunha forthcoming 2017; Coady et al. 2015).

Some LAC countries have mobilized large sums of private investment via PPPs, but contract renegotiation is common

Private sector investment has flowed mainly to energy infrastructure development in Brazil, Argentina, Chile, and Mexico. Reformed markets in LAC—and in Mexico where the electricity law had allowed private participation through independent power production before the reform of the power sector in 2013—attracted a total of $331 billion in private investment over the 1990-2015 period. The funds went to develop projects in generation, transmission, and distribution.

FIGURE 2.5 Evolution of Private Investment by Country (1992-2015) *(USD million, nominal)*



Source: Private Participation in Infrastructure (PPI) (database).

Brazil attracted 61 percent of the total, followed by Argentina (9.8 percent), Chile (6.6 percent), Mexico (6.4 percent), Peru (4.8 percent), and Colombia (4 percent). The remaining 7 percent went in small amounts to other countries, mainly Guatemala, Dominican Republic, and Uruguay. In Argentina, the reform of the power and gas sectors created opportunities for the development of natural gas-fired generation, attracting large private investment flows in the 1992-2000 period, just before the country's economic crisis.[3]

Private investment has gone primarily to generation projects mainly in renewable energy (63 percent). Distribution drew 16 percent, transmission 8 percent, and multi-segment projects 14 percent. Private participation in transmission assets took off after 2000.

A recent study found that in many of the countries that attracted large volumes of private-sector participation, the risk allocation was asymmetrical to the detriment of the public sector (Garcia-Kilroy and Rudolph 2017). Under the IPP program that prevailed in Mexico before the reform in 2013, for example, the risk allocation schemes in power purchase agreements had the government absorb risks that could have been allocated to the private sector. Private investment via PPPs required public-sector guarantees in many cases.

FIGURE 2.6 Clustering of Countries in Terms of Risk Rating and Market Structure

Moody's Risk Rating	Rating	Vertically Integrated Monopolies	Single Buyer with IPPs	Plus Wholesale Competition	Plus Large Customers Choice	Plus Full Retail Competition	New Virtual Utility
Minimum Credit Rating	Aaa					Denmark	USA-California
High Grade	Aa1, Aa2, Aa3				Chile		
Upper-Medium Grade	A1, A2, A3	Bahamas			Peru	Mexico	
Medium Grade	Baa1, Baa2, Baa3	Barbados	Uruguay, Trinidad & Tobago	Panama	Brazil	Colombia	
Speculative Elements	Ba1, Ba2, Ba3	Paraguay	Costa Rica	Guatemala, Bolivia	El Salvador		
Subject to High Credit Risk	B1, B2, B3	Suriname, St. Vincent	Honduras, Belize, Ecuador	Nicaragua, Dominican Republic			
Bonds of poor standing	Caa1, Caa2, Caa3	Venezuela	Cuba, Jamaica		Argentina		

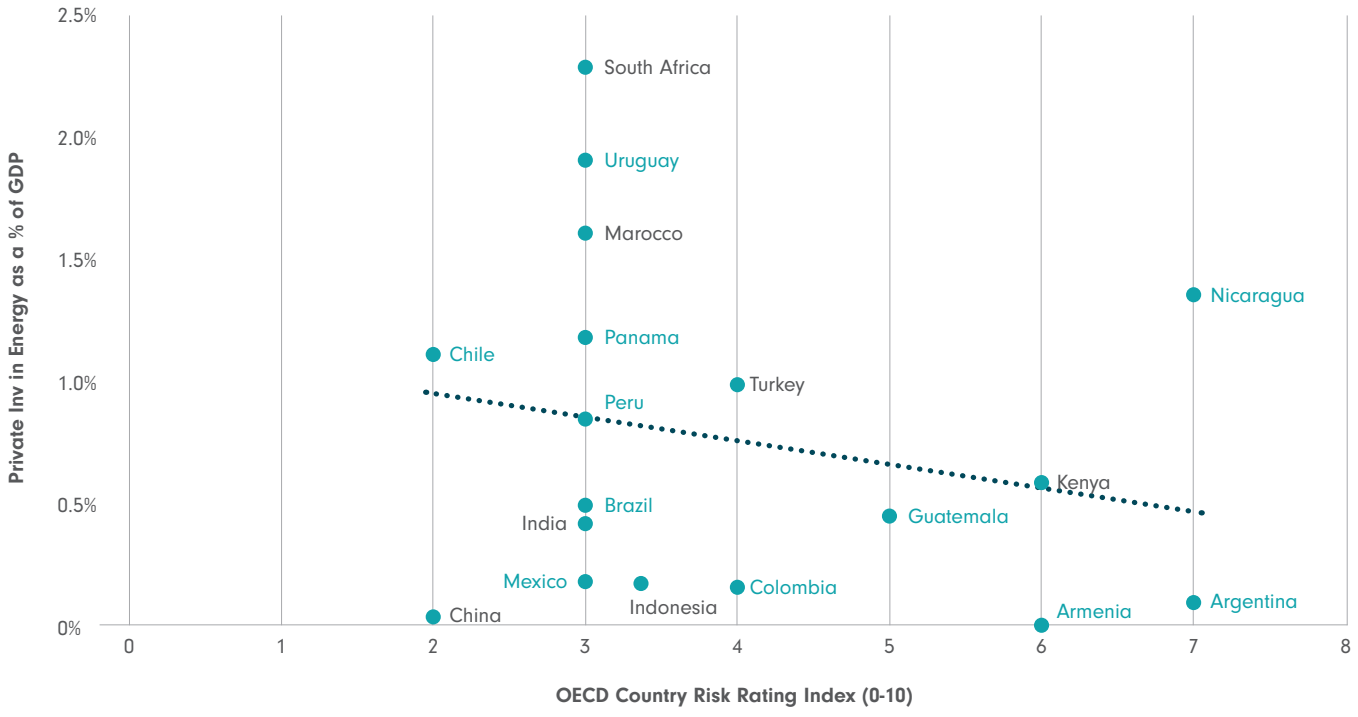
Source: Prepared by authors using Moody's Risk Rating 2016.

There is also frequent renegotiation of PPP contracts in electricity across the region. An ongoing analysis of concession performance suggests that renegotiation of contracts increased from 10 percent in the 1990-2004 period, to 49 percent in 2004-2010 and 43 percent in 2010-2015 (Guasch 2016). These rates are a serious concern in LAC, placing a red flag on the effectiveness of PPP programs.[4]

In the more recent period of 2010-2015, 70 percent of private investment in energy infrastructure was concentrated in Chile, Mexico, and Peru. Figure 2.6 clusters LAC countries in terms of electricity market structure and country risk rating, showing that larger volumes of private investment went to countries with higher credit risk ratings and reformed power sectors. The Infrascope Index, which measures the capacity of countries to mobilize private investment through PPPs, classifies Brazil, Chile, Colombia, Mexico, and Peru as "mature markets" with strong capacity to implement these projects (Economist Intelligence Unit (EIU) 2014). Matrix 2.2 shows an Infrascope benchmarking for different LAC groups and comparators.

Private participation as a percent of GDP in the 2011-2015 period shows a different picture, with private investment comparatively higher in Uruguay and Chile than in other LAC countries, and relatively low in Mexico, Colombia, and Argentina.

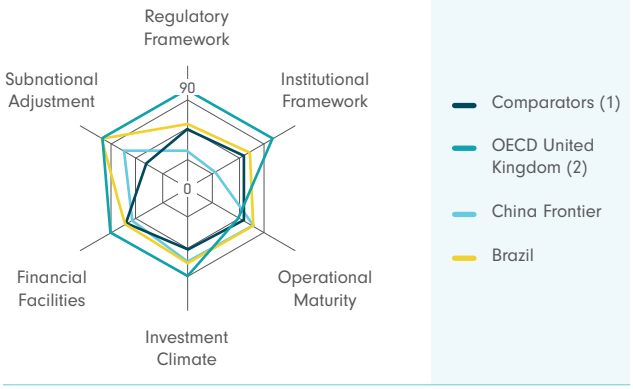
FIGURE 2.7 Private Investment in Energy vs. Country Risk (2011-2015)
(Percent of GDP, vertical axis; OECD Country Risk Rating, horizontal axis)



Source: PPI (database); Country Risk Classification (database) 2015.

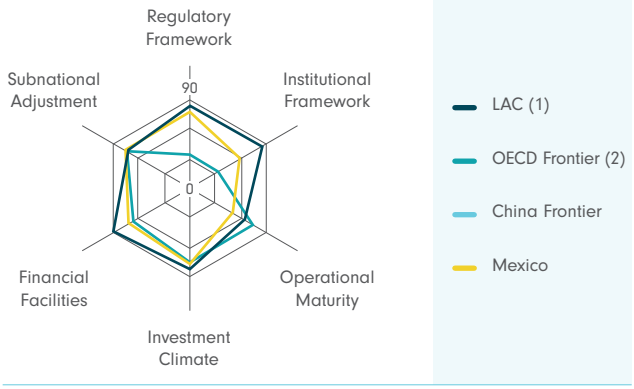
MATRIX 2.2 Infrascope Index: LAC Groups, Peers, and Best Practice Frontier

Brazil



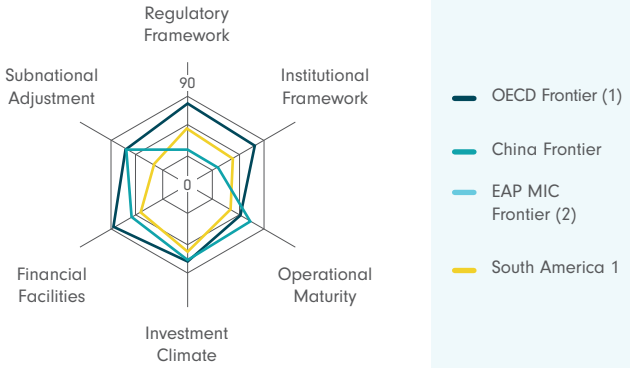
1. Comparators: Korea, Rep. and Thailand
2. OECD best practice frontier: United Kingdom

Mexico



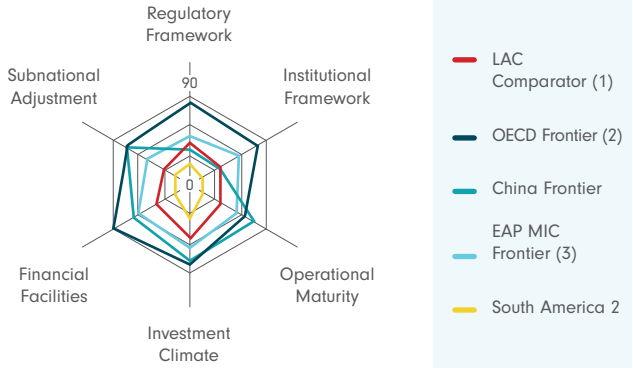
1. LAC: Argentina, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Honduras, Jamaica, Nicaragua, Panama, Paraguay, Peru, Trinidad and Tobago, Uruguay, Venezuela
2.OECD: Australia, Chile, Japan, Korea, Rep., United Kingdom

South America 1



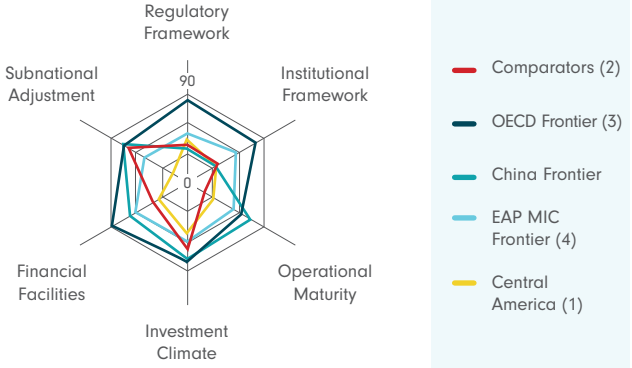
1. Countries in South America 1: Argentina, Chile, Colombia, Peru, Uruguay.
2. EAP MICs: Indonesia, Philippines, and Thailand
3. OECD: Australia, Chile, Mexico, Japan, Korea, United Kingdom

South America 2



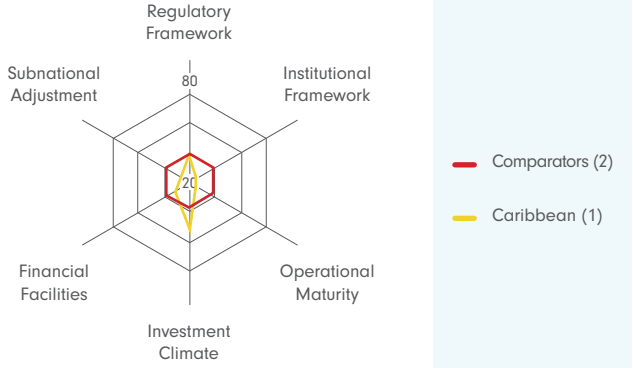
1. Countries in South America 2: Venezuela, Paraguay, Ecuador, Bolivia.
2. LAC: Argentina, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Honduras, Jamaica, Nicaragua, Panama, Paraguay, Peru, Trinidad and Tobago, Uruguay, Venezuela.
3. OECD: Australia, Chile, Mexico, Japan, Korea, United Kingdom
4. EAP MICs: Indonesia, Malaysia, the Philippines, and Thailand

Central America



1. Central America: Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama
2. Comparators: Armenia, Mongolia, and Kazakhstan
3. OECD: Australia, Chile, Mexico, Japan, Korea, Rep., United Kingdom
4. EAP MIC's: Indonesia, Malaysia, Philippines, and Thailand

Caribbean



1. Caribbean: Dominican Republic, Jamaica, and Trinidad and Tobago

INFRASCOPE is an index that measures a country's ability to mobilize private investment in infrastructure through public-private partnerships (PPPs).
The index assesses countries' readiness and capacity for sustainable, long-term PPP projects by scoring aspects of the regulatory and institutional framework; project experience and success; the investment climate; financial facilities; and subnational PPP activity. The 2014 edition, as well as the most recent edition for Latin America and the Caribbean, covers 19 countries of the region.
Source: EIU 2014.

Some utilities in LAC are among the world's best, but many remain far from high efficiency frontiers

The power sector reforms in LAC often strengthened the performance of utilities, helping propel a few to multinational status. Publicly traded utilities sold shares in the stock market and raised cash to finance investment and other expenses that allowed further gains in quality of service.

Chile is a prime example to showcase that benefits can come from pioneering power sector reform. Its energy company ENERSIS reached out across borders to take part in the privatization of distribution companies in several countries of the region. ENERSIS acquired distribution companies in Argentina (Edesur), Peru (Edelnor), Brazil (Ampla and Coelce), and Colombia (Codensa) and helped them adopt the new efficiencies it itself had gained. In some of these companies, distribution losses dropped from the range of 18-24 percent to 6-11 percent in the 1997-2007 period.

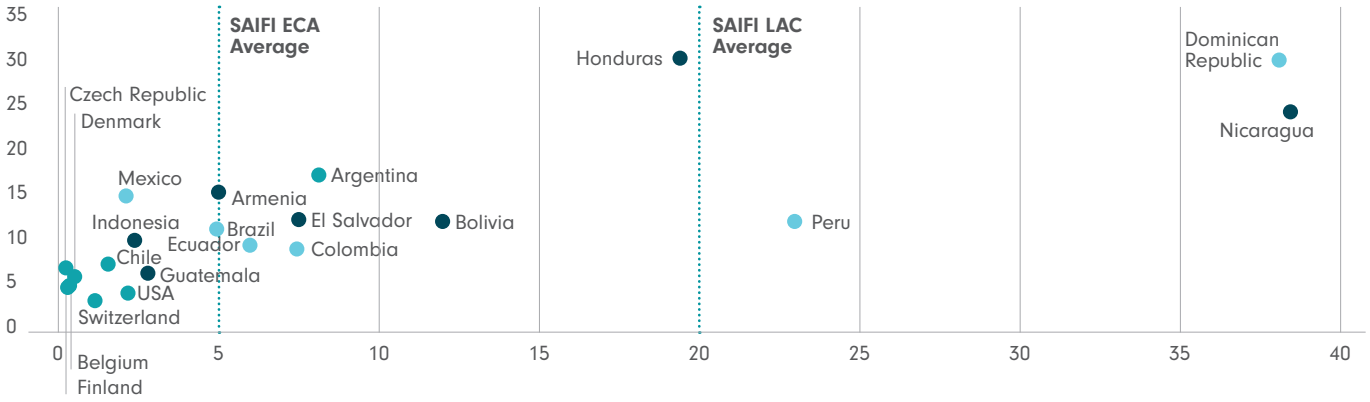
While LAC utilities have evolved with the growing sophistication and maturity of electricity wholesale markets and performance-based tariff regulation, there is still a gap with best global performers. Figure 3.10 benchmarks selected LAC utilities in terms of service quality and transmission and distribution losses against utilities in developed economies.[5]

Higher than reasonable technical and non-technical distribution losses can harm the financial stability of electric utilities and create a vicious cycle. Elevated losses generally imply that a utility is not recovering the costs recognized in electricity tariffs which cap the level of allowed losses. The company therefore lacks funds to cover operating expenses let alone make new investments. Lack of investment in new transmission and distribution infrastructure in turn brings higher technical losses.

Reliability levels in some LAC countries—the largest electric utilities of Chile, Guatemala, Mexico, Brazil, and Ecuador among them—rank close to European and American levels, as measured by System Average Interruption Frequency Index (SAIFI). But other countries are far from this best practice frontier, including Dominican Republic, Nicaragua, and Peru. The regional averages for both SAIFI and System Average Interruption Duration Index (SAIDI), as well as the level of transmission and distribution losses, are still far from developed country benchmarks (See Figures 2.8 and 2.9).[7]

At the same time, large utilities in LAC—in Chile, Mexico, Peru, Brazil, and Colombia, for example—appear to have positive cost recovery ratios (Figure 2.9).

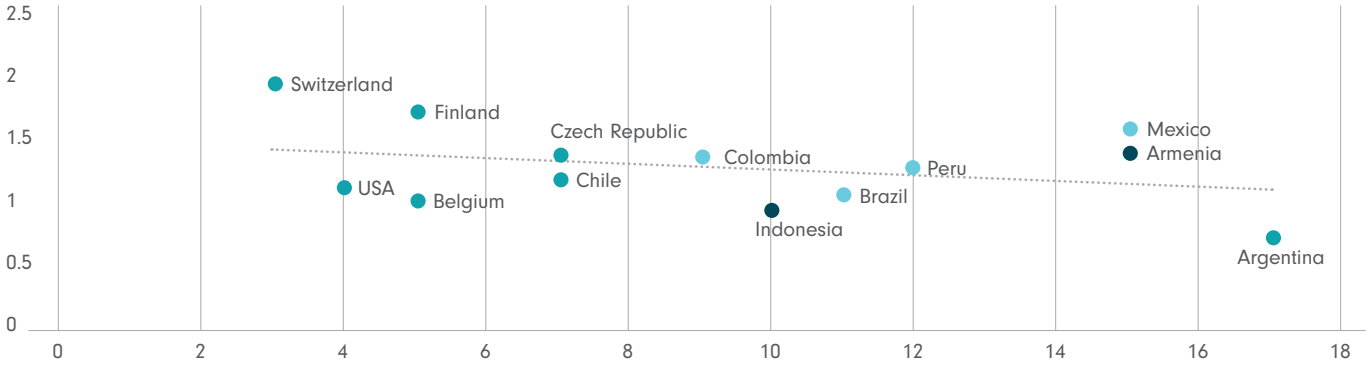
FIGURE 2.8 Quality (reliability indicator SAIFI) vs. T&D Losses
(SAIFI, horizontal axis; T&D Losses, vertical axis)



Source: Regulatory Indicators for Sustainable Energy (RISE) (database); World Bank 2016.

Note: SAIFI is commonly used as a reliability indicator by power utilities, and it is the average number of interruptions that a customer would experience in a given year.

FIGURE 2.9 Operating Cost Recovery Ratio vs. T&D Losses
(T&D losses, horizontal axis; Ratio, vertical axis)



Source: RISE (database).

Note: The Operating Cost Recovery Ratio is calculated as: the ratio of [operating cost/KWH entering transmission and distribution] over [revenue from power sold/KWh sold for final consumption].

Cross-border electricity trade is limited

LAC has developed four clusters of cross-border power integration with roughly 62 gigawatts of transfer capacity: i) Mexico-USA (Texas, California), ii) Central American Regional Electric Market (MER/SIEPAC, covering five Central American countries, but also an interconnection to Mexico), iii) Andean Community (CAN, interconnecting Colombia, Ecuador, Peru, and Venezuela, including an interconnection between Venezuela, Brazil and Chile)[8], and iv) Sothern Cone (MERCOSUR, with interconnections among Argentina, Brazil, Chile, Uruguay and Paraguay).

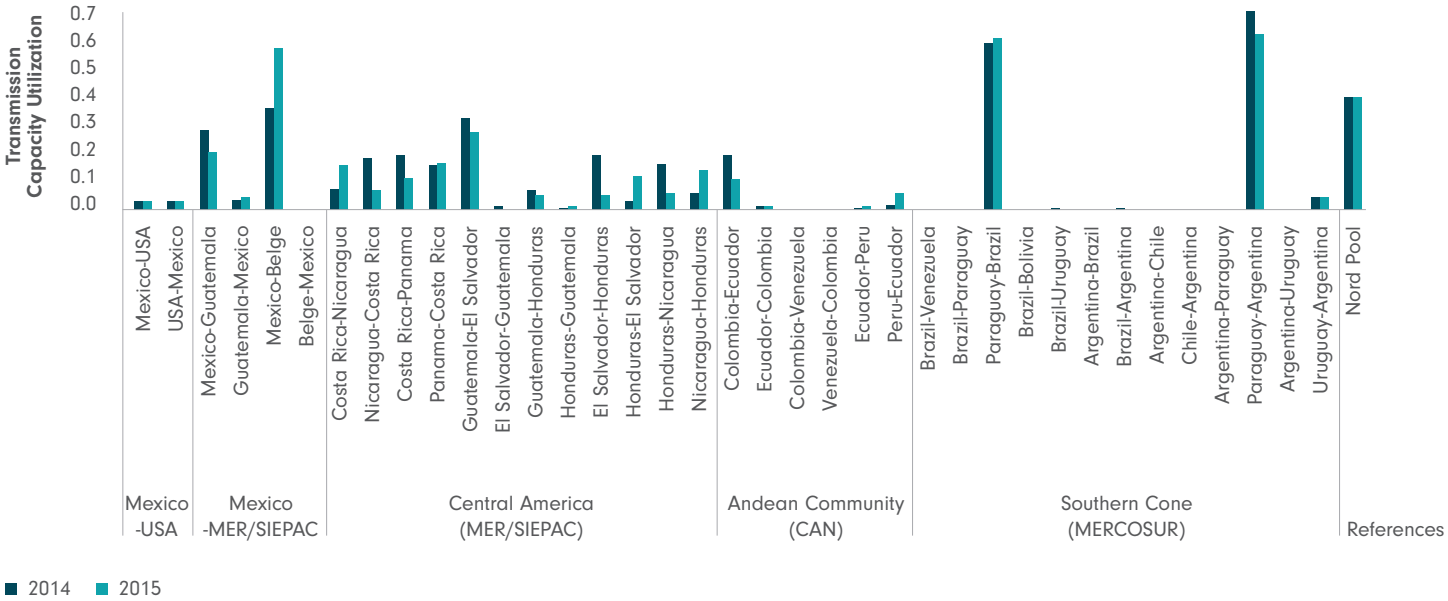
Cross-border electricity trade is however extremely limited (Figure 2.10). Power exchanges in the MERCOSUR region have gradually lowered with time to the point of almost no trade in recent years (except in the interconnection between Paraguay and its neighbors), and in CAN trade is only significant between Colombia and Ecuador (using less than 20% of existing interconnection capacity). Trade in the MER/SIEPAC is fluid in the exports from Mexico to neighboring countries Belize and Guatemala, and between Guatemala and El Salvador, all other exchanges are lower than 20% of the existing transmission capacity.[9]

These paltry levels are due to a number of technical, regulatory, and market barriers, and concerns of national energy security. To realize the benefits of higher interconnection, countries will have to address these barriers. Table 2c in Annex I summarizes some of the key issues.

This is an area where LAC countries need to pay attention and lower geopolitical and regulatory barriers, particularly in Central America where the scale-up of variable renewable energy has grown in recent years, and in the Southern Cone, where resource complementarity among systems -large solar projects in Chile and hydropower in Brazil, Uruguay, and Paraguay- could help increase economic efficiency in this cluster of countries.

Although it is difficult to draw comparisons among power pool structures, the Nord Pool—which connects 19 European countries—has often served as a global benchmark for international trading and as an exemplar of how to create a single electricity market (Oseni and Pollit 2016). In the Nord Pool, trading is about 40 percent of available transmission capacity, which represents a high efficiency frontier. In the Nord Pool, each country has sufficient installed capacity to attend the domestic demand, which seems to be a good pre-condition for mutually beneficial international exchanges.

FIGURE 2.10 Transmission Capacity Utilization (2014-2015)
(Percent, annual average)



Source: Prepared by authors based on data from OLADE-SIER (database); utility data.

Note: Paraguay sells electricity from the Yacyretá and Itaipú hydropower plants to Argentina and Brazil. These plants are international assets, the transfer uses transmission lines of the generation asset, sales are conducted in accordance with pre-existing long term contracts.

Notes

1. For example, in California distributed generation is allowed in projects with capacities below 20 MW, while in Mexico the threshold has been set at 0.5 MW. By the end of 2016, Mexico registered a total of 150.5 MW operating as distributed generation under the recently approved "net metering" scheme (California introduced its net metering policy in 1996, and has reached so far 4.1 GW).

2. In several countries, there are also significant variations among regions and jurisdictions. Therefore, average tariffs should be interpreted as an indicative proxy.

3. Ninety percent of private sector investment for infrastructure development in Argentina happened in the period 1992-2000, before the financial crises of 2001.

4. A renegotiation of a PPP contract implies a change in the initial contractual conditions (not to be confused with, for example, a change in the tariff adjustment mechanisms as defined in the contract). Renegotiations often focus on contractual modifications associated with: (1) a change in risk allocation, or quantification of the magnitude of risk, (2) a change in the scope of the project—so-called complementary contracts, addition of investment or works, (3) other changes associated with contract conditions (durations, terms, schedule, and timing of investment, investment levels, tariff structure, service levels, performance indicators, etc.), and (4) other clarifying or corrective changes. In some cases, the renegotiation of contracts has to do with shortfalls in demand (revenue), rent-seeking opportunities, political opportunities, or aggressive bids or bid mistakes. There are indeed valid reasons to renegotiate PPP contracts, but a high incidence may signal procedural or institutional weaknesses.

5. Data reported by in 2016 by Readiness for Investment in Sustainable Energy (RISE) World Bank considers the largest utility operating in the country (in terms of number of customers). See Table X Annex I for a list of utilities considered.

6. See Table 2b in Annex I for a list of the utilities subject to the RISE and Doing-Business performance analyses.

7. Benchmarking with performance indicators provides a general indication of where utilities stand in terms of quality. However, caution is necessary with these rankings. Reliability indicators reported by Doing Business 2016 follow a specific methodology to ensure a degree of consistency and comparability, yet system characteristics, geography and weather vary across countries and frequency and length of interruptions may result from different underlying factors.

8. The Andean Electrical Interconnection System (SINEA) connects Chile, Bolivia, Colombia, Peru and Ecuador. However, SINEA is not anchored in an international treaty or agreement for power exchanges.

9. The main barriers to cross-border electricity trade are described in Table 2c Annex I.

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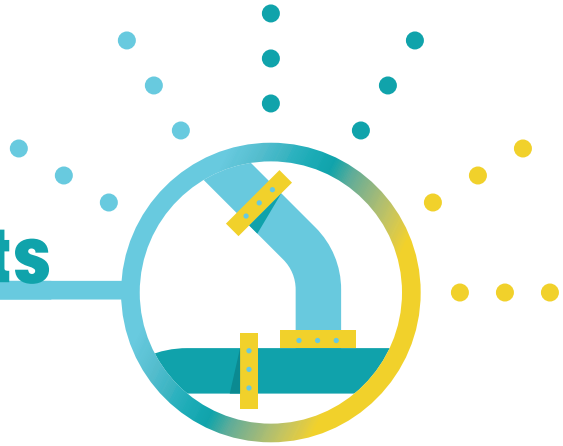
CHAPTER 3

Natural Gas Markets



Despite substantial gas reserves in LAC, few countries remain self-sufficient

Natural gas is abundant in LAC, with estimated proved reserves of 7.9 trillion cubic meters (tcm)—4.3 percent of the world's total—and technically recoverable resources of 83 tcm in 2015. The latter, if proved and commercially viable, could sustain current rates of consumption in the region for more than 340 years. Most of the gas reserves in LAC are associated gas, with Peru and Bolivia as notable exceptions. Significantly, LAC's natural gas reserves are unevenly distributed, with Venezuela accounting for over 71 percent of the total in 2015, followed—at a distant second—by Brazil and Peru, tied at 5 percent.

TABLE 3.1 Natural Gas Proven Reserves in LAC, 1995-2015 *(Trillion cubic meters, tcm)*

	1995	2005	2015
Mexico	1.9	0.4	0.3
Argentina	0.6	0.4	0.3
Bolivia	0.1	0.8	0.3
Brazil	0.2	0.3	0.4
Colombia	0.2	0.1	0.1
Peru	0.2	0.3	0.4
Trinidad and Tobago	0.3	0.5	0.3
Venezuela	4.1	4.3	5.6
Other South and Central America	0.2	0.1	0.1
Total	**7.8**	**7.3**	**7.9**

Source: Prepared by authors based on data from British Petroleum (BP) 2016.

The relatively stagnant reserve growth in LAC over the past two decades hides wide disparities in geography and in time. While Venezuelan associated gas reserves rose steadily between 1995 and 2015 because of oil exploration, gas reserves in Mexico were cut by 84 percent and in Argentina by 50 percent as natural gas use in both countries far outstripped their capacity to add new gas reserves (primarily due to declining upstream investments). Bolivia, in turn, experienced an eight-fold increase in reserves between 1995 and 2005, which have since considerably declined due to a methodology review as well as slowing exploration following the country's nationalization push in 2006. Across the border, Brazil has successfully doubled its reserves since 1995 thanks to its vast offshore finds (80 percent of the country's reserves are off the coast).

While reserves growth has been stagnant, the consumption of natural gas has expanded almost three-fold in LAC, from a 9 percent share of primary energy in 1994 to 26.5 percent in 2015. In many cases, this was stimulated by artificially low end-user prices, economic expansion, and the intermittent availability of renewable power-generation sources (a fast-growing albeit still modest fuel source in the region).[1] This expansion, however, has been uneven over time: average share growth was around 1 percent in 1994-2004 but just 0.3 percent in 2004-14.

There is also strong variation at the country level. In countries such as Suriname, Guyana, Ecuador, Paraguay, and most of Central America and the Caribbean, natural gas demand is small or non-existent. In contrast, Mexico, Argentina, Brazil, Venezuela, and Trinidad and Tobago are large users, primarily for power generation. Mexico, in particular, has played a major role in driving up natural gas use in LAC, accounting for 32 percent of total use in the region in 2015. Argentina comes in second, at 18 percent in 2015. As one of the oldest gas markets in the world with a well-developed infrastructure, Argentina has high gas penetration in all sectors.

The power sector is the largest consumer, followed by residential and commercial, industry, and transport. Argentina is one of the world's largest consumers of natural gas in transport, with very high rates of car conversion from oil to compressed natural gas (CNG) and some progress in river transportation (the Buenos Aires-Montevideo ferry has converted from diesel to gas).[2] Brazil, meanwhile, is the third-largest natural gas market in LAC following a rapid increase in gas-to-power. Natural gas is also used in industry—traditionally the main consumer of gas in Brazil—and in transport (the country has the second-largest CNG fleet in LAC). Residential use of gas is very limited, however, due to various factors including gas-price competitiveness, a limited transport network to bring the gas to consumption centers, lack of urban infrastructure, competition from subsidized liquefied petroleum gas (LPG), and Brazil's mild climate.

LAC's top four natural gas markets are large even when compared with the European Union's well-established markets: In 2015, Mexico consumed more gas than the EU's largest consumer, Germany (83.2 bcm vs. 74.6 bcm). Both Argentina and Brazil consumed more than France, the EU's fourth-largest consumer. Venezuela in turn consumed more gas than the Netherlands, the EU's fifth-largest gas market. In terms of intensity of natural gas use—measured in tons of oil equivalent (toe) per capita—Trinidad and Tobago stands out with 14.2 toe per capita, significantly higher than in the

TABLE 3.2 Natural Gas Production and Consumption in LAC, 1995-2015 *(Billion cubic meters, bcm)*

	1995			2005			2015		
	Prod.	Cons.	P-C	Prod.	Cons.	P-C	Prod.	Cons.	P-C
MEXICO	30	31.4	-1.4	52.2	60.9	-8.7	53.2	83.2	-30
ARGENTINA	25	27	-2	45.6	40.4	5.2	36.5	47.5	-11
BOLIVIA	3.2	*	*	12	*	*	20.9	*	*
BRAZIL	5.1	5.1	0	10.9	19.6	-8.7	22.9	40.9	-18
CHILE	*	1.8	*	*	7.8	*	*	3.9	*
COLOMBIA	4.4	4.4	0	6.7	6.7	0	11	10.5	0.5
ECUADOR	*	0.3	*	*	0.3	*	*	0.6	*
PERU	0.4	0.4	0	1.5	1.5	0	12.5	7.5	5
TRINIDAD AND TOBAGO	7.6	7.6	0	33	16.3	16.7	39.6	21.5	18.1
VENEZUELA	**27.5**	27.5	0	**27.4**	27.4	0	**32.4**	34.5	-0.1
OTHER SOUTH AND CENTRAL AMERICA	**2.5**	**1.1**	**1.4**	**3.2**	**3.4**	**-0.2**	**2.6**	**7.7**	**-5.1**
LAC TOTAL	**105.7**	**106.6**	**-0.9**	**192.5**	**184.3**	**-8.2**	**231.6**	**257.8**	**-26.2**
LAC % OF WORLD TOTAL	**5**	**5**	**N/A**	**6.9**	**6.6**	**N/A**	**6.5**	**7.4**	**N/A**

Source: Prepared by authors based on BP 2016.

Note: Positive numbers mean that the country/region is a net exporter and negative numbers mean that the country/region is a net importer. BP does not provide exact information on Bolivia's natural gas consumption nor on Chile's and Ecuador's production at a disaggregated level.

rest of LAC and the EU, where the top per capita gas user is the Netherlands at 1.7 toe per capita. Venezuela comes second in LAC with 0.9 toe per capita, equivalent to Italy, which ranked fourth in the EU. Finally, Argentina ranked third with 0.8 toe per capita, a level of use that is similar to Ireland's and Hungary's (Hungary ranked seventh in the EU).

Demand for gas in LAC is forecast to continue to grow in the mid-term. Helping drive this trend will be needs for additional power generation as populations and economies grow and for back-up power for non-conventional renewables and hydro. The energy requirements of industry and transportation as cars and trucks switch to CNG and ships to LNG will also play a role. Wild cards will include political stability and economic growth (particularly in the region's largest energy consumers, Mexico, Brazil, and Venezuela), irregular weather patterns, carbon pricing, and introduction of new legislation and regulations promoting or disincentivizing natural gas consumption.

Natural gas production in LAC grew by 2.2 times between 1995 and 2015, a slightly slower pace than the region's gas demand expansion but still quite significant. Production is highly concentrated, with about 88 percent taking place in just six countries. Mexico and Trinidad and Tobago were the largest producers in 2015. While Mexico's levels have remained largely stagnant since 2005, Trinidad and Tobago's

have continued to expand, allowing the country to surpass Argentina, which was the region's second-largest producer in 1995 and 2005. Argentina accounted for 15 percent of total natural gas produced in LAC in 2015, down from 24 percent in 2005, in large part due to the decline in production linked to the 2004 gas crisis.

In 2015, only three producers in LAC—Trinidad and Tobago, Peru, and Colombia—were net exporters of natural gas. Of these, Peru—a mid-size market—stands out for the very fast rate of growth both in production (31 times) and consumption (19 times) in 1995-2015 and high dependency on a single project, Camisea. The region as a whole is a net importer of natural gas and its dependency on imports has been growing: LAC imported only 0.8 percent of its gas in 1995 but a little over 10 percent in 2015. At the country level, Argentina, Brazil, and Mexico are major producers but also major importers of natural gas. Brazil imported 44 percent of its gas needs in 2015, Mexico 36 percent, and Argentina 23 percent. Uruguay and Chile are medium-sized net importer countries, with Chile importing 76 percent of its natural gas needs.

LAC is using trade and LNG to overcome gas supply constraints

Despite its substantial reserves, the region is experiencing a widening gap in the demand and supply of natural gas, as demand growth outstrips production growth. Issues holding back LAC's supply growth include:

- Difficult geography
- Lack of natural gas infrastructure
- Sometimes ambivalent government policy toward the sector
- Weak or outdated legal, regulatory, and institutional frameworks
- Low investor confidence in some governments
- Poor community relations
- Difficulties in mobilizing the guarantees or capital needed
- Unappealing gas pricing policies (subsidized vs. market, "coupled" vs. "decoupled" from international and regional markets)
- Incomplete development and implementation of regional integration plans
- Lack of transparent licensing and rents collection or distribution
- Lack of a "gas culture"
- High break-even costs for new sources of production
- Disappointing drilling results, such as Total's dry well in Uruguay's ultra-deep offshore area

Difficult geography

Several of LAC's largest gas fields are in areas that are remote, environmentally sensitive, or complicated to access, such as the Amazon, the deep offshore (Brazil, Guyana, and Colombia) and the southern tip of Argentina and Chile. The potential for marketing the gas locally is relatively small or non-existent and therefore gas monetization requires expensive logistics and transport, often making the production of this gas uneconomic. As a result, gas present in these types of locations often ends up undeveloped or stranded (particularly non-associated gas reserves), reinjected into reservoirs to aid production,

or flared. About a third of the gas produced in Ecuador, for example, is flared due to the remote location of the producing fields and the limited market for gas close-by.

Reinjection and gas flaring occurs in all types of locations across the region, whether remote or not. As in Angola and Nigeria, PEMEX and Petroleos de Venezuela (PDVSA) officials have historically favored development of oil over gas in view of the higher profit margins and difficulties in developing natural gas markets. In Venezuela, for example, 35 percent of the country's 2014 gross natural gas production was re-injected to bolster crude oil extraction in the country's mature oil fields.

Gas flaring in Latin America, though common, is typically at lower levels than in North America, Russia, and West Africa (see Map 3B in Annex I).[4] For example, 10 bcm of natural gas—35 percent of Venezuela's total gas production in 2013—was flared in 2015, which made Venezuela the top gas-flaring country in LAC and among the top five in the world. Flaring has been expanding in recent years and in 2013 was almost five times higher than the average of 2000-09, principally due to PDVSA's declining technical capacity, poor maintenance of aging facilities, declining international prices, and low domestic prices (until very recently gas field operators were getting only about $1.54 per million British Thermal Units (BTU) (Farina 2010). Gas flaring has been increasing in Mexico, up from an average of 1.5 bcm/year in 2000-09 to 2.2 bcm/year in 2013. A year later, Mexico lost the about 30 percent of its production to flaring (Nemac 2016). Its rank among the world's top ten flaring countries is principally due to difficulties in reconciling oil production and gas utilization goals, bottlenecks in natural gas handling, and low capital for gas utilization projects.

Poor infrastructure

Not only are LAC's gas reserves often in remote locations, the region's demand centers are largely isolated from each other. Argentina, thanks to private participation in the transmission and distribution of natural gas in the 1990s, and parts of Brazil, Bolivia, Colombia, Mexico, and Peru, are the exceptions (see Maps 4.1. and 4.2).[5] The development of an integrated natural gas infrastructure in LAC— including storage, transportation, and distribution—is critical to making natural gas projects commercially feasible. But this development has lagged due to factors including political uncertainty, high cost, and difficult access to funding. In Central America and the Caribbean, for example, total electricity demand was deemed too small to justify investing in the expensive infrastructure needed to import natural gas, contributing to these areas' strong dependence on oil-fired generation. In 11 out of 14 Caribbean countries, oil accounts for at least 75 percent of installed capacity.

Low investor confidence

LAC has legal, regulatory and institutional frameworks that could be strengthened, natural gas pricing policies that in some cases are unsustainable and a history of nationalization in the oil and gas sector through direct, indirect, and creeping expropriation that has undermined investor confidence. Currently, most countries are open to foreign investment but not all offer the best incentives to prevail on investors to bring in the necessary capital, skills, and technology to expand production and build infrastructure. Bolivia is a case in point. It experienced a significant decline in exploration for new fields following the introduction of a restrictive regulatory framework in 2005 and the nationalization of private assets in 2006. Another case is Peru, where highly subsidized natural gas prices ($1 per million BTU) and outdated legal and regulatory regimes have undermined the development of its reserves.

In Venezuela, an estimated 0.5 tcm of non-associated natural gas reserves (equal to Brazil's total proved reserves in 2014) remained in limbo for years. They were stuck between PDVSA, which lacked the money and technical/operational expertise to develop them, and private companies such as Statoil, Mitsubishi, and Chevron, which were uninterested unless they could sell the gas at above $3, approximately double the fixed domestic prices. In 2008, plans emerged to promote liquefied natural gas (LNG) exports and in the process, finally unlock the reserves' development. Since then, however, LNG development has lagged due to low international prices and to capital constraints, causing more than two years' delay in Chevron/YPF's Delta Caribe LNG project (Reuters 2010; Daly 2016). Perla is Venezuela's only operating natural gas project and was largely made possible by PDVSA's commitment to pay $3.69 per million BTU for the gas. Unfortunately for Eni and Repsol, joint owners of Perla, PDVSA has systematically failed to pay since operations started in 2015 (BMI Research 2016).

A final example is Brazil, where in 2010, the government appointed Petrobras as the sole operator in any pre-salt layer project with at least 30 percent interest participation. This proved detrimental to the pre-salt's development, particularly in view of the company's growing indebtedness, and consequent reduction of investment capacity (Starr et al. 2015; Pacheco and Basilio de Barros 2016; Moreira 2011). Recent changes in Brazil's policy—including the October 2016 decision to scrap Petrobras' obligation to be the sole operator in the pre-salt—are expected to bring about much-needed investment into the that resource.

MAP 3.1 Natural Gas Infrastructure in LAC – Pipelines (I)

Source: Pipelines and Gas Journal 2009.

MAP 3.2 Natural Gas Infrastructure in LAC – Pipelines (II)

Source: Pipelines and Gas Journal 2016.

Social conflicts

Social conflicts over the extractive industries are motivated by political objectives and environmental, and social concerns as well as economic considerations—access to rents and benefits is widely perceived to be concentrated in just a select few. These conflicts are on the rise in LAC, posing a significant challenge to both governments and industry (Viscidi and Fargo 2015). Unrest and violent attacks undermine LAC's capacity to expand its production, by delaying exploration and in some cases leading to production stoppages. Peru, Ecuador, and Colombia have been the hardest-hit by these conflicts. In Colombia, disruptions were primarily caused by the Revolutionary Armed Forces of Colombia (FARC), which staged several attacks on the country's gas pipelines (Garcia 2010).

Difficulties in mobilizing capital

In LAC, like in other regions of the world, low international oil and gas prices have strained companies' budgets, making it difficult to sustain production levels. In response, companies are adjusting their capital spending strategies for exploration and development, introducing advanced technologies, and reviewing and redefining relationships with counterparts such as service companies, trade unions, governments, and customers. By achieving greater efficiency, these measures can help make projects economic and thus maintain or increase production and reserves. But they also mean fewer investments in exploration in both conventional and unconventional plays such as shale oil and gas (Box 4.1) and deep offshore projects. Still, when the right conditions are in place in such issues as resource size, regulations, policy, taxes, infrastructure, and secured demand, companies have shown willingness to invest. Examples are Exxon/Hess/Nexen in Guyana (deep offshore), Anadarko in Colombia (deep offshore), and Total in Argentina (shale).

BOX 3.1 Shale Gas in Latin America

Latin America sits atop 28 percent of the world's technically recoverable shale gas reserves, with Argentina, Brazil, and Mexico all ranking among the top 10 countries in terms of reserve potential (Map 3.A in Annex I).

Successful shale development is long-term and capital-intensive, requiring billions of dollars of annual investment. But it can be transformational for a country's energy security and economy, as the experience of the United States shows. As other countries are learning, the early stages of monetizing these assets can be particularly challenging. Currently, only three countries—Canada, China, and Argentina—have been able to produce commercial volumes of either shale gas or tight oil, but at much lower levels than the United States. Notwithstanding this complexity, most countries in Latin America with shale gas potential are moving up—albeit slowly—the unconventionals' learning curve, at times drawing on the experience of U.S. state authorities to address their imbalance of natural gas supply and demand.

Argentina has targeted shale oil and natural gas in the Neuquen's Vaca Muerta shale formation. ExxonMobil, Shell, Total, and others have taken stakes, but only Chevron has advanced into production, in a $16 billion partnership with state-run Yacimientos Petroliferos Fiscales (YPF). In 2017, Total sanctioned the development of the first phase of the Aguada Pichana Este license in Vaca Muerta as well as an increase in its interest in the license from 27 percent to 41 percent. The other firms are conducting pilots, progressing slowly in part due to Argentina's challenging business environment and infrastructure constraints. Difficulties in cutting down drilling and completion costs to profitable levels

are also reducing the pace (the estimated average vertical well cost is $7-14 million in Argentina vs. an average of $5.9 million in the U.S. Bakken play). Costs could be cut, however, if more wells are drilled, creating economies of scale. Argentina has drilled just 400 shale wells vs. more than one million in the United States. Funding these new wells, however, won't be easy, particularly when gas markets are oversupplied and investment budgets for frontier plays are declining. Still, Argentina has introduced the "Program for Stimulation of Unconventional Gas Developments," which guarantees the natural gas price at around $7.50 per million BTU—about three times the average Henry Hub price—until 2021.

Shale oil and natural gas drilling is also underway in Mexico, Chile, Colombia, and Uruguay. Of these, Mexico, Colombia, and Chile have the highest potential success rates. In Mexico, shale development has been slow, undermined by:

- Heavy reliance on Pemex
- High production costs (for instance, service companies are not accustomed to competing, contributing to well costs of $20-25 million)
- Regulatory complexity (companies drilling in Mexico have to deal with as many as 20 regulatory agencies)
- Water scarcity, as the countries shale potential lies mostly in arid areas
- Security concerns linked to drug trafficking

Results have been modest. To date, just 13 wells have been drilled in Mexico, 10 of which are commercial. Initial production ranges from 50,000 to 300,000 cm/d.

In Colombia development of shale has been underwhelming despite the government's efforts to promote it. Unconventional resources pay a lower royalty rate to the government but investors in the country still have to deal with insecurity, attacks on energy infrastructure, delays in permitting, regulatory complexity and uncertainty. Moreover, new rules and regulations for the sector were launched in 2015 and 2016 and environmental opposition continues to grow. Partly because of these issues, both the 2012 and the 2014 shale block auctions organized by the National Hydrocarbons Agency (ANH) were disappointing. In 2014, only 26 of the 95 available concessions secured offers. Still, exploration drilling by Ecopetrol, ConocoPhillips, Exxon, Shell, and others continues.

In Chile, shale development has been led exclusively by the Chilean national oil company, ENAP, and has focused on the Magallanes region. In 2016, following the fall in global prices, ENAP decided to temporarily close its 49 wells in Magallanes, bringing shale development in the country to a halt.

Source: Prepared by authors.

Closing supply gaps through trade in natural gas

In view of the challenges to natural gas production, LAC countries have turned to trade to make up the shortfall in supply. Gas trade within the region, while significant, does not meet LAC's demand. Brakes on this trade's expansion include geographic impracticality, a lack of consensus on key commercial, policy, and regulatory issues such as pricing disputes between Brazil and Bolivia, and lack of public and of private investment. Only 13 percent of total private investment for the energy sector in the region went to support the development of natural gas transmission and distribution infrastructure in 1990-2015. A lack of full trust between neighboring countries, growing in part from unilateral supply

cuts (such as Venezuela and Argentina) and domestic demand prioritization (such as Argentina and Colombia), is also holding back trade.

The natural gas interconnectivity that currently exists in LAC consists primarily of three cross-border gas pipelines: Mexico-United States, Argentina-Bolivia-Chile-Uruguay, and Colombia-Venezuela. These links accounted for 7 percent of world gas pipeline trade in 2015, most of which flowed from the United States to Mexico (29.9 bcm) and from Bolivia to Brazil and Argentina (18.5 bcm). Until the mid-1990s there was only one cross-border gas pipeline in LAC—between Bolivia and Argentina. Following large discoveries of natural gas in Argentina and the inflow of private investment in the sector following liberalization, exports took off. Looking to monetize its gas supplies, Argentina oversaw construction of seven pipelines to Chile between 1996 and 2001. Exports to Uruguay from Argentina started in 1998 and to Brazil in 2000 to compete with the Bolivian gas that began flowing to Brazil in 1999. The pipeline between Colombia and Venezuela started operation in 2007. U.S. pipelines to Mexico doubled capacity in recent years; as buyers have tapped into the United States' low prices, U.S. piped gas sales to Mexico have risen 300 percent since 2010. Now this trade is set to double by 2019, as part of the largest natural gas export capacity expansion in U.S. history: plans call for construction of five more pipelines totaling about 2,400 kilometers and valued at $11.6 billion. These new pipelines are a key feature in Mexico's ambitious strategy to use gas to displace oil and to meet peak demand and growing industrial needs (Nemec 2016).

In addition to the pending new U.S.-Mexico pipelines, there are plans to bring very competitive U.S. natural gas to Central America—a net importer region—via a 600-kilometer, $700 million pipeline linking Mexico, Guatemala, and Honduras. The project is currently in the phase of technical and feasibility studies. Issues delaying construction include concerns over costs and political risk linked to potentially deteriorating U.S.-Mexico relations. Finally, consideration is being given to building a pipeline linking Montevideo and Buenos Aires, to supplement Buenos Aires' supply with gas coming into Uruguay's new LNG import facilities.

Growth in LNG

While moving natural gas by pipeline is generally the most economical means of short to medium-haul transportation,[6] LNG is on the rise in LAC. LNG is seen as a means to supply new markets far from infrastructure and minimize uncertainty linked to cross-border cooperation. LNG can overcome the lack of alternative sources of gas supply (e.g. Dominican Republic, El Salvador, Panama), increase security of supply (e.g. Chile and Uruguay), add much-needed additional volumes to match growing demand (e.g. Mexico, Argentina, and Colombia) and provide flexibility to the system (e.g. Brazil).

LAC received its first LNG in 2008 and volumes rapidly increased from 0.5 bcm that year to 27.1 bcm in 2015. LAC is now a net importer of LNG, with Argentina, Brazil, Chile, and Mexico as the region's main consumers, accounting for 7 percent of global LNG demand in 2015. On the supply side, Trinidad and Tobago met approximately 5 percent of global LNG demand and 39 percent of LAC's LNG demand in 2015. Peru signed a contract to export LNG to Mexico since 2010 and is also selling LNG to other countries on the spot market from its Pampa Melchorita terminal.

There are currently 12 regasification terminals in operation or under construction. Five are floating storage and regasification units, or FSRUs, two are liquefaction terminals (Peru and Trinidad and Tobago) and four are regasification terminals under construction. This last group

MAP 3.3 Natural Gas Major Trade Movements (2015) *(bcm)*

US
Canada
Mexico
S. & Cent. America
Europe & Eurasia
Middle East
Africa
Asia Pacific
Regasification plants
Liquefaction plants

Source: BP 2016.

consists of Uruguay Gas Sayago (FSRU), Panama Costa Norte (land-based LNG), Colombia Cartagena (FSRU), and Jamaica New Fortress Energy (land-based LNG).

Concerning trade, Chile is using its Quintero and Mejillones terminals to regasify gas that is then shipped to Argentina through Chile's extensive natural gas pipeline and distribution network, which had been idled after gas supply from Argentina failed in 2004. Argentina is using the gas to replace the more expensive diesel it had been using in the winter months to meet industrial demand, while focusing gas deliveries on residential consumers for heating.

AES Dominicana, started providing LNG trans-shipment and LNG bunkering services to customers around the Caribbean in 2015. The company wants to act as a hub for purchasing large shipments of competitively priced LNG, possibly from the United States. This LNG will then be redistributed to off-takers in other countries via smaller LNG vessels and containerized LNG cylinders, or in the form of compressed natural gas. This "hub and spoke" approach is well suited to displacing oil-fired generation in the Caribbean by aggregating demand (including that of the Dominican Republic) and thus enhancing the region's negotiation capacity on price. Success would require international cooperation and agreement among off-takers (particularly in view of the upcoming competing LNG project in Jamaica), balancing of the uncertainties and volatility in the market, building trust, and developing distributed, small-scale gas-to-power systems in the Caribbean. These systems have lower capital intensity, can be implemented faster and phased to match load growth, but at the same time, they have reduced economies of scale and therefore higher per unit costs.

An additional 10-15 LNG regasification terminals are under consideration in LAC, including five projects in Brazil. Of these five, four are integrated LNG-to-power projects, involving the construction of FSRUs and power plants. The remaining project is an onshore regasification terminal in Pecem being considered following Petrobras' recent LNG asset divestment. When and if they're built, these projects could increase Brazilian LNG import capacity by over 50 percent.

The region's LNG market stands out for the speed with which it has grown, its variability, and the strong presence of FSRUs.[7] What is also prominent is the reliance of LNG buyers (except for the Dominican Republic and Chile) on spot and shorter-term LNG purchases instead of the more traditional long-term oil-indexed take or pay contracts. Spot LNG imports into Brazil and Argentina have been based on the highest alternative market price, plus a trading margin and a freight differential. Argentina's financial difficulties were the main impediment to long-term contracts, while in Brazil the power sector's demand uncertainty—much depends on hydropower availability—has made planning LNG requirements very difficult.

While LAC buyers are benefiting from today's low gas hub and LNG prices, they were paying some of the highest spot prices just a few years back as a result of high oil prices, strong competition from Asia, and constrained global LNG supply. A return to these high prices is not expected in the near future. LAC is instead expected to benefit from the growing flexibility of the global LNG market brought about by the U.S. gas revolution: U.S. producers offer bountiful gas and so-called tolling contracts, which lack destination clauses and are based on hub prices.[8]

MAP 3.4 LNG terminals in LAC as of 2016

Source: International Gas Union 2017.

LAC is unlikely to be a major LNG market in the future. Its size will ultimately be determined by weather conditions and major consuming countries' success in developing their own natural gas reserves. Demand for LNG in Argentina and Brazil may drop significantly if they succeed in developing Vaca Muerta and the pre-salt plays, respectively. Other factors in the size will be the degree of competition from pipeline gas (the Bolivia-Brazil Agreement ends in 2019, and the Central America pipeline may be built) and incorporation of new technologies such as small-scale gas-to-power projects that make LNG more competitive by being flexible, smaller, and decentralized.

Natural gas markets in LAC are largely incomplete

Six LAC countries have embarked in gas sector reform, including Argentina (1991), Colombia (1994), Chile (1995), Brazil (1998), Peru (1998), and Mexico (in 1995 with very limited scope, and 2013 via an overarching reform of the energy sector). Some of these reforms run in parallel with electricity sector restructurings (Argentina, Colombia, Mexico). Overall, the reforms aimed at modernizing and expanding infrastructure to reduce energy costs, improve quality of service, increase access, and diversify the energy supply basket.

The reforms involved in some instances a combination of privatization with the introduction of new greenfield projects. The new markets introduced a new institutional organization that included independent regulators (in some cases, jointly with electricity regulators), and dedicated specialized system and market operators. The reform was initially built upon the tradition of gas supply agreements with high take or pay levels. Very few countries adopted auctions, or gas dispatch systems integrated with electricity, in competitive terms. In many cases, prices were fixed by national oil/gas companies.

Countries attempted to establish competition in one or more segments of the supply chain via market mechanisms and cost-reflecting tariffs to attract private sector participation, and emphasized transparency to reduce conflicts of interest. The starting conditions were varied, some countries had already solid hydrocarbon industries and national oil and gas companies (Argentina, Brazil, Mexico), while others had to introduce new greenfield markets and invest across all segments of the supply chain (Peru, Chile and Colombia).

Countries that did well in gas market reforms – i.e. experienced increased market penetration, successfully developed natural gas infrastructure - were those that opened the door to private participation and unbundled the gas sector value chain (Argentina initially, Peru and Colombia). Other countries such as Chile allowed wholesale market and large consumers to negotiate contracts independently but have not yet experienced high penetration rates – 25% - in part due to high tariff levels.

In Peru, wholesale market and large consumers are free to negotiate transactions, but supply tenders for distribution companies and for transmission expansion have dominated the market. However, except for the case of Colombia, competitive markets have not matured in these countries, and a regional gas market integration has not consolidated as such.

In Argentina, Brazil and Mexico, the initial reforms were either reversed or unsuccessful. Argentina was relatively successful in the decade after the reform was introduced, however with the macroeconomic crisis of 2002, the Government intervened in market transactions in the sector, introducing administratively-set prices and subsidized tariff arrangements, and it is not until now that a new administration is revisiting the previous reform and revising existing institutional, legal and regulatory frameworks.

The reversal in Argentina had also dramatic consequences in Chile, as the two countries had signed protocol agreements for gas trade, allowing investment in more than six trans-border pipelines to supply mainly different consumer segments in Chile (electricity generators, industrial, commercial and residential). In 2002, the government of Argentina restricted exports, and Chile had to invest in an expensive LNG regasification terminal.

The reforms in Mexico (1995) and Brazil (1995) on the other hand, did not go deep enough into breaking the power of incumbent oil companies PEMEX and PETROBRAS respectively, so competitive markets did not develop in practice.[9]

Indeed, competition has been difficult to establish in all these markets and private sector investment has been limited. Only 13% of total private investment to energy infrastructure in the region over the 1990-2015 period went to the natural gas industry, and mainly to distribution.[10]

At present, practically 25 years after the initial reforms, Argentina and Brazil are going through a new round of revisions and redefinition of existing frameworks, and Mexico is in the process of implementing an overarching reform of the hydrocarbons sector. In all cases, the aim is again to achieve cost-reflective tariffs, subject transactions and pricing to market forces, and ensure transparency.

Chile, Peru and Colombia on the other hand have made great strides -and were relatively successful- in developing functional gas markets. In these three cases, the governments have played a key role in planning and facilitating the evolution of the market. For instance, through the unbundling of the transportation and distribution segments, Peru was successful in scaling-up the use of natural gas particularly for transport and electricity generation; in this case, lower gas prices and extension of transmission and distribution networks resulted in large part from the facilitating role of the Government in supporting projects' structuring and procurement as well as in anchoring gas demand with electricity demand.

In establishing competition Colombia and Argentina (1992-2002) were the most successful; and in developing new greenfield markets, Peru and Colombia have delivered on the reform promises.

One of the key lessons has been that a good level of competition can only be established when governance is strong (functional institutional organization, strong regulatory framework that allow transparent and flexible transactions), and there are market rules that clearly define a path to unbundling, allow pass-through of price changes and create a level playing field among public and private companies. In addition, regulated Third Party Access (TPA) has proven instrumental to competition (e.g.; as opposed to negotiated access).

In greenfield or new natural gas markets, the experience has been that the role of the State as a facilitator and planner is crucial to private investment (including anchoring gas demand to power sector demand, and assessing economic costs and benefits of existing alternatives), and that governance is vital to competition (e.g.; open and transparent procurement, mechanisms to address conflicts of interest).

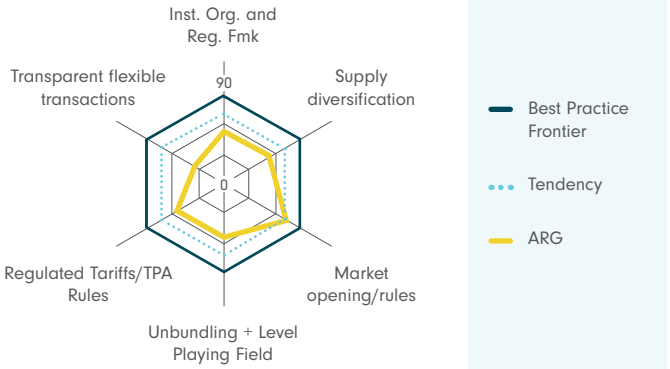
The spiders in Matrix 3.1 and Matrix 3.2 provide a qualitative assessment based on expert opinion, on the status and performance of gas markets in LAC (both competitive and greenfield).

Matrix 3.3 below provides details of market structures in different segments of the supply chain.

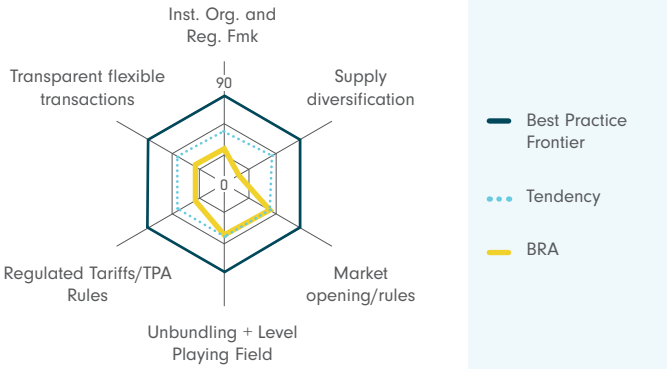
The lessons of experience however need to be adapted to the new context, where abundant and low price LNG is playing a key role in LAC, not only as an additional fuel that contributes to security of supply and expands access to distributed markets, but also as a competing fuel, with the potential to redefine the competitive structure of domestic natural gas markets.

MATRIX 3.1 Competitive Gas Markets: Performance and Tendency

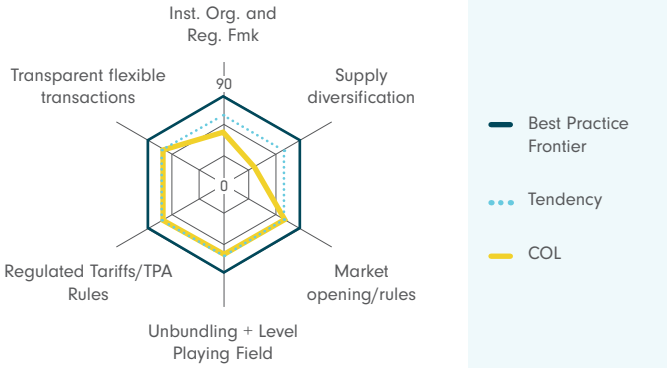
Argentina



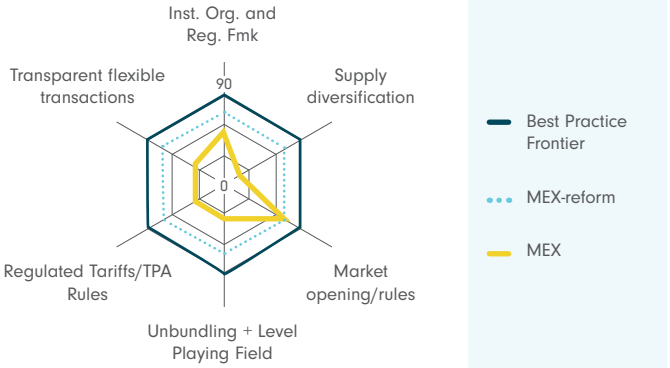
Brazil



Colombia



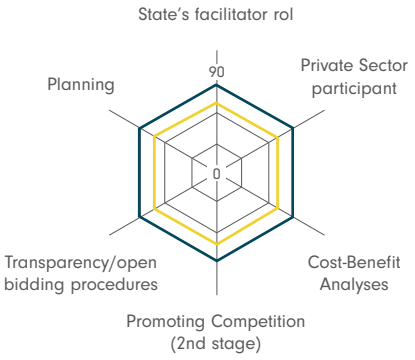
Mexico



Source: Prepared by authors.
Note: This set of indicators measure qualitatively the performance of competitive gas markets. The indicators or attributes are defined in Table 3a, Annex I.

MATRIX 3.2 Greenfield Gas Markets: Performance and Tendency

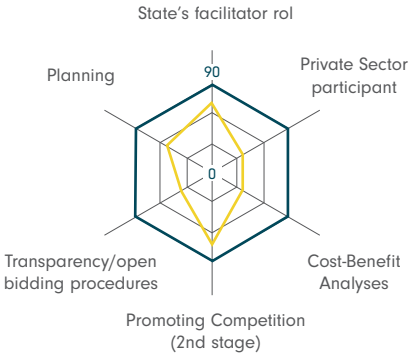
Colombia



Best pratice frontier

COL

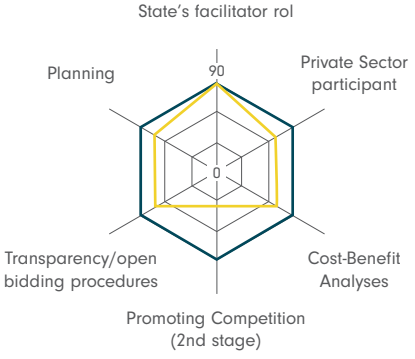
Argentina



Best Practice Frontier

ARG

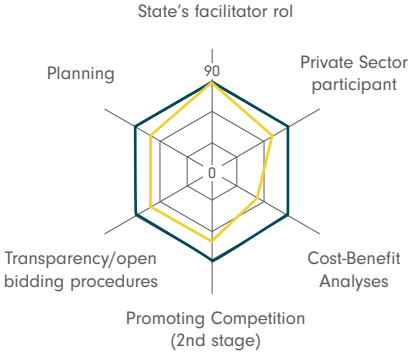
Chile



Best Practice Frontier

CHI

Peru



Best Practice Frontier

PER

Source: Prepared by authors.
Note: This set of indicators measure qualitatively the performance of "Greenfield Markets", i.e.; new markets, or those in which countries had to invest in all segment of the supply chain. The indicators or attributes are defined in Table 3b, Annex I.

MATRIX 3.3 Overview of LAC's Natural Gas Markets

Market Structure	Production/Import (LNG/pipelines)	Transport	Distribution/ carrier	Commercialization	Comments
ARGENTINA					
Gas Law No. 24076 of May 20, 1992 Wholesale Market Free Large Consumers, single buyer, contracts for discos, (sector "paralyzed" for some time, regime/tariffs under review)	Fully unbundled YPF competes with importers, producers, and LNG companies ENARGAS is a single buyer	Two gas pipeline companies: Transportadora de Gas del Norte (TGN) and Transportadora de Gas del Sur (TGS). Largest network of transport and distribution pipelines in the region (50,000 km).	Nine firms: Metrogas, Gas Natural BAN, Camuzzi Gas Pampeana, Camuzzi Gas del Sur, Litoral Gas, Centro, Cuyana, and Gasnor. The first three account for 54% of the gas distributed in the country.	56 commercialization companies	Transport and distribution are considered public service activities The National Gas Regulatory Body (ENARGAS) grants concessions, regulates access to transport and distribution networks and charges, and ensures consumer protection.
BRAZIL					
Gas Law 11909 of March 4, 2009 (yet to be fully implemented) Monopoly or Multiple State Owned Enterprises (currently under review, changes to the natural gas regime may come in short-term)	Petrobras acts as a single buyer and almost single seller of gas, deciding volume and consumers targeted based on market risks Private companies free to invest in LNG terminals	Petrobras controls all existing pipelines and LNG terminals ANP regulates access and tariffs for new pipelines, Private companies free to invest in specific pipelines	27 private and state concessionaries (gas LDCs) Petrobras is shareholder in most LDCs Concessions granted by state governments	State regulatory agencies approve prices and concession contracts LDCs exclusive geographic franchise: 30-50 years Only distributors can commercialize natural gas	Policy set by Ministry of Mines and Energy (MME) Federal regulator: National Petroleum Agency (ANP) 27 state regulators
COLOMBIA					
Electricity Law 142 de 1994 Wholesale Market/ Free Large Consumers are free to negotiate independently; tenders are mandatory to supply gas to distribution companies	Full competition for production (23 companies), imports, and LNG companies Private investments in pipelines	Seven pipeline companies: Promigas and TGI account for more than 90 % of transport	45 distribution companies	93 commercialization companies	Gas tariffs are relatively low National Energy and Gas Regulator (CREG) sets tariffs for transport, distribution, commercialization Reliability payment to ensure the availability of firm energy during dry periods or El Niño events has been a driving force in gas-based generation.
MEXICO					
Hydrocarbons and Revenues Law became effective on August 12, 2014 Wholesale Market/ Free Large Consumers (tenders: contracts for discos and for transmission expansion) There is a competitive landscape, which is expected to gradually evolve into an open market.	SENER is responsible for granting licenses for E&P activities through competitive bidding. Imports/exports allowed. Three LNG terminals: Altamira, Ensenada and Manzanillo,	11 pipeline companies Transport and storage is competitive, bids Private companies can participate in midstream and downstream activities	SENER approves treatment and processing of natural gas; import and export; and integrated pipeline transportation and storage systems	All permit holders providing transportation, distribution or storage services shall provide open and non-discriminatory access to their facilities, subject to available capacity and pursuant to rules to be issued by CRE. They may include the strict legal separation among activities or the administrative, operational or accounting separation of certain	The Energy Regulatory Commission (CRE) approves permits and tariffs for transportation, storage, distribution, compression, liquefaction, decompression, regasification, marketing and retail sale.

Note: Blue cells denote segments where competition is allowed, via auctions, bidding or in the market (however, please note that this does not necessarily mean that competition has been established in reality). (*) In legal framework, and in the process of implementation

Natural gas is key to climate resilience and security of supply in LAC

While natural gas use is likely to continue to grow in LAC in the short- to medium-term, it is not going to replace hydropower as the main source of energy in the region, despite the region's vast base of this resource. Still, natural gas is set to make a significant contribution to the region's climate resilience as well as to security of supply.

In coming years, environmental considerations are likely to boost demand for natural gas in Latin America. Compared to other regions of the world, LAC is the most dependent on water for power generation. Existing plans to meet electricity demand growth include adding 110 GW of hydropower capacity by 2040, most of which would be concentrated in Brazil and Ecuador. These are the plans, though in recent years hydropower has had the highest annual variation of any renewable energy technology due to changes in rainfall and average temperatures. A severe drought across much of LAC has sharply reduced both hydropower output and the amount of water currently stored in its vast reservoirs, which will likely reduce hydropower output for years to come. All of this points to the need to see this variation as "the new normal" and look for ways to make power generation systems more resilient and dependable. This means going beyond the current piecemeal/seasonal responses and instead changing policy and long-term investment strategy to make the power generation system more diversified and resilient as a whole. Success stories in Uruguay, Chile, and Brazil, and the maturity that renewable energy industry is achieving at the regional and global level suggest that non-conventional renewables may be an answer. Natural gas, with its flexibility, dependability, and relatively low carbon footprint, can be incorporated as a complement and support for renewables in the development of a cleaner electricity mix.

"Hybrid" electric systems offer a way to promote the integration of natural gas, solar, and wind. When generation resources are combined, their respective performance advantages compensate for each other's shortcomings. The idea is to create power plants that can do more than the two resources acting independently. The hybrid technology that is probably furthest along in installed capacity is known as integrated solar combined cycle (ISCC). Each of the world's approximately six existing ISCC plants pairs concentrating solar power (CSP) with a conventional combined cycle plant. The main benefit of this set-up is that the two systems employ the same steam cycle, making for substantial cost savings over a conventional CSP plant. It also increases efficiency of the combined cycle plant and reduces total emissions per megawatt. Thus far, most of the completed ISCC plants are in North Africa but Latin America has the potential to surpass it (Overton 2015).

Natural gas is a viable alternative to oil-fired generation in many cases. Regions such as LAC that have growing electricity demand, high electricity prices, and high percentages of oil generation (an average of 40 percent in Central America and 80 percent in the Caribbean) are good candidates for displacing oil with gas-to-power. This is especially true when alternatives such as geothermal are not present or commercial. For the displacement to materialize—and LAC to benefit from lower emissions, energy costs, and trade imbalances—natural gas supply and demand dynamics need to change and investments in infrastructure must be stimulated.

Driven by COP21 commitments and tougher international standards, LAC is looking for ways to reduce emissions in transport (road, river, and maritime). Currently emissions from road transport in LAC are among the highest among developing countries and represent one third of the region's total CO2 emissions. By expanding its CNG fleet, LAC could significantly cut transport-related emissions. Vehicle modeling research shows that replacing diesel with CNG in heavy-duty trucks can reduce greenhouse gases between 13 and 25 percent and NOx between 13 and 88 percent (Jaffe et al. 2015; Schipper et al. 2011; NGV America 2016). An expansion of the use of LNG in shipping (the hybrid ferries of Argentina, for example) could also help meet the 2016 International Maritime Organization standard that sets a 0.5 percent cap for sulfur starting in 2020. It could also reduce air pollution, ranging from the complete end to SOx and PM emissions, an up to 85 percent reduction in NOx emissions, and a 25 percent reduction in CO2 emissions.

Finally, natural gas in the short to medium terms, and under specific circumstances, can be a cornerstone to energy security. Natural gas—particularly LNG—can enhance resilience to supply disruptions, whether caused by climate change, geopolitical events, or unexpected shifts in demand. LNG offers particularly strong advantages in security of supply because it comes from diversified sources (from within LAC and outside it) and can respond to changes in need quickly.

Notes

1. Despite the crash in oil prices (and decline in coal and natural gas prices), investments in clean energy have surged in LAC from $11 billion in 2013 to $15.7 billion in 2014, and $17.46 billion in 2015 (BNEF, 2016). Private investment in solar photovoltaics alone grew from zero in 2010 to $2.2 billion in 2014 (PPI database).

2. The conversion of the Buenos Aires-Montevideo ferry is producing large fuel savings and allowing a faster and more efficient operation than with diesel oil. Small-scale liquefaction terminals were built to supply the ferry. They began operation in 2014—development took one year—and currently produce 70 tons per day of LNG, using the gas pipeline network of Buenos Aires as a source.

3. The IEA predicted in its WEO 2015 report that Latin America and the Caribbean will need to invest $2.8 trillion across the hydrocarbons value chain in the next 25 years ($112 billion per year). That would be an increase of 50 percent from the previous 25 years, funding that most governments in LAC do not have.

4. See map in Annex 3.

5. For more on the development of Argentina's gas infrastructure, see Natural Gas—Private Sector Participation and Market Development, World Bank, 1999.

6. Gas transportation costs vary with distance, scale, and setting. The rule of thumb is that offshore the threshold is around 1,500 kilometers, onshore about twice that. For greater distances, LNG generally makes more economic sense. Notwithstanding, real figures depend on a lot of parameters that are case-specific.

7. FSRUs have been popular in LAC as they require lower upfront costs than onshore LNG terminals (a $40-50 million lease vs. a $1 billion investment) and shorter lead times for design and construction (one to three years vs. four years and up). In addition, they have smaller environmental footprints and can be moved or removed at relatively short notice to respond to highly seasonal gas demand, such as Brazil's increased demand during a drought. For more, see Gas Network Options in Annex.

8. Destination clauses forbid buyers from re-selling the product to a different destination, which allows a monopolist to earn more revenue through price discrimination. In a competitive market, price differentials between locations are limited to the cost of arbitraging between those locations. For more, see Hartley 2016.

9. Incentives to partner with PETROBRAS in the upstream and midstream segments have been low. In addition, from 2019, Brazilian States will replace PETROBRAS and initiate imports from Bolivia. The regulator (ANP) will also allow TPA in LNG terminals to diversify options.

10. This participation was concentrated in Brazil (41.6%) and Mexico (23.8%), the rest distributed among Argentina (10.4%), Peru (9.9%), Chile (4.8%), Colombia (2.8%), and other.

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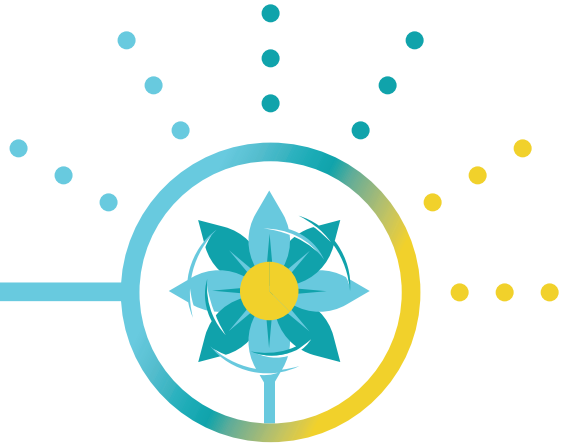
CHAPTER 4

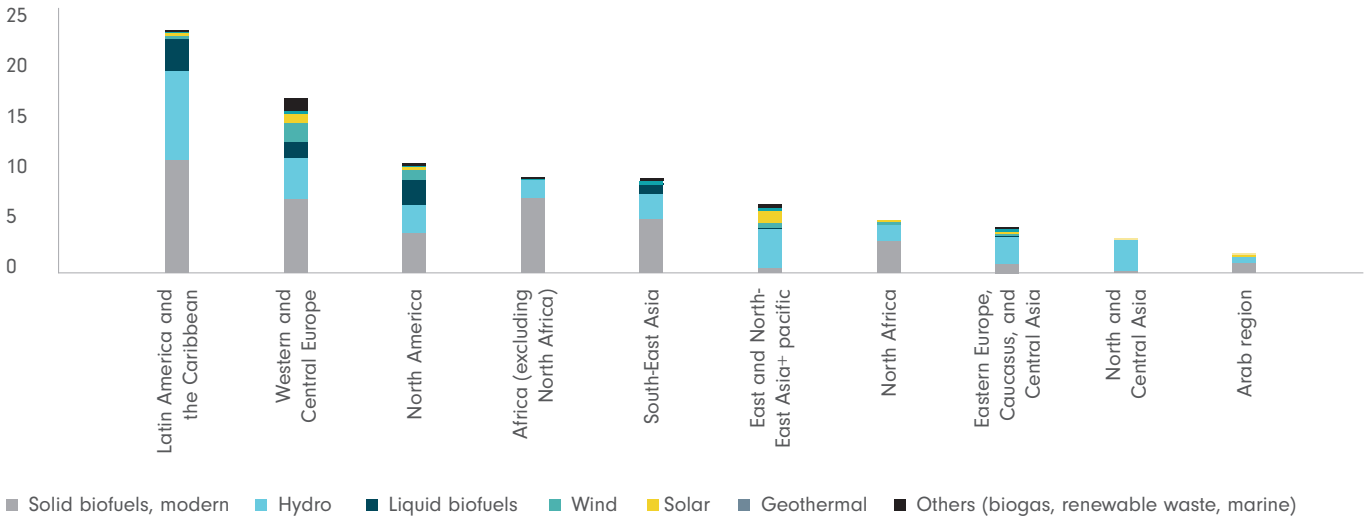
Enabling Sustainable Energy



LAC has the world's highest share of renewable energy in total consumption

The region's share of renewable energy in total final energy consumption—excluding traditional uses of solid biomass— was estimated at 22.8 percent in 2014, the highest in the world among regions (see Figure 4.1). This is largely due to heavy reliance on hydropower for electricity and, particularly in Brazil, use of biofuels for transport. However, total renewable energy consumption—23,293 PJ—is modest in absolute terms, compared to developed countries, East Asia, and particularly, China.

FIGURE 4.1 Share of Renewable Energy in Total Final Energy Consumption, by Region (2014) *(Percent)*

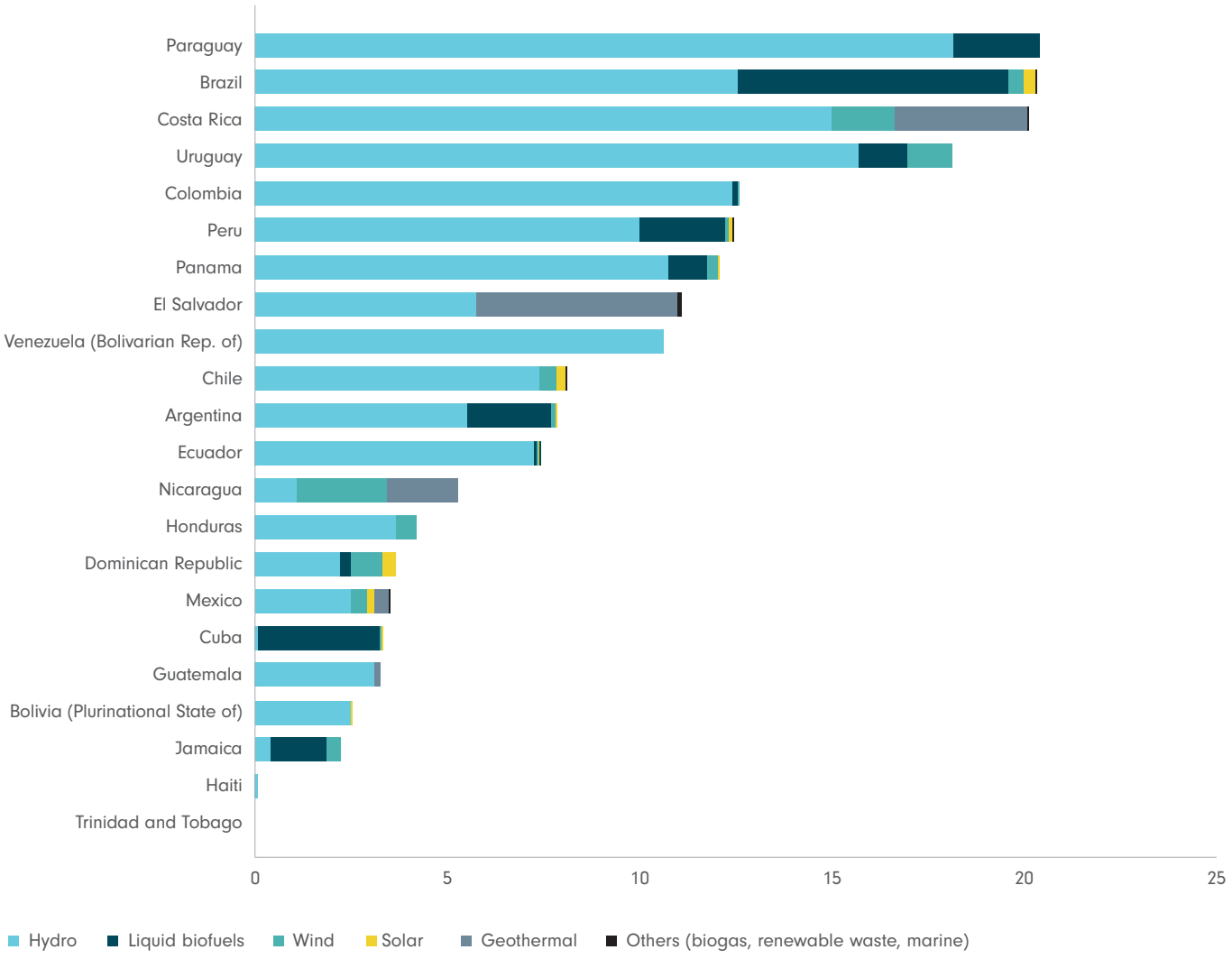


Source: World Bank staff calculations based on data from World Bank and International Energy Agency (IEA) 2017.

Moreover, the overall share of renewable energy has gradually declined, from 32.3 percent in 1990 to 27.3 in 2014 (see Figure 4a in Annex I). Two factors are causing this trend: a significant reduction in the use of solid biomass as more people shift to modern non-solid fuels, and a growth of fossil fuel use at the expense of hydropower. With this last trend, however, has come a decarbonization of the energy matrix, as cleaner-burning gas replaces oil.

LAC countries vary substantially in their energy mixes, as shown in Figure 4.2, with the Caribbean island states in particular using very low shares of renewables, although promisingly, this is starting to change in the last two years.

FIGURE 4.2 Share of Renewable Energy in Total Final Energy Consumption, 2014 *(Percent)*

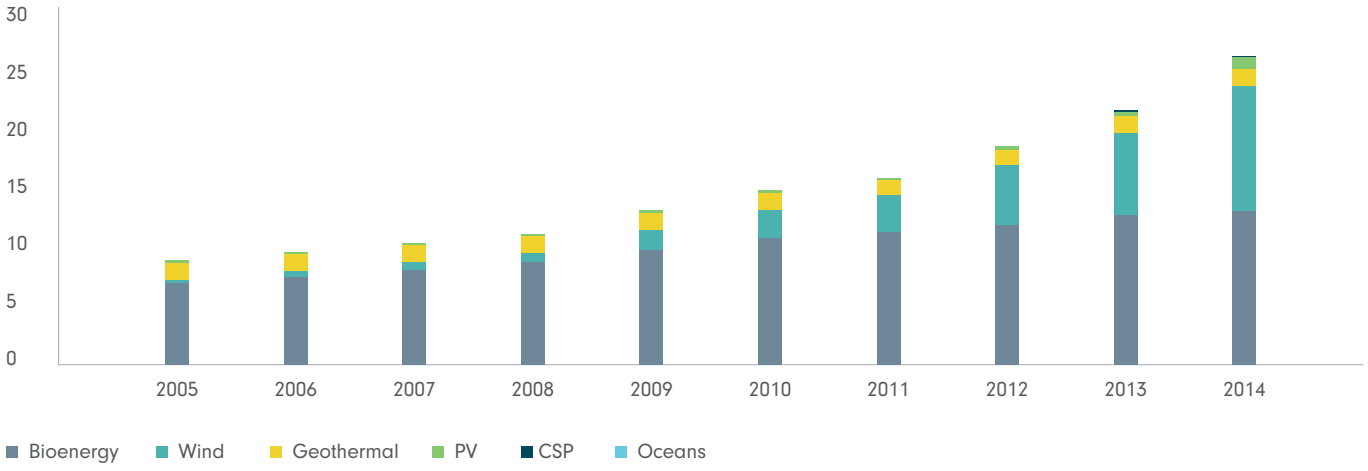


Source: World Bank and IEA 2015.

Note: Excludes modern and traditional uses of solid biomass. Caribbean Islands are mostly reliant on fossil fuels.

In electricity, the share of renewable energy in the region reached 63 percent in 2013, with a total generation of 1,183 TWh. In addition to the significant hydrogeneration, a number of countries in LAC (led by Brazil, Mexico, and Chile) have made some progress in developing other renewable generation technologies—particularly wind and most recently solar photovoltaic, benefiting from global cost reductions (Figure 4.3).

FIGURE 4.3 Non Hydro Renewable Energy Capacity in LAC, by Technology *(GW capacity)*



Source: World Bank and IEA 2017; OLADE-SIER (database).

But modern renewables have not grown as fast as in other regions

Deployment of modern renewables has so far lagged behind progress in other regions. In 2014, LAC accounted for less than 3 percent of globally installed wind capacity and just 0.5 percent of global solar PV capacity. However, the IEA expects the region to make rapid progress with a three-fold increase in wind capacity and a nine-fold increase in solar PV by 2020, driven by a series of planned auctions. Most of this growth will be concentrated in Brazil, Mexico, Chile, and Peru.

These four countries have good resources and financial regimes in place which together remunerate renewable energy generation on the basis of long-term PPAs awarded through competition. Already, these conditions have driven down prices of wind- and solar PV-generated electricity in Brazil and Peru, and more recently Mexico, Chile, and Argentina. Prices for this energy are now among the lowest in the world (see Box 3.3, Chapter 3).

With an ambition to rapidly increase renewables in their electricity supply, a few countries in the region, such as Mexico, have been working on transmission planning and regulatory incentives to integrate an increasing volume of variable renewable energy generation into existing grids.

BOX 4.1 Renewable Energy in the Caribbean

Although petroleum products provide almost all primary energy needs in the Caribbean, CARICOM member states proposed in the Caribbean Sustainable Energy Roadmap and Strategy (C-SERMS) to meet a regional target of 48% of renewable share of installed power capacity by 2027, and renewable energy solutions are gradually being implemented throughout region.

Renewable technology adoption is expected to tackle issues tied to the region's relatively high energy prices from the inefficient generation, transmission and distribution systems, in addition to improving environmental practices. Renewable energy technologies being deployed include solar water heating, wind farms, solar photovoltaics, and geothermal energy.

Solar water heating systems, which use the sun to heat water are being used extensively in Barbados, where nearly half of the households and commercial applications already make use of the technology. Solar photovoltaics (PV) prices have dramatically dropped in price over the last decade. In many cases, electricity from PV is competitive with the existing grid-network supply in the region. There are various countries using the technology on a small scale, including Guyana, Belize, Antigua and Barbuda, Saint Kitts and Nevis, Jamaica, Dominica and Barbados. Likewise, prices have fallen dramatically for wind technology, and it is being deployed in countries such as Jamaica, Dominican Republic, and Aruba.

Finally, numerous countries in the region have significant geothermal potential. The only active geothermal power plant online today in the region is in Guadeloupe, but islands of volcanic origin, such as St. Lucia, St. Kitts and Nevis, Dominica, St. Vincent and the Grenadines, and Grenada are aggressively pursuing geothermal as a clean, renewable, baseload power option.

Source: Prepared by authors.

LAC is the second-largest producer of biofuels in the world

Renewables can also contribute to energy needs for transport, especially through biofuels. LAC was the second-largest regional producer of biofuels for transport in 2015 (behind North America), producing some 39 billion liters, about 30 percent of global production.

Brazil has been a pioneer in bioethanol since the 1970s. In 2015, the country produced 29 percent of the world's bio-ethanol fuel, 29.7 billion liters. Brazil leads the world in use of flexi-fuel vehicles, which allow consumers to use any mix of ethanol and gasoline and to choose according to price and other preferences. Fuel ethanol production in Argentina was around 800 million liters in 2015 and is projected to rise because the blending mandate is due to increase from 10 to 12 percent in early 2016. Elsewhere in LAC, ethanol production and use is expected to grow following establishment of a 5.8 percent ethanol blend program in Mexico, an increase in the national blend rate from 5 percent to 10 percent in Ecuador, and the introduction of

national coverage and availability requirements for E85 distribution in Paraguay. In Colombia, new ethanol production plants coming on line may facilitate an increase in nationwide blending to 10 percent.

Brazil is the second-largest global producer of biodiesel, at 3.9 billion liters per year. It is also a leader in development and production of advanced biofuels, particularly ethanol from sugar cane bagasse. For example, Raizen's large-scale cellulose ethanol plant in São Paulo began operations in 2015 and is projected to produce 42 million liters of cellulosic ethanol annually. Brazil is also a pioneer in using zoning to manage land use for biofuels and limit change effects of indirect land use.[1] Argentina, meanwhile, is also strong in the biodiesel field, ranking among the top 10 biodiesel producers (2.2 billion liters per year) for use internally and for export.

The long-term sustainability of biofuels remains the subject of debate. However, ethanol produced in the region from sugar cane offers one of the best ways to reduce carbon emissions relative to gasoline. Brazilian ethanol qualifies as an "advanced biofuel" under the U.S. Renewable Fuel Standard Program, opening up export opportunities.

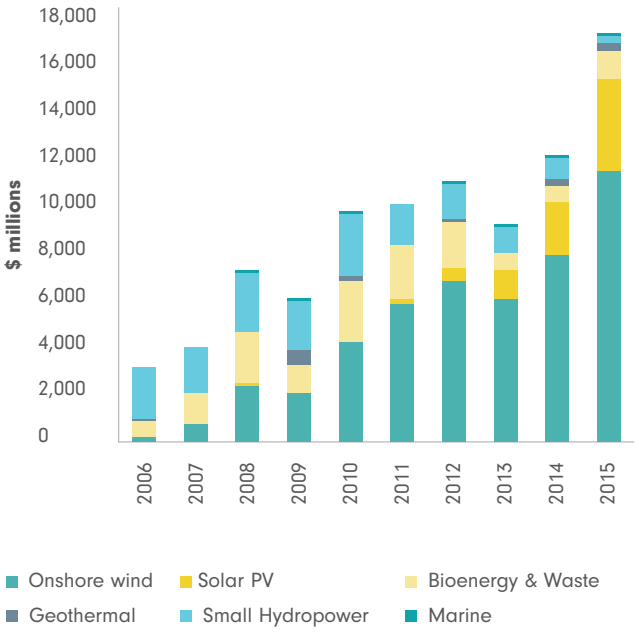
Total investment in renewables has increased, but the enabling environment for private investment is still developing

Some countries in LAC have put in place policies that are fostering growth of renewable generation. Use of auctions to promote wind and solar has been quite successful in Argentina, Brazil, Peru, Mexico, and Chile (see Box 3.3). Other LAC countries are beginning auctions, including Jamaica, El Salvador, and Guatemala.

Total investment in renewable energy is growing in the region (see Figure 6.4). Onshore wind investments have ramped upward consistently since 2008, while solar started to rise in 2012 as prices of solar PV modules fell. Small hydropower and bioenergy remain a visible part of the investment equation every year, while geothermal investment occurs irregularly, given the limited number of projects under development in the region.

Private investment to support renewable energy, mostly wind, has increased gradually in the region, concentrated in Brazil, Chile, Peru, Mexico, Uruguay and Argentina. Recent data however shows a clear decline in private investment in renewable energy, but this goes with a drop in investment to overall energy sector infrastructure (Figure 4.5). In fact, total investment in electricity generation in the period 1990-2015 concentrated in renewables (69%) despite the recent decline. Factors responsible for this decline may include the general economic slowdown in the region, low attractiveness of existing policy incentives, and, notably, constraints in securing land and environmental permits to build new plants.[2]

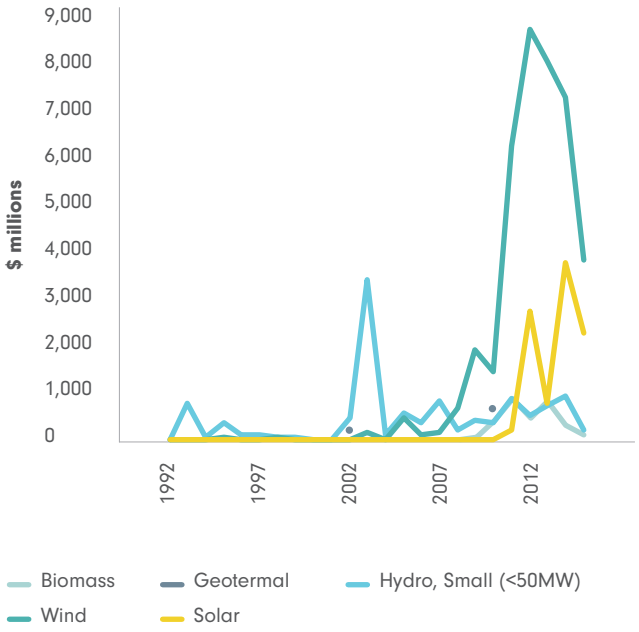
FIGURE 4.4 Total Investment in Renewable Energy *(USD Million)*



Sources: Prepared by authors based on data from Bloomberg New Energy Finance (database).

Notes: Includes both public and private investment. Hydropower larger than 50 MW is not covered in the analysis; however, it is expected to remain the dominant technology for further renewable energy deployment in the region in the long-term.

FIGURE 4.5 Private Investment in Renewable Energy in LAC (1992-2015) *(USD Million)*



Sources: Prepared by authors based on data from PPI (database).

In terms of creating a better enabling environment for private investment in renewable energy, LAC has made progress in its legal and policy frameworks. But the region needs further improvements in planning and regulation if private sector participation in clean energy is to rise to its full potential.

The RISE (Regulatory Indicators for Sustainable Energy) Index provides a proxy for progress in the investment climate for investment in renewables. For the best-performing countries in the region, the index finds that policy readiness to stimulate renewable energy investment is comparable to OECD averages. However, the overall picture is mixed, both in terms of areas and by country.

BOX 4.2 What is RISE

RISE is a product of the UN Secretary-General's Sustainable Energy for All initiative and aligns with the three targets of Sustainable Development Goal 7.

- RISE provides both a dashboard and a tool for policymakers to understand how a country's regulatory environment compares with its peers' and to identify priorities going forward.
- RISE analyzes 27 indicators encompassing 80 sub-indicators and 158 questions that capture the quality of the policy environment for energy access, renewable energy, and energy efficiency.
- RISE covers 111 countries across the developed and developing world that together account for more than 90 percent of global population and energy consumption.
- RISE classifies countries into a green zone of strong performers in the top third, a yellow zone of middling performers, and a red zone of weak performers in the bottom third.
- RISE is underpinned by a vast public information base of primary policy and regulatory documents, available to users at rise.worldbank.org.
- RISE indicators are published bi-annually, with the next report due in 2018.

In its first global roll-out, in 2017, RISE included 14 LAC countries: Mexico, Brazil, Chile, Dominican Republic, Nicaragua, Bolivia, Guatemala, Colombia, Peru, Argentina, Ecuador, Honduras, Haiti, and Venezuela.

The RISE renewable energy index evaluates whether a country has introduced key measures in the dimensions of planning, policies and regulation, and administrative efficiency. It also assesses counterparty risk and the existence of carbon pricing and monitoring.

Source: Regulatory Indicators for Sustainable Energy (RISE) (database).

Most countries in RISE's sample of 14 LAC countries in its first global roll-out have introduced legal and regulatory frameworks, targets, and action plans to promote renewable energy development (Venezuela and Haiti are exceptions). It is in the details of regulation, operational rules, and planning that LAC countries still need to work to approach the best practice frontier.

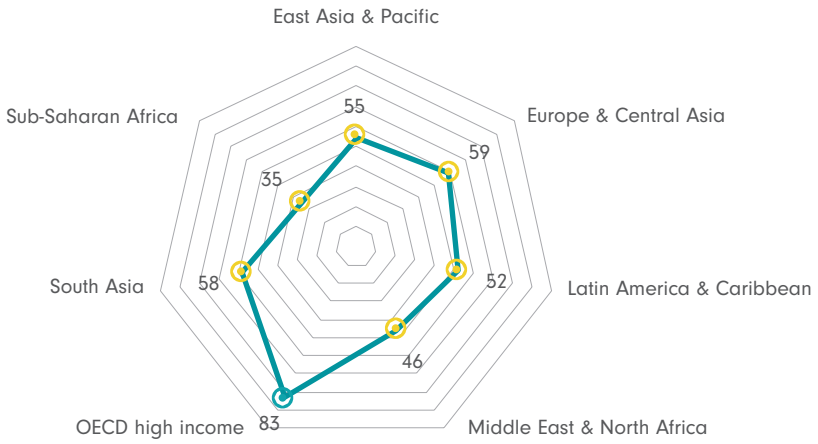
Only a few countries in the sample carry out transmission planning that considers renewable energy scale-up, and very few produce a strategic plan or zoning guidance that provides information on siting, which is essential to investors. Better resource data and mapping are needed.

Most countries would do well to focus as well on the efficiency and effectiveness of the regulatory incentives they've already put in place. Policy and regulatory incentives need not be subsidies such as high-level feed-in tariffs. Competitive platforms such as renewable energy certificate markets and procurement of energy through auctions

introduce competition into deployment of renewable energy. LAC has been a pioneer in the design and implementation of auctions.[3]

Overall, LAC scores a yellow tariff light (a score of 52 percent) in the RISE index, which indicates scope for significant improvement in the business environment for investment in renewables (Figure 4.6). There are of course differences among the LAC countries sampled by RISE (Table 4.1). A comparison of private investment in renewable energy as a percentage of gross national income (GNI) versus RISE scores rates Brazil, Chile, Mexico, and Nicaragua as good performers. Ecuador, Argentina, and Colombia score less well.

FIGURE 4.6 RISE Regional Average Traffic Light Scores for Renewable Energy *(Index)*



Source: RISE (database).

Note: Scores above 66% are given and green traffic light; scores between 33-66% are given a yellow traffic lights, and scores below 33% are given a red traffic light.

TABLE 4.1 RISE Results Renewable Energy Pillar for Selected LAC countries *(Index)*

	Chile	Mexico	Brazil	Dominican Republic	Nicaragua	Bolivia	Guatemala	Colombia	Peru	Argentina	Ecuador	Honduras	Venezuela	Haiti
I. Legal framework for renewable energy	100	100	100	100	100	100	100	100	100	100	100	100	100	0
II. Planning for renewable energy expansion	64	72	85	68	73	68	67	50	40	36	75	59	36	0
III. Incentives and regulatory support for renwable energy	88	88	50	75	100	75	88	63	50	75	50	75	13	0
IV. Attributes of financial and regulatory incentives	100	50	56	89	42	67	56	33	56	44	28	50	0	0
V. Network connection and pricing	92	44	89	92	58	47	22	58	25	33	67	0	0	0
VI. Counterparty risk	100	78	82	12	40	47	64	80	55	60	12	5	22	25
VII. Carbon Pricing and Monitoring Mechanism	0	74	0	0	0	0	0	0	0	0	0	0	0	0

Source: RISE (database).

FIGURE 4.7 Private Investment in Renewable Energy vs. RISE Score
(Percent of GNI, vertical axis; Index, horizontal axis), 2016

Sources: RISE (database); PPI (database)

Discretionary permitting weakens the enabling environment for investment in renewable energy

Many studies indicate that legal certainty and the length of administrative process to issue key permits are among the most relevant aspects influencing the decision to invest in renewable energy (Waissbein et al. 2013). Discretionary permitting processes and complexity of requirements increase the perception of risk and cost of investment.

The RISE data set provides an indication of the time it takes to obtain approval of Environmental Impact Assessments (EIAs) and permits in a selected group of countries. Figures 4c and 4d in Annex 1 compare countries surveyed, and show long periods for the approval of environmental licenses in Honduras, Colombia, Guatemala and Chile -notably for hydropower developments- as well as long periods for the approval of EIAs in Colombia, Guatemala, and Brazil.

The duration of the process however should not be necessarily associated with the efficiency or effectiveness of the administrative or regulatory system per se. Long periods to obtain approval of EIAs and licenses could be attributed to more intensive public consultations or rigorous procedures (World Bank 2017).

While many LAC countries have introduced institutional reforms and legal measures to enhance the efficiency and effectiveness of the IEA and licensing procedures , some studies describe the discretionary nature and procedural complexity of the permitting process in some countries of the region, which generally lead to the imposition of ad-hoc requirements that authorities can hardly monitor and enforce (Acerbi et al. 2014; Sanchez-Triana and Enriquez 2007).

A critical issue is the fact that most LAC countries still really on EIAs as the main instrument to prevent and address social and environmental impacts (even in the absence of the rigorous research necessary to underpin such assessments), as opposed to using a number of complementary instruments such as sectoral and technical standards with strong monitoring and stringent sanctions as in USA and other OECD countries (Meyer et al. 1997; Frank et al. 2000; Hironaka and Schofer 2002; Holder 2006).

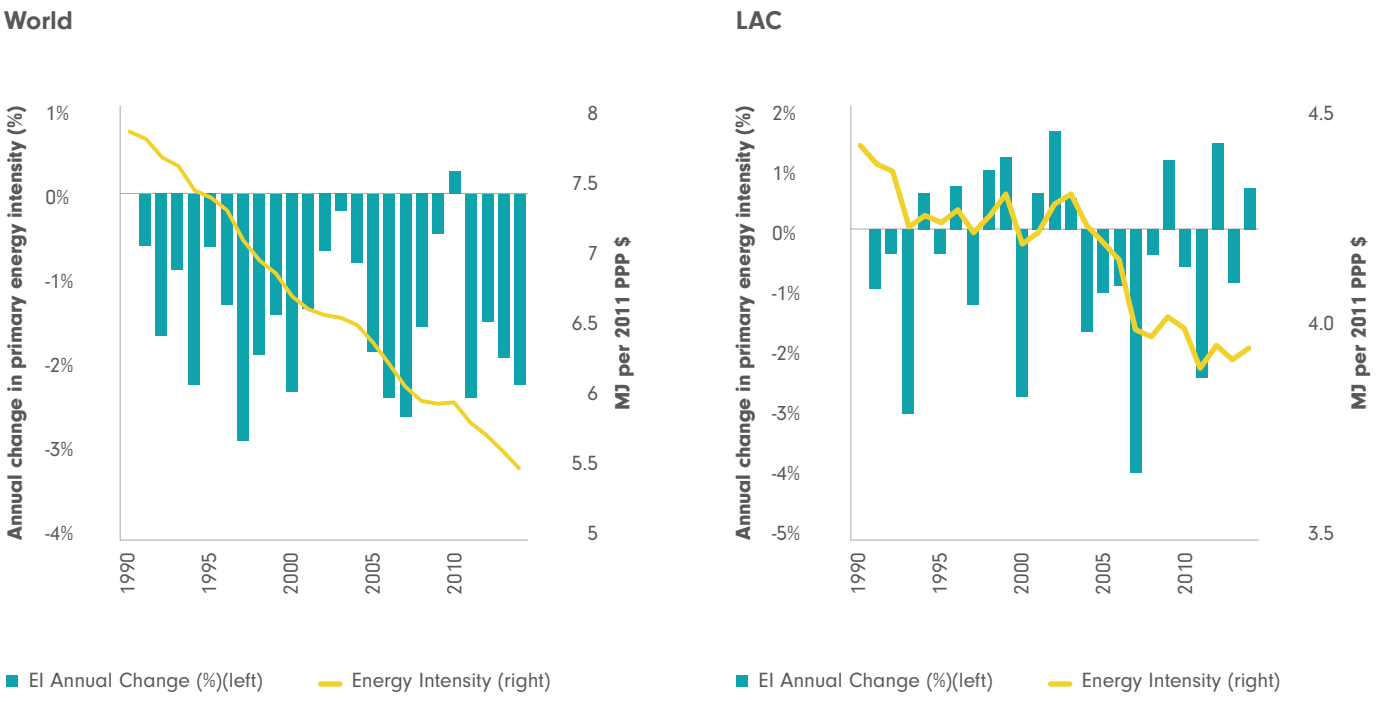
LAC is one of the least energy-intensive regions of the world.

The energy intensity of the region is estimated at 4.1 megajoules (MJ) per 2011 PPP (purchasing power parity of the 2011 U.S. dollar). That is below the global average of 5.8MJ/PPP and only slightly above the levels of Europe, 4MJ/PPP (World Bank and IEA, 2015). Haiti is LAC's exception, with energy intensity above the global average.

Monitoring within the SE4ALL energy efficiency initiative indicates a slight increase in the rate of improvement of energy intensity at the regional level from −0.47 percent in the 2000–2010 period to −0.82 percent in 2010–2012 (Figure 6.8). This is significantly lower than the rates of improvements shown in other regions and countries (North America was at −3.74 percent and China at −1.33 percent). However, the baseline conditions are vastly different. LAC started at much better levels, while, for instance, Eastern Europe and North America—which in 2012 had energy intensities of 8.5 and 5.8 MJ/ PPP, respectively—face more pressure to lower the levels faster.

There is significant variation between countries within LAC, and not all countries are progressing in a positive direction. For example, Mexico and Brazil—which rank among the top 20 energy consumers at the global level—play an important role in the intensity trends for LAC. Brazil increased the energy intensity of its economy from 3.9 MJ/PPP in 1990 to 4.1 in 2012, with energy intensity in households increasing at 0.6 percent per year between 2008 and 2012. Mexico has reduced its rate from 4.8MJ/PPP in 1990 to 4.0 in 2012, although energy intensity in industry increased at a rate of 1.9 percent per year over the same period.

FIGURE 4.8 Evolution of Energy Intensity Trends: World and LAC *(MJ/USD 2011)*



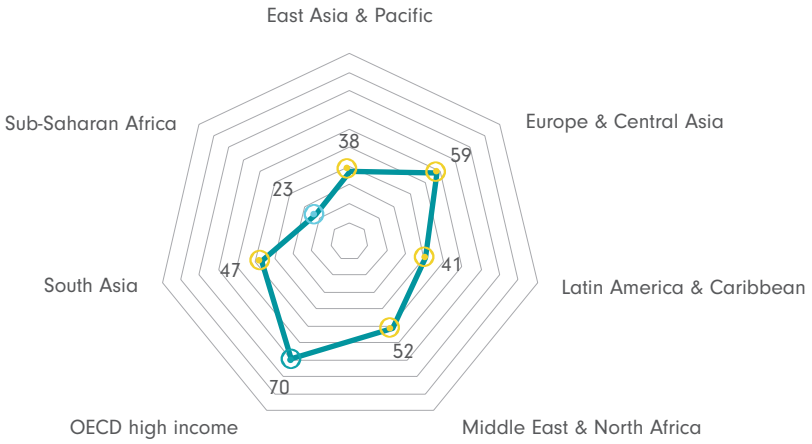
Source: Prepared by authors based on data from World Bank and IEA 2015.

There is major room to further reduce energy intensity levels in LAC

Energy intensity levels could be reduced in LAC across sectors, including transport, agriculture, industry, and commercial services. The RISE index in energy efficiency scores LAC yellow in the traffic light system (41 out of 100 percent), exhibiting a long distance to the best practice frontier—OECD high income economies, which score 70 on average (Figure 4.9). Policy readiness of the region for attracting EE investment and deployment, as analyzed in the RISE survey, ranks the best-performing countries in the region as comparable to the OECD average (notably Mexico, Brazil, Colombia, and Chile) (Table 4.2).

Some LAC countries have introduced energy efficiency policies and new regulatory and institutional frameworks. However, these changes have generally been limited and enacted only in response to crises or deficits in energy supply. In addition, subsidies still play an important role in many LAC economies. Phasing them out will be crucial to further reducing wasteful consumption of fossil fuels.

FIGURE 4.9 RISE Regional Average Traffic Light Score for Energy Efficiency *(Index)*



Source: RISE (database).

TABLE 4.2 RISE Results Renewable Energy Pillar for Selected LAC countries *(Index)*

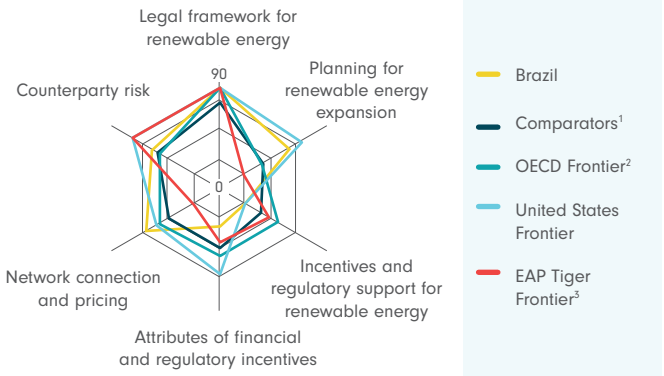
	Mexico	Brazil	Chile	Colombia	Argentina	Venezuela	Ecuador	Nicaragua	Bolivia	Peru	Dominican Republic	Honduras	Guatemala	Haiti
I. National energy efficiency planning	67	75	100	92	33	67	67	67	33	75	33	0	50	33
II. Energy efficiency entities	100	100	71	86	71	71	100	71	71	57	14	17	14	14
III. Information provided to consumers about electricity usage	58	63	63	63	29	69	63	63	57	67	63	46	69	54
IV. Incentives & mandates: utilities	88	29	0	17	42	25	25	0	50	4	0	0	0	0
V. Incentives & mandates: public sector	88	25	25	0	63	25	25	50	0	50	0	0	25	0
VI. Incentives & mandates: large consumers	100	0	22	67	44	56	6	33	22	33	17	0	6	0
VII. Financing mechanism for energy efficiency	83	50	50	92	33	17	17	33	83	0	100	0	50	17
VIII. Minimum energy efficiency performance standards	94	89	33	42	33	44	67	44	17	42	11	42	0	0
IX. Energy labeling system	83	83	83	83	67	50	67	42	50	0	8	42	0	0
X. Building energy system	37	27	53	20	47	0	0	30	0	0	0	0	20	0
XI. Types of electricity rate structures	81	67	100	37	59	81	67	63	56	59	63	63	22	63
XII. Carbon pricing and monitoring	74	0	0	0	0	0	0	0	0	0	0	0	0	0

Source: RISE (database).

Matrices 4.1 and 4.2 show a benchmarking of RISE indexes in renewable energy and energy efficiency for different LAC groups, peers, and comparators.

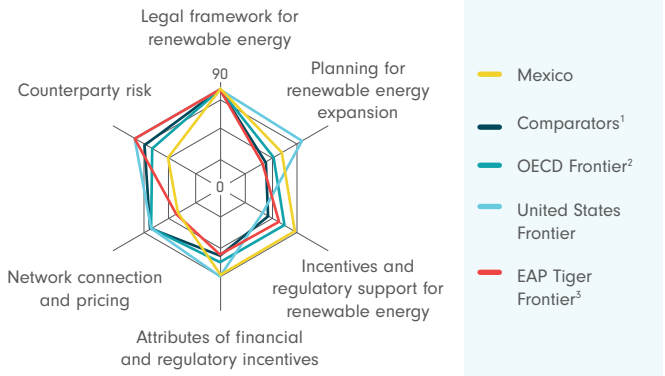
MATRIX 4.1 RISE Index Renewable Energy: LAC Groups, Peers and Best Practice Frontier

Brazil



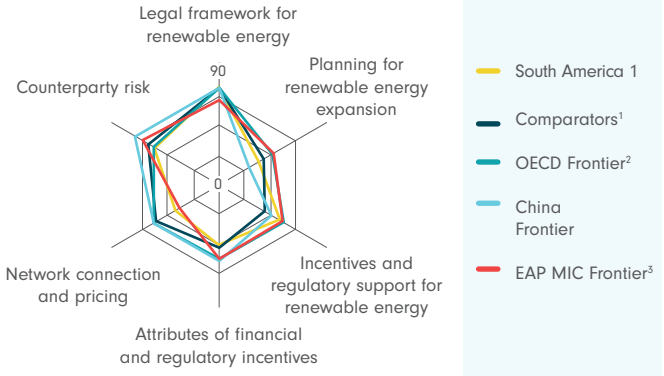
1: "Comparators" average: China, Malaysia, Turkey, Romania and Thailand
2: "OECD" average: Australia, Canada, Chile, France, Italy, Korea, Rep., Mexico, Poland, Portugal, Turkey, United Kingdom
3: "EAP Tigers" average : China, Korea and Singapore

Mexico



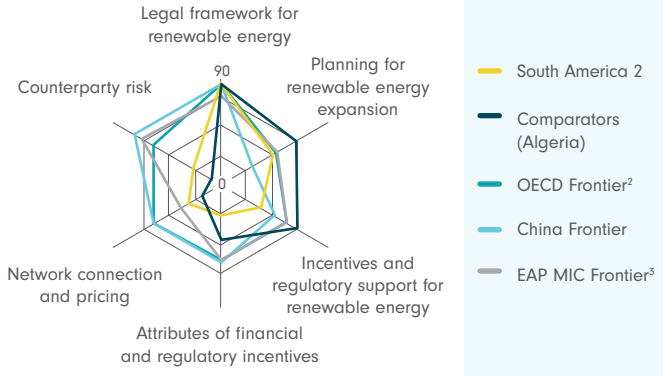
1: "Comparators" average: includes China, Malaysia, Turkey, Romania and Thailand
2: "OECD" average Australia, Canada, Chile, France, Italy, Korea, Rep., Poland, Portugal, Turkey, United Kingdom
3: "EAP Tigers" average: China, Korea and Singapore

South America 1



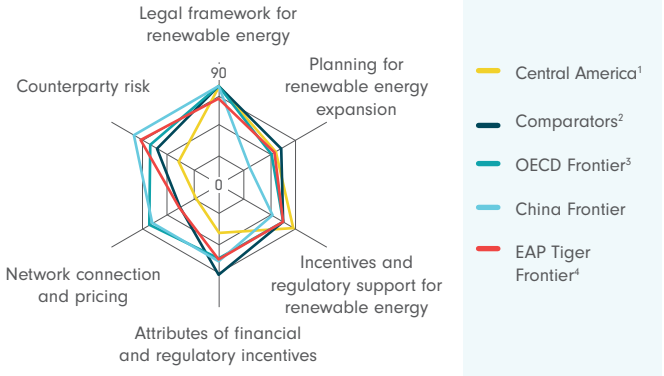
1: "Comparators" average: Romenia, Poland, Turkey
2: "OECD" average: Australia, Canada, Chile, France, Italy, Korea, Rep., Poland, Portugal, Turkey, United Kingdom
3: "EAP MIC" average: Indonesia, Malaysia, the Philippines, and Thailand

South America 2



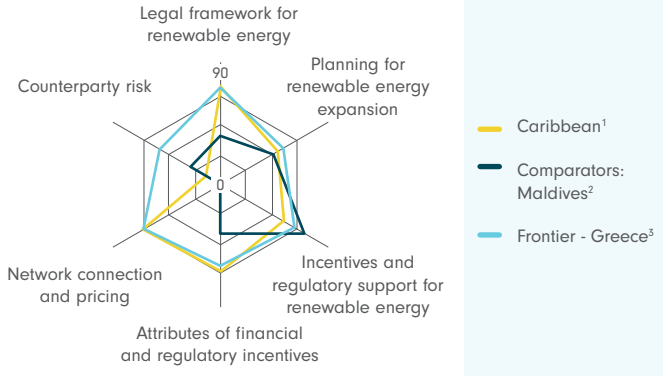
1: "Comparators" average: Algeria
2: "OECD" average: Australia, Canada, Chile, France, Italy, Korea, Rep., Poland, Portugal, Turkey, United Kingdom
3: "EAP MIC" average: Indonesia, Malaysia, Philippines, and Thailand

Central America



1. Central America: Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama
2. Comparators: Armenia, Mongolia, and Kazakhstan
3. OECD: Australia, Chile, Mexico, Japan, Korea, Rep., United Kingdom
4. EAP MIC's: Indonesia, Malaysia, Philippines, and Thailand

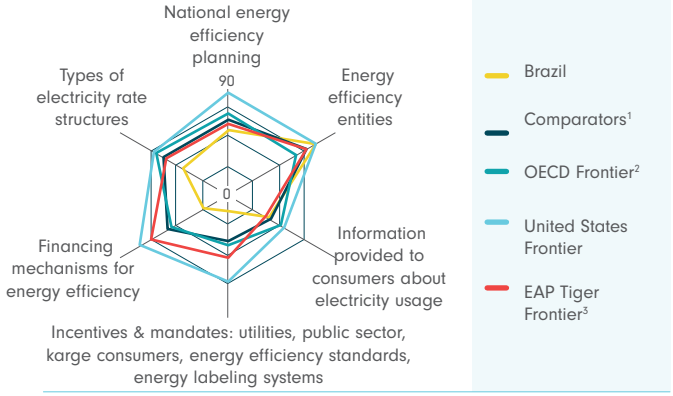
Caribbean



1: "Caribbean" average: Dominican Republic
2: "Comparators" average: Maldives
3. Frontier average: Greece

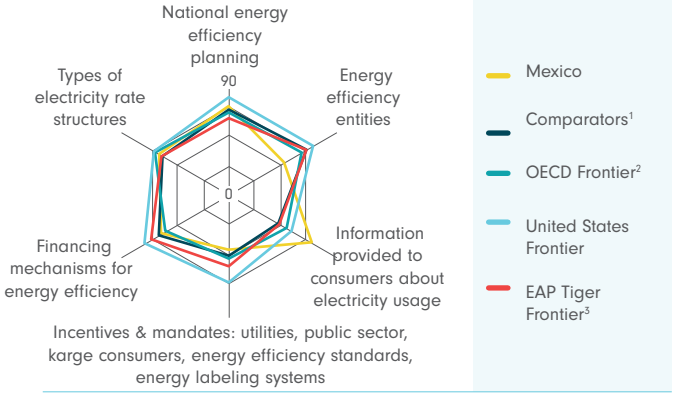
MATRIX 4.2 RISE Index Energy Efficiency: LAC Groups, Peers, and Best Practice Frontier

Brazil



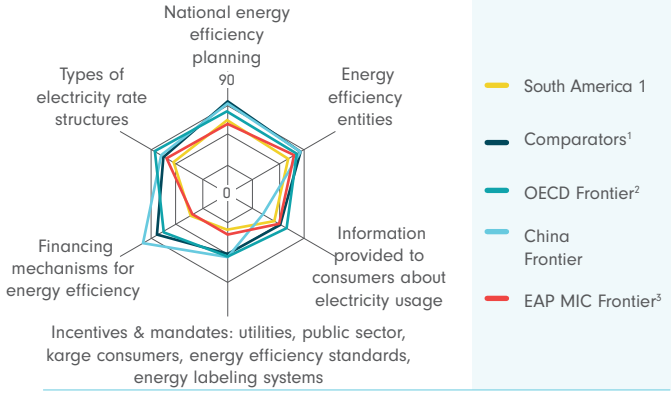
1: "Comparators" average: China, Malaysia, Turkey, Romania and Thailand
2: "OECD" average: Australia, Canada, Chile, France, Italy, Korea, Rep., Mexico, Poland, Turkey, United Kingdom
3: "EAP Tigers" average : China, Korea and Singapore

Mexico



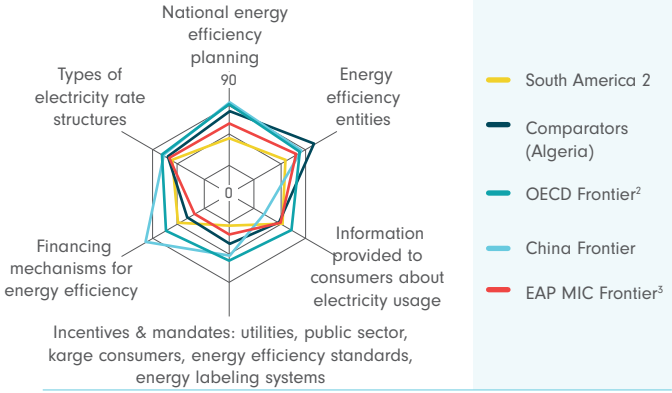
1: "Comparators" average: includes China, Malaysia, Turkey, Romania and Poland
2: "OECD" average Australia, Canada, Chile, France, Italy, Korea, Rep., Poland, Turkey, United Kingdom
3: "EAP Tigers" average: China, Korea

South America 1



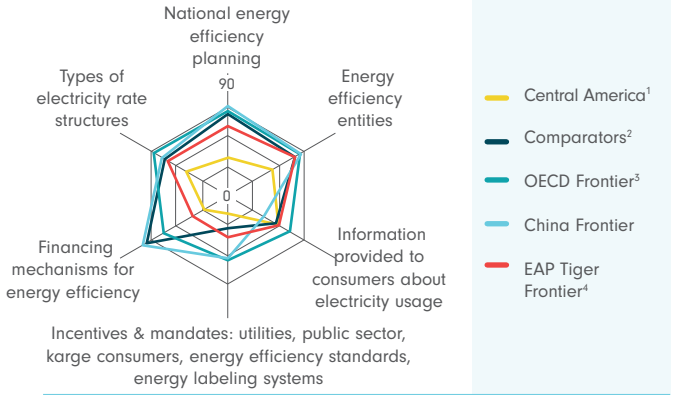
1: "Comparators" average: Romenia, Poland, Turkey
2: "OECD" average: Australia, Canada, Chile, France, Italy, Korea, Rep., Poland, Turkey, United Kingdom
3: "EAP MIC" average: Indonesia, Malaysia, the Philippines, and Thailand

South America 2



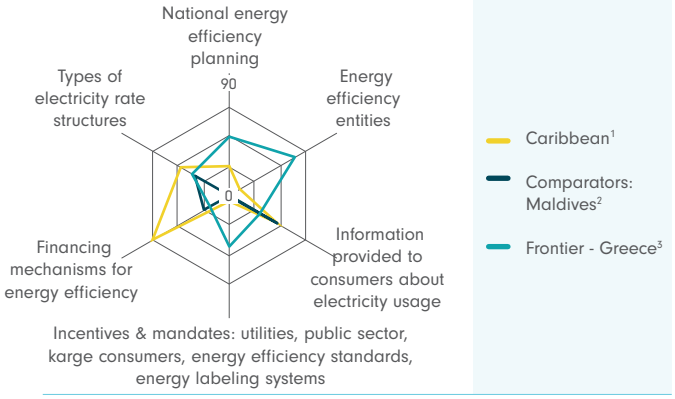
1: "Comparators" average: Algeria
2: "OECD" average: Australia, Canada, Chile, France, Italy, Korea, Rep., Poland, Portugal, Turkey, United Kingdom
3: "EAP MIC" average: Indonesia, Malaysia, Philippines, and Thailand

Central America



1. Central America: Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama
2. Comparators: Armenia, Mongolia, and Kazakhstan
3. OECD: Australia, Chile, Mexico, Japan, Korea, Rep., United Kingdom
4. EAP MIC's: Indonesia, Malaysia, Philippines, and Thailand

Caribbean



1: "Caribbean" average: Dominican Republic
2: "Comparators" average: Maldives
3. Frontier average: Greece

Notes

1. The indirect land use change impacts of biofuels, also known as ILUC, relates to the unintended consequence of releasing more carbon emissions due to land-use changes around the world induced by the expansion of croplands for ethanol or biodiesel production.

2. Figures 4b-d in Annex I provide information on the time it takes to get interconnection and environmental license approvals for different renewable energy types of projects in different countries. Chile, Nicaragua, Brazil, and Argentina have very high average duration for interconnection approvals, and Colombia, Guatemala, and Chile have long times for issuing environmental permits. Environmental Impact Assessment (EIA) procedures are particularly time-consuming in some LAC countries, including Chile, Colombia, Guatemala, Brazil, and Bolivia.

3. Figure 4a, Annex I includes a matrix with the types of policy instruments used in LAC.

4. For example, in 2010 Chile created an Environmental Assessment Service to centralize and expedite procedures, in 2011 Colombia established the National Agency for Environmental Licensing with independence and capacity to attend growing licensing requests, and in 2012 Peru introduced the National Service for Environmental Certification of Sustainable Investments to focus on projects with potential significant impacts. Mexico also recently introduced new legislation mandating the preparation of Social Impact Assessments (SIAs) for energy infrastructure developments to complement EIAs and improve the diagnostics, preventive and mitigation actions on the social front.

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CHAPTER 5

Energy Access and Poverty

LAC has progressed substantially in its energy access agenda

Access to modern energy is a prerequisite for economic development and higher quality of life. The LAC region has achieved generally high access to electricity and modern fuels: 97 percent of its people have access to electricity and 86.5 percent to non-solid fuels. These rates are well above the global averages, estimated at 86 and 59 percent, respectively, and consistent with LAC's high degree of urbanization (World Bank and IEA 2015).

In all LAC countries, electrification is growing at a faster rate than population, meaning that as time goes on, a progressively greater proportion of the region's people is getting connected. Likewise, growth in access to non-solid fuels rates is generally higher than population rates.

But energy poverty endures, and inequality of energy access is still common

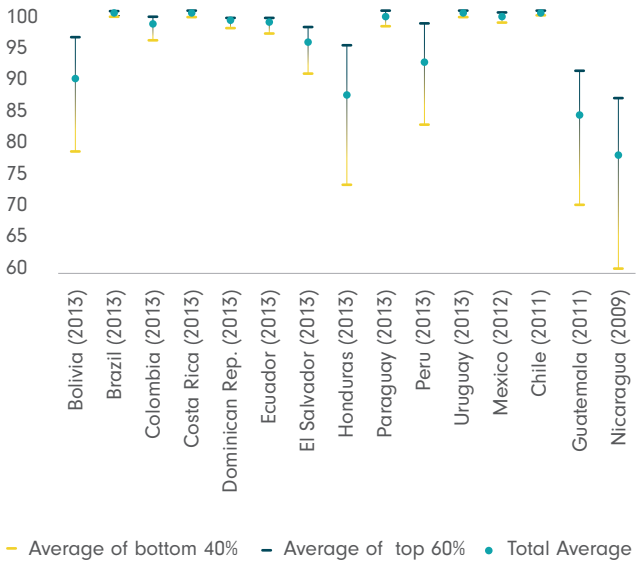
Despite laudable region-wide averages, 18.5 million people in LAC remain without access to electricity. Most live in Haiti and rural areas of Guatemala, Peru, Colombia, Honduras, Nicaragua, Mexico, Bolivia, and Brazil. About 84 million people have no access to modern (non-solid) fuels, a third of them in Mexico and Brazil. The extreme case is Haiti, where electricity access is below 30 percent and access to modern cooking fuel is even lower.

A critical dimension of these numbers is persistent inequality of access between the lower 40 percent of the income scale, and rural populations (Figures 5.1 a-d). This is true not only in countries with generally lower access—such as Haiti, Guatemala, Guyana, and Honduras—but in upper middle income countries such as Mexico, Brazil, and Chile. Remote rural communities often lack electricity, but energy poverty is common in cities too. Many cities include slums where people live with no electricity access at all or rely on power that is tapped illegally from passing utility lines and is unreliable and dangerous. Disparities in access to non-solid fuels follow similar patterns of income and location.

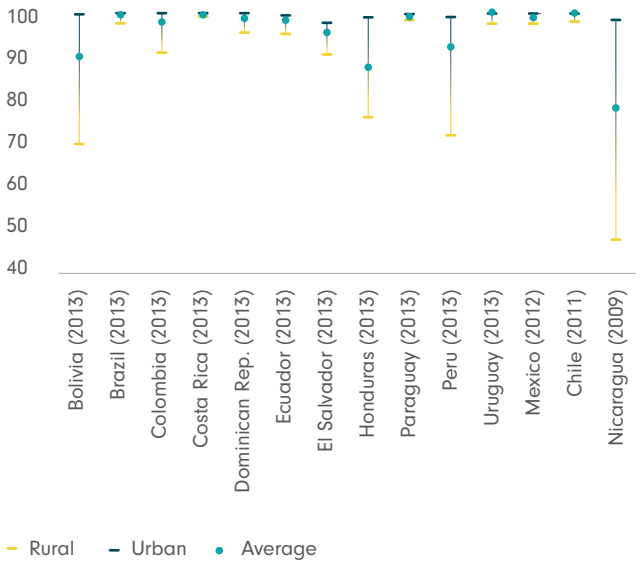
Without access to electricity and non-solid fuels, people have little hope of escaping the poverty trap. Poor quality of life, poor education and medical care, and limited opportunities for increasing incomes and living standards are all associated with lack of electricity service.

FIGURE 5.1 Household Access *(Percent)*

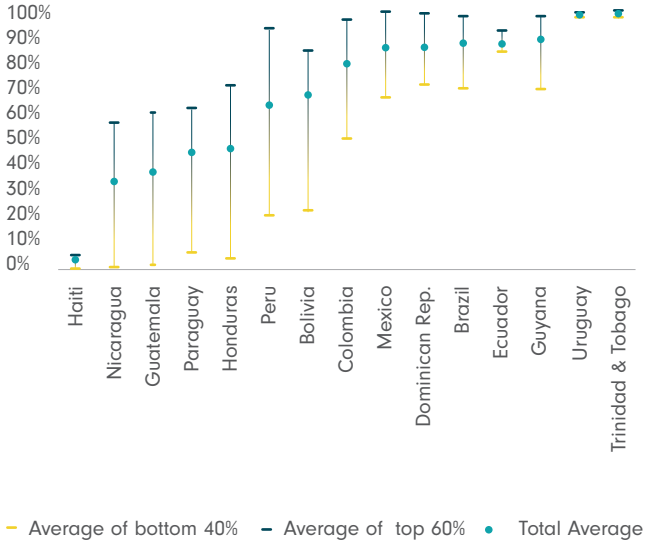
a) Electricity: Top 60% and Bottom 40%



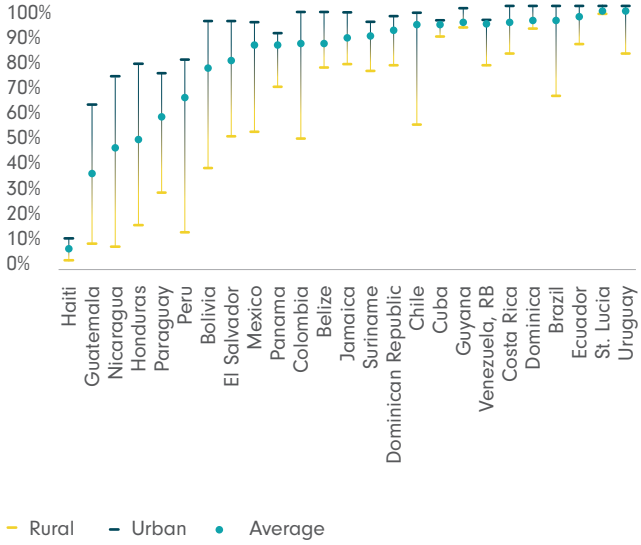
b) Electricity: Urban vs. Rural



c) NSF: Top 60% and Bottom 40%



d) NSF: Urban vs. Rural



Source: World Bank staff estimates based on data from SEDLAC (database) and World Bank and IEA 2015.

Note: Recent data only available for the countries reported in the figures.

Subsidies to liquefied petroleum gas (LPG) have substantially contributed to accelerate the transition from solid biomass -wood, crop residues,straw, shurbs, grass, animal dung- to cleaner fuels in LAC, although in many countries they are highly regressive (Troncoso and Soares da Silva 2017). Still, over 50% of the population of Guatemala, Nicaragua and Honduras (and 90% in Haiti) rely on solid fuels (countries with very low access to LPG).

A recent study has found that the cost of health effects resulting from household air pollution in Haiti, Guatemala, Nicaragua, and Honduras were in the range of 2.3-4.5% of GDP in 2015 (Sanchez-Triana and Larsen 2017).[1] Health effects of household air pollution are also significant in Bolivia, Colombia, Mexico and Peru, with costs estimated in the range of 0.7-1.8% of GDP (Sanchez-Tiana et al. 2017). Cook stove interventions to combat household air pollution are well known and do not require substantial infrastructure. The two major interventions are generally the introduction of improved biomass cook stoves (designed with enclosed chimneys to vent fumes outside), and the replacement of solid fuels with LPG.

The benefits of both interventions significantly outweigh the costs of health effects. However, the adoption of the two interventions mentioned above has been slow in Central America and Haiti.

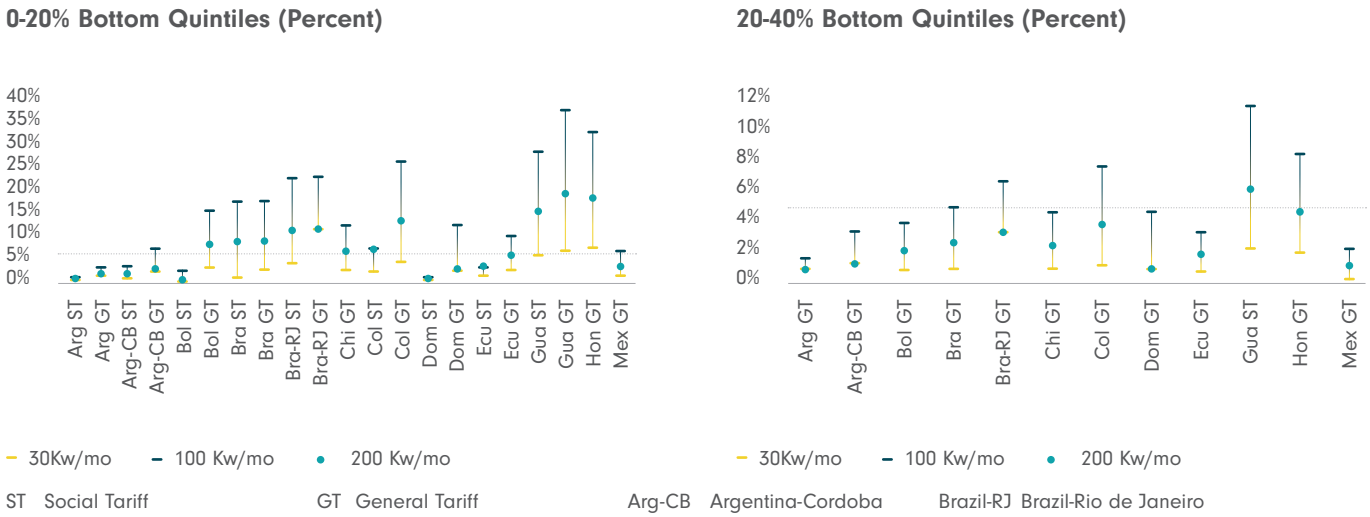
Affordability remains a key barrier to universal energy access in LAC

An examination of social tariffs and income suggests that, even if connections are available, the poor in many countries of the region often cannot afford subsistence electricity. This is still a challenge in Bolivia, Colombia, Guatemala, and Mexico (Figures 5.2). It is critical to focus not only on expanding access to infrastructure but on improving affordability for the bottom 40 percent of the region's income scale.

BOX 5.1 Defining Affordability

Assigning a price to affordability for electricity entails some level of value judgment, depending on spending envelopes and geographic context. But most standards in use today consider electricity to be affordable if the annual expenditure on a minimum volume of subsistence consumption for LAC standards (illustrated here with three levels, 20, 100, and 200 kWh/month) as a percent of 20 and 40 percent household income is no greater than 5 percent. As a reference: 30KWh/months gives the costumer electrical lighting, air circulation, one television and phone charging, 100kWh/month gives you in addition the possibility to have a small refrigerator (or a microwave), and 200 kWh would allow the consumer to have also appliances, and an electric heater.

FIGURE 5.2 Affordability of Subsistence Electricity in Selected Countries



ST Social Tariff GT General Tariff Arg-CB Argentina-Cordoba Brazil-RJ Brazil-Rio de Janeiro

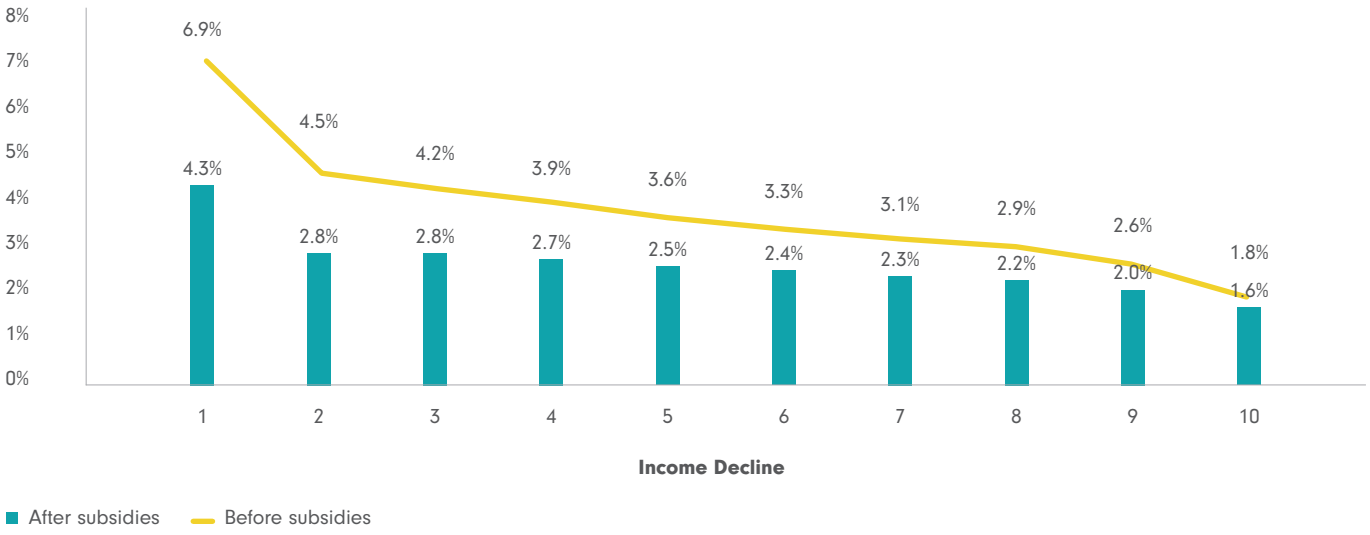
Source: World Bank staff estimates based on data from SEDLAC (database); utility data.

In some LAC countries, subsidies still systematically benefit higher- income households

Many countries foster affordability by subsidizing the price. But these schemes are often poorly targeted and highly regressive. The paradox is that the wealthier a household is, the more electricity it consumes, and the higher its subsidies rise. For every U.S. dollar in subsidies received by individuals in the lowest income quintile in Central America, significantly more than a dollar goes to individuals in the highest quintile (Figure 5.3). El Salvador appears to have the most equal distribution: for every dollar in subsidies for individuals in the poorest income quintile, roughly $1.20 goes to individuals in the wealthiest quintile. This ratio is slightly higher in Costa Rica at $1.30 and Honduras and Guatemala at $1.50, but much higher in Nicaragua and Panama at $3.40. In Panama, the disparity is even more pronounced between the top and bottom income deciles: for every dollar in subsidies spent on the poorest 10 percent of the population, $4.40 is spent on the wealthiest 10 percent.

In recent years, some countries in Central America have undertaken reforms to improve the targeting of electricity subsidies, thus increasing their progressivity while at the same time reducing the fiscal costs. For example, a 2014 reduction in the inclusion threshold for electricity subsidies in Honduras increased the share of subsidies received by the poorest quintile from 11.6 percent to 17.1 percent. Another source of regressivity is the relatively low electrification rates among the poorest households, which by definition leave these households without access to any subsidies at all. As electrification rates increase, so too does the progressivity of some systems (Hernandez et al. Forthcoming 2017).

FIGURE 5.3 Electricity Cost as a Share of Household Income in Central America, by Income Decile *(Percent)*



Source: Hernandez, et al. Forthcoming 2017 based on SEDLAC (database).

Note: This figure presents unweighted means of pre- and post- subsidy electricity costs in income deciles in Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama.

Some LAC countries with the highest energy access deficits have introduced policies to achieve universal access

The energy access "pillar" of the RISE (Regulatory Indicators for Sustainable Energy) index assesses how far individual countries have progressed in introducing key policies and regulations that increase energy access and attract private-sector participation.

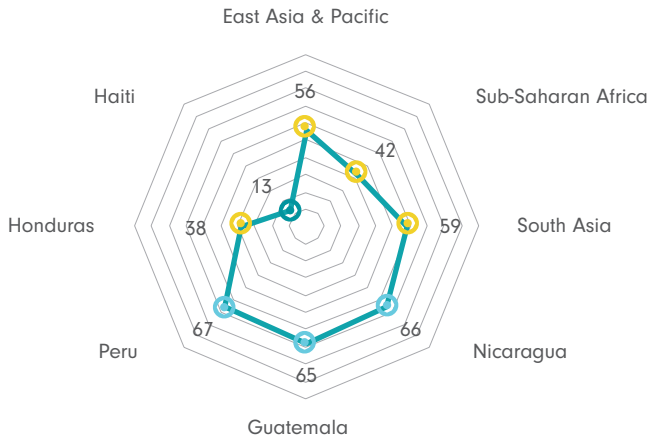
LAC countries with the lowest levels of access—including Peru, Nicaragua, and Guatemala—generally have RISE scores above those of other regions of the developing world (Honduras and Haiti are exceptions, however). That suggests that, on the whole, the countries selected are adopting appropriate policy measures (see Figures 5.4 and 5.6).

However, the RISE evaluation gives Haiti scores that are similar to those of Afghanistan and Somalia, because the country has not prepared most of the elements necessary to implement an energy access program. For instance, it has no officially approved electrification plan, framework for grid electrification, or even a framework for off-grid electrification based on stand-alone systems. The Government of Haiti seems to have focused so far only on the possibility of introducing mini-grids.

Honduras, meanwhile, has progressed slowly on all these fronts, with policy and planning instruments that consider some but not all good practice elements, thereby earning a yellow "traffic light" in the scoring system.

In contrast, Peru, Nicaragua, and Guatemala score green lights, although in most of the key elements evaluated by RISE, the countries still have considerable room for improvement. For instance, Guatemala has yet to consider a framework for off-grid electrification even though the country's electricity access rate remains at 84 percent (and only 70 percent in the bottom 40 percent income block), which translates into about 3.2 million people without access, most of them living in rural areas.

FIGURE 5.4 RISE Energy Access: Traffic Light Scores for Selected Regions and LAC Countries *(Index)*



Source: Regulatory Indicators for Sustainable Energy (RISE) (database).

Note: For regions, the score is calculated as an average across countries. The first RISE global roll out of 2016 only included five LAC countries in its energy access pillar.

FIGURE 5.5 RISE Energy Access Traffic Light Score, Selected Countries *(Index)*

	EA score	Existence and monitoring of officially approved electrification plan	Scope of officially approved electrification plan	Framework for grid electrification	Framework for mini-grid	Framework for stand-alone systems	Consumer affordability of electricity
India	84	80	75	100	77	69	100
Kenya	82	100	50	67	66	93	100
Uganda	78	100	63	67	64	93	100
Guatemala	68	100	75	50	39	33	100
Bangladesh	68	80	25	33	74	80	100
South Africa	68	100	38	100	10	76	100
Peru	67	80	63	83	10	44	100
Nicaragua	66	100	50	83	82	56	100
Indonesia	66	100	75	67	23	11	100

	EA score	Existence and monitoring of officially approved electrification plan	Scope of officially approved electrification plan	Framework for grid electrification	Framework for mini-grid	Framework for stand-alone systems	Consumer affordability of electricity
Pakistan	58	0	0	83	74	73	100
Honduras	38	60	50	50	43	33	50
Afghanistan	28	0	0	67	35	44	50
Haiti	13	0	0	0	43	11	50
Somalia	10	0	0	0	48	22	0

Source: RISE (database).

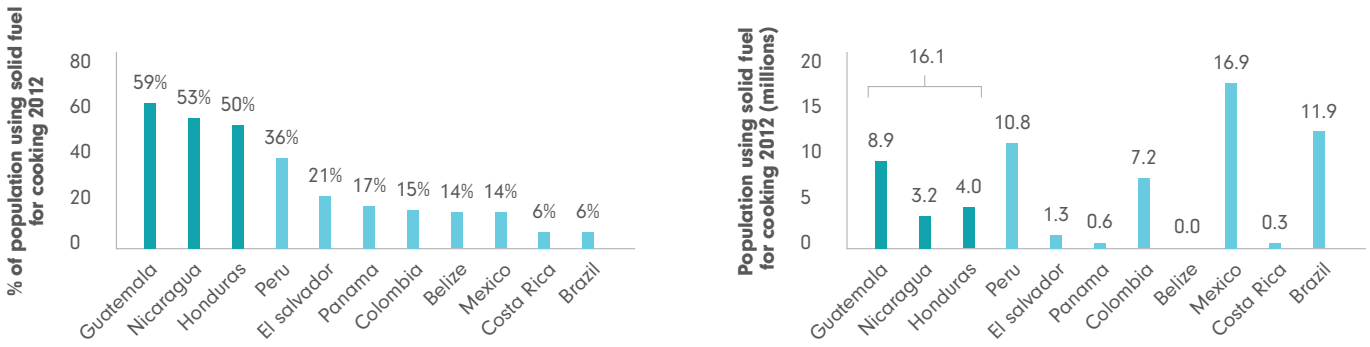
Note: The first RISE global roll out of 2016 only included five LAC countries in its energy access pillar. Developed countries are not scored in the RISE Energy Access Index.

LAC should do more to promote clean, efficient cooking

Access to clean, efficient cooking systems is a question of quality of life, but also health and environmental impact. Studies have documented strong associations between indoor air pollution and acute lower respiratory infection and chronic obstructive pulmonary disease. In addition, growing evidence suggests that global warming is significantly accelerated by black carbon emissions originating from incomplete combustion of biomass fuels, including the wood that is still commonly used in cooking in the region.

Yet LAC countries are not systematically developing interventions to encourage efficient and clean cooking in its millions of wood-burning households. The region needs public and private partnerships to tackle this issue not only through increased access to modern fuels (LPG, natural gas, electricity) and introduction of clean-burning stoves and other modern kitchen equipment, but through education to heighten awareness and foster behavioral changes, particularly in Central America (Figure 5.6).

FIGURE 5.6 More than 50% of the Population of Guatemala, Honduras and Nicaragua Use Solid Fuel for Cooking *(Percent)*



Source: Dalberg Global Development Advisors 2015.

Notes

1. Exposure to indoor air pollution, particularly PM2.5 (particles 2.5 micrometres or smaller in diameter—approximately 40 times smaller than a grain of table salt), causes a number of illnesses, including cardiovascular disease, chronic obstructive pulmonary disease , and lung cancer among adults, and acute lower respiratory infections among young children (Lim et al, 2012). Women and children face greater risks from indoor air pollution because they typically spend more time in indoor environments.

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2

SECTION 2

Drivers of Change and Disruption

Energy demand in the LAC region is expected to grow at a high rate. However, the path and nature of energy infrastructure development may head in promising new directions.

A convergence of trends and emerging disruptions are creating new risks and opportunities with the potential to transform the traditional service delivery model, reshape the stakeholder landscape, and redefine the way in which government agencies and customers engage with energy markets.

Key trends and disruptions

1

Changing patterns in global energy markets, with implications for energy security, trade, and energy cost

2

Increased impact of climate change on energy supply and energy security, and the implications of policy commitments to constrain greenhouse gas emissions

3

Increased urbanization and economic concentration, and their impact on energy supply, income distribution, and air quality

4

Emergence of new technologies which together are enabling the transformation of the service delivery model and its overall performance

5

Increased financial constraints and emerging innovations, which mean that paying for the development of energy infrastructure in the region will continue to be challenging, but that innovative instruments—such as multi asset class guarantees and weather insurance—are emerging to address the new spectrum and magnitude of risks.

All these are in the context of changing and challenging macroeconomic and political factors at the country level. Section 2 discusses in detail the nature of these trends and disruptions in Chapters 6, 7, 8, and 9. Chapter 11 in Section 4 delves into the challenge of financing energy infrastructure.

The key message emerging from the analysisin Section 2 is that **LAC could and should take advantage of emerging innovations to approach higher efficiency frontiers.** On the whole, the region has made great strides in developing sophisticated electricity markets and gaining increased access to natural gas via LNG trade and indigenous resources. Different groups of countries (sometimes with overlapping members) face different challenges, but adopting emerging innovations is key to the future development of efficient energy services in all of them. This path would deliver climate co-benefits such as emissions reductions and enhanced resilience to climatic shocks and would reduce the social and environmental constraints that often accompany development of large infrastructure.

CHAPTER 6

New Patterns in Global Energy Markets

Energy commodity prices have fallen as U.S. energy enters world markets and some consumers cut back

In recent years, global markets for the three principal traded fossil fuels–coal, oil, and gas—have been revolutionized by technological developments and changing patterns of production. Demand trends have also mutated, initially due to global economic crises but more recently to structural changes in major users such as China. These shifts are coupled with improvements in energy efficiency (for example, in vehicles and lighting) and the growth of low-carbon options such as renewables for power generation.

The global market for coal has shifted with development of extensive reserves of low-cost coal, especially in Australia. At the same time, new demand constraints have emerged, notably in China, where the rapid growth of coal burning of recent years has come to a halt, and in the United States, where coal use is tailing off due to low-cost gas and pressures to reduce carbon emissions. In Europe, however, coal has recently gained market share for power generation, though a number of countries (including the United Kingdom and Netherlands) have signaled that they will move completely away from coal in the medium term in favor of renewables and gas. These developments leave the coal market oversupplied, with prices at historically low levels. Most analyses suggest the low prices will persist well into the future.

Oil markets too are currently oversupplied, pushing prices into decline. Driving the trend are the emergence of the United States as a major supplier of low-cost oil, the re-emergence of Iran as a significant oil exporter, and the availability of a range of newer fuels such as shale oil. These supply increases are coupled with emerging reductions in oil demand in a number of key markets, in part affected by improved vehicle efficiency and increased use of electric vehicles. As with coal, most forecasts see oil prices remaining low in coming years. Falling prices have already put a brake on investments in development of new sources of oil.

Increased availability of low-cost natural gas is changing the regional energy outlook

Widespread use of hydraulic fracturing ("fracking") has tapped vast gas reserves that were previously out of reach in the thin non-porous rock known as shale. This development has upended the global gas industry. In particular, fracking has spurred production in the United States, making shale gas a competitive and abundant source of thermal power. The gas has also helped displace coal generation and reduce carbon emissions in that country.

The dramatic rise in U.S. shale gas production grew from a unique combination of geological and industrial factors that is unlikely to occur in other countries to the same extent. Fracking has also brought significant environmental and social concerns, so its future use in Latin America may be constrained by rigorous regulation and political pressure (see box 3.2).

Nonetheless, the U.S. fracking boom is making itself felt in LAC, as low-cost U.S. gas becomes available by pipeline in Mexico and enters the global LNG market. This means that LAC suppliers will face increasing competition from the United States, and possibly scale back their development plans. However, if LAC suppliers can up their games, by optimizing and expanding current resources, reducing flaring, and taking advantage of low-cost opportunities from conventional and fracking technologies, they should remain as major players in the region's market.

While future fossil fuel price movements are difficult to predict, the significant changes in global patterns of energy supply and demand will affect the prospects for fossil fuel producers, exporters and consumers in LAC, and change the prospects for the uptake of renewable energy, energy efficiency, and development of distributed resources.

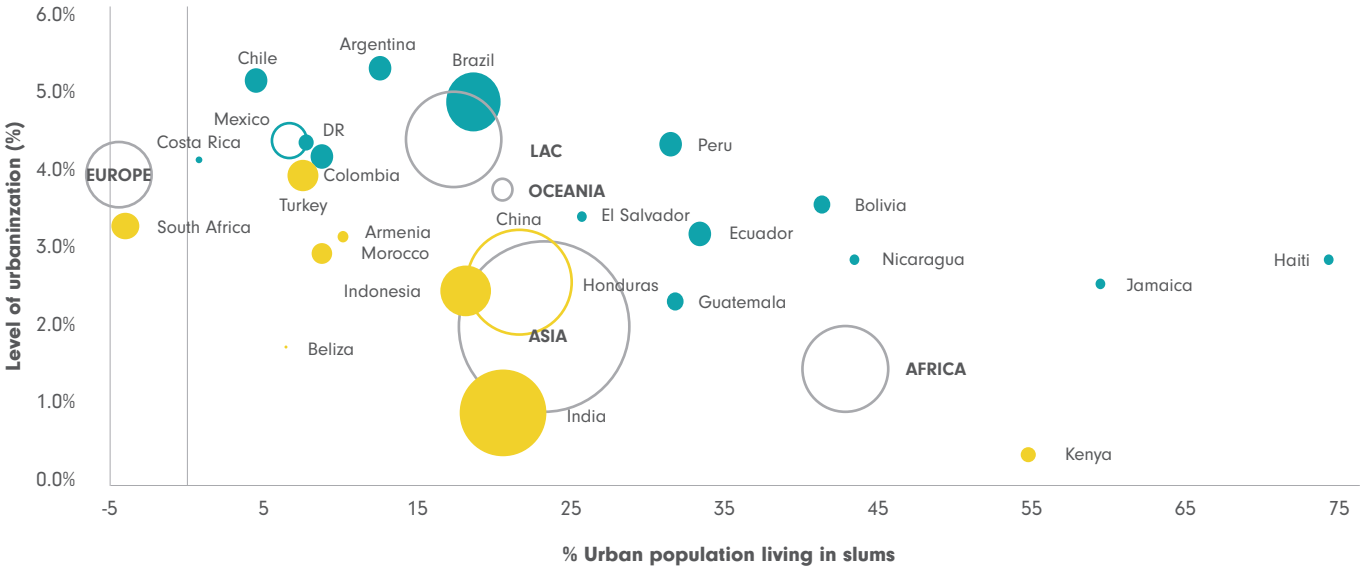
CHAPTER 7

Increased Urbanization

LAC's cities continue to grow, creating new challenges for energy service

Among all the regions of the world, Latin America has the highest rate of urbanization (Figure 7.1). About 80 percent of the population–500 million people–live in cities. Four of the world's 28 cities with more than 10 million inhabitants are in the LAC region. Argentina, Brazil, and Mexico in particular have given birth to sprawling megacities. Mexico City is now the third-largest city globally and São Paulo the fourth, both with nearly with 21 million people, followed by Buenos Aires with 15 million and Rio de Janeiro with nearly 13 million. These cities are engines of economic growth and development: 23 percent of Mexico's GDP, for example, is concentrated in Mexico City.

FIGURE 7.1 Urbanization Rate vs. Percentage Population Living in Slums *(Percent)*



Source: UN-Habitat 2016.

Note: Bubble size depicts total urban population.

From the energy perspective, urban concentration can present the advantage of economies of scale in infrastructure development, that is, denser urbanization can mean reduced infrastructure investment and maintenance costs. But it also poses the challenge of servicing high demand in too little space, with load pockets and concentration of cooling, heating, and electric transportation needs. There is a higher risk of economic loss due to rationing or blackouts during periods of scarcity and bad weather (Box 7.1). As homes and businesses install renewable energy systems in distributed generation schemes coupled with storage technology such as lithium ion battery systems and the market for electric vehicles expands, energy infrastructure and service will change in a major way, and perhaps add higher flexibility and resilience.

An additional challenge is the fact that about 20 percent of the region's urban population (about 105 million people) lives in the peri-urban or sub-urban space. The urban poor face multiple challenges, often similar to those faced by poor rural households. These include very low income and spending levels and lack of access to basic government services (infrastructure, health, and education), credit, and legal land.

BOX 7.1 Cities as "Energy Load Pockets"

Servicing cities can be a weak link in the electricity supply chain, because cities concentrate large volumes of demand into so-called load pockets. These are areas for which utilities lack sufficient transmission capability to reliably supply 100 percent of the electric load from generators at distant places.

The high concentration of customers in cities makes it extremely difficult—if not impossible from a social and environmental perspective, including land use—to install traditional generating plants close to the consumer.

But adding transmission capacity is problematic too, because there is usually strong opposition to installation of overhead and even underground lines. Any expansion of the network in densely populated cities will pass residential neighborhoods, schools, and office buildings, and pose a risk of harm during construction and operation.

The emerging solution for keeping the lights on in dense urban areas is small-scale distributed generation of power, such as solar PV coupled with storage. Demand response, a form of energy efficiency in which variable pricing and other incentives encourage customers to shift their power use to non-peak hours, can also help manage energy loads and reduce interruptions, blackouts, and economic loss.

Source: Prepared by authors.

Increased urbanization has brought high levels of air pollution

High urbanisation rates lead to poor air quality due to high levels of transport and other energy related emissions, According to WHO, 88% of people who live in cities are exposed to air pollution levels that exceed WHO air quality guidelines. About half of the inhabitants are exposed to particulate matter levels at least 2.5 times WHO guidelines including several major cities in LAC.

High pollution levels are exacerbated in areas where there is high use of informal fuels for cooking and heating, poor waste disposal practices and congested urban traffic patterns coupled with poor regulation of vehicle exhaust standards – all factors linked to the high levels of urbanisation and peri-urban poverty associated with many cities in LAC. The levels of pollution and their impact are further exacerbated in cities which are in elevated locations, since the lower concentration of oxygen in the air (up to 25% lower than at sea level) leads to less complete combustion in vehicle engines pushing up emission levels.

Such emissions can be reduced by a coordinated approach to reduce the sources of pollution. For example Mexico City had the worst air pollution levels of any city in the world in 1990's, following a period of rapid population expansion (from 12 million in 1950 to nearly 100 million in 2015) and industrialisation. In 1990 oil was used to generate almost half of the city's electricity. Since then the government has introduced a whole series of measures aimed at reducing the problem including comprehensive monitoring programmes, annual vehicle emissions testing and a contingency plan for periods of peak pollution. This includes a rotating ban on private car use, and a constraint on some industrial activities when pollution is especially high. These and other measures have had a significant impact – nitrogen dioxide levels for example have been reduced by a factor of three.

However Mexico City along with others in Mexico still have pollution levels well above WHO guidelines, and this led Mexico to highlight air quality as one of the main drives behind its COP 21 pledge, setting one of the most aggressive targets for reducing emissions.In 2017, Mexico released its National Air Pollution Strategy, which establishes a modern vision and a set of integral measures to reduce air pollution in cities.

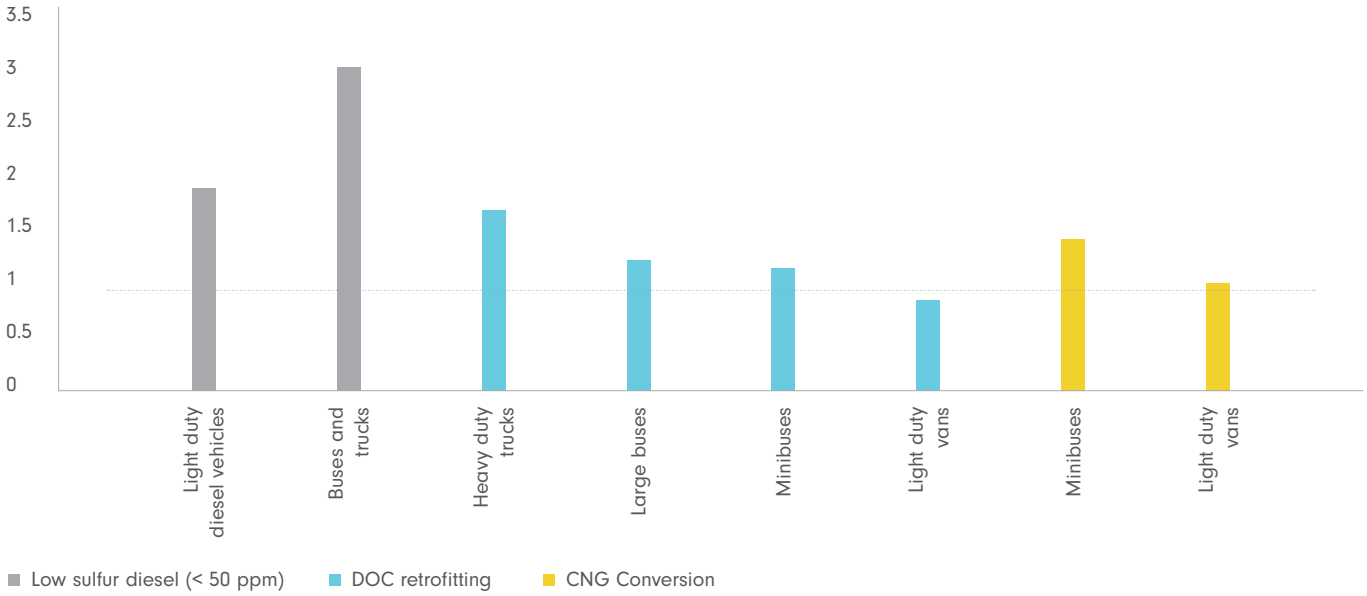
Vehicle use of gasoline and diesel is a major source of air pollution. A number of interventions can contribute to reduce emissions from these sources. Figure 7.2 shows the benefit-cost ratios (BCR) for the following interventions that could be implemented in the Lima-Callao urban area of Peru: 1) the introduction of diesel with a sulfur content of less than 50 part per million (ppm); 2) retrofitting vehicles with a diesel oxidation catalyst (DOC); and 3) converting vehicles so they can use compressed natural gas (CNG) as fuel. Most interventions have BCRs greater than 1, meaning that the health benefits from reduced emissions are larger than the costs of implementing such interventions. Analyses conducted in other LAC countries, including Argentina and Colombia, have found that similar interventions also have positive BCRs.

Fossil fuel combustion for electricity generation emits a relatively small amount of fine particles; however, it is a key source of NOx and SO2, both of which can lead to the formation of particulate matter. SO2 emissions have other effects, including acid rain that affects vegetation and lakes. NOx and Volatile Organic Compounds (VOCs) contribute to the formation of ozone, a pollutant that causes respiratory illnesses. Coal-fired power plants emit mercury, a highly toxic metal. And generation from biomass also produces significant emissions of NOx, particulate matter, and other pollutants.

In contrast, most renewable power plants emit fewer air pollutants than even modern fossil fuel-fired power plants with state-of-the-art pollution control equipment (IPCC, 2014).

Both, electric transportantion and renewable energy could play a major role in addressing the air pollution problem affecting large cities in the LAC region.

FIGURE 7.2 Benefit-cost ratios of selected interventions to reduce ambient air pollution in Lima-Callao, Peru, 2012



Source: Larsen and Skjelvik 2013.

Smart energy city platforms are starting to emerge in the region

In the last two decades, several cities have established systems to make the existing and upcoming infrastructure smarter and greener (the concept of the smart energy city is described in Box 7.2).

Amsterdam, Copenhagen, Genoa, Hamburg, Grand Lyon, Vienna,[1] Barcelona, New York, and Seoul are some of the front-runners in implementing the smart city concept. For instance, the Amsterdam Smart City (ASC)[2] project, established in 2009, has already taken multiple initiatives. These include testing of smart grids and smart meters for close to 1,200 residents; the streamlining of energy consumption in buildings such as office buildings, monuments, swimming pools through an online system of public control of energy use; the collective financing of seven wind farms and 3,000 solar panels in a business district, and the installation of fuel cells in an Eighteenth-century building. Amsterdam is also attempting to find alternative sources for heating as a replacement to gas.

Issyk-les-Moulineaux, a commune in the southwestern suburban area of Paris, France has a smart grid energy management project at the district level. This includes energy-efficient solutions for buildings and homes, automation systems, renewable installations, and stations for charging electric vehicles. Oskarshamm, Sweden, meanwhile, has a project for active control of heating and ventilation and a building management system that helps optimize energy in 28 buildings.

Box 7.2 What is a smart energy city?

A smart energy city is highly energy- and resource-efficient. It relies on insight-driven and multi-sectorial strategies that lay out technology paths, programs, and investment plans for the provision of green and resilient infrastructure and urban services.

To ensure effective implementation of their green or sustainable growth plans, city governments need to foster alliances and close collaboration with a coalition of actors from the national, state, and local levels, and from civil society and the private sector. These coalitions and collaborations enable the creation of multidisciplinary groups or institutions to address some of the big city challenges, including floods, landslides, congestion, blackouts, and pollution.

The smart energy city uses both hardware and software solutions to enhance the economic efficiency and sustainability of energy services. It establishes the platforms necessary to create new interactions between governments, service providers, and consumers.

The smart energy city concept has many dimensions. They include type and quality of fuels used in the urban platform (for transport, electricity generation, heating, and cooling), energy efficiency of utility services including water supply, transport, electricity, and energy efficiency in industry, public and commercial buildings, and households. Thus, energy policies, including those associated with externality pricing, fuel diversity and quality, and energy efficiency, are key to the resilience and sustainability of urban systems.

A number of technologies and tools can contribute to increasing city intelligence and citizen participation for economically efficient, sustainable, and resilient services: ICT and digital technologies, smart grids and meters, electric vehicles, renewable energy in distributed generation schemes, energy storage (such as batteries), and efficient appliances and industrial equipment, among other.

Source: Prepared by authors.

In LAC, Brazil, Chile, Colombia, and Mexico have started to introduce elements of the smart city concept, as well as energy technologies that increase city intelligence (see Table 7.1). However, comprehensive platforms and robust multi-sectorial programs to transform the city ecosystem are yet to appear in most LAC cities.

TABLE 7.1 Examples of Initiatives for Smart Cities in LAC

Country	Initiative
Argentina	**Buenos Aires' integrated response system** *(Centro Unico de Coordinacion y Control, CUCC)* coordinates and controls emergency response via an ICT platform (2011).
Brazil	**Rio Operations Center,** coordinates information and emergency response from multiple government agencies (2010).
	Several cities in Brazil use **advanced meter infrastructure (AMI)** and **efficient public street lighting** (LED luminaries). Electrobras has installed 100,000 smart electronic meters in Brasilia for the remote management of consumption and commercial losses.
	Engagement tools such as **LAB.RIO**, a laboratory that encourages citizen participation in government initiatives, are under development.

Country	Initiative
Chile	**Energy Policy 2050** lays out specifics for the development of smart cities and establishes the *Comuna Energetica* program to help local communities explore the potential for energy efficiency, renewable energy, and sustainable consumption patterns.
	Fundacion Pais Digital coordinates between public and private actors to promote smart cities. Twenty-three municipalities are participating, some of which have already developed energy strategies and plans including renewable energy, energy efficiency initiatives and distributed solar PV.
	Smart City Santiago is an experimental laboratory in a business complex and residential buildings.
	Smart City Gran Concepcion is the first pilot of a comprehensive smart city model.
Colombia	**Medellin Smart City** brings together concepts of early warning emergency systems, sustainable transport systems, and ICT platforms to monitor public services and local environmental performance.
	Bogota City has begun an Integrated Public Transportation System that includes real-time data analysis systems.
Mexico	**National Air Quality Strategy (Vision 2017-2030)** includes among its various objectives two that are relevant to cities: i) achieve sustainable, resilient, inclusive and secure cities, and ii) gurantee access to affordable, reliable, modern, sustainable energy for all.
	Mexico City Climate Action Program establishes residential electricity and fuel consumption reduction targets and has a Green Plan that aims to allocate 8 percent of the city's annual budget to environmentally friendly initiatives.
	Multiple Smart City Initiatives have started in Puebla, Guadalajara, Queretaro, and Jalisco, some of which include smart energy grids, clean energy and distributed generation, promotion of sustainable mobility (bicycle corridors, carpooling), infrastructure for efficient water use, municipal geo-spatial data platforms, and energy efficiency in public buildings.

Source: Prepared by authors.[3]

Notes

1. TRANSFORM is a European Commission initiative within the European Research Framework program focusing on the cities of Copenhagen, Genoa, Hamburg, Vienna, Grand Lyon, and Amsterdam. TRANSFORM's goal is to drastically reduce CO2 emissions in cities, to achieve local and EU 20-20-20 targets: 20 percent lower carbon emissions, 20 percent of energy from renewables, and 20 percent increase in energy efficiency by 2020.

2. Amsterdam Smart City (ASC) was founded by Liander (the regional electricity grid operator) and the network organization Amsterdam Innovation Motor (AIM), in collaboration with city authorities in Amsterdam. It has now branched into a bigger collaborative effort between authorities, companies (including IBM, Accenture and Cisco), academic institutions, and residents.

3. See References section for a full list of sources.

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CHAPTER 8

Climate Change and Resilience

Climate change poses a significant adaptation challenge for the region

Looming over all the energy challenges that LAC faces is climate change. The region has a special vulnerability to it, due largely to the geography. LAC has vast low-lying coastal areas, home to many of its mega-cities. Coastlines are highly exposed to tropical cyclones in the Gulf of Mexico, strong El Niño Southern Oscillation (ENSO) events off South America, and Atlantic Ocean oscillations. Long-term, coastal areas could face permanent inundation as sea levels rise. Other potential hazards for the region as a whole include rising temperatures, the melting of Andean glaciers, and changing patterns of rainfall.

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) predicts that temperature increases in LAC could reach 0.4°- 1.8° C by 2020 and 1°-4°C by 2050, compared to baseline levels for 1961-90. That would make LAC one of the world's regions most affected by warming.

For now, scientists can issue only imperfect interpretations of what the changes mean at the scale of human activities in the long term. But already, climate variability is causing extreme events to rise in frequency, intensity, and duration and one major result is added pressure on energy systems.

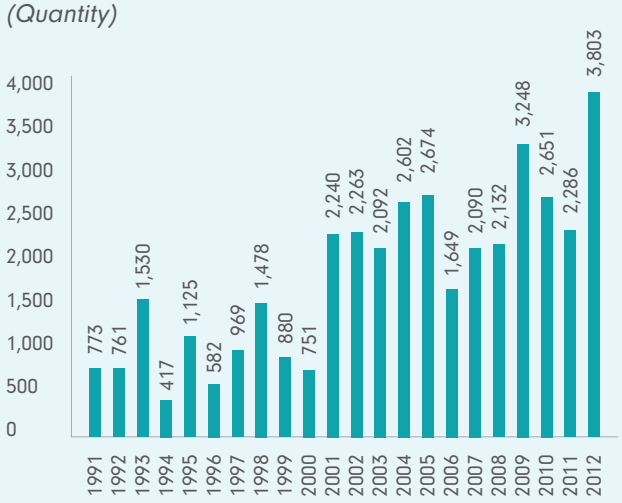
Droughts in Brazil, Venezuela, Colombia, Costa Rica, and Uruguay, and torrential storms and rains in Chile, Bolivia, and Paraguay are threatening the countries' energy infrastructure more frequently. Climate fluctuations are particularly alarming for countries such as Brazil, where hydro accounted for 65 percent of installed capacity in 2016. In years of normal rainfall, hydro supplies more than 80 percent of the country´s electricity, but that figure drops to 60 percent in dry years.

The Global Climate Risk Index (CRI) developed by German Watch, which analyses the impact of extreme weather events both in terms of fatalities and economic loss, has placed four Latin American countries among its top ten most affected countries for the 1995-2014 period. They are Honduras, Haiti, Nicaragua, and Guatemala. (CRI does not include small island states in its analysis due to a lack of data.) For the year 2014, Bolivia joined to the top ten countries with highest direct impacts from extreme weather.

Box 8.1 Climate-Related Natural Disasters in Brazil

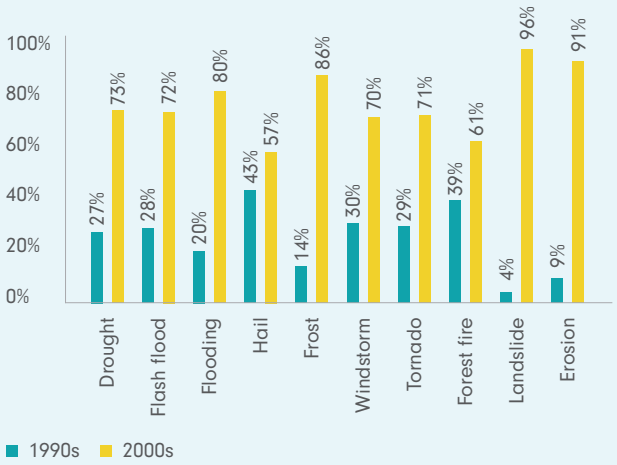
The last two decades have brought a clear worsening trend in terms of the number of natural disasters registered in Brazil. Because of both the size and diversity of the country and the good quality of its monitoring of climate-related events, these results indicate a high probability that a similar trend is likely in the rest of the LAC region, although there may be significant differences in the patterns of events.

FIGURE A Climate-Related Disasters in Brazil *(Quantity)*



Sources: University Center for Studies and Research on Disasters (CEPED) and Santa Catarina Federal University (UFSC) 2013.

FIGURE B Distribution Climate-Related Disasters in Brazil (1991-2000, 2000-2010)*(frequency)*



Source: Prepared by authors.

Note: Considered disasters include: droughts, flashfloods, floods, hailstones, frosts, windstorms, tornadoes, forest fires, landslides, river banks, and coastal erosion.

TABLE 8.1 Global Climate Risk Index (CR): the 10 countries most affected (1995-2014) *(Annual average)*

CRI 1995-2014 (1994-2013)	Country	CRI Score	Death Toll	Deaths per 100,1000 Inhabitants	Total Losses in million US$PPP	Losses per Unit of GDP (%)	Number of Events (Total 1995-2014)
2 (2)	Myanmar	14.17	**7137.20**	14.75	1140.29	0.74	41
3 (3)	Haiti	17.83	**253.65**	2.76	223.29	1.55	63
4 (5)	Philippines	19.00	**927.00**	1.10	2757.30	0.68	337
4 (4)	Nicaragua	19.00	**162.30**	2.97	227.18	1.23	51
6 (6)	Bangladesh	22.67	**725.75**	0.52	2438.33	0.86	222
7 (7)	Vietnam	27.17	**361.30**	0.44	2205.98	0.70	225
8 (10)	Pakistan	31.17	**487.40**	0.32	3931.40	0.70	143
9 (11)	Thailand	32.33	**164.20**	0.25	7480.76	1.05	217
10 (9)	Guatemala	32.50	**83.35**	0.66	407.76	0.50	88

Source: Kreft et al. 2016.

Examples of this effect:

- In Brazil and Paraguay in November 2009, heavy rains and winds caused transformers on a key high-voltage transmission line to short-circuit. This shut down 20 turbines at the world's second-largest hydroelectric dam, disrupting supply to 87 million people.

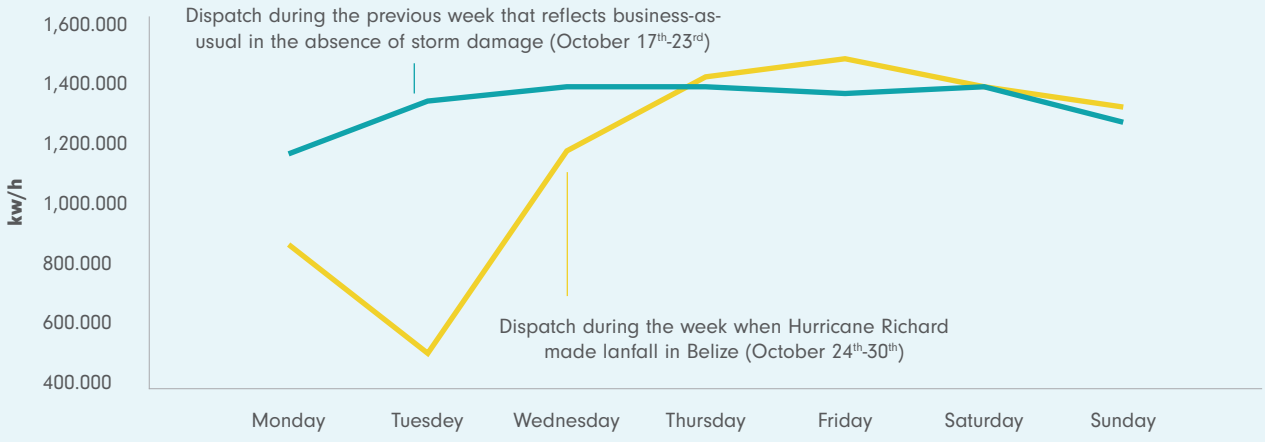
- Data recorded in Brazil for the 1981-2014 period shows that dry seasons have become more extreme with time. The Cantareira watershed, for example, has registered increasingly diminished inflows, to the point that 2014 was its worst hydrologic year, with inflows of only 25 percent of the historical average. In contrast, in the State of Ronônia in the Amazon Region, flooding of the Madeira River in 2013/2014 exceeded all historical records, corresponding to a once in 300 years recurrence event. This happened only one year after the two 3GW hydropower plants of Jirau and Santo Antonio started operation.

- In March 2015, a torrential storm in Chile left thousands without electricity for days due to damage to transmission lines and dam flooding.

Box 8.2 Impact of Hurricane Richard in Belize

Climate change poses special risks for the Caribbean region, and Belize is particularly vulnerable. Hurricanes and tropical storms have inflicted casualties, damage to property, and disruptions in infrastructure services multiple times. For instance, in 2010 Hurricane Richard caused extended power outages. A "trip" in transmission between the substations of Camalote and La Democracia led to a sequence of faults along the East-West transmission line, cascading through the southern line as well. This cut off the 53MW Becol hydro plant from supplying key load centers such as San Ignacio and Belmopan. More than 18,000 customers lost power.

Figure a) Dispatch during Hurricane Richard vs. Business as Usual

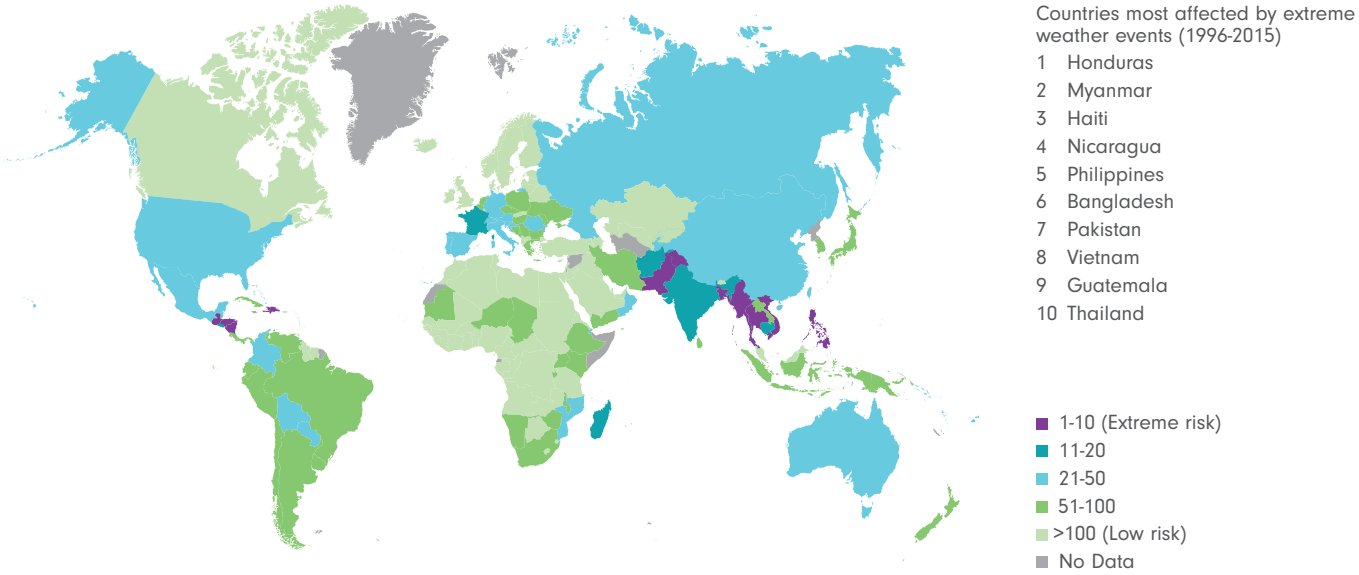


Source: Jayawardena et al. 2016.

- In the last year, countries across the region have suffered droughts due to the meteorological phenomenon El Niño, harming hydropower generation. Colombia endured a long drought between September 2015 and April 2016, and its government was forced to introduce an emergency energy savings program. Power production in Chile and in Brazil also suffered. The Guri, Venezuela's largest reservoir and one of the continent's most important hydroelectric plants, reached a critical juncture when water levels fell to just 1.60 meters above the point at which production would not be possible, according to the Ministry of Electrical Energy. Energy-saving measures carried out by the Venezuelan government include rationing electricity supply to only four hours per day for a total of 40 days.

At the same time, climate change, by causing temperature and precipitation changes, heat extremes, and the melting of glaciers, is likely to have long-term adverse effects on agricultural productivity, hydrological regimes, and biodiversity in the LAC region (World Bank 2014).

MAP 8.1 Level of Risk to Climate Change Impacts



Source: Germanwatch and Munich RE NatCatSERVICE.

LAC's own greenhouse emissions are modest by global standards

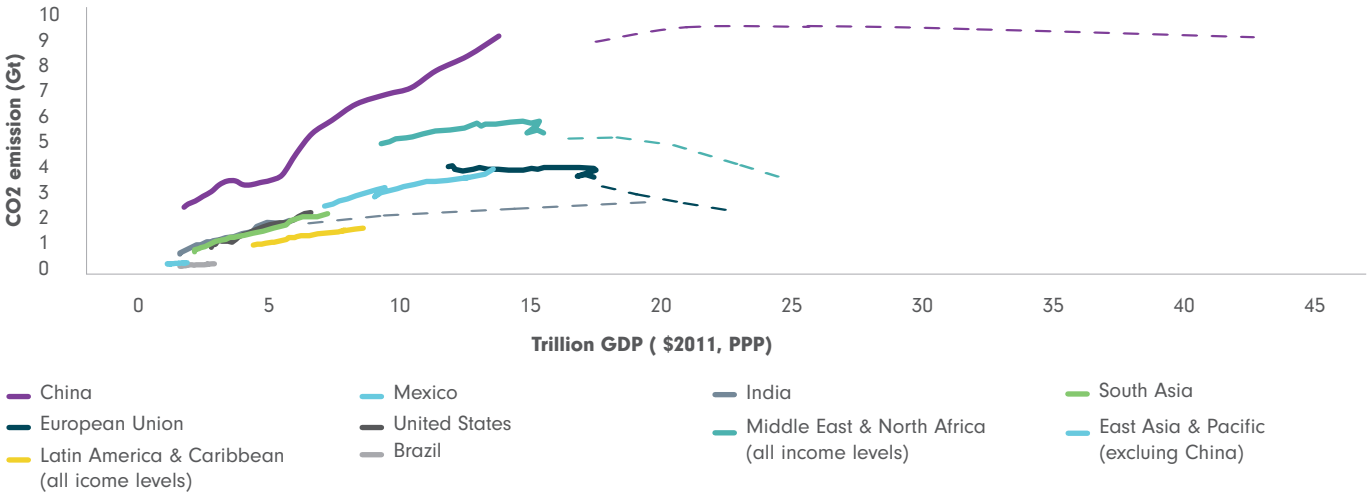
The LAC Region will need to focus on making itself more resilient to the many effects of climate change. At the same time it will have to work toward its own commitments to reduce emissions of greenhouse gases. The region contributes a modest 9 percent to global GHG emissions, the bulk of which come from land use and land use change and forestry (LULUCF). Among regions, it has some of the lowest emissions per unit of primary energy consumption (3.6 tCO2/Mtoe, compared to a global average of 4.4), and its

emissions per capita are more than 30 percent below the world average. These low levels are due mainly to its clean energy mix and gradual trend of decarbonization. Renewable energy sources represent about 25 percent of all primary energy sources, while coal contributes only 5.4 percent.

The magnitude of its energy-based contribution is small in comparison to China, the United States, the European Union, and India (Figure 8.1). Brazil and Mexico are, however, among the top 20 carbon- emitting countries (ranking 11 and 15, respectively).

The region's contribution to the global problem is currently low, but its energy consumption is projected to grow at high rates (with significant variation among countries). So there is a large room in the future for LAC to contribute to GHG emissions abatement. In addition, many countries of the region have increased the carbon intensity of their electricity sectors in the last decade. In sectors such as transport and power, which have long-term path dependencies and are therefore vulnerable to infrastructure and technological lock-ins, transitions to a low-carbon future will need planning and implementation with lengthy lead time.

FIGURE 8.1 Carbon Emission by Region and Emerging Economies (1990-2030) *(Gigatons, Gt)*



Source: Prepared by authors based on data from the IEA Energy Statistics and Balances (database) 2015.

Note: Dotted line depicts expected emission for period 2015-2030

The global agreement reached in Paris in 2015 signaled serious international determination to take measures to constrain climate change. More than 185 countries, which together account for 95 percent of global emissions, made voluntarily reduction commitments in the form of (Intended) Nationally Determined Contributions (INDCs, ratified as NDCs) under the aegis of the U.N. Framework Convention on Climate Change (UNFCCC) Conference of the Parties, known as COP21.

The likely consequences of this global deal:

- More pressure to reduce emissions, putting downward pressure on the use of coal in electricity generation and favoring renewables and gas generation

- More rapid deployment of a number of low-carbon technologies including renewable power generation, advanced low carbon biofuels, and electric vehicles, due mostly to cost reduction
- Enhanced emphasis on energy efficiency, with implications for industrial energy use, urban design, and public transport systems
- Emergence of additional international carbon markets

Under the COP21 framework, many LAC countries have made commitments (NDCs) to reduce emissions, as shown in Table 8.2.

TABLE 8.2 Intended Nationally Determined Contributions Selected LAC Countries

Country	Unconditional Pledge Description (optional)	Type of target (% or MtC=2e)	Total mitigation effort (% or MtC=2e)	Reference Year
Brazil	Percent reduction compared to 2005 (target extended to 2030)	%	43%	2005
Mexico	Percent reduction compared to own baseline forecast	%	22%	Pledge BAU
Chile	Reduction in carbon intensity per unit GDP compared to 2007	% Intensity/GDP	30%	2010
Argentina	Percent reduction compared to own baseline forecast	%	15%	Pledge BAU
Colombia	Percent reduction compared to own baseline forecast	%	20%	Pledge BAU
Bolivia	Actions			
Ecuador	Percent reduction compared to own baseline forecast	%	20%	BAU
Guyana	Actions			
Paraguay	Percent reduction compared to own baseline forecast	%	10%	BAU
Peru	Percent reduction compared to own baseline forecast	%	20%	BAU
Suriname	Actions			
Uruguay	Several sectoral targets. Even though they are quntitative, it's not possible to aggregate them.			
Venezuela	Percent reduction compared to own baseline forecast	%	20%	BAU

Source: Prepared by authors

Carbon trading could reduce emissions and financial burden

One measure that would help drive down emissions is to place a price on them. Some LAC countries are already taking the lead in developing such mechanisms. For instance, in 2014 the Mexican government announced the possible development of an Emissions Trading Scheme (ETS) in the energy sector, and the Ministry of Environment is assessing possible models. This would complement Mexico's tax on fossil fuel sales (excluding natural gas), which went into effect on January 1, 2014. Chile, meanwhile, has passed legislation for a carbon tax to begin in 2017. It would apply to all stationary sources with a thermal input capacity greater than 50 MW.

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CHAPTER 9

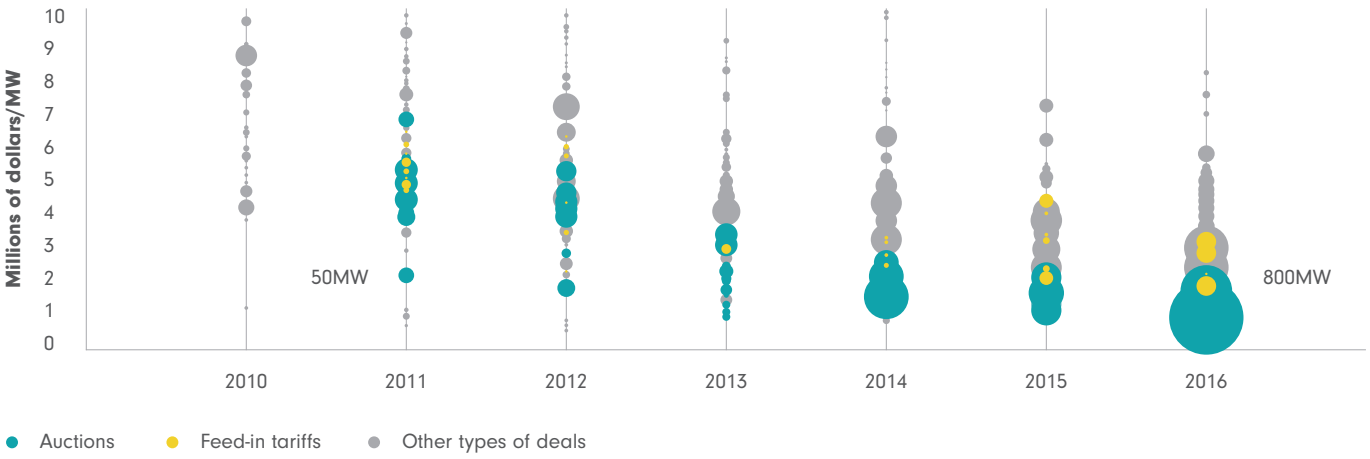
Disruptive Energy Technologies

New technologies offer solutions to long-term energy challenges

Across the world, the last ten years have brought a very rapid expansion of electricity generated from renewable energy sources. In particular, non-hydro renewables wind and solar PV have been growing consistently at very high compounded annual growth rates (CAGRs). These trends are projected to continue. High levels of deployment make the technologies, from a global perspective, technically and commercially mature.

In recent years, growth in capacity of renewables has exceeded that of fossil-based systems. By the end of 2015, the total global renewable installed capacity exceeded that of coal. The costs of wind and solar have been falling consistently due to technology improvement, the scale-up of manufacturing facilities, and other factors. The cost trajectories have followed the classic "learning curve" pattern with learning rates of more than 20 percent.[1] Installed costs of PV, for instance, are now as low as $1 million/MW, especially when procured through auctions (Figure 9.1). Solar PV projects are not only getting cheaper, but larger (See Figure 9a in Annex I). The cost reductions will likely continue in future years.

FIGURE 9.1 Installed Costs of Solar PV (2010-2016) *(USD Million/MW)*



Source: Dobrotkova et al. 2017.

Since renewable technologies still have relatively high capital costs compared to fossil fuel generators[2] but almost zero operating costs, costs of generation increasingly depend on cost of capital used to finance the projects. This in turn is sensitive to prevailing financial conditions in the host country, but also to the ways in which generation is rewarded. Long-term income certainty—for example, through long-term power purchase agreements—reduces risk for investors and brings down generation costs. Under these conditions, electricity from these sources can now be cost-competitive with most new-build fossil fuel generation even at the current low prices for oil, gas, and coal.

LAC is well placed to take advantage of the increasingly low-cost renewable resources with their associated benefits in carbon, energy security, and diversity. Brazil, Chile, Peru, and Mexico have been leaders in introducing policy and regulatory frameworks that provide investors with secure payment streams while at the same time using competition to drive down prices.

Wind and solar generation in LAC are forecast to grow the most rapidly among the world's regions due to plans for auctions in various countries. The region is a priority market for many international renewable developers that want to bring their global experience and purchasing power to bear. But higher penetration of variable renewable energy (VRE) will still require certain preconditions and operational measures (see Box 9.1).

Box 9.1 Integrating Variable Renewable Energy in LAC

Generation from wind and solar sources has implications for the management of electricity systems, because output is intermittent, depending on wind strength and level of sunlight, and not entirely predictable. In principle there is no limit to how much a system can rely on VRE generation, but a number of measures must be employed to make that possible. These include maintaining flexible non-variable generation, modifying the grid to accommodate the new generation and extend the area over which balancing is carried out (in this, international connections can play a very important role), investing in electricity storage, and emphasizing demand-side management.

Measures to improve grid flexibility and accommodate higher levels of variable renewables also make systems more robust and better able to stand other forms of interruption, for example, climate events. Market structures also need to recognize the different economic characteristics of variable renewable generation, notably very low or zero marginal operating costs (which can lead to displacement of conventional generation), and value their contribution to reliability measures during times of water scarcity or fuel price shocks.

In general, LAC countries are far below the level where integration of VRE is seriously challenging existing patterns. Since in most cases electricity demand is still growing, they have the opportunity to plan future system growth with high shares of variable renewables in mind. This opportunity is not available in markets such as the EU, where electricity growth is limited and extra renewables generation generally comes at the expense of incumbent generators.

LAC is particularly well placed to accommodate large shares of VRE because water can be stored in large hydro power reservoirs and used flexibly to complement wind and solar generation.

Source: Prepared by authors.

In other LAC countries, including the Caribbean island states, very little development has so far taken place despite wind, geothermal, and sunlight that can be easily tapped, the high cost of energy from other sources, and dependence on imported fossil fuels or on hydro power that is sensitive to climate change impacts.

The falling cost of PV systems has stimulated rapid growth in utility-scale generation facilities, so-called solar farms that produce power at the multi-megawatt scale. But since the technology is very modular and scalable, low-cost PV also opens up the possibility of much smaller generation. This can take place close to the point of demand and in remote locations where grid extension is too expensive. Distributed generation is also possible in urban locations, reducing problems associated with centralized expansion in load pockets. For example, solar plants can be constructed at commercial sites such as large supermarkets or on the roofs of individual dwellings.[3]

The costs of generation at such sites are now often competitive with power supplied by utilities. At present, the sites usually remain connected to the grid, so they can draw power when solar generation is low (at night, for example) but they export power to the grid when their electricity supply exceeds local demand. Consumers operating their own solar systems proactively are referred to as "prosumers".

Costs of energy storage are also falling rapidly, paralleling developments in solar PV (see Figure X, Annex I for a projected future cost of lithium-ion battery storage). Energy storage is now a major topic for energy research, development, and demonstration (RD&D) worldwide, driven by the emerging electric vehicle industry and the need to accommodate high shares of variable renewable energy. Storage of electricity in large quantities is reaching an inflection point, in fact. In 2009, advanced batteries cost about $1,000 per kilowatt hour. By 2010, new battery-manufacturing facilities were able to deliver the product at just over $500, and the price could drop to $350 when these facilities reach full-scale production over the next few years. Today, storage technology works, it is economically viable, and the market is beginning to develop.

Deployments of energy storage technology in emerging markets are poised for major expansion, with 40-fold annual growth expected over the coming decade. LAC is considered an attractive market for energy storage, given the region's plans for renewable energy roll-out—particularly in Mexico, Chile, and Brazil (IFC 2017).

Distributed generation is starting to gain momentum in LAC. Many countries have introduced incentives for distributed generation such as net metering. Among them are Argentina, Brazil, Chile, Uruguay, Peru, Honduras, Nicaragua, and Mexico. Other countries have pilot programs in progress.

These advances will improve the case for local generation in coming years. They could encourage consumers to disconnect from the utility supply entirely.[4] Taken together, the innovations hold the potential to revolutionize the entire structure of the electricity service delivery model.

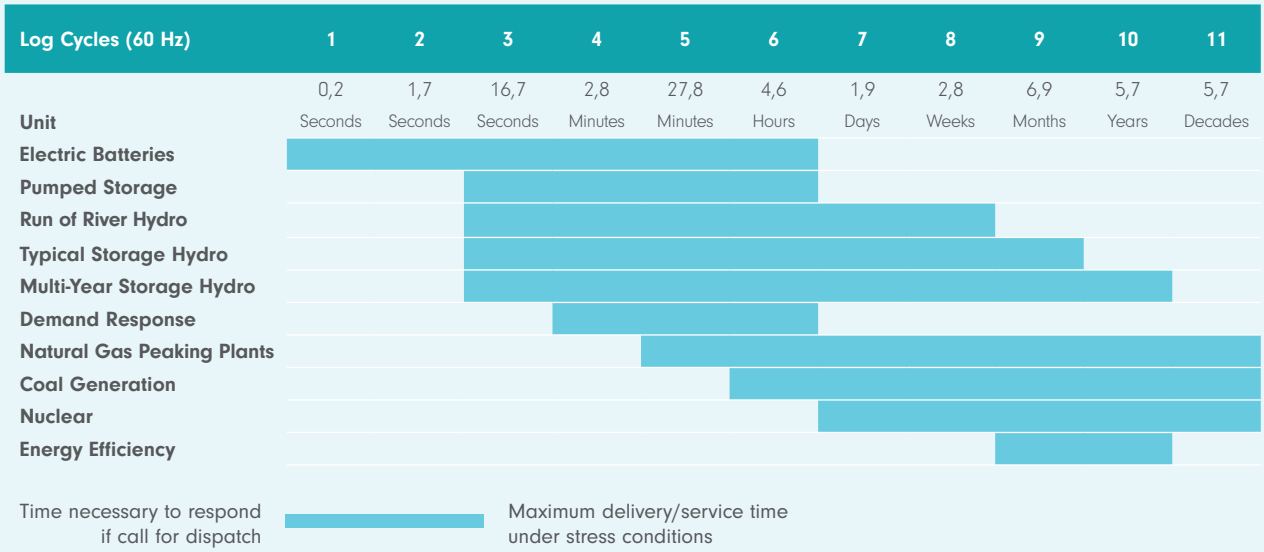
Box 9.2. Storage Technology

Lithium-ion batteries are currently the storage technology of choice. They have declined rapidly in price for more than 20 years—prices for units used in laptop computers and consumer electronics dropped 90 percent between 1990 and 2005, and continued downward after that. For larger-scale systems to store power for a house or business, innovations that use flow batteries, liquid metal batteries, and other technologies could reduce costs to between $150 and $200 per KWH by 2020. This could enable grid storage in every major metropolitan market. At these prices, the United States alone would want to build more than 100 GW of storage over a decade (the capacity equivalent of the current U.S. nuclear generation sector). Power companies could also use storage to smooth variability in power supply, which would allow higher penetration of variable renewable energy and reduce capital requirements for distribution systems.

Battery storage and systems that store energy by compressing air are right on the edge of prices where the arbitrage of shifting electricity prices becomes profitable—filling up batteries with cheap power (from night-time sources, or abundant wind or solar) and using that stored energy later on rather than paying for peak-priced electricity. This arbitrage can happen at either the grid edge (the home or business) or as part of the grid itself. Either way, it taps into a market of potentially hundreds of thousands of megawatt-hours in the United States alone.

For long-term security of supply, needed to blunt climatic or fuel shortage shocks, only hydro, thermal, or nuclear plants, combined with demand-side management, can do the job. For now, batteries can only provide storage for four to six hours. In Latin America, natural gas "peaking" plants and multi-year storage hydro will likely continue to play a key role in supporting renewable energy integration and the transition to low-carbon economic growth.

Response and delivery time by technology under stress conditions *(Duration)*



Source: Prepared by authors.

Electric vehicles are becoming more common sights on the road

Projections show that electric vehicles (EVs) could reach total-cost-of-ownership parity with internal combustion engines when the battery price drops to $250 per KWH. At that point, the global market could increase from the 1-2 million vehicles sold per year today to 15-20 million. If that happens, EVs will dominate the market and disrupt the status quo.

The improved fuel economy of replacing oil with electricity could save consumers more than $500 billion annually. Moreover, customers are discovering that electric vehicles often deliver superior acceleration, safety, and comfort and may accommodate new vehicle-design innovations better than traditional technologies. Today's electric vehicles have lower total costs per mile than equivalent gasoline-powered vehicles, due to lower energy costs of electricity and lower maintenance costs.

Many LAC countries have introduced biofuels (ethanol blends in Brazil, for instance, and CNG in Argentina) to reduce pollution and GHG emissions, but the market for electric vehicles in the region has yet to develop.

Energy systems are becoming "smart"

Low-cost solar PV systems may be the primary driver for higher levels of distributed generation, but the rise will be further enabled by innovations and cost reductions in storage and information and communication technologies (ICT). The result will be a decentralized, service-oriented industry with a more integrated approach to energy demand and supply, particularly in cities.

The new technologies include:

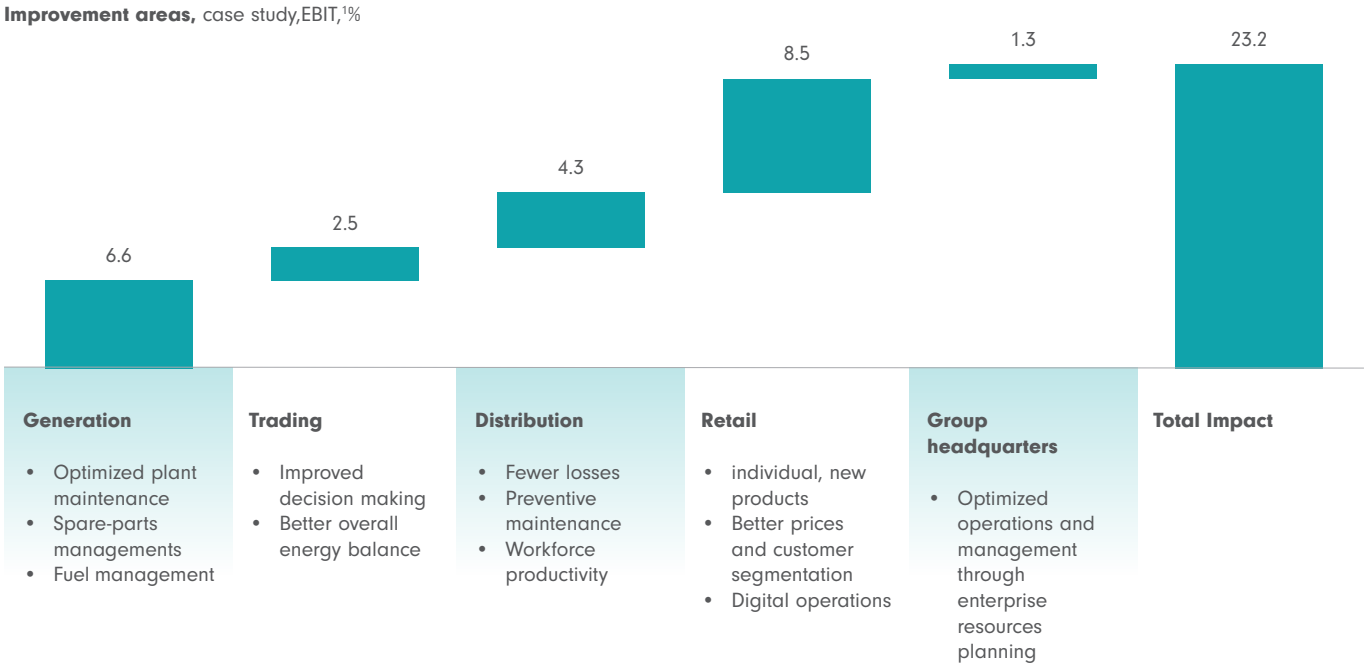
Smart Grid: A smart grid is an electricity network incorporating electricity and communications systems that can intelligently respond to nodes connected to it. Smart grids can include storage and decentralized generation but their salient feature is the integration of high-speed bi-directional communications between systems, customers, and the grid. The digitalization of utilities has already had demonstrable positive impacts on utility earnings, but the potential for further efficiency gains across the value chain is vast (see Figure 9.2).

Advanced Metering Infrastructure (AMI) or "Smart Meters": These are systems that measure, collect, and analyze energy usage and communicate with metering devices. They include hardware, software, communications, in-home displays, controllers, smart switches, customer-associated systems, and meter data management.

The Internet of Things (IOT): The IoT gives Internet connectivity to equipment and devices, distributing computing power across the infrastructure. It facilitates using data analytics that can (1) reduce CAPEX, especially the need of peak generating units and transmission requirements, (2) manage consumption by introducing demand response and dynamic pricing, (3) ensure that the intermittency of renewable production does not compromise the quality of the electricity signal or the stability of the power system, and (4) make the

customer a more active player. Currently, only 1 percent of physical objects are connected to the Internet of Things, but the numbers are growing. Devices such as smart thermostats, refrigerators, plug-load sensors, and smart outlets in the home and machines in factories will have impacts all the way back to the generator. They will help it supply the right amount of electricity to the grid when faced with the aggregate demand of millions of smart devices that are constantly adjusting their demand for power. Technology companies contend that the first step towards a "smart grid" that makes the IOT real will be the mass deployment of smart meters.

FIGURE 9.2 Digitalization has had demonstrable positive impact on utility earnings *(Percent)*



Source: Booth et al. 2016.

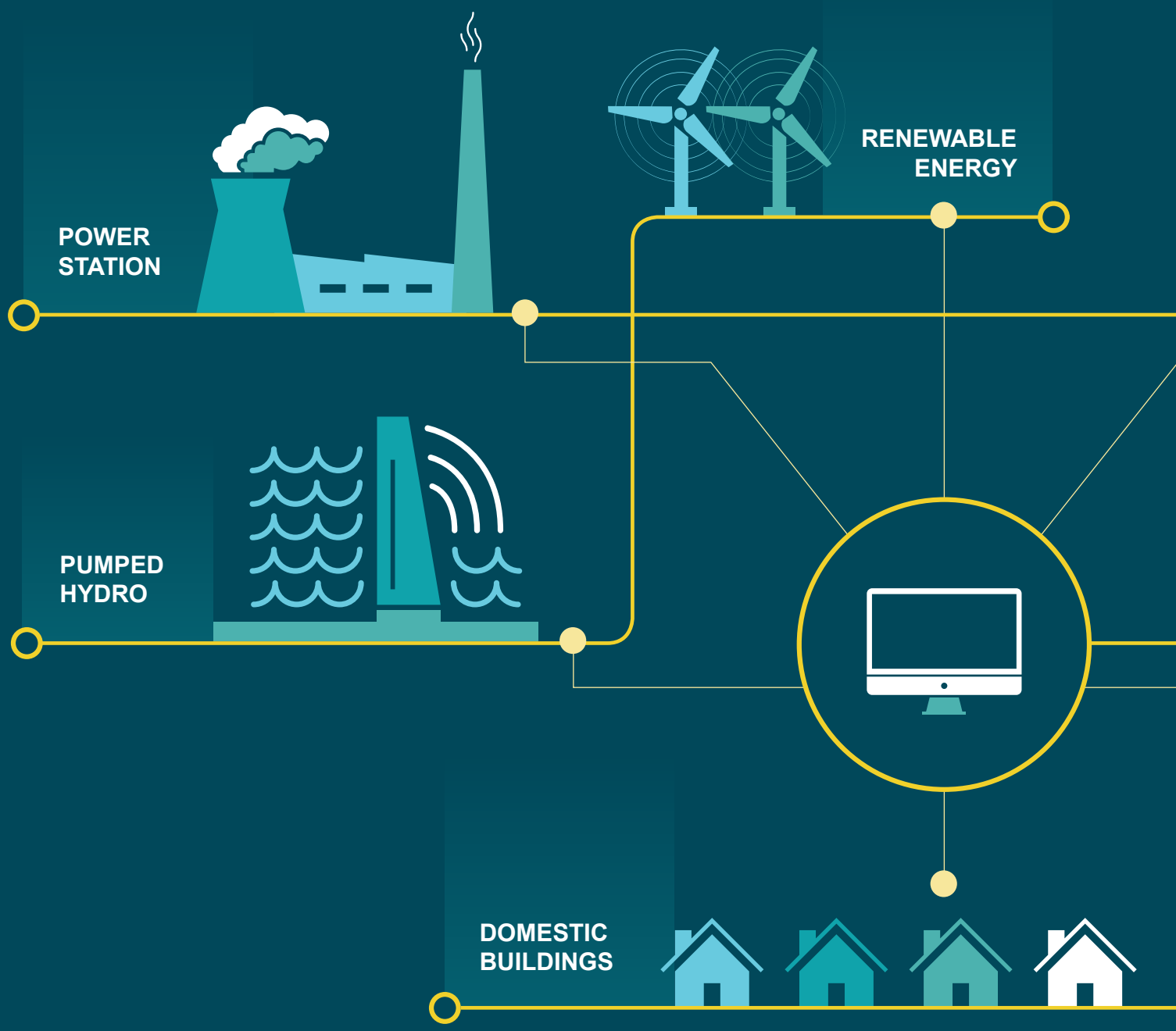
Note: Refers to earnings before interests and taxes.

These new technologies are allowing new forms of interaction between consumers and utilities, and facilitating distributed generation and prosumer activity. For example, smart switches and appliances allow the consumer to shift electrical demand to off-peak hours. "Home energy management systems" and plug-in electric vehicles acting as storeplaces of energy will help the customer benefit from time-of-use pricing. Detailed actionable information will help change behaviors, allowing the customer to react to market incentives and use services that will "think" for him or her. Aiding this will be powerful new computer applications that support decentralized exchange, such as the blockchain, which will allow transactions directly between customers (see Box 9.3).

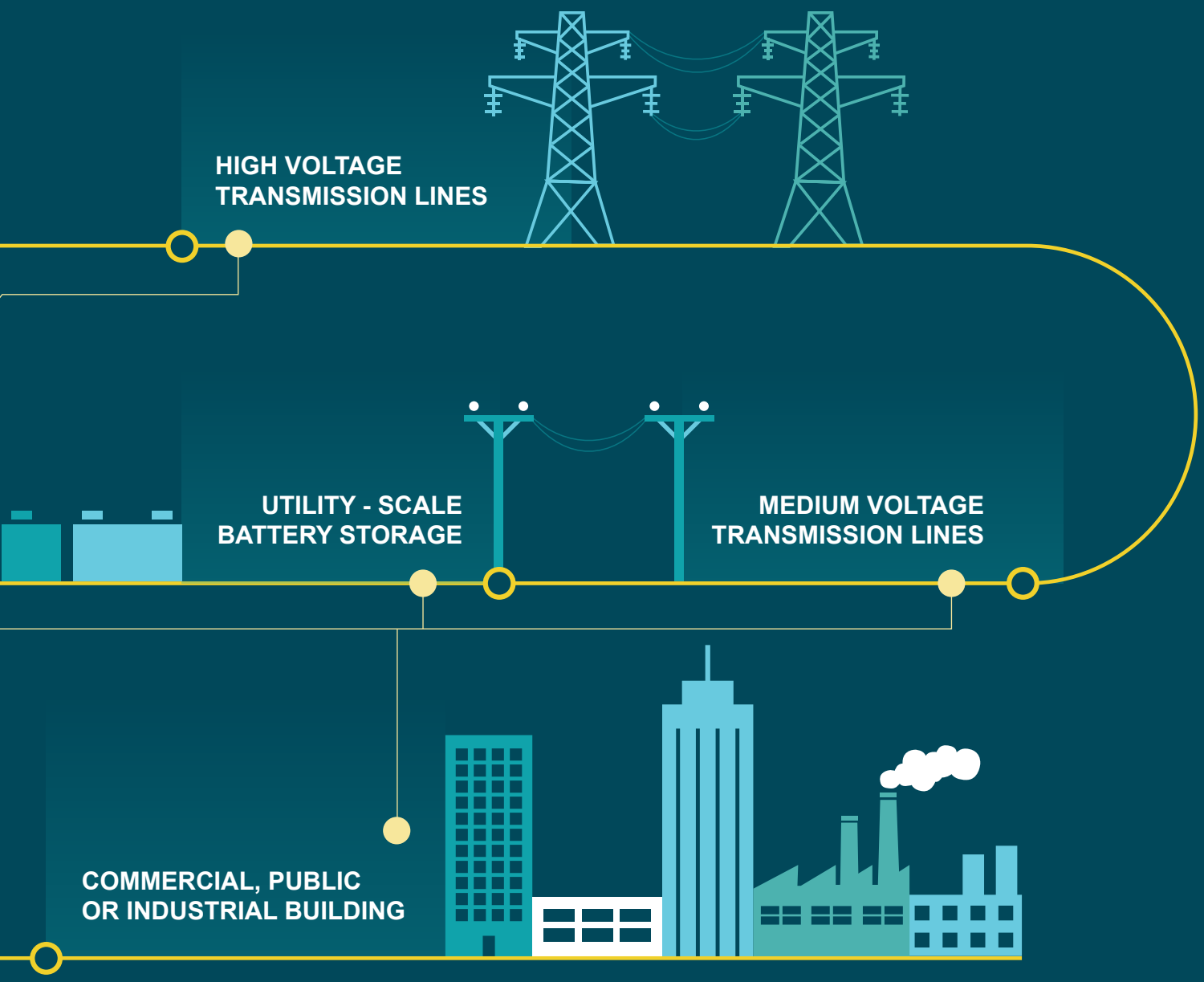
The electricity sector's architecture of the 21st century will look very different from the traditional supply chain of the 20th. Producers, consumers, and networks will interact in real time and push the efficiency frontier (see Figure 9.3).

FIGURE 9.3

Smart grids connect electric and communications systems



Source: ARUP 2016.


HIGH VOLTAGE
TRANSMISSION LINES
UTILITY - SCALE
BATTERY STORAGE
MEDIUM VOLTAGE
TRANSMISSION LINES
COMMERCIAL, PUBLIC
OR INDUSTRIAL BUILDING

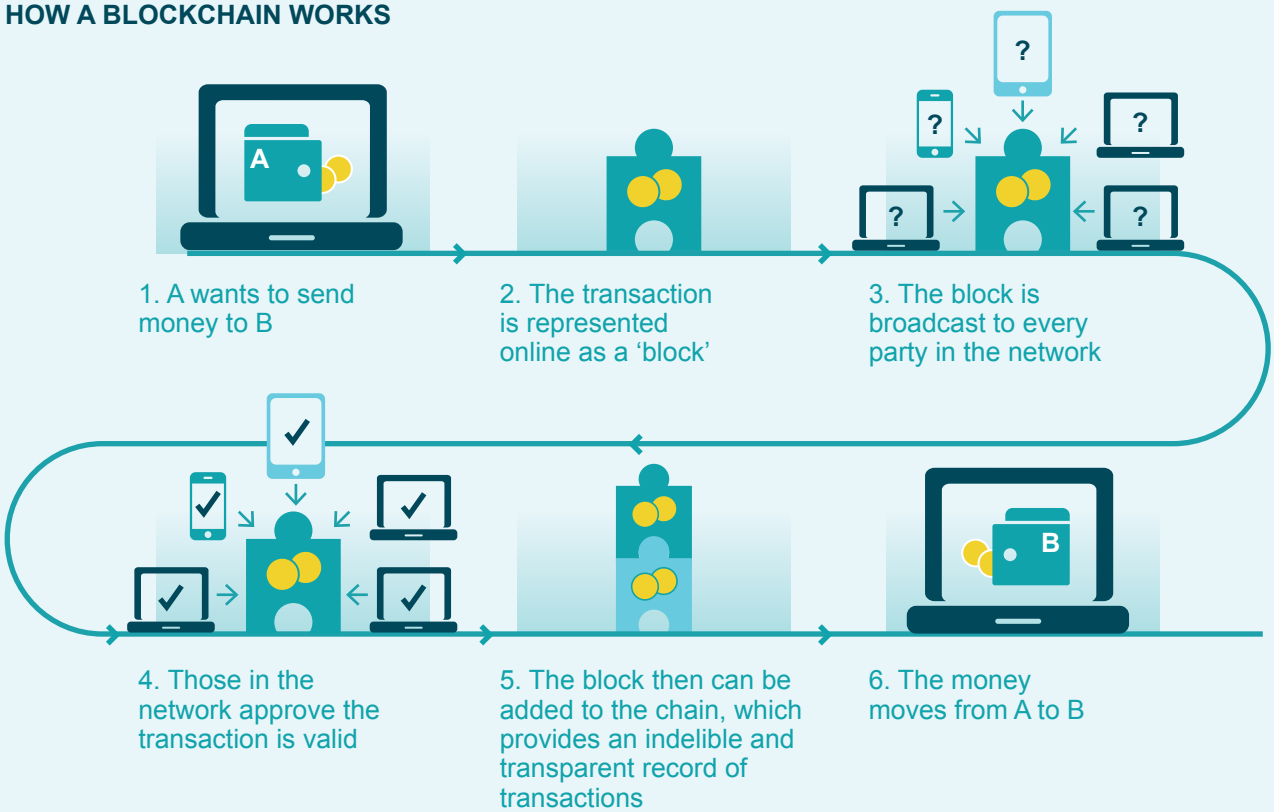
At present there is little "joined-up thinking" which integrates production with customers' use of energy across the energy markets—electricity, heating and cooling, and transport. Future low-emission energy systems in cities are likely to be based on systems that are much more integrated and minimize losses (for example, by producing electricity from thermal sources only if and when the resulting heat can be usefully employed). The systems will also align use patterns more closely with generation patterns from renewable sources. Such integration will depend on intensive data collection and management systems in which utilities are fully plugged into an information-based digital economy.

LAC has already applied some leading edge technologies for systems operation, such as Synchronized Phasor Management in Brazil.[5] Privatization of distribution companies has increased efforts toward distribution automation, reducing losses and operating costs.

Box 9.3 Blockchain technology will allow transactions among consumers

The real power of a home battery and solar panel setup will come from combining it with the blockchain, a distributed ledger system capable of recording, tracking, and verifying transactions across a peer-to-peer network. Instead of only having the option to sell excess energy back to the grid through a local utility provider, this system would allow sale to the highest bidder—a neighbor, local school, or shop, for example—via a local smart grid. This can be leveraged and promoted by smart city platforms.

HOW A BLOCKCHAIN WORKS



Source: Crowdfunding Academy 2015.

Demand becomes increasingly dynamic and "intelligent."

Demand-side participation refers to a wide range of interventions by consumers across the energy supply chain. In electricity, the three key areas are:

- **Demand side management (DSM):** These are specific efforts by utilities or retailers to incent demand side participation from end users.
- **Utility-driven energy efficiency.** Utilities are in a key position to promote energy efficiency, because they understand the behavior of customers and the points along the supply chain where increased efficiency can be realized. Figure 9.4 illustrates the range of steps that utilities can take to increase efficiency. However, utility-driven energy efficiency requires regulations that allow compensation for companies for lost profits derived from investments in energy efficiency.
- **Demand response (load control and time of use rates).** There has been a growing interest among many utilities in "shaping" the load profile, that is, encouraging people to use energy when it is more abundant and to dial down use during peak hours or dry periods of the year. This allows utilities to reduce risk of power outages, better deal with unexpected events, increase capacity utilization, and extend the life of existing assets. Utilities manage the shape of the load profile with price or quantity mechanisms such as time-of-use pricing or load control (controlling the quantity delivered).

Many of these steps depend on widespread deployment of smart meters, but to date they are comparatively few in LAC. The penetration rate of smart meters in the United States, Europe, and the Asia Pacific region is between 60 and 70 percent, while in LAC it is only about 27 percent.[6]

FIGURE 9.4 IFC Utility Driven Energy Efficiency (UDEE) Framework

UTILITY BUSINESS					SEPARATE COMPANIES
Generation	**Transmission**	**Distribution**	**Metering**	**Beyond the Meters**	
Retrofits of existing thermal plants	New SCADA Generation control System	Streamlining commercial processes	Meter with multiple features, including smart ones	EE at customer premises, district cooling	**UTITLITY ESCOS**
Repowering of existing hydro plants	Synchrophasor Wide Area Monitoring	Technical and commercial losses control	In-home display	Load control and load management	
District heating retrofits and expansion	Special controls and smart systems to manage intermittency	Distribution automation	AMI	DG beyond the meter- On Bill financed PV rooftop	**VALUE ADDED SERVICES**
Fuel switching	Transmission enhancements to relieve congestion				

Source: Maurer and Mockel 2014.

Utility-driven energy efficiency is still at initial stages in LAC. Some utilities have shown little interest due to the lack of regulatory incentives that compensate for lost revenue. But a few promising cases are starting to emerge: Brazil has introduced a "wire charge" for energy efficiency, and both Mexico and Colombia are considering the introduction of "white certificates" to provide a premium or incentive for energy saved. At the same time, many LAC countries have introduced energy efficiency programs that encourage replacement of inefficient appliances and equipment, and the labeling and certification of appliances, though there is still much to do on this front (as discussed in Chapter 4).

Emerging technologies could transform the energy service delivery model

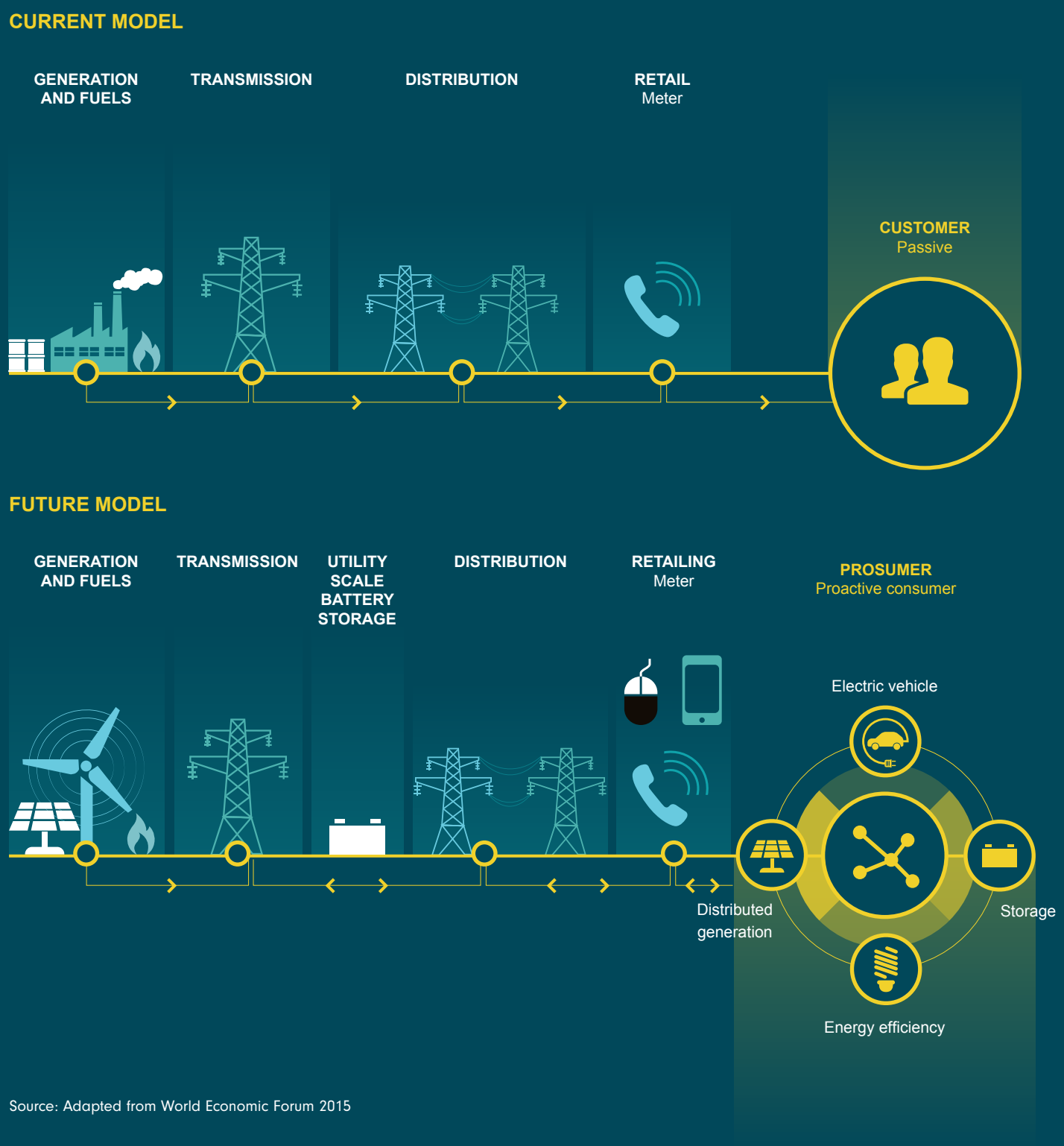
Traditionally, a regulated electric firm makes money by increasing the unit contribution margin or by augmenting the kilowatt hours sold. With the emergence of new technologies and solutions, the business model is set to shift to a new paradigm, where decentralized generation and demand-side activities will play a key role (Figure 9.5).

The mix of flexible resources—on both the supply and demand sides—is diversifying, and new stakeholders are starting to emerge to offer multiple new services. New service-based retail business models could take various forms (PwC 2014):

- **Product Innovator:** It creates a complete suite of products from commodity to device, develops opportunities to integrate energy and other needs, and invests in data analytics to support client relationships (for example, web-based congestion trading).
- **Partner of Partners and Aggregators:** It is the equivalent of the Engineering Procurement Contractor (EPC) role in infrastructure projects. It integrates a suite of products from solution partners (subcontractors), increases the variety of marketing channels, and offers packages of services to customers (for example, an aggregator bundles partner companies for PV installation, cloud and service providers, or efficiency and distributed energy).
- **Value-Added Enabler:** It builds platforms for big data analytics, utilizes data synthesis processes, and forms partnerships with data managers to improve competitive advantages in pricing and services (i.e.; energy internet platforms).
- **Virtual Utility:** It invests in distributed generation and storage projects, partners with IT and data management providers, and increases customer engagement with connectivity and command tools (for example, energy storage services and demand response services).

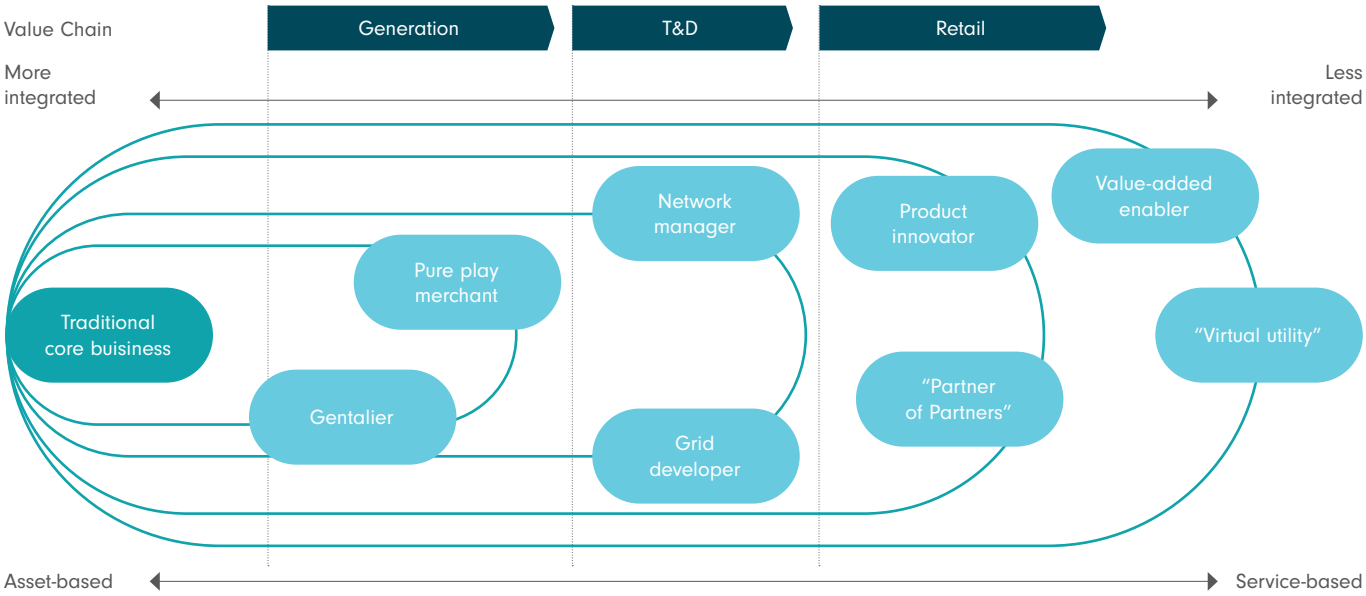
FIGURE 9.5

New Business and Investment Opportunities are Emerging Closer to the Customer



Source: Adapted from World Economic Forum 2015

MAP 9.6 From a Traditional Core Business to Multi-Stakeholder Utility



Source: PwC 2014.

Internet technologies are breaking open the traditional value chain, driving down interaction and transaction costs. In some markets, customers can now plug their consumption data directly into a utility's computer system and shift usage to lower-cost, non-peak periods. Cutting-edge technologies such as electric mobility and hyper-granular real-time metering can turn power consumption into a big data play, opening vast new windows on the behavior and preferences of customers (Heiligtag et al. 2015).

In sum, clean energy and ICT technologies will enable new types of services and a more dynamic and proactive demand-side participation. This will create a more decentralized market with higher numbers of stake-holders.

The new ecosystem of business models and stakeholders will require profound adjustments or even the redesign of legal and regulatory frameworks to address new concepts of ownership rights, obligations, and civil liberties with respect to use of private consumer information, operational and market rules including cost of network and digital platforms and competition regulation. (Table 9.1). The new services platform will rely on market-driven fees and blended yields, as opposed to the traditional concession-based public-private partnerships, which thrive on asset returns and fuel management mark-ups. The two business models are likely to coexist for some time, but there is an emerging consensus that the structure of the sector will look very different in the future (Matrix 9.1).

The appetite for reform and the success to date are a testimony of many LAC countries' willingness to embrace change. However, unlocking demand side resources and operating competitive markets efficiently in a changing technological landscape will require increased complexity of market design and regulation (e.g. from day-ahead to intraday markets, mono-nodal to multi-nodal locational pricing, and fixed to time-of-use tariffs). This of course does not need to happen in smaller systems, where competition is difficult to establish and the benefits of market liberalization are limited.

Nevertheless, strong and agile institutions will be a precondition for embracing the disruption proactively in both liberalized and smaller or non-liberalized systems.

Brazil, Colombia, and Mexico in particular have already introduced market architectures and rules with some level of granularity in pricing and retail competition (see matrix 2.1 in Chapter 2). It is in these markets where the development of new businesses and a vibrant activity on the demand side can first emerge. Other countries in LAC with sophisticated markets such as Peru, Argentina, Chile and certain Central American states could soon follow.

MATRIX 9.1 Traditional and Emerging Market Architectures

	Current Structure	New Architecture
Market Structure	**Energy services:** supplied to inelastic regulated and non-regulated consumers, clustered-class consumers, bus-bar demand aggregation **One-direction business:** traditional horizontal supply chain **Market design:** limited granularity (day-ahead, single pool price, limited retail competition, limited financial hedge) **Trading platform:** energy and reserve, capacity, clean energy certificates, long-term contracts, financial transmission rights	In addition to existing network services: **Demand-side distributed services and prosumers:** re-balancing of the supply-demand equilibrium **Multi-directional trading:** demand-side bidding, trading among consumers (e.g.; facilitated by blockchain technology) **Market design:** increasingly granular and more accurate price signals (intraday, multiple spot prices or nodal/locational pricing, time-of-use tariff, vibrant retail competition, sophisticated financial hedge) **Trading in retail markets (behind the meter):** distributed energy resources (generation, storage, demand-side response, energy efficiency), consumer data N**ew competition dynamics**, new players in retail (demand side) markets, consumers as suppliers of capacity, energy, ancillary services, and data
Business models	**Across traditional segments:** generation, transmission, distribution and retailing	**New ecosystem of multiple business models:** aggregators, shared-asset usage, value-added enablers (digital infrastructure and services, big data platform host), virtual utility **Customer side business model:** more active management of customer interface **Customer choice:** data ownership and leasing, choice of services (bundled)
Regulatory	**Regulation based on cost of service** and allowed revenues, regulatory levies, fees, and taxes **Business models thriving on asset returns** and fuel/supply management mark-ups, tariff-based **Networks:** concessions (rent seeking), guaranteed revenues **Commodities:** energy, capacity, ancillary (rent seeking), guaranteed entry barriers **Trading and retail:** energy volume management mark-ups, supplier and customer capture **Net metering:** important step, but economic efficiency issues	**Need for new policy and regulatory frameworks** that sets clear guidance (co-existence of business models), embraces emerging businesses, aligns cost-recovery mechanisms of electric distribution utilities, and provides incentives for integration of demand side resources **Competition and new players in retail** **Adequate remuneration and incentives mechanisms:** access to markets, compensation (comparable opportunity) **More accurate price signals:** trade-off will be higher complexity and transaction costs, but increased system's efficiency **Privacy and security issues:** data and information and information flows
Financial	**Public and concessional funding**, commercial financing, mortgage-based, concession-based PPP structures **Energy chain supplier (regulated asset rent seeker):** authorized revenues (RoE, equity/debt costs, asset-base)	**Participation of new actors in the financing behind-the-meter installations** **Services platform:** market-driven fees **Specialized vehicles** such as Yield-Cos (retailer, trader), blended yields **Concessional finance and grants for load aggregators** **Millennium investor** approach **New sources of risk:** requires innovative risk mitigation instruments
Governance	**Focus on managerial efficiency** (utilities), regulatory autonomy, transparency, and accountability	**New emphasis** on capacity to embrace change (flexible mindset), leadership and agility of decision making, consultation and adjustment, facilitating active engagement of multiple stakeholders, interagency dialogue

Source: FGV-CERI for World Bank (2017); authors.

New technologies often face political opposition from incumbents

The new business ecosystem where utilities, new entities, and prosumers interact will reduce the need for baseload and peak generation on the supply side, and inevitably reduce dependence on the transmission and distribution grid. This threatens the relevance and very existence of an industry that has not changed structurally for more than a century.

The speed of adoption of new technologies and integration of innovative business models will depend on the strategic interaction among incumbents and new agents, shaped by public policies, quality and nature of regulation, and capacity to adapt innovation. The stakeholders that will determine the speed and depth of the disruption, at least initially, are incumbent electric utilities, policy makers, regulators, investors, financial intermediaries, and members of the smart city ecosystem.

Policy makers face the challenge of issuing measures that address conflicting development objectives: (1) curbing carbon emissions to comply with COP21 and national commitments, (2) ensuring security of supply, and (3) cutting energy costs to foster country competitiveness and industrialization.

In other countries, regulated firms have mounted defensive political and court-room campaigns that serve to slow down introduction of new technologies and frameworks that threaten their business model. They seek to avoid being saddled with "stranded assets," facilities and systems in which they have invested heavily but which become worthless under the new regime, costing their shareholders dearly.

These companies typically use two major types of strategies to blunt the change.

The first is a "restraining" approach. It may include lobbying for legal or regulatory barriers to new investors in decentralized renewable energy parks, or lobbying for preferential economic rights for incumbent distribution companies over prosumers´ surplus electricity. Another tactic is to block rooftop panel installation on grounds it breaches the regulatory compact. Indeed, the strongest opposition to panel installation across the world often comes from distribution company lobbies.

Companies pursuing this strategy will typically make the following arguments:

- "Rooftop solar subsidies may end up concentrated on the wealthiest customers."
- "Distribution firms should be the default buyers of prosumer surpluses under a net metering approach."
- "If the power that prosumers inject into the distribution network isn't sold to the distribution firm, they should pay access and usage fees."
- "Prosumers who claim that they will fully disconnect from the grid will still need centralized supply during maintenance or solar/wind outages. So they should continue paying monthly access rates to the distribution firm."
- Distribution utilities in conservative regulatory environments may have a chance to win litigations about "stranded assets."[8]

The second strategy is an "investing" approach. It seeks to ensure that renewable power station expansion is monopolized by incumbent generators, or to partially or fully divest current assets and shift to a new business model based on a leaner asset base and decentralized trading.

Smart regulation is key to helping new technologies take hold

A conservative regulator may concede to the incumbents a grandfathering system for renewables to avoid disputes over "breaching the regulatory contract." But that will mean in effect that the adoption speed of renewables will depend solely on business opportunities for incumbents. Incumbents will be in a position to neutralize the benefits of renewables.

To enable disruption to take hold, regulation must follow three basic principles:

- *Catch up with emerging regulatory developments.* Measures include fostering smart metering for two-way energy transactions, setting up an electricity forward markets, introducing nodal prices, introducing demand-side response, establishing distribution access charges that do not impede decentralized trading, introducing higher frequency dispatch and secondary markets, reinforcing transmission to facilitate access of remote renewable parks production, crafting sound entry mechanisms for renewables, and getting the renewables pricing right.[9]

- *Allow experimentation in new business models.* Ofgem, the UK gas and electricity markets regulator, is an example of proactive regulatory support to non-traditional business models (NTBM). Ofgem insists that regulation must be open and responsive to innovative and "disruptive" business models. It has started evaluating three wide-ranging NTBM categories: (1) local energy services (such as community services), (2) bundled services (energy service companies) and (3) customer participation (peer-to-peer energy, next generation intermediaries). NTBM ownership structures include private businesses, cooperatives, publicly-owned companies, and hybrid ownership models. Ofgem expects that such new business models will require fundamental changes to regulation, for example, challenging centralized dispatch and creating customer risk protection which might include some form of financial insurance.

- *Anticipate new electricity market architectures.* The energy transition will require market architectures favorable to innovation. For example, the Clean Energy Council of Australia stresses the need to establish best practices to facilitate connection of distributed generation and provide a regulatory framework for energy storage. This is mainly to ensure that monopoly distributions networks do not discriminate against other parties' storage and are not granted powers to control storage systems without providing compensation.

The Smart City (SC) ecosystem can help facilitate the transition to proactive consumption. The gap between technology and public organizational capacities could be sidestepped in LAC's largest capital cities by mobilizing citizens´ initiatives via urban digital platforms supporting new business models, such as collaborative partnerships based on crowdsourcing and crowdfunding.

Citizen engagement is reaching a golden era, propelled by IT developments with spatial and social coverage, such as smart phone utilization. This allows big data and machine learning algorithms to provide useful, real-time information for problem solving. Cities and their individual citizens have become the center of decisions to address transversal issues such as sustainable development and quality of life. Transversal issues cannot be dealt with in isolation by traditional utilities or the local administration in a top-down way, the conventional approach in the past.

Citizen collaboration may emerge in three forms:

- *Crowdsourcing.* Example: using crowd-sourcing methodologies, the city administration organizes a contest to optimize the energy use of public buildings.
- *Crowdfunding.* Example: energy prosumers raise money to invest in medium-sized storage facilities to increase surplus energy value.
- *Alliances.* Example: the energy utility, the transit administration, venture capitalists, and energy prosumers close deals to generalize electricity transportation.

TABLE 9.1 Roles and behavior of actors facing the approaching "disruption"

ACTORS	CONSIDERATIONS	STRATEGIC BEHAVIOR
Utilities	Avoid asset stranding, or Monopolize disruption rents	Lobby to block disruption by new actors Aggressive investment in disruptive assets to gain first-move advantage
Policy makers	Follow trends, or Accelerate disruption adoption	"Cheap talk" statements with no political cost Costly commitment to energy/environment goals
Energy regulators	Avoid conflict with incumbents, or Promote efficiency, experiments and full adoption	Discourage new entry Set catch-up and enabling conditions for disruption
Financing and risk management institutions	Deepen position in new energy technologies and business models	Develop specialized financing vehicles and instruments to attract new asset classes
Smart City platforms	Solve urban problems by mixing citizen engagement, public sector, firms, and technology	Create digital platforms to crowd-mobilize ideas and money for disruption

Source: Prepared by authors.

Utilities in particular will face pressure and competition from new and more agile companies, such as the digital players. As energy is transformed from a commodity to a product wrapped in information, building digital skills will be crucial to developing the value of customer data. Centralized, asset-heavy production of electricity will not disappear, but utilities must explore new horizons in clean energy, downstream markets, and digitally enabled, customer-centric business models

Matrix 9a in Annex II lays out indicative actions to prepare for the emergence of new solutions.

Notes

1. Meaning that for each doubling of global capacity, costs have declined by more than 20 percent.

2. In some jurisdictions, however, renewables have reached grid parity.

3. Distributed generation (DG) is comprised of smaller power sources that can be aggregated to provide power necessary to meet regular electricity demand. Typically, DG refers to power generation at the point of consumption, also called "beyond the meter." DG systems may use any renewable energy source, including solar PV (residential and commercial rooftops), hydro, biomass, biogas, solar power, wind power, and geothermal power.

4. PV is likely to be in the lead in distributed generation, but a wider range of other distributed generation sources will have similar benefits and impacts—for example, smaller-scale local combined heat and power (CHP) systems which provide electricity, heat, or cooling, and systems that treat waste solids, liquids, or gases (for example, at waste treatment facilities or sewage works).

5. Synchronized Phasor Measurement Technologies (SPMT) are smart components to operate large, high voltage transmission systems more efficiently. They enable a closer monitoring and operation of the network resulting in increased reliability and lower risk of cascading black outs.

6. In addition to deployment of smart meters, the other challenge for LAC is to use them to their full potential. In LAC countries, the preferred features are typically automated meter reading, automated disconnection, and fraud/tampering detection. These features are very much aligned with the main objectives of the distribution utilities, namely to reduce technical and commercial losses, and rationalize operational costs, with some extra benefits in term of customer service. However, full functionality of a smart meter should also include in-home displays (for the customer to manage consumption), two-way communication, and load control capabilities. They can also offer some additional features such as pre-payment and power-gas-water integration (taking advantage of the existing IT and telecom backbone). Features of smart meters are closely linked to a more active load control, which is not yet part of the regulatory compact in LAC.

7. The preoccupation with stranded assets did not prosper in other network industries like telecoms with the arrival of mobile telephony. However, the stranded assets issue cannot be dismissed easily in energy, because it touches upon powerful interests beyond distribution companies. Stranded assets include both equipment and "unburnable carbon" reserves.).

8. In the UK energy market, for example, Grubb (2015) contends that the government should compensate the wind generators for any difference between the social cost of carbon and the levy paid for CO2 emissions by fossil-fuelled generators. Grubb states that this is not a subsidy for wind investors, but a measure ensuring that wind generators gain the value agreed to reducing CO2 emissions.

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3

SECTION 3

Energy Infrastructure Growth, Investment, and Financing

Section 3 looks at the investment required to attend energy demand growth at the regional level, and discusses trends and ways of financing energy infrastructure in the region.

Chapter 10 examines existing scenarios of energy infrastructure growth and provides estimates of investment needs focusing on the electricity and gas sectors. It also analyzes two important aspects of the energy agenda in LAC: i) the cost of achieving Nationally Determined Contributions (NDCs), with and without carbon emissions trading, and ii) the cost of achieving universal access of energy.

Chapter 11 looks at the status of financial markets in the region, focusing on Public Private Partnerships (PPPs) as a potential standard framework to increase private sector financing in the region.

Key message

The key message emerging from Section 3 are the following:

1

EMBRACING THE CLEAN ENERGY AND DIGITAL REVOLUTION MAKES ECONOMIC SENSE FOR LAC.

Demand for energy in LAC is projected to continue to grow at high rates. The region would need an estimated US$ 1.3 trillion dollars between now and 2030 to develop its electricity and natural gas infrastructure under a business-as-usual path. However, current investment flows fall short of these needs. Investment requirements could fall considerably under a development path that emphasizes efficient use of existing infrastructure, grid-connected renewables and a menu of demand-side solutions.

2

MOBILIZING PRIVATE INVESTMENT WILL BE CRUCIAL TO THE SUCCESS OF FUTURE ENERGY DEVELOPMENT STRATEGIES IN LAC.

Patterns of private sector participation have registered fluctuations and concentration in only a few countries of the region (larger economies with deeper financial sectors). In addition, the cost of financing is high -notably when the exchange rate risk is high- and subject to availability of risk mitigation schemes.

PPP's are a critical to increasing private sector funding for infrastructure investment. However, there is a limited pool of local project sponsors in LAC with experience and appetite for PPP projects, so direct and indirect government support will continue to play a key role in facilitating such investment.

International commercial banks are the predominant source of energy infrastructure finance in the region, although there is a growing role of domestic banks, which, among other things, are important to increasing the share of financing in local currency. Institutional investors will need to play an increasing role in addressing the investment gap. Promising avenues include project bonds, equity and debt funds.

Development banks will continue to play a role in addressing finance market failures, but they must avoid constraining the development of private sector finance.

CHAPTER 10

Big Plans, Big Costs

Countries are enacting ambitious strategies toward a new energy future

National energy strategies and policies in LAC vary country by country. But they share common themes of ensuring energy security and resilience, improving the sustainability of energy systems, strengthening governance -institutional, legal and regulatory frameworks-, achieving universal energy access, and promoting technology innovation.

Most countries in the region have plans to develop greener economies. At least 18 countries have renewable energy targets, some as ambitious as 80-100 percent share of total electricity generation.[3] Many LAC nations have made voluntary commitments in the form of Nationally Determined Contributions (NDC) to reduce carbon emissions as agreed during COP21 in Paris in December 2015.

Sometimes, sub-regional patterns are visible: For example, countries in the Caribbean are typically most concerned with diversifying their energy matrix (especially those that are fuel oil-dependent) and/or building up the resilience of their energy infrastructure. Diversification with renewable energy in the Caribbean can result in lower electricity cost.

Below the national level, cities and municipalities across LAC are starting to adopt their own measures aligned with smart city platforms, and have progressed considerably in advancing sustainable energy.

BOX 10.1. Energy 2050: Chile charts a policy path to inclusive, competitive, and sustainable energy.

Energy 2050 envisions a reliable, inclusive, competitive, and sustainable energy sector and proposes 20 ambitious goals:

Goals to be achieved by 2035

1. Develop electricity interconnections with CAN and MERCOSUR.

2. Reduce the duration of electricity interruptions (SAIDI) to less than four hours per year. In 11 of the 15 regions, SAIDI reached an average of 15 hours per year, and in two of the regions 30-60 hours per year. The document offers Denmark, Germany, and Switzerland as best-practice benchmarks.
3. Provide 100 percent of "vulnerable families" with access to modern energy services.
4. Make all energy projects contribute to local economic development, introducing mechanisms to associate company with community.
5. Place Chile among the top five OECD countries with lowest electricity price for residential and industrial consumers.
6. Generate at least 60 percent of electricity from renewable sources.
7. Reduce carbon intensiveness by 30 percent (2007 as baseline year)
8. Make 100 percent of large industrial consumers, mining enterprises, and transport systems introduce energy efficiency management systems and use energy efficiently.
9. Treat "forestry biomass" as "solid fuel" in regulation.
10. Procure 100 percent of new vehicles (public transportation/passenger fleet) with energy efficiency as part of evaluation criteria.

Goals to be achieved by 2050

1. Reduce the duration of electricity interruptions (SAIDI) to less than one hour per year.
2. Align GHG emissions reduction commitments from the energy sector to global targets and deliver a relevant contribution for a transition to a low-carbon economy.
3. Ensure universal access to modern, reliable, and affordable energy.
4. Make all planning instruments (land, regional, communal) integrate energy policy prescriptions.
5. Rank Chile among the top three OECD countries with lowest electricity price for residential and industrial consumers.
6. Generate at least 70 percent of electricity from renewable energy.
7. Decouple energy consumption from economic growth as measured by GDP.
8. Make 100 percent of new buildings use OECD standards in energy efficiency, including smart energy technology necessary for demand-side management.
9. Assure that 100 percent of equipment and appliances offered in the market are energy-efficient.
10. Embed the energy culture in all levels of society: producers, commercializing entities, and consumers/users.

The Government of Chile is developing roadmaps to take the country to this energy future.

Source: Prepared by authors based on Chile Ministry of Energy 2015.

BOX 10.2. Mexico's Energy Transition Strategy Promotes the Use of Clean Fuels and Technologies in the Electricity Sector.

Mexico has designed a sophisticated legal framework to deliver a modern, reliable, and sustainable energy system. It includes a number of key pieces of legislation: General Law on Climate Change, Law for the Development and Promotion of Biofuels, Law on Geothermal Energy, and Energy Transition Law.

The Energy Transition Strategy of 2016 articulates a vision to deliver the clean energy agenda, and includes the following goals:

- Increase the contribution of clean energy in electricity generation from 20 percent in 2015 to 35 percent in 2024, 37.7 percent in 2030, and 50 percent in 2050.
- Reduce final energy intensity at an average annual rate of 1.9 percent in 2016-2030) and 3.7 percent in 2031-2050.

The strategy establishes roadmaps to achieve these commitments in the energy and transport sectors.

Notable in this strategy is a stress on using emerging and innovative technologies. These include not only renewable energy and electric transportation (or those necessary for energy efficiency) but also storage, distributed generation, and the full range of ICT innovations that promote better integration along the value chain, such as the "Internet of Things" and "big data" management.

Source: Prepared by authors, based on Mexico Secretariat of Energy 2016.

Modeling gives a glimpse of the investment needs in years ahead

Many global and regional models provide estimates of energy demand growth and evolution of technology choice for the LAC region. GDP and energy demand growth projections across models span a broad range, and different model structures and assumptions deliver varied results (as shown by Bas J. van Ruijven, 2016; see Figures 10a and 10b in Annex I).

However it is useful to discuss investment estimates using a robust modelling framework with clear assumptions and scenarios, such as the one provided by the IEA's World Energy Outlook (WEO), which is updated annually. The scenarios are global but provide regionally disaggregated figures.[4]

Three scenarios are produced by the EIA each year. These reflect the anticipated future trajectory of energy supply and growth under three sets of policy assumptions;

- The Current Policy Scenario (CPS), which is based on policies that have been implemented
- The New Policy Scenario (NPS), which assumes that in addition any relevant measures which have been announced are also fully implemented

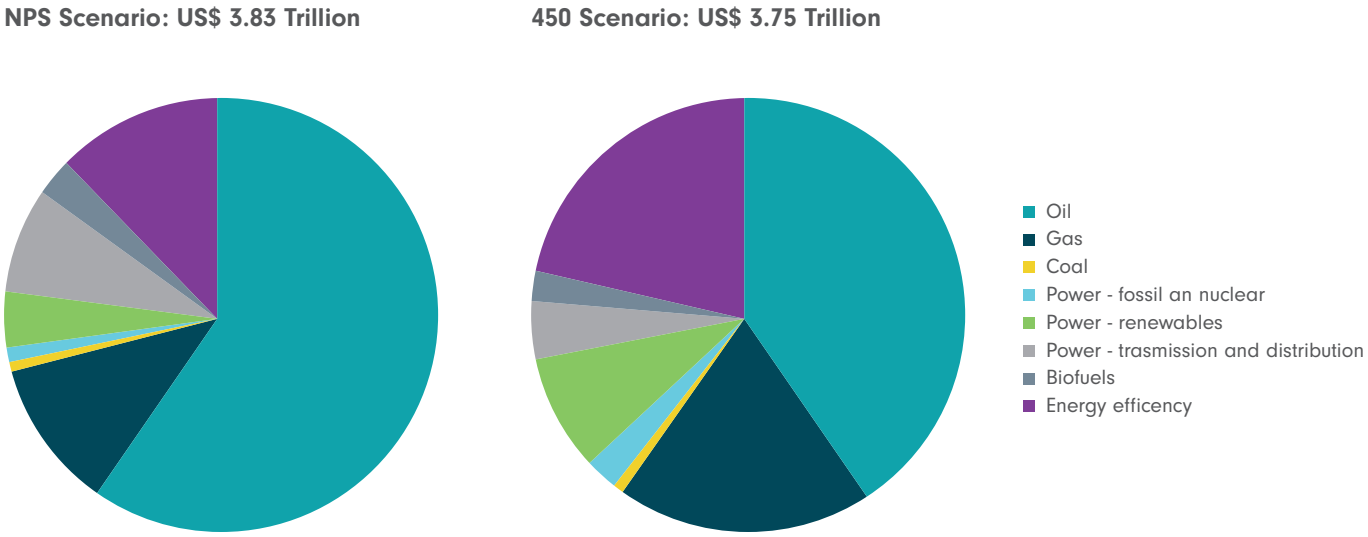
- The 450 Scenario (450), which assumes policies are put in place that keep the energy sector's greenhouse gas emissions to levels that limit the long-term rise in global temperatures to 2o centigrade.

For the purposes of this report, the NPS is used as a baseline scenario.[5]

Results from WEO suggest that cumulative investment in the supply side will reach $3.6 trillion by 2030, with a further $250 billion in energy efficiency in the NPS Scenario.[6] In the 450 Scenario, cumulative LAC investment in energy supply is lower at $3.1 trillion, but with higher investment in energy efficiency at $650 billion. Figure 10.1 shows how this investment would be spread amongst the main elements for the NPS and 450 scenarios. Table 10a in Annex I shows a more detailed breakdown of these investments categories.

In the 2014 analysis, 53 percent of the projected investment in the NPS scenario is linked to the oil industry. The region's investment in power generation would go mainly (80 percent) to renewable energy. In the 450 scenario the balance shifts toward more emphasis on renewable power, biofuels, and energy efficiency, particularly in the transport sector where strong growth in the number of electric vehicles is assumed.

FIGURE 10.1 Distribution of Cumulative Investment for LAC to 2030, NPS and 450 Scenarios *(USD trillion)*



Source: IEA 2014.

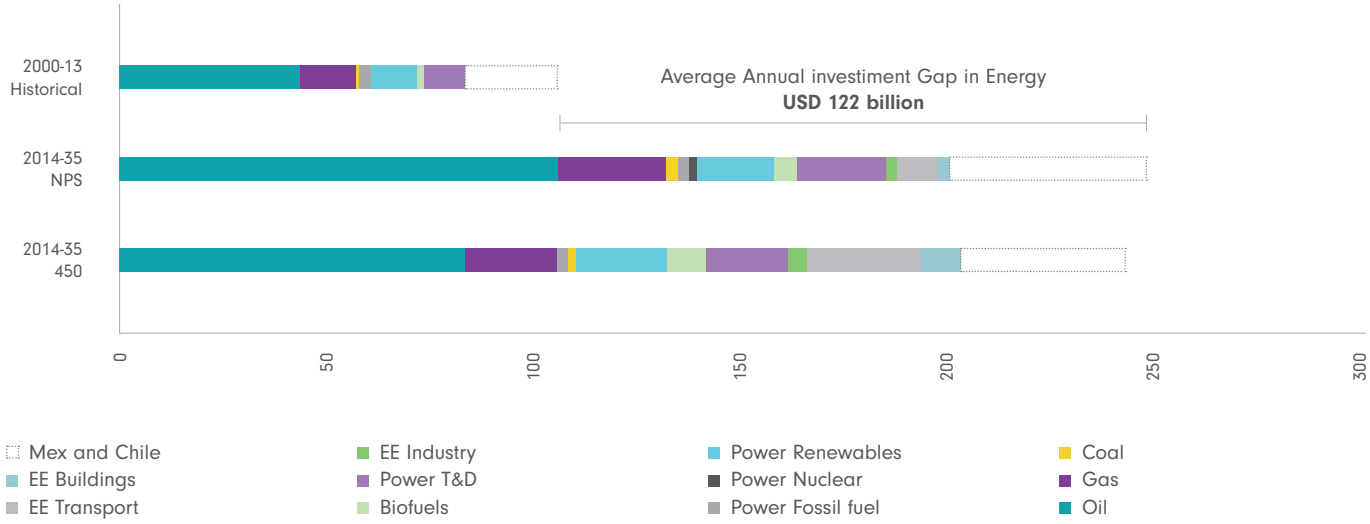
Estimates show a substantial investment gap

Overall, the IEA scenario analysis suggests an investment gap of about $122 billion per year to support the business-as-usual (NPS) development of the energy industry in LAC in the 2014-2030 period (Figure 10.2). The estimated average gap in electricity is $22 billion, of which $7 billion is in generation and $15 billion in transmission and distribution. The gap in generation represents only 39 percent of what has been historically invested, whereas in transmission and distribution the gap amounts to 2.4 times of levels invested annually between 2000 and 2013.

Thus a substantial scale-up for investment in the electricity grid would be crucial to the development of clean energy markets, including renewable energy integration, overall operational efficiency of the sector, and demand-side energy efficiency. Investment to develop the natural gas industry would need to almost double; the estimated investment gap in that sector is $14 billion annually to 2030 (about two times the historical levels). Natural gas will be key for the transition to a clean energy future, most notably in countries with poor hydroelectric resources.

The investment gap will vary among countries given their different sizes, energy demands, challenges, and opportunities. Investment gaps can be much lower if deeper levels of energy efficiency and demand side management are taken into consideration. This is explored next.

FIGURE 10.2 Estimated Average Annual Energy Investment for LAC to 2030 *(USD Billion)*



Source: Prepared by authors base on IEA 2015.

Factoring in introduction of disruptive technology shows major savings

The IEA's 450 scenario put forth measures to attain a global carbon emissions concentration goal of 450 ppm. The planet, however, has already surpassed this concentration, and it is now widely accepted that governments need to intensify their abatement efforts.

A number of research institutes and organizations have been modelling global and regional energy systems to analyze the effect of proposed measures to reduce emissions. Recent modelling for the LAC region as a whole is limited. One of the most recent studies uses the IIASA's Global Energy Assessment (GEA) model to determine a pathway to achieve total decarbonization of the electricity sector (Vergara et al. 2015).[7] However, this exercise does not attempt to predict the investment required to reach such an ambitious goal.

Apart from the modelling exercises described earlier (IIASA GEA and IEA's WEO), there are no recent forecasts of the energy sector in LAC that explore scenarios of disruption, where the full potential for increased operational efficiency and sustainability are considered along the value chain.

For the purposes of this report, the Swedish Royal Institute of Technology (KTH) conducted a planning exercise to assess the investment required under a set of scenarios that explore new and more aggressive measures (see Box 13.3 for a description of the model):

- BAU—Business as Usual, based on existing national expansion plans
- RET—Maximum Renewable Penetration as indicated by existing national expansion plans
- INDC—Based on COP 21 INDCs
- Disruption—Based on more aggressive energy efficiency and demand-side management assumptions, and INDC commitments for renewables

The SAMBA (South America Modelling Base) puts investment needs for continent in the range of $23-26 billion per year—except in the disruption scenario, which has lower investment requirements due to energy savings on both the supply and demand sides (Table 10.3). These numbers are also broadly consistent with IEA scenarios that put annual investment costs in power generation capacity for South America at some $24 billion per year to 2020, rising to $31 billion by 2030. The SAMBA modelling exercise shows that the uptake of a range of technologies and measures on both the demand and supply sides could significantly reduce investment needs in the electricity sector, dropping it from $23.3 billion to $8.4 billion annually between 2018-2031 (see Box 3.3). The exercise also indicates that renewables, including large hydro, wind, and solar, will play a major role in capacity expansion in South American countries (Figure 10.3).

TABLE 10.3 Results from Scenario Analysis with SAMBA

	SCENARIOS				
	Period	**BAU**	**RET**	**INDC**	**Disruption**
Capacity added (MW)	2018-2031	117,621	132,377	119,684	39,648
	2032-2052	357,590	366,552	360,337	253,726
Electricity generated (GWh)	2018-2031	391,400	392,600	390,400	114,900
	2032-2052	980,100	980,100	985,500	715,600
Investment (USD Million)	2018-2031	302,996	336,520	310,068	109,244
	2032-2052	995,761	1,011,637	1,057,876	596,632
Average Annual Investment (USD Million)	2018-2031	23,307	25,886	23,851	8,403
	2032-2052	52,408	53,244	55,678	31,402
GHG emissions (Mt & %)	2018-2052	38,199	39,652	40,234	20,761
	2018-2031	+9.3 MT (6.5%)	+4.4 MT (+3.1%)	+1.3 MT (+0.9%)	-23.1 MT (-18.9%)
	2032-2052	+65.6 MT (43.2%)	+69 MT (+47.2%)	+26.7 MT (+18%)	+6.2 MT (+6.8%)
Cumulative GHG emissions (as % of BAU)	2018-2031	100%	97.90%	97.20%	75.00%
	2032-2052	100%	97.70%	85.60%	42%

Source: KTH Royal Institute of Technology 2016.

BOX 10.3. SAMBA: A scenario of disruption

SAMBA (South America Model Base) analyzes the long-term dynamics of power systems integration in South America using OSeMOSYS (Open Source Energy Modelling System). OSeMOSYS is an optimization software for long-term energy planning developed by the Swedish Royal Institute of Technology (KTH). SAMBA can simulate renewables intermittency, storage constraints in hydro reservoirs, and international electricity trade among South American countries. South American countries modeled using SAMBA include Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Guyana, Paraguay, Peru, Uruguay, and Venezuela.

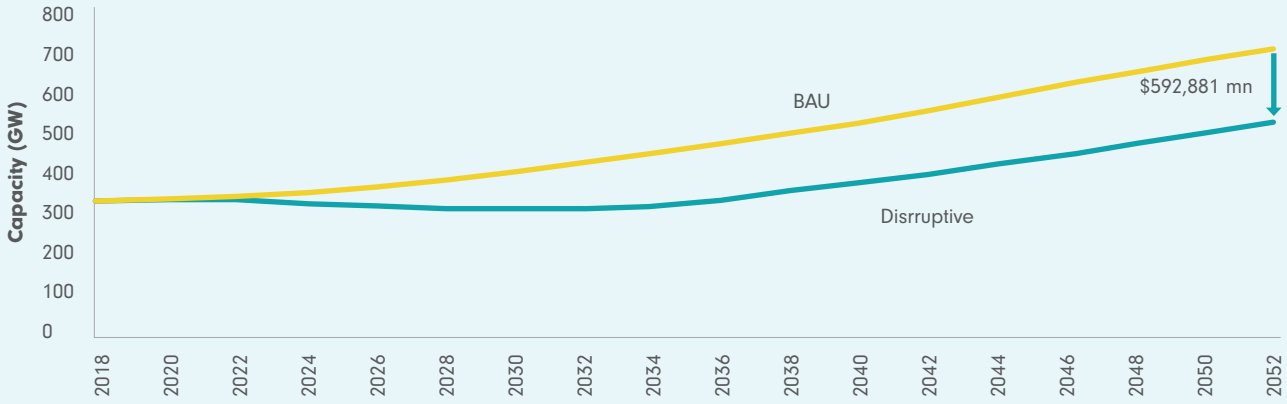
The tool considers 15 electricity generation technologies: large and small (< 30 MW) hydroelectric plants; bagasse thermal power plants (first- and second-generation biofuels); geothermal power plants; wind farms (onshore and offshore); large solar plants (photovoltaic and concentrated); coal plants (pulverized and Clean Coal with Carbon Capture and Storage); fuel oil thermal plants; natural gas (open cycle and combined cycle); and nuclear power plants.

When running a scenario of "disruption" that considers a number of clean energy measures, most notably on the demand side, SAMBA estimates large reductions in the investment needed to meet demand (about $15 billion per year less compared to the BAU scenario), as well as important reductions in carbon emissions (about 25 percent less than BAU) in the period to 2030. These measures include installation of smart grids, distributed generation, demand response (peak reduction), and end-use efficiency, in addition to grid-connected renewables as estimated under NDC commitments.

The scenario and estimates shed light on the potential of demand-side management measures. The realization of this potential depends on strong policy signals and incentives that consider consumer behavior patterns and dynamics.

	First 5 years	From 5 to 10 years	Beyond year 10
Energy Efficiency (Smart Grid)	5% of Baseline (MWh)	10% of Baseline (MWh)	10% of Baseline (MWh)
Energy Efficiency(End-use)	5% of Baseline (MWh)	10% of Baseline (MWh)	10% of Baseline (MWh)
Energy Efficiency (Greening the Grid)	5% of Baseline (MWh)	10% of Baseline (MWh)	5% of Baseline (MWh)
Peak Reduction/Demand Response	10% of Baseline (MW Capacity)	20% of Baseline (MW Capacity)	20% of Baseline (MW Capacity)
Renewables- Utility Scale	INDC Targets	INDC Targets	INDC Targets

South America



Source: Prepared by authors based on scenario analysis using the OSeMOSYS model by KTH Royal Institute of Technology, for the World Bank 2016.

Researchers have also used the OSeMOSYS-SAMBA model to analyze cross-border trade between Brazil and other South American countries (Pinto de Moura et al. 2016). The exercise looks at two scenarios: a reference scenario based on trade forecast in national expansion plans, and an integrated system scenario, in which links to strategic large hydro plants considered by the Brazilian government are added to the reference plans. When considering the "bargaining power" of different countries—using a cooperative game theory approach based on the Shapley value concept—total trade increases by a potential three-fold in the integrated system scenario. The study shows that international interconnectors play an important role in optimizing resources, enhancing system resilience, and contributing to "greening the grid" with increased use of variable renewable energy. Overall, estimates of future investment needs are clearly sensitive to a number of factors including:

- The future development scenario, which is related to economic growth and to the extent to which the link between energy intensity and economic growth is maintained

- The extent to which supply-side investment (in energy efficiency, for example) reduces the need to increase supply-side capacity
- Possible supply-side efficiencies which can come from further international transmission links and trading
- The extent to which regulatory mechanisms including carbon trading can drive good investment decisions, and the extent to which the costs of meeting low emission targets are reduced through international carbon trading.

The modeling work by both the IEA and KTH delivers two strong messages: LAC countries need to continue optimizing their systems to achieve higher levels of technical and economic efficiency, and annual expenditures in new energy infrastructure don't necessarily need to be higher, just smarter and focused on approaching a best practice efficiency frontier via strong policy and regulation and absorption of innovative technologies and practices along all segments of the supply chain.

Carbon trading promises major savings to the energy industry

A final consideration here is the role that carbon trading mechanisms might play in altering investment costs to the industry. Some LAC countries are already taking the lead in developing such mechanisms. For instance, in 2014 the Mexican government announced the possible development of an Emissions Trading Scheme (ETS) in the energy sector, and the Ministry of Environment is assessing possible models. This would complement Mexico's tax on fossil fuel sales, excluding natural gas, which went into effect on January 1, 2014. Chile, meanwhile, has passed legislation for a carbon tax to begin in 2017. It would apply to all stationary sources with a thermal input capacity greater than 50 megawatts.

Simulations made with EVALUATE, a tool for assessment of NDC implementation developed by Enerdata for the World Bank, indicate that without carbon trading, the cost to the energy sector of implementing these mitigation efforts will be significant and vary from one country to another. The estimated total cost of achieving INDCs in the 2015-2030 is roughly $231.6 billion in Brazil, $190 billion in Mexico, and $167 billion in Central America. However, in the scenario with a full-fledged domestic and international trading system, the total costs of achieving NDCs would come down drastically to $3.1 billion in Brazil, $1.7 billion in Mexico, and $900 million in Central America (Box 7.1). These are two extreme scenarios (no carbon trading, full domestic and international trading), but it gives a range of potential NDC cost and illustrates the critical role of domestic and international emissions trading in optimizing the overall economic cost of climate change mitigation.

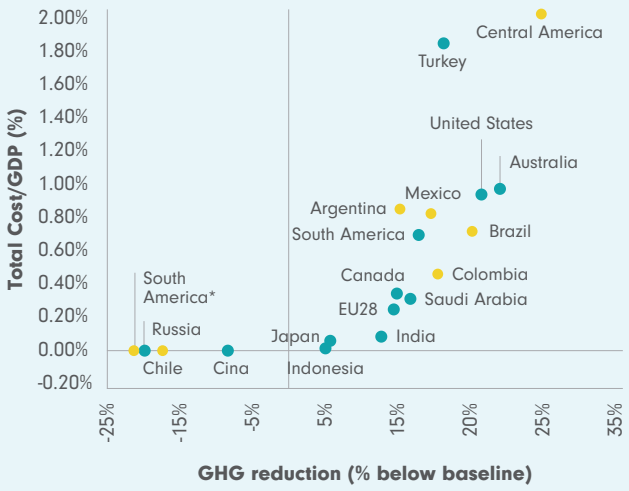
Again, these stylized modelling exercises illustrate the potential of specific policies and technology to significantly reduce energy infrastructure investment needs.

BOX 10.4 THE ECONOMIC COST OF NDCS IN LAC

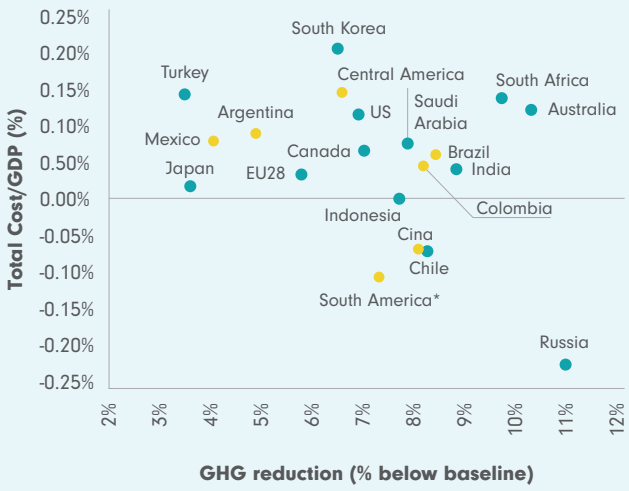
Estimates based on simulations made with EVALUATE, a tool for the comparative assessment of NDCs (based on detailed modelling of energy sectors and the use of Marginal Abatement Costs Curves) developed by ENERDATA for the World Bank, indicate that the cost of achieving carbon emissions mitigation commitments can be drastically lowered under a scenario with full-fledged domestic and international carbon trading.

Cumulative Cost (2015-2030) *(Percent of GDP, vertical axis; Percent of GHG reduction, horizontal axis)*

Without carbon trading



With carbon trading



Source: Prepared by authors based scenario analysis using the EVALUATE model by ENERDATA for the World Bank 2016.

The cost of achieving universal energy access would be a fraction of the investment required for electricity infrastructure

As discussed in Chapter 5, around 84 million people in LAC do not have access to clean cooking fuels. They are concentrated in 5 countries (Mexico, Brazil, Guatemala, Peru and Haiti); and in urban, peri-urban, and rural areas. Haiti has the lowest percentage of the population with clean fuel access – less than 10%.

Access to clean fuels can be provided through access to LPG, which provides a clean cooking solution and avoids unsustainable use of biomass, and is particularly applicable in urban and semi-urban locations where the distribution infrastructure is in place, and where the benefits to air quality are particularly to be welcomed. In more rural areas biomass fuels

can be used in improved cook-stoves which have improved performance as far as emissions are concerned and which can half fuel use with environmental and social benefits.

The investment costs associated in providing these solutions – LPG to urban users and also to 1/3 of users in rural areas, and clean cook-stoves to other rural users - is estimated at USD 0.68 billion. There would also be an annual cost for LPG fuel which is estimated at around USD 138 million per year (Annex III describes the methodological considerations associated with this estimate).

Although good progress has been made in providing electricity access in LAC, with overall access rates of 97%, about 18 million people, the equivalent of the population of Chile, still have no access to electricity. Access to electricity can be provided by extending grid access (appropriate in urban and peri-urban situations) or by providing stand-alone electricity systems, for example using solar PV in individual systems or via separate mini-grids. The investment costs associated with providing access with combination of these solutions is estimated at USD 3.2 billion. The annual fuel cost of generating the additional electricity is estimated to be around USD 120 million (see Annex III for a detailed description of methodological considerations).

Notes

1. The preoccupation with stranded assets did not prosper in other network industries like telecoms with the arrival of mobile telephony. However, the stranded assets issue cannot be dismissed easily in energy, because it touches upon powerful interests beyond distribution companies. Stranded assets include both equipment and "unburnable carbon" reserves.

2. In the UK energy market, for example, Grubb (2015) contends that the government should compensate the wind generators for any difference between the social cost of carbon and the levy paid for CO2 emissions by fossil-fuelled generators. Grubb states that this is not a subsidy for wind investors, but a measure ensuring that wind generators gain the value agreed to reducing CO2 emissions.

3. These include Costa Rica (100 percent by 2021), Ecuador and Belize (85 percent by 2017), Honduras (80 percent by 2038), Bolivia (79 percent by 2030), Barbados (65 percent by 2030), Chile (60 percent by 2030, and 70 percent by 2050), and Mexico (37.7 percent by 2030, and 50 percent by 2050).

4. Under the IEA's definition, Latin America includes most of the LAC countries except for Mexico and Chile, which are included in the agency's America Region along with the United States and Canada.

5. The IEA also projects investment patterns for the Latin America region. The analysis for OECD North America and the United States allow an estimate to be made for Mexico and Chile by excluding the U.S. figures and making an allowance for Canada. Such an analysis suggests that the Latin America figures should be increased by about 25 percent to allow for Mexico and Chile.

6. These results combine LAC (as classified in the WEO), Chile and Mexico (which are included in OECD Americas).

7. The "zero emissions" scenario considers full penetration of renewable energy, a more fluid regional integration of power sectors, and optimal use of hydropower's storage capacity. However, there is no information in the study regarding the magnitude of the investment required to curve emissions from about 1,000 MtCO2e in 2050 to zero.

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CHAPTER 11

Financing Energy Infrastructure in LAC

Mobilizing private-sector money will be crucial to the success of future energy development strategies in LAC. Of all the region's infrastructure sectors, energy has been most successful so far in this regard, followed by transport and water. However, important challenges remain. Private sector investments have been subject to large fluctuations; they fall short of investment needs; their cost of funding is volatile as they are mostly denominated in U.S. dollars though revenues are in local currency; and their "bankability" relies heavily on guarantees or concessional financing from governments or development financial institutions. To date, private-sector financing has been concentrated in a few countries, mostly larger economies with deeper financial sectors, such as Brazil, Chile, and Mexico, and those that have reformed their power sectors.

The need for private-sector financing in local currency in the energy sector is even greater now as the public sector is facing fiscal constraints, aggravated by low growth in LAC, low commodity prices and weakening currencies. The shift in the energy sector paradigm as described in Chapter 9 will require increased private-sector participation with access to innovative and flexible financing options.

This chapter focuses on Public-Private Partnerships (PPP) as a potential standard framework to increase private sector financing for public infrastructure and attract more long-term local currency financing from domestic banks and capital markets. Private sector financing can also bring benefits such as innovation, higher efficiency, and shorter timelines in project implementation. The analysis explores challenges faced by PPP frameworks and financial markets in the region, as well as policy options to increase their role in financing energy infrastructure. The goal is to apply the new approach not only to traditional fields, most notably electricity generation, but also in distribution and new areas of growth such as energy efficiency and demand-side measures.[1]

The private sector's role in financing energy has been uneven over time and by geographical area

As we saw in the previous chapter, from 2014 to 2030, the IEA estimates that LAC demand for new energy infrastructure could amount to $3.6 trillion, with $1.3 trillion of that sum going to develop natural gas and electricity. Overall, investment in electricity and gas infrastructure has

been on the order of $36 billion per year on average for the 2000-2013 period, with the private sector contributing about 57 percent of that.

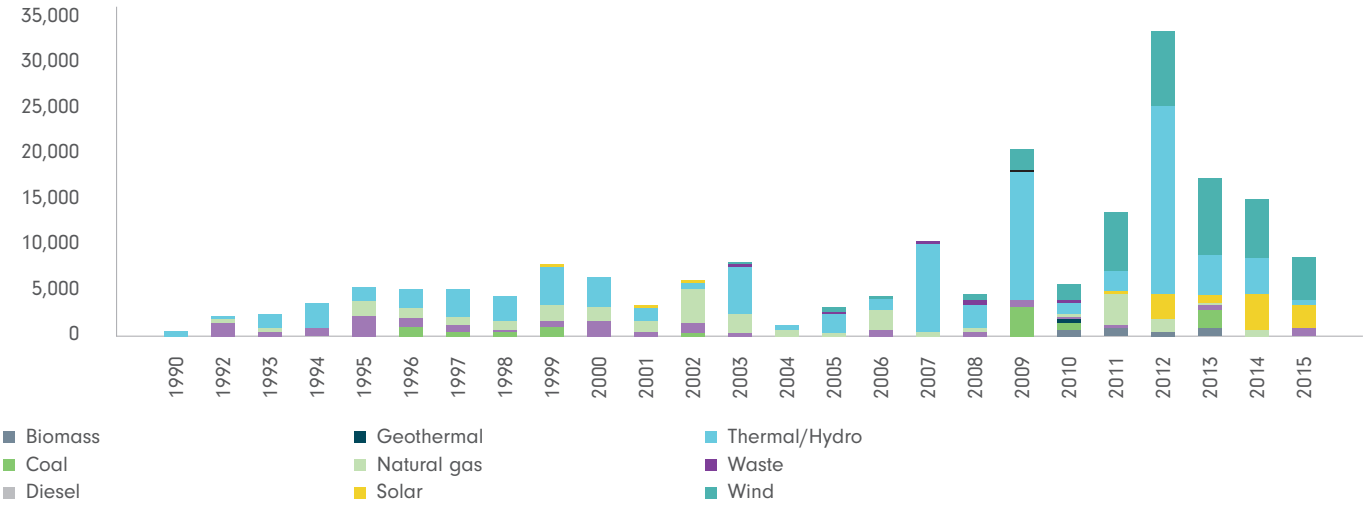
For electricity and natural gas combined, an estimated average annual investment gap of $36 billion is forecasted for the 2014-2030 period. To meet demand, LAC will need to increase annual investment in electricity generation by about 70 percent from historical levels, and at least double annual investments in both transmission and distribution and natural gas infrastructure.

Closing this gap—especially in transmission networks and gas infrastructure—will be crucial to the expansion of grid-connected large-scale renewable energy, continuous decarbonization of primary energy, and green economic growth.

Private financing of public energy infrastructure in LAC has been growing over time. However, as shown in Figure 2.7 of Chapter 2, its levels have fluctuated substantially over the past two decades. In the 2010-2015 period, energy PPPs mobilized more than $109 billion of investment in the LAC region, though it was unevenly skewed geographically and by sector. About 77 percent of investment took place in just three countries, Brazil, Chile, and Mexico.

It is interesting to observe that private-sector participation in electricity generation is increasingly targeting renewable energy; in the 2010-2015 period, 83 percent of the total, with a marked concentration in hydropower (38 percent) and wind generation (32 percent), and the rest in geothermal, solar, and other categories (Figure 11.1).[2] Also, 6 percent of total private investment in generation went to natural gas-based capacity. The fact that the greater share of private sector investments went to renewable energy is due to specific fiscal and financial incentives, as well as increased use of auctions in recent years to deploy such projects using long-term power purchase agreements (PPA).

FIGURE 11.1 Evolution of Private Investment in Electricity Generation (1992-2015) *(US $ million)*



Source: PPI (database).

Note: Thermal/hydro includes large and small hydropower as well combined hydropower and thermal plants.

PPP frameworks are common in LAC but need strengthening

Nineteen countries have now implemented PPP legislation (including 17 with some form of PPP unit), and many of these frameworks have been revised and improved as experience in the market grows. For example, Brazil, Chile, Colombia, Mexico, and Peru have recently revised their legal and/or policy frameworks to refine their strategies with respect to financial guarantees, unsolicited proposals, risk allocation, governance, project selection, the accounting and management of contingent liabilities, conflict resolution, and renegotiation.

LAC countries have also been moving toward more comprehensive financial management of PPP projects by the public sector, which is critical to ensure fiscal sustainability. Chile, Colombia, and Peru, for example, now evaluate and account for the fiscal commitments related to PPP projects. Peru has expanded business-case requirements to include ceilings on government financial commitments, whether funding or contingent liabilities. In Chile, the Ministry of Finance has developed a sophisticated model for valuing minimum revenue exchange rate guarantees. The state of São Paulo in Brazil has created the São Paulo Partnerships Corporation to provide and account for fiduciary guarantees to PPP projects. Moreover, new accounting standards for PPPs and concession arrangements such as IPSAS 32 are starting to come into use in the region.

According to the Infrascope index (EIU 2014), which measures a country's ability to mobilize private investment through PPPs, only Brazil, Chile, Colombia, and Jamaica have strong capacity (see matrix 2.1 in Chapter 2). However, other countries—especially those classified as emerging, such as Mexico, El Salvador, Honduras, and Uruguay—have a degree of maturity that can form a good starting point for developing solid PPP frameworks.[3]

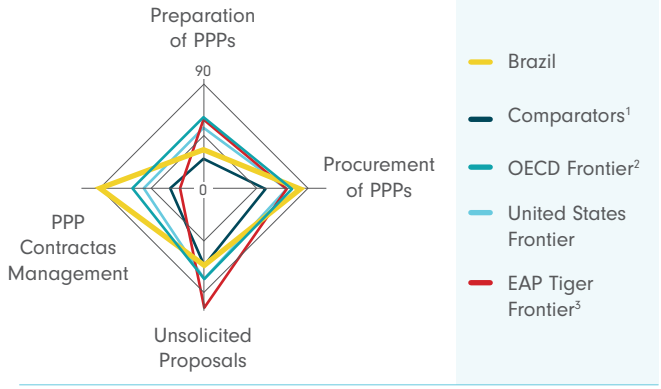
Since the first Infrascope benchmarking analysis in 2009, the scores for most countries have risen, with the average for the region improving by nearly 25 points between 2009 and 2017, from 33 to 59. Moreover, scores in each of five categories of the analysis have improved since 2009, which is very promising for the region. Despite recent improvements in PPP frameworks, challenges remain. In particular there is a lack of adequate project preparation to facilitate non-recourse project finance. In many countries, projects tend to begin procurement without adequate project preparation because of the constraints of the political cycle and a lack of internal capacity and budget (see matrix 11.1). The lack of information, particularly detailed engineering studies defining scope and performance specifications, increases the uncertainties associated with estimating construction costs and other risks that sponsors are being asked to assume (see box 11.1).

Poor quality of project preparation and a shallow pool of experienced domestic sponsors and financiers brings two main negative consequences. In some countries, the government takes on unusual levels of project risk, including construction risk, therefore reducing the "value-for-money" of PPPs. In other countries, the result is high incidence of scope changes and renegotiated contracts, which, in turn, has increased project costs and caused costly delays in reaching financial close and, ultimately, project delivery (see box 11.2). The length of delays common in LAC markets undermines the market's appeal to sponsors, investors, and lenders, particularly foreign ones that could bring competition and knowledge transfer to the PPP market.

Project financing, meanwhile, has been limited, but played a significant role in a few countries—Peru, Chile, and Panama—and in renewable energy (Figures 11.2 A and B).

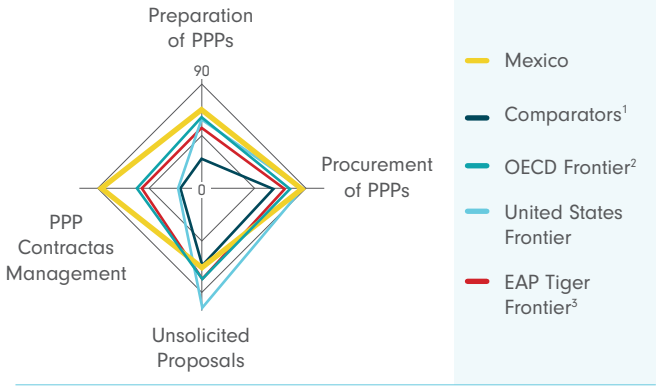
MATRIX 11.1 Benchmarking PPP Procurement: LAC Groups, Peers and Best Practice Frontier

Brazil



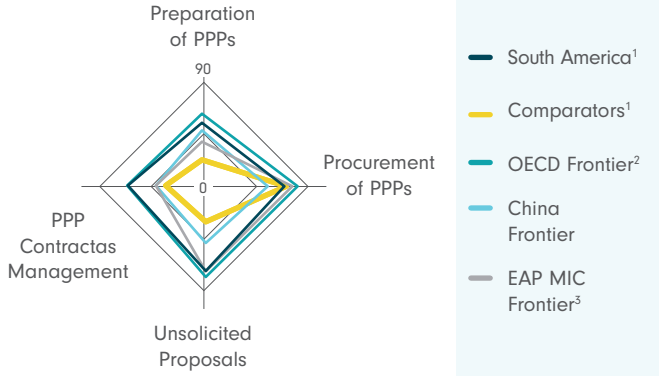
1. Comparators: China, Malaysia, Turkey, Romania and Thailand
2. OECD: Australia, Canada, Chile, France (PPP), Italy, Korea, Rep, Mexico, Poland, Portugal, Turkey, United Kingdom
3. EAP Tigers: China, Korea and Singapore

Mexico



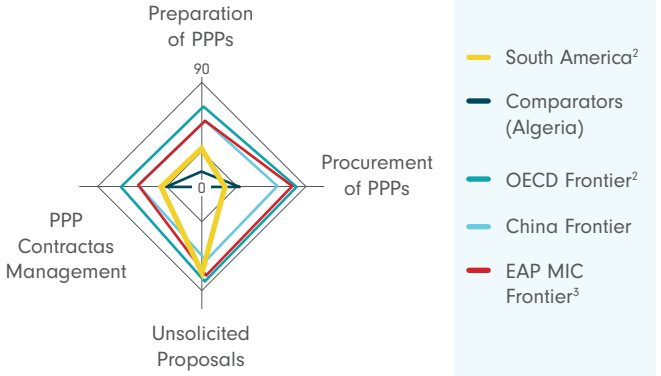
1. Comparators: China, Malaysia, Turkey, Romania and Thailand
2.OECD: Australia, Canada, Chile, France (PPP), Italy, Korea, Rep., Poland, Portugal, Turkey, United Kingdom
3. EAP Tigers: China, Korea and Singapore

South America 1



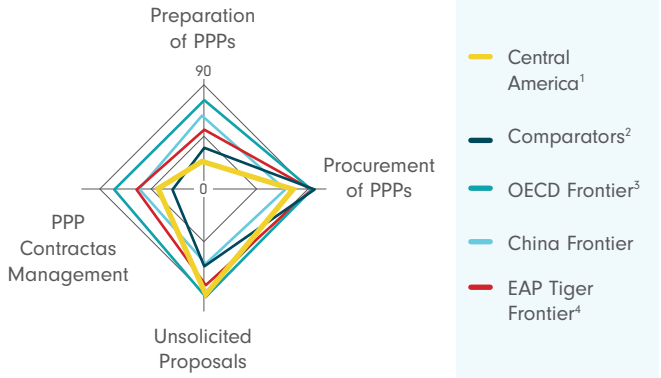
Countries in South America 1: Argentina, Chile, Colombia, Peru, Uruguay.
1. Comparators: Bulgaria, Romania, Poland, Turkey
2. OECD: Australia, Canada, Chile, France (PPP), Italy, Korea, Rep., Mexico, Poland, Portugal, Turkey, United Kingdom
3. EAP MICs: Indonesia, Philippines, and Thailand

South America 2



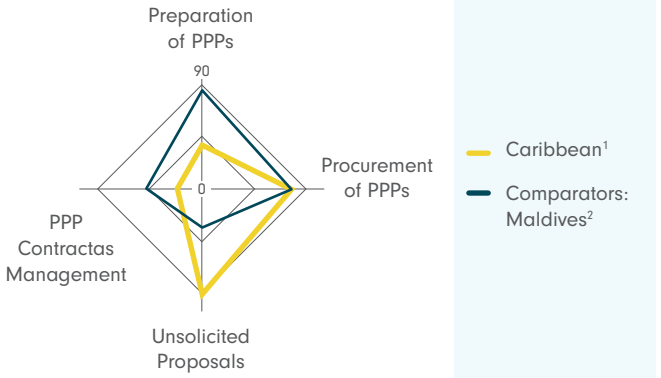
Countries in South America 2: Bolivia, Ecuador, Paraguay, Venezuela.
1. Comparators: Bulgaria, Romania, Poland, Turkey
2. OECD: Australia, Canada, Chile, France (PPP), Italy, Korea, Rep., Mexico, Poland, Portugal, Turkey, United Kingdom
3. EAP MICs: Indonesia, Philippines, and Thailand

Central America



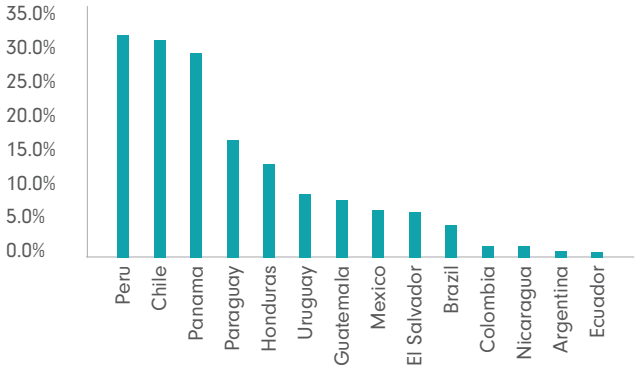
1. Central America: Costa Rica, Guatemala, Honduras, Nicaragua, Panama
2. Comparators: Armenia, Bosnia and H, Bulgaria, Sri Lanka
3. OECD: Australia, Canada, Chile, France (PPP), Italy, Korea, Rep., Mexico, Poland, Portugal, Turkey, United Kingdom
4. EAP MIC's: Indonesia, Malaysia, the Philippines, and Thailand

Caribbean



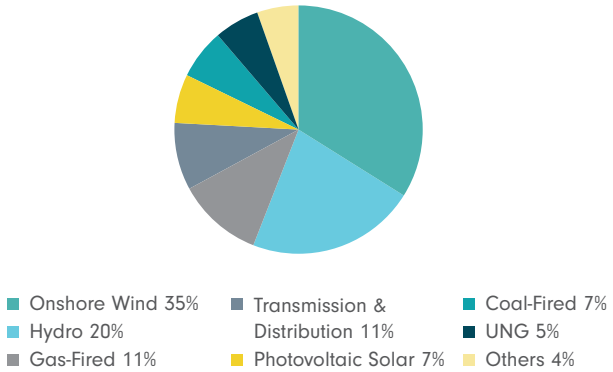
1. Caribbean: Dominican Republic and Jamaica
2. Comparators: Mauritius

FIGURE 11.2A Project Finance in Energy (9 year cumulative) (2014) *(Percent)*



Source: IJGlobal (database).

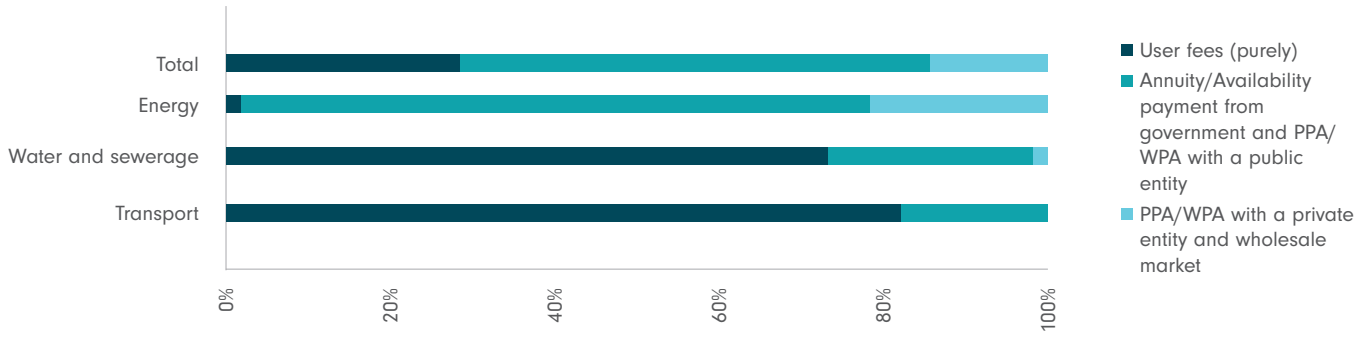
FIGURE 11.2B Energy Project Finance in LAC, by sector (2011-2016) *(Percent)*



In this context, direct and indirect government support continues to play a critical role in facilitating private sector investment in infrastructure projects in the region. Public authority expenditures and/or public user fees ultimately pay for infrastructure assets. Governments can directly support project funding through annual "availability" payments or upfront grants. Such support also serves to offset "viability gaps" in attracting private financing. In some cases, governments have provided indirect support through the use of guarantees to mitigate some risks, such as demand risk, termination risk, and exchange rate risk. Governments have also mitigated demand risks through flexible term concessions, granted according to the criteria of minimum net present value of revenues. Use of performance-based availability payments or other government obligations is also common in the region.

Projects in energy have been supported mainly by payment guarantees, in contrast to the transport sector, which has mainly used revenue and construction guarantees (Figure 11.3). The percentage of projects that require direct and indirect government support decreases with the maturity of the market.

FIGURE 11.3 Revenue Sources of PPP Infrastructure Projects by Sector (2010-2015) *(Percent)*



Source: PI (database).

BOX 11.1 SHORING UP THE INSTITUTIONAL FRAMEWORK FOR PROJECT BANKABILITY

Shortcomings in Procurement, PP contracts, and Risk Allocation

Procurement:

- Detail of information available to potential bidders is insufficient in most LAC projects.
- Timeline of the procurement process is too short to prepare quality bids.
- Level of interaction with bidders is low, which reduces quality of RFP.
- Prequalification criteria do not ensure best quality of bidders.
- Bidding criteria lack properly balanced technical and financial criteria.
- Competition rules discourage unsolicited proposals.

Contract and risks allocation:

- PPP framework and process result in greater risk and cost on the government side.
- Pre-construction risk has high sponsor exposure.
- Main contract risks have suboptimal allocations in such fields as construction, demand, E&S.
- Contracts lack standard project finance clauses and lenders security packages.
- High rates of renegotiation occur for contracts.

Key Policy recommendations:

- Heighten competition as the best way to increase construction of more and better infrastructure.
- Improve technical studies, which will be a powerful tool to increase competition and mitigate risks and reduce the time between commercial and financial close.
- Increase predictability and safety of investment, which will attract both international and national bidders.
- Create a robust institutional framework to send the right signals to the market.

Source: Neves et al. chapter 2 in Garcia-Kilroy and Rudolph 2017.

BOX 11.2 RENEGOTIATION OF PPP CONTRACTS IN LAC

The LAC region has a strong tradition of renegotiating PPP contracts. It is true that renegotiations can be unavoidable in long-term contracts such as PPPs, where many events cannot be predicted. But since it typically lacks competition and transparency, renegotiation carries many risks and opportunities for abuse and corruption and tends to increase project costs and reduce benefits. It also leads to an expectation of renegotiation in future deals and undermines the credibility of the whole PPP initiative.

After more than 25 years and more than 7,000 PPPs awarded in LAC countries, the incidence of renegotiation stands in the range of 50 to 80 percent. For example, Peru over the 1998-2012 period had a rate of 69

percent for all sectors. The average number of renegotiations for each concession/PPP contract was 2.3 times, according to Guasch 2015. Numbers like these reflect governments' general willingness to renegotiate a project rather than cancel it. (Less than 3 percent of PPP projects in LAC countries have been canceled). Still, the high frequency has led some countries (Chile, 2010; Colombia, 2011; Mexico, 2012; and Peru, 2008) to implement legislation to provide a framework and limit the negative impacts of renegotiation on governments and public authorities. Key elements of these "renegotiation platforms" include:

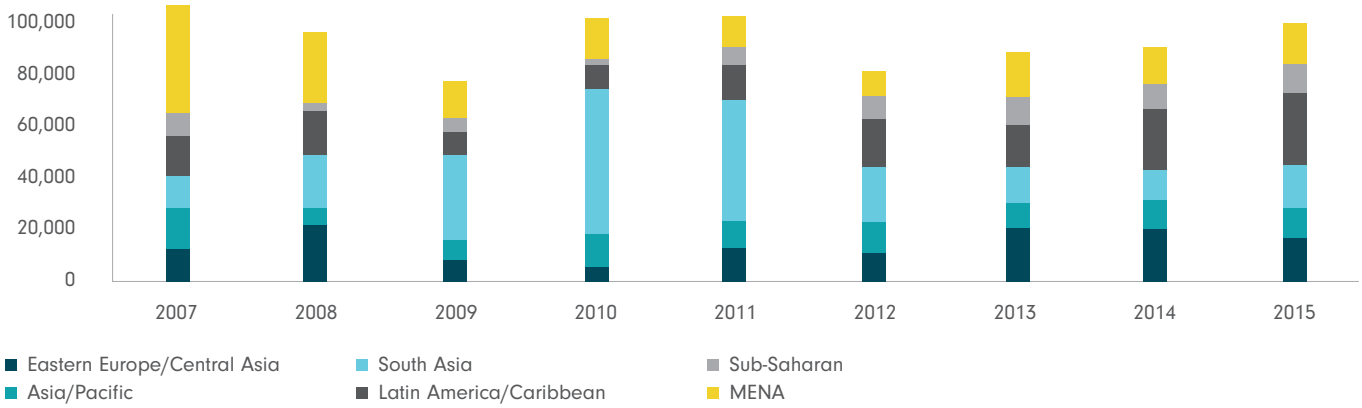
- Establishing by law or regulation that the matrix of risks allocation cannot be modified by renegotiation
- Requiring the winning sponsor to provide its financial model to the public authority
- Establishing in the procurement process the right to evaluate and reject overly aggressive bids (as defined by the difference between the highest bid and the second highest and the average bid), supported by instruments such as performance bonds that can be adjusted upwards as required
- Establishing a transparent framework of conflict resolution (including a panel of experts and arbitration) to deal with aggressive bidding, renegotiation requests, arbitration, and tariff setting

Source: Neves et al. chapter 2 in Garcia-Kilroy and Rudolph 2017.

International banks are the predominant source of financing of energy infrastructure in LAC

The 2008 financial crisis led commercial banks to sharply pull back from project finance, including infrastructure, both in advanced and emerging-market economies. However, in the LAC region, after a 42 percent drop in 2009, the project finance market had the strongest recovery among the emerging markets, doubling the region's pre-crisis market share of the global project finance market from 14 to 28 percent in 2005 (see Figure 11.4). As in other regions, international commercial banks have been the main suppliers of financing in infrastructure projects in LAC countries in the last five years.

FIGURE 11.4 Project Finance Loans, EMEs *(US $, millions)*



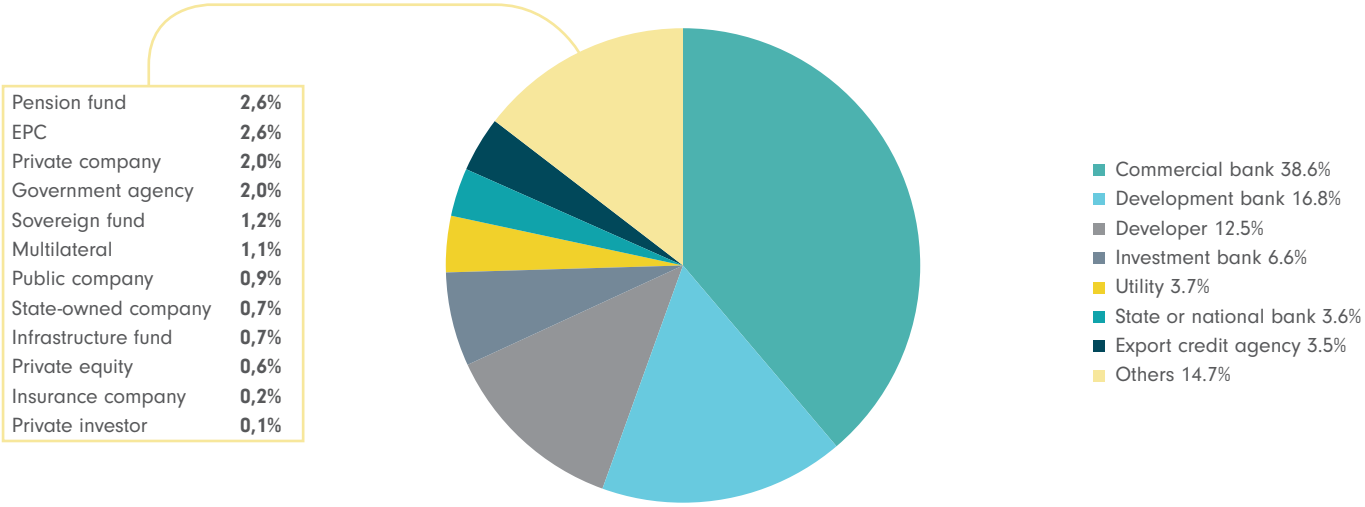
Source: IJGlobal (database).

After government agencies, banks remain the most important source of financing for infrastructure in both advanced and emerging economies. This is likely to continue, though complementary financing from capital markets will be needed particularly in longer-term financing. In the case of LAC, commercial banks represent more than 38 percent of total project financing, followed by about 16 percent provided by development finance institutions (see Figure 11.5).

Globally, the country of origin of lead banks had started to shift before the crisis and was reinforced after 2007. U.S. banks fell to a very small market share, whereas European (42 percent) and Japanese (25 percent) banks dominated in market share in 2015, followed by emerging market, Canadian, and Australian banks (see Table 11.1).

The LAC region has faced a similar structural shift in the composition of lead international banks, though with some differences. U.S. banks' share dropped by more than a quarter to less than 5 percent on average between 2013 and 2015, European banks kept a dominant market share at 48 percent, and Japanese banks almost doubled their share to 16 percent. European banks include not only Spanish and Portuguese institutions that have cultural affinities with the region, but ones from France, Germany, and other European countries. In addition, the share of LAC banks increased to an average of 28 percent, due largely to domestic and cross-regional financing from Brazilian and Colombian banks.

FIGURE 11.5 Suppliers of Capital to Infrastructure Projects in LAC (2011-2015) *(Percent)*



Source: Prepared by authors based on data from IJGlobal (database).

TABLE 11.1 Market Shares of Banks in Project Finance *(Percent)*

Market % of Top 10%	1997	2002	2007	2009	2014	2015
US	50.20%	18.80%	3.70%	0.00%	6.80%	4.20%
Canadian	0.00%	0.00%	0.00%	0.00%	6.90%	4.80%
European	49.80%	66.40%	75.90%	49.90%	41.60%	41.80%
Japanese	0.00%	11.60%	13.80%	12.40%	25.50%	24.50%
Australian	0.00%	3.10%	0.00%	4.90%	12.70%	4.30%
Developing Country	0.00%	0.00%	6.60%	32.80%	6.40%	20.30%
	100%	**100%**	**100%**	**100%**	**100%**	**100%**

Source: Thomson Reuters Project Finance International (PFI) (database).

Getting domestic banks to step up in project finance in LAC is vital on three accounts. First, domestic banks are essential to increasing the share of local currency financing of infrastructure projects and providing more stability in project finance by eliminating exchange risk. Second, domestic banks need to become competitive in project finance if LAC countries are to achieve the full benefits of PPPs. With the exception of Chile and Mexico, project finance has been scarce in the region. Third, with the right capabilities, LAC domestic banks could drive infrastructure finance in countries where international banks are reluctant (see box 11.3 for recommendations to strengthen the capacity of domestic banks).

However, domestic banks are only part of the solution. Only large domestic banks could have dedicated project finance operations, as is true in advanced economies, but they could be critical in attracting other sources of financing. Even if the project finance segment grows significantly, it is unlikely to represent a large share of banks' assets. In the case of international banks, project finance rarely constitutes more than 3 percent of assets. So even in the best scenario, domestic bank financing will fall short of LAC infrastructure needs. However, these banks could still have a central role in project structuring and financing certain segments of projects (such as tranches of the construction phase) that could attract financing from domestic and international institutional investors.

International banks have an important role to play both as providers of financing and in transferring project finance skills to domestic banks. However, they face three types of challenges to become more relevant in the region. First, they generally lend in hard currency, so they increase the project risk to the sponsor or government, unless the project generates hard currency revenues. One way to overcome this obstacle would be to facilitate local currency funding by international banks by allowing them to issue domestically or through local currency loans from a domestic DFI. Second, their flows can be affected by trends in the global bank market, which is beyond the control of the region's governments. Third, banks get involved in project finance mostly to follow their clients' demands. Therefore PPP programs need quality international sponsors.

Otherwise, even the large countries would have little hope for the virtuous circle of international banks creating competition and skills transfer to domestic banks, which in turn would help mobilize institutional investors.

In general, Basel III seems to have had only minor impact on the tenors of project financings globally. However, the additional capital that must now be allocated to long-term loans has increased their pricing. Already we see a trend toward shorter-term lending through "mini-perms," which reinforces the need to support longer-term financing through capital markets solutions.

BOX 11.3 STRENGTHENING THE CAPACITY OF DOMESTIC BANKS

If LAC's domestic banks are to fulfill their potential role in project financing, they will need policy reforms aimed at:

Strengthening the institutional and legal framework

- Promote proper legislation and practice regarding PPPs.
- Reduce political and regulatory risk.
- Provide trustable administrative and legal procedures.

Strengthening bank regulatory frameworks and supervision procedures

- Improve regulatory frameworks to facilitate engagement of banks in infrastructure financing, while preserving financial stability.
- Strengthen supervision procedures and train supervisors in project finance.

Generating a pipeline of bankable public infrastructure for project finance

- Design a medium/long-term infrastructure plan, with feasible timetables.
- Design infrastructure projects that are "financeable" with proper risk sharing among parties.
- Encourage banks to devise a capital increase plan according to the needs of infrastructure project finance.

Generating a proper environment for project finance

- Put in place practices and a track record regarding project finance.
- Promote project finance dissemination and training activities in the public and private sectors.
- Encourage international banks with experience in project finance to work in association with local ones.
- Promote participation of international construction companies in association with local ones.
- Involve development banks in project finance, assigning them functions not performed by commercial banks.
- Build frameworks to mitigate currency risk and lengthen tenors of local currency loans.

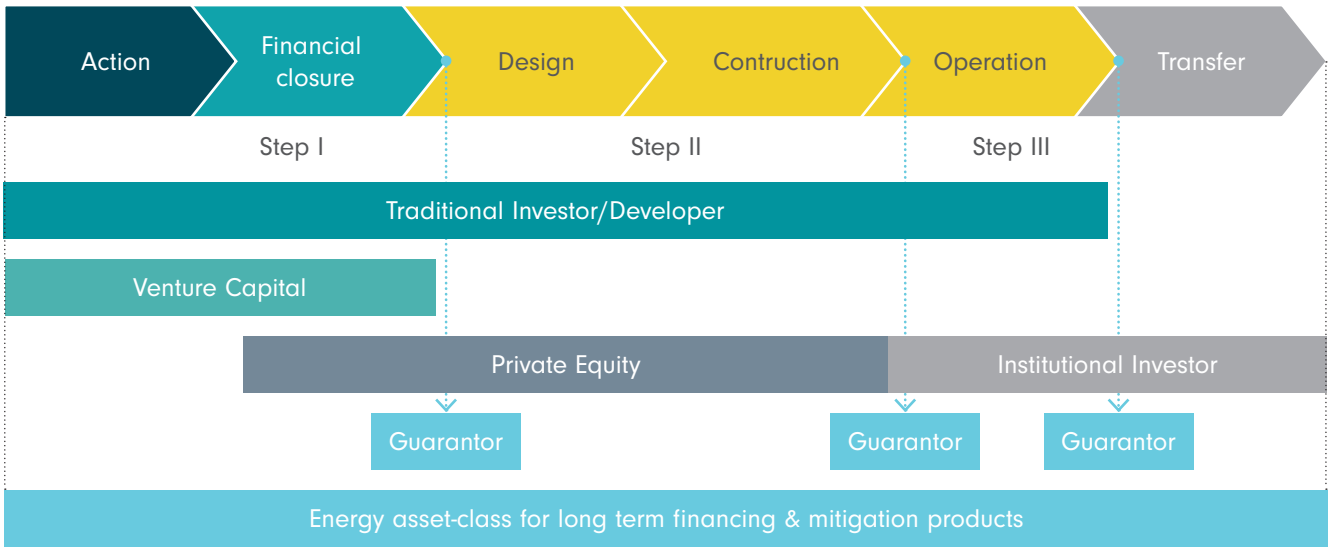
Source: Bolzico et al. chapter 2 in Garcia-Kilroy and Rudolph 2017.

As capital markets financing takes shape, a broad range of instruments is being tested

Since the 2008 financial crisis, governments have increasingly looked to institutional investors to assist in financing public infrastructure. The sheer size of financing needed to fill the "infrastructure gap" has outstripped the funds available from commercial banks and sponsors, which have in the past provided most private-sector financing. The role of institutional investors will probably grow substantially in the future. Globally, new instruments are under development to make infrastructure investments more attractive to institutional investors, and governments are modifying regulatory guidelines to draw in this critical group of financiers.

Yet long-term investors can only become complements, not substitutes, to traditional sources of financing from banks and sponsors. They can provide substantial volumes in long tenors in infrastructure projects, but only if they partner with banks and sponsors that have highly specialized knowledge in project finance and infrastructure, higher risk appetite, and capacity to manage it. This is particularly the case in the riskier construction phase of projects, in which more flexibility is also needed in reacting to events such as delays and cost overruns that may lead to debt restructuring. An example of the roles of different financiers in long-term financing and risk mitigation of energy asset classes is given in Figure 11.6. However, certain institutional investors are increasingly participating in the construction phase of projects in partnership with banks.

FIGURE 11.6 Turning Infrastructure into Asset Classes



Source: FGV-CERI for World Bank 2017; authors.

TABLE 11.2 Challenges in Financing Infrastructure with Capital Markets Instruments

Feature	Possible Solutions/Investor Trade-off
Low liquidity	Yield pick up
Low degree of instrument standardization	Hybrid structures
Voting rights in event of project contingencies	"Deemed consent" to special agent with thresholds
Controlling of disclosure regime	Third party agent
Unsuitability of disclosure regime	Creation of a special disclosure regime and role of credit ratings
Low degree of information standardization	Initiatives to standardize information disclosure
Higher than acceptable credit risk	Public and private sector risk mitigation
Lack of market for valuation	Valuation methodology as alternative asset
Lack of performance benchmarks	Development of benchmarks overtime

Source: Prepared by authors.

Another obstacle to greater participation by institutional investors in PPP infrastructure is that these assets are often misaligned with rules governing where these investors can put their money. The most important misalignments are the assets' low liquidity, low degree of standardization, lack of performance and valuation benchmarks, the need for partial drawdowns of funds in projects' construction phase, and a high probability of project contingencies that lead to renegotiation of project covenants. In most countries, institutional investors are required by law to invest only in listed instruments subject to mark-to-market valuation. See Table 11.2 for how these obstacles might be overcome.

Solutions for capital markets financing need to be flexible and open to a broad range of instruments that match project needs and the different risk-return profile of investors. Globally, there is a trend blurring the dividing line between banking and pure capital market instruments to finance infrastructure, particularly in greenfield projects. These hybrid instruments are able to address some of the challenges facing pure capital markets solutions. They allow banks to provide financing in shorter tenors and assume the function of controlling creditor, while institutional investors take the longer tenors and rely, in part, on banks' greater expertise in infrastructure finance. Projects in the less risky operation and maintenance phase with stable cash flows can be more easily financed with capital markets instruments only.

The challenge in the LAC region is to explore in a more systematic way the new vehicles and instruments. Those with the most promising results include project bonds, equity, and debt funds, though in some special cases direct investments may be the best option. Project bonds are gradually developing in the LAC region, although they are still facing the challenge of evolving into standardized structures and credit risk levels acceptable to a broader investor base (see Figure 11.7 for global share of project bonds). The availability of credit enhancement instruments provided by development banks or multilaterals is important in the initial stages of project bond innovations. Infrastructure debt funds are showing promising prospects in the LAC region to attract domestic investors and provide long-term financing along with banks, starting with the construction phase. Infrastructure equity funds are already present in the region but could be further developed to provide capital to domestic sponsors.

FIGURE 11.7 Project Bonds in Relation to Total Lending to Infrastructure (2006-2015) *(US$ billion)*

Source: IJGlobal (database).

Robust PPP and project finance frameworks are a critical precondition for the success of financing from capital markets. With some exceptions, as explained above, both frameworks have been missing across the LAC region. In their absence, financing infrastructure for capital markets instruments has been either sporadic or concentrated in offshore instruments or in structured government bonds that are fiscally unsustainable. Exceptions include Chilean project bonds insured by monolines until the start of the financial crisis, when monolines were downgraded and could no longer provide AAA ratings to project bonds, and Mexican local currency project bonds that have refinanced projects after the construction phase.

Only a small number of countries in the region can be expected to mobilize financing for infrastructure through capital markets in a systematic way. Prerequisites include the existence of long-term domestic institutional investors and a minimum depth of their government debt market providing price benchmarks. Additional conditions that would help include quality credit ratings agencies, a supportive framework for institutional investors from both issuers and investment regulators, and credit enhancement options to support the initial stages of capital market innovations (see box 11.4).

BOX 11.4 POLICY ELEMENTS FOR INFRASTRUCTURE FINANCING THROUGH CAPITAL MARKETS

Quality PPP and project finance frameworks are essential for infrastructure financing through capital markets. Liquidity is, however, not as important as regulators' flexibility towards financial innovations given the growing importance of unlisted instruments, restricted public offerings, infrastructure funds for equity and debt, and hybrid loan-bond solutions.

Policy should focus on establishing minimum thresholds for capital markets development that are supportive of infrastructure finance, including:

- Quality of price formation, through the long-term government bond yield curve and credit rating agencies
- Reliable indices tracking inflation for indexed-linked debt
- Flexibility in hybrid offering regimes for professional investors
- Incentives for participation by foreign investors, who are the main source of long-term maturities and knowledge transfer

Availability of credit risk enhancement from national development banks and multilateral banks is critical for both domestic and international investors.

Source: Garcia-Kilroy et al. chapter 4 in Garcia-Kilroy and Rudolph 2017.

Pension funds can play a vital role, but mobilizing these resources in LAC will be difficult

The region's pension funds remain highly invested in government securities and bank deposits. Although the lack of diversification is partially due to lack of financial instruments, regulations tend to bias pension funds toward shorter-term securities.

Defined contribution open pension funds are the predominant pension fund model in the LAC region. These systems exist in Chile, Colombia, the Dominican Republic, El Salvador, Mexico, Peru, and Uruguay (see Table 11.3). Contributions are mandatory for all dependent employees. The funds are managed by pension fund management companies (PFMCs), which the employee can shift at any time. Legislation in most of the countries allow PFMCs to offer different pension portfolios (multifunds). In the defined contribution pension system, pensions are calculated as a function of the value of the assets accumulated up to that point. With the exception of Chile, which has a developed annuity market, retirement options in the rest of the countries are still under consideration, including in Peru, which recently allowed contributors to withdraw a large majority of their savings at retirement age.

Defined contribution pension funds are not necessarily long-term investors, and neither are they natural buyers of infrastructure bonds. This is largely because regulatory incentives promote competition on short-term returns and discourage assuming liabilities.

Chile has been something of an exception. There, the depth of the long-term sovereign bond market and the strong long-term demand from annuity companies encouraged pension funds to invest in infrastructure bonds. In the absence of an annuity market, defined contribution pension funds in the rest of the LAC region have not been active in buying long-term infrastructure bonds.

Regulatory amendments may help to align the investments of defined contribution pension funds with the long-term objectives of contributors. In the absence of long-term liability for pension funds, countries may consider modifications in the investment regulation of the mandatory pension funds, by introducing a minimum duration in the fixed income portfolio. This regulation would need to align with the available supply of instruments in a way that would avoid distortions in the yield curve structure. Alternatively, the regulatory framework may consider use of long-term portfolio benchmarks for pension funds that takes into consideration the contributors' long-term objectives.

The development of annuity markets is a key step in engaging pension funds in long-term investments, including infrastructure. Since they manage long-term liabilities that are indexed to inflation, annuity providers are strong supporters of inflation-linked infrastructure bonds. By creating demand in the long end of the yield curve, they also incentivize participation of direct contribution pension funds that may try to compete in those maturities, provided they have freedom to sell the assets if conditions change. Since open pension funds tend to herd in their investment behavior, the presence of other institutional investors with different risk appetites reduces the risk of investing in long-term assets.

While defined benefit pension funds are also supporters of infrastructure bonds, most of the existing plans are gradually reducing the term of their liabilities. Brazil has a large number of defined contribution funds, but more than 80 percent of the funds are in defined benefit schemes. Since they face a long-term liability, defined benefit schemes are potentially strong supporters of infrastructure investments. To the extent that these funds are not open to new entrants, and their liabilities are shortening over time, their appetite for investing in long-term bonds is gradually decreasing.

FIGURE 11.8 Assets under Management Pension Funds in Latin America (2014) *(US$ million)*

Country	US$ million	% of GDP	Country	US$ million	% of GDP
Brazil	$ 250,528	12	**Uruguay**	$ 10,957	21
Mexico	$ 181,881	16	**El Salvador**	$ 7,993	32
Chile	$ 165,432	68	**Dominican Republic**	$ 6,892	11
Colombia	$ 63,742	20	**Costa Rica**	$ 5,846	12
Peru	$ 38,360	20	**Panama**	$ 384	1

Source: Prepared by authors based on data from national central banks and statistical institutes.

For institutional investors to go in for infrastructure financing, it is essential that instruments have acceptable risk-sharing arrangements. The contractual arrangement should specify the type of risks that bondholders are willing to take. Pension funds typically are not comfortable with engaging in the construction phase, and are unlikely to take demand risk in infrastructure projects. Standardization of contracts would facilitate the engagement of pension funds in multiple projects.

In addition, investments through intermediaries, such as investment funds, may increase the capacity of institutional investors to monitor the projects. By pooling resources through a collective undertaking, pension funds may also increase their exposure to infrastructure. However, it is essential to have in place a collective undertaking agreement in which the responsibilities of the general partners are properly defined.

BOX 11.5 POLICY RECOMMENDATIONS TO ATTRACT PENSION FUNDS

Why are defined contribution open pension funds reluctant to invest in energy projects?

- Regulatory framework does not necessarily encourage long-term investments.
- Pension funds compete on short-term performance.
- Mark-to-market valuation is required.
- Minority stakeholders have scarce incentives to evaluate complex projects.

Policy recommendations

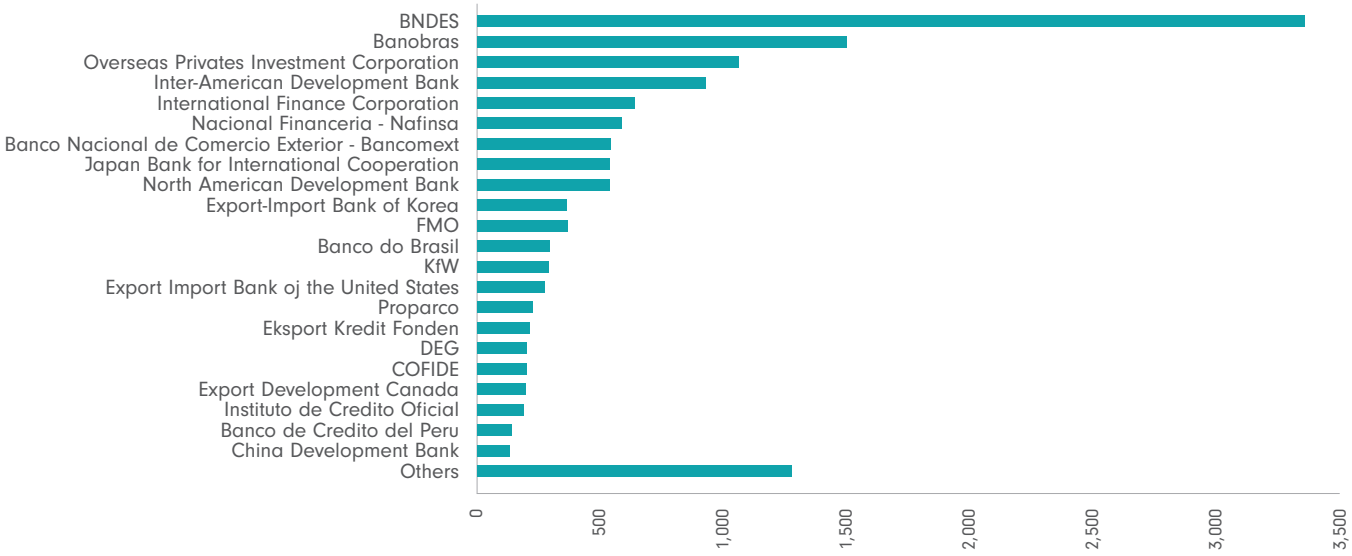
- Concerning investments through intermediaries, ensure transparency of transaction, limit conflicts of interest, and help funds use other financial sector entities to monitor performance of projects.
- Require regulatory framework to impose minimum duration on the fixed income or promote the use of long-term portfolio benchmarks.
- Develop an annuity market that can increase the demand for infrastructure bonds.

Source: Rudolph chapter 5 in Garcia-Kilroy and Rudolph 2017.

Development financial institutions have an important role in infrastructure projects

Public sector financial institutions and multilateral development banks contributed 27 percent to total PPP financing in LAC's energy sector between 2011 and 2015 (Figure 11.7). These lenders, known collectively as development financial institutions (DFIs), take many forms—national development banks, export credit agencies, multilateral developments banks, and infrastructure financing facilities—and have different mandates and governance structures, resulting in diverse strategies for energy infrastructure development in the region.

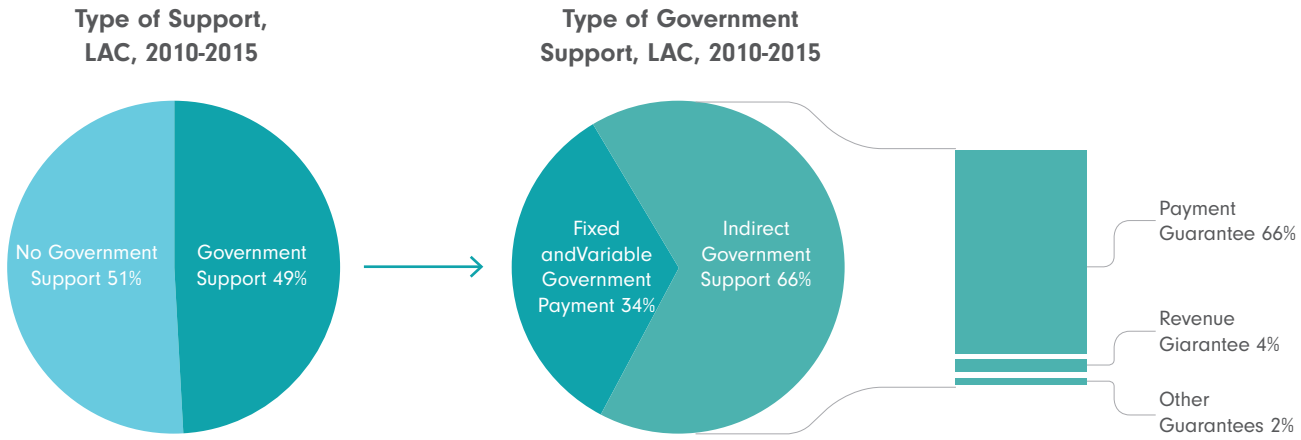
FIGURE 11.9 Public Support to Energy Project Finance in LAC (2011-2016) *(US$ million)*



Source: IJGlobal (database).

Half of projects in electricity and natural gas infrastructure received some type of government support in the 2010-2015 period (Figure 11.8). Backstopping obligations was the most common type of government support. Among infrastructure sectors, energy had the highest volume of payment guarantees.

FIGURE 11.10 Government Support in LAC *(Percent)*



Source: PPI (database).

DFIs can play a supplementary role in infrastructure financing. Their role is particularly valuable in two types of circumstances: as pure financing interventions to address financial market failures, and to deploy their expertise to support PPP authorities to improve the quality of project preparation. In this way, DFIs can have a catalytic role in "crowding in" private-sector finance in LAC countries while PPP and financial sector reforms are being implemented.

Here are some market failure situations in which development finance institutions can be catalytic in infrastructure financing:

1. **Lack of relevant expertise in the domestic financial sector.** The financial sector in most LAC countries lacks the expertise required for typical project finance structures, with no recourse to the sponsor´s balance sheet. DFIs can step in to provide technical capacity to banks and other private financial institutions.

2. **Lack of size, depth, and sophistication in the domestic financial sector.** This reduces the ability to offer long-term financing tenors. DFIs can support the provision of long-term financing through such means as second-tier long-term lending to banks, long-term loans complementing banks' shorter-term loans, and partial guarantees crowding in institutional investors.

3. **High project risk due to asymmetric information in early or revised phases of the PPP implementation.** Some Latin American countries have been developing PPP frameworks for two decades or longer, but many of these programs have failed to attract private-sector financing or have created losses among private financiers. Support from DFIs may help to reinforce credibility of PPP programs.

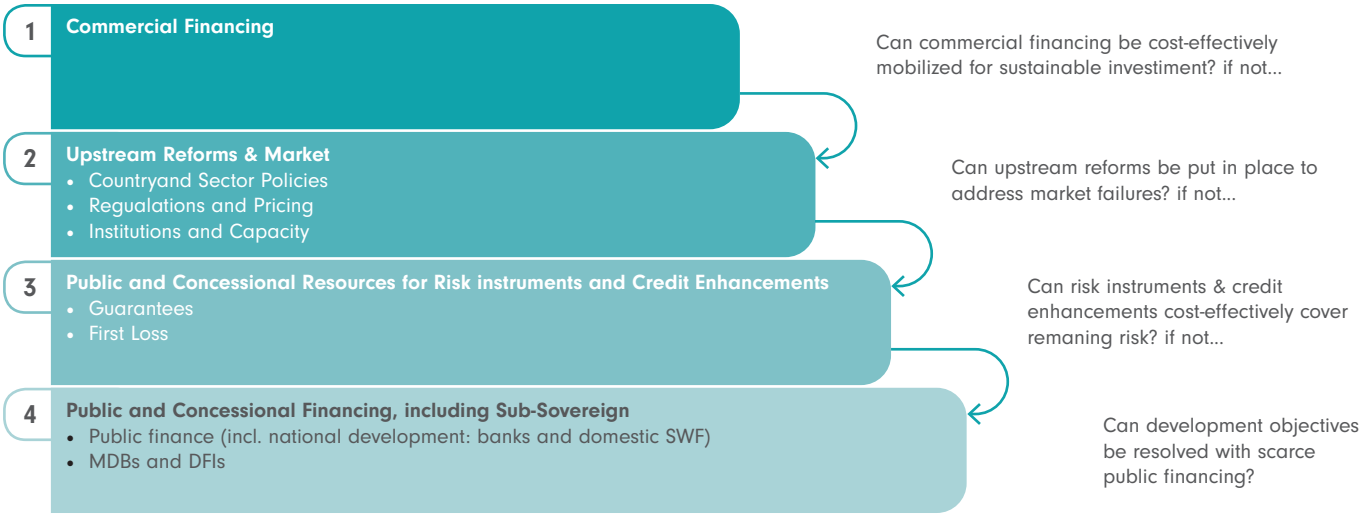
4. **Counterparty risk from central or subnational governments with low credit ratings.** Although larger countries in the LAC investment-grade credit ratings have counterparty risks that are typically manageable for investors, some of the smaller economies with credit ratings below investment grade and shallow financial markets may find it difficult to attract international investors to their PPP projects. DFIs can be instrumental in supporting early stages of PPP framework implementation, by providing partial guarantees while the PPP framework is tested and consolidated.

5. **Lack of preparedness by the local concessionary companies.** This is a common issue in the LAC region. By providing technical expertise through strategic partners and fostering private capital in infrastructure, DFIs can help prepare local concessionary companies for competitive biddings. This is especially important where participation by foreign sponsors is small.

6. **Lack of a long-term currency hedge market.** Currency risk is one of the most hazardous aspects of project financing. Since local financial sectors might be unable to finance extensive PPP programs, they might need participation by foreign financial institutions. On the debt side, foreign financiers are often reluctant to finance projects that generate revenue in local currency, particularly in smaller markets. Countries with more-developed capital markets, such as Chile, may encourage foreign banks to take part if they can issue long-term debt in local currency. Although the alternative of passing currency risk is limited, DFIs and a government's treasury might need to provide transitional support to address foreign exchange risks while markets mature.

A decision-making framework to ensure the judicious use of scarce public and concessional finance has been recently proposed by the World Bank (2017), and summarized here below.

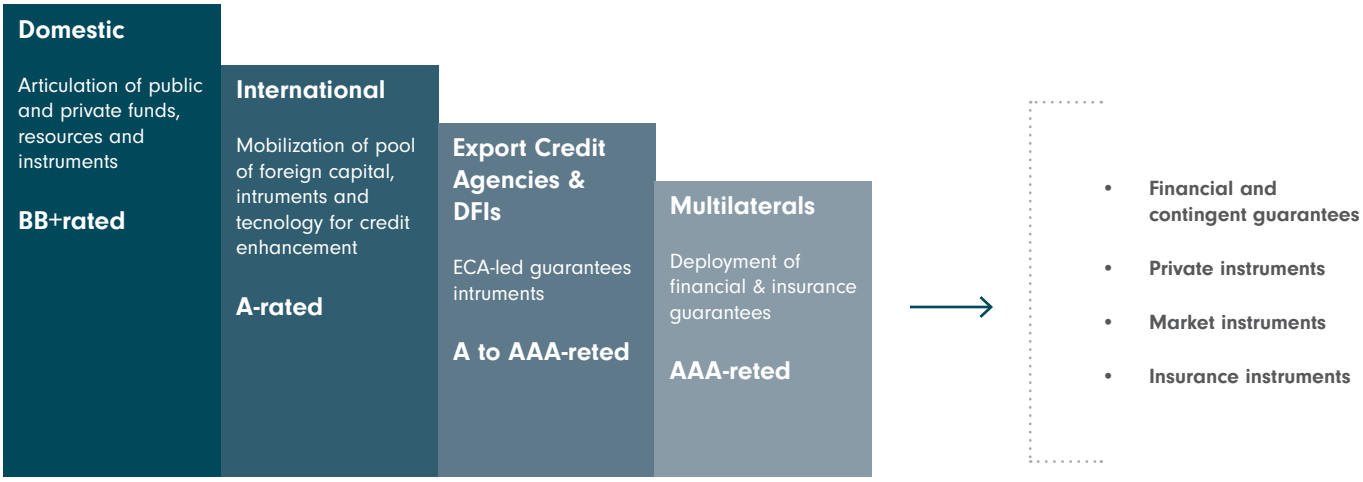
FIGURE 11.11 Cascade Approach for Infrastructure Financing



Source: PPI (database).

Thus, an approach to energy infrastructure financing could take the following form (Figure 11.9).

FIGURE 11.12 Concept Architecture for Energy Infrastructure Financing



Source: FGV-CERI for World Bank 2017; authors.

Notes

1. This chapter is largely based on Garcia-Kilroy and Rudolph 2017.

2. Calculations based on PPI data.

3. Infrascope is an informational tool and benchmarking index that assesses the capacity of countries in Latin America and the Caribbean to carry out sustainable public private partnerships (PPPs) in infrastructure. This is not intended for and should not be used for making investment decisions or drawing inferences on the overall competitiveness and economic performance of a country. The tool provides a context for PPP capacity only and does not reflect the enabling environment for infrastructure investment in general. Other options are available for infrastructure besides the modality of PPPs.

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4

SECTION 4

Towards the Next Frontier

Section 1 looked at regional energy trends and examined how LAC's energy markets have evolved over the last few decades. It considered differences among countries and intraregional patterns, and established a distance to best practice frontiers.

The analysis shows that the region has made great strides in developing a relatively low carbon energy system and has put several sophisticated market structures in place. However, energy use and economic development are strongly linked, and parts of the region still rely heavily on imported fossil fuels.

In terms of quality of service and security of energy supply, many LAC countries still lag behind their world competitors. And the region's regulatory frameworks and businesses are not yet fully adapted to using clean energy resources and delivering energy efficiently. In addition, energy poverty continues to be a challenge in rural and peri-urban areas.

Section 2 described emerging disruptions and discussed the new risks the region is confronting, particularly on the climate change front. It also examined emerging technologies and practices with the potential to transform the traditional service delivery model, reshape the stakeholder landscape, and redefine the way in which government agencies and customers engage with energy markets. The analysis compared traditional and emerging market architectures, and delved into the political economy of the approaching disruption.

Section 3 discussed future energy infrastructure development scenarios and the investment associated with different paths. The analysis of public and private investment and the forecasting of investment needs make it clear that governments in the region will not be able to shoulder future energy infrastructure investment needs alone, and that mobilizing private financing continues to be critical. The analysis emphasized that unlocking the potential of demand-side participation could substantially lower future investment needs, so the expected disruption—despite adding complexity and in some cases political opposition—can in the end bring substantial benefits. The analysis also looked at patterns of energy infrastructure financing and discussed new financial concepts and innovations.

This section, concludes with a brief discussion of the key challenges and the measures necessary to move in the direction of increased technical and economic efficiency, approach best practice frontiers, and improve public spending.

Key message

The key message emerging from Section 4 is that LAC is uniquely positioned to embrace and lead the transformation given its high energy demand growth rates, abundant indigenous resources and pioneering culture, but new measures need to be adopted:

1

PLANNING STRATEGICALLY.

A new approach to planning and decision making (one that considers the full menu of supply and demand side resources, consumer behavior and multi-sectorial dynamics) can significantly reduce public expenditures, avoid stranded assets and increase efficiency across the value chain. Factoring in new sources of risk is vital to a sustainable and resilient energy infrastructure.

2

IMPLEMENTING NEXT GENERATION MARKETS.

Embracing innovation is critical for transforming markets and moving towards higher efficiency frontiers. LAC countries will need to systematically adopt—or enhance existing—policies, regulations, market design features, organizational structures, and processes to support the entrance of new and smart solutions. It will also be important to enhance electricity trade in existing cross-border interconnections and consider new integration where politically feasible.

3

CREATING SMART ENERGY CITIES.

City governments could also play a key role in "smarting up" the energy infrastructure and growing the clean energy economy via specific incentives and investment. Distributed energy markets will in fact evolve in the city context and enhance the resilience, sustainability and efficiency of multiple sectors (mobility, water and wastewater services, etc.).

4

STRENGTHENING GOVERNANCE.

All these steps would require strong (sector and corporate) governance, agile decision making, clear and mutually complementary public and private sector roles, and a solid enabling environment for private investment.

CHAPTER 12

Addressing Energy Sector Challenges

Planning strategically can bring increased efficiency and climate resilience

A new approach to planning and decision-making can significantly reduce public expenditures and avoid both inefficiency across the value chain and stranded assets. Factoring in new sources of risk, especially those associated with climate change, is also vital to a sustainable and resilient energy infrastructure.

Understanding potential disruptions is important for planning new capacity additions, especially if the power system is becoming more distributed and dynamics are shifting to the demand side. Concerning electricity, policy makers and regulators could effectively use transitional rules to avoid stranded assets caused by defection from the grid.

One of the most important constraints of traditional least-cost investment modelling tools (which use non-linear stochastics approaches) is that they are solely based on optimization of supply side interventions. Policy makers have lacked planning tools or algorithms that simulate demand side and consumer behavior, that is, an elastic or more responsive demand. But that is changing. Today they have access to new and expanded modelling tools that account for the integration of demand side resources. These will become increasingly important as new ICT and clean energy technologies—including cloud and data services, power storage in distributed energy applications, and electric vehicles—penetrate the markets and prosumers emerge as active market participants.

The use of Integrated Resource Planning (IRP) modelling tools can also be effective for constructing scenarios that consider supply and distributed or demand side resources, as well as multiple sectors, such as nexus energy and water, or energy and transport. Other modelling approaches such as System Dynamics (SD) simulate complex systems to gain a mid- or long-term foresight of game-changing factors or disruptions that are approaching. SD tools can be used, for instance, to model the impact of regulatory measures on wholesale prices and investment decisions considering the strategic behavior of multiple agents (box 13.1).

BOX 12.1: Using System Dynamics to Gain Mid-to-Long-Term Foresight of Technology Disruption

System Dynamics (SD) is an approach based on theories of nonlinear dynamics and feedback control. It is used to represent and understand the structure and dynamics of complex systems.

SD models have been particularly useful in simulating the impact of technology transformation, new types of regulatory mechanisms (or the interaction among various policies), investment under uncertainty, and the behavior of participants in the context of a power system or market. Recently, SD tools have been used to simulate the effect of rapid technology transformation (a disruptive change) on incumbent electric utilities, so as to obtain mid-to-long term foresight of the sector. The National University of Colombia is using this approach to simulate technology disruption, the effect of intense solar PV deployment policies of power systems in Colombia, Brazil, and Argentina.

Figure A. Dynamic Hypothesis of Electricity Markets

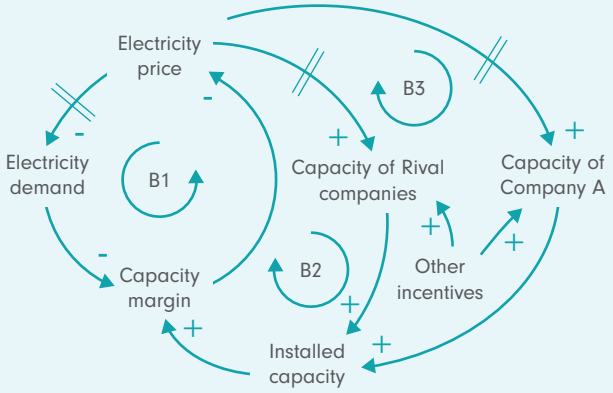


Figure B. Utility Death Spiral

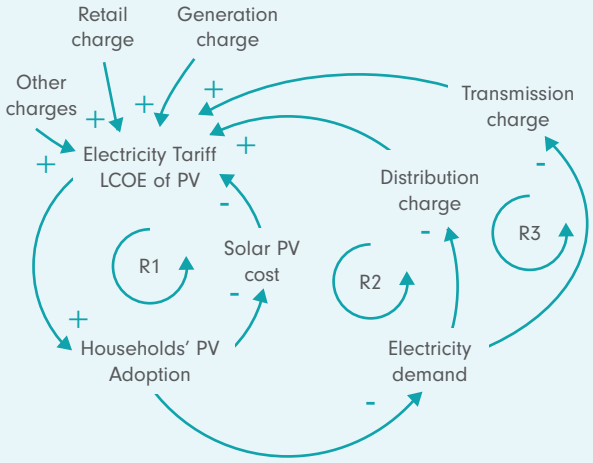
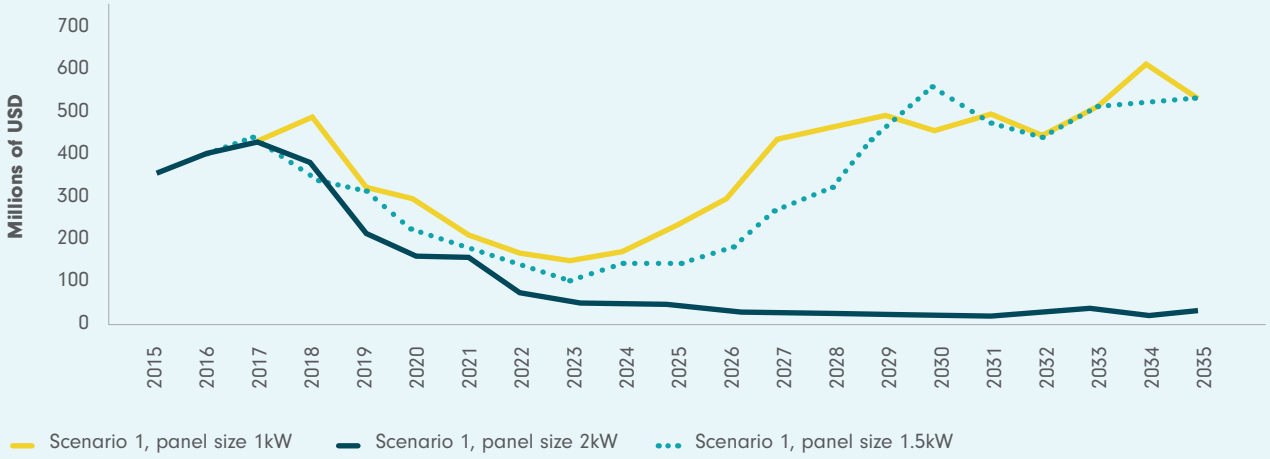


Figure C. Profitability of Incumbent Utility Under Different Scenarios of PV Penetration and Size



Source: Castaneda et al. (forthcoming).

Understanding consumer behavior and modelling demand-side resources and dynamics is thus critical to long-term energy infrastructure planning (as illustrated in box 10.3, Chapter 10). Today it is imperative for policy makers to keep informed of emerging innovations and consider them in possible future scenarios to establish an agile foresight and avoid technology lock-in. Adaptation to climate change will also require better long-term planning for resilient infrastructure and emergency response. On this front, *non-probabilistic decision making under uncertainty* methodologies can become extremely useful.[1]

Embracing innovation is critical for transforming markets and moving towards efficient frontiers

LAC countries will need to systematically adopt—or enhance existing—policies, regulations, market design features, organizational structures, and processes to embrace innovation and support the entrance of new and smart solutions.

The new technologies described in Chapter 9 have the potential to significantly increase efficiency and reduce investment needs for energy infrastructure. Therefore, it is critical that policy makers and regulators foresee and factor in these options in the creation of alternative development paths.

Central to energy infrastructure development is understanding and facilitating the uptake of exponential technologies that will help address the big challenges of the region: poverty, shared prosperity, climate change, and big cities. However, technology alone will not produce a paradigm shift. Moving closer to high efficiency frontiers will require political commitment, strong governance, capable institutions, a new way of planning, and appropriate legal and regulatory frameworks.

A real transformation of energy systems will come both through gradual steps and leap-frogging. Either way, reaching the desired future will require a vision, strategic planning, and a new willingness of organizations to embrace change.

In terms of the complexity and performance of energy systems, this report has shown that there is significant variation within LAC. There is a group of countries that still need to focus on enhancing basic pre-conditions for a modern energy or electricity system, including introducing cost-reflective pricing, minimizing energy subsidies or making them "smart," and strengthening the institutional capacity and managerial efficiency of electric utilities (matrix 12.1). At the other end of the spectrum of performance are LAC countries that have pressed forward assertively on governance, energy pricing, procurement, and quality of service, and have adopted aggressive clean energy goals. These countries are better placed to make a faster transformation through adoption of clean and smart technologies and are better equipped to accommodate and benefit from the so-called disruptive technologies.

MATRIX 12.1 Path to Transformation: Indicative Actions

	Step 1. Overhaul	Step 2. Catch Up	Step 3. Transform
Country Readiness	Countries with heavy energy subsidies, oil dependent (1)	Countries with cost-reflective tariffs that need to increase efficiency (2)	countries with aggressive clean energy DG agendas (3)
Governance	Incentive regulation and subsidy reform	Regulatory streamining	Regulation favoring innovation
Market architecture	Accountable, conventional supply	Intraday, zonal and dynamic pricing, innovation pilots	Transactive model, Smart City platform
Technology and Climate	Move to natural gas generation and renewable Demand side management / energy efficiency	Smart metering and grids, move to renewable and natural gas generation, demand side management / energy efficiency	Full digitalization, storage
Financial Markets	Guarantee products	Innovative risk mitigating structures New energy asset classes	Innovative risk mitigating structures New energy asset classes

(1) Haiti, Honduras, Nicaragua, Guatemala, Dominican Republic, Ecuador, Bolivia, Venezuela

(2) Argentina, Peru, Panama, Colombia, Paraguay

(3) Mexico, Brazil, Chile, and centralized systems with aggressive clean energy agendas (Costa Rica, Uruguay)

Source: Prepared by authors.

Stronger governance is key to efficient energy services

While the specifics vary considerably, enhancing governance is a challenge that all LAC countries share. The task is to develop energy sectors where the roles of all public and private actors are clearly defined and mutually complementary, institutions are held accountable for performance, and a solid enabling environment attracts long-term financing and private investment.

Strong governance also means that policy, regulation, and PPP contract design are coherent and transparent. Ultimately, governance determines to a large extent the degree of private sector participation, and the cost and nature of financing. Strong governance is also critical to avoiding the high incidence of contract renegotiation, an issue of particular concern in the region.

Concerning state enterprises, good governance entails a clear role for the state as owner, regulator, and policy formulator; a level playing field for public and private agents to avoid distortions and inefficiencies; explicit legal mandates that regulate the provision of

public service obligations; clear and equitable rules for all stakeholders (including small investors); and corporate autonomy and accountability.

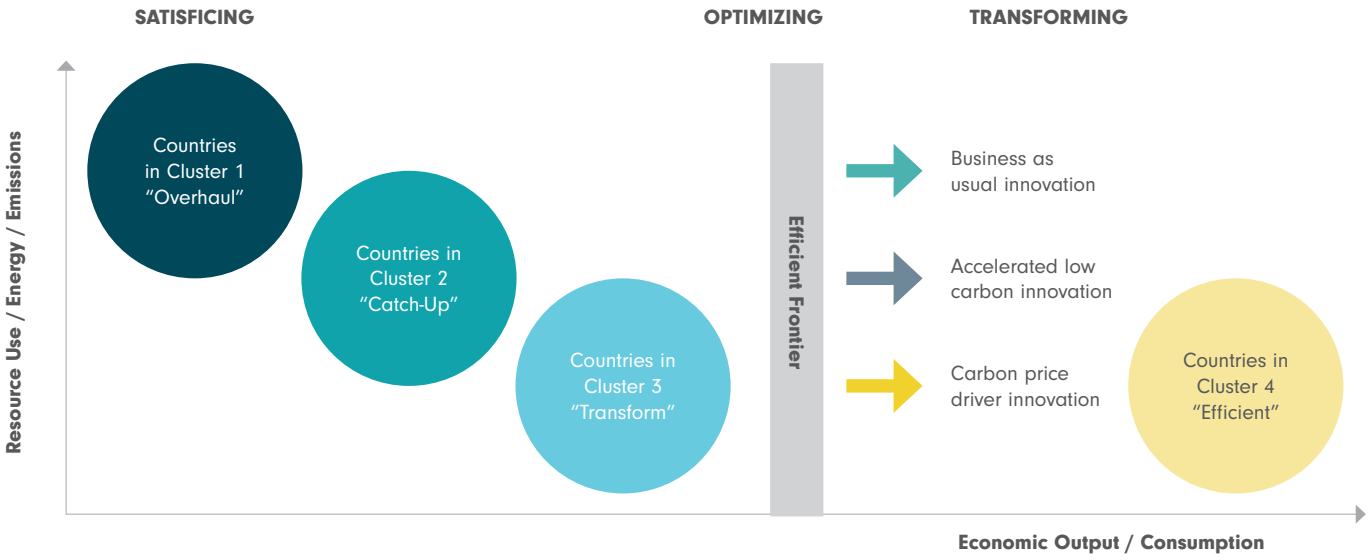
One aspect of good governance that needs special emphasis in these times of rapid change is "institutional agility."

For now, the utility industry has a base of heavy assets that amplify the forces of inertia. Policy makers and regulators too often are slow in adjusting to technology change and innovation on the business side and thus delay efficiency gains. But the new emerging players—such as digital and distributed generation companies—are agile by nature. The efficiency frontier moves very fast.

This means that, moving forward, policy makers and regulators need to become more attuned to technology changes and foreseeable disruptions. They can gather information, allow experimentation and pilots, and reallocate resources. They can promote analysis and collaboration, create networks for the sharing of knowledge and skills, understand consumer behavior, and foster partnerships.

All of these actions add up to institutional agility. It is not enough for a country to be in a stable or "satisficing" stage, trying just to keep up with demand for energy for growing economy. It must move towards an efficient or best practice frontier (Figure 12.1). This will entail using less energy for the same or higher economic output. Approaching the best practice frontier requires also a deep understanding of behavioral and organizational economics, and an emphasis on efficiency in all segments of the supply chain. Today, agile institutions are those that know what kind of transformation they want to lead, and what route, policy tools, and strategic investment will take them there.

FIGURE12.1 Energy Use vs. Economic Output in Three Domains



Sources: Adapted from Grubb 2015.

LAC should create smart energy cities

Transforming cities to provide citizens with high-quality services and clean ecosystems is one of the biggest challenges facing the region, as discussed in Chapter 8.

This will require multi-sectorial approaches to craft strategies that bring integrated solutions to such goals as reducing pollution, improving mobility, ensuring access to affordable and reliable water and energy, increasing wastewater treatment, maximizing recycling and appropriate disposal of waste, and preparing for emergencies.

Meeting the city challenges will entail institutional coordination, collaboration among multiple stakeholders, and citizen proactivity. They will work to deploy multiple new technologies that can support the urban transformation and the more efficient use of fiscal resources.

The policy-making and regulatory functions to ensure sustainable urban development are extremely complex tasks. Incentives and penalties need to be carefully crafted to develop livable cities and find the proper balance between the functions of markets and governments. In addition, citizen engagement platforms hold a huge potential for empowering citizens and transforming their behavior as consumers, for instance, in relation to resource use and time-of-use, which is especially critical in mobility and electricity consumption to better manage network congestion.

The emergence of distributed energy markets will change the city ecosystem, and city governments will need to understand and facilitate the transition as well as interlinkages with other sectors, notably water and transport. Energy is needed for water pumping, for example, and electricity to power the increasing numbers of electric vehicles.

LAC needs better public spending—a more private financing

This report discusses ways in which LAC governments could improve public spending in energy. These include (1) reducing inefficient energy subsidies and designing smart progressive public support that benefits the poor,(2) pricing energy services adequately to incentivize high quality of service as well as judicious consumption,(3) reducing exposure to oil price fluctuations and diversifying the energy matrix using indigenous renewable energy resources, (4) enhancing connectivity regionally and internationally, (5) allowing carbon emissions trading, (6) adopting smart and efficient technologies, and (7) developing demand-side resources for increased economic efficiency.

Chapter 10 examines scenarios of future investment and discusses the powerful role that demand-side initiatives could play in reducing investment needs. Indeed, improved efficiency is not just good policy. It may well be the only option in the short-to-medium term to increase resources available for energy infrastructure given the region's tight fiscal position.

At the same time, scarce public resources need to be used strategically to mobilize and attract private financing. Attracting different types of investors will entail turning energy infrastructure investments into asset classes, introducing innovative financial products and facilities to support long-term financing, and addressing, managing, and allocating risk more effectively.

Notes

1. To account for deep uncertainties, non-probabilistic approaches are needed—often called decision making under uncertainty (DMU) methodologies. Rather than weighting futures probabilistically to define an optimal strategy, these methods seek to identify robust strategies—those that satisfy decision makers' objectives in many plausible futures, see Lempert et al. 2013 and Kalra et al. 2014.

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Lempert, Robert J., Steven W. Popper, David G. Groves, Nidhi Kalra, Jordan R. Fischbach, Steven C. Bankes and Benjamin P. Bryant. 2013. Making Good Decisions Without Predictions: Robust Decision-making for Planning Under Deep Uncertainty. RAND Corporation, Washington, D.C. http://www.rand.org/pubs/research_briefs/RB9701.html

CHAPTER 13

The Next Frontier

A secure, clean, resilient, and sustainable energy future is not a pipe dream—LAC can get there

Many countries in LAC have pioneered reforms—in institutions, policies, and regulations—that helped their energy sectors evolve into mature systems. Yet, a continuous process of adjustment is necessary to address emerging trends and disruptions.

One bloc of LAC countries has shown it can attract private-sector participation and innovate in policy, regulation, and technology. These countries are ready to introduce transformative solutions. A second bloc is working to develop stronger institutions and markets, and has made significant progress on some of the vectors and indicators discussed in this report. However, there is a third group of countries that will need serious revamping of efforts toward better operational and financial performance if they are going to deliver sound services and attract long-term financing.

We close this report with Matrix 13.1, which organizes potential actions toward a bright energy future into five pillars—efficiency, quality, sustainability, security supply, and energy equity. Matrix 13.1 in Annex 1 offers a more detailed set of indicative actions -with levers and cross-cutting areas- that may enable LAC's countries to achieve the clean, modern energy systems that their citizens deserve.

MATRIX 13.1 Next Frontier Indicative Actions

	Efficiency	Quality	Sustainability	Security of Supply	Equity
Public Policies	Cost-reflective tariffs, improved market design	Incentives for digitalization	Incentives for trade and renewable adoption	Credit enhancement, competitive entry mechanisms	National programs and policies for universal access, smart progressive subsidies
Firms and Citizen Initiatives	Firm innovation and prosumer participation	New business models based on renewables	Robust generation portfolio	Decentralized exchange and new business	Community microgrids

Source: Prepared by authors.

This report concludes with 5 central messages:

1 THE CONVERGENCE OF MULTIPLE TRENDS IS DISRUPTING THE STATUS QUO AND EVOLUTION OF ENERGY MARKETS GLOBALLY AND IN LAC.

These include new dynamics in global energy and fossil fuel markets, high urbanization rates, climate change, disruptive technologies, and increased financial constraints. Emerging technologies in particular—renewables, storage, smart grids, digital solutions, and small LNG among them—are transforming energy systems not only because they are increasingly cheap, but because they will unleash new and vibrant energy markets on the consumer side.

The region already has the cleanest energy matrix in the world due to a gradual substitution of oil for natural gas, and high use of hydropower and biofuels. But it is only starting to develop non-conventional renewables despite abundant indigenous resources and has lagged other regions in improving energy efficiency and rationalizing energy consumption. A key challenge in the region is that rainfall variability and Niño events are increasingly impacting hydropower output.

2 LAC COULD AND SHOULD TAKE ADVANTAGE OF EMERGING INNOVATIONS TO APPROACH HIGHER EFFICIENCY FRONTIERS.

On the whole, the region has made great strides in developing sophisticated electricity markets and gaining increased access to natural gas via LNG trade and indigenous resources. Different groups of countries (sometimes with overlapping members) face different challenges, but adopting emerging innovations is key to the future development of efficient energy services in all of them. This path would deliver climate co-benefits such as emissions reductions and enhanced resilience to climatic shocks and would reduce the social and environmental constraints that often accompany development of large infrastructure.

3 EMBRACING THE CLEAN ENERGY AND DIGITAL REVOLUTION MAKES ECONOMIC SENSE FOR LAC.

Demand for energy in LAC is projected to continue to grow at high rates. The region would need an estimated US$ 1.3 trillion dollars between now and 2030 to develop its electricity and natural gas infrastructure under a business-as-usual path. However, current investment flows fall short of these needs. Investment requirements could fall considerably under a development path that emphasizes efficient use of existing infrastructure, grid-connected renewables and a menu of demand-side solutions.

In medium and large size countries, the sensible goals are diversification and cost reduction. Renewable energy and ICT technologies are now ready to contribute to these goals. Natural gas will continue to play a key role in reducing costs and strenhtening energy security.

4 POLICY MAKERS AND REGULATORS NEED TO CREATE THE MARKET ARCHITECTURE AND INCENTIVES NECESSARY TO DEVELOP DEMAND-SIDE AND DISTRIBUTED RESOURCES.

This will require planning that considers the full menu of supply- and demand-side resources as well as proactive regulation that creates the pricing and incentives necessary to develop them. Markets will need to increase electricity trade in existing cross-border interconnections and consider further integration where politically feasible. City governments could play a key role in "smarting up" the energy infrastructure and growing the clean energy economy via new incentives and investment. All these steps would require strong institutional capacity and agility.

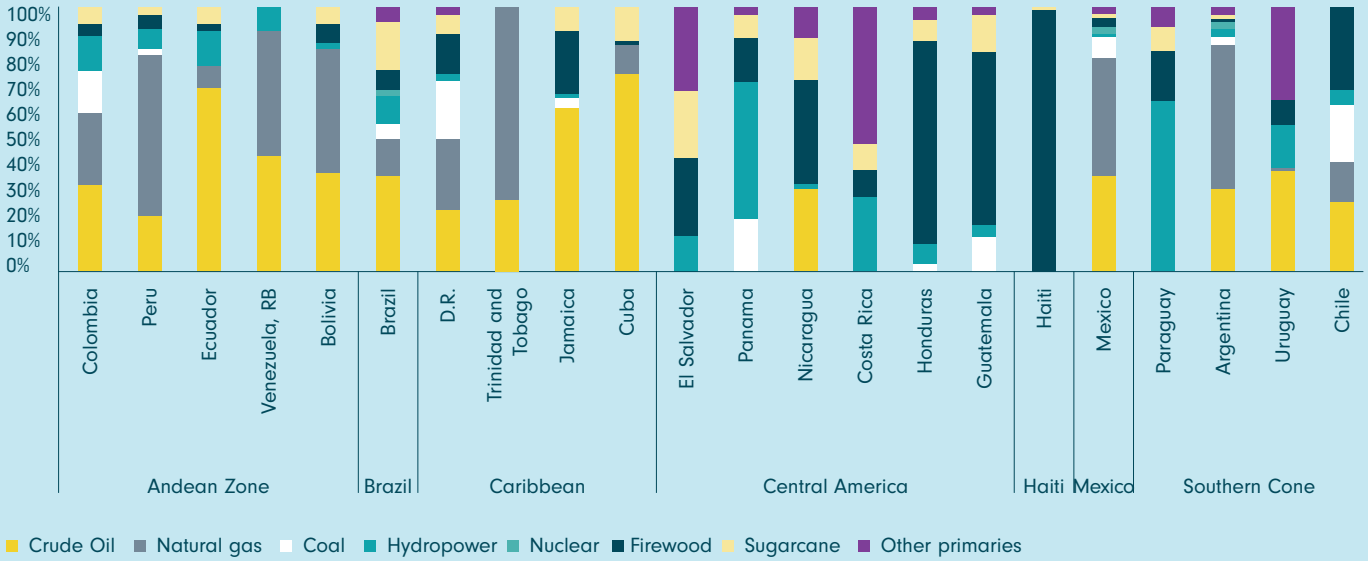
5 CREATING NEW ASSET CLASSES WILL REQUIRE FINANCIAL INGENUITY.

Mobilization of debt and institutional investor resources will only happen after affordable risk management instruments and innovative products are in place.

ANNEX I.
Additional Data

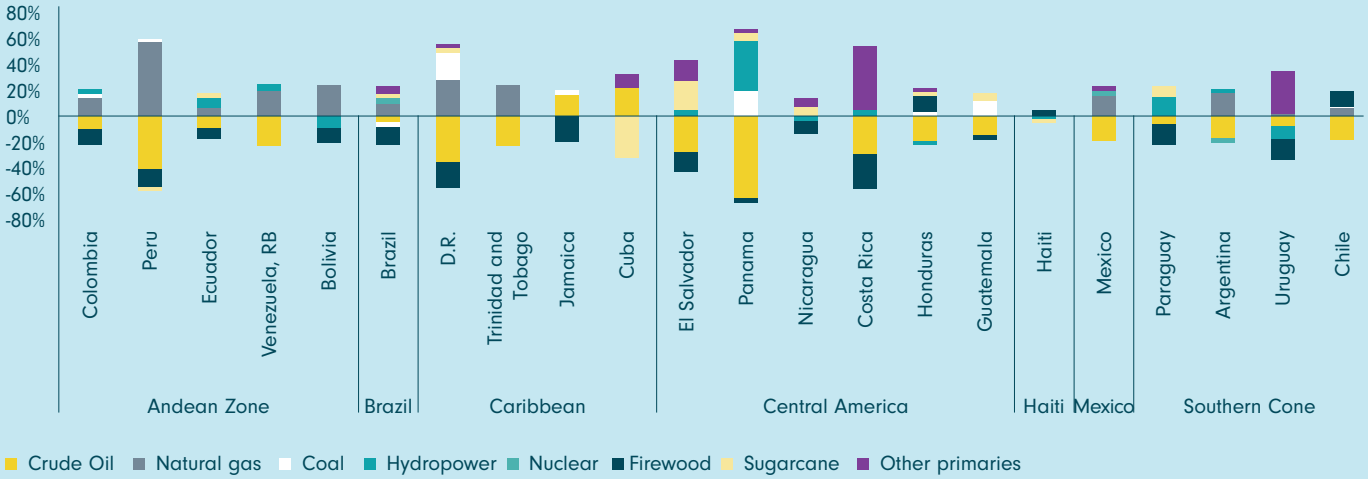
CHAPTER 1

FIGURE1.A Primary Energy Supply by Source (2015) *Percent*



Source: Prepared by authors based on data from OLADE-SIER (database).

FIGURE1.B Fuel Source of Primary Energy Supply (1990-2015) *(Percent change)*



Source: Prepared by authors based on data from OLADE-SIER (database).

CHAPTER 2

TABLE 2A Caribbean Utilities and Ownership Status

Country	Power Utilities	Ownership	IPPS for Power Generation
Antigua and Barbuda	Antigua Public Utilities Authority (APUA)	State-Owned	Limited
Bahamas	Bahamas Electricity Corporation (BEC)	State-Owned	No
	Grand Bahama Power Company (GBPC)	Privately-Owned	No
Barbados	Barbados Power & Light (P&L)	Privately-Owned	No
Belize	Belize Electricity Limited	State-Owned	Yes
Dominica	Dominica Electricity Services Ltd. (DOMLEC)	Privately-Owned	Limited
Dominican Republic	Multiple	State-Owned and Privately Owned	Yes
Grenada	Grenada Electricity Services Ltd. (GRENLEC)	Privately-Owned	Limited
Guyana	Guyana Power & Light Inc. Stat (P&L)	State-Owned	Yes
Haiti	Haiti Electric Company (EDH)	State-Owned	Yes
Jamaica	Jamaica Public Service Company (JPSCo)	Privately-Owned	Yes
St. Kitts and Nevis	St. Kitss Electricity Department (SKELEC)	State-Owned	Limited
	Nevis Electricity Company LTD. (NEVLEC)	State-Owned	Limited
St. Lucia	St. Lucia Electricity Services Ltd. (LUCELEC)	Private/Public entity	Limited
St. Vincent and the Grenadines	St. Vincent Electricity Services Ltd. (VINLEC)	State-Owned	No
Suriname	Energy companies Suriname (EBS)	State-Owned	Yes
Trinidad & Tobago	Trinidad & Tobago Electricity Commission	State-Owned	Yes

TABLE 2B Utilities Considered for the Utility Performance Analysis

Income	Country	Company
HIC	Argentina	EDENOR
	Bolivia	DELAPZA
LMIC	Armenia	CJSC
HIC	Belgium	Eandis/Eletrabel
UMIC	Brazil - Sao Paolo	ELECTROPAULO
HIC	Chile	CHILECTRA
UMIC	China	State Grid Power Corporation of China
UMIC	Colombia	CONDENSA
HIC	Czech Rep	PRE Distribue A.S.
HIC	Denmark	DONG Energie
	DR	EDESUR
	Ecuador	EEQ

Income	Country	Company
HIC	Finland	Helen Oy
LMIC	Guatemala	EEGSA
	Haiti	EdH
	Honduras	ENEE
LMIC	India	Reliance Infrastructure Limited
LMIC	Indonesia	PTPLN
UMIC	Mexico	CFE
LMIC	Morocco	LYDEC
UMIC	Peru	EDELNOR
HIC	Poland	RWE Stoen
HIC	Spain	IBERDROLA
HIC	Switzerland	EKZ
HIC	USA	CECONY
HIC	Venezuela	CORPOELEC

TABLE 2C Challenges to Cross-Border Electricity Trade

Challenge	Details
Lack of comprehensive regional treaty or framework	• High level of uncertainty deter investment • Bilateral contractual agreements exposed to risk of government intervention
Lack of harmonization of legal and regulatory frameworks among countries	• Regulatory harmonization includes spot markets, generation scheduling and dispatch (day-ahead and real time), congestion management, transmission pricing and transit. • Differences in system security standards, types and volumes of ancillary reserves do not allow synchronous operation and limit exchanges to emergencies. • Traders and suppliers cannot develop cross-border transactions (e.g.; distribution companies can only sign a contract for energy imports if the contract is awarded as a result of a tender; generation located in a neighboring interconnected country not eligible for participation in national tenders). • Transmission rights and rules that protect contracts between parties during low reserves and shortages may be necessary.
High level of legal and regulatory complexity	• Both expanded bilateral power trading and more formal power pools require broader pre-commitment to free trade or economic integration • Complex rules slow down trading and require a high level of political will from trading parties
Prioritization of national energy security over maximization of benefits	• Power trade limited to opportunity trading, (e.g.; hydro surplus) • Regional integration dynamics still not embedded in planning, policy and operations at the national level - Lack of understanding regarding the benefits of integration (e.g.; connectivity as a mechanism to diversify risk, or trade as an additional flexible resource).
Lack of planning at the regional level	• Lack of transmission interconnection planning studies • Lack of consideration to the concept of "regional security of supply"
Large price differential among trading parties	• Significant price differentials constraint regional trade (large differences among marginal costs difficult to reconcile). • Government intervention through arbitrary changes to pricing policies have an impact on trade (e.g.; countries with spot prices below short run marginal costs). • Carbon emission factors' differentials may also affect trade.
Weak national transmission infrastructure	• Congestion affects trading transactions

TABLE 3A Competitive Gas Markets Performance Indicators

Indicator	Elements
Institutional regulation	• Separation of stakeholders' roles (public and private sectors). Extent to which roles are overlapped. • Level of conflicts of interest (between stakeholders) • Regulatory Independence • Level of competition allowed in regulatory framework • Quality of Regulation: Maturity, effectiveness and inter-temporary consistency of energy policy
Supply diversification	• Degree of competition in supply side (concentration of gas suppliers) • Level of concentration in domestic production • Free entrance of importers • Degree of participation of marketers/retailers in the supply side
Market opening /rules	• Large and diversified eligible users to participated in deregulated market (declared market opening) • Customer choice procedures/rules (less restrictive/free election of supplier) • Level of opening and options for electricity users (power generator as single gas buyer)
Unbundling / Level Playing Field	• Restrictions on vertical /horizontal integration along gas value chain • Level of segmentation (ring-fencing between regulated (T&D) vs. Unregulated segments (Gas commercialization) • Unbundling of Transmission System Operator- TSO (ownership, legal, management, account)
Regulated Tariff / TPA Rules	• Regulated tariff vs. negotiated tariffs • Thirty Party Access (TPA): effective/non- discriminatory • Existence of Gas System Operator • Effective TPA on border gas pipelines • Standard contracts models, level of conflicts
Transparency flexible transactions	• Regulated vs. liberalized gas markets • Market clearing gas prices for gas imbalances • Pass through mechanisms to transfer gas prices to end users/ captive markets (not open gas markets) • Bilateral contracts vs. auctions • Long term vs. spot gas contracts • Contracts flexibility • Development in secondary markets

Note: This set of indicators qualitatively measures the performance of competitive gas markets.

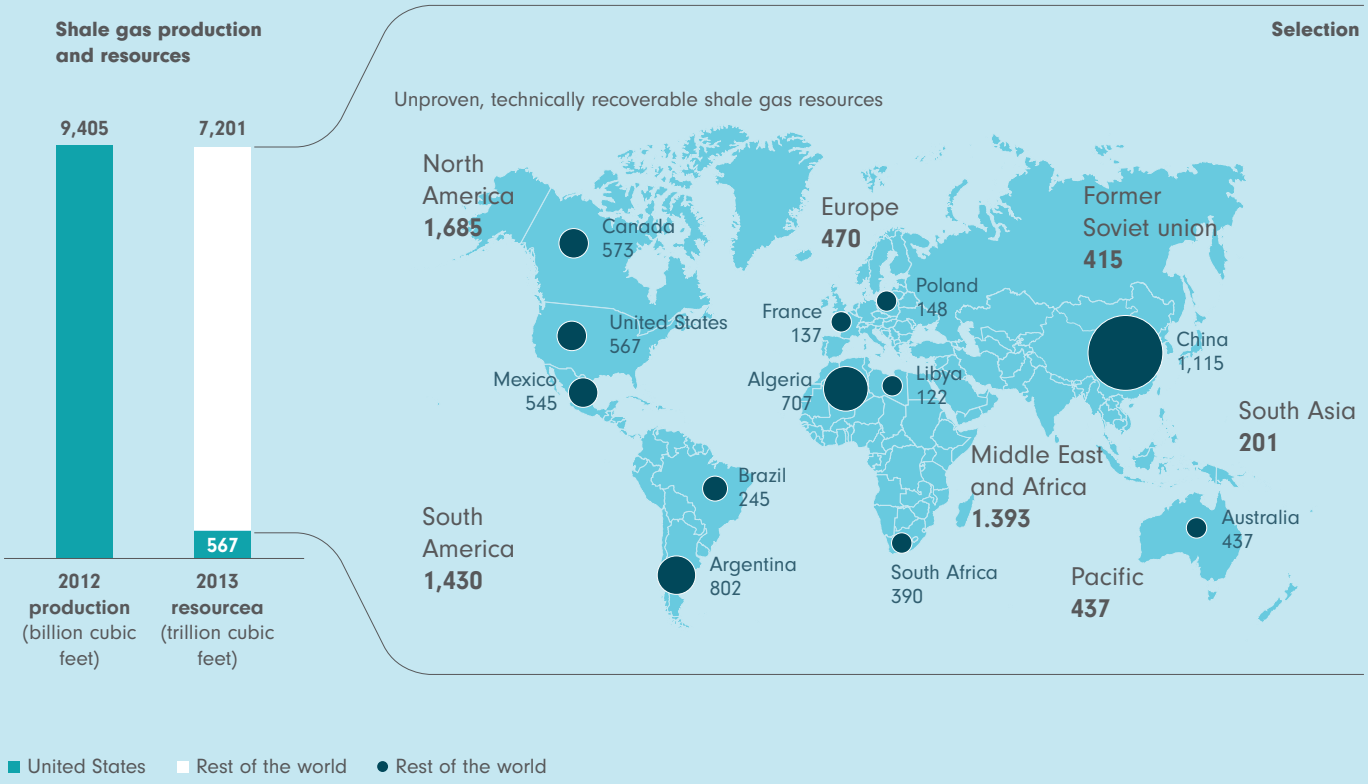
TABLE 3B Greenfield Gas Markets Performance Indicators

Indicator	Elements
State role as a facilitator	• Active role of the government in structuring infrastructure projects, and promoting investment (e.g.; through Ministry of Energy o other entity) • SOEs participation in infrastructure projects • International protocols / bilateral transaction Rules
Private sector participation	• Level Playing field between stakeholders (incumbents, SOEs, new players) • Interface with Electricity sector. Pricing rules in the electricity Sector: power purchase bidding and Electrical distributors shall purchase electric power from generators through long-term contracts and use various fuels (gas, LNG) • Level playing Field (between SOEs and private agents)

Indicator	Elements
Planning	• Integrated Planning (planning with a broad and multi-sectorial view) • Government planning as a reference and guidance for investments by private/public agents.
Cost-Benefit analyses	• Capacity to conduct a systematic approach for evaluating the strengths and weaknesses of energy projects with alternatives for the society (evaluation of options that provide the best approach to achieve benefits while preserving savings)
Promotion competition in Second Stage	• The regulatory framework is gradually modified to include competitive mechanisms as the industry and market matures. • Evolution of access to networks as the market matures (from close access to third party access (TPA) and rules that encourage open access, competition).
Transparency/open bidding procedures	• Regulatory framework established and clear to bidders before tenders/bidding • Free entry of competitors through open bidding processes carried out by the Governments.

Note: This set of indicators qualitatively measures the performance of "Greenfield Markets", i.e.; new markets, or those in which countries have to invest in all segments of the supply chain.

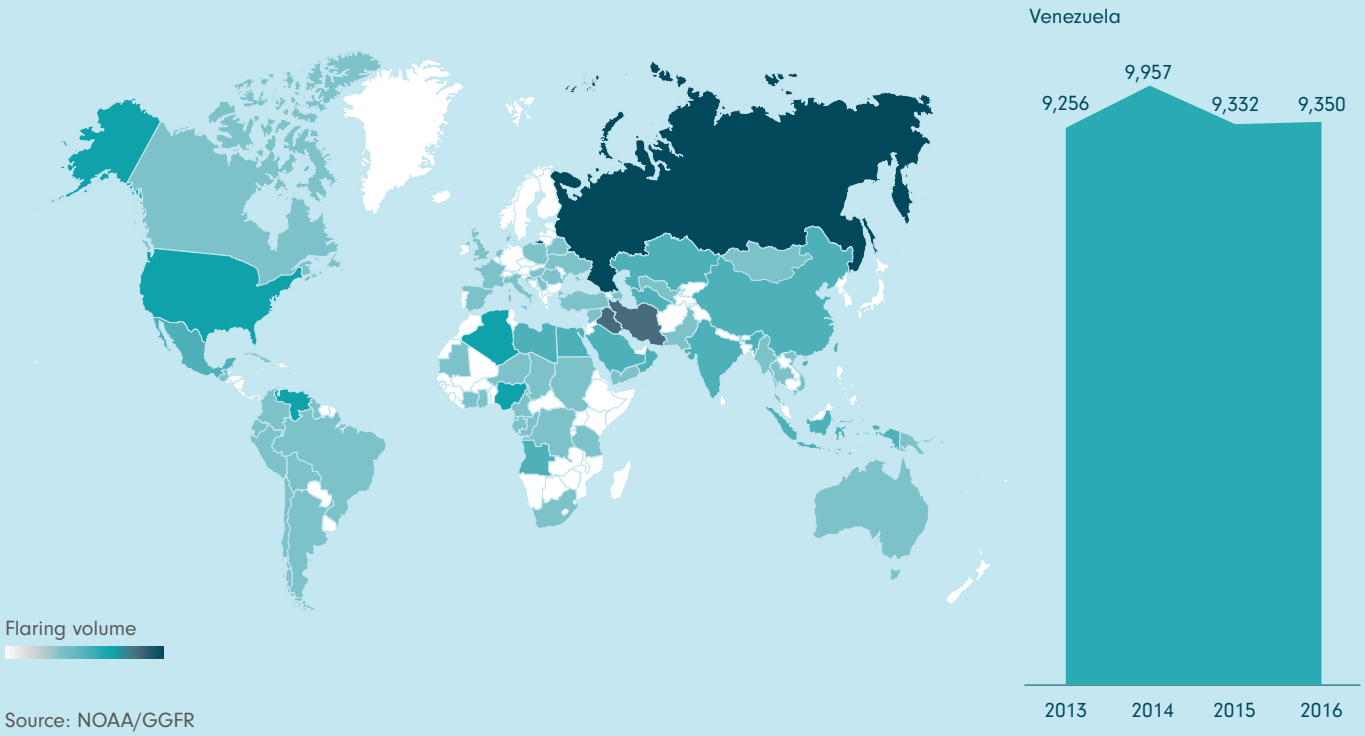
MAP 3A Resources Allocation of technically recoverable shale gas *(Trillion cubic meters)*



[1] Annual estimate based on daily U.S, production

Source: U.S. energy Information Administration study of 42 countries; A.T. Kearney analysis

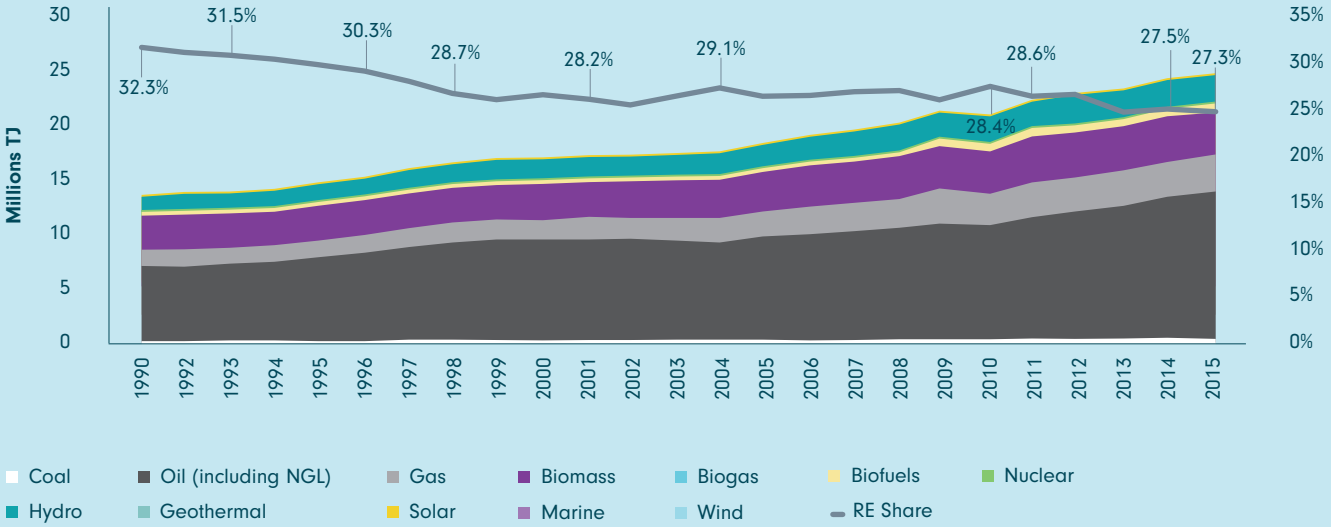
MAP 3B Upstream Gas Flaring *(Million cubic meters)*



Source: NOAA/GGFR

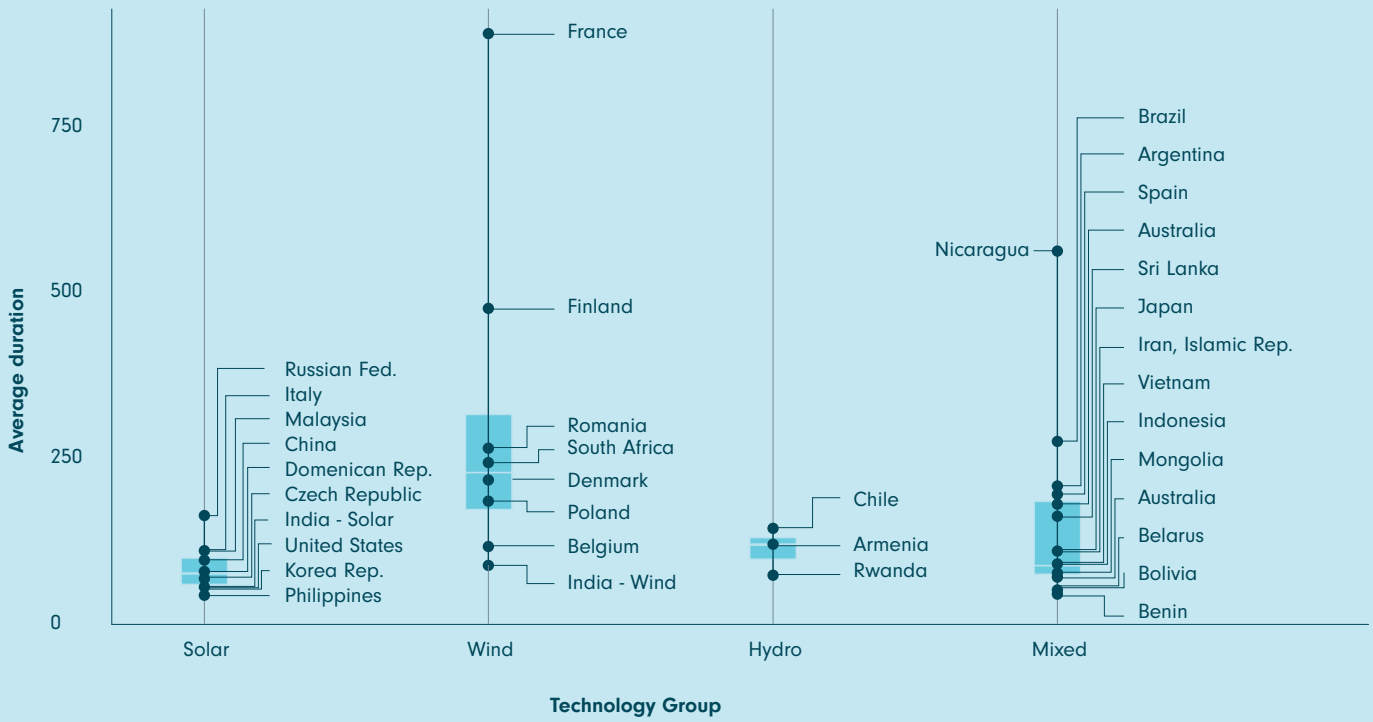
CHAPTER 4

FIGURE 4A Evolution of TFEC in LAC, by Fuel (1990-2015) *(Millions of terajoules (TJ), left axis; percent, right axis)*



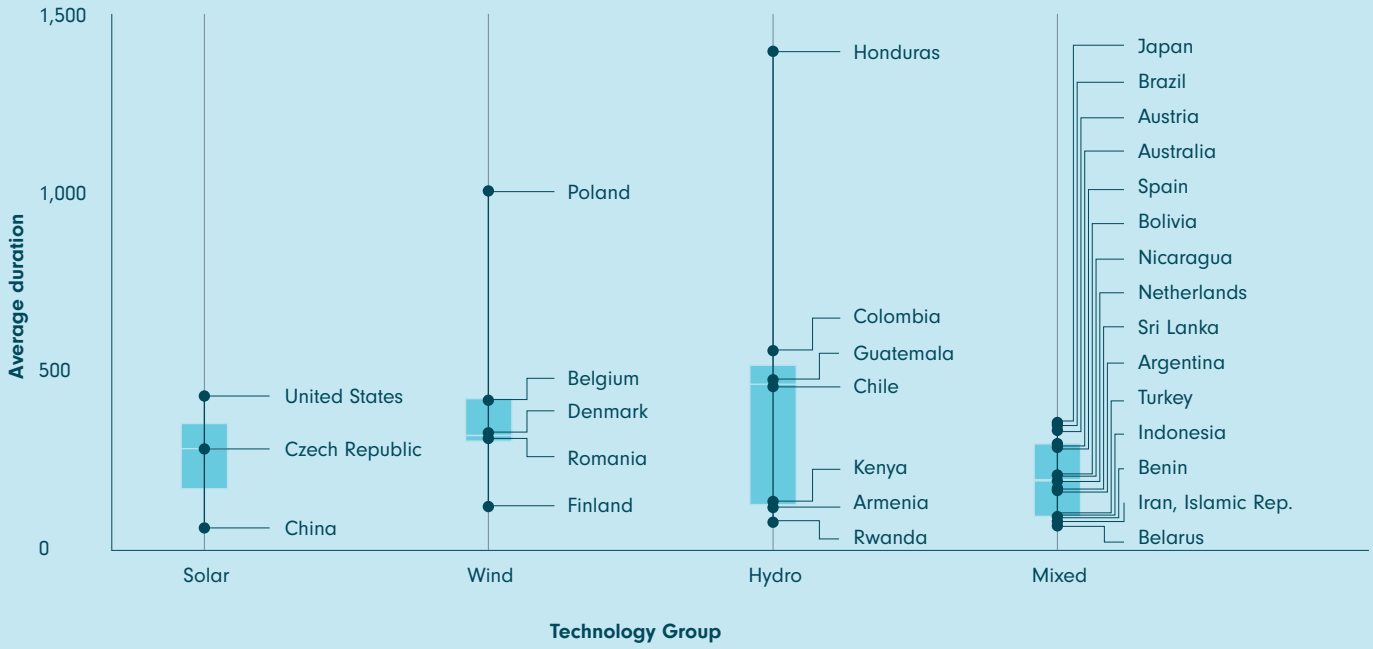
Source: Prepared by authors based on data from OLADE-SIEE 2016(database).

FIGURE 4B Average Time for Issuing an Interconnection Approval *(Days)*



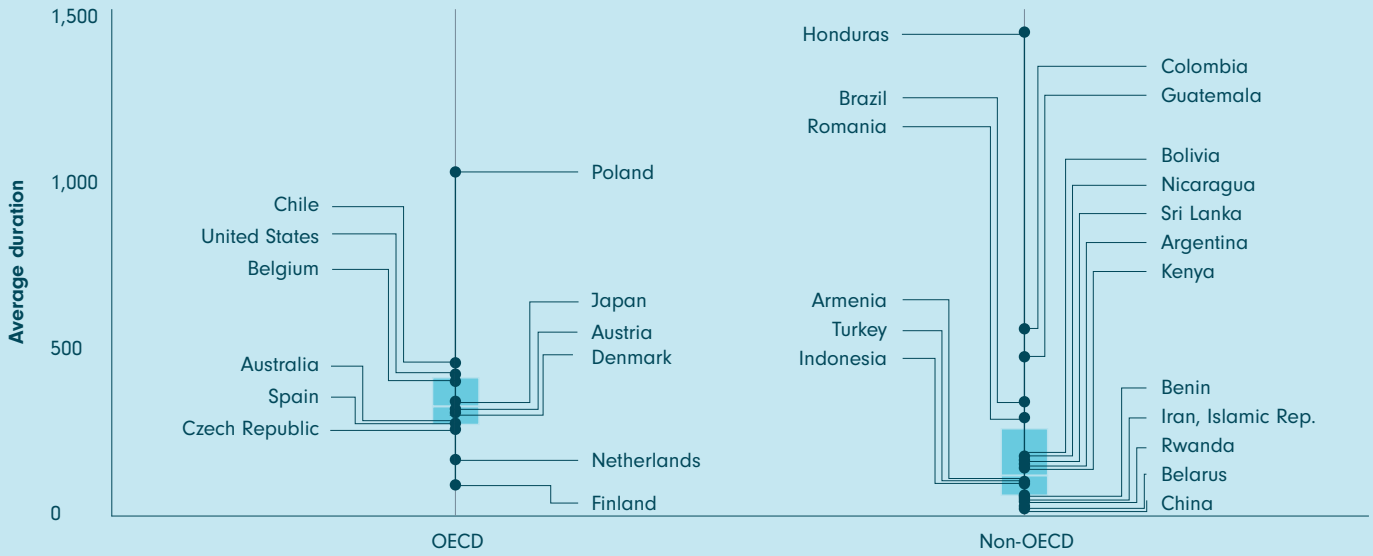
Source: RISE (database)

FIGURE 4C Average Time for Issuing an Interconnection an Environmental Permit *(Days)*



Source: RISE (database)

FIGURE 4D Average Time for EIA Procedures *(Days)*



Source: RISE (database)

MATRIX 4A Renewable Energy Targets and Policies in Selected Countries of LAC

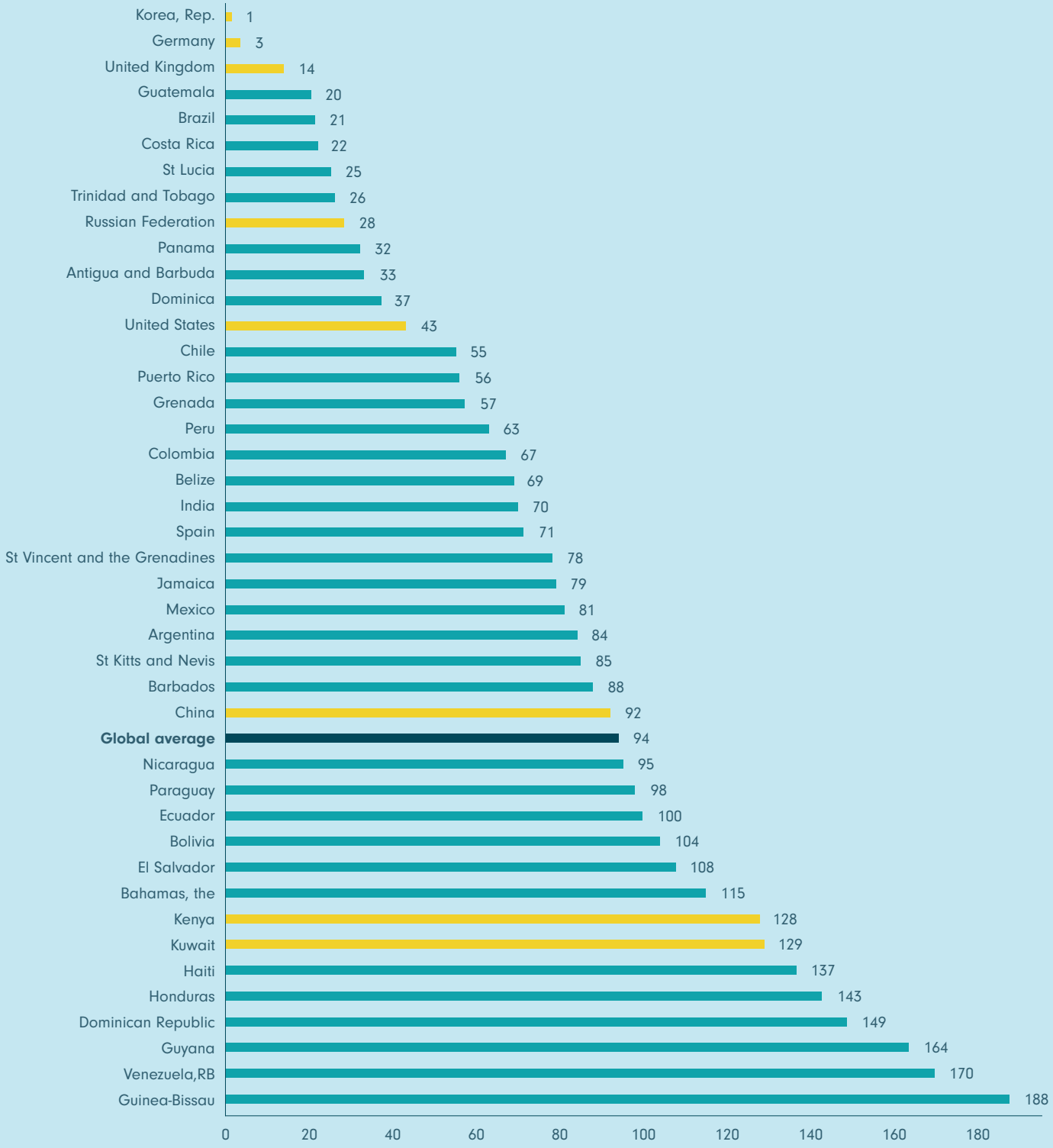
Type of Country	Country	Renewable energy targets	Regulatory policies							Fisical incentives and public financing				
			Feed-in tariffs premiums	Quota obligations/RPS	Net metering	Biofuels obligation/ mandates	Heat obligation/mandate	Tradable REC	Tendering	Capital subsidy, grant or rebate	Investment/production tax credit	Reductions in sales, energy, CO_2, Vat or other taxes	Energy production payment	Public investment, loans or grants
High income	Barbados (1)	r			o							o		o
	Chile	r		o	o				o	o	o	o		o
	Trinidad and Tobago	o									o	o		
	Uruguay	r	o		o	o	o		o	o		o	o	o
Upper-middle income	Argentina (2)	o	o		o	r			•	o	o	o	o	o
	Brazil	r			r	r	•		–		o	r		o
	Colombia	o			•	o					o	o		o

Type of Country	Country	Renewable energy targets	Regulatory policies							Fisical incentives and public financing				
			Feed-in tarifss premiums	Quota obligations/RPS	Net metering	Biofuels obligation/ mandates	Heat obligation/mandate	Tradable REC	Tendering	Capital subsidy, grant or rebate	Investment/production tax credit	Reductions in sales, energy, CO2, Vat or other taxes	Energy production payment	Public investment, loans or grants
Upper-middle income	Costa Rica	r	r		o	o			o			o		
	Dominican Republic	o	o		o				o	o	o	o		o
	Ecuador	o	r			r			o			o		o
	Granada	r			o							o		
	Jamaica	o			o	o			o		o	o		
	Mexico	r			o				•		o			o
	Panama	o	o		o	o			o		o	o	o	
	Peru	o	o	o	•	o			•			o		o
	St. Lucia	o			o							o		
	St. Vincent and the Grenadines (1)	o			o									
Lower-middle Income	Guatemala	r			o	o			o		o	o		
	Guyana	r										o		
	Honduras	o	o		o				o		o	o		
	Nicaragua	o	o			o					r	o		o
	Paraguay (2)					o						o		
Lower income	Haiti	r												o

Notes: HI- High Incom; LI= Low Income; o= Existing National Policy; *= New National Policy Introduced in 2016; r= National Policy Revised in 2016; e= Existing State/Provincial Policy. [1] Certain Caribban countries have adopted net metering and feed-in policies whereby redisential consumers can offset power while commercial cosumers are obligated to feed 100% of the power generated into the grid. These policies are defined as net metering for the purposes of the GSR. [2] The latest results are from the REN21 2015.

Source: REN21 2016.

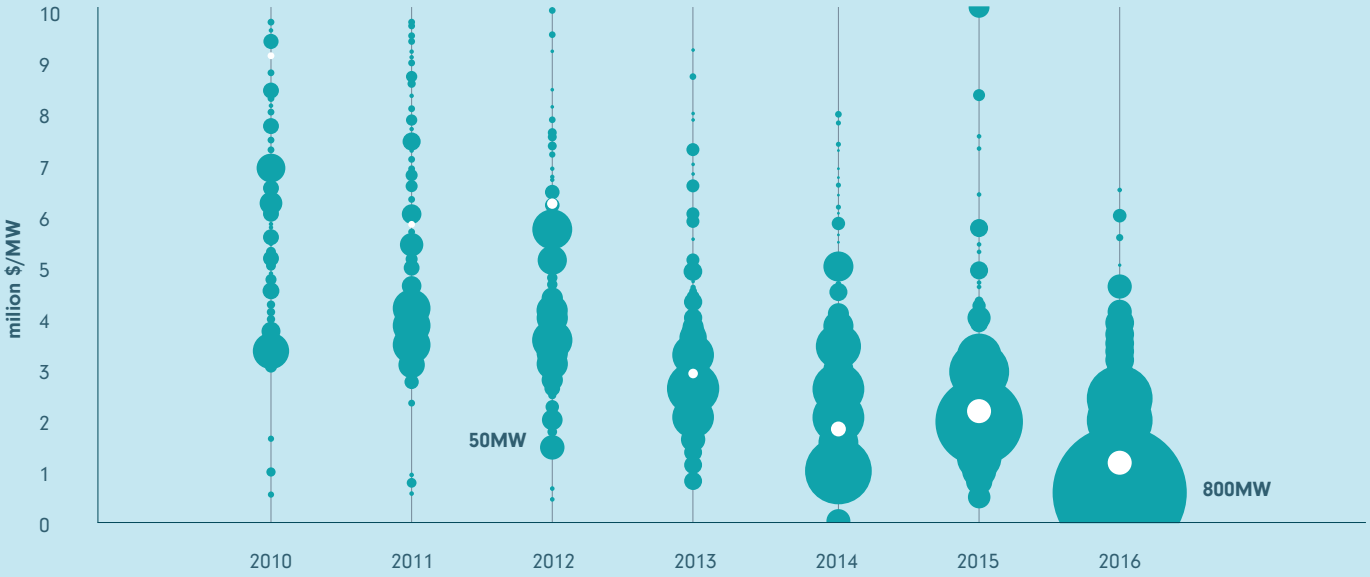
FIGURE 4E Ease of Getting an Electricity Connection: LAC Countries and Comparators *(Index)*



Source: RISE (database)

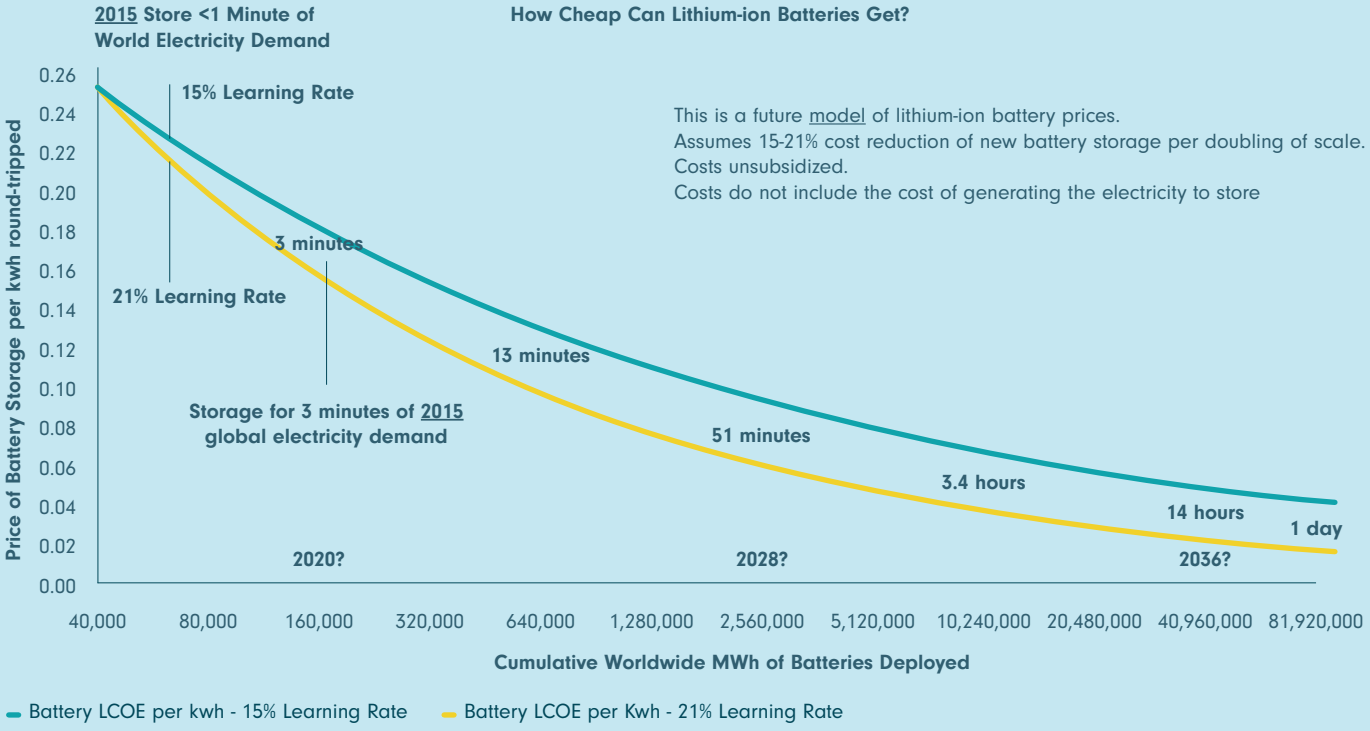
CHAPTER 9

FIGURE 9A Evolution of Solar PV Project Price *(USD Million/MW)*



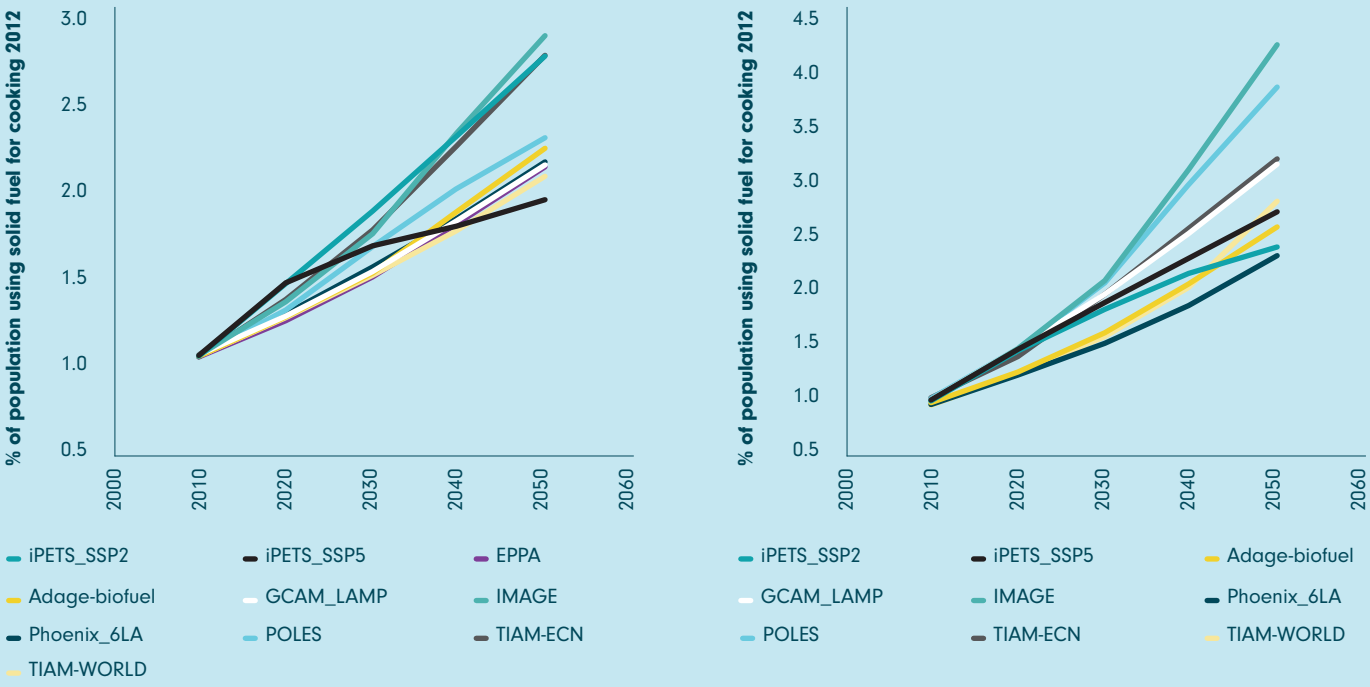
Source: World Bank based on IHS data.

FIGURE 9B Evolution of Solar PV Project Price *(USD Million/MW)*



Source: Naam 2015.

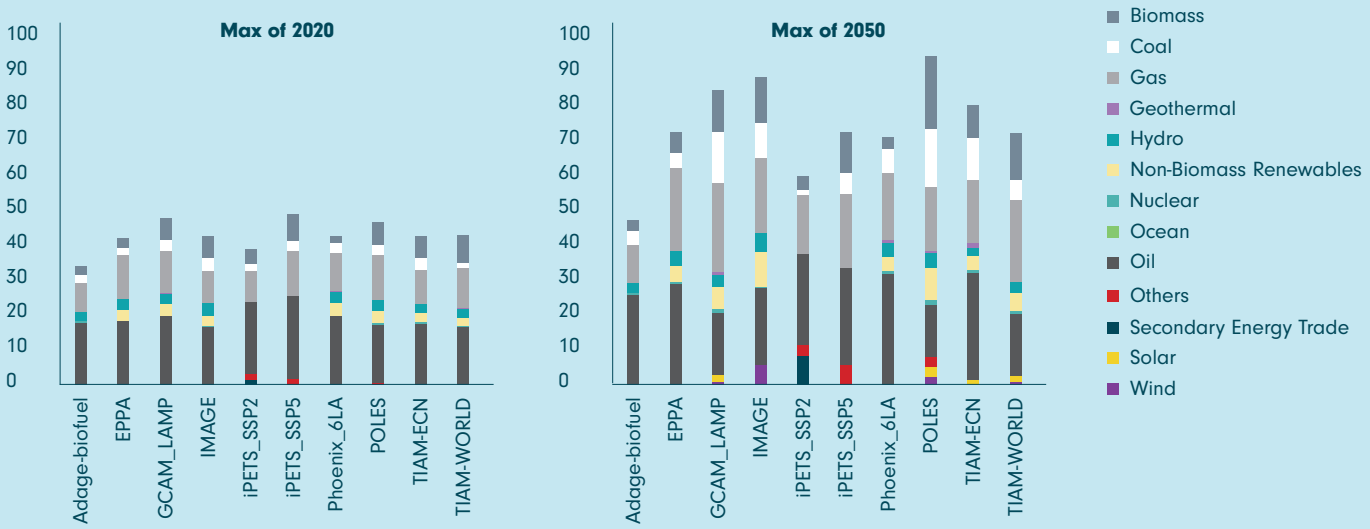
FIGURE 10A Final Energy Consumption in Latin America *(Index, 2010=1)*



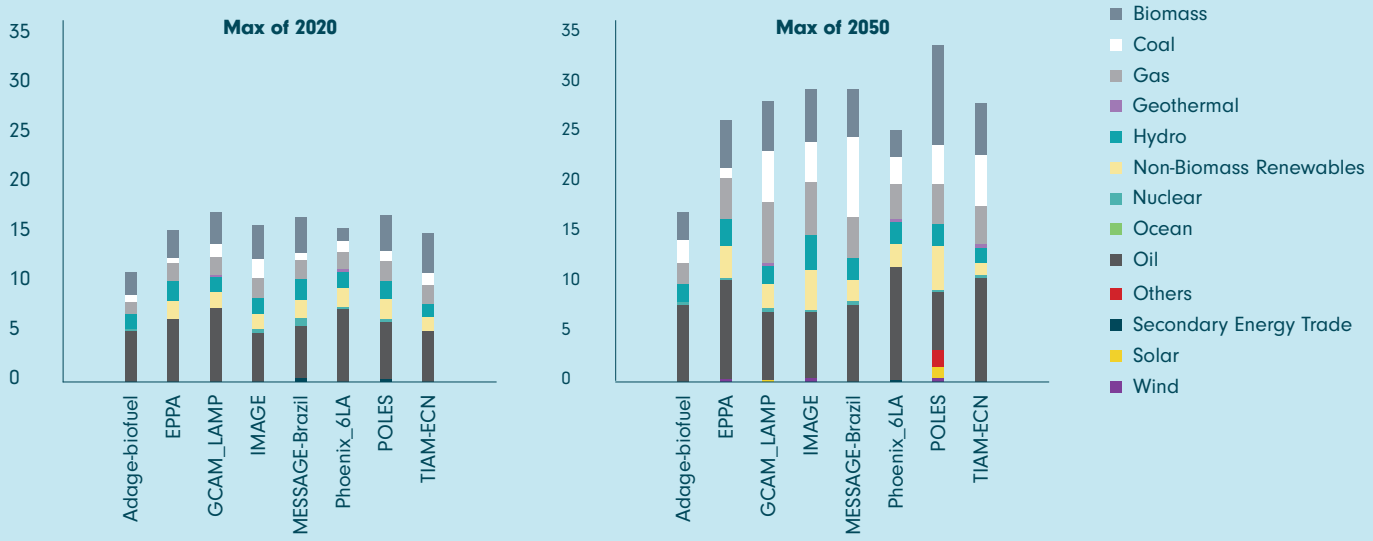
Source: Ruijven et al. 2016.

FIGURE 10B Primary Energy Use for Latin America, Brazil, and Mexico in the Core Baseline Scenarios of Selected Models (2020 and 2050) (Units)

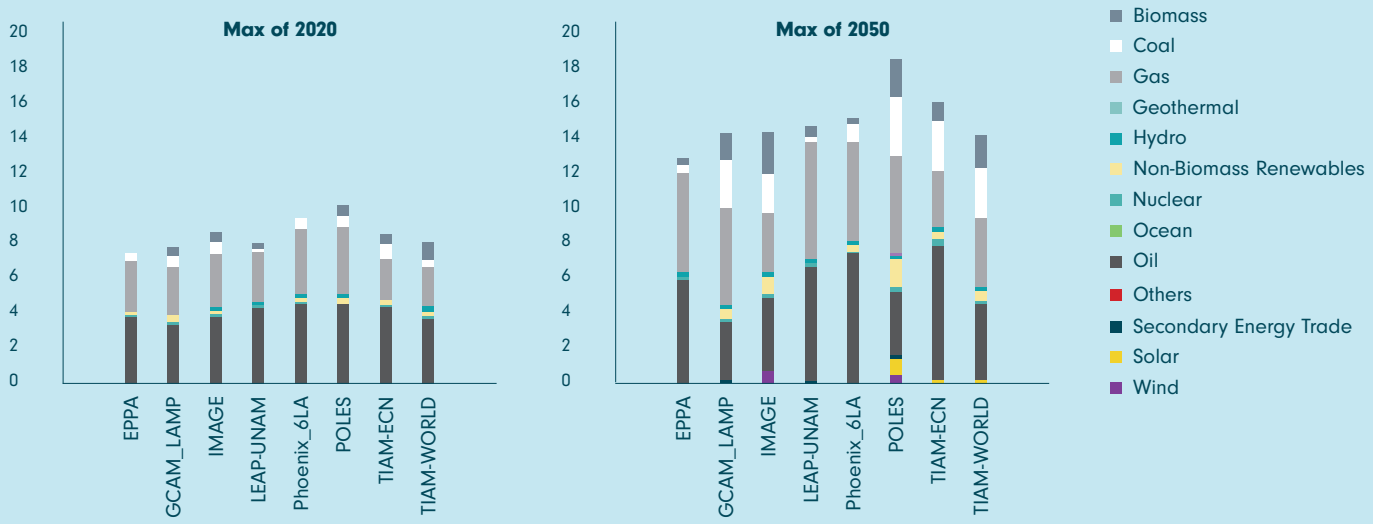
Latin America



Brazil



Mexico



Source: van Ruijven et al. 2016.

CHAPTER 11

BOX 11A. Infrascope Index

The Infrascope index comprises 19 indicators, both qualitative and quantitative in nature. Data for the quantitative indicators are draw from the Risk Briefing service of The Economist Intelligence Unit (EIU) and from the World Bank. Gaps in the quantitative data have been filled by estimates that have been developed by the EU project team.

The qualitative data come from a range of primary sources (legal texts, government websites, press reports and interviews), secondary reports and data sources adjusted by the EIU. The main sources used in the index are the EIU, the World Bank, Transparency International and the World Economic Forum.

The categories and their associated indicators are as follows (Appendix II provides detailed definitions of the categories and indicators):

1. Legal and regulatory framework (weighted 25%)
1.1 Consistency and quality of PPP regulations
1.2 Effective PPP selection and decision-making
1.3 Faimess/openness of bids, contract changes
1.4 Dispute-resolution mechanisms

2. Institutional framework (weighted 20%)
2.1 Quality of institutional design
2.2 PPP contract, hold-up and expropriation risk

3. Operational maturity (weighted 15%)
3.1 Public capacity to plan and oversee PPPs
3.2 Methods and criteria for awarding projects
3.3 Regulators' risk-allocation record
3.4 Experience in transport, water and electricity concessions
3.5 Quality of transport and water concessions

4. Investment climate (weighted 15%)
4.1 Political distortion
4.2 Business environment
4.3 Political will

5. Financial facilities (weighted 15%)
5.1 Government payment risk
5.2 Capital market: private infrastructure finance
5.3 Marketable debt
5.4 Government support and affordability for low-income users

6. Subnational adjustment factor (weighted 10%)
6.1 Subnational adjustment

Source: Economist Intelligence Unit 2014.

BOX 11B. Peru: ABENGOA Transmission Sur PPP Refinancing (2014)

Description of the Project and Characteristics

- Refinancing will be used for the construction of an 883 km 500kV transmission line, the expansion of three substations –Chilca Nueva 500/220 kV, Marcona 220 kV and Montalvo 220 kV– and the construction of three new substations.
- Revenue basis: Availability payments, based on tariff payments denominated in US dollars and indexed to US inflation.
- Risk mitigation: fixed price operating contract.

Financial Structure

- D/E = 75:25.
- Equity: Abengoa S.A. with 61.1% (Spanish company) and the Spanish development bank, COFIDES, is holding the remaining 38.9% of the equity through its fund for foreign investment (FIEX).
- Debt consists in a Commercial Bond (US$ 432.00 million) with a fixed rate and interest of 6.88%. This is the largest ever dollar-denominated project bond to come out of Peru. It is also thought to be the first ever issued with a 29-year tenor in Latin America. HSBC and BNP Paribas underwrote the bond. Fitch provisionally rated the notes 'BBB-', investment grade.
- More than three-quarters of the bond were placed with US institutional investors, the remainder was placed in Europe, Asia and locally.

Lessons Learned

- Conditions for international investors' appetite for infrastructure project bonds: i) well-structured brownfield project bonds; ii) investment grade (at least BBB-); iii) hard currency; and iv) low demand risk.

Source: Prepared by authors.

BOX 11C. Uruguay: Weather and Oil Price Insurance Transaction

Uruguay's state-owned public electric company generates more than 80 percent of its energy needs from hydropower plants. When rainfall or accumulated water reserves are low, the company is forced to purchase fuels (mostly oil-based and natural gas) to use as inputs for electricity production. When the price of oil is high, generation costs skyrocket, affect the firm's bottom line, increasing prices for consumers and affecting the national budget.

For example, in 2012 the company had projected the cost of supplying electricity at 953 million dollars, but water shortages meant the utility had to purchase other sources of energy. The cost of supplying energy reached a record 1.4 billion dollars. It became obvious that the company needed to manage these risks and hedge against the financial exposure to low rainfall and high oil prices.

On December 2013, the World Bank executed a 450 million dollar weather and oil price insurance transaction for UTE (the state-owned utility). The transaction insures the energy company for the following 18 months against drought and high oil prices. To measure the extent of a drought and potential insurance payout to the company, the transaction measures and collects daily rainfall data at 39 weather stations spread throughout the different river basins. If precipitation falls below the level set up as trigger of the contract, the state-owned company will receive a payout of up to USD $450 million based on the severity of the drought and oil price levels. If oil prices are high, the payout will be larger to offset the high cost of fuel purchases.

This is the largest transaction in the weather risk management market and the first time that a public utility company has used this type of risk management tool. It is important to note that this contract is part of a broader framework to reduce vulnerabilities, including stabilization funds and contingent financing with private banks. This type of transaction is replicable in other countries.

Source: Prepared by authors.

BOX 11D. Argentina FODER Renewable Energy Fund: A Programmatic Guarantee Scheme

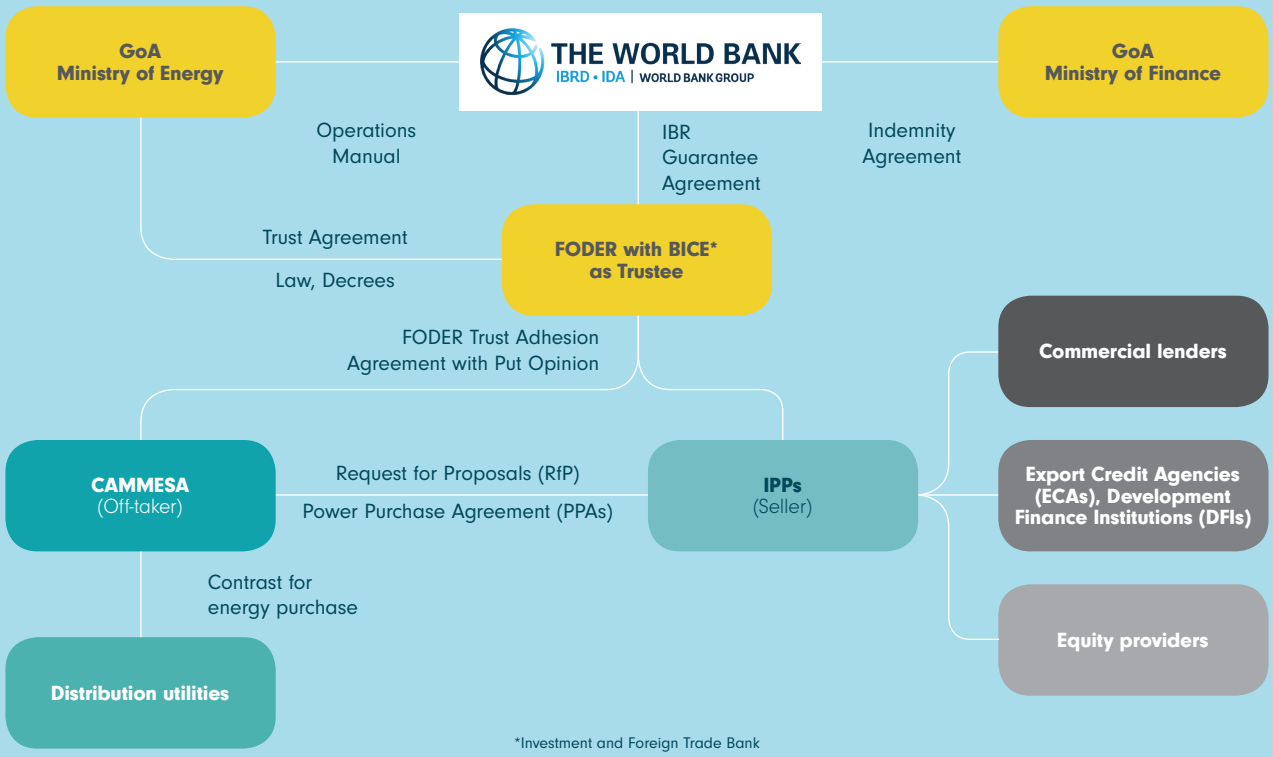
Context. In February 2017, the World Bank approved an IBRD guarantee in support of the FODER Renewable Energy Fund in the Argentine Republic in the amount of US$480 million. Through the guarantee project the World Bank supports the Government of Argentina (GoA) in the implementation of its RenovAr Program, which has awarded renewable energy generation capacity for more than 2.4GW (7 percent of the current installed capacity) from private investors at competitive prices. Under the RenovAr Program, CAMMESA, the

wholesale energy market administrator, is the off-taker and signatory of the Power Purchase Agreements (PPAs) with the Independent Power Producers (IPPs). To achieve Argentina's mandatory renewable energy targets, the new renewable energy law created the Fund for the Development of Renewable Energy (FODER) to facilitate the financing for renewable projects, and mitigate liquidity and country risks.

Project Description. The IBRD guarantee project backstops GOA's and FODER's obligation to pay a pre-determinable price to eligible renewable energy investors when they have the right to sell the project to FODER if specific macroeconomic, sector or other government-related risks materialize.

Innovative Features. This IBRD guarantee project is one of the first payment guarantee operations undertaken by the Bank at a program level. Up to now most payment guarantee projects have supported an individual project instead of a group of projects clustered under a program. The programmatic guarantee scheme has a multiplier effect as it contributes to mobilize US$3.2 billion investment into the Argentine renewable energy sector (representing about 6.7 times the amount of the IBRD guarantee), with US$2.5 billion from commercial sources.

Development Impact. The IBRD guarantee project represents a transformative opportunity to link Latin America and Caribbean Region's renewable energy potential to private investments, competitive electricity prices, and innovative financial schemes that could be replicated and scaled-up to other regions and sectors. It creates a new market through leveraging private investment, which is of particular importance for Argentina at a time when international investors are interested to return to the country after years of absence. The IBRD guarantee project has ultimately supported a middle-income client country to diversify its energy matrix, benefit from the associated climate co-benefits and meet its NDC goals.



Source: Prepared by authors.

MATRIX 13A Next Frontier Indicative Actions

	Economic/fisical efficiency	Quality of infrastructure	Resilience/sustainability	Energy security	Energy equity
Enhance governance **Strengthen policy and regulation**	Energy price formation that minimzes/avoid economic distortions (transparent/ smart subsidies, fair and vigorous competition) Introduce regulation to support energy efficiency across value chain (e.g.; Time-of Use Tariffs)	Promote higher connectivity/trade Ensure financial sustainability of utilities Anticipate measures to support supply chain/utility transformation/avoid lock-in/leapfrog (institutional agility)	Appropriate regulation for increased energy trade, and sustainable energy Externality/carbon pricing Risk Management Framework for Resilience and Climate Adaptation	Appropriate regulation to ensure adequacy/reliability (including under ENSO events) Enhance use regional transmission infrastructure/ optimize trade Increase connectivity via LNG	Well-designed public support for universal access: Smart/progressive subsidies National program targeting universal access: Focused on rural/ peri-urban areas, focused on NSF
Enhance market design/ performance	Emphasize and promote energy efficiency across all segments of the value chain Introduce day-ahead, intraday, forward markets Nodal/locational/dynamic pricing	Introduce AMI. Introduce incentives for the adoption of emerging technology (smart grids/ meters, digitalization) Strengthen power exchange platforms (stock/derivative exchanges)	Strengthen grid resilience and responsiveness Enhance dispatch of VRE Enhance DSM Day-ahead optimization, scheduling of regional trade	Develop natural gas markets Design capacity markets that consider climatic risk	Ensure reliability, quality, affordability and legality of service for low income and rural consumers
Enhance planning	Use supply and demand side resources efficiently to minimize costs and public sector investment needs	Regional/national Consider emerging technologies and business models Avoid technology lock-in Increase connectivity	Multi-sectorial Optimize/tap into indigenous, RE and flexible resources Develop grid codes Mainstream climate risk	Regional integration and enhanced connectivity Energy intelligence and analytics	Urban/rural Planning of mini-grid and grid-off grid technical economic frontier
Attract PSP	Fisically responsible PPPs Balanced allocation of risks in PPPs Optimize use of concessional finance	Introduce PPP Frameworks Enhance PPP contract design to avoid frequent renegotiation	Introduce enabling environment for investment exposed to climate shock risk	Well-designed capacity markets Financial contracts	Innovative business models/contracts
Unlock financing	Well-designed public finance mechanisms to leverage and unlock financing	Enhance investment climate addressing key risks and attract institutional investors Crowd-in non-traditional LTF	Credit enhancement, risk mitigation, and insurance products/ Instruments to hedge climate risk	Well-designed capacity markets/ auctions Turn infrastructure into an asset class	Consider output/ performance-based subsidies
Promote innovation **Entrepreneurial activity**	Develop national capacities and boost competitiveness Examine global role in clean energy trade, technologies and knowledge Leverage partnerships	Promote vision/cultural shift (Future Utilities) Embrace technology change and leapfrog	Build technical competencies Support national RD&D Promote knowledge Exchange	Open route for demand side entrepreneurs	Promote innovation/ entrepreneurial activity in rural areas (energy for economic growth and productive activity)
Promote consumer and citizen participation	Support the "entities" emerging to inform consumers and aggregate demand ("value added enablers") Develop energy/smart city platforms	Promote demand side management Communicate value-proposition of new products and services	Enable and develop energy and smart city platforms	Promote demand side management	Support community/rural economic growth/ productive activity Identify gender opportunities

Source: Prepared by authors.

ANNEX II.
Preparing for the Disruption

CHAPTER 9

TABLE 9A Indicative Actions

	Phase 1 Pre-conditions / Preparation	Phase 2. New Market Architecture
Policy makers	*Introduce clean energy policy goals* across value chain (renewable energy, energy efficiency/demand side management incentives). *Coordinate long-term energy contract auctions* with the regulator as entry mechanism for clean energy. *Mandate integrated planning and operation* of existing resources and emerging solutions (e.g. grid codes, T&D investments, storage, and other grid integration investments). *Introduce externality pricing* (emissions trading or carbon tax).	*Update/adjust goals.* *Assess effectiveness* of entry mechanisms. *Rely* on technological progress and market-priced credit enhancement to support competitive entry.
Regulators	*Introduce forward and intraday markets.* Forward markets reduce incumbent market power and will provide hedging in the more volatile decentralized trading platform of the future. More frequent dispatch will help capture the time value of intermittent energy. *Implement new tariff policies:* Nodal pricing will help monetize congestion reduction and other local energy services in mini- and pico-grids. Access pricing in distribution networks must reflect the future value of distribution services when bidirectional flows become frequent. *Encourage smart grid and metering for demand side participation and dynamic pricing.* Distribution firms should receive incentives to invest in smart grids and smart meters to support demand-side response (behind the meter) and intraday pricing. *Stage the first round of long-term contract auctions.* Lowest cost auctions for renewables entry will maximize competition and fair value for new investors. *Begin new business model pilot projects.* The energy regulator summons frequent meetings to foster, evaluate, and disseminate experiences with non-traditional business models, following leading practices such as those of the UK´s Ofgem.	*Build a new market architecture.* New entry, transactions, and classical network and Smart Grid remuneration rules to support the development of "Transactive Energy Models." *Foster consolidation of retail markets.* Digitalization will take place after smart grids and metering consolidate.
Financing and Risk Management Institutions	*Upgrade financing vehicles and credit enhancement.* This might include new asset classes, investment via specialized vehicles (such as YieldCos) and risk mitigation instruments (guarantees).	*Financing and risk markets mature for new energy.* Financial markets could offer credit enhancement products for assets that have zero marginal cost but high output volatility and face counterpart risk.
Smart City Platforms	*Contribute to developing the disruption ecosystem.* Nurture networks of prosumers, investors, equipment producers, and city government to identify new business models and tap into citizens´ entrepreneurship drive.	*Scale new energy deals.* Prosumer and investor networks reach a critical mass that supports a sustained deal flow in decentralized energy trading and services.

Source: Prepared by authors.