

# RENEWABLE ENERGY MARKET ANALYSIS

LATIN AMERICA



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## ABOUT IRENA

The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that supports countries in their transition to a sustainable energy future, and serves as the principal platform for international co-operation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy, in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity.

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Latin America hosts some of the world's most dynamic renewable energy markets, building on the historical role of hydropower – the cornerstone of the region's power sector development – and liquid biofuels, driven by Brazil's early determination to diversify its transport fuel mix.

Since 2004, renewable energy investment in the region (excluding large hydropower) has grown 11-fold, compared with a 6-fold increase worldwide. Investment trends attest to the rapid evolution of the region's energy mix towards a more diversified set of technologies and countries. For the first time in 2015, in addition to Brazil, both Mexico and Chile joined the list of the top 10 largest renewable energy markets globally.

In recent years, energy security has been a key driver for energy diversification to limit adverse macroeconomic effects due to the high reliance on fossil fuels and to reduce vulnerability to recurring climate events impacting hydropower generation. The imperative to decarbonise, together with national energy security concerns, in the context of rapidly falling costs of non-hydropower renewables, provides a compelling case for broader renewable energy development in Latin America.

Enabling policies have played a decisive role in the region's uptake of renewables. Policy instruments, from renewable power auctions, to solar thermal requirements, to biofuels blending mandates, have helped drive crucial cost reductions. Latin America boasts highly competitive development costs, notably for onshore wind and more recently, solar photovoltaic. In addition, policy makers increasingly recognise renewables as a catalyst for job creation, GDP growth, development of local industries, and energy access. For countries with high shares of hydropower, investment in non-hydropower renewables promises valuable complementarities – climatic, technical and economic – and greater power system reliability.

*Renewable Energy Market Analysis: Latin America* aims to capture the region's wealth of knowledge and draw key lessons from the region's experience. Building on earlier IRENA work, this ambitious report identifies emerging renewable energy trends and explores key themes at the intersection of public policy and market development.

Among those themes is the evolving investment landscape. While investment depends on country conditions, common factors – chiefly, access to funding and the cost of finance – underlie successful experiences across the region. The ability to leverage local capital, including from Latin America's strong national development banks, and to allocate risks between the public and private sectors, will be crucial to raise finance for renewables.

Energy security, environmental sustainability and economic competitiveness are all at stake in the region's delicate balancing act. With low technology costs, rapid policy learning curves and some of the world's best resources, rising energy demand presents an opportunity for the region to move to a more sustainable energy system based on higher shares of renewables.

Latin America's policies and achievements, furthermore, bring valuable insights for other renewable energy markets. IRENA's series of regional market analyses consolidates the growing knowledge on policies, finance, costs, benefits, resource potential, technologies and other dimensions into a coherent narrative. This report provides a strong basis to disseminate best practices for renewable energy development, both among countries in the region and in other regions that see comparable challenges and opportunities.



**Adnan Z. Amin**

*Director-General*  
IRENA



# RENEWABLE ENERGY MARKET ANALYSIS

**LATIN AMERICA**



Herve el agua, geothermal, Oaxaca, Mexico © sunsinger | Shutterstock.com

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## ABBREVIATIONS

<b>Box 4.4</b>	The early role of the IFC and the IDB as catalysers for wind power financing in Mexico. . . . .	87	<b>ABRAVA</b>	Associação Brasileira de Refrigeração, Ar Condicionado, Ventilação, Aquecimento (Brazilian Association of Refrigeration, Air Conditioned, Ventilation and Heating Services)
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			<b>ENSO</b>	El Niño – Southern Oscillation



<b>EPC</b>	Engineering, procurement and construction	<b>PPA</b>	Power purchase agreement
<b>EU</b>	European Union	<b>PPP</b>	Purchasing power parity
<b>FDI</b>	Foreign direct investment	<b>PV</b>	Photovoltaic
<b>FINEP</b>	Financiadora de Estudos e Projetos (Funding Authority for Studies and Projects; Brazil)	<b>R&amp;D</b>	Research and development
<b>GDF</b>	Geothermal Development Facility	<b>SCF</b>	Strategic Climate Fund
<b>GDP</b>	Gross domestic product	<b>SEM</b>	Sustainable Energy Marketplace
<b>GIZ</b>	Deutsche Gesellschaft für Internationale Zusammenarbeit (German Agency for International Cooperation)	<b>SENER</b>	Secretaría de Energía de México (Energy Secretariat of Mexico)
<b>GW</b>	Gigawatt	<b>SICA</b>	Sistema de la Integración Centroamericana (Central American Integration System)
<b>ICS</b>	Improved cook stove	<b>SIEPAC</b>	Sistema de Interconexión Eléctrica de los Países de América Central (Central American Electrical Interconnection System)
<b>IDB</b>	Inter-American Development Bank	<b>SINEA</b>	Sistema de Interconexión Eléctrica Andina (Andean Electrical Interconnection System)
<b>IEA</b>	International Energy Agency	<b>SREP</b>	Scaling up Renewable Energy in Low-Income Countries
<b>IFC</b>	International Finance Corporation	<b>SUDENE</b>	Superintendency for the Development of the Northeast (Brazil)
<b>INDC</b>	Intended Nationally Determined Contributions	<b>SWH</b>	Solar water heating
<b>IPO</b>	Initial public offering	<b>TFEC</b>	Total final energy consumption
<b>IRELP</b>	IRENA Renewable Energy Learning Partnership	<b>TPES</b>	Total primary energy supply
<b>IRENA</b>	International Renewable Energy Agency	<b>UK</b>	United Kingdom of Great Britain and Northern Ireland
<b>ISIC</b>	International Standard Industrial Classification	<b>UN</b>	United Nations
<b>KfW</b>	Kreditanstalt für Wiederaufbau (German Reconstruction Credit Institute)	<b>USA</b>	United States of America
<b>kW</b>	Kilowatt	<b>USD</b>	U.S. dollar
<b>LCOE</b>	Levelised cost of energy	<b>VAT</b>	Value-added tax
<b>LCR</b>	Liquidity coverage ratio	<b>WACC</b>	Weighted average cost of capital
<b>LNG</b>	Liquefied natural gas	<b>WITS</b>	World Integrated Trade Solution
<b>LPG</b>	Liquefied petroleum gas		
<b>MW</b>	Megawatt		
<b>NAFIN</b>	Nacional Financiera (National Development Bank of Mexico)		
<b>NAMA</b>	Nationally Appropriate Mitigation Actions		
<b>OECD</b>	Organisation for Economic Co-operation and Development		
<b>OPEC</b>	Organization of the Petroleum Exporting Countries		
<b>OPIC</b>	Overseas Private Investment Corporation		

A night-time photograph of the Panama City skyline, showing numerous high-rise buildings with lights on, overlooking the Bay of Panama. The image is framed by decorative geometric patterns in orange, blue, and white on the left and right sides.

# EXECUTIVE SUMMARY

Panama City, city center skyline and Bay of Panama, Panama © Alfredo Maiquez| Shutterstock.com

## TOWARDS A MORE DIVERSIFIED MIX OF TECHNOLOGIES AND COUNTRIES

Latin America<sup>1</sup> has seen significant investment in renewable energy in recent years, exceeding USD 80 billion over the period 2010-2015 (excluding large hydropower<sup>2</sup>). In 2015, total renewable energy investment in the region amounted to USD 16.4 billion, representing about 6% of the global total. The composition of these investments attests to the rapid evolution of the region's energy mix towards a more diversified portfolio of renewable energy sources (figure ES.1).

Between 2005 and 2009, Brazil accounted for over 70% of renewable energy investment, but since 2010 the gap between the top investment market and the rest of the region has been progressively narrowing. In 2015, investment in Brazil represented a little over 40% of the region's total, equivalent to USD 7.1 billion (Bloomberg New Energy Finance, 2016).

The second highest destination was Mexico, where renewable energy investment doubled

between 2014 and 2015 to reach USD 4 billion. Chile ranked third with USD 3.4 billion invested, a 150% growth from 2014. For the first time, in 2015, both Mexico and Chile joined Brazil on the list of the top 10 renewable energy markets globally. Uruguay comes fourth with investment of around USD 1.1 billion. After a record year in Central America in 2014, activity slowed down in 2015, with the notable exception of Honduras, the region's highest investment destination for renewables as a share of GDP. In addition, IRENA estimates total regional investment in large hydropower at USD 9 billion in 2015.

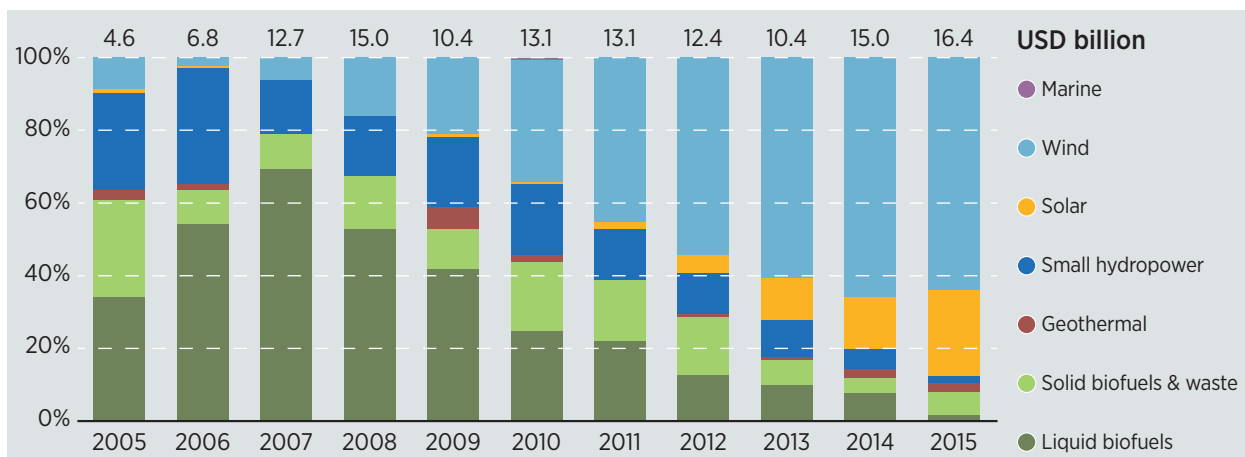
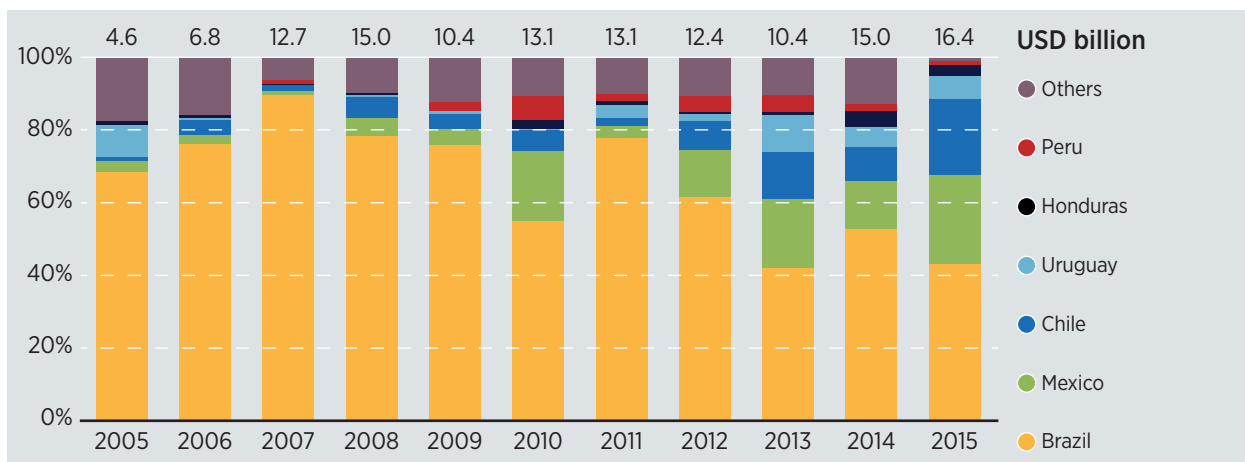
By technology, the trend over recent years reflects a decrease in investment in liquid biofuels, compensated by remarkable growth in wind investment and, more recently, solar. Lower investment in liquid biofuels in Brazil since 2008 is one of the reasons for the decline in aggregate investment between 2009 and 2013. In the past three years, surging investment in wind represented about two-thirds of renewable energy investment, excluding large hydropower, mostly led by

1. The five main sub-regions used in this report to highlight key trends are the following: Mexico; Central America (Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama); Andean States (Plurinational State of Bolivia, Colombia, Ecuador, Peru and Bolivarian Republic of Venezuela); Brazil; and Southern Cone (Argentina, Chile, Paraguay, and Uruguay).

2. Bloomberg New Energy Finance considers as large hydropower those plants larger than 50MW.



**Figure ES.1** Investment in renewable energy, 2010-2015: by country (top) and by technology (bottom)



Source: Bloomberg New Energy Finance, 2016

Brazil, Uruguay and more recently Mexico. Since 2012, the region has seen the emergence of solar photovoltaic (PV) as a significant focus of investment, mainly in Chile, Brazil and Mexico.

# ES

## LATIN AMERICA'S CHANGING ENERGY SUPPLY AND DEMAND PROFILE

Rapid growth in energy demand amid energy security concerns and increasing climate impacts present Latin American countries with an opportunity to rethink their energy mix. The region is endowed with vast energy resources, both fossil and renewables. The prominence of oil and gas in the region's energy mix largely derives from Latin America's role as a key oil and gas producer with some of the world's top 10 oil exporters. Oil, accounting for 46% of the region's primary energy supply (TPES) in 2013 (figure ES.2), holds a much higher share than the world average of 31%. Oil is used mainly in transport, while its use in other sectors has decreased. In the power sector, it has been substituted mainly by natural gas which makes up 23% of TPES.

At the same time, Latin America has one of the largest shares of renewables, deriving from the historical development of hydropower and bioenergy. Bioenergy is mainly used in the industrial and transport sectors, and its share in TPES has decreased since 1990, due to the declining use of solid biofuels in the residential sector. It accounted for 16% of TPES in 2013. The share of hydropower has been slowly but steadily declining since 1990, representing 8% of TPES in 2013 (figure ES.2).

Transport and industry dominate regional energy consumption. Transport represents a larger share than in other major regions of the world, due mainly to a less efficient vehicle fleet and differing modal composition. A higher energy use in industry partly reflects the economic structure of Latin America and the important role of energy-intensive industries, in particular extractive industries. The relatively small residential consumption is partly due to the lower use of space heating appliances due to mild weather.

However, the use of cooling in some sub-regions is rapidly increasing.

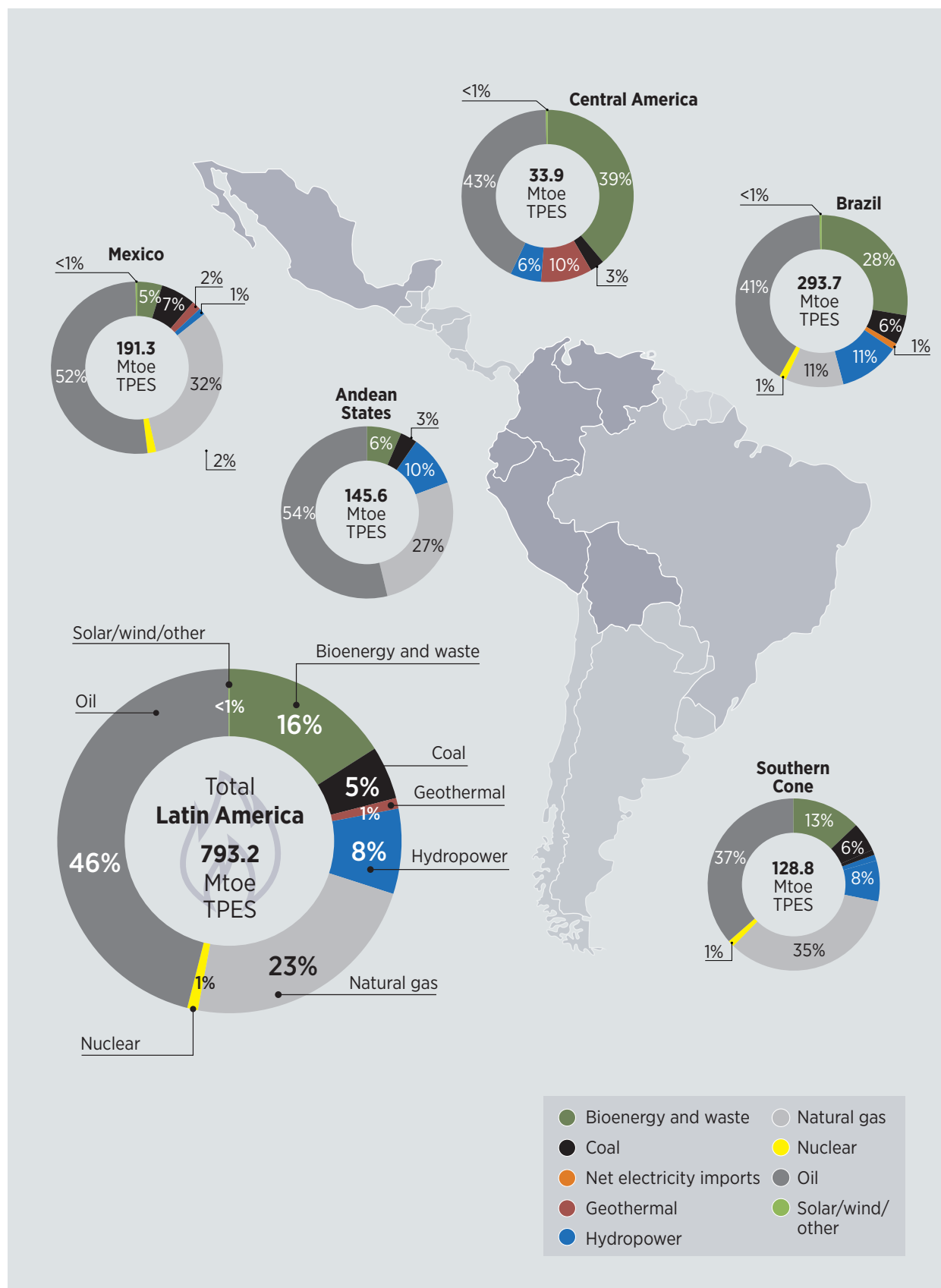
Power generation in Latin America has been expanding at a steady pace, and more than quadrupled between 1980 and 2013, increasing its contribution to total final energy consumption more than any other source. Electricity demand growth has been driven largely by economic growth, urbanisation, higher living standards and the successful expansion of electricity access, which currently reaches close to 95% of the population. While hydropower remains the main electricity generation source, natural gas and non-hydropower renewables are the fastest growing.

## THE RISE OF NON-HYDROPOWER RENEWABLES

A distinctive feature of Latin America's power generation mix is the predominance of hydropower, due largely to the high share in Brazil, which generates 40% of total regional electricity – almost twice as much as Mexico. However, the relative share of hydropower in total renewable capacity has been steadily declining, from 95% in 2000 to 83% in 2015, due to slower capacity additions and the concerns created by major droughts across the region. As a result, recent years have seen impressive growth in non-hydropower renewables, whose installed capacity has more than tripled between 2006 and 2015, from 10 GW to 36 GW (IRENA, 2016a; figure ES.3).

Bioenergy for power and onshore wind are the two technologies whose capacity has grown the most in absolute terms since 2000. The main bioenergy generation source is bagasse (sugarcane residue), primarily found in Brazil. Wind power is growing the most in Brazil, where a record capacity of 2.7 GW was commissioned in 2015 – almost three times the level installed in 2013. Mexico added 700 MW of wind power in 2015, doubling 2013 additions. Uruguay and Panama also significantly increased their wind capacity in 2015, with additions of 300 MW and 230 MW, respectively.

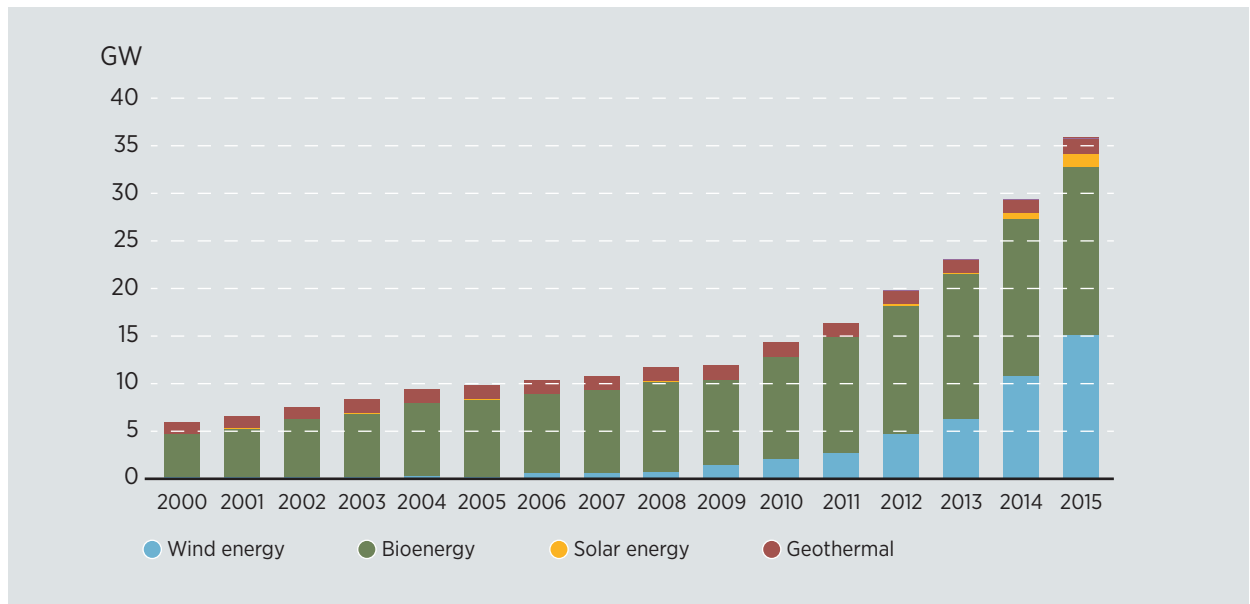
**Figure ES.2** Total primary energy supply by sub-region in 2013



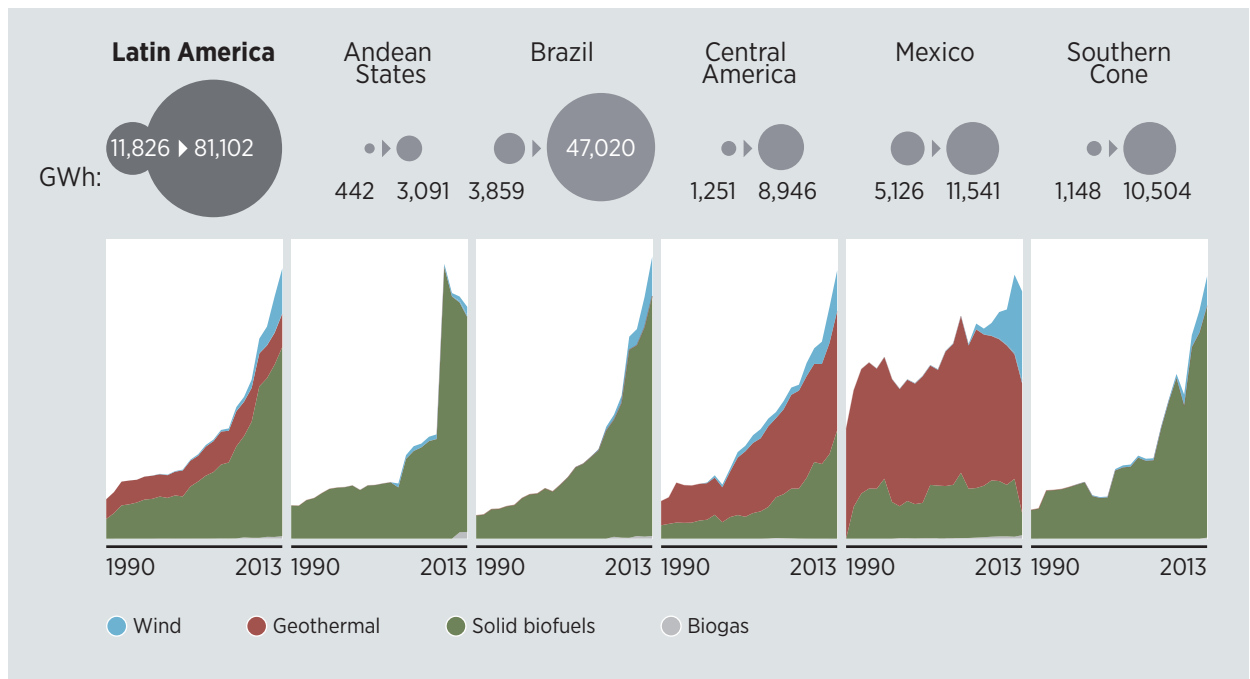
Source: IEA, 2015

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**Figure ES.3** Renewable power capacity (top) and generation (bottom), excluding large hydropower



Source: IRENA, 2016a



Source: IEA, 2015

The share of geothermal power in the region has remained stable in Mexico, Costa Rica, El Salvador and Nicaragua, with capacity growing at the same pace as overall renewable power capacity. Installed capacity of solar power (mainly PV) remains relatively small, but has grown significantly in recent years in Chile, Mexico, Peru and Uruguay.

The diversification towards non-hydropower renewables is also reflected at the sub-regional level (figure ES.3). All Latin American sub-regions show exponential growth for non-hydropower renewable electricity, despite significant local differences. These developments have created opportunities to benefit from complementarities between large hydropower and other renewable energy technologies.

## COMPLEMENTARITY BETWEEN HYDROPOWER AND OTHER RENEWABLES AS A LEVERAGING FACTOR

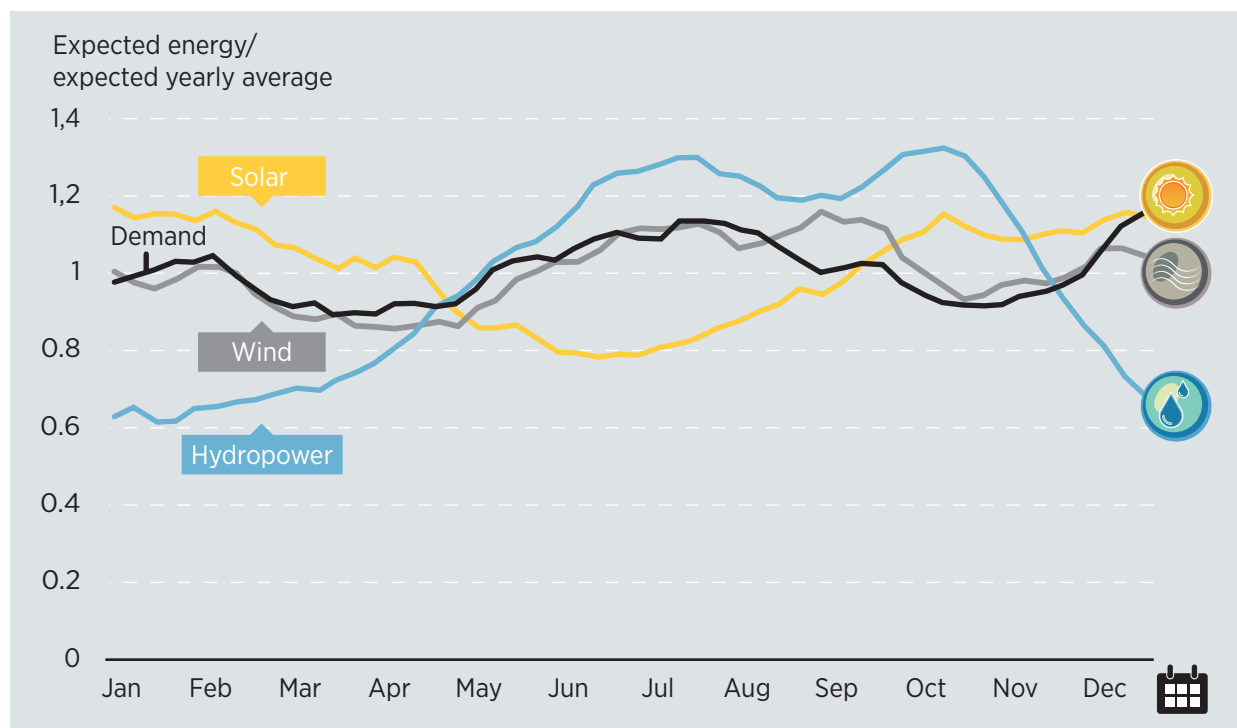
The high share of hydropower in the electricity mix of some Latin American countries (from 100% in Paraguay to 9% in Mexico, and averaging 50% for the whole region) creates opportunities for scaling up other renewable energy technologies, particularly by harnessing a range of complementarities. Chief among these are climate synergies (figure ES.4) (non-hydropower renewables can compensate reduced hydropower supply in dry seasons, recently exacerbated by climate variability); improved economic performance and reliability of power systems (hydropower with reservoirs can counteract the short-term variability, or store the excess production, of other renewables more cost-efficiently than alternatives like natural gas generation); and market entry opportunities for new, smaller players (through modular wind and solar generation).

While many synergies relate to hydropower and variable renewables (solar and wind), others ap-

ply to bioenergy and geothermal power, due to different generation patterns and technological characteristics. A well-developed electricity grid, connecting distant locations and ensuring enough transmission capacity, is key to harnessing these synergies. In addition, cross-border interconnections allow neighbouring countries (including those with lower hydropower shares) to benefit from complementarities. Importantly, exploiting the synergies in a sustainable manner requires paying close attention to the social and environmental impacts of large transmission and generation projects.

Several countries in the region possess valuable experience in exploiting some of the capabilities of hydropower with reservoirs, such as the provision of flexibility and storage capacity to the system. In the past, these flexible assets allowed to conveniently deal with many of the requirements of power sector management. Now, the increased recurrence of climate events, concerns about security of supply, rapid demand growth and the rising penetration of variable renewables

**Figure ES.4** Yearly complementarity between renewable energy sources and demand in Uruguay



Source: Chaer et al., 2014

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call for a more robust, comprehensive approach to power sector management.

Such an approach would internalise, in a systematic way, the value that the complementarities between hydropower and other renewables can bring by improving the system's reliability and economic efficiency. An understanding of the full range of complementarities can help identify those most relevant for each country with a view to improving policy and regulatory conditions.

### RENEWABLES AT THE CROSSROADS OF MULTIPLE DRIVERS

Since the late 2000s, Latin America has seen a rapid and more diversified development of renewable energy sources, favoured by the convergence of overall drivers at the crossroads of energy security, economic competitiveness, and social and environmental sustainability.

Fundamental among those is energy security, which takes on two main forms for the region's energy importers (*i.e.*, the majority of countries): the need to reduce the adverse economic effects of price volatility and the risk of supply disruptions. These risks are exacerbated by the expanded role of natural gas since the late 1990s. The prominent role of hydropower (half of regional generation) creates further energy security concerns, given the changes in hydrological cycles (such as those occurring in El Niño years). Taking advantage of existing complementarities with non-hydropower renewables, and technology cost reductions through the use of market-based policy instruments, energy diversification through renewables has been contributing to energy security while also ensuring more stable electricity prices.

Renewable energy sources also contribute to energy sector decarbonisation. Although low by global standards, Latin America's greenhouse gas emissions are growing steadily. The reduced local health and environmental impacts of renewable energy sources compared with fossil fuels, highly relevant to reduce urban pollution, are also an important benefit. In addition, because of their modular nature and more limited social

and environmental impacts, wind and solar PV generally have a significant advantage in terms of operational feasibility and social acceptability. The region faces growing popular resistance to large hydropower plants, resulting in delays of new projects.

More recently, the socio-economic benefits of renewables have become an important consideration for policy makers. These benefits include employment creation, the development of local value chains and access to modern energy. To bring about effective renewable deployment, these drivers need to translate into renewable energy targets, supporting policies and a broad enabling framework.

### ENABLING POLICIES CENTRAL TO DEPLOYMENT

The analysis of regional and sub-regional dynamics clearly demonstrates the crucial role of renewable energy policies at the centre of deployment. Highly dynamic, particularly in the current context of accelerated deployment and rapid cost declines, the renewable energy policy landscape is marked by increasing political commitment, diversity and sophistication. With more than 300 policies identified, support for renewable energy is found in virtually all countries in the region (IRENA, 2015a).

Fiscal incentives, regulatory instruments and financial mechanisms are widespread policies to promote renewable energy sources (figure ES.5), identified in most countries in the region, and across sectors. The most common power sector policies in the region include auctions, with over 54 renewable energy auctions identified in 12 countries, and grid access policies, identified in 13 countries. In the transport sector, biofuel blending mandates, identified in 10 countries, are the main policy instrument. For heating purposes, a small, but growing number of countries are adopting solar thermal mandates. Furthermore, renewable energy use in industry is growing, notably thanks to suitable contractual arrangements, the removal of price distortions and green labelling, which can open new market opportunities.



Enabling policies have played a decisive role in renewables investment. Some of the countries that attracted the highest investment levels in recent years – such as Brazil, Chile, Mexico and Uruguay – have received consistently high evaluations of their legal, institutional and administrative framework in investment surveys. This illustrates the variety of institutional, economic and regulatory conditions conducive to renewable energy investment in the region.

Countries with different degrees of power sector liberalisation, such as Chile or Brazil, ranked among the top destinations of renewable energy investments. Yet, top performers also include Uruguay and Costa Rica, which have vertically-integrated utilities and where private participation in the power sector follows the model of independent power producers.

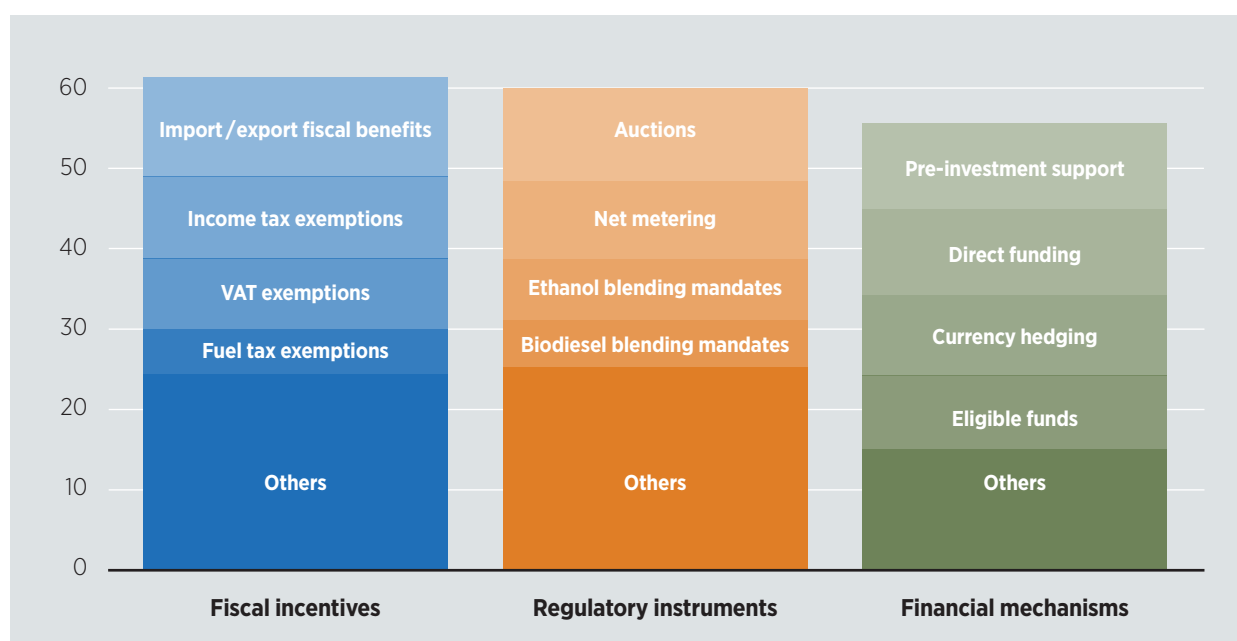
Therefore, the region demonstrates that there is no one-size-fits-all policy mix, and that regulatory stability and transparency are essential to enable the further development of market-based financing schemes for renewables. One of the main challenges for renewable energy deployment in

Latin America is to meet the increasing demand for capital at an affordable cost.

### KEY ROLE OF PUBLIC FINANCING INSTITUTIONS IN LATIN AMERICA

A notable characteristic of Latin America's renewables sector is the key role played by national public financing institutions to promote investment in renewable energy. In 2015, they accounted for over one-third of new clean energy project finance in Latin America. Among these, national development banks have been leaders in the provision of loans for the large-scale deployment of renewable energy in some Latin American countries, offering particularly attractive conditions and covering a large share of the demand for debt by project developers. As such, they have been instrumental in advancing public policy goals such as the development of domestic markets (Chile, Honduras, Nicaragua, Mexico) or the creation of local value chains (Brazil, Uruguay), notably by conditioning loans to the use of domestic workforce and locally manufactured equipment.

**Figure ES.5** Selected renewable energy policies in Latin America (number of countries having adopted each policy)



Source: IRENA, 2015a

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Public financing institutions play a crucial role to catalyse financing for renewable energy projects, notably by providing financial products targeted specifically at renewable energy such as dedicated credit lines, currency hedging, and guarantees. At least 14 Latin American countries have established renewable energy public funds, while 10 countries have currency hedging mechanisms and 6 have guarantees to mitigate investment risks. In addition, several national public finance institutions foster renewable energy technological advance in the region through grants and subsidised loans for research, development and demonstration projects.

In many Latin American countries without domestic public financing institutions, or with limited financing capability, foreign public financing institutions have been important sources of capital for investment in renewable energy. Among these, multilateral development banks and overseas development agencies have been influential in kick starting deployment of some renewable technologies by combining risk mitigation funds, dedicated investment credit lines with long-term tenors, and technical assistance (e.g., the Geothermal Development Facility). Multilateral development banks have also supported nascent off-grid markets (e.g., Nicaragua, Bolivia, and Argentina) and built related capacity, including for regulators, financial institutions and

developers across the region. Looking ahead, climate finance can support the accelerated deployment of renewables in Latin America by increasing the volume of capital and offering specialised expertise.

### RECENT EMERGENCE OF PRIVATE INVESTORS IN RENEWABLES

Private financing institutions (both domestic and foreign) have lately shown significant activity in the renewable energy sector in Latin America. These have been mostly concentrated in the more mature renewable energy technologies and markets in the region, including Brazil, Chile and Mexico, with increasing participation in countries considered stable economies with sound renewable energy policy mechanisms.

Private finance for renewable energy has a special role in certain niche segments such as short-term and bridge loans; refinancing; financing the acquisition of already operational assets; and mezzanine financing. Equity is a key component in the capital mix of renewable energy projects in Latin America, where the perceived financial risks require a higher share of equity. Latin American countries with more experience with renewables are currently witnessing an increased interest from infrastructure and pension funds, generally considered a sign of market maturity.



## CATALYSING PRIVATE FINANCE TO SCALE UP INVESTMENT

Public finance has limitations, in particular regarding the long-term sustainability of development policies and the potential impact on public accounts. An important means to address this gap is to use the available public capital as a catalyst for private finance.

When the enabling framework is in place, public financing institutions can leverage the participation of private institutions in the capital mix of renewable energy investments through a range of financial instruments, including dedicated credit lines and guarantees to mitigate lending risks, particularly in countries where there is already some interest from private investors in the sector. One such example is the credit line offered by Chile's Economic Development Agency to partially hedge risks of venture capital funds investing in renewable energy technologies. Another approach is through structured arrangements between public institutions and private commercial banks, in the form of syndicated loans (e.g., in Mexico), which help to decrease banks' exposure to risk and leverage national development banks' resources.

Although more risk mitigation and financial facilitation measures are needed, specific mitigation instruments should be used carefully and selectively to address well-defined market failures. Public sector financiers should give priority to risk mitigation aimed at mobilising private finance, but be selective when deciding to de-risk private sector investment in renewable energy (IRENA, 2016b).

Project planning is an important part of the renewable energy project cycle (IRENA, 2015b). However, this stage is often overlooked when designing policies, and more emphasis usually is given to the financing and operational phase of the enabling environment, assuming that attractive projects will be developed anyway. This is a critical bottleneck in Latin America as in other regions, and technical assistance and project development funding schemes therefore have an important role to play in ensuring bankable project pipelines.

Looking forward, access to capital markets will be decisive, as non-bank financing plays a crucial role in scaling up renewable energy investment to the level required to meet global climate goals. One promising approach to leverage institutional investor finance in Latin America would be to further develop the "financial value chain" so that developers, independent power producers, utilities and banks would have larger roles in construction stage financing, allowing them to then refinance operative assets after reaching the operational stage.

Lower financing costs and larger investment volumes combined with technological improvements and supply chain development are among key factors driving cost reductions.

## DECLINING COSTS AND GROWING BENEFITS BOOST THE CASE FOR RENEWABLES

Renewables in Latin America are making strides in terms of cost reductions and are increasingly competitive with fossil fuels (IRENA, 2016c). In Latin America, the levelised cost of electricity has decreased by over 50% for solar PV since 2012, and by around 20% for hydropower and onshore wind since 2010, ranking among the lowest globally. Hydropower has historically been, and still is, one of the most cost-efficient technologies in the region. The competitiveness of solar PV is contributing to achieving record-low prices, such as in the recent PV auctions in Mexico and Peru, with prices of 36 USD/MWh and 48 USD/MWh respectively for the lowest bids. These reductions are underpinned by technological progress, local supply chain development, resource quality, reduced financing costs and growing sector maturity.

In parallel with cost reductions, the socio-economic benefits of renewable energy technologies are gaining prominence in the region, as they are globally. Renewables create jobs, support local industrial development, and have the potential to boost the region's economies. According to IRENA analysis, ramping up renewables in line with REmap 2030 could lift the GDP of Brazil and Mexico by more than 1% in 2030. Such economic improvement would also lead to net job creation (IRENA, 2016d).

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As of today, close to two million people already work in renewables in the region (Figure ES.6). Liquid biofuels is the main employer, accounting for nearly 1 million jobs, mostly in Brazil, Colombia and Argentina. The next employer is large hydropower with more than half a million jobs, and wind at 64,000 jobs (IRENA, 2016e).

Renewables are also supporting the creation of local industries, especially if synergistic activities already exist, as the case of the Brazilian wind sector shows. This is an attractive proposition for a region with a relatively low contribution of manufacturing to GDP. Several countries such as Brazil, Ecuador, Honduras, Panama and Uruguay have combined deployment policies with local content requirements in order to maximise local value creation from renewables.

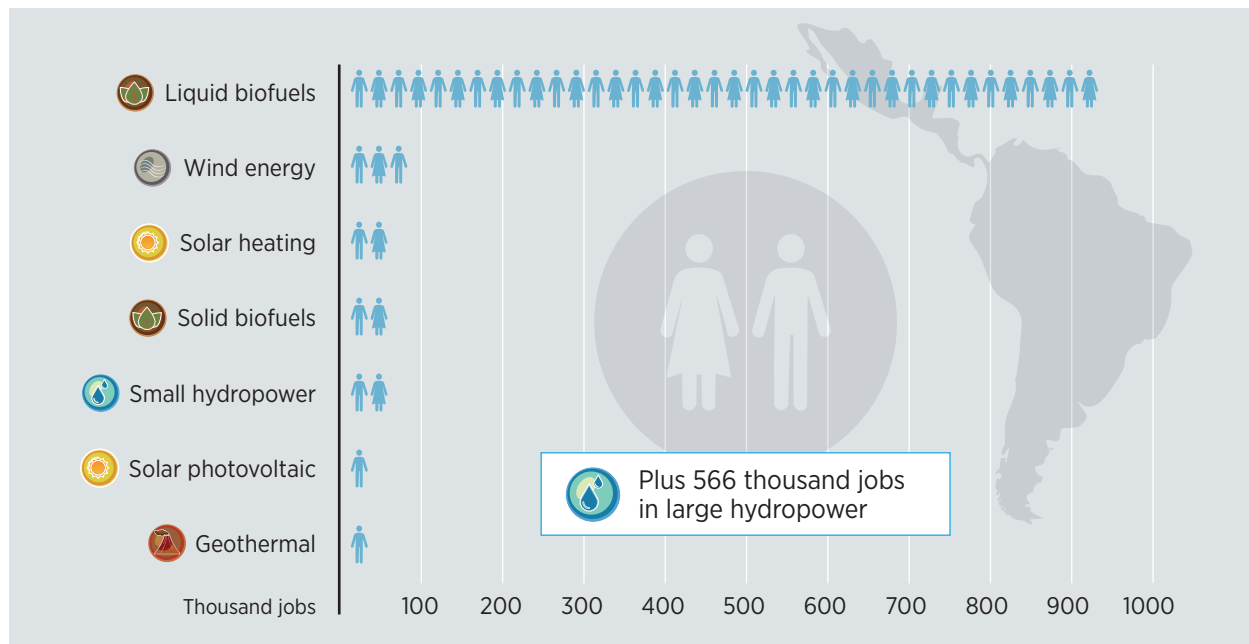
The potential for local value creation from renewable energy is not limited to large industries. In the rural context, off-grid renewables can encourage small-scale economic activity and entrepreneurship. Latin America is close to achieving universal energy access, yet 15 million people live without electricity and over 56 million people rely on traditional uses of solid biofuels for cooking and

heating. Recognising the importance of renewable energy technologies for energy access, at least 18 countries in the region have included them in energy access policies and at least nine countries have renewable energy funds for access.

The interlinkage between the water, energy and food supply systems is beginning to emerge as a major consideration in the region's sustainable development strategies, given the high shares of hydropower and bioenergy. Some renewables can play a key role in decoupling the energy sector from water availability and use. Several countries in the region are ensuring that biofuels production does not compete with food supply and are increasingly taking into account the trade-offs between different water and land-uses (IRENA, 2015c).

This report finds that rapid cost reductions, maturing renewable energy technologies and the consolidation of renewable energy policies in a region endowed with some of the world's best renewable resources offer an unprecedented opportunity to accelerate the uptake of renewables across all sectors. At stake is a balancing act between energy security, environmental sustainability and economic competitiveness.

**Figure ES.6** Renewable energy jobs per technology in Latin America (direct and indirect)

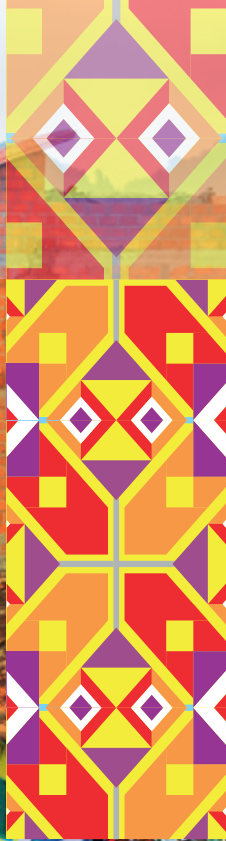


Source: IRENA, 2016e



# BACKGROUND AND ENERGY OVERVIEW

Cobblestone street in Guatapé, Antioquia, Colombia © Jess Kraft | Shutterstock.com





Latin America experienced a deep economic and social transformation in the last 20 years. Favourable external conditions and the implementation of market-oriented economic reforms fuelled economic output in the 20 countries of the region<sup>1</sup>, which grew more than high-income countries between 2005 and 2013. Sustained high commodity prices, combined with strong demand from China and other emerging economies during the past decade, were central for the region's growth. During the same period, Latin America has witnessed a steady decline in poverty and inequality and the advent of a burgeoning middle class, but these achievements need to be further enhanced.

However, the region's economic activity has gradually slowed down since 2011 on the back of declining commodity prices and weaker demand from China. The recent decline in external demand for Latin America's commodity exports is revealing the structural weakness of the region's commodity-based growth and points to the importance of economic diversification and par-

ticipation in global value chains (OECD/ECLAC/CAF, 2015). In addition, lagging investment in infrastructure for improved transport and energy services has contributed to the economic slowdown. And despite significant improvement, Latin America remains the most unequal region in the world in terms of income<sup>2</sup>.

Latin America is home to some of the largest oil exporters in the world (Brazil, Mexico and Venezuela, ranking 9th, 10th and 12th, respectively) and holds the second largest proven reserves in the world after the Middle East. Although the period of high commodity prices generated high oil revenues for some Latin American countries, this trend also exacerbated the impacts of energy dependency in some countries who import a large share of their oil. The presence of abundant resources, and South America's market liberalisations, triggered a period of high investment in natural gas, which contributed to the diversification of the region's electricity mix away from hydropower. The importance of bioenergy is a key historical feature of the region's energy mix,

1. The report focuses on 20 countries of continental Latin America, excluding the Caribbean: Argentina, Belize, Plurinational State of Bolivia (Bolivia), Brazil, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Guyana, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Suriname, Uruguay and Bolivarian Republic of Venezuela (Venezuela).

2. Measured through the Gini coefficient which is a "statistical measure of the degree of variation or inequality represented in a set of values, used especially in analysing income inequality: an increase in the Gini coefficient suggests that income is becoming more unevenly distributed".

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mainly driven by Brazil's sugarcane industry. Overall, Latin America's energy sector stands as a key pillar of the region's economic activity, with profound implications for domestic and regional dynamics.

Rapid growth in energy demand, in a region endowed with vast energy resources, presents Latin American countries with an opportunity to rethink their energy mix (IRENA, 2015; IDB, 2013). At stake is a balancing act between energy security, environmental sustainability and economic competitiveness. This report posits that rapid cost reductions, maturing technologies, the consolidation of renewable energy policies and vast untapped potentials for renewables offer an unprecedented opportunity to accelerate the uptake of renewable energy sources in the region.

This chapter examines Latin America's main economic and social trends to understand how energy supports the region's economic structure. The first section describes macroeconomic trends across the region and looks at the sectoral composition of Latin America's gross domestic product (GDP). It further introduces the region's social advances in terms of poverty reduction and discusses current challenges and opportunities looking ahead. The second section presents an overview of the region's energy sector by source and by end-use and highlights the main drivers shaping regional energy dynamics. The third section discusses the region's changing energy dynamics and sets the scene for the growing role of renewable energy.

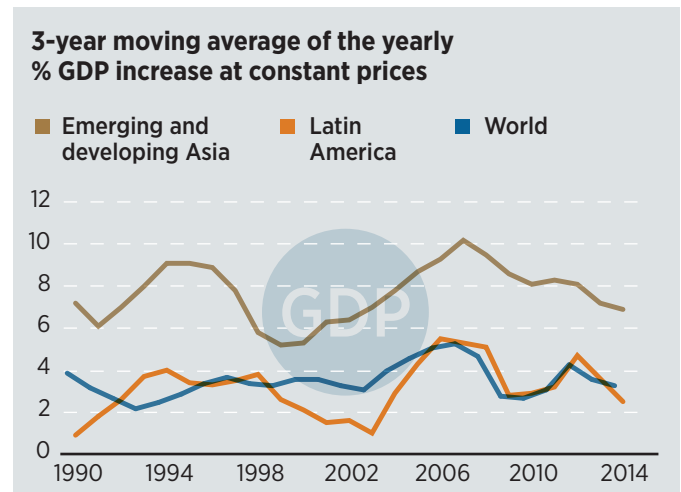


## 1.1 BACKGROUND

Following a decade of debt crises and severe inflation, the 1990s started with the adoption of the *Washington Consensus*, with countries in Latin America implementing a set of market-oriented reforms setting a sounder macroeconomic basis (Fraga, 2004; Rodrik, 2006).

The turn of the century was marked by a severe recession in Argentina, which had ripple effects in other countries in the region, notably Brazil. The rest of the first decade of the 2000s, and especially its second half, witnessed high economic growth (see figure 1.1), attributed mainly to a commodity boom fed by the growth in some emerging Asian economies, loose monetary policies in the United States and enabling socio-economic policies that supported middle-class consumption. The 2008 financial crisis affected mainly those countries with greater economic ties to the United States, such as Mexico and Central America, whereas economies linked to commodity ex-

**Figure 1.1** GDP growth in Latin America, emerging and developing Asia, and global average, 1990-2014



Source: IMF, 2015a

ports to Asian and other emerging economies were largely unaffected.

An important characteristic of the region is its high level of urbanisation, the highest in the world, with four-fifths of the population currently living in urban areas (see box 1.1). Latin American cities generate more than two-thirds of the



### Box 1.1 Key facts about Latin America's geography and demography

Latin America, comprising 20 countries, encompasses two hemispheres and covers 20 million square kilometres, equivalent to the surface area of China and the United States combined (World Bank, 2016a). The diversity of regions and climates ranges from the Atacama Desert, the driest desert in the world, to the tropical Amazon rainforests, and from the plains of Patagonia to the mountains of the Andes.

In 2014, Latin America had a total population of 584 million inhabitants, or 8% of the global population (World Bank, 2016a). In many Latin American countries, inhabitants tend to be concentrated in large cities, with very high population densities. For example, about 80% of the Brazilian population lives in a dozen cities only, with a very high density. Average population densities tend to be greater in Central America, with values comparable to Europe, whereas Argentina, for example, has very low densities, comparable to Saudi Arabia. The low population density brings specific challenges when providing rural energy access, which contrasts with the energy demands of high-density urban areas, such as São Paulo and Mexico City. These urbanisation patterns are a key characteristic of the region.

region's GDP, as they are home to industry and services (UN Habitat, 2013).

### Divergent macroeconomic trends across the region

Current Latin American GDP amounts to around USD 8 trillion, roughly half that of the United States, China or the European Union. A few countries constitute the bulk of the region's economy, with Argentina, Brazil, Chile, Colombia, Mexico, Peru and Venezuela accounting for 91% of GDP in 2014. Brazil and Mexico alone account for 62% of regional GDP (World Bank, 2016a).

Overall, between 1990 and 2014, Latin America's GDP more than doubled, in line with global GDP, keeping the contribution of Latin America to global GDP constant at around 9%. By comparison, the GDP of emerging and developing Asia grew six-fold, driven mainly by China. On a per capita basis, Latin America has a slightly higher

GDP than the world, but the global average has increased faster, driven by significant gains in China (World Bank, 2016a; IMF, 2015a).

In recent years, Latin America has been experiencing a slowdown in its GDP growth (see figure 1.1). In 2014, the region's average growth rate was lower than in high-income (OECD) countries for the first time in 10 years (World Bank, 2016a; OECD/ECLAC/CAF, 2015). Following a contraction in regional output in 2015, the region's overall growth in 2016 is expected to be negative for a second consecutive year. However, economic activity across the region may pick up again in 2017 as weaker currencies boost exports and as commodity prices recover gradually (IMF, 2016).

The region is characterised by significant heterogeneity, in line with countries' macroeconomic policies. Negative economic growth is driven mainly by Brazil's projected contraction of 3.8% in 2016 (-3.8% in 2015) (IMF, 2016) due to a combination of macroeconomic weaknesses and political turbulence, as well as by Venezuela's deepening recession, with output projected to shrink by 8% (-6% in 2015) due to longstanding fiscal imbalances and unsustainable policies. Argentina also is expected to contract by 1% in 2016 as a result of a macroeconomic overhaul following years of fiscal imbalances. Despite the regional recession, most countries are expected to continue to grow, albeit moderately (IMF, 2016).

Divergent trends also can be linked to trade patterns. Commodity-exporting countries in Latin America are facing significant losses in export revenues and weakening investment as demand from China and other emerging economies is slowing (see figure 1.1), and commodity prices have tumbled. Among the commodity-exporting countries, those that have implemented sound monetary and fiscal policies have so far avoided contraction (*e.g.*, Chile, Colombia and Peru). Mexico and Central American countries are continuing to grow, in part because they are manufacturing exporters integrated into the value chain of the US industry and are broadly benefiting from the US economic recovery as well as lower oil prices (The Economist, 2015; IMF, 2016). Latin America's economies therefore reveal the structural weak-

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## Services and extractive industries as pillars of GDP

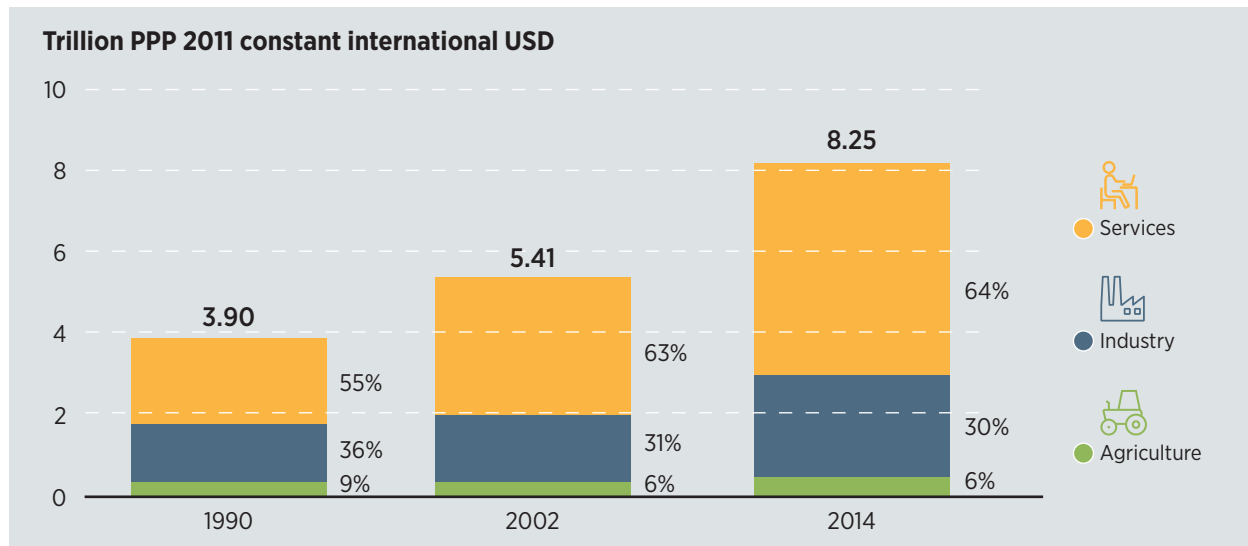
Since 1990, Latin America's GDP growth has been fuelled mostly by the services sector and by industry (see figure 1.2). Within industry<sup>3</sup>, non-manufacturing industries have seen the largest growth – notably related to commodity exports such as food and extractive industries<sup>4</sup>. Meanwhile, manufacturing industries and agriculture remained stable or even slightly decreased their contribution to total GDP (World Bank, 2016a). In 2014, services, industry and agriculture represented 64%, 30% and 6% of the region's GDP, respectively (World Bank, 2016a). These figures are in line with other regions at a similar level of development<sup>5</sup> (UNIDO, 2013).

The services sector accounted for 64% of the region's GDP in 2014 and represents the highest share of GDP in Brazil (69%), Costa Rica (69%)

and Panama (74%) (World Bank, 2016a). The sector is composed mainly of public administration, finance, tourism, transport and real estate. In 2014, the public administration sub-sector ranged from 23% of GDP in Argentina to 12% in Panama, while finance accounts for 24% of GDP in Chile and Panama, and 6% in Peru. The total contribution of tourism to the region's GDP was over 9% and is forecast to continue to grow (WTTC, 2015). Across the region, the revenues from tourism have grown by 50% in the last decade (IDB, 2016a).

Industry represented 30% of the region's GDP in 2014. The largest contribution of industry to GDP is in countries such as Venezuela, Ecuador and Bolivia, although this is due largely to extractive industries and not to manufacturing. At a regional level, the share of manufacturing within overall industrial activity is significantly lower than in comparable regions (UNIDO, 2013). This is due in part to the recent decline of manufacturing in the region, but also to the fact that non-manufacturing industries (notably those related to extractive industries) have a prominent role.

**Figure 1.2** GDP in Latin America in 1990, 2002 and 2014



Source: World Bank, 2016a

3. As per the World Bank's definition, "industry" comprises manufacturing, mining, construction, electricity, water and natural gas. A sub-classification of "industry" that is useful in this report includes two main sub-categories: "manufacturing industry" and "non-manufacturing industry" (which includes all the rest). These sectors correspond to International Standard Industrial Classification (ISIC) divisions 10-45. Manufacturing alone includes ISIC divisions 15-37. The ISIC divisions refer to ISIC Rev.3.

4. Including mining of fossil fuels, metal ores and other mining and extractive industries.

5. Measured as GDP per capita.

The countries where the agricultural sector represents a greater share of the GDP tend to be those with lower levels of GDP per capita, namely Bolivia, Central American countries and Paraguay. The agricultural production of the region predominantly includes meat, coffee, corn, sugar and soya, most of which, as global commodities, have also seen price declines in recent years (OECD/ECLAC/CAF, 2015).

The region is rich in natural resources, as attested by the important role of industries involved in resource exploitation. In terms of minerals, South America has two-thirds of the global reserves of lithium and around 40% of those of silver and copper (ECLAC & UNASUR, 2013). The region has vast oil and gas reserves, such as in the Orinoco Oil Belt in Venezuela and the Santos basin in Brazil (see section 1.2). As a result, the total contribution of natural resources to regional GDP is high, up to 30% in Venezuela and 18% in Chile, compared to 48% in Saudi Arabia and 5% on average globally (World Bank, 2016a).

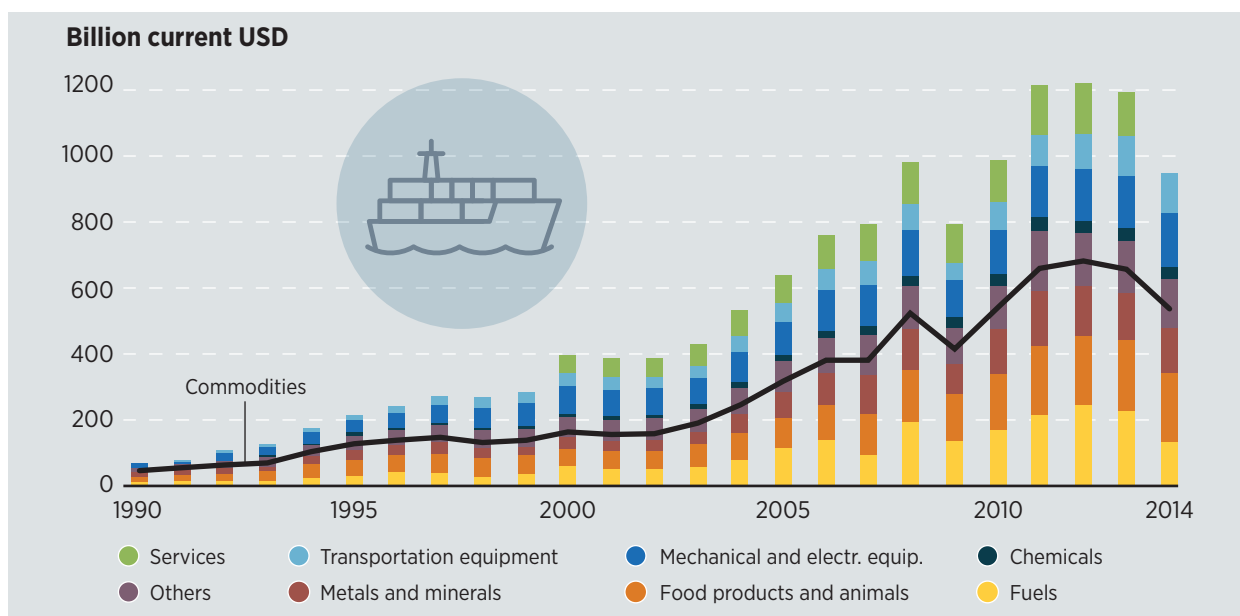
Latin America has become a key commodity exporter, especially to Asia and Europe. Total exports of goods and services more than doubled

during the 2000s, with food products, minerals, metals and fuels making up around half of these and contributing greatly to economic growth (see figure 1.3). Consequently, in 2011, 60% of goods exported (in value terms) were commodities, compared to 40% in 2000 (ECLAC, 2015a). The value of exports increased mainly because of higher prices, not larger volumes (OECD/ECLAC/CAF, 2013). The subsequent fall in global commodity prices over the last two years has meant a significant decline in the value of Latin American exports (WITS, 2015), representing about a 30 to 50% decline relative to peak prices, depending on the country.

### Social advances, challenges and opportunities

The economic growth in the region has resulted in higher employment and wages and has raised the proportion of formal jobs with social benefits (ECLAC/ILO, 2012). These, together with public policies aimed at reducing inequality within the population, such as expanded education and health services, cash transfer programmes and higher pensions, have brought significant societal change in Latin America. Accordingly, the middle

**Figure 1.3** Value of exports of goods and services from Latin America



Notes: "Services" data only available from 2000 to 2013. "Others" includes wood, textiles and clothing, stone and glass, plastic or rubber, hides and skins, footwear and miscellaneous according to WITS classification.

Source: WITS, 2015; UN Statistics Division, 2015

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class<sup>6</sup> grew by 50% between 2003 and 2009, to account for 30% of the region's population (Ferreira *et al.*, 2013; World Bank, 2013a).

Although income inequality in Latin America has fallen in recent years, the region still has the highest inequality in the world. The Gini coefficient has declined steadily from a peak of almost 0.6 in 1996 to 0.5 in 2012, the lowest in 30 years, but important inequalities remain between countries within the region (World Bank, 2013a; The Economist, 2012). The current economic slowdown is creating difficult trade-offs between poverty reduction policies and tightening government budgets (World Bank, 2016a).

Targeted policy interventions in the region towards poverty reduction, such as Brazil's "Bolsa Familia" and Mexico's "Cruzada Nacional contra el Hambre", have helped bridge inequality through improvements in secondary education and healthcare access. Public spending has risen at the regional level since 1990, from 11% to almost 18% of GDP in 2009, with a focus on social protection, health and education (Prado, 2013). Marked improvements in access to education have been achieved in the region. Free primary education is legally guaranteed in most countries, and primary enrolment is nearly universal (with rates similar to those in the OECD). However, the quality of education and training requires further policy attention (OECD/ECLAC/CAF, 2015) to improve the region's productivity, notably by strengthening workers' skills.

Similarly, access to health services has been a priority in government policies and has seen significant advances. Examples include Costa Rica, which has increased life expectancy and lowered infant mortality to levels comparable to Western Europe, and Chile, where the Social Health Insurance programme allows for nearly universal healthcare coverage (World Bank, 2013b).

These social policy interventions have been most successful at the bottom of the pyramid, reducing extreme poverty from 26% to 13% in the re-

gion between 1995 and 2011 (World Bank, 2013a). However, around 80 million people still live in poverty (World Bank, 2013a).

In the context of the current economic slowdown and tightening government budgets, further improvements in equality will prove challenging. This is especially true given other competing policy areas that require public expenditure in a region where the burgeoning urban middle classes are demanding greater personal security, improved local environments, better jobs, and enhanced public services and infrastructure (OECD/ECLAC/CAF, 2013).

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***The middle class grew by 50% between 2003 and 2009, to account for 30% of the region's population.***

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Latin America's productivity gains have been lower than those of other regions (IDB, 2014a; OECD/ECLAC/CAF, 2015). The proceeds from commodity exports have been used mainly for consumption and imports, rather than for productive investments (Perry and Forero, 2014). As a result, infrastructure, quality of public services, human capital and innovation have improved only marginally (Talvi, 2014; ECLAC, 2015a). Latin America could capture further local value from its natural resource exports (*e.g.*, through processing) and play a larger role in global value chains (The Economist, 2015; ECLAC, 2015a; OECD/ECLAC/CAF, 2015).

The region has some important strengths that can help it surpass current challenges. To name a few, trade integration is slowly becoming a reality, for example through the creation of the Pacific Alliance, which encompasses 36% of the region's population and 35% of its GDP (Ramírez, 2013). The region's sound macroeconomic performance has resulted in improved credit ratings (Ruiz, 2014; Talvi, 2014; Vanham, 2015; Naim 2014) and has opened space for monetary and fiscal expan-

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6. Ferreira *et al.*, (2013) uses as middle-class thresholds the values of PPP USD 10 and PPP USD 50 of income per capita per day.

sion, such as in Chile and Peru (OECD/ECLAC/CAF, 2013). Economic diversification has progressed in some countries, although the GDP contribution of commodity exports has grown less than in other regions (UNDP, 2011).

A key enabling feature of future growth in the region will be investment, which historically has been relatively low at 23% of GDP, compared to values of 30 to 40% in the rapidly growing region of Southeast Asia (The Economist, 2015; Prado, 2013; World Bank, 2016a). The share of total Latin American investment going to infrastructure represents a mere 3% of GDP (The Economist, 2015). In order to meet the growing demand for infrastructure, the region will require an annual investment of at least 5% of GDP up to 2020 (ECLAC, 2011). As it stands, roads are deteriorating, logistic capabilities are limited, and railways are scarce. Additionally, regional energy infrastructure lacks capacity given the increased demand that has occurred with recent economic growth.

In a region endowed with vast energy resources, future growth and development will depend highly on development of the energy sector. Development plans in some countries in the region suggest that a large share of the anticipated demand for energy could be supplied with fossil fuel sources and hydropower (IDB, 2013). However, the mounting climate change imperative, combined with the structural volatility of fossil fuel prices and the rapidly falling cost of renewable energy technologies present Latin American countries with an opportunity to redefine their energy mix.

## 1.2 ENERGY OVERVIEW

In the last decade, many Latin American countries benefited from rising commodity prices, which helped to increase oil export revenues. This period of relatively high oil prices played an important role in fiscal and redistributive policies in the region's main oil-exporting countries (Mexico, Venezuela, Colombia and Ecuador). On the whole, Latin America is a net oil-exporting re-

gion, but once Venezuela, Mexico and Brazil are excluded, it is a net oil importer. Beyond widely different country conditions, the energy sector is a key pillar of the region's economic activity, with profound implications for domestic and regional dynamics.

This section presents an overview of the region's energy sector and highlights the main drivers shaping regional energy dynamics.

### Enduring predominance of oil in primary energy supply

Historically, Latin America has been a key oil and gas producer. Venezuela was one of the five founding countries of the Organization of the Petroleum Exporting Countries (OPEC) in 1960. The region holds 20% of the world's total proven oil reserves, ranking second only behind the Middle East in reserves (BP, 2015). Latin America's oil reserves have increased substantially in the last decades, for two main reasons. First was the discovery and reclassification of bitumen as heavy crude oil in the Venezuelan Orinoco Belt. Second, albeit to a lesser extent, was the discovery of deep-water crude oil in the Brazilian offshore pre-salt<sup>7</sup> fields, notably in the Santos basin, one of the largest discoveries in the world in the last 30 years, which have contributed to Brazil's goal of net self-sufficiency in oil.

Except for Venezuelan heavy oil from the Orinoco Belt<sup>8</sup>, the region does not hold large unconventional oil reserves. Crude oil extraction in the region has remained at the same level since the late 1990s, due mainly to stagnating production in the two major producing countries (Venezuela and Mexico) and resulting from insufficient investment in exploration and production, which was not compensated by higher production in countries such as Brazil and Colombia (BP, 2015).

Latin America's natural gas reserves are smaller than those of oil (only 4% of global reserves as of 2013, compared to 20% for oil) and are located mostly in Venezuela and associated with oil<sup>9</sup> (BP, 2015). However, Argentina, Mexico and Brazil

7. These large oil deposits are called "pre-salt" because they predate the geological formation of a thick salt layer, which can reach up to 2,000 metres, itself below a layer of rock approximately 2,000 metres deep, lying under 2,000-3,000 metres of the Atlantic Ocean.

8. Some sources (e.g., BP) consider heavy oil as conventional, while other sources (e.g., IEA) consider it as unconventional.

9. When natural gas is a by-product of crude oil extraction.

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potentially hold significant unconventional natural gas resources.<sup>10</sup> The presence of abundant resources, and South America's market liberalisations in the 1990s, triggered a period of high investment in natural gas, with Argentina and Bolivia rapidly increasing production and building pipelines to export to neighbouring countries. In the last decade, however, due to unsound economic policies, the region increasingly has relied on international gas imports in the form of liquefied natural gas (LNG), and regional natural gas pipeline infrastructure has stalled. To benefit from its natural gas resources, the region will require more-coherent long-term planning and institutional co-ordination at the country and regional levels (Rudnick *et al.*, 2014).

Most coal reserves in the region are located in Colombia and Brazil. The quality of Colombia's coal is superior, with high energy content (Steiner & Vallejo, 2010). Coal mining in the region takes place mainly in Colombia, where it has quintupled in the last two decades (mostly for exports), making Colombia amongst the world's top five net coal exporters (IEA, 2015a). Coal also is mined in the south of Brazil, where large, low-grade coal reserves are used for power generation. The use of coal within the region is overall low, mostly for heavy industries and power generation.

The total primary energy supply (TPES) in Latin America<sup>11</sup> almost doubled in the last two decades as a result of population growth and economic development (see figure 1.4). Total per capita primary energy use in the region has grown significantly, but remains 30% below the global average (World Bank, 2016a).

Due in part to Latin America's historical role as a producer, oil is the main source of TPES, followed by natural gas, bioenergy and hydropower. At 46% of TPES in 2013, oil's share is similar to that in OPEC countries and is much higher than the world average of 31% (IEA, 2015b). Oil is used

mainly in transport (more than 50% of its use), while its use in other sectors has decreased, particularly in power generation where it has been substituted mainly by gas. Natural gas accounted for 23% of the region's TPES in 2013 (compared to a 21% global average), and bioenergy accounted for 16% (compared to 10% globally). Bioenergy is a key energy characteristic of the region, used in the industrial and transport sectors, but its share has decreased since 1990, due mainly to the declining use of solid biofuels in the residential sector. Hydropower has remained constant at a share of 8% of TPES, a level four times higher than the global average (IEA, 2015b).

Coal (employed mainly for power generation and heavy industry) and nuclear are much smaller, maintaining a stable share since 1990. The share of other renewable sources in TPES, while relatively limited in 2013, has since been growing rapidly, thanks mainly to geothermal energy (in Central America and Mexico) and wind (throughout the whole region) (IEA, 2015b).

A sub-regional overview<sup>12</sup> highlights key differences across the energy mixes (see figure 1.4). In the Andean States, the share of fossil fuels is the second largest after Mexico. Oil products are used in the transport and industrial sectors (mainly in Venezuela and Colombia) and for power generation (primarily in Venezuela and Ecuador). Natural gas is dominant in power generation (mainly in Venezuela and Peru) and in industry (notably in Venezuela). The substantial decrease in the use of solid biofuels in Colombia's residential sector explains the decline in bioenergy use in this sub-region since 1990 (IEA, 2015b).

Brazil's energy mix is characterised by the predominance of oil followed by bioenergy, in which the country is a historical leader (see box 1.2) (IEA, 2015b).

The share of natural gas has increased in Brazil's TPES, used mainly for power generation and in-

10. According to the U.S. Energy Information Administration, unconventional gas reserves in Latin America could amount to more than 45 trillion cubic metres, almost twice those of the United States.

11. The IEA data used for this analysis do not contain information on Belize, Guyana and Suriname, so these three countries were excluded.

12. The five main sub-regions used in this report to highlight key trends are the following: i) Mexico; ii) Central America (Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama); Andean States (Bolivia, Colombia, Ecuador, Peru and Venezuela); Brazil, Southern Cone (Argentina, Chile, Paraguay, and Uruguay). Renewable energy developments in Guyana and Suriname are discussed in following chapters.

dustry. Electricity imports, mainly from Paraguay, have remained stable (relative to TPES) and represent one of the largest electricity exchanges in the world. The Itaipu Dam bordering Brazil and Paraguay is the world's second largest hydro-power plant in installed capacity, after the Three Gorges Dam in China. The capacity is owned in equal shares by the two countries. Paraguay covers over three-quarters of its electricity from its generating units and exports the rest to Brazil (Vice-Ministry of Energy and Mines of Paraguay, 2014).

The energy mix in Central America is dominated by oil products (43% of TPES in 2013), used mainly for transportation and power generation, and by solid biofuels (primarily fuelwood) for residential uses (cooking). The high share of solid biofuels for cooking is more pronounced in the rural areas of Guatemala, Honduras and Nicaragua. Since 1990, the use of oil products has increased mainly for power generation, transport and as a substitute to traditional solid biofuels for cooking (mainly LPG<sup>13</sup>). More recently, the use of bioenergy has increased again, mainly traditional solid

### Box 1.2 The importance of bioenergy in Brazil

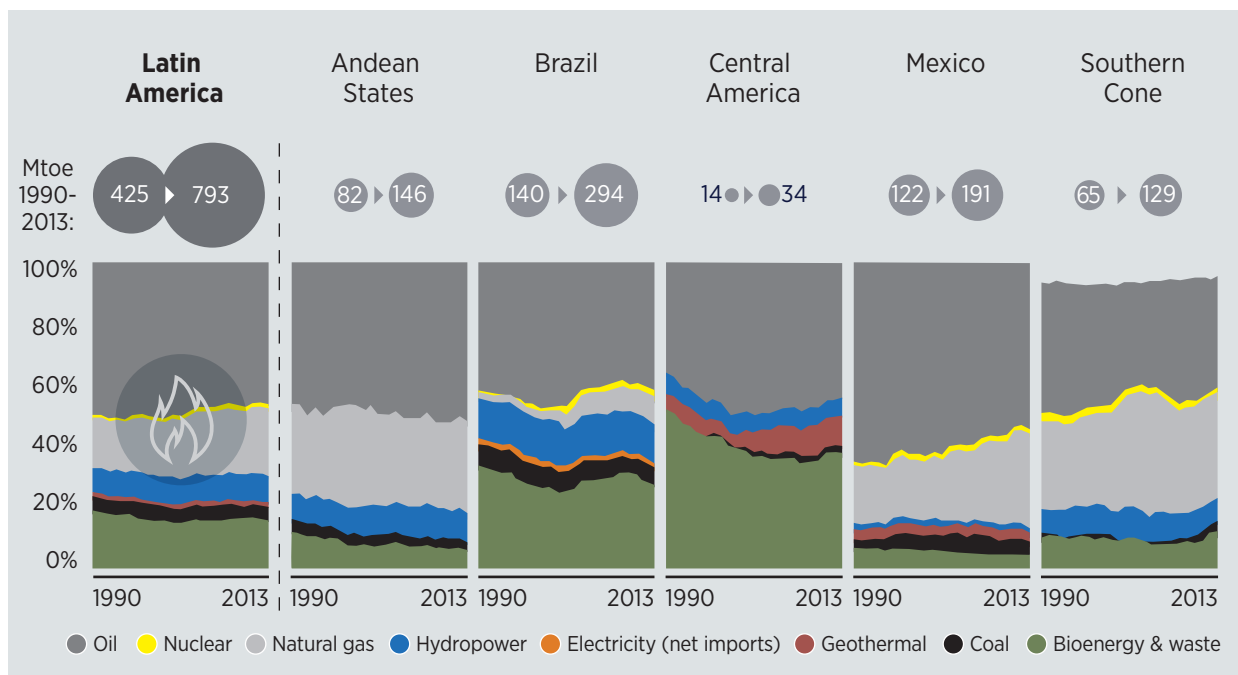
Brazil is the main consumer of modern bioenergy in Latin America, and one of the largest globally. Its main applications are co-generation fired with solid biofuels (mainly sugarcane bagasse), charcoal for industrial uses and sugarcane ethanol for transport. The latter deserves special attention, since it results from the country's historical policy to diversify its transport fuel mix since the first oil shock in 1973.

Due to lower government support to the ethanol industry, the use of ethanol decreased between 1990 and the early 2000s. In the mid-2000s, the deregulation of the industry and the introduction of flexible-fuel cars gave new momentum to the market and increased the availability of bagasse for power generation.

The trend reversed again in the late 2000s, due to an economic crisis in the sector which resulted in part from efforts to keep retail gasoline prices artificially low to fight inflation.

Sources: IEA, 2015b; Walter and Dolzan, 2014

**Figure 1.4** Total primary energy supply (TPES) by energy source in Latin America and the sub-regions, 1990-2013



Note: the values for the Southern Cone do not add up to 100% because of net exports of electricity from Paraguay to Brazil.  
Source: IEA, 2015b

13. Liquefied petroleum gases (e.g., butane or propane), a type of oil product.

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biofuels (cheaper than LPG in residential applications) and residues (biogas and bagasse co-generation in the sugar industry).

The growth of oil products has slowed in Central America since the early 2000s as a result of growing renewable electricity production (hydropower, geothermal, solid biofuels, wind and, since 2014, solar photovoltaics, PV), a moderate diversification into coal for power generation (especially in Guatemala and to a lesser extent in Honduras and Panama) and energy efficiency programmes in response to high oil prices. Geothermal energy is used for power generation in some countries in Central America and has increased (nearly five-fold since 1990), notably in El Salvador, the country with the second largest geothermal generation share after Iceland (IEA, 2015b), and in Costa Rica.

Mexico has the highest share of fossil fuels in the region, driven largely by its historical role as a producer. The country has diversified its energy mix through the increased use of natural gas to replace oil, mainly for industry and for power generation. Meanwhile, bioenergy use has been



reduced due to the lower demand in the residential sector and in the food and tobacco industry. Geothermal and hydropower, both for electricity generation, have remained largely constant in relative terms between 1990 and 2013 (IEA, 2015b).

Finally, the share of natural gas in the Southern Cone has increased, driven largely by Argentina, specifically for power generation, residential use and transport. Argentina has one of the highest shares of natural gas vehicles in the world, representing about 25% of the country's total fleet<sup>14</sup> (IEA, 2010). The surge in bioenergy supply in the last few years is explained by its use in Chile's paper industry and residential sector, by biodiesel production in Argentina, and, at a smaller scale, by wood use in Paraguay and bioenergy for industry in Uruguay (IEA, 2015b).

### Growing role of electricity in final energy consumption

Power generation in Latin America has been growing at a steady pace and more than quadrupled from 1980 to 2013, increasing its contribution in total final energy consumption more than any other source (IEA, 2015b). Electricity demand increases have been driven largely by economic growth, urbanisation, higher living standards and the successful expansion of electricity access, which currently reaches close to 95% of the population<sup>15</sup> (IEA, 2015c).

A distinctive feature of Latin America's power generation mix is the predominance of hydropower, due largely to the high share in Brazil (see figure 1.5) (IEA, 2015b). Since 1990, the share of all renewable technologies in the region's power mix has fallen from 64% to 55%, due mainly to the growth in natural gas-powered generation in a period of abundant and competitive gas supply to meet fast-growing electricity demand. Although not visible at the level of the region's TPES (see figure 1.4), a notable trend is that the share of hydropower generation decreased from 67% in 1990 to 50% in 2013 due to slower capacity additions and the effect of major droughts. As

14. Among the Andean States, Colombia also has a high share of natural gas vehicles, representing around 25% of the country's total fleet.

15. Significantly lower electrification rates remain in some Central American countries as well as in Bolivia and Peru (IEA, 2015c).



a result, the power mix of the region has diversified through natural gas generation, which now ranks second, growing from 10% of power generation in 1990 to 26% in 2013 (IEA, 2015b).

Natural gas and renewables other than hydropower are the fastest growing energy sources for electricity generation in the region, as illustrated in figure 1.6. The graph also shows the large role of Brazil in the region's total electricity generation: Brazil generates 40% of regional electricity, almost twice as much as Mexico (IEA, 2015b).

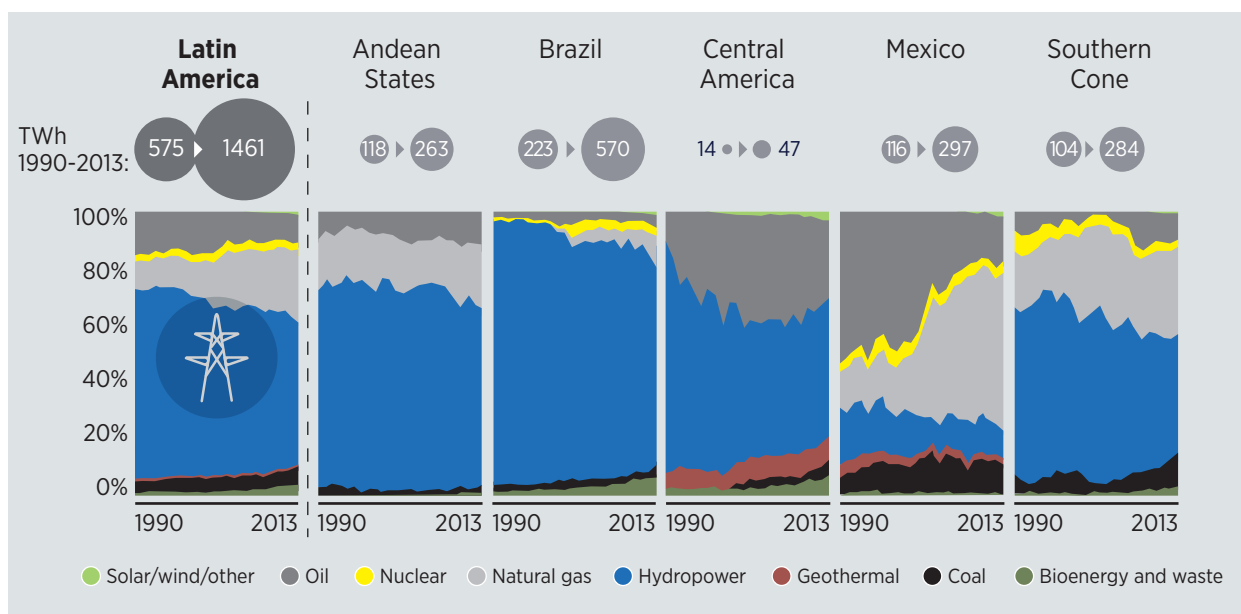
Hydropower is the main electricity source in four of the five sub-regions, reaching high shares in some countries (100% in Paraguay, nearly 75% in Brazil and around 70% in Colombia, Venezuela and Costa Rica). In the Andean States, natural gas and oil are gaining importance and already contribute more than one-third of power generation (natural gas is the main source in Bolivia and the second in Venezuela, Colombia and Peru). The contribution of hydropower is also declining in Brazil, especially given recurrent droughts (two important droughts have occurred in Brazil since 1990, which is reflected in the overall regional hydropower generation shown in figure 1.6). Bioenergy, natural gas and wind are filling the gap.

In Central America, the contribution of hydropower decreased until 2000 and has remained stable since, with oil declining due to the larger share of coal and non-hydropower renewables (which are the second largest power source in Costa Rica, El Salvador, Guatemala and Nicaragua). Fossil fuels dominate the Mexican power mix, with natural gas substituting oil in the last years, while the role of hydropower has declined slightly. Nuclear and coal remain stable. In the Southern Cone, natural gas-fired generation has increased steadily, as have, more recently, coal and oil, reducing the relative contribution of hydropower (IEA, 2015b).

The expansion of the infrastructure supporting power transmission and distribution has been shaped by a number of key features: the large surfaces that need to be covered (e.g., the power grid in Brazil alone covers a surface equivalent to the whole European network), the geophysical challenges (e.g., the Andes mountain range and the Amazon) and the large distances between electricity demand and supply centres (e.g., hydropower stations).

More recently, power grids in Latin America have faced the challenges of rapidly increasing demand, a certain degree of fragmentation (due in

**Figure 1.5** Electricity generation by energy source in Latin America and the sub-regions, 1990-2013



Source: IEA, 2015b

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part to the physical characteristics mentioned), some degree of ageing, and losses, among others. Access to grids is a key challenge for the expansion of power generation in some countries and, in particular, for the penetration of renewable energy sources. Nevertheless, the region has been at the forefront of implementing innovative mechanisms and initiatives for grid operation, expansion and cross-border integration (see box 1.3).

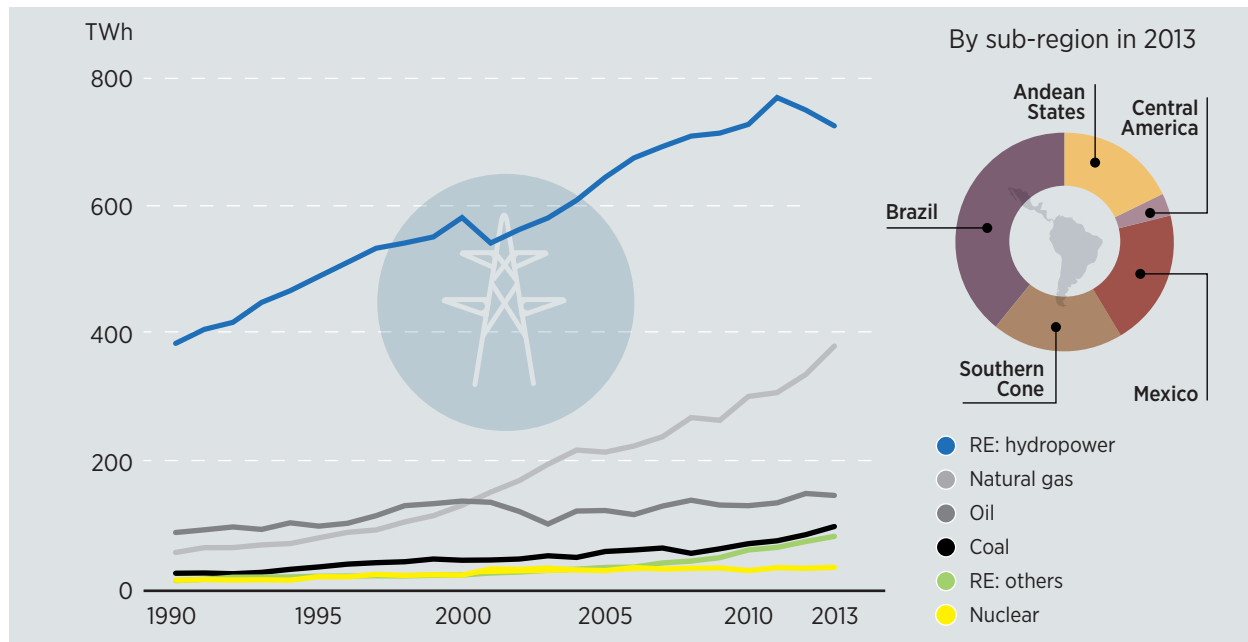
***A distinctive feature of Latin America's power generation mix is the predominance of hydropower, the main source in four of the five sub-regions.***

The region has developed some state-of-the-art mechanisms to expand power grids, in light of rapid renewable energy deployment, including the *open seasons*<sup>17</sup> in Mexico and proactive trans-

mission planning for high-resource areas (e.g., in Brazil and under study in Colombia). Chile is developing new mechanisms for transmission expansion planning with the concept of *generation poles*, where future generation expansion is foreseen (e.g., based on renewable energy potential), which form the basis for the planning of priority transmission lines that will benefit from mainstreamed environmental and social permits to accelerate construction. Peru is using auctions to allocate concessions for the construction and operation of transmission lines to isolated areas (e.g., the city of Iquitos in the Amazon region).

From a historical point of view, South America has been at the vanguard of electricity sector liberalisation and reform, starting with Chile in 1982, while Argentina, Peru, Colombia and Brazil undertook partial reforms throughout the 1990s (Rudnick *et al.*, 2005). In contrast to other countries, the liberalisations took place during years of important expansion of the electricity sector

**Figure 1.6** Electricity generation by source in Latin America, 1990-2013, and by sub-region in 2013



Source: IEA, 2015b

16. Spanish acronym for *Sistema de Interconexión Eléctrica de los Países de América Central* (Central American Electrical Interconnection System).

17. Mexican open seasons ("temporadas abiertas") are calls for connection requests from renewable generation projects, associated with joint efforts to plan transmission capacity additions. They also involve guarantees of transmission capacity conditioned to firm commitments of payment from project developers (Comisión Reguladora de Energía, 2012).

**Box 1.3 Power integration in Latin America**

The region hosts several relevant power inter-connection initiatives. The SIEPAC<sup>16</sup> project in Central America can be considered an international model of regional integration (Pérez-Arriaga *et al.*, 2008). The transmission line was completed in late 2013 (SIEPAC, 2013) and, to realise its full potential, the project currently focuses on institutional co-ordination and regulatory harmonisation across the six Central American countries (ECA, 2010; Zarnikau *et al.*, 2013). In this context IRENA, together with the Central American Integration System (SICA), has been contributing to the Clean Energy Corridor of Central America (CECCA), aimed at integrating renewable energy into the Central American power system.

Transmission links between Brazil, Argentina and Uruguay were implemented in the late 1990s and early 2000s to take advantage of the complementarity between southern Brazilian hydropower plants and thermal plants in Argentina, as well as the different hydrological cycles in southern and central Brazil and Argentina (see chapter 4 for a further discussion on the complementarities between technologies). Another recent integration project, the Andean Electrical Interconnection (SINEA) project, including Peru, Colombia, Chile, Ecuador and Bolivia, is also gaining momentum (SINEA, 2012; IDB, 2015).

(except in the Brazilian case), with substantial demand growth rates having been maintained more or less up to now. This required sustained generation expansion in a market environment.

As a result, South American policy makers have implemented a number of pioneering solutions to regulate the industry (Batlle *et al.*, 2010; Mastropietro *et al.*, 2015), and the region has become one of the most dynamic and diversified environments for electricity markets. As shown in figure 1.7, seven countries in the region currently have a liberalised sector with competition at the wholesale level or, in the case of Colombia, also at the retail level. Meanwhile, other countries in the region have vertical integration of activities, either in the form of a regulated monopoly or allowing for independent generators.

**Figure 1.7** Electricity market structures in Latin America



Source: IEA, 2016

### Expanding share of transport and industry in final energy consumption

Latin America's total final energy consumption (TFEC) increased at an average of 2.7% per year between 1990 and 2013, and 3.2% per year between 2003 and 2013, fuelling rapid economic growth and higher living standards; however, it has since lost momentum due to the economic slowdown (IEA, 2015b). In the complete 1990 to 2013 period, the region's TFEC grew by 85%, while the global equivalent figure was 48% (IEA, 2015b).

This overall increase in final energy consumption conceals significant fluctuations, however, reflecting a series of economic and financial crises (see figure 1.8). After the slowdown in the 1980s, final energy consumption growth gained momentum in the 1990s on the back of market liberalisation and high levels of investment across all energy sources. It decreased again after financial and economic crises in the early 2000s in large Latin American economies like Brazil, Argentina and Colombia, and following the severe droughts in 1997-2001 in countries that are heavily reliant

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on hydropower generation (Brazil, Chile and Colombia).

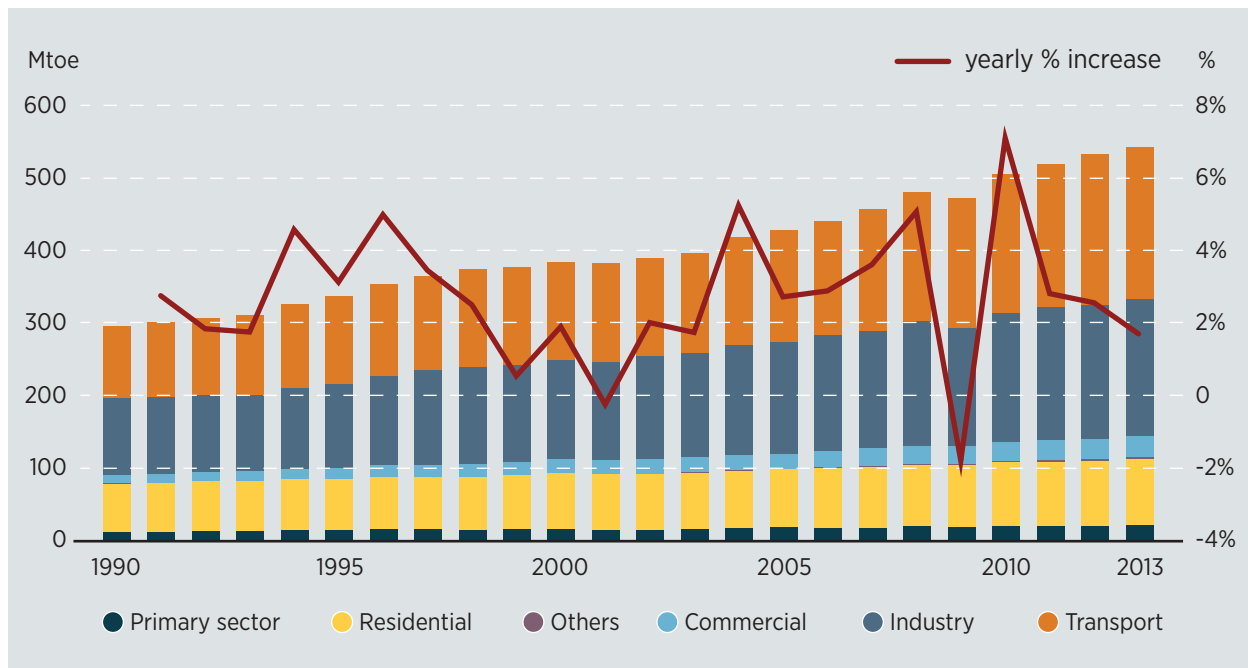
Looking at today's consumption structure, figure 1.9 summarises current TFEC by sector in Latin America and in the different sub-regions. At a regional level, transport and industry dominate energy consumption, with 39% and 35% of overall final consumption, respectively. Transport represents a larger share in Latin America than in the OECD, due mainly to a less efficient vehicle fleet (less stringent mileage standards<sup>18</sup> and cheaper fuel prices in some countries) and to a different modal composition (e.g., a lower share of rail transport). The higher energy use in industry derives in part from the economic structure of Latin America, where industry represents a higher share of GDP than in OECD countries and globally due to the important role of energy-intensive industries, such as extractives, in the region. The relatively small residential consumption is partly

due to the lower use of space heating appliances due to overall mild weather, however, in some sub-regions the use of cooling is rapidly increasing. The dynamics of energy consumption in the industrial, transport and residential sectors are analysed in more detail in the following sections.

#### ■ Transport is the fastest growing end-use sector

The transport sector is the largest energy consumer in Latin America, accounting for 39% of TFEC in 2013. By sub-region, the share varies from 29% in Central America to 45% in Mexico, due to the different socio-economic characteristics (IEA, 2015b). Latin America's growing economy, improved living standards and urbanisation trends have raised demand for mobility in the region<sup>19</sup>. The latter, according to the limited data available<sup>20</sup>, seems to remain below the levels observed in advanced economies, i.e., an average person moves around 16,000 km/year in

**Figure 1.8** Evolution of total final energy consumption (TFEC) by sector in Latin America; 1990-2013



Source: IEA, 2015b

18. Mileage standards refer to energy efficiency standards that motor vehicles need to comply with in order to be able to circulate in the country. Their name comes from the fact that they normally are measured as distance travelled per unit of fuel (e.g., miles per litre). The first mileage standard of Latin America was introduced in 2013 in Mexico, and it is the only Latin American country with an enforced standard as of today. In Brazil there is a proposed standard for 2017 (ICCT, 2015).

19. For a discussion on how rising living standards affect mobility, see Schäfer et al., 2009.

20. Mexico is the only country in Latin America for which the OECD has transport statistics.

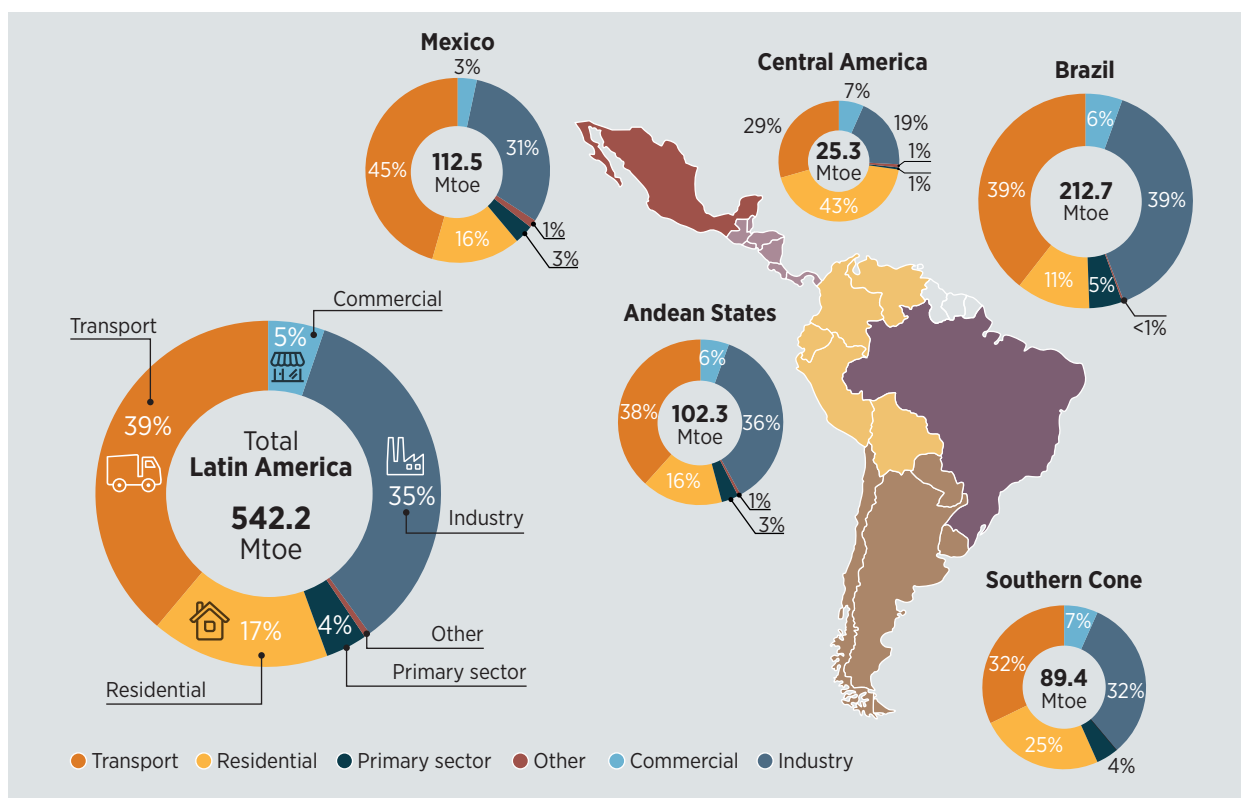
the United States, 10,000 km/year in the OECD countries, 4,000 km/year in Mexico and around 2,000 km/year in China<sup>21</sup> (OECD, 2015a).

The demand for mobility in Latin America is met mainly by road transport, given that nearly 80% of the region's population lives in cities, where there is a deficit of mass transportation systems such as trains and subways (the highest rail network densities<sup>22</sup> in the region, found in Argentina, Chile and Uruguay, are half of those found in the United States and less than one fifth of those in the European Union or Japan (CIA, 2015; World Bank, 2005; Statista, 2015). Consequently, most energy demand in the transport sector is for cars, trucks and other motorised vehicles, which over-

all have less stringent energy efficiency standards than in other regions (GFEI, 2016). In addition, some countries in the region have relatively low fuel prices (see box 1.4), which affects vehicle efficiency and the level of travel.

As a result, Latin America's energy demand for transport has more than doubled in the last two decades, making it the fastest growing end-use sector, in line with the rapid expansion of the vehicle fleet. With a combined population of 600 million, rising purchasing power and a large demand for vehicles, Latin America is one of the world's fastest growing vehicle markets (EY, 2013). Most of this demand is met by oil products, with bio-fuels and natural gas a distant second and third,

**Figure 1.9** Total final energy consumption (TFEC) by sector in Latin America and the sub-regions, 2013



Note: "Primary sector" includes agriculture, fishing and forestry.  
Source: IEA, 2015b

21. These values have been calculated by taking the value of the variable "Total inland passenger in million passenger-km" in 2012 and dividing by 2012 population, expressed in millions, obtaining an average per person mobility in 2012 expressed in km/year. The mobility statistics used include rail, private car, bus and coach. Mobility per capita is positively correlated with GDP per capita (Schäfer et al., 2009), and Mexico is among the countries with the highest GDP per capita in Latin America (World Bank, 2016a). Hence if mobility per capita in Mexico is below other advanced economies, the same could be assumed for other countries in the region.

22. Rail network density refers to the ratio of the length of railway network (in km) by the surface of the country (in square km), and can be used as a first approximation to the level of development of this mode of transport. Where not available, rail density has been calculated taking the total length of railways in km (CIA, 2015) and dividing by the surface of the country.

**Box 1.4 Energy pricing in Latin America**

Latin America has some of the highest, and some of the lowest, energy prices in the world. This is explained by diverse market fundamentals and pricing policies and has a clear impact on the energy mix in each country, affecting the development of renewable energy in particular.

Oil subsidies in the region are concentrated in a handful of oil-producing countries. Notably, Venezuela has the cheapest gasoline prices in the region (and in the world) as a result of one of the highest subsidisation levels in the world (ranking third in the world, and comparable to major oil producers (IEA, 2015a)). Meanwhile, other countries such as Uruguay, Peru and Chile have gasoline prices in line with European ranges (CAF, 2013).

Natural gas prices show a similar pattern and are much lower in Venezuela than in natural gas importing countries such as Uruguay and Brazil (CAF, 2013). As in other regions, industrial consumers in Latin America tend to enjoy lower natural gas prices than residential consumers.

Even though electricity subsidies in the region are almost as large as oil subsidies (around 1% of regional GDP in 2011-2013), they are spread over more countries in the region and, hence, are on average lower in terms of each country's GDP (IMF, 2015b). The lowest-income countries (Central America, Bolivia) in the region tend to subsidise electricity prices the most, notably for low-income residential consumers. High electricity subsidies also exist in Venezuela and Argentina due to pricing policies. In line with market-based pricing policies, Chile has amongst the highest electricity prices (a key issue for its industry).

Cost-reflective pricing policies are a key determinant of the competitiveness of energy sources by reducing distortions and allowing price comparisons to drive investment decisions. While high electricity prices are a clear driver for the adoption of wind and solar by some mining companies in Chile, for example, low residential natural gas and electricity prices are a key barrier for the adoption of solar thermal and distributed solar PV in other countries (e.g., Argentina).

while the use of electricity is almost negligible due to the marginal role of electric-powered railways<sup>23</sup> (see figure 1.10).

The predominant role of oil products for transport has triggered policy interventions aimed at diversifying the fuel mix of the sector. The best example is Brazil, currently the second largest producer of ethanol in the world and where flex-fuel<sup>24</sup> cars (able to run on any combination of gasohol<sup>25</sup> and hydrated ethanol) account for the large majority of the car fleet (ANFAVEA, 2013). Argentina, Peru and some Central American countries are likewise promoting biofuels. Natural gas is also used in the Southern Cone and Andean States, thanks to favourable pricing policies mostly for urban fleets (e.g., taxi, bus) (CAF, 2013). In conclusion, diversification policies result in an increasing albeit

small overall participation of biofuels and natural gas in Latin America's transport sector.

#### ■ Extractive industries drive industrial energy use

Industry is the second largest energy consumer in Latin America (35% of TFEC), with shares ranging from 39% in Brazil to 19% in Central America. The contribution of industry<sup>26</sup> to Latin America's GDP is 32% (slightly higher than the 29% global average) and within industry, manufacturing has a smaller role than would be expected from the level of development of the region (World Bank, 2016a; UNIDO, 2013). Moreover, the energy-intensive industries related to natural resource exploitation (e.g., mining) play a significant role in the region, which is why the industrial sector as a whole has

23. Although less than in other regions, railways are used in Latin America, but they are powered mostly by oil products.

24. A flexible-fuel vehicle (FFV) or dual-fuel vehicle is an alternative fuel vehicle with an internal combustion engine designed to run on more than one fuel, usually gasoline blended with either ethanol or methanol fuel, and both fuels are stored in the same common tank.

25. Gasohol is a mix of gasoline blended with anhydrous ethanol.

26. As per the World Bank's definition, "industry" encompasses ISIC divisions 10-45 and includes manufacturing (ISIC divisions 15-37). It comprises mining, manufacturing, construction, electricity, water and gas. The ISIC divisions refer to ISIC Rev.3.

a high energy intensity<sup>27</sup> (Altomonte *et al.*, 2011). For example, the mining sector in Chile accounts for 35% of total electricity consumption in the country (MINENERGIA, 2013). As a result, energy use from industry represents a higher share of TFECE than in other regions.

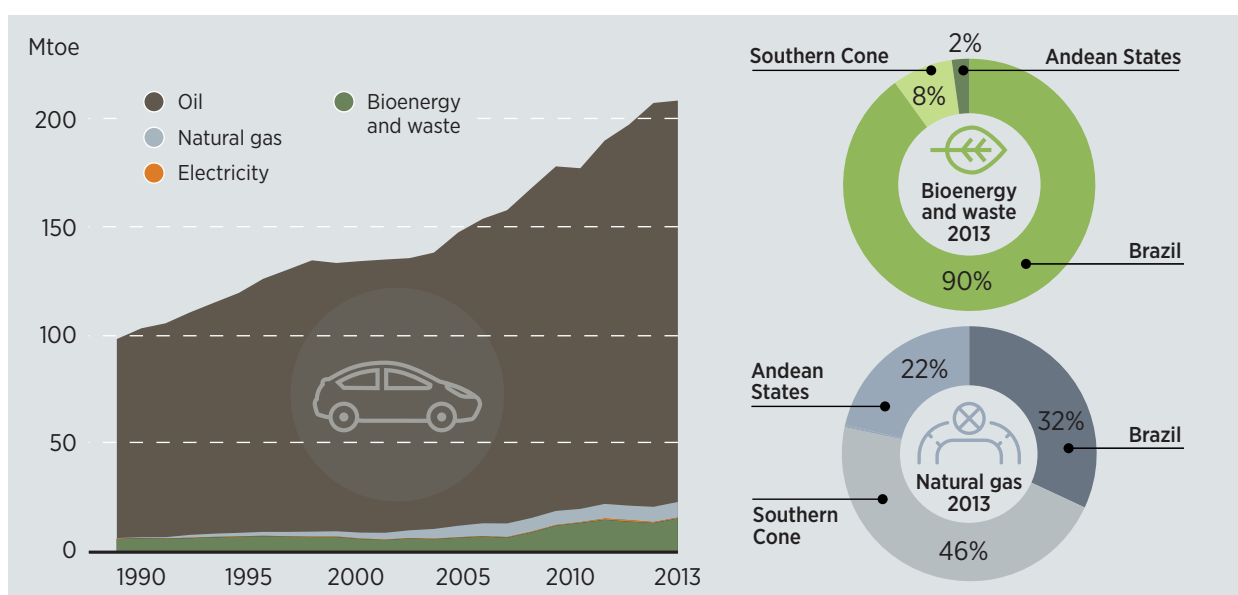
The presence of extractive industries is especially relevant in the Andean States (the oil sector in Venezuela produces more than 30% of GDP, the copper and gold sectors in Peru produce 14% of GDP), Brazil (e.g., iron and steel industries account for about 5% of GDP) and Southern Cone (e.g., copper in Chile contributes to around 15% of its GDP). Meanwhile, manufacturing industry is concentrated in Mexico, Brazil and Argentina (ECLAC, 2015b).

Figure 1.11 shows the evolution of industrial energy consumption in different Latin American

sub-regions. Since 1990, the largest increase has taken place in the Southern Cone and Brazil, while in Mexico the growth has been the smallest. This is due in part to the fact that the most energy-intensive industries are located in South America, and to the fact that Asian demand for industrial exports from South America has been higher than that of the United States, to which Mexican industry is mostly linked.

The increase in industrial<sup>28</sup> energy demand in the Southern Cone, driven largely by mining and other industries<sup>29</sup> (e.g., cement, paper, iron, steel and aluminium) in Argentina and Chile, has relied mainly on electricity and oil products. In the case of Brazil, the largest increase in consumption came from natural gas used in the chemical and petrochemical, non-metallic minerals (e.g., cement) and other industries. More than one-third (36%) of Latin America's industrial heat<sup>30</sup>

**Figure 1.10** Final energy consumption in the transport sector, by energy source, complete region (left) and detail on bioenergy and natural gas use in 2013 by sub-region (right)



Source: IEA, 2015b

27. Energy intensity is defined as the energy consumption per unit of gross value added produced by the industry.

28. The definition of "industry" as per the World Bank and the IEA are slightly different, since the World Bank uses the industrial classification ISIC Rev. 3 and the IEA uses ISIC Rev.4. In addition, the IEA definition of industry excludes energy-extractive industries (e.g., coal mining). The reader should take this into consideration when analysing the economic statistics (obtained from the World Bank) and the energy statistics (obtained from the IEA) presented in the current report.

29. IEA data do not provide further detail on which industries, because the category where the increase of electricity consumption is observed is labelled as "Non-Specified (Industry)".

30. In this report, and based on an IEA definition, "heat" is defined as the consumption of energy sources (excluding electricity) to produce heat in stationary applications (i.e., mainly industry, residential and others, excluding the transport sector). With the exception of heat from solar, geothermal and ambient sources, the energy source is directly supplied as a combustible fuel and transformed into heat in the end-use sector itself. It should be noted that part of that fuel may be used for non-heat applications, such as motive power.

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demand is met by bioenergy, the highest share in the world, due in large part to the importance of agroindustry (notably sugar, food and tobacco) and pulp and paper.

### ■ Residential demand grows as living standards rise

The residential sector consumes 17% of TFEC in Latin America, less than half the share consumed by transport (39%) and industry (35%). Significant divergences exist, from 43% of energy consumption in Central America to 11% in Brazil, mainly because of reduced consumption from industry and transport in Central America. Population and economic growth experienced by Latin America in the last decades, together with the expansion of the middle class, have raised energy consumption in the residential sector by about 38% since 1990, which is however relatively low compared to the growth in transport and industrial consumption (112% and 84%, respectively).

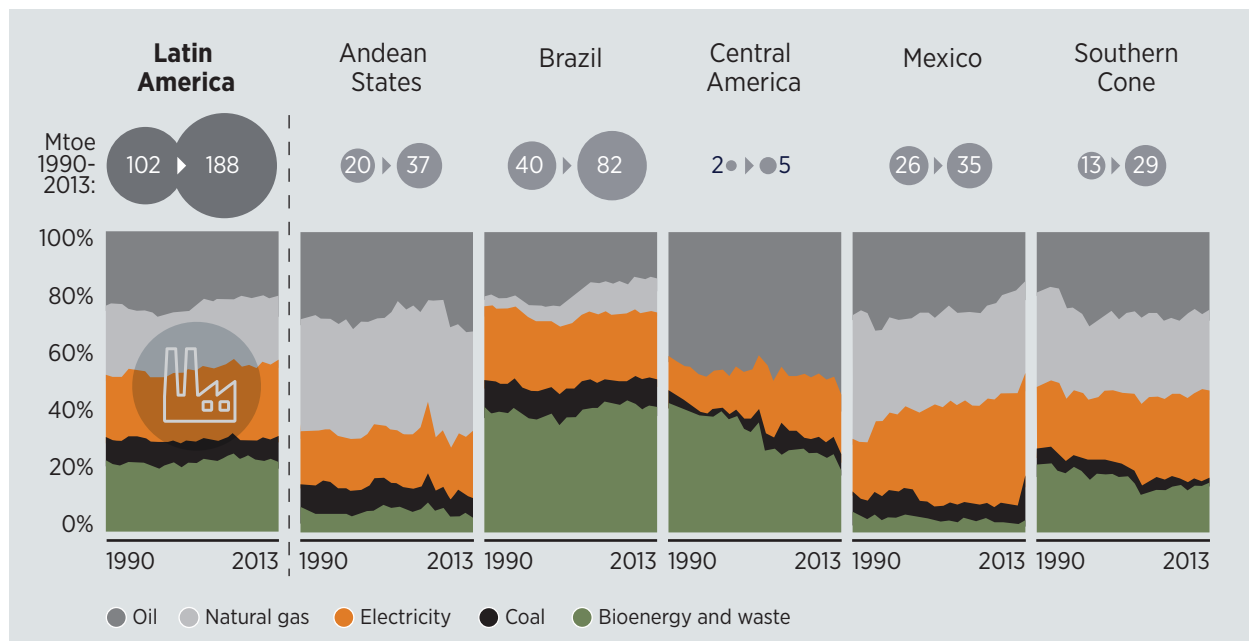
The use of energy in Latin America's residential sector is becoming more efficient, with traditional solid biofuels<sup>31</sup> being substituted by much more efficient appliances using oil products (no-

tably LPG), electricity and natural gas (ECLAC & GIZ, 2010). This trend has been more pronounced in some sub-regions than in others (e.g., Brazil and the Andean States have seen the largest reduction of solid biofuels). It also should be noted that, in some cases, the consumption of electricity and natural gas can be inefficient, especially when prices are not cost-reflective. This is the case for some electricity-based water heating applications in the region. As shown in figure 1.12, the increase in residential energy demand has relied mainly on increased use of electricity (notably in Brazil, Mexico and Argentina) and natural gas (mainly in Argentina, but also in Peru through the Natural Gas Gasification Programme, and in Ecuador through the Electricity Cookers programme (Chávez-Rodríguez *et al.*, 2014)).

### Varying regional dynamics impact energy trade

In 2013, Latin America was an energy exporter, thanks largely to oil and coal. The region historically has been a large exporter of oil, with Venezuela and Mexico ranking amongst the world's top 10 exporters (IEA, 2015a). In the past, the region produced enough natural gas for its own

**Figure 1.11** Final energy consumption in the industrial sector in Latin America and the sub-regions, 1990-2013



Source: IEA, 2015b

31. Data regarding traditional uses of bioenergy present significant uncertainty.



consumption; however, the growing use of natural gas in the 1990s and early 2000s, unmet by new production, has turned the region into a natural gas importer in the last years.

Figure 1.13 shows the import and export flows<sup>32</sup> of energy commodities in each country relative to their TPES. The figure conveys several features with important implications for regional energy dynamics. First, energy exports are concentrated in a few countries (Venezuela, Colombia, Ecuador, Bolivia, Mexico, Paraguay and Peru). The largest volumes of trade (in energy terms) correspond to oil, where the main exporters in 2013 were Venezuela, Colombia, Ecuador, Mexico and Brazil, whereas Brazil, Mexico and Chile were the main importers. Given the profile of some refineries and of the demand for oil products, some countries, such as Brazil, both export and import crude oil and oil products. Mexico is a significant crude oil exporter but a net importer of refined oil products. Regarding natural gas, as of 2013, exporters were Bolivia and Peru, while the larger importers were Mexico, Brazil and Argentina. Bolivia exported mainly to Brazil and Argentina (via

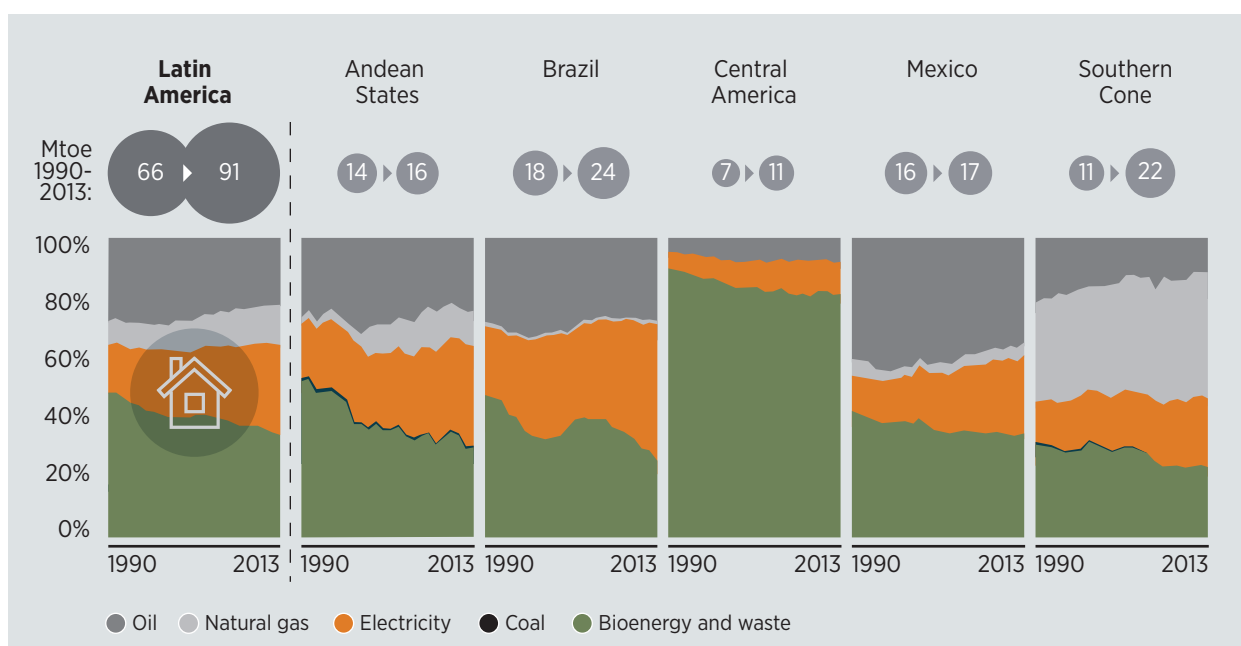
pipeline), and Mexico's imports came mostly from the United States, also via pipeline (BP, 2015).

A second notable feature is the importance of energy exports relative to the size of some countries' energy use (measured as TPES). For example, Colombia's energy exports equal three times its domestic energy use, while those of Bolivia, Ecuador and Venezuela are about one-and-a-half times their national energy use. Paraguay's electricity exports to Brazil and Argentina represent a large share of Paraguay's TPES, yet are barely noticeable in the overall TPES of either Brazil or Argentina.

Third, some countries are highly reliant on energy imports, representing over 50% of their TPES. The main energy importers are Uruguay, Chile and Central American countries. Oil imports in Central America are, on average, over half of their total TPES. Panama's import of over 100% of its TPES can be explained by sales for the refuelling of international maritime transport (bunkers) associated with the Panama Canal.

Another important feature is the growing mismatch between in-country demand and supply

**Figure 1.12** Final energy consumption in the residential sector in Latin America and the sub-regions, 1990-2013



Source: IEA, 2015b

32. The figure also shows that some countries may both export and import a particular energy source. This is especially the case with oil, when some countries export crude and import refined products, or vice versa.

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for refined products. Ecuador, Mexico and Brazil are all both exporters and importers because they mainly export crude oil but import most refined oil products. Latin America's gasoline and diesel deficit has increased greatly in the last 40 years (e.g., local refineries produce heavy products such as fuel oil, while the demand is for lighter products such as gasoline).

The concentration of fossil production in a few countries and the high levels of imports in half of the countries reflect the distinctive energy dynamics of the region.

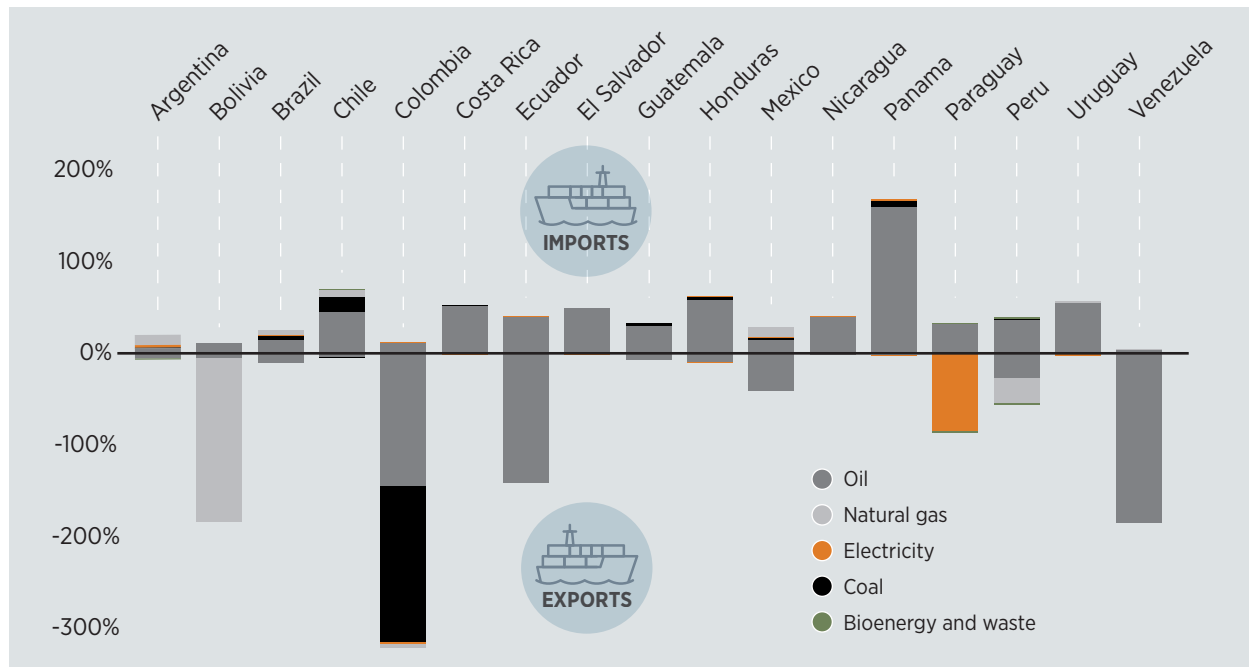
### 1.3 ENERGY SECTOR DYNAMICS

The energy landscape in Latin America shows the wide range of opportunities and challenges that shape the region in the oil and gas sector, as well as in the power sector. Despite large energy resource endowments, both renewable and non-renewable, many countries have faced diffi-

culties in meeting energy demand since the early 2000s. With a population of close to 600 million people and growing economies after the current downturn, even with modest GDP growth, the overarching challenge for Latin American countries is to meet increasing energy demand with efficient, diversified and sustainable sources. This section explores the region's changing energy landscape and sets the scene for the emerging role of renewable energy.

Latin America is home to the second largest oil reserves after the Middle East. Although the region as a whole is a net oil exporter, if one excludes the historical large oil exporters such as Mexico, Venezuela and, more recently, Brazil and Colombia, it becomes a net oil importer. Even in oil-exporting countries, the reality is more complex. Mexico's oil production has decreased substantially in the past decade, and the country currently imports about half of its oil products. Venezuela's oil production is also declining due

**Figure 1.13** Exports and imports of energy relative to total primary energy supply (TPES) in Latin American countries in 2013<sup>33</sup> (%)



Source: IEA, 2015b

33. These figures have been obtained by dividing the exports and imports of each energy source (electricity, bioenergy and waste, coal, natural gas and oil, all in Mtoe) by the TPES of the country (also in Mtoe), in order to obtain the relative importance with respect to the country's energy use. For bioenergy and oil, the trade of both primary and secondary products is included (e.g., the category "oil" includes both crude and refined products).

to inefficient management of the sector and lack of investment. In the case of Brazil, given recent major challenges of the state-owned oil company, Petrobras, the expected substantial increase of oil production coming from pre-salt oil fields may face uncertainties and delays.

Countries without oil reserves are aiming to reduce their imports through energy efficiency measures or by substituting oil with natural gas or liquid bio-fuels. These countries also are focusing on improving the capacity, reliability and efficiency of the distribution of oil products, and on increasing strategic storage (e.g., Costa Rica). In addition, many countries, both exporters and importers, are looking to improve their oil refining capabilities, both in terms of capacity and of adequacy to the required mix of products (e.g., Mexico).

The presence of abundant natural gas resources and energy sector liberalisation in the 1990s created dynamic natural gas industries in Argentina, Bolivia and Peru, changing their energy mixes and those of their neighbours (Chile, Uruguay and Brazil). Natural gas-based generation

became a compelling low-cost, cleaner alternative to coal-based power generation, and it reduced over-reliance on hydropower. Neighbouring countries rapidly diversified their electricity mix with natural gas, through the development of natural gas pipelines connecting Argentina to Chile, Bolivia to Argentina and Brazil, and Colombia to Venezuela.

Due to unsound management of natural gas resources and pricing policies, cross-border natural gas trade came to a halt in the mid-2000s (Rudnick *et al.*, 2014). In Argentina, a major macroeconomic and natural gas crisis in 2003-04 led to the unilateral suspension of natural gas exports to Chile, which faced severe energy shortages and price increases. Given a long history of border disputes between Chile and Bolivia (Bolivia lost its access to the Pacific in a 19th-century war with Chile), Bolivia refused to export natural gas, leaving Chile with no regional alternatives for natural gas supply. Likewise, historical border disputes with Peru played a part in its decision to export its natural gas as LNG to Mexico, despite



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the proximity, along its southern border, of Chile, which is now fully reliant on LNG imports (Mares & Martin, 2012).

Venezuela, Bolivia and Ecuador all nationalised their hydrocarbon sectors during the 2000s on the back of high oil prices. These nationalisations focused on maximising oil revenues from foreign companies and on government spending for social policies. Despite their large endowments in natural gas, Brazil, Argentina and Venezuela have become net natural gas importers, and the region has become increasingly dependent on LNG imports from the global market. As a result of these dynamics, the region – which includes 3 of the top 10 countries in shares of natural gas reserves and potentially could be self-sufficient in or even export natural gas – is currently a net importer. The recent history of the natural gas trade illustrates the need for diversification in both fuels as well as in supplying countries.

The vital importance of diversification is also apparent in Latin America's power sector. Historically, oil and hydropower dominated the energy mix in the region, and the high reliance on both sources of energy has created a set of energy security concerns. Countries with a high share of hydropower in their electricity mix moved to diversify away from it, partly due to the climate vulnerability of hydropower plants, with severe droughts threatening electricity supply and damaging economic activity, notably in Brazil (Schaeffer *et al.*, 2013). In the 1990s, this diversification was done with cheap, abundant natural gas but came to a halt after the natural gas crisis of the early 2000s. In Central America, countries with a high dependence on oil products for power generation are actively promoting alternative generation sources in order to reduce oil price volatility and fiscal impacts from oil imports. In both cases, renewable energy technologies, whose competitiveness has been bolstered by dramatic cost reductions in recent years, provide an important means for diversification in the region.

Electricity trade in Latin America increased in the 1980s and 1990s with the adoption of several bi-national agreements, but, since 2004, it has declined, reflecting concerns over security of

supply. Regional energy integration challenges are exacerbated by the absence of a unified institutional co-ordination mechanism at the regional level. Institutions were introduced to enhance market integration as a mechanism to improve energy security in the relatively fragmented Latin American energy markets. Several regional institutions have been set up with the aim of fostering market harmonisation and energy integration (see box 1.5).

#### ■ Mexico: Historic reform to revitalise energy sector and ensure sustainability

Mexico is the world's tenth largest oil and natural gas producer. However, crude oil production has been declining steadily since 2004 in the context of expanding oil and gas production in the rest of North America, while natural gas, oil products (e.g., the country imports over 50% of its gasoline) and coal imports are growing significantly. The oil and gas sector plays a major role in Mexico's economy and provides about one-third of the federal budget. The fundamental energy reform under implementation aims to improve the institutional and fiscal structure of the national state oil company, Pemex, as well as to promote private sector participation to restore oil production (IMF, 2014; Lajous, 2014).

Mexico's dependence on natural gas – which supplies over 50% of the energy for power generation – has become a major concern in the power sector. In addition, the country has the highest carbon dioxide (CO<sub>2</sub>) emissions from electricity and heat production in the region (IDB, 2014b). To address these and other challenges, Mexico passed a series of energy reforms in December 2013 aiming to open the energy sector to private investment, to gradually remove subsidies for oil products and electricity tariffs over the coming years and to diversify the energy mix with clean energy sources. To this end, Mexico aims to supply 40% of its electricity from clean energy sources by 2035, and 50% by 2050. These objectives have strengthened the case for renewable energy deployment (IRENA, 2015a).

### Box 1.5 Regional energy integration institutions in Latin America

Since the 1960s, several institutions for energy integration have been set up in the region. The Regional Energy Integration Commission (CIER) was established in 1964 to promote and support electricity integration in the region. The Latin American Reciprocal State Oil Assistance Association (ARPEL) was established in 1965 to contribute to the industrial consolidation and competitive growth of Latin America's oil, natural gas and biofuels sector companies. And the Latin American Organization for Energy Development (OLADE) was set up in 1973 in the context of the global oil crisis. The recently created Union of South American Nations (UNASUR), an intergovernmental mechanism to integrate customs regulations between Mercosur (the regional trading bloc of Brazil, Argentina, Paraguay and Uruguay) and the Andean Community trade bloc is generating positive momentum as new opportunities for cross-border energy trade emerge, notably in Central America with the construction of the SIEPAC transmission line and in South America with the SINEA project.

#### ■ Central America: Reducing oil dependency through diversification in the power sector

Central America is particularly vulnerable to oil price volatility and to the fiscal impact of oil imports. The share of oil products in TFEC in the sub-region increased from 34% in 1990 to 45% in 2012. Oil imports are used both in the transport (54% of the total) and electricity sectors (Dolezal *et al.*, 2013). In 1990, hydropower supplied 90% of electricity generation in Central America. However, between 1990 and 2004 the region's electricity sector shifted to fossil-based generation. Following power sector liberalisation in the early 1990s, private investors favoured thermal power plants because of the small size of power systems and the perception of high investment and country risks in many Central American countries. The risks associated with the high dependence on imported fuels were highlighted during the steep oil price increase in 2008, which endangered the financial viability of the power sector in most countries of the region. In 2012, Central American countries spent about USD 13 billion in oil imports, twice the amount spent in 2006 (Dolezal *et al.*, 2013).

Accordingly, all countries in Central America are actively diversifying their electricity mixes to reduce their vulnerability to oil price volatility by promoting the development of renewable energy sources. Since 2004, at least two-thirds of new installed capacity was renewable. Most countries in the sub-region have developed strategies and policies to promote renewable energy deployment and are seeing rapid capacity installations, in particular with wind and solar. In addition, Central American countries are expanding their transmission systems to facilitate the incorporation of large amounts of renewable energy and have jointly developed a regional transmission line, the Central American Electrical Interconnection System (SIEPAC), to enable international power exchanges (ECA, 2010).

#### ■ Andean States: Energy exporters with different degrees of liberalisation

The Andean States, including Bolivia, Colombia, Ecuador, Peru and Venezuela, are composed of major oil and natural gas producers. In the 1990s, Andean countries followed the global trend of energy sector liberalisation pioneered by neighbouring Chile. In the 2000s, however, Bolivia, Venezuela and Ecuador reversed this trend and implemented reforms to reassert state control of the energy sector. Venezuela has played an important role in the trend towards resource nationalism in the region. In the 2000s, centralised, state-owned companies regained control of both the oil and gas and the electricity sectors. In 2006, Bolivia nationalised its energy sector, as well as mining and telecommunications, with the objective of providing equitable service to all Bolivian citizens. Since 2006, Ecuador has followed a similar trend. In all three countries, oil production has stagnated over the past decade (Chávez-Rodríguez *et al.*, 2014; Fontaine, 2011). In contrast, Colombia and Peru have maintained their liberalised energy markets with high levels of private participation and investment. As a result of their rich fossil fuel resources and low electricity tariffs, Andean countries' main objective is to meet energy demand as well as social objectives. Given rapid cost declines, some Andean countries may consider diversifying their energy mixes with renewable sources, in particular for energy access.

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### ■ Southern Cone: The impetus of energy diversification

There are major differences within the Southern Cone sub-region. Argentina is the largest natural gas producer in South America, while Paraguay is the third largest electricity exporter in the world and the largest in the region. Chile, Uruguay and Argentina face challenges in meeting their energy demand. Argentina's most pressing challenge is to reverse its decline in natural gas production, at the risk of facing an ever growing energy trade deficit or drastically curtailing domestic demand.

Chile is one of the most energy-import-dependant countries in the Southern Cone and imports close to three-quarters of its primary energy use. As a result, it has pursued an active strategy to diversify its electricity mix, in particular with natural gas during the 1990s. Natural gas-based generation went from zero in 1990 to 35% at the peak of Argentinean imports in 2004. Following the gas crisis, Chile has diversified its power mix through LNG, coal and, in recent years, wind and solar. It has a vast renewable energy potential, high de-

mand growth rates, high electricity prices and a favourable investment climate.

Uruguay likewise has followed a strategy to diversify away from the twin reliance on oil and hydropower generation. The country has seen a remarkable increase in its renewable capacity through the rapid development of its wind sector and solid biofuels co-generation. Argentina has policies to promote renewable energy sources, but the limited availability of local and foreign financing, and energy subsidies have limited the development of renewables to date. The new government recently undertook an overhaul of the energy sector to promote investment, particularly in renewables.

### ■ Brazil: Leader in oil self-sufficiency and low-carbon energy sources

Energy security and trade balance concerns in the wake of the first oil shock were the main drivers of Brazil's early determination to diversify its transport fuel mix away from fossil fuels. Exceptional natural resource endowment strongly supported this strategy. The resolve to minimise reli-



ance on imported oil products was reinforced by the volatility in oil prices since the first oil shock. Domestic discoveries of oil and gas progressed steadily throughout the 1990s and 2000s until the major discovery of the Brazilian Tupi oil field (renamed Lula field in 2010), the first of many important discoveries in the pre-salt formations in Brazil's offshore.

The favourable regulatory framework supported these discoveries and triggered significant private investment. However, more recent regulatory changes aimed at securing higher public revenue from the pre-salt combined with Petrobras's recent financial and institutional challenges have slowed its development. Brazil's twin objectives are to meet growing energy demand while achieving self-sufficiency. As of 2014, around 75% of Brazil's electricity came from renewable sources, one of the highest shares in the world, and around 15% of consumption in the transport sector is met with domestically produced biofuels (EPE, 2015).

Brazil's power generation is dominated by large hydropower, which accounted for 66% of total generation in 2014 (EPE, 2015), down from around 70% in 2013 and much lower than the 80% average over the 2004-12 period (EPE, 2015). Concerns about extreme droughts that have led to energy shortages, and delays in new large energy projects are important drivers for the country to diversify its electricity mix away from hydropower. Only 20% of power capacity is based on fossil fuel sources, mainly fuel oil, natural gas and coal. Nevertheless, the share of natural gas is increasing steadily, and wind capacity – and to a lesser extent, solar PV – are deploying very rapidly thanks to enabling policies.

■ **Energy security and climate concerns:  
Paving the way for accelerated renewable  
energy deployment**

Historically, energy security has been a main driver of domestic and regional energy strategies. More recently, the recurrence of extreme climate events (e.g., Brazil's drought in 2014 and 2015) has given prominence to local and regional climate impacts. As a result, energy security in-

creasingly encompasses climate change considerations.

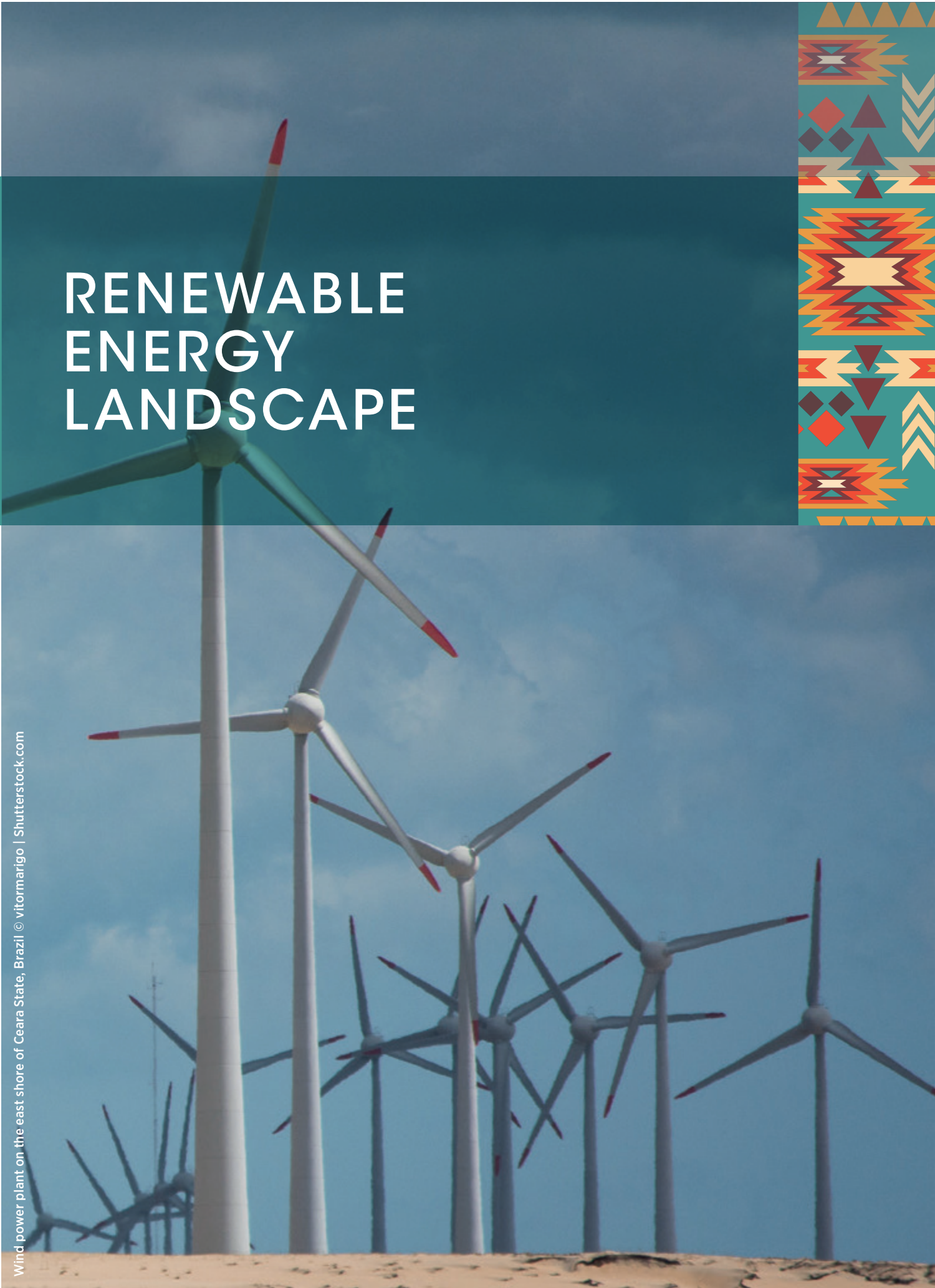
The region's greenhouse gas emissions from energy use historically have been below those of OECD countries in relative terms, due largely to the relatively clean electricity mix of the region, concentrated on hydropower (52%) and natural gas (25%). Recently, greenhouse gas emissions from energy use in the region are growing steadily and reaching OECD levels. Compared to other regions, the share of transport-related emissions (31%) is higher than in the rest of the world (18%), whereas the power sector accounts for 29% of energy emissions, compared to 44% globally (IDB, 2014b).

Despite Latin America's relatively small contribution to global greenhouse gas emissions from energy use, governments are committed to maintaining a low-carbon energy mix. In recent years, the multiplication and frequency of extreme climate events in the region, including floods, droughts and glacial retreat, are putting particular strain on the water supply and are challenging energy, water and food security. This is driving Latin America's energy strategies to increasingly take into account the effects of climate change both in terms of adapting current energy infrastructure and promoting mitigation strategies. Some countries have passed climate change laws (e.g., Mexico in 2012 and Guatemala in 2013), and others have set a goal of carbon neutrality (e.g., Costa Rica in 2007). Starting in 2016, countries will start implementing their Intended Nationally Determined Contributions (INDCs) under the United Nations Framework Convention on Climate Change, the majority of which give a prominent role to the development of renewable energy.

Overall, driven by energy security and climate change concerns, many Latin American countries have come to prioritise the development of a portfolio of renewable energy sources. Rapid cost reductions, maturing technologies, the consolidation of renewable energy policies in the region, and vast untapped potentials offer an unprecedented opportunity to further the deployment of renewable energy sources across the region.

# RENEWABLE ENERGY LANDSCAPE

Wind power plant on the east shore of Ceara State, Brazil © vitormarigo | Shutterstock.com







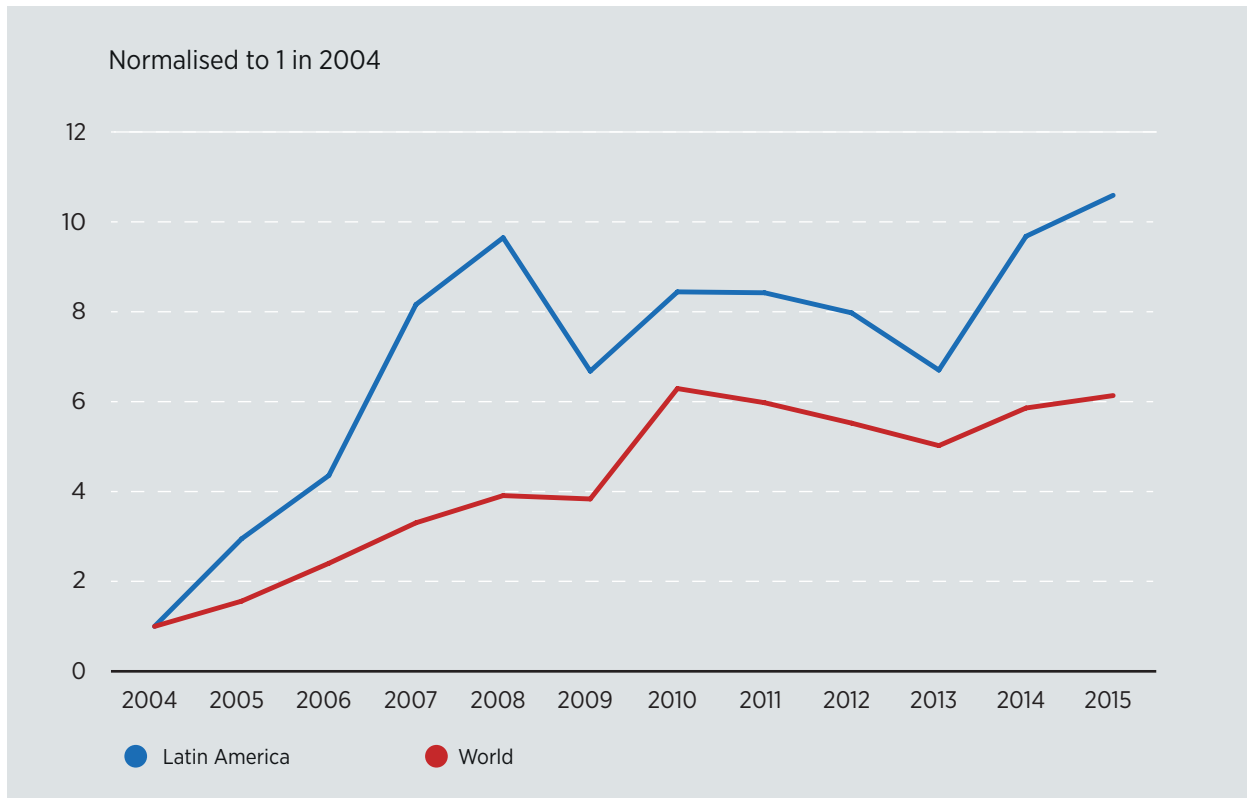
Latin America has one of the world's highest shares of renewable energy, due to the large historical development of hydropower and the role of bioenergy in the transport, residential and industrial sectors, which stand out as distinct features of the region. Hydropower was the cornerstone of the region's power system development, with vertically integrated, state-owned utilities harnessing abundant resources through megaprojects, which often exceeded demand requirements throughout much of the 20<sup>th</sup> century. The importance of bioenergy can be traced to sugarcane plantations in colonial Latin America and, more recently, to Brazil's landmark *ProÁlcool* programme, established in 1975 to simultaneously protect Brazil against rising oil import costs and support the growth of its domestic sugarcane industry.

The poor performance of public monopolies and a series of droughts gave rise to Latin America's electricity sector reforms in the 1990s, which aimed to diversify the electricity mix away from hydropower while improving economic and financial management. The liberalisation process resulted in a more balanced supply mix between hydropower and fossil fuel-powered production, more resilience to droughts and the emergence of private actors. However, it created a new gen-

eration of energy security issues in the form of vulnerability to oil price volatility and dependence on natural gas imports. The recurrence of extreme climate events has raised additional energy security concerns related to hydropower generation.

Against this backdrop, rapidly decreasing renewable energy costs combined with supportive policies are driving a remarkable deployment of non-hydropower renewable sources, in particular wind and solar, to meet demand growth in the region. Since 2004, renewable energy investment in Latin America (excluding large hydropower) has grown 11-fold, in comparison with a 6-fold increase worldwide (see figure 2.1) (BNEF, 2016). A detailed overview of renewable energy investment trends in the region is presented in chapter 4.

This chapter starts with a presentation of the profile of renewable energy sources in demand and supply (section 2.1), followed by an overview of wind and solar potentials. Section 2.2 reviews renewable energy drivers at the regional and sub-regional levels and presents the region's policy landscape for renewables, including the institutional framework and sector-specific policies for power, heat and transport.

**Figure 2.1** Evolution of renewable energy investments in Latin America and the world, 2004-2015

Source: BNEF, 2016

## 2.1 RENEWABLE ENERGY SUPPLY AND DEMAND

This section presents the profile of renewable energy supply and demand in Latin America, including: 1) renewable energy for power generation, 2) renewable energy consumption in the industrial, transport and residential sectors, and 3) wind and solar potentials. This overview sets the scene for a discussion of the drivers and policies behind these trends (section 2.2).

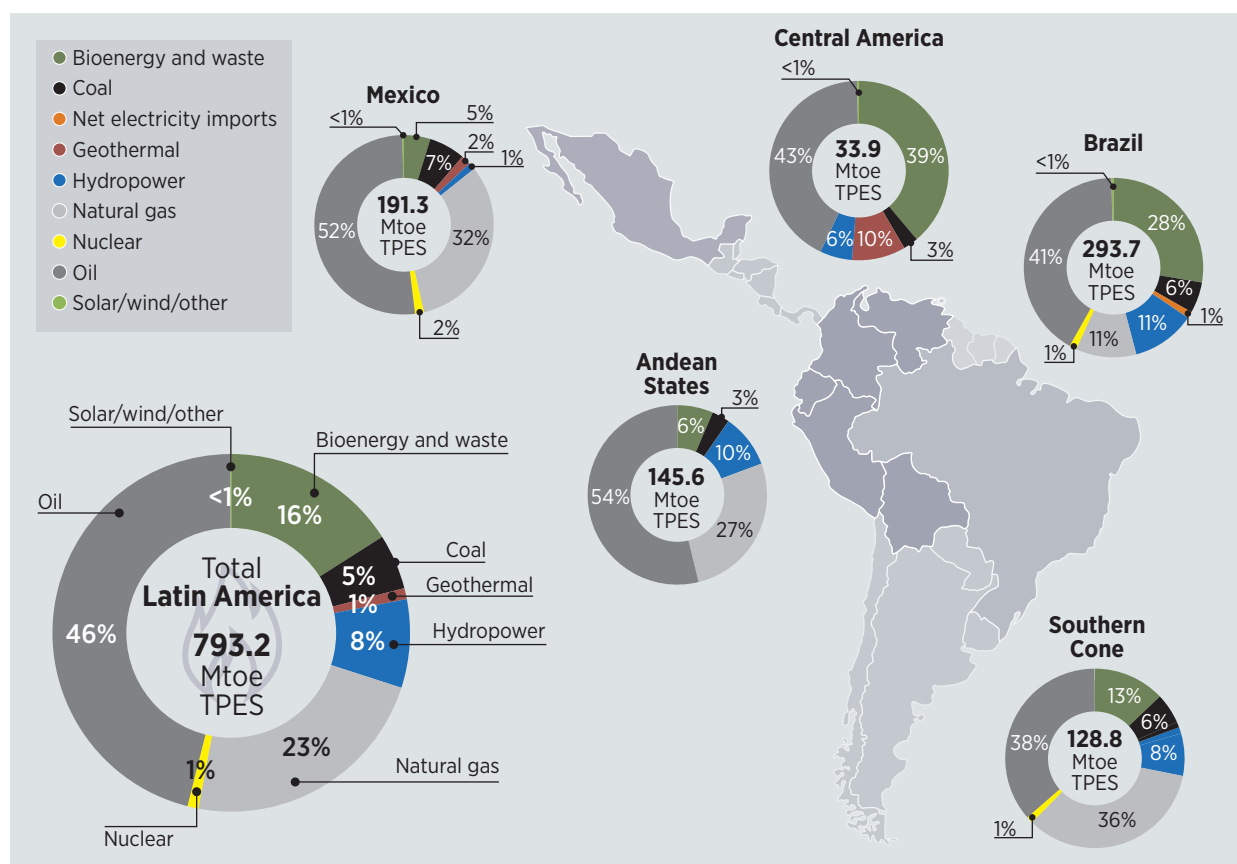
With renewable energy accounting for 25% of total primary energy supply (TPES) in 2013 (see figure 2.2), Latin America is at the forefront of renewable energy use globally (the global share of renewables in TPES was 13% in 2013). Solid biofuels (57%) and hydropower (31%) are the main sources of renewable energy in the region's primary energy mix, followed by liquid biofuels (8%), geothermal (3%) and other renewable energy sources.

In relative terms, Central America has the highest share of renewable energy (55% of TPES, although around half is traditional solid biofuels), followed by Brazil (39% of TPES, mainly for end-uses and power generation). Mexico has the region's smallest share of renewables in TPES (8%).

As in most regions of the world, electricity generation accounts for the highest share of primary renewable energy use, at 41%, followed by end-uses (23% in the industrial sector, 17% in residential and 8% in transport). The other uses of primary renewable energy are mainly co-generation and charcoal production.

### Renewable electricity

Renewables are at the core of Latin America's electricity mix, due mainly to the historical role of hydropower (see figure 1.6). At 55%, the share of renewables in power generation in Latin America is far larger than in other regions (the world average was 21% in 2013) (IEA, 2015b). In terms of total installed capacity, in 2014 the share of renew-

**Figure 2.2** Total primary energy supply by sub-region in Latin America, 2013

Note: The percentages for Southern Cone add 102%, since there is a negative contribution to TPES of -2% (net electricity exports) which is not represented in the circular chart. Source: IEA, 2015b

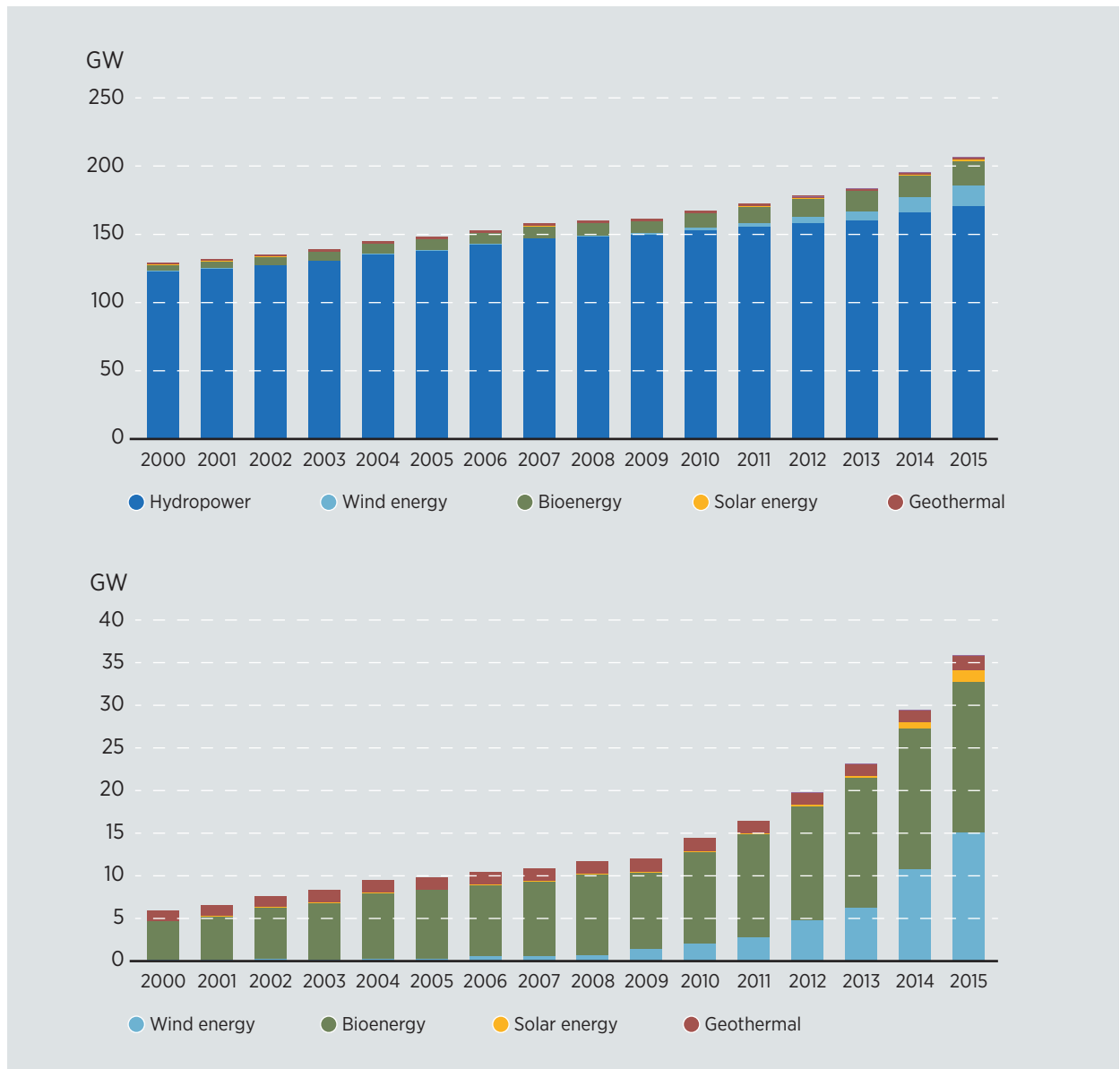
ables in Latin America was 56% (with 47% from hydropower alone), compared to a world average of 25% (17% from hydropower) (BNEF *et al.*, 2015; CIA, 2015; IRENA, 2016a). A recent trend in the region, as shown in figure 2.3, is the rapid growth of non-hydropower renewables, the installed capacity of which has more than tripled between 2006 and 2015, from 10 GW to 36 GW. As a result, the relative share of hydropower in the region's total renewable capacity is declining (83% in 2015 versus 95% in 2000) (IRENA, 2016a).

As a mature technology and because of its scale, large hydropower is often considered differently than the other renewable energy sources and is usually referred to as a "conventional" source of energy in Latin America. In the region, a clear distinction is made between large and small hydropower. The legal definition of small hydropower varies across countries: up to 10 MW in Colombia and Panama; 20 MW in Chile, Costa Rica and

Peru; 30 MW in Brazil; and 50 MW in Argentina. These threshold values do not reflect other aspects often considered in official definitions such as reservoir area, dam height and water flow. Despite significant hydropower capacity additions in the region – including the start of operations at part of the large Jirau (3.75 GW) and Santo Antonio (3.6 GW) plants in Brazil, as well as at the Sogamoso plant in Colombia (850 MW) – hydropower output has been impacted severely by a historical drought, particularly in Brazil, with some reservoirs at all-time lows in 2014 and 2015 (EPE, 2015).

Bioenergy for power and onshore wind are the two technologies whose capacity has grown the most in absolute terms since 2000. The main bioenergy generation technology is bagasse (sugarcane residue), primarily in Brazil and followed distantly by Guatemala, Mexico and Argentina (IRENA, 2016a).

**Figure 2.3** Installed renewable power capacity in Latin America, 2000-2015; all technologies (top) and excluding hydropower (bottom)



Note: Bioenergy includes solid and liquid biofuels and biogas.

Source: IRENA, 2016a

Wind power is growing the most in Brazil, where a record capacity of 2.7 GW was commissioned in 2015 following the recent auctions – almost three times the level installed in 2013. Mexico added 700 MW of wind power in 2015, doubling 2013 additions (IRENA, 2016a). Uruguay and Panama also made significant wind capacity additions in 2015, of 300 MW and 230 MW, respectively (IRENA, 2016a).

The share of geothermal capacity in the region has remained stable, with capacity growing at the same pace as overall renewable power generation capacity. The countries with the largest installed capacities are Mexico, Costa Rica, El Salvador and Nicaragua (IRENA, 2016a).

Solar installed capacities, mainly PV, in the region are still relatively small, but they have grown significantly in recent years in Chile, Mex-

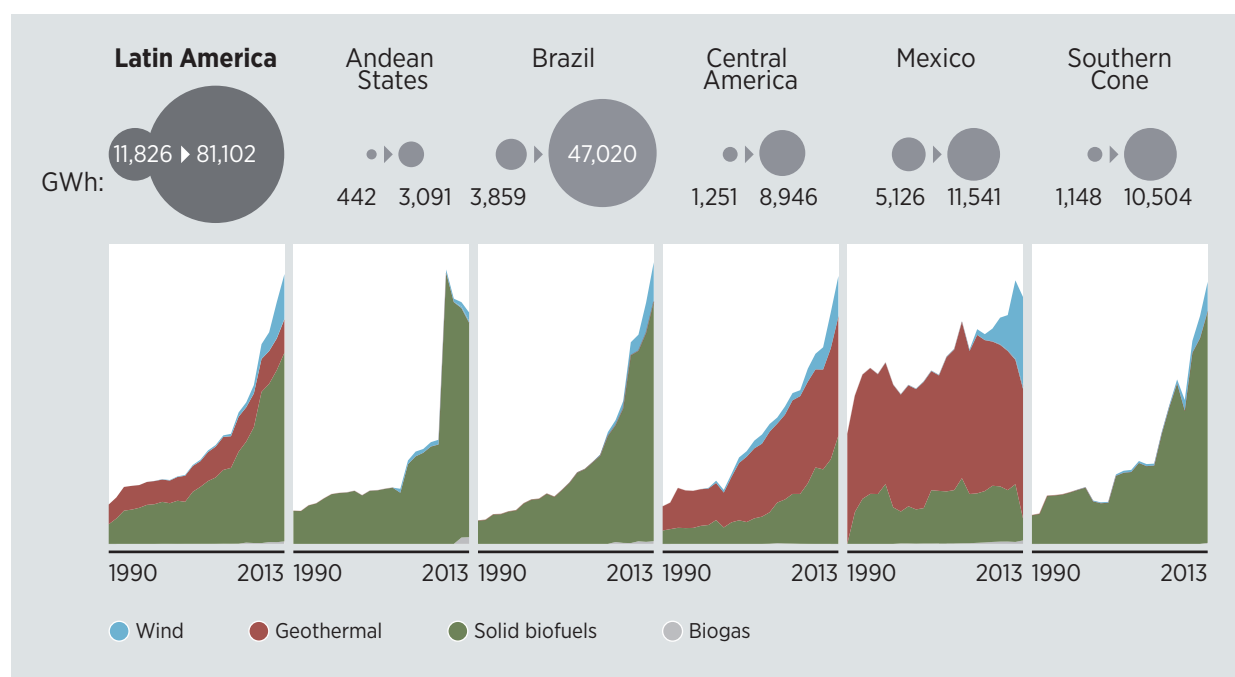
ico, Peru and Uruguay. In 2015, Chile added over 400 MW of solar PV for the second consecutive year, and 110 MW of solar CSP is under construction (the first CSP project in Latin America). Brazil recently awarded more than 890 MW of utility-scale PV projects; Uruguay awarded contracts for 190 MW, Guatemala for 80 MW and Honduras for at least 350 MW; and Panama held its first solar PV auction.

The diversification towards non-hydropower renewables is reflected in the generation mix, where the share of hydropower in total renewable generation fell from 92% in 2011 to 73% in 2014 (IEA, 2015d). Figure 2.4 highlights the rapid growth of renewable energy generation from non-hydropower sources through 2013. All sub-regions except Mexico show exponential growth for non-hydropower renewable electricity, with significant differences across sub-regions. Solid biofuels clearly dominate in Brazil, the Southern Cone and the Andean States. Geothermal generation continues to grow in Central America and is stable in Mexico. Wind penetration can be observed in all

sub-regions, with the highest values in Brazil and Mexico. Available data show a doubling of onshore wind generation for the region as a whole in 2014 compared to 2013 levels (IEA, 2015d).

Trade in renewable electricity is concentrated among a few bi-national hydropower plants, e.g., Itaipu (Brazil-Paraguay), Yacyreta (Argentina-Paraguay) and Salto Grande (Argentina-Uruguay). Paraguay is the main intra-regional exporter of renewable electricity (mainly to Brazil and Argentina). The Central American Electrical Interconnection System (SIEPAC by its Spanish initials), completed at the end of 2013, allows for the trade of electricity between Panama, Costa Rica, Nicaragua, Honduras, El Salvador and Guatemala. Other interconnections exist in the region, such as between Chile and Argentina (reactivated in 2015 following a period of power scarcity), Venezuela and Colombia, Colombia and Ecuador, and Ecuador and Peru (CIER, 2014). Several hydropower projects aiming to export electricity are at different stages of development in the region.

**Figure 2.4** Renewable power generation in Latin American sub-regions, 1990-2013 (excluding all hydropower)



Note: Different scale for each sub-region.

Source: IEA, 2015b

## 02

### Renewable energy in final consumption

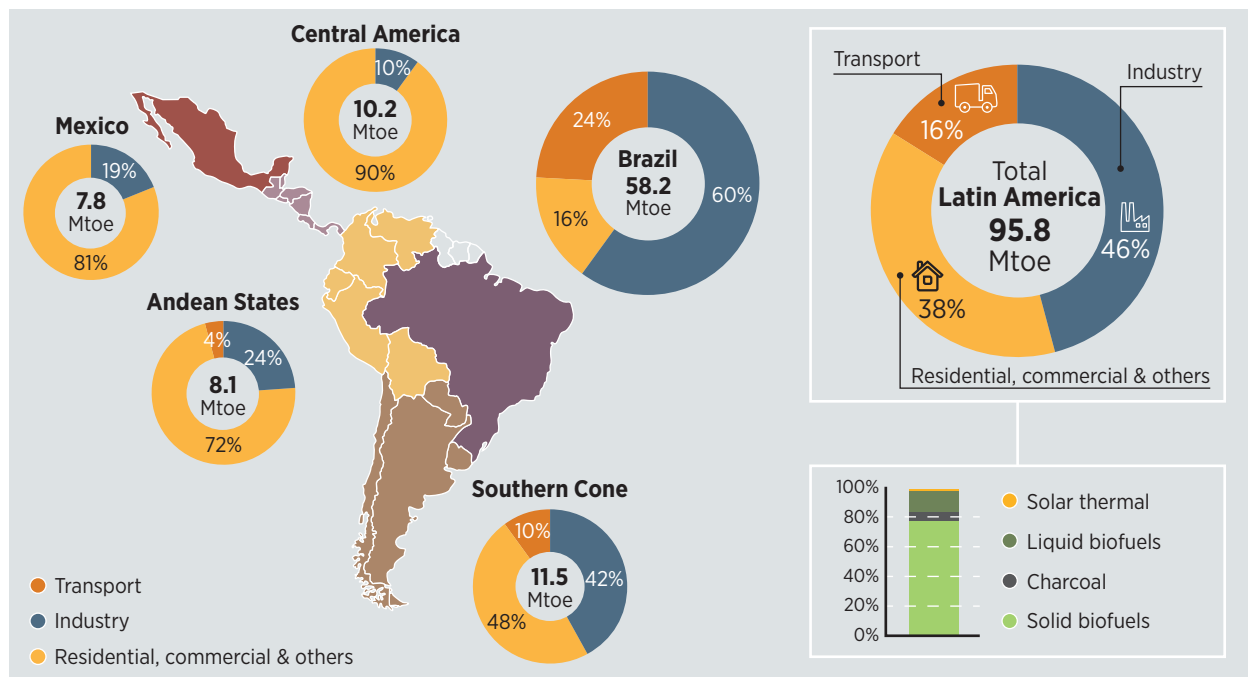
The share of renewables in total final energy consumption (TFEC) in Latin America is one of the highest in the world, reaching 27% in 2013, compared to a global average of 18%<sup>1</sup> (IEA, 2015b). Within Latin America, this share ranges from 9% in Mexico to 66% in Guatemala.

Over the last two decades, the share of renewable energy in Latin America's TFEC has decreased slightly (from 32% in 1990 to 27% in 2013) following a drop in the consumption of traditional solid biofuels and an increase in non-renewable sources<sup>2</sup>. The share of renewable energy in the residential sector has decreased overall (see figure 1.12), due mainly to the substitution of traditional solid biofuels. Renewable energy consumption in the industrial sector has increased significantly in absolute terms since 1990, surpassing its use in the residential sector. Within the industrial sector, the largest increases include solid biofuels<sup>3</sup> in the

food, beverages and tobacco industries (mainly in Brazil) and in the pulp and paper industries (mainly in Brazil, Chile and Uruguay). Within the transport sector, the high proportion of renewable energy is explained historically by liquid biofuels consumption in Brazil since the mid-1970s and in Argentina, Peru and Paraguay since the mid-2000s (albeit at a smaller scale).

It is important to note that Latin America's final energy use for heat accounts for close to half of TFEC in the region. Renewables (mainly bioenergy but also solar thermal) supply 35% of heating uses, out of which around one-quarter is traditional solid biofuels. The extremely large use of solid biofuels in Brazil's industrial sector dwarfs other uses and other regions (see figure 2.5). Other important final uses of renewables are bioenergy in the residential sector (mainly in Brazil, Central America and Mexico) and liquid biofuels in Brazilian transport. At a minor scale, relevant

**Figure 2.5** Final consumption of renewable energy in end-use sectors, 2013



Note: "others" includes public services, agriculture and forestry, fishing and «non-specified» (the last one, as defined by the IEA).

Source: IEA, 2015b

1. Including the renewable component of consumed electricity.
2. Due to data limitations, the following discussion excludes the renewable component of consumed electricity.
3. Following the IEA definition of traditional solid biofuels, i.e., solid biofuels used in the residential sector in non-OECD countries (normally with very low combustion efficiency). Note that two countries in Latin America belong to the OECD Chile (since 2010) and Mexico (since 1994).

applications include the use of charcoal in Brazilian industry and in the Southern Cone's residential sector, and the use of solar thermal in Brazilian and Mexican residential and commercial sectors (IEA, 2015b).

### ■ Industrial sector

Latin America's industrial sector is characterised by the clear dominance of modern solid biofuels in Brazil due to the country's large sugarcane and pulp and paper industries. However, in the case of the sugarcane industry, the use of bagasse historically has had low efficiency since many generators were not able to sell all generated power to the grid, reducing the incentive to maximise efficiency in the process (see section 2.2). Brazil is also the largest consumer of industrial charcoal globally, using around 4 Mtoe annually in iron

and steel and cement industries (IEA, 2015b), although use has been decreasing recently from a peak of around 6 Mtoe in 2004. The other industrial powerhouse, Mexico, has a much smaller share of renewable energy (4% in industrial TFEC in Mexico, compared to 42% in Brazil<sup>4</sup>).

Many renewable heating technologies are reaching maturity and can be cost-competitive with fossil fuel-based heat in an increasing number of countries – notably solar water heating in the residential sector, but also solar thermal applications in the mining, dairy processing and textile sub-sectors (IEA-ETSAP and IRENA, 2015a). The region therefore presents a significant potential for further renewable energy use in the industrial sector, specifically for heating purposes, as shown in the *In Focus* sub-section below.



4. Excluding the share of renewables in consumed electricity, which would make the comparison even more favourable for Brazil because the Brazilian power mix has a larger share of renewables than the Mexican one.

## 02

IN FOCUS: RENEWABLE ENERGY FOR HEATING APPLICATIONS IN INDUSTRY<sup>5</sup>

Latin America's final energy use for industrial heat<sup>6</sup> accounts for a quarter of TREC in the region (IEA, 2015b). The share of renewables with that heat is high in comparison with the world average (31% compared to 10% globally). Among the Latin American sub-regions, the highest share is found in Brazil at 54%, followed by Central America at 25% and the Southern Cone at 24%. The other sub-regions have much smaller shares (IEA, 2015b). Some individual countries stand out, such as Paraguay (96% of industrial heat coming from renewables), Uruguay (80%) and Costa Rica (63%). Even if the share in Brazil is relatively lower (54%), the dominance of Brazil within Latin America's total energy consumption is largely responsible for the high regional share. The industries with the largest shares of renewables for heat are food and tobacco; paper, pulp and printing; and wood products. Other industries in the region that use significant amounts of renewables are iron and steel and non-metallic minerals.

Bioenergy dominates in the high shares of renewables for industrial heat. The industries with the highest shares of renewables are closely related to agriculture and forestry activities, where bioenergy can be conveniently sourced. The specific types of bioenergy used by these industries are solid biofuels such as bagasse, but also charcoal (primarily for the iron and steel industry). A much smaller amount of other bioenergy sources is used, mainly liquid biofuels. The IEA energy balances do not provide further granularity on the specific types of solid biofuels used. IRENA is working to improve data availability, using information from questionnaires and official sources such as national energy balances. According to these balances, the most-used solid biofuels are bagasse, black liquor, wood waste, firewood and charcoal. Other solid biofuels – such as rice husks, straw, palm tree waste and other food processing waste – are starting to be used in the region.

With the exception of the sugarcane industry, notable data gaps exist regarding bioenergy use in Latin America's industrial sector. Statistics are available for the sugarcane industry because of the sale of surplus electricity to the grid, which is reported in official information. The data gaps in other types of bioenergy are due to two main reasons: 1) these uses are more recent than the sugarcane industry, and 2) most importantly, the way energy is used by private companies is not reported in most energy balances. Although this raises questions about the actual magnitude of bioenergy use, the fact remains that it is broadly used and is far ahead of other renewables.

Other sources of direct renewable heat suitable for industrial applications are solar and geothermal. According to IEA statistics, geothermal is not used in industrial applications in the region. However, there is some anecdotal evidence, especially by agricultural industries in Central America (see section 3.2). Solar thermal, meanwhile, is growing exponentially, given its significant potential in industries that require low – or medium – temperature heat. For example, Chile's mining industry is taking a proactive role in developing solar thermal in the country's isolated northern region. In 2013, the world's then-largest solar thermal plant was inaugurated in the Antofagasta region, which supplies 85% of the heat demand of the Gabriela Mistral (Gaby) copper mine, owned by the state company Codelco (Codelco, 2013). Other similar projects exist at a smaller scale, such as Minera Constanza (Minería Chilena, 2013).

Additional solar heat applications are emerging in the agro-processing sector, among others. Mexico has 15 ongoing projects with solar thermal applications, including in the dairy processing and textile sub-sectors (IEA-ETSAP and IRENA, 2015a), and small but growing markets exist in Argentina, Costa Rica and Uruguay. Box 2.1 discusses the main drivers and barriers to renewables-based heating in the industrial sector in Latin America.

5. The analysis presented in this sub-section is based largely on field and desk research carried out by IRENA. This research included in-depth analysis of three case studies: the Pampa Elvira Solar solar thermal plant at the Minera Gaby copper mine (Chile), use of agricultural residues by the coffee co-operative Coopodota (Costa Rica) and valorisation of wood residues at a plywood factory owned by Weyerhaeuser Products S.A. (Uruguay).

6. According to the definition provided in chapter 1. For the purpose of analysing industrial heat, a sub-division between "direct" and "process" heat could be developed, but there are significant data gaps.



## Box 2.1 Drivers, barriers and potential solutions to scale up renewable energy for industrial heating applications

### Main drivers

The first driver for the adoption of renewable heat sources relates to industrial competitiveness and risk reduction (*i.e.*, to ensure a constant supply of heat at a pre-defined price), instead of the price volatility associated with other energy sources. An interesting example is the business model adopted by Chilean Codelco for the Gabriela Mistral (Gaby) copper mine. A 10-year heat supply power purchase agreement (PPA, a type of contract normally used in the power sector) was signed with a solar thermal plant owned and operated by the Chilean-Danish consortium Energía Llama-Sunmark.

The competitiveness rationale also applies in the case of bioenergy, for example with process residues that are obtained at a predictable rate and can be used for energy purposes, as illustrated by the plywood factory owned by Weyerhaeuser in Uruguay. Importantly, using bioenergy residues also reduces the costs of disposing them, which has been a driver of bagasse usage in the Brazilian sugarcane industry for years.

A second driver is marketing, since “green” labelling can open new markets. The Costa Rican coffee co-operative Coopedota uses the residues of coffee processing as fuel for producing the heat needed to dry the coffee. As a result, the co-operative uses less fuelwood from forests, reducing the environmental impact of its operations. In 2011, the co-operative received carbon neutrality certification for its products, allowing them to access new international markets and to receive a price premium on sales.

### Barriers and potential solutions for further development of industrial renewable heat

The potential for renewables for industrial heat applications goes far beyond current developments. Some of the most relevant barriers and potential solutions that have been identified include:

- **Lack of comprehensive, regular and consistent statistical information**, a direct consequence of the lack of reporting from industrial companies on the sources of energy they consume and its specific uses. Data currently come from energy distribution companies. This could be complemented with resource-intensive field studies including surveys of final energy consumers and, in some cases, capacity building for them to correctly report on their energy uses (IRENA is working on statistics capacity building, *e.g.*, through workshops and a manual on bioenergy statistics).

- **Lack of knowledge in most of the industrial sector about renewable energy technologies available for heat uses**, their operational characteristics, their potentials and their costs. Some examples exist of companies with such knowledge, but systematic information-sharing mechanisms, especially with small and medium-sized companies, could greatly expand the market for renewable heat. IRENA’s work on renewable energy potentials (*i.e.*, the Global Atlas) and costing aim to improve the knowledge in these areas.

- **Difficulty in ensuring constant bioenergy supply, and price volatility**. In the case of Brazil, the price of bagasse varies greatly depending on the harvest period, ranging from USD 0 to USD 27 per ton, with the average price around USD 11 per ton. The problem with low-cost agricultural feedstocks is that, in the case of independent power producers, the amount of bagasse available depends on the opportunity cost of ethanol versus sugar production, depending on market prices. This makes it difficult to negotiate long-term contracts to reduce price risk and guarantee security of feedstock supply, except where a captive feedstock exists (*e.g.*, the pulp and paper industry).

- **Access to adequate financing** has improved in recent years in several countries in which some private banks, sometimes managing credit lines from national or regional development banks, offer credit for energy efficiency, renewable energy and emissions reductions (*e.g.*, Mexico, Brazil, Peru and Colombia). But this is recent, and such credit lines often are not adequately designed for those purposes and for industrial companies. In addition, there are important information challenges, notably with small and medium-size industries that may not know about financing possibilities.

- **Energy pricing regimes**. Some Latin American countries subsidise several types of energy sources for industrial applications (*e.g.*, natural gas), reducing the economic case for the use of renewables such as agricultural residues.

Policies for renewable industrial heat have the potential to unlock a substantial market in Latin America, particularly given the existing high use of bioenergy for industrial heat in the region. There are some indications that if an adequate enabling framework is in place, renewable heat can be competitive in a broad set of industries, with multiple economic, social and environmental benefits.

## 02

### ■ Residential and commercial sectors

In other sectors, mainly residential, solid biofuels (both modern and traditional) represent a significant share of final consumption in all sub-regions. Overall, Latin America has witnessed a slight decrease in traditional uses of solid biofuels<sup>7</sup>, most notably in Brazil and the Andean States. This is mainly a result of rural-urban migration<sup>8</sup> and the adoption of (sometimes subsidised) LPG or natural gas (Jannuzzi & Goldemberg, 2014; Lucon *et al.*, 2004). However, some countries have seen a different trend. In Chile, the consumption of firewood has grown since 1990, mainly in the south, as a result of improved living standards and higher gas prices, leading to worsening air quality in some cities (IIASA, 2012).

Traditional solid biofuels in the form of firewood still represent a significant share of residential energy consumption, notably in Central America, Paraguay, Peru and Bolivia (WHO, 2013). This is particularly the case when LPG is relatively expensive or unavailable (*e.g.*, in isolated communities). The use of firewood in the region, however, does not imply significant deforestation overall (Kissinger *et al.*, 2012). In Central America, an estimated 20 million people are dependent on firewood (mainly for cooking), mostly in rural areas of Guatemala, Honduras and Nicaragua (WHO, 2013). In this sub-region, traditional solid biofuels represent over 80% of consumption in the residential sector. In Guatemala, Honduras and Nicaragua, over two-thirds of households rely on traditional firewood for cooking. Such high levels of firewood use have serious health and environmental impacts which warrant specific policy attention. Some countries have strategies to promote the sustainable use of firewood and have joined forces with the Global Alliance for Clean Cookstoves (GACC). For example, Nicaragua has adopted a “National Firewood and Charcoal Strategy”.

Since the mid-2000s, solar thermal has started to play a role in the *other uses* sector (as per IEA sta-

tistics), mainly in Brazil (primarily for residential uses) and in Mexico (in the residential, commercial and public sectors). Solar thermal projects also are emerging in the industrial sector, including the Pampa Elvira solar project in Chile (see box 2.1) and in the dairy processing and textile sub-sectors in Mexico (IEA-ETSAP and IRENA, 2015a). Brazil ranked third globally for new installations of solar water heating systems in 2013 (Mauthner *et al.*, 2015). Market growth is driven largely by municipal mandates (see section 2.2) and social housing programmes, supported by institutions such as the state-owned bank CEF (Caixa Economica Federal). Mexico also has an incipient market, ranking 11<sup>th</sup> globally for capacity additions in 2013 (Mauthner *et al.*, 2015), and other small markets are emerging in Central America and the Southern Cone.

### ■ Transport sector

In the transport sector, Latin America uses the highest share of renewable energy globally, due to the important role of liquid biofuels, which accounted for 7% of the sector’s TFEC in 2013 (IEA, 2015b). The region currently produces 27% of global biofuels, and production more than doubled between 2001 and 2013. In 2013, Brazil produced 28 billion litres of bioethanol, the second largest volume globally after the United States. Most Brazilian bioethanol production (above 80%) is consumed locally<sup>9</sup>, the blending mandates being among the world’s highest. Argentina is one of the world’s top biodiesel producers (12% of global production in 2012), with around 70% of domestic production for exports to Europe and, more recently, the United States (EIA, 2015).

Whilst Brazil and Argentina dominate production in the region, other countries – including Colombia, Costa Rica, Ecuador, Guatemala, Honduras, Mexico and Peru – have invested in biofuel production to diversify their transport fuel mix. Many countries in the region have at least one type of

7. Data are especially challenging. In some countries, different data sources differ by more than 100%.

8. Such migration is a result, for example, of social support programmes that provided cash transfers to families linked to children attending school, lifting millions out of poverty and creating the incentive to move to more urbanised areas (*e.g.*, Brazil’s Bolsa Familia).

9. In the case of Brazilian ethanol, besides anhydrous ethanol blending for gasohol, pure hydrated ethanol is used in flex-fuel cars.

blending mandate for bioethanol and/or biodiesel – including Argentina, Brazil, Colombia, Costa Rica, Ecuador, Guatemala, Mexico, Panama, Paraguay, Peru and Uruguay (see table 2.3).

### Wind and solar potentials

Overall, the rapid growth of renewable energy in Latin America, both for power generation and in end-use sectors, attests to the large resource endowments of the region. Several studies document renewable energy's immense technical potential (Hoogwijk & Graus, 2008; Meisen & Krumper, 2009; Poole, 2009; ICA, 2010). However, it is important to note that the analysis of a country or region's renewable energy potentials is not an exact science. It provides orders of magnitude, not precise numbers. More specific mapping tools are only beginning to assess the technical potential of some of these technologies. Renewable energy resource maps can raise investor awareness of the considerable renewable energy potential at the country level.

There is no standard methodology for estimating renewable energy potential. Although some common parameters can be found for solar and wind technical potentials, each study has its own methodology, leading to significantly different results, which are valid for a specific set of assumptions. The Intergovernmental Panel on Climate Change's special report on renewable energy (IPCC, 2011) details the various methods and denominations of assessing renewable energy potentials. Recent improvements in the quality of public resource maps are creating a paradigm shift in the analysis of renewable energy potentials globally. It is currently possible to initiate the prospection of future project areas based on geospatial analysis (see box 2.2).

#### Box 2.2 Geospatial analysis of renewable energy potentials in Latin America with IRENA's Global Atlas

Geospatial analysis consists of one or several maps overlapping resource potential data with other relevant parameters such as distance to grids, transportation networks, topography, land cover, population density, protected areas, etc.<sup>10</sup> No such analysis has yet been performed for the entire Latin American region. However, mapping tools and technical assistance are available across the continent and are being referenced through the Global Atlas initiative co-ordinated by IRENA. For Latin America, the Global Atlas references national resource atlases, as well as the outcomes of international studies<sup>11</sup>. National maps can be used as a basis for national-level analyses. Additional datasets available through the Global Atlas include the location of power lines and connection points, population density, protected areas, land cover and topography. The Global Atlas provides access to all datasets under a single access point.

For the purpose of this report, IRENA carried out a geospatial analysis of wind and solar resources in Latin America by developing *suitability maps* for the whole region. These maps factor in the solar and wind resource, distance to the grid, population density, protected areas, land cover and topography (see figures 2.6 and 2.7). The methodology and discussion of the results are detailed in IRENA (2016b). The resulting maps show suitability scores (0-100%) over the entire continent, for solar PV and wind energy, grid-connected and off-grid<sup>12</sup>. For each of the four configurations, three grid distances are simulated – 50 km, 100 km and 150 km – for a total of 12 continental maps<sup>13</sup>.

10. National resource atlases often provide this information. The IRENA Global Atlas provides access to the national atlases of Chile, Peru, Mexico and Uruguay. See [www.irena.org/globalatlas](http://www.irena.org/globalatlas).

11. For example, maps of the Danish Technical University (DTU), US National Renewable Energy Laboratory (NREL), German Aerospace Center (DLR), Spanish Center for Renewable Energy (CENER), Masdar Institute and Mines ParisTech extend over multiple countries.

12. In the context of this study, off-grid can be seen as suitable locations that are far away from existing grids (for each of the grid distances simulated). It represents, for instance, potential locations for off-grid residential communities or industrial sites, e.g., mines.

13. The calculations were performed at 0.7 km resolution for an average of 100,000,000 pixels per map. The suitability maps are freely available through the IRENA Global Atlas at <http://irena.masdar.ac.ae/?map=2012>.

**Figure 2.6** Examples of wind power suitability maps: grid connected (left), off-grid (right)

*Note: The maps show spots with a suitability for wind projects of 60% or higher at a grid distance closer to 75 km for grid-connected (left) and farther than 75 km for off-grid (right). The colour scales ranges from 60% suitability (yellow) to above 80% suitability (red). The maps are available on the IRENA Global Atlas website (<http://irena.masdar.ac.ae/?map=2012>). The analysis was carried out, for both solar and wind, for grid-connected and off-grid, and for several grid distances, using IRENA's Renewable Energy Suitability Analysis methodology (IRENA, 2016b). The maps are displayed using IRENA's Global Atlas with Google Hybrid Map (Google, 2016) as base map.*

This approach provides relevant information while avoiding confusion with energy scenarios or energy system modelling. For example, the installation density is the same for grid-connected and off-grid systems, therefore results can be compared in a qualitative manner, not as absolute values. It is also important to note that the results can be greatly improved by using country – or regionally – validated resource atlases or detailed maps of power grids.

Instead of showing go/no-go zones, suitability maps indicate the likelihood of discovering a favourable location, with a level of confidence that can justify further exploration. Such information provides a first overview of possible areas of interest for further investigations. The maps do not allow for detailed site assessment and do not

provide “bankable” information. Instead, they are a first step towards initiating a dialogue within countries, energy authorities (e.g., ministries, renewable energy promotion agencies, rural electrification agencies, etc.) and potential renewable energy investors and project developers.

These suitability maps can be converted into equivalent GW, using simple assumptions. The objective of this exercise is not to provide definite values of wind or solar technical potentials, but to help the reader grasp the scale of the opportunities highlighted by the maps. For instance, if 1% of the region-wide surface with suitability above 60% is developed, the total installed capacity would be 240 GW for grid-connected wind<sup>14</sup>, i.e., 16 times the current installed capacity of 15 GW.

14. The approach is detailed in IRENA (2016b).



**Figure 2.7** Examples of wind power suitability maps: southern Mexico grid-connected



*Note: This map is a zoom on southern Mexico of the grid-connected map from the previous page. It shows spots with a suitability for wind projects of 60% or higher at a grid distance closer to 75 km. The colour scales ranges from 60% suitability (yellow) to above 80% suitability (red). The map includes a rectangle over north-western Yucatan Peninsula, where 60 MW of wind projects have been recently announced, and it also includes (marked as green triangles) the location of current wind farms. The maps are available on the IRENA Global Atlas website (<http://irena.masdar.ac.ae/?map=2012>). The analysis was carried out, for both solar and wind, for grid-connected and off-grid, and for several grid distances, using IRENA's Renewable Energy Suitability Analysis methodology (IRENA, 2016b). The maps are displayed using IRENA's Global Atlas with Google Hybrid Map (Google, 2016) as base map. Wind farm locations are from (The Wind Power, 2016).*

*Source: IRENA, Global Atlas*

## 02

## 2.2 DRIVERS AND POLICIES FOR RENEWABLES

Earlier parts of this chapter described the current status and recent trends in renewable energy deployment in Latin America. A set of increasingly inter-related drivers are behind these trends. Their relative importance depends on specific country and sub-regional characteristics. Building on these overarching drivers, the deployment of renewable energy critically depends on a sound policy framework to attract investment. A wide variety of policies and financial mechanisms have proven effective to promote renewable energy in Latin America. This section provides an overview of the main drivers for the deployment of renewables, the institutional setting for policy making and the wealth of experience in renewable energy policies in the region.

### Regional and sub-regional drivers

Since the 2000s, Latin America has seen a rapid and more diversified development of renewable energy sources, favoured by the convergence of overall drivers at the crossroads of energy security, economic competitiveness, and social and environmental sustainability.

Chief among those is energy security, which takes on two main forms for the region's oil and gas importers (*i.e.*, the majority of countries in Latin America): 1) the need to reduce the adverse macroeconomic effects of high dependence on

fossil fuel imports due to price volatility, and 2) the risk of supply disruptions arising from nationalisations (Bolivia) or domestic demand surges in producing countries (Argentina). These risks are due in particular to the expanded role of natural gas, which accounted for 20% of power generation in 2014 compared to 8% in 1990 (World Bank, 2016a). The same driver applies to the transport sector, where several countries seek to diversify fuel sources through the implementation of blending mandates (most notably in Brazil).

Since the natural gas disruptions in South America in 2004, energy security has been a driver for energy diversification away from *both* natural gas *and* hydropower, to reduce the vulnerability to changes in hydrological cycles (such as those occurring in El Niño years) which affect hydropower output, the main source of electricity in the region (hydropower decreased from 73% of the region's total generation in 1990 to 55% in 2014) (World Bank, 2016a). Taking advantage of technology cost reductions (in particular for bioenergy, wind and, more recently, solar PV; see chapter 3) through the use of market-based policy instruments, energy diversification through renewables has been contributing to energy security while also ensuring more stable electricity prices.

Renewable energy sources further enhance the decarbonisation of the region's energy sector. Although by global standards greenhouse gas emissions from the region's power sector are relatively low, emissions from energy use (*i.e.*, including transport and agriculture) are growing steadily and reaching the levels of OECD countries. In many national energy plans and laws, the reduced health and environmental impacts of renewable energy sources compared with fossil fuels, particularly at the local level, are stated as an important benefit. In addition, the region faces growing popular resistance to large hydropower as well as other large conventional power plants, resulting in delays of new projects. Because of their modular nature and more limited social and environmental impacts, wind and solar PV projects in particular, have a significant advantage in terms of operational feasibility and social acceptability.



More recently, the socio-economic benefits of renewables have become an important consideration for policy makers. These benefits include employment creation and the development of local value chains, including through local content requirements to help develop nascent domestic renewable energy industries (chapter 3).

Given the vastness of the Latin American region as a whole, looking at sub-regional level drivers shows how renewable energy deployment has been shaped by local and country-specific conditions, macroeconomic trends, the structure of the energy sector, resource endowments and development priorities.

### ■ Mexico recasting its energy mix towards clean sources

Mexico depends heavily on fossil fuels, but strong policy attention aims to diversify the energy mix with “clean energy sources”<sup>15</sup>, including renewable energy. Mexico accounts for one-fifth of all energy use in Latin America, and the demand is growing fast. Business-as-usual growth would result in an increase in installed power generation capacity from 64 GW in 2013 to 118 GW in 2030 (IRENA, 2015a). Mexico is the region’s largest producer of natural gas and its second largest producer of oil, but it also is a net importer of refined fuels, mainly from the United States, and Mexican imports of natural gas and coal are growing. Mexico’s dependence on natural gas for power generation has become a major concern for national energy policy.

To address these and other challenges, Mexico has enacted a series of energy reforms since December 2013. These have opened the energy sector to private investment, aim to establish a competitive wholesale power market and are set to gradually remove subsidies for oil products and electricity tariffs over the coming years. Mexico has the highest carbon dioxide (CO<sub>2</sub>) emissions from electricity and heat production in the region. To help meet its GHG emission reduction goals, it has set targets for 35% of electricity from clean energy sources by 2024, 40% by 2035 and

50% by 2050. These trends have boosted the case for renewable energy deployment (IRENA, 2015a) and recent years have seen an investment boom in wind (the Oaxaca state is considered to have some of the world’s best wind resources) and more recently in solar PV (Mexico is ideally located in the so-called Solar Belt). The Energy Reform envisages the issuance of clean energy certificates as the primary mechanism to promote investment in clean energy sources by translating the national goals of clean energy generation into individual obligations for all agents of the new electricity market.

### ■ Diversification through renewables and integration in Central America

Central America’s regional power demand grew 65% over the last decade. The sub-region’s electricity mix is currently split between two main sources: hydropower (48%) and oil products (35%) (IEA, 2015b). Historically, Central America has been powered mostly by hydropower, but in the mid-1990s the share of hydropower started to decrease due to additional oil-based generation and, more recently, coal generation. The structure of the sub-region’s electricity mix has generated concerns about energy security, especially given severe droughts in the 1990s that resulted in electricity shortages.

This has led Central American countries to devise strategies to strengthen security of supply through: 1) the diversification of their energy mix to include other renewable energy sources, and 2) the development of the Central American Electrical Interconnection System (SIEPAC) line. In the mid-2000s, increasing shares of renewables – such as wind in Costa Rica, Honduras and Nicaragua; biomass in Belize and Guatemala; and new hydropower in all countries – started to ease the sub-region’s dependence on oil. Geothermal energy is used for power generation in some countries in Central America and has increased (nearly five-fold since 1990), notably in El Salvador (which has the world’s second largest share of geothermal generation after Iceland, at 25%; IEA, 2015b)

15. “Clean energy”, as defined in Mexican legislation, includes renewables, co-generation, nuclear energy, fossil fuels with carbon capture and storage (CCS), and “other low-carbon technologies”.

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and Costa Rica (17%). As a result, the sub-region has the highest share of renewables in TPES (54%) and the most diverse mix of renewable energy sources, including bioenergy, geothermal, hydropower, wind, and more recently solar PV.

In late 2013, completion of the first SIEPAC transmission line saw the start of international energy exchanges and the creation of a regional market for electricity (MER by its Spanish initials) from all sources. These strategies have built on the synergies between renewable energy and climate change policies in the sub-region. In 2007, all members of the Central American Integration System (SICA) adopted the “Central American Sustainable Energy Strategy 2020”, which aims to increase the share of renewable energy in the regional market by 11% and to reduce greenhouse gas emissions by 20% (Dolezal *et al.*, 2013). The SIEPAC interconnection has enabled Central American countries to cope with recent droughts and reduced hydropower generation between 2013 and 2015 without rationing electricity (CEPAL, 2015). The next stage of integration will require the harmonisation of the regulatory framework for electricity trade across the region’s different power market structures (see figure 1.9).

#### ■ Off-grid renewable energy opportunities in the Andean States

The Andean sub-region includes four major fossil fuel producers (Venezuela, Bolivia, Ecuador and Colombia), a factor that has shaped the region’s energy and electricity mixes. The sub-region’s electricity mix is one-third fossil-based and two-thirds hydropower-based. Other renewable electricity generation beyond hydropower is still limited in the region. Given the sub-region’s fossil fuel resource endowment, the emphasis on developing them, and high subsidy levels, it faces challenging conditions for renewable energy development. However, increasing concerns over energy security due to fossil price volatility and climate variability may drive Andean States to further develop their renewable sources beyond hydropower. Accordingly, in 2014, Bolivia published Decree 2048, which establishes remuneration prices for renewable energy producers, and Ecuador’s 2015 Electric Law puts emphasis on the promotion of

renewable energy sources. Since 2009, Peru has been using technology-specific auctions to promote renewable energy sources both on-grid and off-grid. In Venezuela, the development of non-hydropower renewables has been minimal, and exclusively focused on off-grid.

Importantly, with over 5 million people lacking access to modern energy, Andean States are promoting off-grid renewable energy solutions to provide access to their isolated, rural populations. Excellent solar resources (see section 2.1), as well as the falling costs of wind and solar PV and their unique suitability to isolated, low-density areas, make them a compelling solution to provide electricity to unserved populations, particularly in Bolivia, Peru and Ecuador, which have the lowest access rates. Examples are Bolivia’s *Electricity and Renewable Energy Access* programme, Ecuador’s efforts to promote solar PV in the isolated areas of the Galapagos Islands or the Amazon region, Peru’s ambitious *National Photovoltaic Household Electrification Programme* aiming to provide electricity access to 2 million people by end 2016, and Venezuela’s *Sowing Light* programme (*Sembrando Luz*) providing water and energy services in remote and indigenous areas through solar PV and hybrid (PV-wind-diesel) systems.

#### ■ Brazil as a powerhouse for non-hydropower renewables

Brazil is the largest economy in Latin America and has an installed capacity of 123 GW, approximately twice that of the region’s next largest economy, Mexico. Only 20% of Brazil’s power capacity is based on fossil fuel sources, mainly fuel oil, natural gas and coal. The share of natural gas has notably increased since the early 2000s. Brazil’s power generation is dominated by large hydropower, which accounted for 66% of total generation in 2014 (EPE, 2015), down from around 70% in 2013 and much lower than the 80% average over the 2004-12 period (EPE, 2015). Important drivers for diversifying Brazil’s electricity mix away from hydropower are concerns about extreme droughts that have led to energy shortages, and construction delays in new large energy projects. A key problem is related to the limited expansion of reservoirs. Since the early 2000s, most hydropower



plants in Brazil have been built without technically recommended reservoirs due to environmental restrictions. This, together with severe and long dry seasons, has led to energy shortages (Tancredi and Abbud, 2013).

After a major drought and power crisis in 2001-02, Brazil undertook to diversify its electricity mix through the development on natural gas-fired generation and non-hydropower renewables. In 2002, the government launched the *Incentive Programme for Alternative Electric Energy Source* (PROINFA) to promote the development of wind, biomass and small hydropower. At the end of 2008, for new renewable energy projects the PROINFA system was replaced by a procurement process of auctions of power purchase agreements (PPAs). Brazil's auction system has driven the massive development of the country's wind sector, which saw installed capacity increase from 606 MW in 2009 to 5 GW at the end of 2014 (IRENA, 2016a).

A historical drought in 2014-15 has further reinforced the need for diversification and the importance of distributed generation to facilitate the integration of small-scale renewables into the distribution grid. Therefore, both auctions and net metering policies will continue to play a crucial role in the development of Brazil's power sector. Given recent hydropower scarcity and the need to add new capacity to meet demand, in 2014, the government conducted auctions for a total of 4 GW of biomass, solar, small hydro and wind. The 2014 auction was particularly noteworthy for the solar PV sector, which was included for the first time in the country's auction system. The Brazilian government has also supported solar applications in rural areas. The rural electrification programme *Light for All* has a significant focus on renewables, and considers PV systems as the most cost-competitive electrification option for small isolated communities in the Amazon region.

Importantly, Brazil has actively sought to maximise the socio-economic benefits of renewable energy deployment. Through its industrial policy and local content requirements, it has developed local value chains in all of the country's renewable technologies, most notably in the wind sector



(see chapter 3). Local content requirements are not specific to renewable energy technologies in Brazil, as eligibility for funding from Brazil's Development Bank (BNDES) requires a certain level of local content for a range of infrastructure projects.

#### ■ Chile and Uruguay leading renewable energy development in the Southern Cone

The electricity mix in the Southern Cone is dominated evenly by natural gas and large hydropower, which account for 31% and 41% of generation, respectively (IEA, 2015b). However, major differences exist within the sub-region. Argentina is the largest natural gas producer in South America, while Paraguay is the third largest electricity exporter in the world and the largest in the region.

Chile leads the sub-region in investment renewable energy, in particular wind, solar PV and CSP. It has a vast renewable energy potential, high demand growth rates, high electricity prices and a favourable investment climate. Strong public opposition to new large hydropower and coal projects has also favoured renewables.

Following years of underinvestment, in 2005 Uruguay implemented a paradigm shift from a pure market approach to a public strategic planning approach. As a result of a successful enabling policy and regulatory framework, Uruguay has seen a remarkable energy transition towards the objective of 100% renewable electricity in just over a decade. Renewable electricity deployment has

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achieved higher capacity and lower costs than originally anticipated. In 2015, the country far exceeded its targets, and renewable electricity accounted for 94.5% of total power generation.

Given its vast hydropower production, Paraguay has met most of its electricity demand through its three mega-hydropower plants, with little incentive to promote other renewable energy sources except for biofuels in the form of a blending mandate for gasoline and diesel. Paraguay's main driver to develop non-hydropower renewables relates to the high rate of power demand growth currently between 10-12% (Vice-Ministry of Energy and Mines of Paraguay, 2014), in part due to low electricity prices, which mean that by 2030 the country could consume all of the electricity it produces thereby potentially reducing exports to Brazil and Argentina to zero.

Argentina has policies in place to promote renewable energy sources, but the dominance of fossil fuels and large hydropower (which accounted for 64% and 30% of the country's power mix in 2014) and high levels of energy subsidies have limited the development of renewables to date. However, the country is endowed with vast renewable energy resources (e.g., solar in the northwestern regions and wind in Patagonia). The new government has announced that the country's energy matrix must be diversified through nuclear and renewable energy sources to reduce the use of hydrocarbons. Following the adoption of a new renewable energy law at the end of 2015 (see box 2.3), a new strategy is being developed to pro-

### Box 2.3 Argentina's renewable energy law

In September 2015, Argentina's Congress approved a law mandating that the country consume 8% of its electricity from renewable energy sources, excluding hydropower plants larger than 30 MW, by 2017. The law also calls for this target to increase to 20% by 2025. The law modifies Law 26190, established in 2006, which mandated similar targets but did not result in the development of a national renewable energy market due to lack of investment. In April 2016, the government published Decree 531, which regulates the new and improved renewables law 27191.

mote renewable energy investment , including an auction for 1 GW of renewable power scheduled in 2016.

The above review of regional and sub-regional dynamics points to the crucial role of renewable energy policies as a key driver of deployment. Although the choice of policy instrument varies depending on countries' macroeconomic conditions, energy sector structure and resource endowment, the institutional framework plays a central part in effective policies.

### Institutional setting

The institutional setting for renewable energy policy in Latin America is as complex as the field it tries to encompass. An initial survey of national public institutions with renewable energy attributions in Latin America conducted by IRENA in 2015 showed that there are at least 120 public institutions working on aspects such as renewable energy policy, regulation, research, innovation, finance, procurement, investment promotion, co-operation, etc.

Public institutions working on renewable energy can be placed along a spectrum according to their original mission. On one end are the institutions that were established with a non-renewable mission and were given renewable energy attributions either for historical reasons or because renewables are part of a broader energy mandate. This includes, for example, regulatory authorities in charge of fiscal incentives and fixing tariffs for renewable energy fuels and electricity, mining institutions regulating geothermal energy, and financing of renewables by development funds and public banks. On the other end are institutions created specifically for a renewable energy purpose. This includes, for example, renewable energy funds, dedicated research centres, ministries in charge of renewable energy or units within ministries, and inter-ministerial co-ordination mechanisms.

Most of the surveyed institutions, however, are found somewhere in the middle of the two ends of the spectrum. They had energy attributions in their original mission and, as renewables gained relevance, those attributions evolved to include

renewables. Such institutions range from energy ministries and departments making policies for and regulating renewables, to transmission system operators establishing dispatch rules for variable renewable generation, to public oil companies distributing biofuels, to rural electrification funds using solar PV, to name just a few.

The most common types and attributions of renewable energy institutions include: policy making and implementation; sectoral regulation (electricity, biofuels, environment, food); planning; advisory and co-ordination; education and training; research and development; energy access; development of technical norms and standards; setting of tariffs, taxes and subsidies; finance (loans, grants, pre-investment); project development; system operators; and public energy companies (electricity and oil).

Depending on the needs, capabilities and institutional legacy of each country, those attributions may be spread across several institutions (such as in Brazil, Colombia and Mexico, with over 10 identified institutions each) or concentrated in just a few (such as the Guyana Energy Agency or the Belize Public Utilities Commission). The assignment of attributions is not necessarily clearly delineated, with frequent regulatory overlaps, for instance in the case of biofuels (energy, agriculture, trade institutions) or geothermal (energy, mining and water institutions). Formal and informal co-ordination mechanisms are often, but not always, established, and this role frequently is assumed by industry associations and other non-public players.

From an organic and decision-making perspective, a wide variety of relationships exists among renewable energy institutions. In some cases, a strict hierarchy exists. For example, in Venezuela, all identified renewable energy institutions (public utility CORPOELEC, electrification foundation FUNDELEC, energy research institute FIDELZ and dispatch centre CDC) report to the Ministry of Popular Power for Electric Energy (MPPEE). In other cases, institutions form an organic part of a ministry or larger institution, but have *de facto* or *de jure* independence. This is the case of many specialised funds or national public research cen-

tres. In other cases, institutions compete over attributions, or the relationships are not clearly defined.

As renewables continue to gain prominence in Latin America, the number of institutions involved in one aspect or another of renewable energy will only grow. In a sense, the proliferation of renewable energy institutions is a manifestation of the dynamism of the sector, as well as of the important role of the public sector in renewable energy development in the region.

From a legal perspective, the existence of framework laws for electricity and other relevant sectors, as well as the institutional structure of the energy sector, guide the nature of renewable energy policies (law, decree, regulation, norm, etc.), at what level they are approved and by whom. Renewable energy laws, whether general or technology/resource-specific, provide a tangible framework and enabling conditions for the development of renewable energy sources. Eleven countries have renewable energy national laws or strategies, and an additional fourteen have renewable energy technology-specific laws (see table 2.1).

However, some renewable energy laws can take several years to be officially implemented through specific decrees or regulations. In addition, the majority of renewable energy laws are non-binding (IDB, 2014c) – that is, they do not include specific enforcement mechanisms – and should be interpreted in a broader political, economic and social context; they tend to be greatly contingent on political commitment and government priorities.

More generally, two overarching and often alternating conceptual views regarding energy resources and services are at play in the region: one towards greater government control, and one towards greater involvement of the private sector. Combined with a culture of policy innovation in the region, all these factors have resulted in a large array of renewable energy policies, promoting the use of renewable energy from one or more sources in the electricity, transport and heat sectors, as well as aiming at other goals through the use of renewables, such as local value creation.

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**Table 2.1** Renewable energy policies in Latin America, 2015

	National Policy							Fiscal Incentives							Grid Access						
	Renewable Energy Target	Renewable Energy Law / Strategy	Solar Heating Law / Programme	Solar Power Law / Programme	Wind Power Law / Programme	Geothermal Law / Programme	Biomass Law / Programme	Biofuels Law / Programme	VAT Exemption	Fuel Tax Exemption	Income Tax Exemption	Import / Export Fiscal Benefit	National Exemption of Local Taxes	Carbon Tax	Accelerated Depreciation	Other Fiscal Benefits	Transmission Discount / Exemption	Priority / Dedicated Transmission	Grid Access	Preferential Dispatch	Other Grid Benefits
Argentina	Active	Active			Active			Active	Active	Active	Active	Active		Active	Active						
Belize	Active	Active																			
Bolivia	Active							Expired, superseded or inactive				Expired, superseded or inactive	Expired, superseded or inactive								
Brazil	Active			Expired, superseded or inactive			Active		Active		Active	Active			Active	Active					
Chile	Active	Active	Active	Active		Active	Active						Active		Active	Active		Active			
Colombia	Active	Active						Active	Active	Active	Active			Active	Active					Active	
Costa Rica	Active					Active	Active			Active	Active				Active						
Ecuador	Active					Active	Active			Active	Active							Active	Active		
El Salvador	Active		Active							Active	Active							Active	Active		
Guatemala	Active						Active	Active		Active	Active				Active	Active		Active			
Guyana	Active							Active			Active										
Honduras	Active	Active					Active			Active	Active				Active	Active	Under development	Active			
Mexico	Active	Active	Active			Active	Active					Active	Active	Active		Active	Active	Active		Active	
Nicaragua	Active	Active				Active	Active	Active		Active	Active	Active			Active	Active			Active	Active	
Panama	Active		Active	Active	Active		Active	Active	Active	Active	Active	Active		Active	Active	Active				Active	
Paraguay							Active	Active	Expired, superseded or inactive		Active				Active	Active		Active			
Peru	Active	Active	Active			Active	Active	Active		Active	Active			Active	Active		Active	Active	Active	Active	
Suriname	Active																				
Uruguay	Active	Active	Active				Active	Active	Active	Active					Active	Active			Active	Active	
Venezuela	Active	Under development						Expired, superseded or inactive	Expired, superseded or inactive						Expired, superseded or inactive						
TOTAL (Active)	19	11	4	4	2	6	8	11	9	6	10	12	5	2	5	12	7	3	8	5	6

Active
  Expired, superseded or inactive
  Subnational level
  Under development

Regulatory Instruments														Finance						Other						
Auctions	Feed-in Tariff	Premium	Quota	Certificate System	Hybrid	Net Metering	Ethanol Blending Mandate	Biodiesel Blending Mandate	Solar Mandate	Registry	Currency Hedging	Dedicated Fund	Eligible Fund	Guarantees	Pre-investment Support	Direct Funding	Renewable Energy in Social Housing	Renewable Energy in Rural Access Programmes	Renewable Energy Cookstove Programme	Local Content Requirements	Special Environmental Regulations	Food / Bioenergy Nexus	Social Requirements			
																									Argentina	
																										Belize
	○																									Bolivia
																										Brazil
																										Chile
																										Colombia
																										Costa Rica
																										Ecuador
																										El Salvador
																										Guatemala
																										Guyana
																										Honduras
																										Mexico
																										Nicaragua
																										Panama
																										Paraguay
																										Peru
																										Suriname
																										Uruguay
																										Venezuela
12	4	3	4	2	4	10	7	6	4	4	10	9	9	6	11	11	5	18	4	5	5	5	4	5	TOTAL (Active)	

For details on specific country policies, please refer to the relevant IRENA Renewable Energy Policy Brief: Argentina, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Guyana, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Suriname, Uruguay and Venezuela.

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Overall, renewable energy policy development in Latin America is marked by increasing political commitment, diversity and sophistication, with policy support for renewable energy found in virtually all countries in the region. More than 300 of these policies are reflected in table 2.1. A detailed description of those policies at the country level can be found in IRENA's *Renewable Energy in Latin America 2015: An Overview of Policies* and the supporting renewable energy policy briefs for the 20 Latin American countries (IRENA, 2015b).

### Policy landscape

#### ■ Renewable energy targets

One of the first elements of an enabling policy framework is renewable energy target setting, which manifests long-term government commitment. The ambition and vision of Latin American countries to develop renewable energy sources have typically translated into renewable energy targets, providing a trajectory for the development of renewable energy sources and indicating the timeline envisioned by governments (IRENA, 2015c). Targets have been identified in 19 Latin American countries, as summarised in table 2.2, with the majority relating to electricity. Different types of targets (e.g., scope, technology or timeline) often co-exist and overlap. A clear specificity of Latin American targets is that they distinguish between *large* and *small* hydropower plants, the latter being considered as a non-conventional renewable energy source of electricity generation (see section 2.1). Unless otherwise specified, table 2.2 refers to renewable energy sources other than large hydropower<sup>16</sup>.

The level of ambition of renewable energy targets varies widely across the region, in line with country conditions, investment frameworks and enabling policies. Some countries are on track to (or are already) exceeding their targets, especially for power generation. Uruguay and Costa Rica,

for example, have made remarkable progress in the past decade thanks to clear political commitment and a favourable policy and investment climate.

As shown in table 2.2, the majority of renewable energy targets and strategies in Latin America are stipulated in five - or ten- year electricity expansion plans or integrated resource plans (e.g., Brazil, Mexico). In most cases, these renewable energy targets are not accompanied by a binding obligation. Chile is the only country in the region to have established its target as binding by law, defining penalties for non-compliance and a clear monitoring and enforcing mechanism (MINENERGIA, 2013b). In the context of the 2015 United Nations Climate Change Conference in Paris, Latin American countries have embedded their renewable energy targets in their Intended Nationally Determined Contributions (INDCs). For example, Brazil's INDC states a targeted share of 23% non-hydropower renewable electricity supply by 2030, from 9.3% in 2014 (EPE, 2015).

To be seen as credible by investors and to provide a clear trajectory for the future evolution of the energy mix, renewable energy targets need to be translated into specific policies and measures. The implementation of such policies points to the importance of institutions and how their design suits specific country and market conditions.

#### ■ Power sector policies

By far the most popular policy instrument in Latin America to promote renewable electricity is the use of auctions<sup>17</sup> to procure electricity from renewable energy sources. To date, more than 60 renewable energy auctions have been identified in 12 Latin American countries, with auctions schemes in Argentina, Belize, Brazil, Chile, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama, Peru and Uruguay (IRENA, 2015b). Auctions can be technology-neutral, *i.e.*, open to all technologies including renewable and non-re-

16. As a mature technology and because of its scale, hydropower is often considered differently than the other renewable energy sources and is often referred to as a "conventional" source of energy in Latin America.

17. For an in-depth analysis of renewable energy auctions please refer to IRENA (2015c) *Renewable Energy Auctions: A Guide to Design*. For details of renewable energy auctions in Latin America please refer to table 3 in IRENA (2015b) *Renewable Energy in Latin America 2015: An Overview of Policies*.

**Table 2.2** Renewable energy targets in Latin America.

Country	Renewable energy target	Reference	Year
Argentina	<ul style="list-style-type: none"> <li>• 8% of electricity consumption by 2017</li> <li>• 20% of electricity consumption by 2025</li> </ul>	Law 27190 promoting the use of renewable energy sources	2015
		Law 27190 promoting the use of renewable energy sources	2015
Belize	<ul style="list-style-type: none"> <li>• 50% of electricity generation by 2033</li> <li>• 15 MW additional hydro by 2033</li> <li>• 5 MW solid waste generation by 2020</li> </ul>	National Sustainable Energy Strategy	2012
		National Sustainable Energy Strategy	2012
		National Sustainable Energy Strategy	2012
Bolivia	<ul style="list-style-type: none"> <li>• Increase hydro to 70% of total generation and 4% of other renewable energy by 2025</li> <li>• 183 MW renewable generation by 2025</li> </ul>	Bolivia Electric Plan 2025	2014
		Bolivia Electric Plan 2025	2014
Brazil	<ul style="list-style-type: none"> <li>• 45.2% of primary energy supply by 2024 (from 39.4% in 2014)</li> <li>• 86% of electricity generation by 2024</li> <li>• Increase wind power share to 8% in 2024 (from 2% currently)</li> <li>• 23% of electricity generation from non-hydro renewables by 2030</li> </ul>	10-Year Energy Expansion Plan 2024	2014
		10-Year Energy Expansion Plan 2024	2014
		10-Year Energy Expansion Plan 2024	2014
		Intended Nationally Determined Contribution	2015
Chile	<ul style="list-style-type: none"> <li>• 20% of electricity generation by 2025</li> <li>• At least 60% of electricity generation by 2035</li> <li>• 70% of new capacity installed between 2015 and 2050</li> </ul>	Law 20698: Expansion of the energy mix through non-conventional renewables	2013
		Energy Roadmap 2050	2015
		Energy Roadmap 2050	2015
Colombia	<ul style="list-style-type: none"> <li>• Total renewable installed capacity of 6,179 MW<sup>1</sup> by 2028, including 3,689 MW of non-hydropower</li> </ul>	Generation Expansion Plan 2014-2028	2014
Costa Rica	<ul style="list-style-type: none"> <li>• 98% of electricity generation by 2035 (74% hydropower, 15% geothermal, 9% wind-biomass-solar)</li> </ul>	Generation Expansion Plan 2014-2035	2014
Ecuador	<ul style="list-style-type: none"> <li>• 60% of installed capacity by 2017 (from 43% in 2012)</li> <li>• 4.2 GW hydropower by 2022</li> <li>• 277 MW non-hydro renewables by 2022</li> </ul>	Institutional Strategic Plan 2014-2017	2014
		Electrification Master Plan 2013-2022	2013
		Electrification Master Plan 2013-2022	2013
El Salvador	<ul style="list-style-type: none"> <li>• By 2026: 60 MW wind, 90 MW solar PV, 200 MW solar thermal, 60-89 MW geothermal, 162.7 MW small hydro (&lt;20 MW), 45 MW biomass and 35 MW biogas</li> </ul>	Masterplan for the Development of Renewable Energy	2012
Guatemala	<ul style="list-style-type: none"> <li>• 60% of electricity generated by 2022</li> <li>• 80% of electricity generated by 2027</li> </ul>	Electric System Expansion Plan 2014-2028	2014
		National Energy Policy 2013-2027	2012
Guyana	<ul style="list-style-type: none"> <li>• CARICOM target for renewable electricity: 20% by 2017, 28% by 2022 and 47% by 2027</li> </ul>	Caribbean Sustainable Energy Roadmap	2013
Honduras	<ul style="list-style-type: none"> <li>• 60% of energy demand supplied by renewables by 2022</li> <li>• 80% of electricity generation by 2034</li> </ul>	National Vision and Plan 2010-2038	2010
		National Vision and Plan 2010-2038	2010
Mexico	<ul style="list-style-type: none"> <li>• Clean energy<sup>2</sup> share of total electricity generation: 25% by 2018, 30% by 2021, 35% by 2024</li> <li>• By 2018: 13,030 MW hydropower, 8,922 MW wind, 1,018 MW geothermal, 748 MW bioenergy and 627 MW solar</li> </ul>	Energy Transition Law	2015
		Long-term Program of Renewable Energy Development	2014
Nicaragua	<ul style="list-style-type: none"> <li>• Increase the renewable share of electricity from 51% in 2013 to 91% in 2027</li> </ul>	Electricity Expansion Plan 2013-2027	2013
Panama	<ul style="list-style-type: none"> <li>• Install an additional 706.3 MW hydropower between 2009 and 2023</li> <li>• At least 70% of electricity from renewables by 2050<sup>3</sup></li> </ul>	National Energy Plan 2009-2023	2009
		National Energy Plan 2015-2050 (upcoming)	2016
Peru	<ul style="list-style-type: none"> <li>• 5% of electricity generation by 2018 (excluding hydro)</li> <li>• 60% of electricity generation by 2018 (including hydro)</li> </ul>	Decree 1002	2008
		National Energy Plan 2014-2025	2014
Suriname	<ul style="list-style-type: none"> <li>• CARICOM target for renewable electricity: 20% by 2017, 28% by 2022 and 47% by 2027</li> </ul>	Caribbean Sustainable Energy Roadmap	2013
Uruguay	<ul style="list-style-type: none"> <li>• 50% of the primary energy mix by 2015</li> <li>• 90% of electricity generation by 2015<sup>4</sup></li> </ul>	National Energy Policy 2005-2030	2008
		National Energy Policy 2005-2030	2008
Venezuela	<ul style="list-style-type: none"> <li>• 613 MW of additional renewable electricity capacity between 2013 and 2019, of which 500 MW is wind</li> </ul>	Development Plan for the National Electric System 2013-2019	2013

1. 1,422 MW of wind; 2,267 MW of biomass, solar and geothermal; 2,490 MW of hydropower.

2. "Clean energy" includes renewables, co-generation, nuclear energy, fossil fuels with CCS and "other low-carbon technologies".

3. An October 2015 working document from the National Energy Commission mentions electricity generation from 2.1% solar and 8% wind; see <http://www.energia.gob.pa/admin/gal/277/files//Presentacion%20Escenario%20de%20Referencia.pdf>

4. 40% of non-conventional renewable energy sources (mainly wind, but also solar PV and biomass waste), in addition to 55% hydropower; see *Intended*.

*Nationally Determined Contribution at <http://www4.unfccc.int/submissions/INDC/Published Documents/Uruguay/1/INDC Uruguay English-unofficialtranslation.pdf>*

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newable; open to all renewables; or technology-specific, including combinations of renewables and renewables/non-renewables. Most countries in the region have a combination of different types of auctions.

The number of auctions in the past five years has increased steadily, dominated by technology-specific auctions, with over 20 such auctions<sup>18</sup> observed in the 2013-15 period. New types of auctions also are emerging, for example auctioning public land in high-potential locations to facilitate the development of renewable energy projects<sup>19</sup>, or auctions for specific time blocks when power is needed most, allowing, for instance, PV projects to win daytime slots against conventional sources. Auctions are attractive to regulators because they achieve cost-efficient deployment of the targeted amount of renewables while controlling the overall cost and with generally low transaction costs (IRENA, 2015c). Auctions also are an effective tool for price-discovery, a particularly valuable feature in the current context of steep price declines for renewable energy technologies. Underbidding, a problem with early auctions, can be limited by the use of strong financial guarantees, for example in Peru (see box 2.4).

#### Box 2.4 Peru: auctions and financial guarantees

Peru's renewable energy auctions use stringent guarantees to achieve a simple and low-overhead auction system. In addition to strong pre-operational guarantees (e.g., a USD 50,000/MW bid bond and USD 250,000/MW construction bond in the 2013 auction), any shortcoming in the contracted amount of electricity results in a reduction of the guaranteed tariff by the same percentage for that year. For example, if a producer generates only 85% of the contracted electricity in a given year, he or she will receive only 85% of the guaranteed tariff for all electricity sold that year.

Feed-in tariffs (FiTs), renewable portfolio standards and other certificate systems, which are regulatory instruments commonly used in other regions, have had limited success in Latin America. Argentina, Brazil and Ecuador each established FiT schemes, all of which are no longer active. Several of the FiT policies in Latin American countries resulted in limited renewable energy development either because their levels were set too low (Argentina), because of an absence of official regulation to implement laws (Ecuador) or, more frequently, because an adequate enabling environment was not in place (e.g., lack of clarity on interconnection rules, lack of standard contracts for IPPs, etc.). Honduras, Nicaragua and Uruguay have limited yet effective application of FiTs, and Peru uses FiT design elements in its auctions system.

*Renewable energy policy in Latin America is marked by increasing political commitment, diversity and sophistication.*

Only Chile has a pure renewable energy certificate system<sup>20</sup>, while Mexico has a "clean energy" certificate system. Other than in Mexico, where the system is geared towards the possibility of clean energy exports to the United States (where certificate systems predominate), it does not seem that certificates will play a significant role in Latin America's near-future policies for promoting renewable electricity.

Residential and small-scale net metering or net billing policies are found in Brazil, Chile, Colombia, Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Panama and Uruguay. Actual penetration of grid-connected small-scale self-generation is still very low in the region. However, given declining costs, particularly for rooftop solar, rapid deployment may occur in jurisdictions with net metering policies and high electricity retail prices,

18. Specific for only one or two renewable energy technologies.

19. In January 2016, Chile auctioned 3,000 hectares of public land with high resource potential for the construction of renewable energy projects in several locations; see <http://www.pv-tech.org/news/chile-tendering-nearly-3000-hectares-of-land-for-renewables-projects>.

20. For an in-depth analysis of the energy and food nexus, see IRENA (2015d), *Renewable Energy in the Water, Energy & Food Nexus*.



as has been the case in some US states and EU countries. The rapid adoption of net metering in some countries faces opposition from some incumbent utilities, who see their business models threatened, and raises issues such as rate design, cross-subsidies, income effects, reserve capacity and cost recovery. However, Mexico and Chile (see box 2.5) recently have established specific programmes for public buildings to start developing their markets.

#### Box 2.5 Chile: Public Solar Roofs Program

In 2014, the Chilean Energy Ministry, supported by the BMUB-GIZ project “IKI-Solar”, initiated the Public Solar Roofs Program in order to stimulate the market for rooftop PV solutions by fostering demand from public buildings. The programme also generates capacities and experience in Chilean technicians, makes prices more transparent via tendering processes and generates public informational resources on self-consumption of solar PV in Chile. In addition, the programme serves as a hands-on evaluation of the implemented regulation for that segment, and it reduces electricity costs in public buildings.

### Grid access

Renewable energy grid access policies have been identified in 13 Latin American countries (see box 2.6). These include mandated grid access, discounts and exemptions from transmission fees, preferential dispatch, priority or dedicated transmission and planning considerations. Grid access policies are an important component for the deployment of renewable energy technologies, which otherwise often find themselves unable to reach the market due to technical and commercial barriers. In the long run, however, there is a need to differentiate those grid access policies that constitute a rent transfer for renewables (usually at the expense of someone else and with no net gain for the system, such as a transmission fee exemption) from those that maximise the use of the resource and constitute a net gain for the system, such as technology-specific dispatch provisions.

#### Box 2.6 El Salvador: priority dispatch

In 2012, El Salvador enacted grid access provisions for renewable electricity, including priority dispatch for biomass, solar and wind power, as well as specific dispatch rules for hydropower and geothermal. The decree provides that producers smaller than 20 MW are not subject to dispatch.

### Transport-specific policies

Over 80% of Latin America’s population lives in cities, resulting in significant demand for transport fuels. Renewable energy policies in the transport sector focus mainly on the use and production of biofuels. The main objectives of biofuel production in Latin America are the reduction of fossil fuel imports, development of local agro-industry and, in some cases, the promotion of export markets.

Fiscal incentives are an important component of biofuels support policies in many Latin American countries. The most common fiscal incentives for biofuels are tax exemptions and income tax exemptions. In addition to fiscal incentives, the main policy instrument to promote biofuels is biofuel blending mandates, effective in eight Latin American countries (see table 2.3): Argentina, Brazil, Colombia (see box 2.7), Ecuador, Mexico, Paraguay, Peru and Uruguay. A policy instrument endemic to Brazil and Paraguay is fiscal incentives for *flex-fuel vehicles*, which can run on different blending mixes of gasoline and bioethanol.

#### Box 2.7 Colombia: biofuels blending mandates

Colombia established a blending mandate for bioethanol in 2001, followed by a blending mandate for biodiesel in 2004. Both mandates are currently for a 10% blend. These measures were accompanied by the enactment of technical standards for biofuels and vehicles.

A different policy intervention, price regulations for biofuels, is found in Argentina, Colombia, Costa Rica and Ecuador. It is difficult, however, to reach an optimal balance in these regulations,

**Table 2.3** Biofuel blending mandates in Latin America, 2015

	Argentina	Brazil	Colombia	Costa Rica <sup>1</sup>	Ecuador <sup>2</sup>	Guatemala <sup>3</sup>	Mexico <sup>4</sup>	Panama <sup>5</sup>	Paraguay	Peru	Uruguay
<b>Ethanol</b>	10%	27%	8-10%	0-8%	5%	5%	6%	5%	25%	7.8%	5%
<b>Biodiesel</b>	10%	7%	10%	0-5%	5%				1%	5%	5%

1. Currently 0% until regulated; 2. Ethanol blend only in Guayaquil; 3. Not implemented; 4. Only in Guadalajara, Monterrey and Mexico D.F.; 5. Temporarily suspended.  
Source: IRENA, 2015b

particularly in export-oriented markets, because of fluctuations in international commodity prices for oil, sugar and soya. Colombia's biofuel prices are established following a methodology that includes factors such as the international prices for sugar and palm oil. Increasingly, renewable transport policies address the potential food security issues derived from biofuel production, with restrictions and food prioritisation measures in place in Costa Rica, Ecuador, Mexico and Uruguay (see section 3.2).<sup>21</sup>

### ■ Heat-specific policies

With a significant endowment in renewable energy sources, Latin America has a large untapped potential for renewable energy heating and cooling applications. Currently, policy support for the use of renewable energy sources for heating purposes, both residential and commercial/industrial, is limited in Latin America, as in many other regions.

Market growth is driven largely by municipal mandates (see box 2.8) or national plans (see box 2.9) in a handful of countries, related mostly to solar water heating and improved cookstoves. Solar mandates, identified in Brazil, Costa Rica, Mexico, Panamá and Uruguay, have great potential in the region. They can be enacted at any governance level, from local to regional to national, and can be incorporated into the general building code or into social housing programmes.

### Box 2.8 The Solar Ordinance of São Paulo

The 2007 Solar Ordinance of São Paulo aims to lower electricity demand for water heating and requires new residential, commercial and industrial buildings to install solar water heating systems to cover at least 40% of the energy used for heating water. It will result in significant reduction in electricity consumption from the city's residential sector, due to the predominance of instantaneous water heaters, and an estimated and avoided expenditures of more than USD 400 million between 2007 and 2015, according to DASOL ABRAVA (the Brazilian Association of Refrigeration, Air Conditioned, Ventilation and Heating Services) (IRENA/ICLEI, 2012). The ordinance is now being replicated in several cities across Brazil.

Source: IRENA/ICLEI, 2012

When designing solar mandates, however, product certification is an important success factor – e.g., including minimum quality and performance standards as well as consumer information campaigns to ensure support from a broad range of stakeholders (IRENA/ICLEI, 2012).

In some countries, an important policy parameter for the development of solar water heating (SWH) markets is the relative price of the energy carrier that is being substituted, e.g., the prices of subsidised LPG in Mexico, or of natural gas (cost-

21. For an in-depth analysis of the energy and food nexus, see IRENA (2015d), *Renewable Energy in the Water, Energy & Food Nexus*.

**Box 2.9 Uruguay's residential solar plan**

Most domestic water in Uruguay is heated by electricity. In 2012, the country established a Solar Plan providing five-year financing on a not-for-profit basis from the public mortgage bank (BHU), with payments included in the electricity bill. Systems include a five-year warranty and full insurance from the public insurance bank (BSE). Electricity savings per household are estimated at 15-20%. As an incentive the public utility (UTE) offers the first 2,000 users an electricity bill discount of about USD 30 per month for 24 months, equivalent to a subsidy of 50% of the installation cost. The deployment of solar water heaters has been slower than anticipated, and the government is considering additional measures to speed it up.

Source: IRENA, 2015e

ing less than USD 0.05 per m<sup>3</sup>) in Argentina's cities. Fuel subsidies can hinder the economic case for SWH. When tariffs are more in line with costs, the introduction of SWH can generate attractive financial savings for ratepayers. In Brazil, the repayment period for the upfront SWH investment costs has been estimated between 24 months to 36 months with substantial additional financial savings for the remaining operational life span of SWH of about 20 years (IRENA/ICLEI, 2012). For municipalities, financial savings can be significant. For example, according to the Brazilian Association of Solar Equipment Producers (DASOL ABRAVA), the São Paulo Solar mandate saved an estimated USD 400 million between 2007 and 2015 in avoided expenditures.

Despite the substantial experience in the region's food processing, tobacco, and pulp and paper industries with using biomass resources for process heat, this is not a focus of policy attention. The competitiveness of renewables heat is clearly conditioned by pricing policies and the overall enabling environment, which often extends beyond the renewable energy policy sphere (see box 2.1). The most relevant interventions have been related to co-generation.

Historically, bagasse residues from ethanol production were burned relatively inefficiently, as regulation did not allow the sale of surplus electricity to the grid. The objective was to maximise the amount of bagasse burned, since the residue was difficult to store or to sell (Dantas *et al.*, 2013). Electricity regulations were amended in 2008 with the launch of biomass-specific auctions, which triggered investment in more-efficient co-generation systems and led to process heat integration in the sugar mills and associated distilleries (IRENA, 2012a; Ecofys, 2012). As of 2012, about one-quarter of Brazil's sugar mills had upgraded to higher-efficiency boilers, but there remains a large untapped biomass potential either in the form of residues and/or energy crops to be used in industrial processes, which could be unlocked by dedicated policies and the creation of a level-playing field (see box 2.1).

There is further scope for renewable heat policies in the region to be more closely integrated with energy efficiency measures to develop a systemic approach which can be embedded in sectoral policies and regulations for end-use sectors, *i.e.*, residential, commercial (both of which include buildings) and industry.

## CONCLUSION

This chapter provides an overview of the current use of renewable energy in Latin America, which is a historical leader in hydropower and bioenergy use and is witnessing a rapid uptake of other renewable energy technologies, notably wind and, more recently, solar PV. This overview highlights the rapid evolution of the region's energy mix towards a more diversified portfolio of different renewables, which has been driven in great part by a mix of enabling policies. Existing policies were designed to kick-start renewable energy markets and the creation of local supply chains, or to consolidate mature renewables such as hydropower and bioenergy.

Recent developments show that the region's renewable energy policy landscape is highly dynamic and reflects an acceleration of the development of the renewable energy market, in line with rapid declines in the costs of renewable energy technologies, as discussed in chapter 3.

# COSTS AND BENEFITS

Pisac Market in the Peruvian Andes, Pisac, Peru © ostill/Shutterstock.com





Combined with the mix of policies discussed in chapter 2, cost competitiveness has been one of the main drivers for the rapid deployment of renewables in Latin America in recent years. The economic case for renewables in the region has been strengthened by the growing recognition of the multiple socio-economic benefits that they bring, in particular the opportunity to add local value and create jobs. This chapter discusses the latest trends in renewable energy costs in the region, including for solar, wind and hydropower. It then focuses on renewable energy socio-economic benefits in terms of GDP growth, employment, creation of local value, energy access and the water-energy-food nexus.

### 3.1 RENEWABLE ENERGY COSTS

#### ■ Overall installed costs and LCOE

Renewable energy technology costs in Latin America have fallen dramatically over the past decade. They are increasingly competitive with fossil fuels and are among the lowest globally for some technologies. Key variables explaining dif-

ferences in the participation of renewable technologies in the power mix across Latin America include factors affecting the levelised cost of electricity (LCOE), local energy prices from competing technologies (including subsidies), differences in enabling policies and investment conditions. The LCOE of some renewable technologies is significantly affected by the weighted average cost of capital (WACC) and the availability of local supply chains or labour, which vary widely across countries.

According to the IRENA Renewable Cost Database<sup>1</sup>, the costs of renewable energy technologies in Latin America since 2010 have dropped for all the technologies included in the database, *i.e.*, hydropower, solar PV and onshore wind (IRENA, 2016c). This applies to both installed (or investment) costs and LCOE. Solar PV and onshore wind are now in the range of fossil fuel generation costs and are competitive not just in local terms but internationally as well. The cost declines for hydropower, the most mature technology, have been slower.

1. The IRENA Renewable Cost Database holds more than 900 utility-scale Latin American projects spanning all renewable energy technologies. The present report discusses, from the database, two main types of costs: LCOE and installed costs. The installed cost data in the IRENA Renewable Cost Database is typically *ex-ante* project data, as are capacity factor values. All costs are reported in 2014 USD, and the LCOE is estimated using a real 7.5% weighted average cost of capital for OECD countries and China, and 10% for the rest of the world.

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Technological progress and the development of different stages of the local supply chain in some Latin American countries have changed the profile of installed costs since 2010, which also are greatly affected by resource quality. For instance, although the installed costs for wind power in Latin America are somewhat higher than those found in India and China, the persistent wind regimes, which translate into capacity factors of 35% or more in some regions (e.g., even 50% in some areas of Brazil), result in the weighted average LCOE in the region closely matching those of India and China (see figure 3.1) (IRENA, 2016c). In addition, the increased maturity in certain markets is helping to reduce financing costs and WACCs, contributing to lower production costs.

### Hydropower

Hydropower is one of the least expensive electricity generation sources globally, in locations where economical unexploited resources still exist. This applies to Latin America, where in 2010, installed costs<sup>2</sup> ranged between USD 1,000 per kW and USD 5,500 per kW (IRENA, 2016c). The weighted average installed cost was

USD 2,600 per kW. The range of installed costs – at between USD 700 per kW and USD 3,900 per kW, with a weighted average installed cost of USD 2,200 per kW – was 15% lower in 2014 than in 2010 (IRENA, 2016c). Given the lumpy nature of investments in hydropower, this variability also is experienced around the world as well as within the region. However, it is worth noting that in some Latin American countries, installed costs actually are increasing as a result of social and environmental challenges.

Weighted average capacity factors<sup>3</sup> also have improved since 2010, for a number of reasons including technological improvements and better hydropower resources (e.g., new developments in unexploited regions). The weighted average capacity factor was 54% in 2010 and rose to 62% in 2014 (IRENA, 2016c). Such high capacity factors give advantage to hydropower as a supplier of base load power and as a complementary resource to variable renewables, as discussed in chapter 5.

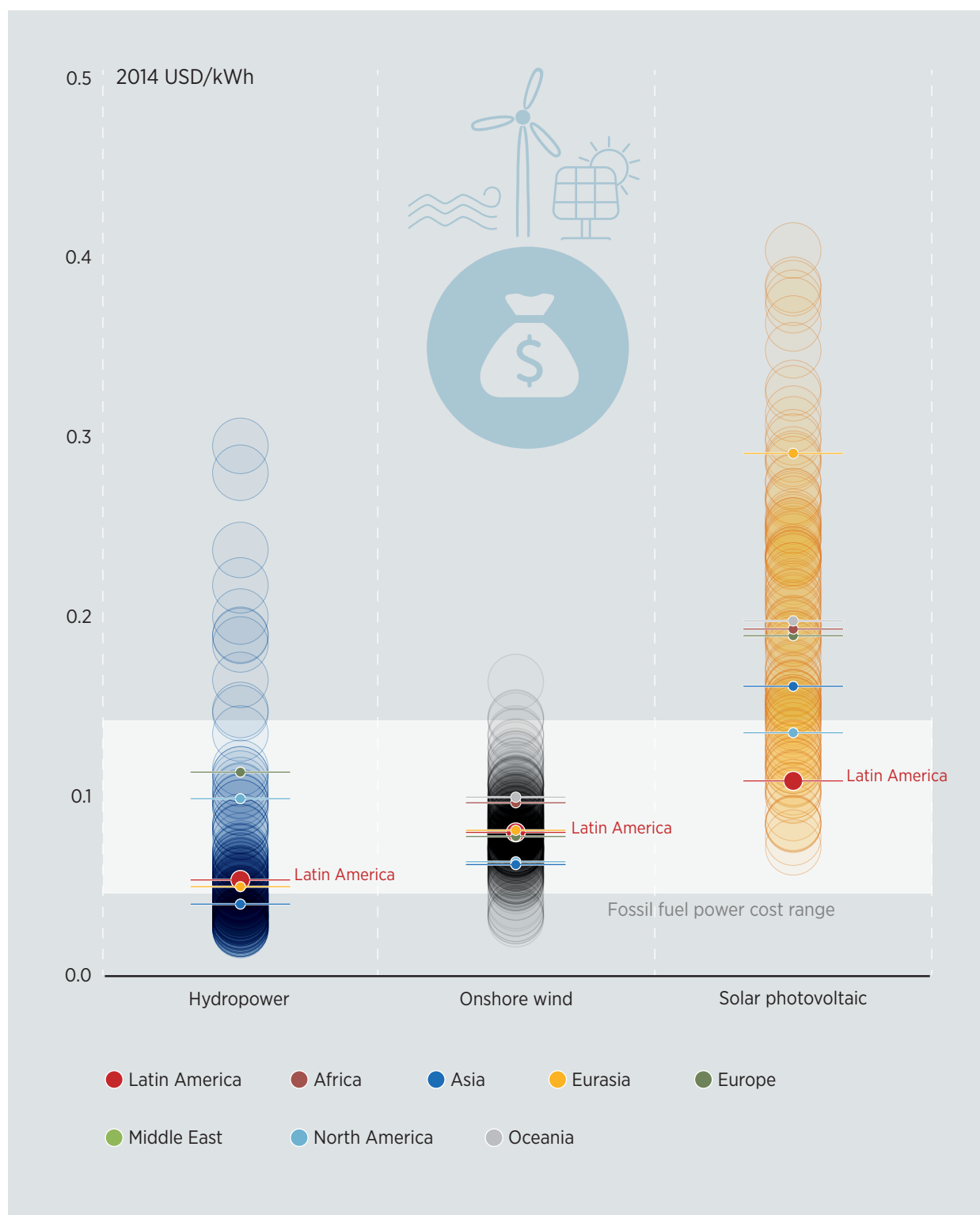
The estimated weighted average LCOE dropped from USD 65 per MWh for the projects in the IRENA database in 2010 to USD 52 per MWh



2. Including the cost of the reservoir for the relevant projects.

3. Ex-ante capacity factors, i.e., those estimated by project developers before the actual operation of the hydropower plants takes place.

**Figure 3.1** Typical levelised cost of electricity and regional weighted averages by technology, projects commissioned in 2014



Note: Each circle identifies a project independent of its geographical origin. The centre of each circle is the value for the cost (LCOE) of each project on the y-axis. The coloured bars represent the weighted average LCOE for an individual region. Real weighted average cost of capital is 7.5% in OECD countries and China, and 10% in the rest of the world. The date is for planned commissioning; sometimes projects are delayed.

Source: IRENA, 2016c

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in 2014 (see figure 3.2). All Latin American hydropower projects in the IRENA database have LCOEs either within the range of fossil fuel generation plants or below. However, hydropower is a mature technology with generally less scope for cost reductions, as many countries have already exploited their most economic sites.

### Solar PV

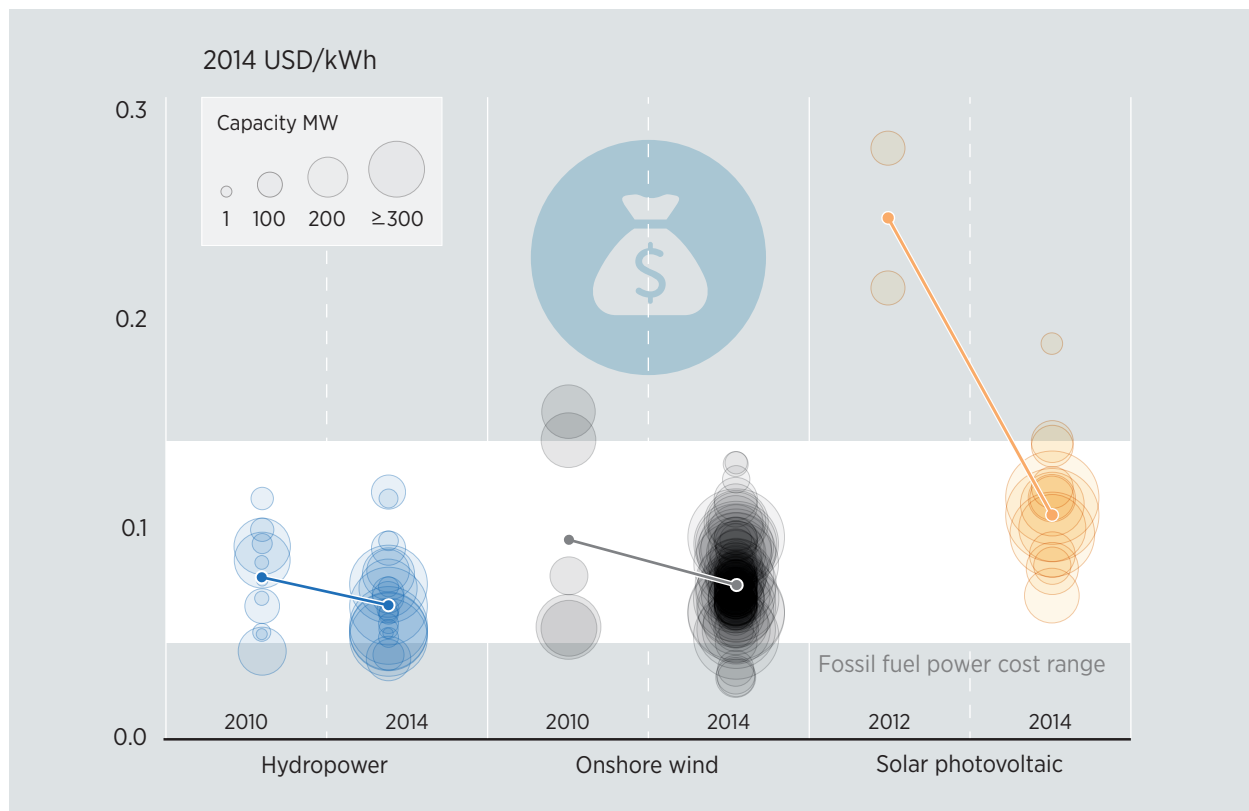
Having seen one of the most dramatic cost reductions among renewable energy technologies, the competitiveness of solar PV in the region is achieving world records, such as in the recent PV auctions in Mexico and Peru, at prices of USD 36 per MWh and USD 48 per MWh, respectively for the lowest bids. Costs are likely to be reduced further in the years ahead.

PV installed costs in 2014 ranged between USD 1,355 per kW and USD 4,000 USD per kW, with a weighted average of USD 2,160 per kW

(IRENA, 2016c). This represented more than a 60% reduction in the installed cost of solar PV compared to 2012.

The weighted average capacity factor of solar PV deployment in the region, 24% in 2014, is among the highest in the world (e.g., factors up to 30% can be reached in Chile if tracking is included). As a result, the estimated levelised cost of electricity ranged between USD 210 per MWh and USD 280 per MWh, with a weighted average LCOE of USD 240 per MWh in 2012. In 2014, the LCOE of solar PV followed the steep decline in installed costs (see figure 3.2). The range of LCOE was between USD 70 per MWh and USD 190 per MWh. The weighted average LCOE was USD 110 per MWh, 54% lower than in 2012, mirroring almost one-to-one the drop in installed costs. The estimated weighted average Latin America LCOE for solar PV, USD 110 per MWh, is the lowest

**Figure 3.2** Levelised cost of electricity from utility-scale renewable energy technologies in Latin America



*Note: Size of diameter of the circle represents the size of the project. The centre of each circle is the value for the cost of each project on the y-axis. Real weighted average cost of capital is 7.5% in OECD countries and China, 10% in the rest of the world. The date is for planned commissioning; sometimes projects are delayed.*

*Source: IRENA, 2016c*



among all regions for projects commissioned in 2014 (IRENA, 2016c).

### Onshore wind

Onshore wind has seen a strong positive evolution in the region, led by deployment in Brazil (see box 3.1). If this positive evolution spreads to other countries, Latin America could become the most competitive wind market in the world. The installed costs of onshore wind in 2010 ranged between USD 2,500 per kW and USD 3,250 per kW, with a weighted average installed cost of USD 2,900 per kW, however with a small number of projects (IRENA, 2016c). In 2014, the ranges decreased to between USD 1,000 per kW and USD 2,990 per kW, resulting in a weighted average installed cost of USD 2,260 per kW, 20% lower than in 2010.

#### Box 3.1 Wind in Brazil: a virtuous circle of deployment and falling costs

The case of Brazil shows how scaling up deployment can drive down installed costs rapidly. After a doubling in the installed capacity between 2012 and 2015, and thanks to a significant development of local value chains and expertise, the estimated weighted average generation cost (LCOE) of onshore wind in Brazil was USD 0.06 per kWh in 2015, 25% lower than its level in 2012, and it is expected to experience further reductions in the next few years, reaching USD 0.05 per kWh by 2018. The most competitive projects in Brazil today strike an LCOE of only USD 0.045 per kWh, close to the world's lowest.

*Source: IRENA, 2016c*

The weighted average capacity factors (42% in 2014) in Latin America are by far some of the highest in the wind industry worldwide, attesting to the high quality of wind resources in the region. As a result, the weighted average LCOE of onshore wind dropped from USD 100 per MWh in 2010 to USD 80 per MWh in 2014 (IRENA, 2016c).

Overall, technological improvements, supply chain development and market maturity are among key factors driving cost reductions. As a result, wind and solar PV are already competitive

with fossil fuels in a number of locations, in addition to the more mature hydropower, which had been the most cost-efficient technology for decades in some countries. In parallel with gains in competitiveness, the growing recognition of their multiple benefits has further strengthened the case for renewable energy in the region.

### 3.2 SOCIO-ECONOMIC BENEFITS OF RENEWABLES

Cost competitiveness, conducive policy frameworks and their role in energy diversification have driven the deployment of renewable energy technologies in Latin America. More recently, their socio-economic benefits in terms of job creation, GDP growth, local value, energy access and the water–energy–food nexus have come at the forefront of the policy agenda. Many countries see opportunities in the development of a renewable energy value chain, with the potential to increase income, create jobs, contribute to industrial development and improve livelihoods.

#### Measuring macroeconomic benefits

The business case for renewable energy is strengthened by the macroeconomic benefits that they offer. Renewable energy investments can trigger ripple effects throughout the economy, stimulating activity in new sectors and fostering economic diversification, an essential area of attention in many commodity-dependent economies in Latin America (see chapter 1). The emergence of studies looking at the influence of renewables on countries' GDP highlights the potential relevance of these effects in countries that are at the beginning of their renewable energy transition.

For example, an input-output analysis in Mexico estimated that developing 21 GW of renewable power capacity (mainly wind) by 2029 could lead to a cumulative increase in GDP of around USD 27 billion compared to business as usual (representing around 2% of the country's GDP in 2013), as well as the creation of 134,000 jobs (PwC, 2015). A similar study conducted in Chile estimated that supplying 20% of electricity from renewables by 2020 would contribute an additional USD 2.3 bil-

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lion to the GDP (+0.6%) and generate 7,800 jobs (NRDC & ACERA, 2013).

However, the knowledge base on the macro-economic benefits of renewables remains limited. Over the years, IRENA has contributed to this field (see box 3.2). Building on this body of work, the 2016 IRENA report *Renewable Energy Benefits: Measuring the Economics* quantifies the global impacts of renewable energy deployment on GDP, employment, trade and welfare, using the macroeconomic model E3ME<sup>4</sup> (IRENA, 2016d). Although the analysis is global, some results are relevant to Latin America.

### Box 3.2 IRENA's work on renewable energy benefits

IRENA has been analysing the benefits of renewable energy since 2011. This workstream includes the reports *Renewable Energy and Jobs* (2013); *The Socio-Economic Benefits of Solar and Wind* (2014); *Renewable Energy in the Water, Energy & Food Nexus* (2015); *Renewable Energy Benefits: Measuring the Economics* (2016) and *Renewable Energy Jobs – Annual Review* (yearly since 2014).



According to the study, in line with IRENA's RE-map analysis, the overall economic impact of advancing renewable energy deployment in Latin America is positive. This is due mainly to reduced energy imports (excluding the case of net energy exporters) and to the increased investment required, which (provided that crowding out is not important) boosts output throughout the economy. These effects could result in a GDP in 2030

that is higher than in the business-as-usual scenario: 1.1% higher in Brazil and 1.3% higher in Mexico (IRENA, 2016d).

In general, increased adoption of renewable energy leads to higher investment in the power sector and to reduced investment in the fossil fuel sectors. Therefore, the magnitude of the economic impacts varies depending on whether the former outweighs the latter, especially in oil-exporting countries. This is the case in Mexico, for example, where total investments in the economy are expected to have a net gain, leading to a GDP increase. In addition, possible decreases in electricity prices because of renewables could lead to economic gains through increased disposable income of households (the reverse being true for an increase in electricity prices). In Brazil, such increased disposable income offsets the overall negative impacts on investment (due to reductions in oil and gas investments), resulting in an overall positive impact on GDP (IRENA, 2016d).

The macroeconomic benefits of renewable energy deployment are also analysed in terms of job creation. The assessment shows that the net employment impacts are positive, despite a potential decrease in sectors such as oil and gas.

### Analysing the potential for job creation

Job creation is gaining prominence in the global renewable energy discourse. IRENA's *Renewable Energy and Jobs* report (IRENA, 2013) provided a first comprehensive view of the various dimensions of renewable energy employment. In its *Annual Review 2016*, IRENA estimates that the renewable energy sector supported 8.1 million direct and indirect jobs in 2015, plus an additional 1.3 million direct jobs in large hydropower (IRENA, 2016e). The renewable energy sector has already become a major employer globally (similar to the complete automobile industries in Germany and the United States together) and has the potential to support more than 24 million jobs by 2030 (IRENA, 2016d).

4. E3ME, developed by Cambridge Econometrics, links together the energy system with the world's economies to provide estimates of the macro-economic impacts of changes in the share of renewables. The model covers 43 economic sectors in 59 countries. This geographical coverage includes most large economies in the world, accounting for 76% of global GDP (as of 2014) and almost 90% of global energy use.

In Latin America, liquid biofuels is the largest employer, accounting for nearly 1 million jobs (see figure 3.3). Brazil has the largest workforce, with 821,000 employed, making it the region’s country with the highest number of renewable energy jobs. This does not account for the significant numbers of informal and part-time harvest workers not included in official databases. Formal employment in Brazilian sugarcane cultivation declined to around 268,000, due mainly to increasing mechanisation (MTE/RAIS, 2016). Jobs in ethanol manufacturing declined slightly to 190,000 jobs (MTE/RAIS, 2016), reflecting a consolidation of distilleries from 430 in 2010 to 390 in 2014 (USDA-FAS, 2014). The number of workers in Brazil’s biodiesel production, mainly soya-based, has more than doubled since 2009 (ABIOVE, 2015). IRENA estimates 163,000 jobs in biodiesel in 2015. Other major biofuel job markets in Latin American include Colombia and Argentina.

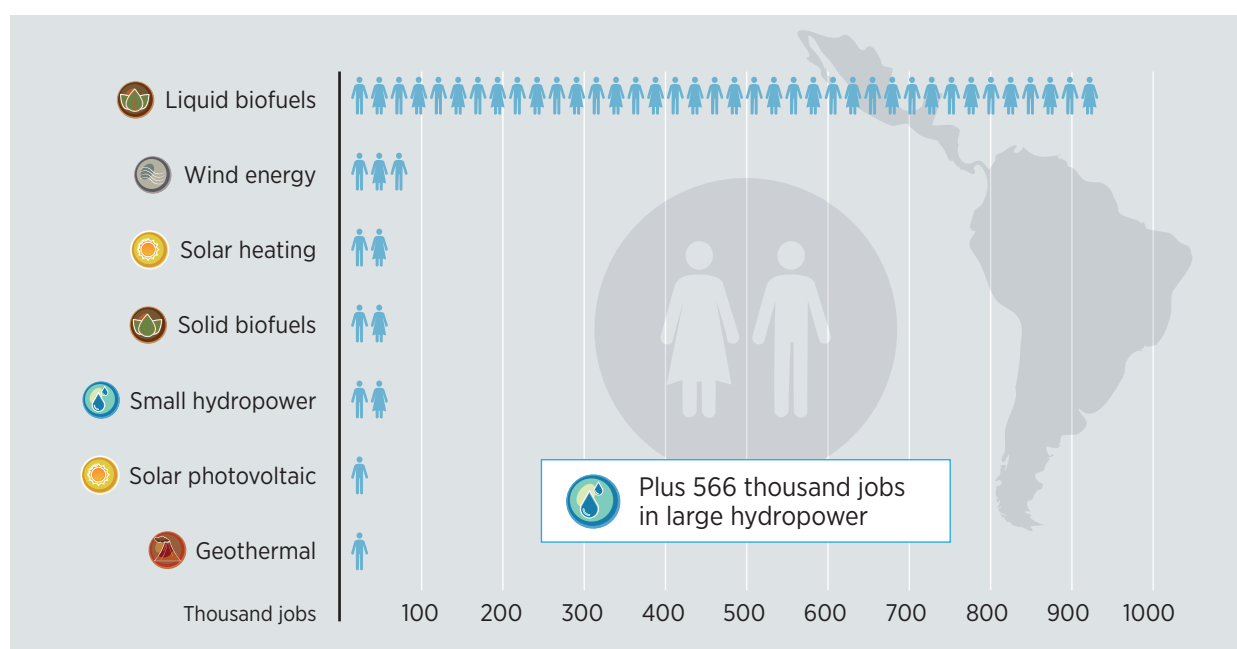
Data for large hydropower are far less available. IRENA has performed a separate estimation, finding that this technology is the second major employer, with around 566,000 direct and indirect

jobs. A large share of the employment is located in Brazil, the country with the largest hydropower sector in the region, but also in countries such as Paraguay and Venezuela.

At a distant third place, but worth mentioning for its dynamism, the wind energy sector supports approximately 64,000 jobs, concentrated mostly in Brazil, Mexico and Uruguay. The region’s wind market rapid development and considerable potential can lead to further employment in the sector along the different segments of the value chain, including project planning, operation and maintenance, and even manufacturing.

Brazil is one case in point where the wind industry has developed to create employment, with 41,000 jobs estimated in 2015, representing 64% of wind employment in Latin America. A majority of these jobs are estimated to be in construction and installation, with the rest in manufacturing due to the ongoing establishment of factories along the wind supply chain (IRENA, 2016e). Mexico’s employment in the wind sector is growing rapidly (see box 3.3) and is the second largest in Latin America, with close to 13,000 jobs in 2015.

**Figure 3.3** Renewable energy jobs per technology in Latin America (direct and indirect)



Note: Separate employment factor-based estimation done for large hydropower.  
 Source: IRENA, 2016e

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Solar heating employs close to 41,000 people, mostly in Brazil where the solar heating market has expanded strongly in the past decade. Three-quarters of these jobs are in manufacturing (Alencar, 2013), with the rest in installation<sup>5</sup>.

As the renewable energy sector expands in the region, employment opportunities will continue to grow. However, fully realising the socio-economic benefits of renewable energy requires the implementation of a broad range of cross-cutting policy instruments.

### Box 3.3 Mexico's wind power employment boom

Mexico is experiencing a wind power boom, due in part to the important legislative reform that has taken place, falling costs, new financing opportunities, improved mapping of the country's wind resources and growing environmental awareness. Installed capacity has expanded from just 100 MW in 2006 to over 3 GW in 2013 (IRENA, 2016a). Nationwide capacity could reach 15 GW by 2029. By that year, wind power might offer direct employment to 48,000 people, and a total of 182,000 direct and indirect jobs could be created in all renewable energy technologies combined (PwC, 2015).

### Maximising benefits through policies

In most Latin American countries, the contribution of manufacturing to GDP is below the level of similar countries around the world, as discussed in chapter 1 (UNIDO, 2013; World Bank, 2016a). With notable exceptions such as the automobile industry in Mexico or the aerospace industry in Brazil, the region has focused largely on exporting commodities, without further developing them and with limited integration in global supply chains (The Economist, 2015).

Renewable energy deployment can trigger local industrial development and diversify the economy, especially when synergistic industries already exist. This is, for example, the case of the aeronautic sector in Brazil, with know-how that could

be of use for the wind blades industry, as shown by the case of Tecsis (Larive International, 2014). Such development needs an adequate policy mix, tailored to specific country conditions, including the level of maturity of the renewable energy sector (IRENA, 2014a).

Policies to support deployment are essential market-creating measures, as they trigger investments in the sector (see section 2.2). A stable and predictable policy environment anchors investor confidence, bringing long-term investments and associated socio-economic benefits. Depending on the type of deployment policy adopted, the benefits achieved can vary in intensity along different segments of the value chain. Some instruments targeted only at promoting deployment, such as tax reductions, tend to create more economic activity in installation and operations and maintenance. Peru, for instance, has been implementing renewable energy auctions since 2009 without any local content requirements (LCRs), and now imports a significant part of its renewable energy-related products (Jochamowitz, 2012).

Auctions and other schemes such as feed-in tariffs or feed-in premiums can also be coupled with policies to support the development of a domestic industry, such as LCRs. This has been the case in Brazil and Uruguay. In Uruguay, at least one-quarter of the installed costs need to be sourced locally (MIEM DNE, 2012). With the implementation of LCRs (a common practice in the region's oil and gas industries for decades), benefits also can be realised in upstream supply chain segments, such as manufacturing. For example, both Ecuador and Uruguay impose percentages of employees that must be local. In addition, Uruguay requires that the renewable energy plant control centre be based in the country. In the Brazilian case, LCRs are a pre-requisite to access preferential financial terms provided by the national development bank, BNDES (see chapter 4), not only for renewable energy but also for other types of infrastructure projects. This policy has contributed to the growth of domestic supply chains for wind and solar. In April 2016, a total of

5. IRENA calculation based on Brazilian market data (Paukowski Moreno, 2013) and a solar heating and cooling employment factor (Mauthner et al., 2015). The estimate for manufacturing jobs is provided by Alencar (2013).

17 solar equipment manufacturers qualified to receive funding from BNDES (BNDES, 2016).

The effects of LCRs are dynamic and depend on several factors, including the size of the potential market, renewable energy deployment policies, the maturity of a particular technology, and the industrial and educational structures in the country. Some countries have opted to implement investment promotion and facilitation measures to create an enabling environment for foreign direct investment (FDI), including investments in renewable energy projects and manufacturing facilities. This has been the case for attracting FDI in Costa Rica, for example (IRENA, 2014a). A partnership on an investment in a solar project estimated at USD 10 million has been formed with the Chinese companies Guoxin Group (PV manufacturer) and Nari Group Corporation (a power management company), with a local group formed by Azucarrera El Viejo and the equipment supplier Greenersys.

Overall, the net benefit of LCR policies must be assessed in economic terms, as there may be a cost associated with constraining a company's choice of suppliers. Accepting a higher cost in exchange for an LCR implies that the country is "investing" in the domestic economy, hoping to achieve benefits later on. Especially in the case of LCR, it is important to evaluate whether this investment is likely to pay off, resulting in the formation of a national industry that may compete with international manufacturers once it matures. The use of LCRs has been positive for the development of the domestic wind industry where it has contributed to developing a local value chain (IRENA/GWEC, 2012). Brazil currently has seven wind manufacturers producing towers to blades locally (BNEF *et al.*, 2015). This is an important result of the country's LCRs and policy mix, combined with the size of its market and its industrial base.

However, Brazil's LCR policy also has resulted in a higher cost of wind turbines due to Brazil's high steel prices (about 70% higher than imported steel; OECD, 2015b) and in significant initial delays in the installation of some wind power plants (Rennkamp & Westin, 2013).

Therefore, LCRs should be timebound, closely linked to a learning-by-doing process, and accompanied by a mix of policies (skills, innovation, etc.) (IRENA, 2014a) that supports the creation of a competitive domestic industry integrated into global supply chains (see chapter 1).

In particular, Meeting the growing skills needs requires adequate education and training measures. Such initiatives have been developed in countries such as Mexico, for example, where a dedicated curriculum for renewable energy is offered at the Universidad Nacional Autónoma de México and Centres for Innovation in Renewable Energy have been developed, specifically in geothermal, wind and solar energy. IRENA is also working on renewable energy education, *e.g.*, through the IRELP initiative.

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***As of 2015, close to 2 million people worked in renewables in the region.***

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The potential for local value creation from renewable energy is not limited to large industries. In the rural context, off-grid renewables can encourage small-scale economic activity and entrepreneurship. For instance, as of 2013, the 3,000 solar home systems installed by Acciona Microenergía in Peru and Mexico employed almost 40 maintenance technicians, most of which had established a local shop (Acciona Microenergía, 2013).

### **Enabling access in rural areas**

Universal energy access is one of the 2030 Sustainable Development Goals. Latin America is close to achieving universal energy access, with 95% electricity access (99% urban and 82% rural, as shown in figure 3.4) and 85% of the population using modern fuels for cooking (IEA, 2015c). Yet, a substantial number of people lack access to modern energy services.

- Over 56 million people rely on traditional uses of biomass for cooking and heat applications, concentrated mostly in Peru, Guatemala, Colombia, Bolivia, Honduras, Paraguay, El Salvador and Nicaragua (IEA, 2015c).

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■ Nearly 15 million people (IEA, 2015c) live without electricity access, most of whom are located in isolated rural areas with low population densities. Rural electrification rates fall below 85% in several countries: Argentina, Bolivia, Ecuador, El Salvador, Guatemala, Guyana, Honduras, Nicaragua, Panamá and Peru (IEA, 2015c). In most of these countries, expanding the grid to reach small, isolated communities (often in mountainous regions) is not economically viable.

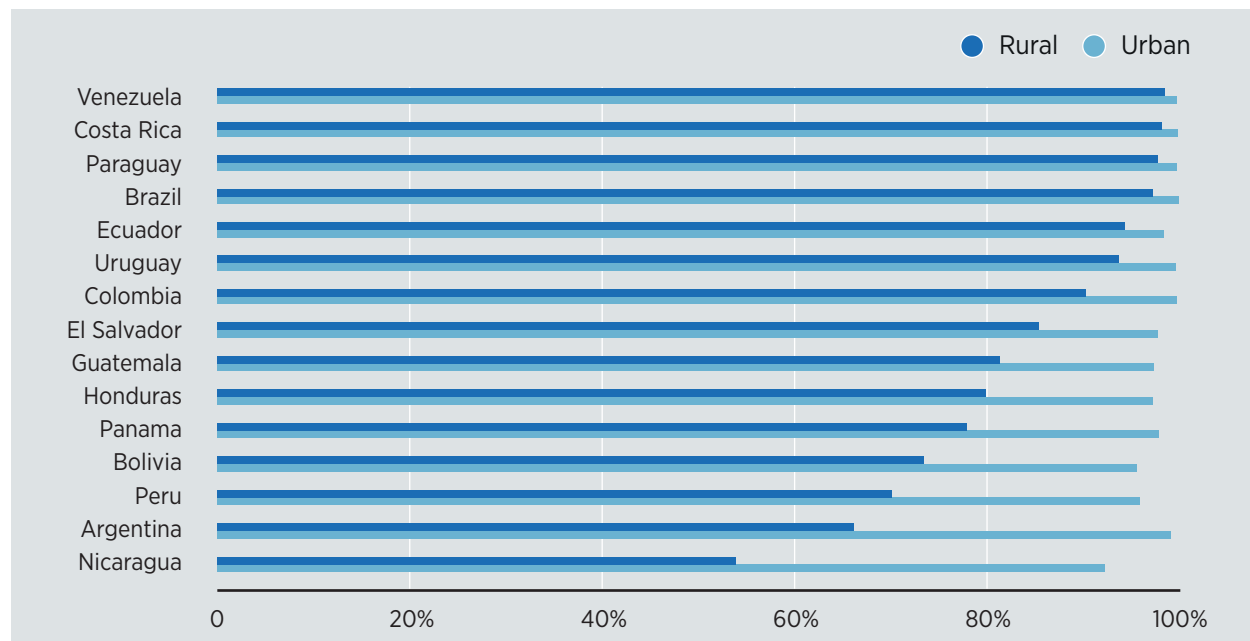
Achieving universal access will require a combination of decentralised and centralised approaches to extend last-mile access to modern energy services. Off-grid solutions – such as mini-grids and stand-alone systems, which can be deployed rapidly and can be customised to local needs – are particularly relevant in Latin America’s rural areas where grid extension is technically or financially not viable. Recent cost reductions in renewable energy technologies make them (in particular solar PV) the most cost-effective option to expand electricity access in many rural areas of Latin America that have high-quality resources such as solar PV in the Andean highlands, and wind or micro – and mini-hydropower in mountainous ar-

reas, notably in Peru and Ecuador or in the Amazon regions of Brazil.

Accordingly, rural electrification strategies and policies in the region increasingly recognise the important role of off-grid renewables, with 18 countries in the region having included renewable energy technologies in policies, programmes and projects for energy access (see the example of Peru in box 3.4). Examples include: Argentina’s *Project for Renewable Energy in Rural Markets*, Bolivia’s *Electricity and Renewable Energy Access* programme, Brazil’s *Light for All* programme, Guyana’s *Hinterland Renewable Energy* project, Honduras’ *Rural Electrification Programme with Solar Energy*, Mexico’s *Isolated Communities Electrification* project, Nicaragua’s *National Programme for Sustainable Electrification and Renewable Energy*, Peru’s ambitious *National Photovoltaic Household Electrification* Programme, as well as Venezuela’s *Sowing Light* programme.

Among the most popular policy instruments are concessions to provide energy access through solar home systems. The concessions can be awarded via direct contract, as in Argentina, or through auctions, as in Peru. Direct subsidies for energy

**Figure 3.4** Rural and urban electrification rates in Latin American countries, 2013



Source: IEA, 2015c

**Box 3.4** Peru's Rural Electrification Plan

Peru has made significant efforts to improve its national electrification rate, which has increased from 55% in 1993 to 87.2% in 2012. In 2013 Peru launched the *National Photovoltaic Household Electrification Programme*, with the aim of providing electricity to 2 million people and 500,000 households with solar PV, reaching 96% energy access by 2016. To achieve this objective, Peru held the first off-grid renewable energy auction in 2014 for 15-year power supply concessions using solar PV. The bid guarantee per project was USD 1 million, the construction guarantee USD 10 million and the contract guarantee USD 2 million. The auction had a non-disclosed price cap. Three projects from the same bidder were awarded all contracts covering 500,000 users in the North, Central and South zones. For the period 2013-22, the 2013-22 *National Rural Electrification Plan* plans to invest USD 53 million in small hydropower plants, USD 294 million in solar PV modules and USD 42.5 in wind power plants.

Source: IRENA, 2012b; IRENA, 2015f

access are provided by several countries, including Nicaragua, Bolivia, Brazil and Argentina, and at least nine countries have established dedicated renewable energy funds or renewable energy-eligible funds for energy access (IRENA, 2015b).

Renewable energy-based mini-grids traditionally have been supported in the region, especially solar - and micro-hydro - based grids given the abundance of these resources in remote areas (IRENA, 2016f forthcoming). For example, a revolving fund was set up by the Inter-American Development Bank called the *Micro Hydro Promotion Fund* to provide loans for micro-hydro schemes in Peru. Over 50 micro-hydro schemes have been deployed, with average electrical power of 33 kW, to provide metered electricity to about 5,000 families. About 40% of the cost of the micro-hydro scheme is paid by community members, partly using loans from the revolving fund. Most schemes are run by a local management group which sets a suitable tariff structure so that revenues cover loan repayment, and operation and maintenance costs (Tarnawiecki, 2005).

Furthermore, in 2009, the Brazilian electricity regulatory agency, ANEEL, acknowledged that grid extension was not a viable solution to provide access to an estimated 250,000 households mainly located in the Amazon region. As a result, the Ministry of Mines and Energy issued a *Special Project Manual* to support mini-grids (including an 85% capital subsidy, especially for renewable energy). Brazil's minigrid programme in 2010 operated at least 15 small hydropower plants and one solar PV plant in remote Amazon areas. (Deshmukh *et al.*, 2013). In addition, utilities are mandated to develop mini-grid systems in their service territories where the grid is not going to reach remote areas, like in many regions in the Amazon basin. More recently, private actors have been contracted to implement mini-grids under a Build-Own-Operate (BOO) arrangement (EUEI PDF, REN21 & ARE, 2015).

In parallel, new end-user financing mechanisms have been developed to enhance the ability of rural households to purchase products or pay for electricity services. As in other regions, microfinance has emerged as a significant mechanism to promote off-grid renewable energy solutions, with more than 60 microfinancing institutions operating in the region (IFC, 2013). Given the high level of remittances in the region, in particular in Mexico, which receives more than one-third of all remittances sent to the region, and in Central American and Andean countries (IDB, 2016b), pilots projects promoting the use of remittances for clean energy have already been launched in Bolivia and Peru (IFC, 2013). Other mechanisms, such as micro-leasing and pay-as-you-go metering systems, suited to off-grid areas, may offer promising financing options for poor consumers in the future. Micro-leasing efforts have been piloted in several Latin American countries, including Brazil and Honduras, and pay-as-you-go metering systems are being piloted in Nicaragua. The multiplication of tailor-made delivery models attests to the dynamism of the off-grid renewable energy sector in the region, led by local enterprises and by a wide range of initiatives covering electricity as well as clean cooking solutions in rural areas.

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For a majority of the households relying on the traditional use of solid biofuels for cooking, improved cookstoves (ICS) represent a key solution to increase combustion efficiency, decreasing forage and reducing indoor air pollution. The ICS sector in Latin America is dominated largely by institutional and NGO-based distribution with a limited commercial component. In Peru, for example, about half of ICS distribution is managed through government channels, and the other half through NGOs. Countries like Mexico and Peru have long-standing programmes, and others, such as Nicaragua, Guatemala and Honduras, are currently developing ICS programmes (Putti *et al.*, 2015).

There is growing evidence that off-grid renewable energy solutions can create value locally in terms of employment and economic growth, in particular when renewable energy projects are well integrated with local commercial activities (IRENA, 2012a and 2013). Dedicated off-grid renewable energy policies integrated across various policy spheres and institutions are necessary to achieve universal access to modern energy in Latin America, as in other regions (IRENA, 2012b and 2015f). This is also a subject of IRENA's ongoing work on off-grid renewable energy as part of the International Off-grid Renewable Energy platform. In this context, IRENA has been analysing the policy and regulatory frameworks needed to facilitate private sector involvement in the mini-grid sector (IRENA, 2016f forthcoming).

### Understanding interlinkages between water, energy and food

The interlinkage between the water, energy and food supply systems – the *nexus* – is beginning to emerge as a major consideration in the sustainable development strategies of Latin American countries. Rapidly growing demand, uneven distribution of resources and uncertainties introduced by climate change are all contributing to growing pressures on the respective sectors as well as intensifying competition between them. These dynamics are particularly relevant for Latin American countries given the region's large reliance on hydropower and bioenergy.

### ■ Energy–water nexus

Hydropower is the predominant source of electricity in Latin America (as discussed in section 2.1 and chapter 5). Although a low-cost and reliable power generation option, hydropower is vulnerable to low water flows in the dry season. This is exacerbated by the impacts of climate variability as well as climate change on rainfall patterns and the frequency and intensity of droughts, as seen in the case of Brazil (see box 3.5). Moreover, in a water-constrained environment, conflicts could arise with other end-uses, such as agriculture, and could intensify social and environmental impacts. With access to water increasingly recognised as a risk for energy security, it is becoming necessary to decouple energy sector expansion from water availability and use.

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### *Off-grid renewable solutions are particularly relevant in Latin America's remote areas.*

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Renewable energy technologies can facilitate this decoupling by enabling an accelerated, secure and environmentally sustainable expansion of the energy sector, while reducing water use. Conventional power generation options – including coal, natural gas and nuclear energy – consume up to 200 times more water than solar PV and wind, the most rapidly growing renewable energy technologies globally. Substantial water savings are already being realised in markets where these technologies have been deployed at scale. Indeed, the business case for renewable energy is further strengthened by the opportunities it offers for water conservation (IRENA, 2015d). Renewable energy also represents a cost-effective and reliable option to meet energy needs across the water supply chain, including for pumping, treatment and heating.

### ■ Energy–food nexus

Energy crops for bioenergy are one of the activities where the energy–food nexus is more readily apparent. As demand for biofuels continues to increase as a result of national targets and mandates, the risk of competition with food crops



### Box 3.5 Why the nexus is now a major concern: the case of Brazil

Brazil is an example of a hydro-dependent country that is vulnerable to climate change. A major drought in south-eastern Brazil in 2014 affected more than 4 million people and caused important water shortages, with São Paulo's Cantareira reservoir system falling below 5% of its capacity. The drought caused Brazil's three largest states (including São Paulo and Minas Gerais) to compete over access to the Rio Jaguari shared river basin.

The drought also forced trade-offs between different water uses including urban supply, waste water treatment and hydropower generation. With the disputes threatening to reach Brazil's Supreme Court, the National Water Agency mediated an agreement between the three states to preserve water supply and energy production.

*Source: Bellfield, 2015; Belt, 2015*

for water and land needs to be carefully examined. Many countries' legislations note the importance of ensuring food security, and some have taken specific measures to that effect. Mexico, for example, restricts the use of corn for biofuels production only to those years with an official national surplus of corn. Ecuador has zoning restrictions for palm oil, and both Ecuador and Costa Rica have specific laws prioritising food production over biofuels production. Uruguay has established that biofuels production should minimise competition with food production for land and water (IRENA, 2015b). The potential trade-offs also could be minimised by investing in agricultural waste as a source of biofuels, promoting biofuel production on marginal agricultural land, agro-ecological land-use zoning and prioritising biofuels that thrive on marginal agricultural lands (Bellfield, 2015).

Another dimension of the food-energy nexus is the energy required for the entire food system, including food production, harvesting, transport, processing, packaging and marketing. Renewable energy technologies can be deployed along different segments of the food supply chain and provide electricity, heat or transport fuels. In El

Salvador, for example, waste heat and steam condensates from geothermal plants are being used to water plants and dehydrate fruits for subsistence and commercial sale. One particular initiative covers 15 rural communities and benefits over 45,000 people while avoiding 1.8 tonnes of CO<sub>2</sub> per year (UNFCCC, 2014). Recognising these potential benefits, Chile launched an auction process in 2014 targeted at promoting renewable energy deployment in the forestry, food and agriculture industries (PV Insider, 2014).

## CONCLUSION

Renewables in Latin America are making strides in terms of cost-competitiveness. The levelised cost of electricity has decreased by over 50% for solar PV since 2012, and by around 20% for hydropower and onshore wind since 2010, ranking among the lowest globally and increasingly competitive with fossil fuels. These reductions are a consequence of technological progress, local supply chain developments, resource quality, reduced financing costs and overall sector maturity, among others.

In parallel, the socio-economic benefits of renewable energy technologies are increasingly recognised in the region as well as in the world. Renewables already employ close to 2 million people in Latin America, are supporting local industrial development and have the potential to boost the region's economic growth in the future. In addition, renewables are key to achieving access to modern energy services in rural areas and to ease resource constraints in the interaction between the energy, water and food sectors. Thanks to these developments, Latin America has the potential to meet its future energy needs in a cost-effective manner through renewable sources while creating new sources of growth and employment.

The growing business case for renewables is reflected in recent investment trends, which demonstrate the rapid evolution of the region's energy mix towards a more diversified portfolio of renewable energy technologies. Chapter 4 analyses the current status of renewable energy investment and finance in the region.

# RENEWABLE ENERGY INVESTMENT AND FINANCE





Latin America has seen significant investment in renewable energy in recent years, with accumulated figures in the period 2010-2015 exceeding USD 80 billion. The consolidation of renewable energy policies in the region, with an effective use of regulatory instruments ranging from auctions for renewable generation to blending mandates for biofuels (chapter 2), combined with rapid reductions in technology costs (chapter 3) are among the factors contributing strongly to these investment levels.

This chapter starts by providing a snapshot of recent investment trends in Latin America and examines the main components of the capital mix for investment in renewable energy. The chapter then reviews some of the key barriers to renewable energy investment in the region and discusses some of the solutions that have been used to address them.

#### 4.1 RENEWABLE ENERGY INVESTMENT IN LATIN AMERICA

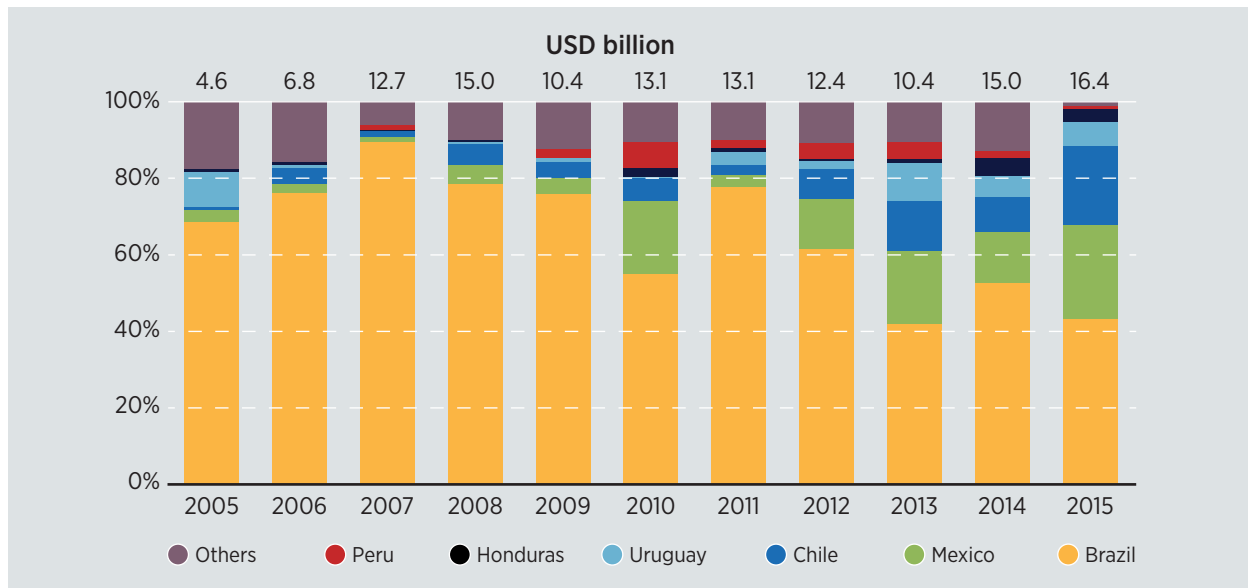
In 2015, total renewable energy investment in Latin America (excluding large hydropower<sup>1</sup>) was USD 16.4 billion, or close to 6% of the global total.

Figure 4.1 shows the composition of investment by country.

Brazil invested a total of USD 7.1 billion, a slight decline over 2014 but still a significant rebound from 2013, due in large part to the country's wind power auctions. The gap in investment between Brazil and the rest of Latin America has been historically notable, but has been narrowing in recent years. The second highest destination of investment in 2015 was Mexico, where renewable energy investment doubled with respect to 2014 to reach USD 4 billion, mostly in wind (BNEF, 2016). Renewable energy investment in Chile ranked third in 2015, up 150% from 2014, totalling USD 3.4 billion, mostly in solar (Frankfurt School-UNEP Centre/BNEF, 2015). For the first time in 2015, in addition to Brazil, both Mexico and Chile joined the list of the top 10 largest renewable energy markets globally (Frankfurt School-UNEP Centre/BNEF, 2016).

Uruguay came in fourth, having invested around USD 1.1 billion for the third consecutive year, mostly in wind. After a record year for investment in Central America in 2014, activity slowed in 2015 (BNEF *et al.*, 2015). The only exception was Honduras, which saw investments of around

1. Bloomberg New Energy Finance (BNEF) considers as large hydropower plants larger than 50 MW.

**Figure 4.1** Investment in renewable energy by country in Latin America, 2005-2015

Source: BNEF, 2016

USD 0.5 billion for the second consecutive year due to the country's solar PV feed-in-tariff.

In addition to these investment figures, IRENA estimates regional investment in large hydropower at around USD 9 billion in 2015 and USD 37 billion cumulatively since 2010<sup>2</sup>.

By technology, the trend over the past years reflects a decrease in investment in liquid biofuels, compensated by remarkable growth in investment in wind and, more recently, solar (see figure 4.2). Investment in liquid biofuels in Brazil, which has the largest country share in the region for this technology, tends to fluctuate according to various factors including sugar prices, weather conditions and petrol prices in the national market. A combination of adverse conditions across these factors have contributed to the decline in investment since 2008.

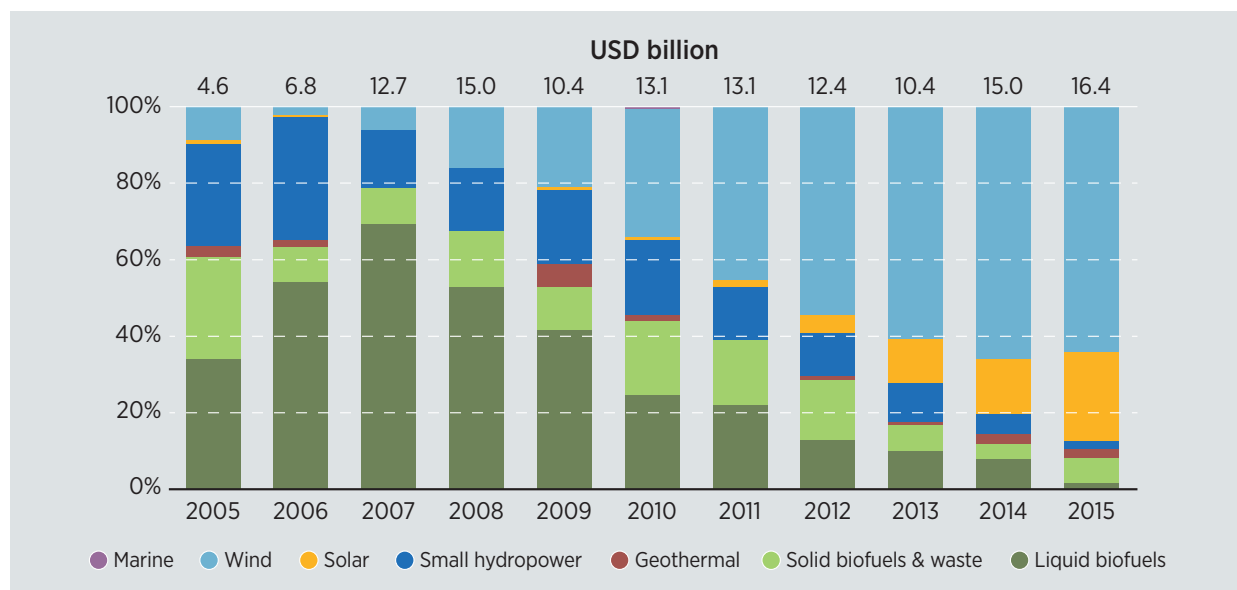
Lower investment in liquid biofuels since 2008 is one of the reasons for the decline in aggregate investment until 2013. The gap was progressively compensated by a surge in wind investment, which in the past three years represented about

two-thirds of total renewable energy investment in Latin America, excluding large hydropower. In 2015, the Brazilian Development Bank (BNDES) provided USD 1.4 billion for wind energy projects, up 85% from 2014, as part of the bank's Green Economy initiative (BNDES, 2016). Mexico's Development Bank Nacional Financiera (NAFIN) has invested an estimated USD 2.2 billion in a wind farm portfolio (Frankfurt School-UNEP Centre/BNEF, 2016).

The past couple of years have seen the rapid emergence of solar PV as a significant focus of investment, mainly in Chile, Brazil and Mexico. In Chile, 2014 saw a record USD 2.4 billion investment in solar with Abengoa's notable USD 1 billion Atacama 1 solar hybrid complex combining both PV and CSP, which will be Latin America's largest solar thermal project once completed. The trend was stable in 2015, with solar representing two-thirds of the total investment in renewable energy, amounting to USD 2.3 billion (BNEF, 2016).

Brazil is resolutely expanding its nascent solar industry aiming to replicate the successful develop-

2. This estimate adopts IRENA's definition of large hydropower, which refers to plants larger than 10 MW. Some overlap exists with the BNEF figures (in particular, for hydropower plants between 10 and 50 MW), although this investment is estimated to be small (around USD 500 million in 2014) in comparison with the reported investment numbers and therefore does not affect the overall estimate, which is in the same order of magnitude as the estimates provided by Global Data (2016) and IEA (2014).

**Figure 4.2** Investment in renewable energy by technology in Latin America, 2005-2015

Source: BNEF, 2016

ment of its wind sector. Over USD 650 million was invested in solar, notably through PV auctions. The year 2015 also saw record solar investment in Mexico, totalling USD 286 million. These investment trends by technology and by sub-region demonstrate the rapid evolution of the region's energy mix towards more diversified participation of renewables.

The region has shown that regulatory stability and transparency are essential to enable the further development of modern and market-based financing schemes for renewables. Some of the Latin American countries that attracted the highest investments in renewable energy in recent years – such as Brazil, Chile, Mexico and Uruguay – have received consistently high evaluations of their legal, institutional and administrative framework in recent specialised surveys (BNEF *et al.*, 2015; EY, 2015; World Bank, 2016b). Conversely, countries with weaker institutional and enabling frameworks have attracted lower volumes of investment in renewable energy, even though electricity demand growth rates in some of these countries could result in sizeable markets.

The high levels of renewable energy investment in the top countries illustrate a variety of institutional, economic and resource conditions. Countries with different degrees of liberalisation in the power generation sector, such as Chile and Brazil, ranked among the top destinations of renewable energy investments. Yet, top performers also include Costa Rica and Uruguay, which have vertically integrated utilities and in which private participation in the electricity sector occurs via independent power producers.

Although the exact characteristics of the framework for investment in renewable energy depend on specific country conditions, there are common underlying success factors – chiefly, access to financing and the cost of capital. These are strongly influenced by the availability of mechanisms to leverage the sources of capital available and to allocate risks between the public and private sectors in the most efficient way. The following section considers the main components of the capital mix available for investment in renewable energy in Latin America.

## 4.2 EVOLUTION OF THE CAPITAL MIX IN RENEWABLES INVESTMENT

### Domestic public financing institutions

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Many Latin American countries with national public financing institutions that have large financing capabilities, most of them categorised as development banks, have actively relied on these institutions to enable investment in renewable energy. National public institutions accounted for over one-third of new renewable energy project finance in the region between 2013 and 2015 (BNEF, 2016; IRENA, 2016g), notably in Brazil (e.g., BNDES and Superintendency for the Development of the Northeast, SUDENE) and in Mexico (e.g., NAFIN, Bancomext and Banobras). The role of BNDES, which financed close to 50% of new-build renewable energy projects in Brazil in 2014, is remarkable in this regard. Likewise, in 2015, NAFIN financed close to half of new renewable energy projects in Mexico (BNEF *et al.*, 2015).

The role of public financing institutions in the capital mix of renewable energy investment in Latin America is driven by three main objectives: implementing deployment policies, catalysing financing sources and supporting technological progress. These objectives are not mutually exclusive, and a loan or grant for a single renewable energy project developer usually serves more than one purpose. Each of them is further analysed below.

Whereas private investors seek to maximise financial returns, public investors tend to pursue additional dimensions in their overall investment goals, in particular to develop markets and enhance positive externalities including economic, social and environmental benefits. Public investors accept a lower return on investment for some renewable energy projects by taking on longer term commitments in order to advance public policy goals such as the development of a domestic market or the creation of a local value chain. National development banks supporting such policy goals can engage the private sector by taking on the riskier components of debt packages, enabling commercial investors to provide the rest of the financing (IRENA, 2012a).

Public financing institutions have been leading in the provision of loans for the large-scale deployment of renewable energy in some Latin American countries, offering particularly attractive conditions and covering a large share of the demand for debt by project developers. Loans can be conditioned to requirements regarding the use of local workforce and locally manufactured equipment, with the objective of contributing to the consolidation of supply chains and local economic development (see chapter 3). The prominent example of BNDES, which accounted for close to 20% of clean energy investment in the region as a whole in 2014, is illustrated in box 4.1.

#### Box 4.1 Recent activities of Brazil's BNDES in the renewable energy segment

The most remarkable example of a deployment strategy via loans from a national public financing institution in Latin America has been that of Brazil's Banco Nacional de Desenvolvimento Econômico e Social (BNDES). In recent years, BNDES offered low-cost, long-term loans for up to 70% of total capital requirements of renewable energy projects in the country, predominantly in the project financing modality. BNDES' National Climate Change Fund credit line, with debt costs as low as 2.5% (in Brazilian reals, BRL), is an example of an attractive loan. This resulted in a large demand for BNDES loans: in 2014, the bank invested USD 3.2 billion in wind, small hydro and biofuels, accounting for approximately 50% of new projects in Brazil (BNEF *et al.*, 2015).

BNDES imposes local content requirements as a condition for awarding loans, particularly regarding the share of locally manufactured equipment. The local content policy has been one of the main contributors to the development of all stages of the wind value chain, with several international companies developing manufacturing plants. In light of the current delicate fiscal situation of the Brazilian public sector, BNDES recently decreased its share in loans for several segments of the energy sector and even temporarily halted the concession of new loans via the National Climate Change Fund line (BNDES, 2015a).

An important aspect of financial policies to deploy renewables is how they can be sustained in the long term. Maintaining the attractive conditions of loans by public financing institutions and supplying a large portion of the demand for capital ultimately impacts public accounts. These limitations highlight the importance of establishing finance policies to diversify capital sources for investments in renewable energy and to access private capital alongside the use of public financing. The case of BNDES, described in box 4.1, also illustrates this point.

Another important role that national public financing institutions can play is to catalyse financing for renewable energy projects, *i.e.*, leveraging the participation of private institutions in the capital mix of renewable energy investments. There are different approaches for such a catalytic role. The first is to create financial products accessible by local private financing institutions and targeted specifically at renewable energy, such as credit lines directed to renewable energy investments or guarantees to mitigate investment risks. These measures are particularly effective in countries where there is already some interest from private investors in the renewable energy sector (IRENA, 2012a). At least 14 Latin American countries have established dedicated renewable energy public funds or renewable energy-eligible funds (IRENA, 2015b). Each fund has its own funding sources, including government *ad hoc* or regular contributions, specific taxes, cross-subsidies, donations from international development partners or sales of public enterprises.

Public financing institutions can participate in structured arrangements of a group of lenders, in the case of syndicated loans. The process of syndication results in spreading risks between different lenders, which enables the engagement of private investors in loan arrangements. By taking riskier components of debt packages, public financing institutions can facilitate the entry of private agents in the process (box 4.2).

National public financing institutions also can act as enablers of technological progress, by provid-

#### **Box 4.2** Syndications as mechanisms for enabling commercial bank participation in Mexico

Syndicated loans in Mexico have become common, with state-owned financial institutions Bancomext, Banobras and NAFIN financing new projects, along with local private banks and subsidiaries of international banks. Such loans spread the risk between different lenders, thus improving the conditions for private participation. Most of the new clean energy<sup>3</sup> infrastructure in Mexico, especially wind, is financed by syndicated loans, whereby a group of lenders (foreign or domestic) jointly provide financing for a specific plant.

Among the largest projects financed in 2015, the 138 MW Phase II of the Piedra Larga wind farm in Oaxaca, received USD 229 million in debt financing from five local commercial banks. This structure can help mitigate financial risks for bank and reduce the load on local lenders. In 2012, local lenders in Mexico financed renewable projects worth USD 507 million, amounting to 31% of total investments in energy (BNEF *et al.*, 2014). The case of Mexico is therefore an interesting example for how public financial institutions can enable the participation of local private financing institutions in renewable energy project financing.

ing funds to the deployment of renewable energy technologies that are not yet commercially mature. Grants or subsidised loans from these institutions can be channelled towards the initial stages of development of new technologies, namely for research and development (R&D) and demonstration projects.

Although technological innovation in renewable energy in Latin America has moved at a slower pace in comparison to other regions such as the United States and Europe, some public financing institutions have implemented such programmes, as illustrated in box 4.3.

#### **Foreign public financing institutions**

In many Latin American countries without public financing institutions, or in those with public institutions that have limited financing capabili-

3. "Clean energy", under Mexican legislation, includes renewables, co-generation, nuclear energy, fossil fuels with CCS and "other low-carbon technologies" (BNEF *et al.*, 2015).

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ty, foreign public financing institutions have been important sources of capital for investment in renewable energy.

Most of the foreign public financial institutions active in Latin America are multilateral development banks (MDBs) – such as the Central American Bank for Economic Integration (CABEI), the Latin American Development Bank (CAF), the

#### Box 4.3 Examples of funding for technological innovation in renewable energy in Latin America

In 2013, a joint initiative of the Brazilian Financier of Studies and Projects (FINEP), the Brazilian development bank (BNDES) and the Brazilian electricity regulation agency (ANEEL) was established to support renewable energy research and development (R&D). The programme, *Inova Energia*, has a budget of approximately USD 1 billion and provides funds for research and development, and technology demonstration projects in three main areas: energy generation through renewable energy sources, smart grids and hybrid vehicles (BNDES, 2015b). Approximately one-third of this budget was provided by BNDES.

In Chile, financial support from the Chilean Economic Development Agency (CORFO) had a key role in enabling the establishment of the Research Center for Solar Energy Technologies, focused on applied R&D. The centre, inaugurated in 2015, is an important component of Chile's strategy to explore the vast solar energy potential in the country. The government also created the Solar Energy Research Center, where CORFO is leading the development of a Solar Strategy for Chile.

Another example is Mexico, where the Energy Secretariat (SENER) and the National Council on Science and Technology (CONACYT) invested USD 37.8 million in a sectoral fund for the establishment of three innovation centres for renewable energy. The three centres are specialised in geothermal, solar and wind energy, respectively. There are also initiatives to support innovation at a regional level. In 2012, the Latin American Development Bank (CAF) and the Brazilian FINEP mobilised USD 200 million to finance clean energy technologies researchers in Latin America and to support start-up companies (Bloomberg Business, 2012).

Inter-American Development Bank (IDB) and the World Bank – whose mandates include support for local development benefits. Other foreign public financial institutions are active in the region through bilateral arrangements, such as the German development bank (Kreditanstalt für Wiederaufbau, KfW) and the US development finance agency (the Overseas Private Investment Corporation, OPIC). Together with domestic public finance institutions, the MDBs and bilateral financiers are referred to as Development Finance Institutions (DFIs), and can play a critical role in scaling up renewable energy investment.

With the objective of achieving long-term development, and in line with the activities of domestic public financing institutions, foreign development financiers often take on higher risks and offer longer tenors (*i.e.*, term lengths), in addition to providing technical assistance for renewable energy projects. In some cases, they offer concessional loans (*i.e.*, with rates below market terms). Thus, they have the potential to catalyse private investment in renewable energy like domestic public financing institutions.

#### *Foreign public financing institutions have been important sources of capital in countries with limited public financing capabilities.*

In addition, DFIs can have an instrumental role in capacity building, by funding targeted initiatives. An example is a grant of USD 25 million awarded by the IDB to Guyana, to fund programmes that include the development of a renewable energy policy and the strengthening of technical capacity within the country's environmental sector (BNEF *et al.*, 2014). DFIs also have financed projects and programmes targeted specifically at domestic financial institutions that have incipient experience with renewables, to disseminate best practices in financial analysis procedures and project structuring techniques in Latin America. One such example is the development of wind finance in Mexico, presented in box 4.4.



#### Box 4.4 The early role of the IFC and the IDB as catalysers for wind power financing in Mexico

Wind power project financing in Mexico began when the International Finance Corporation (IFC) and the Inter-American Development Bank (IDB) agreed to provide an anchor investment of key senior and subordinated debt for the first Mexican wind farm, totalling approximately USD 525 million in 2007. The availability of concessional resources of the Clean Technology Fund (CTF, see box 4.5) was key in this process.

The sponsors invited the national development banks NAFIN and Bancomext to co-finance the project, which would provide national private banks with significant experience in financing wind projects. Other lenders included foreign private banks from Spain and Portugal, and further Mexican wind projects followed. The multilateral institutions thus effectively catalysed debt financing for wind projects. A key part of this process was their capacity-building function: once they demonstrated how to evaluate renewable energy projects for debt financing, the local banks were able to replicate.

As in the case of Mexico, DFIs can catalyse national public investments by building a learning curve in project financing.

Other types of foreign public financiers also have been active in Latin America. These include export credit agencies, such as the US Export-Import Bank (EXIM) and the Danish Export Credit Agency (EKF), which provide loans and guarantees for projects involving exports of supply services or equipment from these countries. Among these institutions, EXIM has been the most active in the Latin American renewable energy sector, offering loans at attractive conditions, with tenors that can extend up to 18 years at fixed interest rates (Essien, 2015). EXIM recently provided finance for wind power projects in Costa Rica, Peru and Uruguay. In fact, the surge of renewable energy investment in Uruguay in 2013, with nearly USD 1.1 billion invested in wind energy and bioenergy, was financed largely by foreign public financing institutions, including MDBs and export credit agencies (BNEF *et al.*, 2014).

#### Debt financing by private financing institutions

Domestic and foreign private financing institutions have shown significant interest in the renewable energy sector in Latin America. Several private financing institutions with recent activity include Brazilian banks Bradesco and Itau, Spanish banks Santander and BBVA, Banorte from Mexico, Chilean CorpBanca and German Deutsche Bank (see table 4.1).



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**Table 4.1** Activities of selected private financing institutions in Latin America

Institution (country)	Recent activity in renewable energy sector in Latin America
<b>Bradesco (Brazil)</b>	The second largest Brazilian private bank was the main private financier in all Latin America in 2013, with over USD 220 million awarded to several projects.
<b>Santander (Spain)</b>	In 2014, Santander borrowed USD 150 million from the European Investment Bank (EIB) to finance solar (PV and CSP) and biomass projects in Latin America. In 2013, the total volume of funds directed to renewable energy projects was USD 210 million, closely following that of Bradesco. The bank is a key player in wind financing in Mexico.
<b>Itau (Brazil)</b>	In 2015, Itau borrowed a combined USD 400 million from the IFC and a group of commercial lenders (Japan's Mizuho Financial Group Inc., Bank of America Merrill Lynch and Germany's Commerzbank AG) to fund renewable energy projects in Brazil. Between 2012 and 2015 Itau financed 42 renewable energy projects.
<b>BBVA (Spain)</b>	In 2013, BBVA granted a USD 150 million loan to Enel Green Power Chile to fund 190 MW wind and other solar and geothermal projects, and a USD 250 million loan to Enel Green Power in Mexico to fund the installation of 144 MW of wind power.
<b>Banorte (Mexico)</b>	Banorte is the main Mexican private financier for renewable energy, with over USD 110 million funded in 2013.
<b>HSBC (UK)</b>	HSBC's financing of renewable energy projects in Latin America amounted to over USD 100 million in 2013.
<b>Rabobank (Netherlands)</b>	In 2013, Rabobank, IFC and OPIC jointly secured the financing of a 100 MW solar PV project in Chile, with approximately USD 260 million. The volume of funds from Rabobank for renewable energy projects in Latin America in 2013 was USD 70 million.
<b>Deutsche Bank (Germany)</b>	At the beginning of 2015, Deutsche Bank financed its first renewable energy project in Latin America, underwriting USD 92 million in debt for a USD 144 million wind power project in Uruguay.
<b>CorpBanca (Chile)</b>	In 2013, CorpBanca and BBVA closed a USD 130 million debt-financing arrangement for the construction of a 70 MW solar plant in Chile.

The following section describes markets with a higher participation of private debt for renewable energy investment. First, private debt tends to have a stronger participation in countries with more mature renewable energy sectors and/or more stable economies. Second, certain niches of the financing market also have a higher participation of debt from private financing institutions.

Unsurprisingly, the activity of private commercial banks has been concentrated in the most mature renewable energy sectors in the region, particularly those with a steadier flow of projects, includ-

ing in Brazil, Chile and Mexico. Countries with a somewhat smaller track record, but that are perceived as stable economies and have implemented sound renewable energy policies, such as Uruguay, also have seen an increased participation of private banks in recent years. Private financing institutions have a clear preference for mature and proven renewable energy technologies, which explains their focus on wind power in Latin America. In addition, they tend to focus on large projects, in part to lower the transaction costs. As such, small and medium-sized projects tend to face challenges in obtaining private financing.

The typically higher debt costs and shorter loan tenors offered by private commercial banks make them the second choice for project developers in countries where domestic public financing institutions have been capturing a large share of the demand for debt. This has been the case in Brazil, where the low-cost financing from BNDES has supplied a predominant share of finance for renewable energy projects. However, the recent contraction of BNDES' financing capability in the context of tighter fiscal policy in Brazil has resulted in higher demand for private debt and has resulted in the emergence of new finance mechanisms.

There are niches of the debt market in Latin America, where private institutions have a significant role. The first is short-term bridge loans. Lengthy administrative procedures and financial assessments from some public financing institutions can negatively impact renewable energy projects with tight implementation schedules. This results in a demand for shorter-term bridge loans from private institutions.

A second example is refinancing. Public development banks often focus on loans targeted at enabling the implementation of new projects, which makes refinancing, or financing for the acquisition of operational assets, another niche segment for private financing institutions. The dynamics between private and public resources in the refinancing model are an example of the catalytic role of public financing. In particular, public debt can represent a higher share of the capital mix during the construction stage of renewable energy assets, which typically involves higher risks. Once projects become operational, the risks associated with the asset decrease, reducing the cost of debt from private financiers and increasing the attractiveness of refinancing. Such refinancing entails the repayment of public debt, which replenishes the capital of public financing institution, allowing these resources to finance other early-stage projects.

Another possible niche for the participation of private commercial banks is via mezzanine finance<sup>4</sup>. If renewable energy projects fail to access sufficient senior debt, mezzanine loans rep-

resent an alternative way to attract private debt finance, and is less costly than equity. Mezzanine finance has been nonetheless relatively scarce in Latin America, especially before the consolidation of renewable energy sectors. Public financing institutions have also provided mezzanine finance for renewable energy projects. For instance, the Chilean CORFO has a financing line for quasi-equity targeted specifically at innovative projects in renewable energy, energy efficiency and other environmental investments.

### Private equity and capital markets

Equity is a key component in the capital mix of renewable energy projects, particularly in developing countries, where the perceived higher financial risks may impose a lower share of debt in the capital mix. Besides equity from renewable project developers and independent power producers, other sources of equity are venture capital funds, private equity funds, and infrastructure and pension funds.

Venture capital funds typically focus on the initial, higher-risk stages of development of commercial technology enterprises (IRENA, 2012a; UNEP-SEFI, 2008). The participation of this type of agent in renewable energy investment in Latin America has been very limited – reflecting in part the relatively low levels of technological innovation (World Bank, 2013c). Yet, some experiences with venture capital in the renewable energy sector exist, as seen in Chile. The Chilean state-owned CORFO offers a credit line targeted especially at hedging part of the risk of private capital funds investing in environmentally friendly technologies. Under this line, CORFO contributes up to 40% of the equity of the funds, with the remaining 60% provided by private investors, and absorbs part of the risks of the investment. The facility has triggered the emergence of Chilean venture capital funds interested in renewable energy investments, such as the IM Trust Energías Renovables (CORFO, 2009).

An example of a private equity fund with notable activity in the Latin American renewable

4. Mezzanine debt is a junior tranche of the debt provided to a project, which is senior only to equity within the capital structure, meaning that a mezzanine loan will be repaid only after senior debt.

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energy landscape is the ACON Latin America Opportunities Fund. In 2012, the fund acquired a majority stake in a Panamanian company operating 30 MW of small hydropower plants. In April 2016, BNDES announced a commitment of up to USD 200 million across five private equity/venture capital funds investing in logistics, energy, renewable energy and innovation in Brazil. One of the factors that enable a higher participation of private equity funds (as well as other private investors) in Latin America is the liquidity of the market for trade sales<sup>5</sup> and the recent experiences of renewable energy companies with initial public offerings (IPOs) in capital markets. One example is that of the Brazilian CPFL Energias Renováveis, whose IPO in July 2013 raised funds of approximately USD 460 million. Maintaining and increasing the liquidity of the market for trade sales is important to provide exit options for private investors in renewable energy, allowing them to replenish capital for new project developments, creating a virtuous cycle within the private sources of finance.

The liquidity of the market for acquisitions in Latin America has been increasing in recent years. This is illustrated by the fact that approximately 30% of total investment in renewable energy (excluding large hydropower) in the region between 2006 and 2014 – including asset finance, venture capital and private equity, merger and acquisition (M&A) and public markets – went to finance M&A deals (BNEF *et al.*, 2014; BNEF *et al.*, 2015). M&A activity in Brazil is significant and represented about USD 7 billion in 2014, of which USD 3.6 billion went to finance acquisition deals for wind (BNEF *et al.*, 2015). The increase in the liquidity of the market for trade sales has accompanied its maturity, with the emergence of more specialised players, such as independent project developers who usually sell their projects through M&A transactions in the investment phase.

Infrastructure and pension funds typically are interested in lower-risk and longer-term investment, with a notable risk-averseness in the case

of pension funds. Therefore, their participation in renewable energy investment generally is considered as a sign of market maturity. Latin American countries with more experience in renewables have been witnessing an increased interest from these funds. Examples include that of Cubico, a joint investment vehicle from Santander; the Ontario Teachers' Pension Plan; and PSP Investments, whose asset portfolio includes investments in wind and solar power projects in Brazil, Mexico and Uruguay (in addition to European countries such as Italy, Portugal, Spain and the United Kingdom).

Domestic pension funds also are beginning to invest in renewable energy. A relevant example is the acquisition of shares from the renewable energy company ERSA by the Brazilian Fundo Brasil Energia, which channels investments from some Brazilian pension funds.

Raising capital directly in capital markets – either equity in stock markets or debt in bond markets – is also an option for renewable energy companies. The example of the IPO of Brazil's largest renewable energy private company, Renova Energia, illustrates how relevant this option can be for capitalisation. In July 2010, the company raised around USD 100 million in its IPO, compared to an original target of USD 400 million. This example also illustrates that raising capital directly in stock markets can be challenging, and there are still few such examples for renewable energy companies in the region. Renova Energia is, however, one of the top equity investors in the region, with about USD 880 million of equity in 2014 (BNEF *et al.*, 2015).

Most of the activity of renewable energy companies in capital markets in Latin America has been concentrated in the countries with the largest, deepest<sup>6</sup> and more diversified (in terms of financial assets) markets. Figure 4.3 shows the total capitalisation of stock markets of selected Latin American economies as a function of their GDP in 2012. Chile stands as an outlier, with the

5. The term refers to the exit (sale) of a company, and it is mostly used in the context of venture capital.

6. The depth of a market refers to its ability to sustain large market orders without impacting the price of the traded security. Market depth is closely related to the traded volume and liquidity in the market.

**Figure 4.3** Total stock market capitalisation and levels of GDP of selected Latin American countries

Note: All monetary figures expressed in nominal USD of 2012.

Source: QUANDL, 2015; World Bank, 2016a

size of its stock market comparatively large for its GDP. Chilean capital markets also are remarkable for their depth – not only for stocks, but also for bonds. The availability and volume of trade bonds, denominated in local currency, often has been mentioned as a characteristic of the Chilean capital market that greatly eases financing for international investors interested in all segments of the infrastructure sector (Economist Intelligence Unit, 2014), including renewable energy.

Capital markets also have been important in the financing of renewable energy projects in Brazil. In recent years, Brazil has been introducing incentives to increase the participation of bond markets in the capital mix of infrastructure projects, as part of a broader strategy to diversify and mitigate dependence on subsidised BNDES loans. In 2015, Brazilian developer Casa dos Ventos Energias Renovaveis sold the equivalent of USD 129 million of one-year bonds to refinance five wind projects (Frankfurt School-UNEP Centre/BNEF, 2016). The same year, Mexico's NAFIN issued USD 500 million worth of five-year bonds to contribute to the development of a wind portfolio (Frankfurt School-UNEP Centre/BNEF, 2016).

Another relevant example of the role of capital markets in renewable energy investment is infrastructure debentures. Introduced in 2011 in Brazil, infrastructure debentures are bonds issued by infrastructure companies. Tax relief benefits apply to holders of such financial instruments to incentivise their purchase. Since this mechanism was established, around USD 75 million in infrastructure debentures have been issued for wind deployment, and USD 500 million for hydropower projects. The issuances were denominated in national currency.

Other Latin American countries also see a strong participation of local capital markets in the finance mix of renewable energy projects. This is, for instance, the case of Argentina. Taking into account the country's precarious fiscal situation, foreign private and development financing institutions generally have been reticent to funds renewable energy projects, and project developers have resorted to the acquisition of debt in local bond markets as a means of complementing the financing obtained from state-owned banks.

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Green bonds have recently emerged as dedicated financing instruments for environmentally-friendly or climate-related investment and have been used to raise debt for renewable energy project development in Latin America. A recent example is the Peruvian energy producer Energia Eolica SA, an indirect subsidiary of Contour Global, which issued green bonds of USD 204 million in 2015. These bonds were denominated in USD and underwritten by Goldman Sachs and Bank of America Merrill Lynch. There also has been experience with the issuing of green bonds denominated in local currencies. Examples include green bonds issued by the IFC in Peruvian soles, and several issuances from the World Bank in Brazilian reals. The experiences with green bonds earmarked to Latin American projects and denominated both in international and local currencies suggest that it is possible to use these instruments to cater to specific needs and to address currency exchange risks of local and international investors. However, bond financing is typically available either for re-financing operative assets, or against a corporate balance sheet, whereas it seldom can be used for construction-stage project finance.

Yieldco structures have lately emerged as an option for energy utilities and other renewable energy asset owners to spin-off operative assets from their balance sheets to develop, finance and implement new projects. Some initial experiences with this instrument has been gained in Latin America. For instance, Abengoa Yield's assets include 100 MW of wind power in operation in Uruguay, and TerraForm Global holds wind, solar and hydropower projects in Brazil, Costa Rica, Honduras, Nicaragua, Peru and Uruguay. These examples suggest that the investment environment and the remuneration schemes in several Latin American countries are mature enough to allow the inclusion of operating renewable energy projects into a low-risk asset portfolio. Yieldcos have emerged as potentially efficient vehicles to re-finance project developers' operative assets, and thus release their capital for the deployment of new projects. More information on emerging instruments such as green bonds and yieldco structures can be found in IRENA (2016h).

### Climate funds and other specialised sources of finance

Dedicated financial instruments also have found their way into the capital mix of renewable energy projects in Latin America. Yet, their effectiveness in meeting the capital needs of project developers varies greatly among instruments, reflecting their level of maturity at the global level as well as the specificities of some Latin American countries.

Climate funds and other specialised funds for renewables can be an important source of finance for renewable energy deployment. Project developers may resort to a variety of global climate funds to obtain various types of capital: grants, debt (including concessional debt at low costs), mezzanine finance and even equity. Some of the funds also provide financial instruments to catalyse funding from third parties, such as guarantees. A good example is the Geothermal Development Facility (GDF), which includes stakeholders such as KfW, the IDB, the CAF, the EIB, the World Bank and the Deutsche Gesellschaft für Internationale Zusammenarbeit (German Agency for International Cooperation, GIZ). The GDF's activity covers all Central American countries as well as Colombia, Peru, Bolivia and Chile and aims at lowering the risk of geothermal exploration and offers financing for geothermal projects. It functions based on three components: a risk mitigation fund, bridge/investment financing lines and a technical assistance forum. Other examples of global funds and their geographical coverage in Latin America are listed in table 4.2.

Because climate funds have a global coverage, they are channelled to local investments through international, regional or even national development financing institutions. In Latin America, many of these funds can be accessed through the IDB or the World Bank, and also through other regional institutions, such as CABEL and CAF. The Climate Investment Funds (CIF) have been some of the most active global climate funds in Latin America. Climate funds make it possible to address specific barriers that MDB financing cannot, in particular risk barriers. An example is the

**Table 4.2** Recent activity of global funds for renewable energy in Latin America

Fund	Type of funding	Manner of accessing the fund	Recent coverage in Latin America
Global Energy Efficiency and Renewable Energy Fund	Equity	Indirectly, channelled through programmes of development banks	Central America
Climate Investment Funds	Grants, concessional debt, guarantees, equity	Indirectly, channelled through programmes of development banks	Mexico, Chile, Colombia, Honduras
Canadian Climate Fund for Private Sector in the Americas	Grants, concessional debt	Indirectly, channelled through programmes of development banks	Chile, Mexico
Nordic Climate Facility and Nordic Environment Finance Corporation	Grant co-financing	Based on call for proposals, where project developers can apply directly	Nicaragua, Honduras, Bolivia
Global Environment Facility	Grants	Indirectly, channelled through programmes of development banks	All Latin American countries
Nordfund	Grants	Project developers can apply directly	Central America
Climate partnerships with the private sector	Equity, debt, mezzanine	Project developers can apply directly, by submitting proposals	Mexico, Brazil
Sustainable Energy and Climate Change Initiative	Grant, technical assistance	Project developers can apply directly, with applications being reviewed by IDB	All Latin American countries



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Dedicated Private Sector Programs (DPSP) for geothermal projects, where CIF resources specifically address the resource risk during early exploration. Box 4.5 briefly describes the CIF funds and highlights their recent activities in the region. Looking forward, the Green Climate Fund (GCF) is expected to play a significant role. At the end of 2015, it had reached a capitalisation of over USD 10 billion.

#### Box 4.5 Climate Investment Funds (CIF) in Latin America

The Climate Investment Funds (CIF) are one of the largest global climate mechanisms. Created in 2008, the CIF uses a blend of financial instruments, including grants, concessional loans and guarantees, accessible through regional development banks. The IDB and the World Bank are the channels for Latin America. The CIF include the Clean Technology Fund (CTF) and the Strategic Climate Fund (SCF). The SCF includes the Program for Scaling up Renewable Energy in Low-Income Countries (SREP) as well as two thematic Programs on Forests and Resilience.

As of mid-2015, USD 6.1 billion had been pledged to the CTF and the SREP (USD 5.3 billion for the CTF and USD 0.8 billion for the SREP), endorsing 187 projects and programmes in 30 countries and expecting co-financing of USD 533.5 billion from other sources (Climate Investment Funds, 2015). The CTF and SREP countries in Latin America are Mexico, Colombia, Chile, Honduras and Nicaragua. CIF resources include nearly USD 1 billion to be channelled by the IDB and the World Bank Group for renewable energy and energy efficiency, according to the semi-annual reports and operational reports. The CIF has significant activity in Latin America, enabling the development of key projects by bringing together global capital and specialised expertise.

NAMAs (Nationally Appropriate Mitigation Actions) are another instrument to access climate finance and have contributed to the promotion of renewable energy in Latin America (IRENA, 2012c; IRENA, 2014b). The total funds mobilised so far have been, however, more modest than those of other instruments discussed earlier in the chapter. Box 4.6 provides the example of a NAMA in Chile.

#### Box 4.6 A NAMA for expanding self-supply renewable energy systems in Chile

Chile is currently in the process of implementing a NAMA to expand the self-supply of renewable energy, which already received USD 15 million from the NAMA Facility and the International Climate Initiative of the German environment ministry (NAMA, 2015).

There are three main components in its implementation. The financial component provides incentives to leverage investments by third parties: pre-investment grants to undertake feasibility studies for potential projects; subsidised loans at favourable rates and repayment terms; and grants of up to 20% of the total investment cost of installation of self-supply renewable energy projects. The technical component aims to provide capacity building regarding self-supply of renewable energy. The third component aims at increasing public awareness, via public media campaigns and technology roadshows and demonstrations. The initiative started in 2012, and its goal is to enable reductions in greenhouse gas emissions of 1.7 million tonnes of CO<sub>2</sub> - equivalent until 2030 (NAMA, 2015).

### 4.3 BARRIERS TO RENEWABLE ENERGY INVESTMENT

Latin American countries face a number of barriers in attracting renewable energy investments, which are discussed in this section and grouped in three categories: 1) macroeconomic factors, 2) structure and organisation of the energy sector, and 3) finance sector.

#### Macroeconomic factors

As in other regions, uncertain macroeconomic conditions in some Latin American countries can dissuade both local and foreign investment in renewable energy. The perception of risk in certain countries due to a lack of track record with certain types of investments or to past experience with policy changes, can lead to reluctance on the part of investors, and raise the cost of capital to ensure adequate risk-adjusted returns.

Inflation is among the key macroeconomic factors with direct and indirect consequences on the



perceived attractiveness of investment in some countries. Higher and less predictable inflation rates than those of developed countries directly affect the operational costs of renewable energy projects, as well as debt costs. This can even impact projects with inflation-indexed contracts, if the index does not reflect the actual variation of the relevant cost components for project developers<sup>7</sup>. Additionally, inflation can lead to changes in monetary policies and therefore interest rates and debt costs.

Economic growth rates in Latin America have been comparatively higher than those of developed countries, but growth has proven relatively volatile (see chapter 1). This can cause volatility in energy demand, which impacts the prospect of a sufficient flow of local projects in which to invest. This also can result in difficulties for the consolidation of a local renewable energy supply chain.

The fragile fiscal situation of several Latin American countries, due to factors ranging from dependence on tax revenues from commodity sectors to inefficient public expenditure, also can represent a barrier for renewable energy investment by increasing the uncertainty associated with government funding. Country risk premiums escalate significantly in periods of fiscal imbalance, increasing the costs of capital – either equity or debt – for renewable energy investors. Countries across Latin America have very different levels of country risk, as reflected by their diverse credit ratings<sup>8</sup>.

Finally, the volatility of currency exchange rates of several Latin American countries represents a particularly relevant risk factor that constrains foreign investments. This volatility increases risks of mismatches between revenues and costs, when they are denominated in different currencies. It is, therefore, essential to match power purchase agreements (PPAs) and debt currencies (as well as other key contracts, e.g., engineering, procurement and construction (EPC)) or to use currency hedging. If there is enough depth in the local financial market, the

debt can come from local financial institutions in local currencies, in which case the PPA also can be formulated in the local currency. Contracting locally denominated debt contributes to mitigating currency exchange risks, when PPAs (and other main agreements) also are denominated in local currencies. Accordingly, almost half of the project finance for new clean energy in Latin America was obtained locally in 2013 (BNEF *et al.*, 2014).

However, in some Latin American countries, local currency funding is not available, and investors prefer to denominate the PPA, loan and all other agreements in international currencies. In recent years, there have been experiences with remuneration of renewable energy projects in international currencies in Latin America, e.g., in Honduras, Nicaragua and Peru (IDB, 2014d). Finally, the currency denomination of other types of contracts, such as EPC, matters as importing renewable energy equipment and services from other countries, which represents a significant share of capital expenses, also exposes the investors to currency exchange risk.

### Structure and organisation of the energy sector

This section analyses the barriers in the structure and organisation of Latin America's energy sector that can hinder investment, including pricing and market barriers, contract design, and technical and labour constraints.

#### ■ Pricing and market barriers

Energy subsidies and price controls for fossil fuels and electricity can represent a significant barrier as they affect the overall cost-competitiveness of renewable energy technologies. In 2013, pre-tax energy subsidies represented 9% of GDP in Venezuela, 7.5% in Ecuador, 6% in Bolivia and almost 4% in Argentina (IMF, 2015c). A second related barrier is the pricing of renewable energy, particularly given that the environmental and social costs of non-renewable energy production are

7. This may happen, for instance, due to methodological shortcomings in the calculation of indices, or because the contract should have been pegged to an index more representative of its costs (e.g., producer versus consumer price indices).

8. A credit rating is an evaluation of how credit-worthy a debtor is. These evaluations normally are performed by private rating agencies.

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not internalised (IRENA, 2012a). Accounting for externalities in the energy sector is a challenge on a global scale, often due to insufficient access to information and technical capability to allow effective decision-making. IRENA analysis shows that, if external costs are taken into consideration, the costs of doubling the share of renewable energy in the global mix by 2030 are negative (IRENA, 2016d).

Mechanisms to enable private participation in various segments of the energy sector are available in many Latin American countries, mostly as a result of liberalisation measures. However, entry mechanisms for private players also exist in countries with significant vertical integration within the energy sector. This is the case of Uruguay, where independent power producers are allowed to sell power to the vertically integrated utility.

Even where formal entry mechanisms for private players exist, the perceived financial attractiveness of renewable energy projects ultimately determines the actual private participation. Immature market environments therefore can hinder market entry. Uncertainty on the long-term demand for renewable energy and on the ability to remunerate investments can deter the entry of private players. This can happen when market designs are based on conventional technologies (e.g., by requesting only baseload technologies or by assigning low capacity factors to renewables in the design of capacity payments), or if little incentives exist to add flexible resources to the system and therefore accommodate variable renewable energy technologies. Unclear administrative procedures, such as those required to obtain permits and licences, also can result in entry barriers for renewable energy investors. The length, complexity and costs of these administrative procedures in several Latin American countries can result in large transaction costs (IDB, 2014d).

Lastly, insufficient infrastructure capacity can deter entry from developers. The development of electricity transmission infrastructure to allow the integration of renewable generators requires not

only sizeable investments, but also complex efforts by planning authorities. Examples of Latin American countries in which transmission recently constrained the integration of renewables to the grid include Brazil, Guatemala and Panama, among others.

#### ■ Contractual arrangements

Investments for new power generation entail large capital expenses and warrant long-term commitment from the developers. Financing in Latin America is generally acquired through project finance<sup>9</sup>. The cash flows of the project are relied upon to repay the long-term debt, within a given comfort level required by the financiers. When building new generation capacity, developers strive to minimise project risks in order to enable access to affordable capital.

A long-term electricity forward contract – *i.e.*, a PPA – provides revenue stability to investors and protects them from many of the effects of government interference in the spot market. Several Latin American countries have used auctions for long-term energy contracts for new capacity targeting the regulated market (see chapter 2 and IRENA's work on auctions – IRENA, 2015c). Deregulated consumers (e.g., large industries) can decide freely on their own contractual arrangements for energy supply but often are not willing to enter long-term contracts, e.g., due to their reluctance to lock-in energy prices for a long time period. This creates a dilemma for the financing of new generation that relies on contracting in deregulated markets. Whereas generators prefer long-term contracts because lenders require them as a pre-requisite for providing long-tenor debt, consumers want shorter contracts.

Many Latin American countries that are using auctions for long-term PPAs as central mechanisms of their renewable energy policies tailor contracts to the particular requirements of variable renewable generators, in order to reduce the exposure of project developers to production risks – *i.e.*, the risks that the profile of delivered production does not match contractual obligations (see box 4.7). Nonetheless, the same conditions often do

9. A long-term financing modality, normally used in infrastructure and industrial projects, which is based upon the cash flows generated by the project, rather than on the balance sheet of the sponsors.

not apply for contracts negotiated bilaterally with deregulated consumers, which often prefer technologies whose generation profile matches their demand.

#### **Box 4.7 Long-term PPAs and creditworthiness of counterparties in Uruguay**

Uruguay is the largest renewable energy investor in South America relative to GDP (BNEF, 2016). The secure remuneration mechanism is a key feature for attracting foreign and domestic investors. In particular, generators can secure 20-year PPAs with the state-owned utility *Administración Nacional de Usinas y Trasmisiones Eléctricas* (National Administration of Power Plants and Electrical Transmissions, UTE), which guarantees a stable price and allows investment recovery. The off-taker of the PPA, UTE, is a credible and creditworthy company, backed by the government of a country that has a stable political environment, has never defaulted on its debts and is attractive for long-term investments (Watts, 2015).

In several Latin American countries with auctions for renewable energy, such as Panama and Brazil, a pooling mechanism is used to collect revenues to remunerate generators. A set of off-takers, often distribution companies on whose behalf the auction is carried out, act jointly as counterparties for each contract awarded in the auction, which results in the spreading of payment obligations and thus in the mitigation of counterparty default risks (*i.e.*, when the off-taker does not fulfil its payment obligations as per the PPA). Counterparty risks are, however, not entirely absent in Latin America (BNEF *et al.*, 2014), and off-taker counterparty risks can be a hurdle for renewable energy investment.

#### **■ Labour and technical constraints**

The renewable energy industry faces challenges in employing and retaining a qualified workforce in all stages of the value chain of projects on a global scale (IRENA, 2013). Despite the recent improvement in education indicators of several Latin American countries (see chapter 1), attracting and retaining a qualified workforce can still represent a barrier to renewable energy deploy-

ment in Latin America. Retaining qualified workers is a particular challenge in the countries with the most significant growth of renewable energy technologies, such as Brazil, Mexico and Chile.

The lack of technical standards and norms for the certification of equipment can represent a barrier both for the development of local supply chains and for the use of international components by renewable energy project developers. The Brazilian Association of Photovoltaic Solar Generation recently reported that certification issues have been slowing the deployment of distributed solar PV in the country (Canal Energia, 2015). To help control the quality of renewable energy products and services, mitigate technical risk and build up market trust, IRENA has published guidelines on developing and implementing quality control for renewable energy technologies (IRENA, 2015g).

#### **High cost of capital**

Specific financial elements hindering renewable energy investments in Latin America are the high cost of capital and the shortage of financing (*e.g.*, for small and medium-sized projects). The relatively high cost of capital reflects more complex underlying barriers and a range of risk factors, as well as the limited diversification of capital sources and limited knowledge of the renewable energy sector.

#### **■ Effects of risks on cost of capital and scarcity of risk mitigation instruments**

As discussed in the section on macroeconomic factors, the uncertain economic situation of some Latin American countries has a direct impact on the cost of capital. Financial instruments are, in theory, available to mitigate the risks associated with renewable energy investment. These include guarantees, currency hedging and liquidity facilities, which are discussed in more detail in IRENA (2016h).

To address currency risk, for instance, development financiers, export credit agencies and even the private sector can provide instruments to hedge against currency exchange risks, *e.g.*, political risk, for some of the larger currencies such as the Brazilian real or the Mexican peso. In practice, however, the availability of such instruments

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is limited and their costs are high for currencies traded less frequently, including those of several Latin American countries. Similar problems exist for other financial risk mitigation instruments (IRENA, 2016h).

#### ■ Diversification of capital sources

Another relevant factor to explain the typically higher debt costs and shorter tenors in Latin America, as well as differences across countries, relates to the diversification of capital sources. Attracting private capital is a strategy pursued actively by several Latin American countries – even if the costs of private capital are higher than those of the public sector. Yet, the success in doing so has not been uniform across the region (Latin America and Caribbean-OECD Investment Initiative, 2014). This is illustrated by the different levels of participation of private capital – both debt and equity – in Latin American countries. As seen in previous sections, private capital participation tends to concentrate on the most mature markets and the most sizeable economies of the region. Understanding the reasons behind this concentration can offer insights into the underlying barriers and help identify strategies that can be replicated in other countries.

However, some of the characteristics in countries that have shown larger levels of private participation are not immediately replicable by other Latin American peers. Liquidity in capital markets helps to mitigate exit risks, larger and deeper markets result in higher liquidity, which offers investors enhanced opportunities to trade assets rapidly without losing value. Policy makers can do little to increase the overall liquidity of local capital markets in the short term, and therefore the replicability of this experience in this time frame is limited.

Overcoming barriers related to access to finance can be more challenging for small and medium-scale renewable energy projects, whose scale may not be sufficient to allow access to the most common instruments from development banks. Therefore, diversifying capital sources can be of particular relevance for projects with this scale – the alternative being the creation of mechanisms that facilitate the bundling of small and

medium-scale projects for the purposes of financing.

#### ■ Limited renewable energy finance knowledge and capacity

Financing institutions of Latin American countries that have limited experience with renewable energy projects may not yet have developed the technical capabilities to adequately assess the risk profiles of these projects, which can deter approval of finance – especially in the project finance modality – for renewable energy project developers.

Moreover, both project developers and financing institutions may lack sufficient knowledge about the financing instruments that best fit the requirements of renewable energy projects, considering their relatively high upfront capital requirements, long amortisation periods and risk profiles. For instance, the possibility of using project finance for renewable energy projects is sometimes unknown to local banks. Limited technical expertise and access to up-to-date information about financing mechanisms can discourage renewable energy investments.

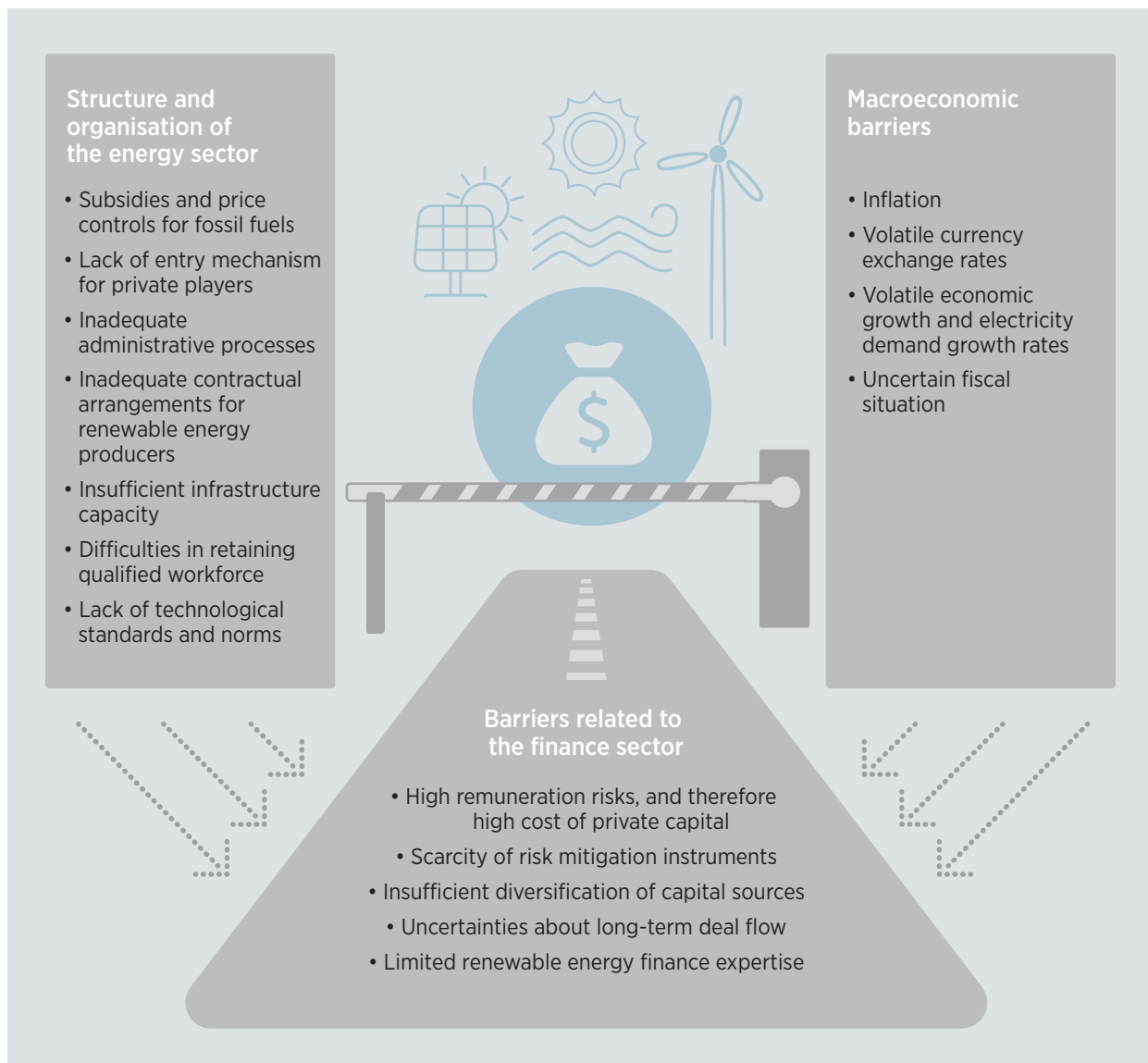
Correct assessment of uncertainties and pricing of risks play a role in securing financing in a competitive environment, both for centralised and distributed generation. Figure 4.4 summarises the barriers to investing in renewable energy in Latin America.

### 4.4 OVERCOMING FINANCIAL BARRIERS TO RENEWABLE ENERGY INVESTMENT

This section discusses how to overcome barriers to renewable energy investment and decrease the cost of capital in Latin America, drawing on recent global analysis. The financial sector has an important role to play in scaling up the level of finance available for renewable energy investment, and, in particular, in devising the most efficient allocation of risks between private and public investors, while avoiding having public spending “crowd out” private investment.

#### ■ Catalysing private capital finance

Because the share of public finance is not ex-

**Figure 4.4** Barriers to renewable energy investment in Latin America

pected to increase above the current level of 15% globally (IRENA, 2015h), the bulk of new investment in renewables will have to come from private finance. To reach the necessary scale, catalysing private capital participation may have the highest impacts on the availability and cost of capital for renewable energy investment. Tools to unlock renewable energy investments include enabling policies, capital structures, financial risk mitigation instruments and various structured finance mechanisms (IRENA, 2016h).

Capital structures that finance renewable energy projects, such as debt and equity, can reduce risk, to enable the development of a greater

number of projects. However, as discussed earlier, in Latin America, few project developers have access to such capital structures due to the high cost of capital and the lack of familiarity with the technical specificities of renewable energy technologies.

Given the region's energy market structures, Latin American public financial institutions (e.g., BNDES, NAFIN) are the main providers of capital for renewable energy projects, often with established local networks and experience. To leverage further capital, the financial resources of these institutions offer financial instruments that mitigate risks and reduce the risk premiums required

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by private players. Examples of domestic financing institutions that follow this approach in Latin America were reviewed in section 4.2, including, for example, the credit line offered by the Chilean state-owned CORFO to partially hedge risks of venture capital funds investing in renewable energy technologies. However, the requirements on the capital-coverage ratio of development banks impose limits to the amount of risk that these institutions can absorb. This means that the supply of the above mentioned risk mitigation instruments is limited, and technically sound processes should carefully select the projects to which such instruments are awarded, including an assessment of the risks of the underlying renewable energy assets.

Although DFIs are well-positioned to mitigate investment risks, they have dedicated only about 4% of their total infrastructure risk mitigation issuance value to renewable energy, according to a survey (IRENA, 2016h). DFIs have an important role to play in raising the profile of existing risk mitigation instruments to attract private investment in renewables, for example through information campaigns, by streamlining application procedures for risk mitigation instruments or by re-orienting institutional incentives to drive greater issuance of risk mitigation instruments for renewable energy projects (IRENA, 2016h).

The dynamics between public and private capital sources in refinancing schemes discussed in section 4.2 is an important element for catalysing private capital participation. As renewable energy markets mature in the region, independent developers, IPPs, utilities and banks will have larger roles in construction stage financing, and then refinancing operative assets after they become operational. This could be done in two ways: by packaging attractive assets to be held over the long term by institutional investors, and by speeding up the circulation of their own capital to be used in the development and construction of new assets (to then be refinanced by capital markets again).

Finally, transaction costs may be one of the main factors behind the difficulties that small and medium-sized projects face in obtaining finance

from development or commercial banks. To further advance financing of renewable energy projects, processes such as terms of reference, documentation and payments can be standardised. This also would support the aggregation of renewable energy projects, making such assets more attractive to private investors. A relevant example in the region was the project bundling achieved by the Mexican rooftop solar PV installer Ilios, which was the first international acquisition of the US company SolarCity.

#### ■ Enabling technological progress

Support from public financing institutions to projects related to the early-stage development of a renewable energy technology, notably R&D and demonstration, also can be considered a way to catalyse financing. These projects typically carry more risks than those at the deployment stage, when the technology is already mature. Therefore, the private sector may be more reticent in committing resources to R&D and demonstration projects. Also, as technologies move from the R&D stage to the commercial maturity stage, their costs decrease.

Thus, public financing can have an important role in bringing renewable energy technologies down the cost curve (IRENA, 2012a). By providing financial resources for technologies in the R&D and demonstration stages, public development institutions can enable investments of the more risk-averse private sector at the subsequent deployment stage.

Another approach is to support targeted renewable energy innovation and entrepreneurship for applications of relevance to the region. Some Latin American utilities are spending substantial financial resources for energy efficiency and renewable R&D programmes, many of which can be turned into commercial projects or help create new markets for renewable energy technologies. For example, under Brazilian Law, 0.5% of the annual net operating revenue of the Brazilian electricity regulatory agency and 0.5% of the net income of electricity distributors must be directed at the development of strategic energy efficiency and R&D projects, amounting to USD 1.25 billion

between 2008 and 2015 in renewable energy-related projects (Pompermayer, 2015).

### ■ Accelerating the learning curve

A third set of measures aims to disseminate information and build technical capacity within the financial sector. Sharing information on effective financing mechanisms for renewable energy can facilitate the access to these sources of finance by local project developers or even by financing institutions that can access specific credit lines. Also, disseminating information on local renewable energy markets – including on market rules and requirements – among international companies can contribute to attracting foreign investment in the sector.

Policy makers can play a decisive role in disseminating knowledge by lowering the costs of acquiring information. Public institutions such as regulators or domestic development banks may include on their websites material and information on applicable financing instruments. Links to online tools made available by IRENA, including the Project Navigator and the Sustainable Energy Marketplace, operated for Latin America in partnership with the IDB, can be instrumental in these efforts. The Marketplace aims to make project pipelines visible and easily accessible for investors, and to enable project developers to identify suitable sources of financing, technical assistance, services and technologies according to their needs. The Marketplace thus seeks to improve the transparency and liquidity of renewable energy projects. Ministries and institutions with international visibility also can use the Marketplace, in addition to their own webpages, to provide easily accessible information on local renewable energy markets, and even organise roadshows at major investment events.

Policy makers, DFIs and local financing institutions can contribute by supporting comprehensive capacity-building initiatives, both to train financing institutions about the specificities of renewable energy projects and to bestow project developers with the expertise required to structure project finance. Capacity building on portfolio financing can be particularly relevant to create alternatives for renewable energy project devel-

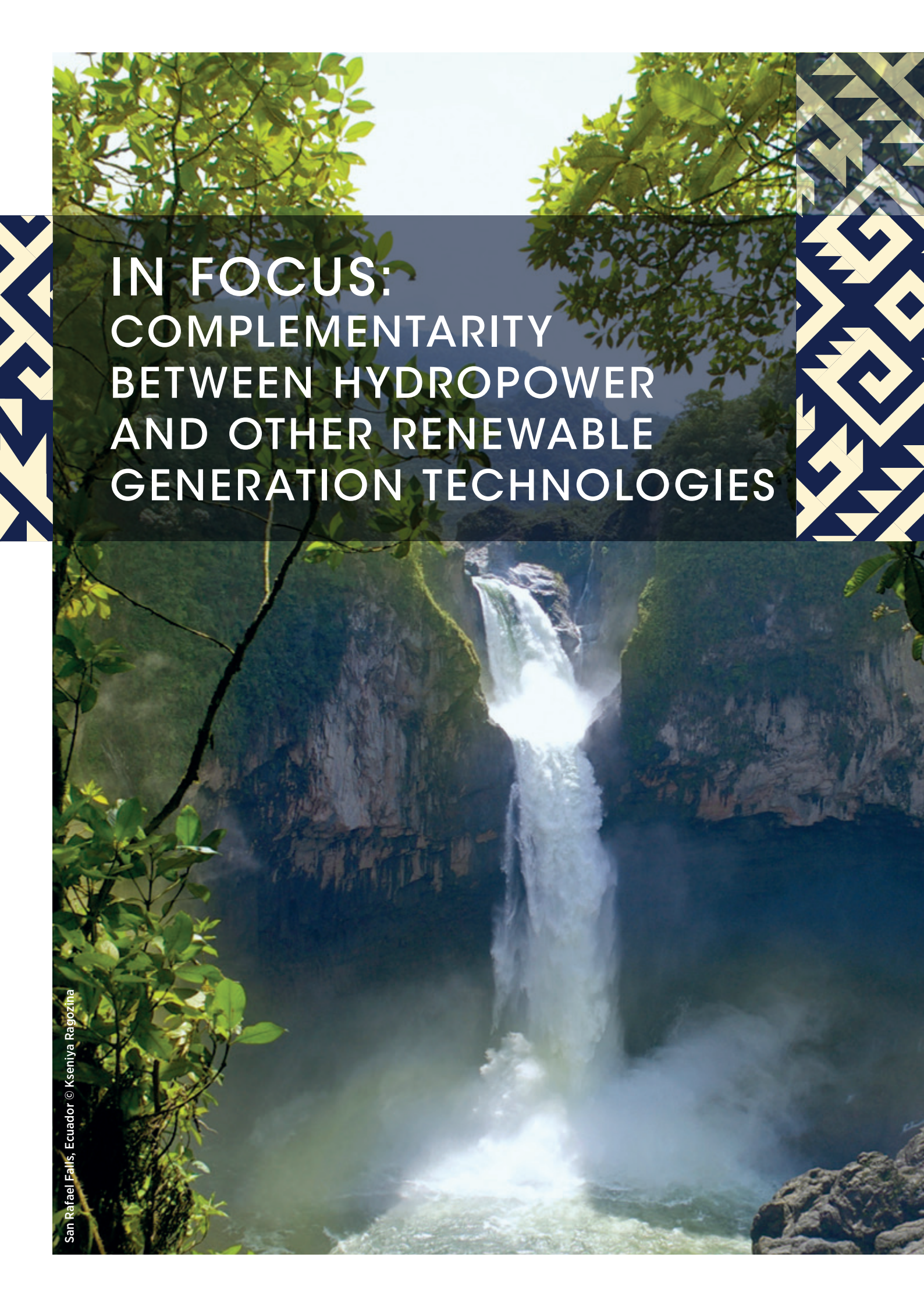
opers entering contracts with deregulated consumers, as mentioned in the discussion on production risk dilemma.

## CONCLUSION

As discussed throughout the chapter, the main challenge for renewable energy deployment in Latin America is to satisfy the increasing demand for capital at affordable cost. An important means to address this gap is to use the available public capital as a catalyst for private finance. In Latin America, as in other regions, the primary and most cost-efficient way to promote renewable energy financing is to create stable, predictable, credible and long-term policies, regulations and incentives. Although more risk mitigation and financial facilitation measures are needed, specific mitigation instruments should be used carefully and selectively to address well-defined market failures. Public sector financiers should give priority to risk mitigation aimed at mobilizing private finance, but be selective when deciding to de-risk private sector investment in renewable energy.

Project planning is an important part of the renewable energy project cycle (IRENA, 2015h). However, this stage is often overlooked when designing policies, and more emphasis usually is given to the financing and operational phase of the enabling environment, assuming that attractive projects will be developed anyway. This is a critical bottleneck and technical assistance and project development funding schemes therefore have an important role to play in ensuring bankable project pipelines.

Looking forward, access to capital markets will be decisive, as non-bank financing play a crucial role in scaling up renewable energy investment to the level required to meet global climate goals. One promising approach to leverage institutional investor finance and access to capital markets in Latin America would be to further develop the “financial value chain” so that independent developers, IPPs, utilities and banks would have larger roles in construction stage financing, allowing them to then refinance operative assets after reaching the operational stage.



# IN FOCUS: COMPLEMENTARITY BETWEEN HYDROPOWER AND OTHER RENEWABLE GENERATION TECHNOLOGIES





The high shares of hydropower in the electricity mixes of several Latin American countries create major opportunities for scaling up other renewable energy technologies, including geothermal, biomass, wind and solar.<sup>1</sup> A combination of hydropower and other renewables offers *complementarities*<sup>2</sup>, including climate synergies (e.g., dry seasons having higher wind speeds) and the potential to cost-efficiently counteracting short-term solar and wind variability through the flexible operation of hydropower. Non-hydropower renewable energy technologies can help to mitigate problems associated with hydropower, such as scarcity of supply in dry seasons, or market concentration due to the large size of hydropower plants. The advantages are reciprocal, turning these sources into complements rather than competitors. With cross-border electricity interconnections, the complementarity between hydropower and other renewable energy technologies can extend to countries with lower shares of hydropower. Fossil-fuelled generation can also support higher shares of renewables in some Latin American countries, especially those with less hydropower generation.

The objectives of this chapter are twofold. First, it describes the mechanisms through which hydropower and other renewable energy technologies complement each other, and their positive effects on the economic performance and reliability of power systems. This is the essential first step in adjusting the policy environment. In some cases, hydropower's synergies are exclusively with variable renewable sources, such as solar and wind plants. Other synergies apply to non-hydropower renewables with different profiles – e.g., biomass fed by seasonal agriculture; or geothermal technologies that can reduce climate vulnerability in hydropower-dominated countries. By describing the full range of synergies, this study aims to help policy makers identify those most relevant for each country.

Second, the chapter illustrates how policy makers can act to harness synergies between hydropower and other renewable energy technologies. In general, such actions aim to ensure that the economic value of the complementarities is internalised. The benefits of complementarity mostly relate to physical characteristics of hydropower

1. Throughout this chapter, “other renewable energy” refers to all technologies excluding hydropower.

2. Some of the complementarities apply to hydropower with reservoirs, while some others apply to run-of-river hydropower. Furthermore, some complementarities are also applicable to other non-hydropower technologies which, like hydropower, are able to vary their output as required by the system (e.g., biomass, solar CSP with storage, or even fossil fuel-based generation plants).

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plants and other renewable energy technologies. However, the extent to which different stakeholders will perceive and respond to the economic value of these synergies will depend on the policies and regulations in place.

The focus is mainly on the complementarity between hydropower – particularly with reservoir capacity – and variable renewables like solar PV and wind. Yet some of the findings apply to complementarities across other technologies (e.g., run-of-river hydropower, biomass, geothermal, concentrated solar power, or even non-renewable technologies). Demand-side measures (e.g., shifting or reducing power demand for space cooling, introducing grid-connected electric vehicles) can also enhance flexibility and improve power system operation. This discussion, however, is beyond the scope of this chapter.

Section 5.1 provides an overview of the role of hydropower in Latin America's electricity mix. Section 5.2 presents the main complementarity mechanisms between hydropower and other renewable energy technologies, providing insights into the possible benefits of combining these resources. Sections 5.3 and 5.4 present recommendations on how Latin American policy makers can create an enabling policy environment to harness these synergies (5.3 focuses on system *expansion*, and 5.4 on system *operation*).

## 5.1 STATUS OF HYDROPOWER IN LATIN AMERICA

Latin America is one of the regions of the world with the highest share of hydropower in electricity generation. In 2013, hydropower accounted for more than half of the total electricity produced in the region, with significant variation among countries (see figure 5.1).

The natural endowments of Latin American countries are among the most important factors to explain both the overall share of hydropower and its regional distribution. The development of hydro-

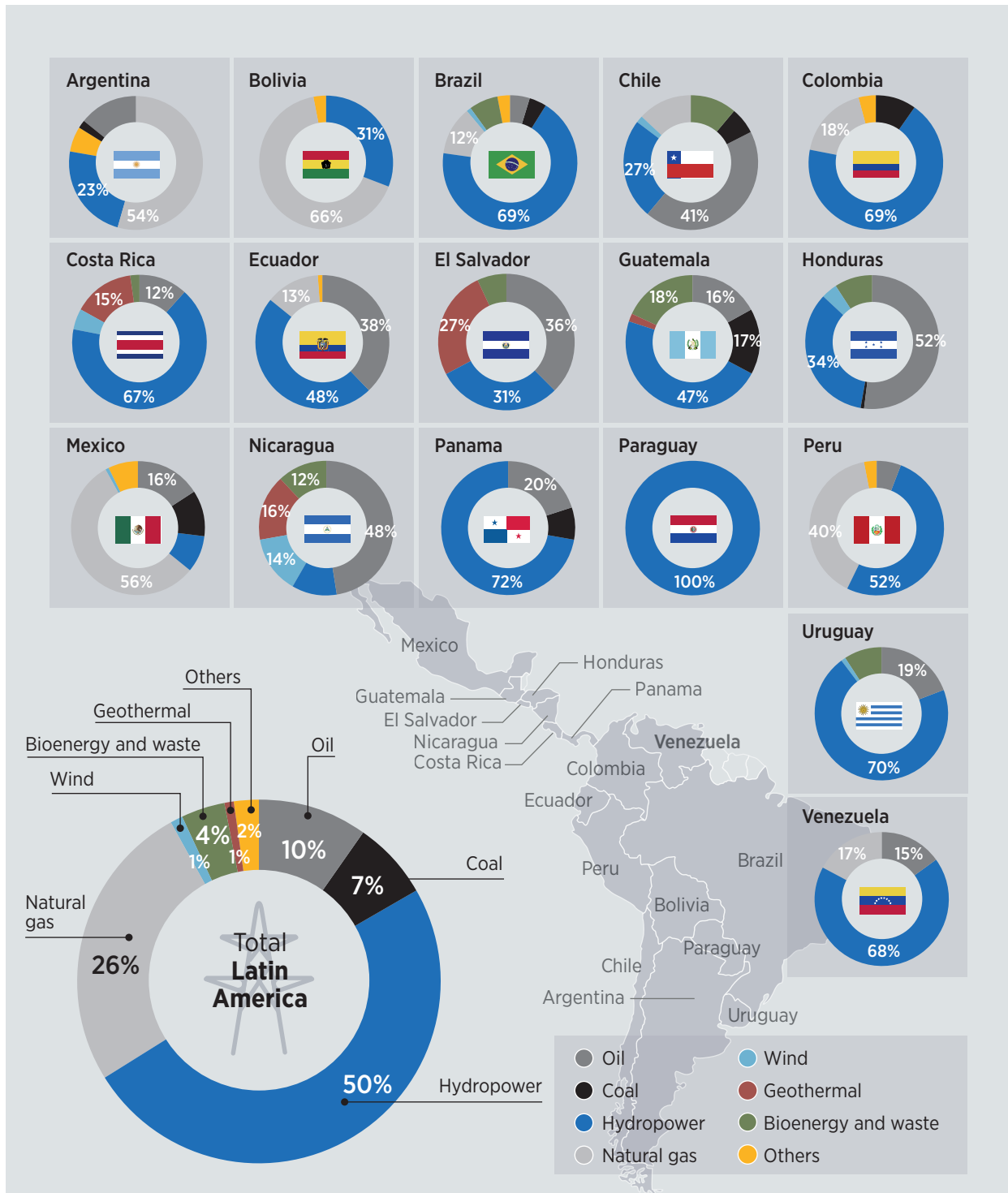
power started as the natural option for countries that had few other energy sources available. The oil price shocks of the 1970s strengthened this trend in an effort to reduce dependence on fuel imports. The geographical characteristics of the region also allowed most hydropower plants to be constructed with significant storage capacity. This later became an important leveraging factor to increase the penetration of non-hydropower renewable energy technologies in the region, especially variable ones.

With the first wave of electricity sector reforms consolidated in the 1990s, the remaining hydropower potential in several countries became an attractive investment opportunity. The second wave of reforms in the 2000s resulted in the introduction of generation capacity adequacy mechanisms<sup>3</sup> that increased the role of governments in guiding system expansion in some countries (Battelle *et al.*, 2010). The development of hydropower remains a policy priority in many countries.

Latin America is still endowed with untapped hydropower potential, with new projects being developed. However, a number of challenges in the recent past have resulted in a majority of hydropower plants being built without significant storage capacity and overall increasing the cost of hydropower deployment. First, the social and environmental challenges have lately been a major burden for large hydropower (see box 5.1). Secondly, the increasing role of the private sector in generation expansion changed the paradigm. When hydropower belongs to government-owned utilities, the objective is often to support local economic development, to keep electricity prices low, or to optimise the use of the water resource for several purposes, including irrigation, flood control and water supply. When hydropower is privately owned, the government seeks income from taxes or royalties, while the financiers and private developers require maximum commercial returns.

3. These mechanisms try to complement the electricity market with additional payments to generators in exchange for their capacity being readily available to the system, even if the generator is not generating electricity. The final aim is to ensure that there is enough generation capacity in the system to cover the peak demand in the worst case scenario. Examples of such mechanisms are capacity markets, capacity payments or reliability options.

**Figure 5.1** Electricity generation mix in Latin America in 2013



Note: Data for Belize, Guyana and Suriname were not available and were not considered for determining the aggregated generation breakdown of Latin America to the right of the figure.

Source: IEA, 2015b

**Box 5.1 Considering social and environmental impacts of hydropower projects**

Ensuring that social and environmental dimensions are properly reflected when assessing hydropower dams and power transmission projects and weighting negative and positive impacts is an important consideration for policy makers which requires co-ordination among various levels of government and non-governmental and private sector entities. The proper consideration of the social and environmental dimensions can leverage on local know-how, developed in the course of the extensive hydropower experience in Latin America. This expertise can be complemented by internationally recognised best practices and protocols, including the works by the World Commission on Dams and the Hydropower Sustainability Assessment Protocol.

The first step towards managing environmental and socio-economic impacts of hydropower projects, particularly those with reservoirs, is to recognise that these impacts may exist and that their prevention and mitigation requires attention and action. Possible environmental impacts relate to water use and quality, impact of both the dam and the reservoir on biodiversity and migratory species, anthropogenic activity in areas in which it was scarce before, reservoir sedimentation and debris, and greenhouse gas emissions. Socio-economic impacts may relate to indigenous peoples and ethnic minorities, as well as interference with urban and rural population settlements (IEA-ETSAP and IRENA, 2015b).

The idea that smaller projects should be preferred over larger-scaled ones can be misleading. The cumulative burden of various small hydropower plants may be more significant – and require more efforts for observability and evaluation, which may lead to oversight – than those of large projects with equivalent output. Hence the need to employ a comprehensive approach to sustainable hydropower capacity expansion planning, assessing and comparing alternatives under clear and preferably measurable criteria, adequate spatial scope for planning and evaluation of multiple uses of water:

- Clear and preferably standardised protocols should support decision makers in the tasks of comparing alternatives for project development, establishing criteria for the assessment of the benefits of a project considering all multiple uses of water, and all potential environmental and socio-economic impacts, risks and benefits. Importantly, the assessment should consider climate-related risks and the possible climate resilience provided by res-

ervoirs (e.g., irrigation and flood control services). Moreover, the evaluation should cover all stages of a project's life cycle: conception, preliminary feasibility studies, implementation, operation and, in specific cases, dismantlement. Guidelines prepared by several multilateral institutions, offering countries the possibility of customisation to their particular requirements, are available to assist in the creation of such protocols.

- The spatial scope of hydropower planning and implementation should allow at least the integrated evaluation of a river basin. The integrated assessment of alternatives for the partition of the total water head of a river basin is of utter importance to optimise the performance of all feasible hydropower undertakings. An example of a protocol for the integrated river basin approach is the Brazilian *Manual for Hydropower Inventory Studies of River Basins* (Ministério de Minas e Energia & CEPEL, 2007).

- The assessment of a hydropower project shall not only be oriented towards environmental and social impacts, but also take into account the multiple anthropogenic uses of water and purposes of reservoirs. The evaluation of impacts of reservoirs over water supply, navigation, recreational activities, tourism and flood control, besides electricity generation, is required to achieve a sustainable plan for hydropower development, as these multiple purposes of reservoirs may be complementary or competing.

Finally, it is important to note that ensuring sustainability requires efforts not only during the planning and implementation stage of hydropower projects, but also during their operation. The qualification of the workforce and the use of computational tools to guide decision making are crucial to ensure that the portfolio of hydropower projects in a given region is operated to maximise the benefits obtained from the multiple anthropogenic uses of water, while observing any environmental constraints to operation, such as maintenance of adequate ecological water outflow levels. The preponderance of hydropower in the electricity matrix of Latin American countries led to a notable development of technical competence in some countries in the region that has been exported to other countries with a significant participation of hydropower (e.g., Turkey and Vietnam). The co-operation and information exchange between government bodies, such as electricity regulators and environmental agencies, is also critical to maintain a sustainable operation of hydropower systems.

## 5.2 COMPLEMENTARITIES BETWEEN HYDROPOWER AND OTHER RENEWABLE TECHNOLOGIES

This section presents the main synergies between hydropower and other renewable energy technologies, providing insight into the benefits of combining these resources.

When presenting the complementarity mechanisms, a distinction is made between stages of the power system management related to *expansion* and *operation*. Expansion involves decisions on the implementation of new capacity and the deployment of new resources and technologies to ensure that future electricity needs are met optimally. Operation relates to the optimal management of existing assets. Table 5.1 introduces the complementarity mechanisms present at each stage, all of which are further developed in this chapter.

### Expansion: meeting future electricity needs optimally

The synergies presented in this section are grouped into four categories, each presented in one of the following subsections: 1) climate variability and adequacy of supply, 2) climate change vulnerability and strategic system expansion, 3) implementation of generation infrastructure and 4) diversification of ownership and spreading of risks for financiers.

#### ■ Climate variability and adequacy of supply

Long-term adequacy of electricity supply refers to ensuring that the generation system is expanded to meet long-term demand growth reliably, economically and sustainably. Risks of dry seasons and long-lasting climate events affecting hydropower generation are important for the security of supply in a system with significant hydropower penetration. A climate variability event relevant for several Latin American countries is the El Niño Southern Oscillation (ENSO), a semi-periodic phenomenon resulting in changes in rainfall patterns and affecting the availability of hydropower generation. The ENSO can result in periods of scarcity that significantly affect prices and reliability of supply, notably in Latin American countries with large hydropower penetration

(although it should be noted that in some other cases, such as parts of Chile, El Niño increases rainfall).

While fossil-fuelled thermal generation, notably natural gas plants such as in Peru or Colombia, can reduce the exposure of hydropower-dominated systems to these events, non-hydropower renewable energy technologies represent a low-carbon alternative to hedge against these risks. Some non-hydropower renewable energy technologies are essentially unaffected by long term-climate events – such as geothermal or some categories of biomass-fired generation. Furthermore, even the variable renewable energy technologies, such as wind or solar generation, can be a viable alternative whenever their production patterns differ from those of hydropower plants. During dry periods, wind or solar generators are not subject to output reductions, and, in some cases, they even produce more power exactly in these time intervals, as illustrated in box 5.2.

Taking advantage of this long-term climate synergy between hydropower and other renewable energy technologies results in a system that is more resilient to the effects of the ENSO. This benefits consumers, as it enhances the reliability of supply and the stability of electricity prices.

Where wholesale electricity markets are in place (and under a proper market design), adequately valuing this complementarity mechanism also impacts the economic value of non-hydropower renewable energy technologies to investors, since resources able to maintain or increase their generation during dry ENSO events will receive somewhat higher market prices and therefore increase their remuneration. In the absence of functioning electricity markets, government assessments of these higher values are essential (e.g., by increasing the remuneration of generators that are able to generate more in dry periods). It also should be mentioned that a high penetration of non-hydropower renewable energy may limit the increase of short-term energy prices during dry seasons, in this case benefiting hydropower investors whose assets have a lower generation during these periods, since they may

**Table 5.1** Overview of the complementarity mechanisms and their descriptions

Stage	Mechanism	Description
System expansion	<b>Climate synergies: climate variability and adequacy of supply</b>	When generation of hydropower plants is lower due to climate variability (e.g., the El Niño Southern Oscillation, ENSO), the generation of some other (non-hydropower) renewable energy technologies is not reduced or even increases.
	<b>Climate synergies: climate change vulnerability and strategic expansion</b>	Climate change can result in reduced output of important hydropower plants, and there is high uncertainty on the severity of future changes in rainfall patterns. Diversifying the generation matrix with help of other renewable energy technologies provides resilience to climate change.
	<b>Implementation of generation infrastructure</b>	Modular non-hydropower renewable energy technologies with short construction times can be built quickly to partially counteract circumstantial imbalances in supply/demand, especially if delays in implementation of large power plants (e.g., hydropower) occur.
	<b>Ownership diversification</b>	Smaller-scaled non-hydropower renewable energy technologies allow diversification of project ownership; smaller investors can participate, facilitating the entry of new players in the power market and reducing its concentration.
System operation	<b>Hydropower flexibility used to counteract short-term variability of other renewable energy technologies</b>	Hydropower plants with reservoirs are flexible assets, and the costs of using existing plants to counteract the short-term variations in the production of variable non-hydropower renewable energy technologies is lower than that of other generation technologies, notably natural gas.
	<b>Seasonal complementarity</b>	Hydropower generation is lower during drier seasons, but the generation of some non-hydropower renewable energy technologies is not reduced or even increases during these events.
	<b>Portfolio diversification</b>	The production of a diversified portfolio of non-dispatchable renewable energy plants, including run-of-river hydropower, is less volatile in the short term than that of each individual plant.

have to resort to short-term markets to purchase electricity to cover contractual obligations.

In systems with vertically integrated utilities (as in the case of Uruguay, see box 5.3), this complementarity reduces the costs of energy production, ultimately impacting electricity prices to final consumers.

#### ■ Climate change vulnerability and strategic system expansion

Even if the ENSO *already* clearly illustrates the link between climate and the adequacy of electricity supply in Latin America, policy makers in the region also are faced with other climate change-

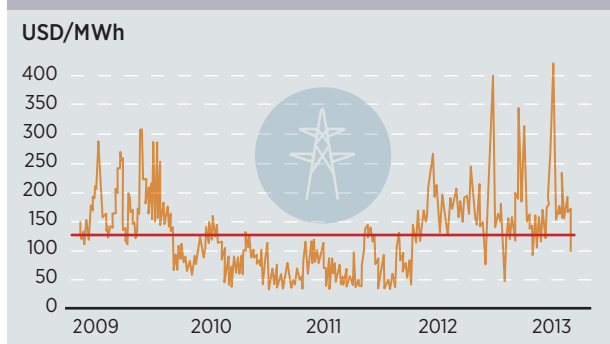
related events, which can affect security of supply in hydropower-dominated systems. Thus, a second aspect of climate synergies between hydropower and other renewable energy technologies refers to the vulnerability of hydropower-dominated electricity systems to climate change.

Climate change may impact precipitation patterns in river basins that have great relevance for hydropower generation in Central and South America (CEPAL *et al.*, 2012; UPME and OPTIM Consult, 2014). These changes in precipitation patterns are the climate change effects that have the highest potential impacts on hydropower.

**Box 5.2 El Niño and complementarity between hydropower and wind generation in Colombia**

The significant penetration of hydropower in Colombia is one of the factors contributing to significant long- to mid-term price volatility, as illustrated in figure 5.2. With more than 70% of the generation coming from hydropower sources every year, during the dry periods of the ENSO the country's power system faces very high prices.

**Figure 5.2** Spot wholesale electricity prices in Colombia, 2009-2013



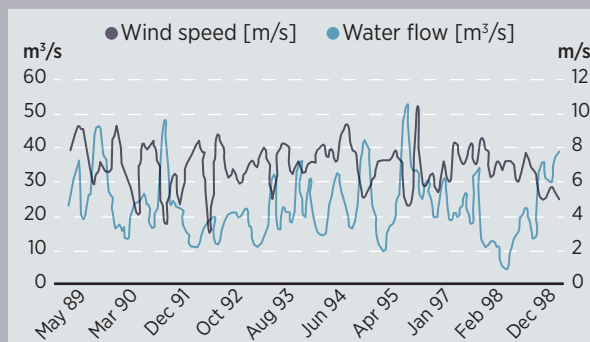
Source: XM, 2016

A study conducted by the World Bank (Vergara *et al.*, 2010) analysed opportunities to introduce wind power generation to reduce exposure to the ENSO. The study concluded that wind power appears to be available when its contribution to the system is most needed, namely during the El Niño.

The existing power generation data from Jepírachi wind farm (the only wind power project in Colombia) and wind speed data from the northern Caribbean coast were compared with the water flows in the four rivers with hydropower development. As seen in figure 5.3, when water inflows are low during most El Niño occurrences, the Jepírachi region and the other wind reference stations analysed displayed high wind speed (Vergara *et al.*, 2010).

In the World Bank study, the complementarity also was explored through a simulation of the *firm energy*<sup>4</sup> obtained by the hypothetical joint operation of simple power systems consisting of the Jepírachi wind farm with a hydropower plant representative of each of the rivers considered. Figure 5.4 presents the results for two of the rivers (Nare and Guavio). In both cases, the firm energy obtained by the joint operation is significantly higher than the sum of the firm energies of the isolated plants, pointing to a statistically significant complementarity. Despite complementarity being higher in the case of large reser-

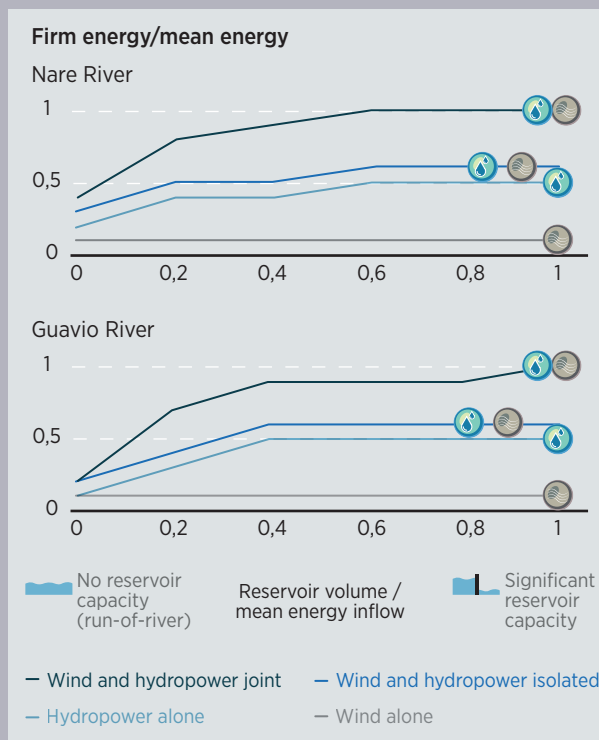
**Figure 5.3** Water regimes in the northwest of Colombia and wind speeds at the Jepírachi wind farm



Source: Vergara *et al.*, 2010; Dyner, Olaya and Franco, 2011

voir capacities (which allow for reduced hydropower generation in periods of high wind), the conclusion also holds in the case of run-of-river plants. Importantly, the report also concludes that such complementarity is not rewarded in the current Colombian regulatory framework.

**Figure 5.4** Simulation analysis of the complementarity of wind energy and hydropower from two rivers in Colombia



Source: Vergara *et al.*, 2010

4. In the study, firm energy is defined as "the maximum monthly energy that can be produced without deficits during the analysis period" (Vergara *et al.*, 2010).

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**Box 5.3** Wind power in Uruguay and reduced vulnerability to droughts

Wind, biomass and solar power have been increasing in the last decade in Uruguay. Adding to the existing hydropower, renewables now account for 94.5% of the country's electricity generation. This has reduced vulnerability to droughts by 70% – a significant accomplishment given that a dry year used to cost the country nearly 2% of its GDP (Watts, 2015). In addition, Uruguay has managed to reap other benefits: electricity tariff levels are currently lower than in the past (in real terms), the reliability of supply has increased and there are fewer power cuts (Watts, 2015).

Changes in evapotranspiration<sup>5</sup> due to temperature increases also may impact water cycles and have secondary effects on hydropower generation (CEPAL *et al.*, 2012).

Even though changes in rainfall patterns are not expected to be uniform, different studies highlight possible reductions in water inflows to important hydropower dams in the region, which can affect the reliability of supply. Also, there is high uncertainty about the exact impacts of climate change, in terms of both the severity of the reductions in rainfall and their spatial distributions (*i.e.*, which river basins will experience the highest effects). Considering these factors, diversifying the generation matrix away from heavy reliance on hydropower can increase the resilience of the system against climate change.

Climate change also may impact the availability of primary energy resources for some non-hydropower renewable energy technologies, including wind regimes and the yield of crops (a factor that is relevant for biomass generation). Other technologies, such as geothermal, would be less affected. Accounting for the resilience of each individual other renewable energy technol-

ogy while devising a diversification strategy is necessary to properly internalise the value of the synergy mechanism discussed in this section.

Finally, renewable generation technologies have another intrinsic value when climate change is considered: they contribute to reducing the emissions of greenhouse gases that are at the core of the problem. This is an important driver in the choice between hydropower<sup>6</sup> and non-hydropower renewable generation technologies.

Considering these factors, some Latin American countries with significant shares of hydropower in their electricity matrix have already started building strategies to increase the resilience of their power systems to climate change. These countries have identified the diversification of generation sources through non-hydropower renewable energy technologies as a potentially attractive measure (see box 5.4).

**■ Implementation of generation infrastructure**

Implementation of generation infrastructure involves environmental licensing, acquisition of equipment and of rights to use land, construction and the execution of commissioning tests. The lead times required for these actions provide opportunities to harness synergies between hydropower and other renewable energy technologies. Due to their modularity and reduced scale, most non-hydropower renewable energy technologies can be constructed more quickly and generally experience lower construction delays (Sovacool, Gilbert and Nugent, 2014a). Studies indicate that the average implementation delay for wind farms and solar plants is 9.5% and 0.2% of initial time estimates, respectively, while that of hydropower dams is 63.7% of initial estimates (Sovacool, Gilbert and Nugent, 2014b). Hydropower development in the region currently includes several large projects<sup>7</sup>, which are socially and environmentally more complex and ultimately more prone to delays.

5. Direct water evaporation and plant transpiration.

6. The topic of greenhouse gas emissions from hydropower dams is, however, worthy of attention. Studies suggest that processes ranging from the decomposition of organic material to an increase of plankton activity in flooded tropical areas can significantly contribute to greenhouse gas emissions (Fearnside, 2015).

7. Some of the new hydropower plants expected to be built in the years to come are large-scale projects. Examples include the 11,233 MW Belo Monte plant in Brazil and the 2,400 MW Pescadero plant in Colombia, both under construction.



#### Box 5.4 Strategies to enhance resilience to climate change: examples of Latin American systems with significant shares of hydropower

##### Colombia

In 2014, the Planning Unity of the Colombian Ministry of Mines and Energy (UPME) carried out a study to establish a roadmap for adapting the energy sector to climate change (UPME and OPTIM Consult, 2014). A strategic goal laid out in the roadmap was to diversify the generation technology mix in Colombia, in order to reduce the vulnerability to changes in hydropower generation patterns. The diversification strategy involves both local fossil fuel resources and, more importantly for the discussion of this report, non-hydropower renewables.

Among the measures identified to reach the resource diversification goal are: 1) improvements in market rules to ensure a market remuneration of non-hydropower technologies (termed non-conventional energy sources in the roadmap) commensurate with their actual contribution to the electricity supply, 2) improvements in regulation, to remove barriers to the development of distributed generation, including that of renewable sources, 3) improvement of economic signals for generation in isolated systems, removing subsidies for fossil fuels and facilitating the use of renewable generation, 4) development of public databases on primary energy resources for non-hydropower technologies and 5) roll-out of R&D initiatives for wind and solar generation technologies. Other measures identified in the study to adapt the electricity sector to climate change included: increasing the forest cover (via afforestation or reforestation) of river basins that are expected to be impacted by climate change; deploying energy efficiency and demand-side solutions to reduce overall electricity consumption levels; and optimising the operation of existing generation resources (not only hydropower, but also fossil-fuelled thermal generation) (UPME and OPTIM Consult, 2014).

##### Chile

In the recently published roadmap for the energy sector for 2050 (MINENERGIA, 2015), Chilean authorities recognise the need to adapt the energy sector to climate change as one of the environmental sustainability criteria to guide policy decisions. On one hand, this has resulted in the integration of measures to internalise the social and environmental externalities of electricity generation in the roadmap through price mechanisms (such as carbon taxes or cap-and-trade mechanisms) and other measures. On the other hand, the roadmap explicitly mentions that, for the purposes of expansion and operation planning in the electricity sector, the generation potential of renewable technologies, including hydropower, should be corrected according to the climate vulnerability of the resources –e.g., the vulnerability to changes in temperature, precipitation or even exposure to extreme events such as storms. The roadmap calls for the elaboration and implementation of a Climate Change Adaptation Plan for the energy sector.

##### Central America

In 2012, institutions of the power sector of various Central American countries engaged ECLAC and other sponsors in a study to analyse the potential impacts of climate change on the output of two hydropower plants selected as case studies: the Cerrón Grande project in El Salvador and the Chixoy plant in Guatemala (CEPAL *et al.*, 2012). The initial phase of the study included a more general assessment of possible impacts on rainfall in several river basins in Central America, concluding that one possible consequence of climate change would be a substantial reduction of precipitation in most of the region –the sole exception being localised areas in Costa Rica and Panamá. This study indicated that the shift towards an energy matrix based on local renewable resources would increase energy security in Central America.

In addition to reducing delays, modular renewable energy technologies can serve to hedge against demand growth uncertainties. The shorter construction times<sup>8</sup> of modular renewable energy technologies allow quick adjustments in power system expansion plans to cope with circumstan-

tial mid-term imbalances between supply and demand. In power systems with centralised expansion planning, the government can directly use modular non-hydropower renewable energy technologies as solutions for short-term imbalances, whereas under a market environment, the

8. In some cases, resource measurement may be required prior to the implementation of some projects, possibly increasing the required time for deployment.

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opportunities to capture transitory price increases due to the structural imbalances serve as incentives for private developers of non-hydropower renewable energy technologies. In other words, the shorter construction time of certain non-hydropower renewable energy technologies is an attribute that has an economic value, functioning as a *real option* to the system planning activities.

The possibility of adjusting expansion plans in response to construction delays in generation can be of great value for countries that have a significant share of large hydropower dams in future electricity mixes, due to the frequent time overruns associated with these projects (see box 5.5). This enhances the value of modular non-hydropower renewable energy technologies, and their shorter construction times represents an important complementarity mechanism with economic value.

#### ■ Diversification of ownership and spreading of risks for financiers

The typically reduced scale of several renewable energy technologies – including small hydropower plants – allows for *diversification of the ownership profile* of generation assets and *spreading the risks perceived by financing institutions*. The volume of capital expenditures required for implementing large generation projects, notably large hydropower plants, can limit the number and profile of investors, reducing competition. It also can place significant burdens on financing institutions, which may increase the risk premium embedded in the debt costs due to the commitment of large monetary amounts to a single project.

Small-scale renewable energy technologies (in this case, including small hydropower), especially modular technologies, allow for diversification of the ownership profile of generation assets. Moreover, this facilitates the entry of new players in liberalised electricity markets. If there is some structural concentration in the generation market, new entrants help reduce the market power of single entities, which ultimately benefits consumers.

For financing institutions, mobilising capital in a portfolio of smaller-scale projects, rather than in large projects, can theoretically reduce risks and

allow for a reduction in loan costs, which, again, may benefit electricity consumers as a whole. However, obtaining financial resources for several smaller projects may be more difficult than for a single large project, with transaction costs increasing the final debt costs. The two phenomena – risk reduction due to the portfolio effect and increasing transaction costs – thus have opposite effects on the final loan costs.

A possible strategy to prevent the predominance of increased transaction costs would be to create a bundle of small projects to jointly access funds, if financiers are willing to offer financing products targeted at asset portfolios. Yet, as mentioned in chapter 4, portfolio financing mechanisms are still to emerge in Latin America. Also, combining diversified project ownership with centralised financing portfolios would require additional layers of co-ordination from financing institutions, at least internally, to ensure that risk is managed within a portfolio of loans.

#### Operation: making the most of existing assets

The synergies between hydropower and other renewable energy technologies in system operation refer to: 1) the *cost-effectiveness of using hydropower to counteract the short-term variability* of some other renewable energy technologies; 2) *seasonal complementarities* and 3) decreased volatility in total generation achieved by a *diversified portfolio of renewable energy*.

#### ■ Hydropower's flexibility as a means to cost-effectively counteract short-term variability of other renewable energy technologies

Hydropower plants with reservoirs are very flexible generation assets. Their production can be varied quickly, allowing them to effectively counteract short-term variations in the balance between electricity supply and demand. The possibility of storing water in reservoirs – sometimes even pumping water in moments of low demand and high generation – allows for the shifting of energy production from one moment to the next in order to improve the overall reliability and efficiency of the system, at negligible variable costs.

**Box 5.5 Implementation delays in Latin American hydropower projects**

Table 5.2 shows selected examples of hydropower projects implemented in Latin America. The data aim to illustrate that the delays in the implementation of hydropower plants can sometimes exceed 30 months, a period sufficient to implement modular non-hydropower renewable energy technologies. Despite the benefits of hydropower dams, there are risks during their construction stage. Many engineering challenges cannot be mapped entirely before the beginning of the on-site works; moreover, other implementation risks, such as those related to social and environmental issues, can cause not only delays, but also, at times, the cancellation of projects, also impacting the balance between supply and demand.

A recent example is Brazil's Belo Monte dam, for which the start of operation has been postponed following a court

judgement that operators have yet to provide adequate support to indigenous groups affected by the large-scale construction. Situated on the Amazon River, a centre of ethnic and biological diversity, the dam is cutting off the water supply and fishing stocks of the indigenous groups. The 11.2 GW power plant is expected to operate at less than half capacity so that indigenous lands will not be flooded. Already years behind schedule, the dam is expected to be fully operational by 2019.

In a similar example, the first plant in Chile's HydroAysen hydropower complex will not be operational before 2022, four years later than initially planned. Environmentalists have opposed the 2.75 GW plant and the entire hydropower complex because of its plans to flood large swaths of unspoiled land.

**Table 5.2** Selected hydropower projects in Latin America with implementation delays

Project	Country/Countries	Date	Capacity (MW)	Delay (months)
Bayano	Panama	1970	190	18
Sixth Power Project	Honduras	1973	40	42
Nispero	Honduras	1977	22	18
Fourth Guadalupe	Colombia	1980	213	12
Playas	Colombia	1981	200	30
Tucuruí (Stage 1)	Brazil	1984	4,200	12
Chixoy	Guatemala	1986	300	48
Itaipu	Brazil, Paraguay	1991	12,600	116
Pehuenche	Chile	1991	500	-17 (advance)
Yacyreta	Argentina, Paraguay	1994	3,100	108
Sogamoso	Colombia	2014	820	18
Jirau	Brazil	2015	3,750	17 <sup>a</sup>
El Quimbo	Colombia	2015	400	6
Baixo Iguaçú	Brazil	2016 <sup>b</sup>	350	39

<sup>a</sup> Jirau is not fully operational yet. This is the delay currently recognised by the project developers.

<sup>b</sup> Baixo Iguaçú is expected to be operational in 2016, according to the Brazilian regulator.

Source: Sovacool, Gilbert and Nugent, 2014b; ANEEL, 2015a

Even though this chapter focuses on complementarities between hydropower and other renewables, it is worth highlighting that the faster construction times of modular renewable generation technologies such as wind and solar result in the possibility of their use as a hedge against delays in the implementation of generation projects other

than hydropower plants. Other generation technologies, such as coal-fired and nuclear plants, or even geothermal plants, also typically face important challenges regarding their implementation schedules. Delays due to social and environmental issues are not uncommon for these technologies, particularly for large-scale coal and nuclear plants.

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This enables existing hydropower plants that have reservoirs<sup>9</sup> – with hourly to multi-year regulation capacity – to vary their active power output flexibly and to *cost-effectively* counteract the short-term fluctuation of variable renewable energy technologies such as wind and solar plants<sup>10</sup>, whose production can change significantly over minutes or even seconds. Hydropower plants therefore can be regulated more efficiently than thermal power plants, whose use to counteract short-term variability results in higher costs to the system (due to efficiency losses, higher commitment and cycling costs, etc.).

Due to their flexibility, hydropower plants are very efficient in providing a wide range of *ancillary services*. The flexibility and efficiency in changing the active power output explains why hydropower plants are preferred assets to provide one specific class of ancillary services: those related to the control of active power and frequency. However, other classes of ancillary services also can be efficiently provided by these assets (see box 5.6).

Both hydropower plants and other renewable energy technologies can benefit from the com-

### Box 5.6 Brazil: Hydropower plants as cost-effective providers of ancillary services

The reliable operation of power systems requires power plants to do more than just generate electricity. These additional services normally are called *ancillary services*, which can be grouped<sup>11</sup> in three general categories. The first refers to keeping the balance between active power load and generation in the system in order to prevent frequency problems. Services in this category include the provision of load-following and frequency regulation, as well as spinning and cold (non-spinning) reserves. The second category is reactive power support, which is required to keep voltages in the system at acceptable levels. The third refers to black-start capability – *i.e.*, the ability to produce electricity without relying on the network, to restore the electricity system after a blackout.

Hydropower plants, especially those with reservoirs, have the technical capability to provide all of the above-mentioned services and can do so in a very cost-effective manner (IEA, 2012; EPRI, 2001). This is illustrated by the case of Brazil, where hydropower plants account for 65% of generation capacity and historically have been the preferred providers of ancillary services (due to the ability of plants with reservoirs to cost-effectively respond to quick variations in electricity supply and demand). In fact, the service of *secondary frequency control* (part of the first

category) is provided exclusively by hydropower plants. Also, all but one of the plants currently providing reactive power support are hydropower, and the same applies for plants providing black-start capability<sup>12</sup>. Unlike for thermal technologies, the ramp-up times and fuel consumption for hydropower plants under a black start are almost negligible.

Despite recent technological improvements that are starting to allow non-hydropower renewable energy technologies to provide some of these services, an increased participation of variable renewable energy technologies in power systems makes the provision of ancillary services – especially these of the first two categories – an even more critical matter. The short-term variations in their output emphasise the need to keep balance between active power load and generation. Moreover, the different patterns in the power flows through networks, due to the short-term variability of variable non-hydropower renewable energy technologies, enhance the criticality of reactive power support to keep voltages at acceptable levels. Thus, the ability of hydropower plants to cost-effectively provide ancillary services can be seen as an important aspect of the complementarity mechanism described in this section.

9. Pumped-storage hydropower plants also represent alternatives to provide operational flexibility to the system. Despite the relatively low current participation of pumped-storage plants in Latin America, due in part to the possibility of taking advantage of existing hydropower plants with reservoirs to provide operational flexibility, some countries are beginning to place more emphasis on the study of pumped storage as a future alternative for system expansion. For instance, pumped storage is mentioned as a storage technology that can provide flexibility to the Chilean system in the future (MINENERGIA, 2015).

10. Hydropower plants with reservoirs also are important to counteract the variability in the output of run-of-river hydropower, which is, however, typically lower in the short term than that of solar and wind.

11. There is no internationally standardised definition/classification of ancillary services, with each system operator having its own. However, the information provided here is sufficiently accurate for the purpose of this study. Specialised readers may need further reading.

12. In both cases, only one thermal plant provides the service, which is required basically due to transmission constraints and to the local need for reactive power support and black-start capability.

plementarity mechanism described here. By cost-effectively counteracting the short-term variability of the non-hydropower renewable energy generation, the flexible hydropower plants allow for the integration of these technologies in the system at low costs, which presents an opportunity for their development. Under sound regulatory mechanisms, as discussed further in sections 5.3 and 5.4, hydroelectric generators also may capture additional remuneration for their flexibility and ability to balance supply and demand. Naturally, the valuation of this complementarity also results in opportunities to keep energy prices and tariffs at affordable levels for consumers.

### ■ Seasonal climate complementarity

Price seasonality in power systems that have a significant share of hydropower is a result of the cyclical behaviour of hydrology, with prices typically decreasing in the rainy season and increasing in the dry season. The seasonal behaviour of the production of some non-hydropower renewable energy technologies is often complementary to that of rainfall – e.g., higher average wind speeds often are verified in drier months in many Latin American countries (see box 5.7). The availability of sugarcane *bagasse* (the main feedstock for

biomass power in the region) for electricity generation is typically higher in dry months, which coincide with the crop season. Indeed, the crop season overlaps with the drier months for most feedstocks. Such seasonal complementarities help to alleviate the supply and demand balance and to reduce the seasonal variation of energy prices. Some non-hydropower renewable energy technologies, such as geothermal, do not display a strong seasonal component and are roughly constant throughout the months of the year.

This contributes to a lowering of price seasonality, with both hydropower plants and other renewable energy technologies benefiting from it: hydropower plants are exposed to fewer severe price spikes in the dry periods, during which their output is lower and they may need to resort to the spot market to cover contractual obligations. On the other hand, the other renewable energy technologies can take advantage of somewhat higher prices in drier seasons.

The same relief of seasonal supply and demand constraints that contributes to reducing seasonal spikes in prices also contributes to enhancing the reliability of supply in the system, which is an important benefit for consumers.



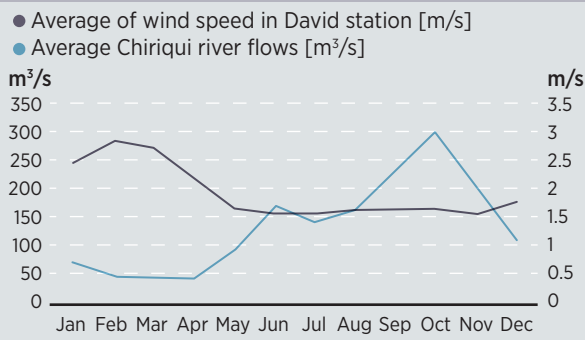
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## Box 5.7 Panama, Uruguay and Brazil: Seasonal complementarity between hydropower and other renewables

### Panama

In Central America, seasonal complementarity between hydrology and wind incidence is confirmed through observations (BCIE, 2010). Figure 5.5 compares historical (1974-2005) wind speed measured at the David station on the Pacific Coast of Panama to the flows of the Chiriquí River, located in the same region.

**Figure 5.5** Comparison of the flows in the Chiriquí River and the wind speed at David station

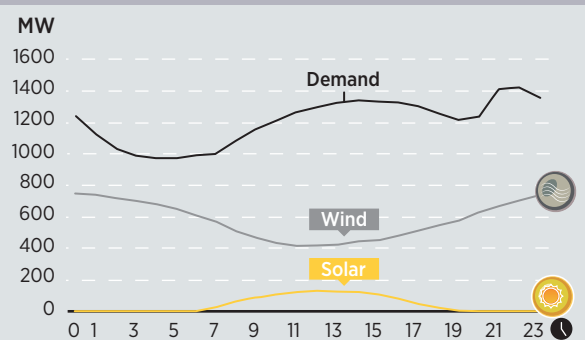


Source: ETESA, 2015

### Uruguay

Complementarity patterns also have been observed in Uruguay, between wind, solar and hydropower generation, both at daily and seasonal scales. Figure 5.6 shows the expected daily profile of demand, and of wind and solar generation. It shows complementarity between wind generation, which decreases generation in the daytime hours, and solar generation, which increases generation in these hours. Similarly, figure ES.4 illustrates the expected yearly profiles of demand and wind, solar and hydropower generation.

**Figure 5.6** Daily complementarity between renewable energy sources in Uruguay



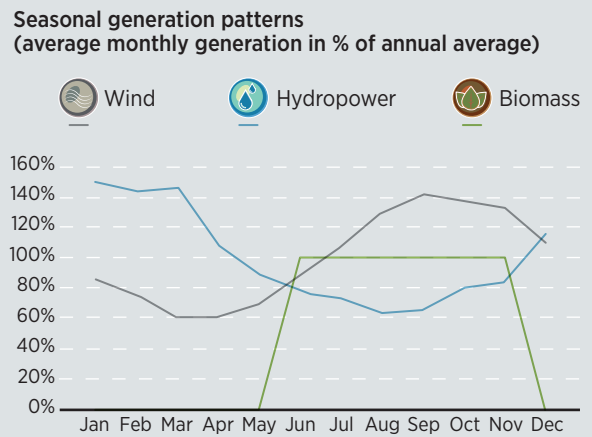
Source: Chaer et al., 2014

### Brazil

Both small hydropower and sugarcane biomass suffer from the highly seasonal availability of their resources, which forces producers to discount (or price) the risks faced when selling energy contracts. However, recognition of the complementarities between these two energy sources results in the development of trading strategies in Brazil's hydropower-based energy market. On the one hand, energy production of biomass cogeneration plants occurs only during the sugarcane harvest period (from May to November), coinciding with the dry season of the hydropower system. On the other hand, small hydropower faces the hydrological risk during dry periods, but it can complement the unavailability of biomass cogeneration during the rest of the year. To harness this synergy, a portfolio based on these two renewable sources can be developed that should be able to mitigate hydrological and fuel unavailability risks and provide a safe and competitive firm energy delivery over a given time horizon (Barroso, Hammons and Rudnick, 2008; Neto, Risso and Beluco, 2014).

Figure 5.7 shows the seasonal complementarity between biomass and hydropower production: the output of biomass plants is higher when there is less water stored in reservoirs. Seasonal complementarity between wind regimes (specifically wind regimes from north-eastern Brazil) and hydropower production also can be observed.

**Figure 5.7** Seasonal complementarity between hydropower reservoir levels and wind and biomass power generation in Brazil.



Source: Batlle, 2014

## ■ Portfolio diversification

A diversified renewable energy portfolio is less volatile, as highlighted by Costa Rica's strategy to diversify the power mix (see box 5.8). Two main mechanisms can be used to obtain a diversified portfolio of renewables. The first is to interconnect projects of the same technology that are located far from one another. The different climate characteristics of each location will result in a variation of availability patterns of primary energy resources. The second is to interconnect plants of different technologies (e.g., hydropower and wind plants) located in the same geographical region. In this case, climate will affect the technologies in different ways. For instance, strong winds may bring clouds that reduce solar irradiation to solar PV panels, but would increase the production of wind farms.

It is also important to highlight that a more diverse portfolio of renewable sources plays a relevant role on the commercial side –particularly with respect to financing. As mentioned in chapter 4, several Latin American markets are maturing to the point that some investors are bundling operational renewable energy projects into low-risk portfolios to then raise further capital. The complementarity between renewable energy technologies would make the output of these portfolios even more predictable, further reducing their risk.

As will be discussed in table 5.3, all of the complementarity mechanisms described above have commercial impacts for hydropower plants and other renewables. These impacts range from the reduction of price shocks when generators are “short” in their market positions (i.e., when they are unable to meet contractual obligations with their own production), to the reduction of energy price volatility in the long term. In all cases, harnessing the complementarities increases the economic value of at least one of the classes of assets (hydropower or other renewables), facilitating access to capital. This and other impacts on the remuneration and risks of generators are summarised in the next section.

## Summary of complementarity mechanisms

Table 5.3 summarises the synergy mechanisms presented in this chapter, showing, for each of

### Box 5.8 Costa Rica's 100% renewable portfolio target

Costa Rica currently supplies nearly all of its total electricity needs from renewable energy sources, mostly from domestic hydropower. Due to the significant hydrological risk for the country's electricity system, however, Costa Rica has adopted a strategy to diversify its electricity mix by developing other forms of renewable energy such as solar, biogas, geothermal and wind power. The country aims to supply 100% of its electricity from renewable sources by 2021 (San Martin, 2015).

The diversified renewable portfolio enabled Costa Rica to generate 99% of its power from renewable sources in 2015 (Ministry of Energy and Environment, 2016). Geothermal plants served as base-load generation during that time. Wind and solar power contributed according to the availability of their resources. Hydropower remained the largest contributor to the energy mix as well as the main provider of operational flexibility to the system.

The lesson to be learned from Costa Rica's experience is that the solutions to cope with variable renewable generation lie in diversifying and using complementary renewable sources, such as wind and hydropower, using smarter grids to manage variations better, and having more interconnections to allow for electricity exchanges that make it possible to take advantage of flexible resources and complementarities at a regional level.

In its renewable energy policy framework, Costa Rica combines technology-specific auctions, tax incentives and other policy instruments (see table 2.1) as key mechanisms to reach its ambitious targets for 2021. The country has been attracting investments that are significant for its size, with geothermal and small hydropower (and more recently wind) as flagship technologies (BNEF *et al.*, 2014).

them, the description of the complementarity, the system profile for which the complementarity applies and the impacts on stakeholders. The impacts indicated for *vertically integrated utilities* apply only to countries with a corresponding structure for the electricity industry. In countries without wholesale energy markets, impacts related to prices captured by project owners and exposure to remuneration risk do not apply. Correspondingly, impacts related to market entry are

**Table 5.3** Summary of complementarity mechanisms between hydropower and other renewable energy technologies

Mechanism:	Description:	System profile:
05  Climate synergies: climate variability and adequacy of supply	<p>When generation of hydropower plants is lower due to climate variability (e.g., the ENSO), the generation of some non-hydropower renewable energy technologies is not reduced or even increases during these events.</p>	<p>Systems with heavy reliance on hydropower (either with reservoir or run-of-river)</p>
	<p><b>Impact on stakeholders:</b></p> <p><b>Non-hydropower renewable energy technologies:</b> Capture higher energy prices during long-duration droughts when supply-demand balance is tighter; economic value of asset increases</p> <p><b>Hydropower:</b> Non-hydropower renewable energy technologies reduce sustained price increases; hydropower with short contractual positions during droughts purchase power to fulfil obligations at lower prices; lower economic losses for assets</p> <p><b>Consumers:</b> Lower price shocks; higher supply reliability</p> <p><b>Vertically integrated utilities:</b> Lower costs of production (ideally transferred to final tariffs) and service with higher reliability</p>	
Climate synergies: climate change vulnerability and strategic expansion	<p>Climate change can result in reduced output of important hydropower plants. There being high uncertainty on the severity of future changes in rainfall patterns, diversifying the generation matrix with help of other renewable energy technologies provides resilience to climate change</p>	<p>Systems with heavy reliance on hydropower (either with reservoirs or run-of-river)</p>
	<p><b>Non-hydropower renewable energy technologies:</b> Become a strategic alternative to generation system expansion (thus gaining market share), since they help to enhance climate change resilience through diversification of energy sources and even to mitigate climate change (<i>clean</i> technologies); economic value of assets increase if attributes are internalised</p> <p><b>Hydropower:</b> Non-hydropower renewable energy technologies have the potential to reduce future scarcity events and thus sustained price increases, during which hydropower plants with reduced output due to climate change would incur losses</p> <p><b>Consumers:</b> Higher supply adequacy; reduction of uncertainty about future impacts of climate change on prices</p> <p><b>Vertically integrated utilities:</b> Service with higher reliability (resilience to climate change)</p>	
Implementation of generation infrastructure	<p>Modular non-hydropower renewable energy technologies with short construction times can be built quickly to partially counteract circumstantial imbalances in supply/demand, especially if delays in implementation of hydropower plants occur</p>	<p>All systems; but particularly relevant where delays in implementation of large hydropower plants are frequent</p>
	<p><b>Non-hydropower renewable energy technologies:</b> Circumstantial imbalances are windows of opportunity for investors to develop these technologies</p> <p><b>Hydropower plants (delayed ones):</b> If penalties due to delays include the obligation to purchase power in the short-term market to balance contractual conditions, lower prices due to the building of renewables will reduce economic losses for assets</p> <p><b>Consumers:</b> Lower price shocks due to construction delays; higher supply reliability</p> <p><b>Vertically integrated utilities:</b> Lower costs of production (ideally transferred to final tariffs) and service with higher reliability</p>	



<b>Ownership diversification</b>	Smaller-scale non-hydropower renewable energy technologies allow for diversification of project ownership: smaller investors can participate, facilitating market entry and reducing concentration	All systems, but most relevant where large investments required for hydro-power dams have historically limited the number of potential investors
	<p><b>Generation investors (including vertically integrated utilities) and financiers:</b> Possibility of diversifying project portfolios by investing in non-hydropower renewable energy technologies</p> <p><b>Non-hydropower renewable energy technologies:</b> Drive towards diversification represents opportunities for market entry</p> <p><b>Consumers:</b> Declines in market concentration reduce opportunities to exercise market power, impacts on prices; portfolio effect reduces impacts of any problems with single assets on reliability and costs of supply</p>	
<b>Hydropower flexibility used to counteract short-term variability of other renewable energy technologies</b>	Hydropower plants with reservoirs are flexible assets, and the cost of using existing plants to counteract the short-term variations in the production of variable non-hydropower renewable energy technologies is lower than that of other generation technologies	Systems with large participation of hydropower plants with reservoirs
	<p><b>Non-hydropower renewable energy technologies:</b> Lower costs of counteracting the variability of non-hydropower renewable energy technologies with hydropower typically will result in lower price spikes in the short term (especially under the cost-based dispatch predominant in Latin American countries); non-hydropower renewable energy technologies with short contractual positions thus will purchase power to fulfil obligations at lower prices, having lower economic losses</p> <p><b>Hydropower:</b> Capture higher energy prices during time periods in which output of other renewable energy technologies is lower; participate in and receive income from ancillary services markets (if they exist); economic value of asset increases</p> <p><b>Consumers:</b> Lower short-term volatility of prices; higher supply reliability</p> <p><b>Vertically integrated utilities:</b> Lower costs of production (ideally transferred to final tariffs) and service with higher reliability</p>	
<b>Seasonal complementarity</b>	Generation of hydropower plants is lower during drier seasons, but the generation of some other renewable energy technologies is not reduced or even increases during these events	Systems with heavy reliance on hydro-power (either with reservoir or run-of-river)
	<p><b>Non-hydropower renewable energy technologies:</b> Capture higher energy prices during dry seasons; economic value of asset increases</p> <p><b>Hydropower:</b> Non-hydropower renewable energy technologies reduce seasonal price oscillations; hydropower with short contractual positions during dry seasons purchases power to fulfil obligations at lower prices.</p> <p><b>Consumers:</b> Reduced seasonal oscillation of electricity prices; higher supply reliability</p> <p><b>Vertically integrated utilities:</b> Lower costs of production (ideally transferred to final tariffs) and service with higher reliability</p>	
<b>Portfolio diversification</b>	The production of a diversified renewable energy portfolio of non-dispatchable renewable energy plants, including run-of-river hydropower plants, is less volatile in the short-term than that of each individual plant	All systems with run-of-river hydro-power plants and other classes of renewable energy generation projects
	<p><b>Variable renewable generation technologies, and financiers:</b> Reduced variability of output of portfolio of non-dispatchable renewable generation plants, including run-of-river plants, results in lower price volatility and reduces commercial risks perceived by these technologies.</p> <p><b>Consumers:</b> Reduced short-term price volatility; increased reliability of supply</p> <p><b>Vertically integrated utilities:</b> Lower volatility in production costs and service with higher reliability</p>	

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relevant only in countries where there are mechanisms that allow the entry of new players in the generation segment.

### 5.3 HARNESSING COMPLEMENTARITIES IN ELECTRICITY SYSTEM EXPANSION

This section offers recommendations on how governments can set the necessary policy conditions to internalise the value of synergies between hydropower and other renewables. It presents recommendations on policies targeted at the power system expansion tasks, identifying good practices and challenges faced by Latin American countries.

Many Latin American countries are uniquely positioned to harness these synergies, due to the long track record of best practices of system planning activities and to resource availability. However, many opportunities still exist to improve the policy and regulatory environment in the region. Good practices already are emerging as the participation of non-hydropower renewable energy technologies in the electricity generation mix increases. Yet, these often are isolated cases, resulting from *ad hoc* regulatory efforts in response to specific problems faced. The creation of a coherent and robust policy framework for considering the large share of hydropower as a unique asset of the region will contribute to scaling up renewable energy in Latin American countries in the most economically meaningful way. Ideally, such a coherent policy framework should be laid out before large-scale deployment of non-hydropower renewable energy technologies to avoid issues with the allocation of costs and responsibilities resulting from *ex post* adjustments.

The topics explored in the following subsections refer to different steps of the power system expansion: *planning, procurement, financing and implementation*.

Before exploring each of these steps, it is worth recalling that short-term prices also serve as signals for expansion planning. The expectation of high levels of short-term electricity prices in the future serves as an incentive for the expansion of generation capacity, since investors will seek to capture these high prices by implementing new

projects. Therefore, the measures of section 5.4, which deal with system and market operations, also are important from the point of view of system expansion.

However, most Latin American markets do not rely exclusively on short-term prices as the only signals to drive generation capacity expansion. Rather, they combine these with indicative planning by governmental institutions and with procurement mechanisms based on competition for long-term contracts. With this in mind, the measures indicated in the following sections should be evaluated jointly with those of section 5.4, if a comprehensive valuation of complementarities between hydropower and other renewables is sought.

#### Expansion planning

Planning the expansion of the power system involves evaluating the adequacy of generation to meet future electricity demand. Due to its role in directly or indirectly driving expansion decisions, the planning function ideally should be the starting point for internalising the economic value of complementarities between hydropower and other renewable energy technologies. Policy makers should establish guidelines to ensure that procedures, methodologies and criteria used in expansion planning internalise them. Box 5.9 provides recent examples of ongoing programmes in Latin America that illustrate efforts of this type of guideline.

The impacts of complementarities over the economic and technical performance of the power system should be fully quantified when evaluating different expansion alternatives. A topic of particular relevance for many Latin American countries is the economic valuation of hydropower as a flexible resource to counteract the short-term variability of other renewable energy technologies. However, the methodologies for assessing this complementarity in the context of expansion planning are not fully established or tested, as addressed by IRENA's *Addressing Variable Renewables in Long-Term Energy Planning* (AVRIL) project (IRENA, forthcoming). It is crucial that policy makers establish guidelines to modernise planning criteria and methods.

**Box 5.9 Modernisation of planning procedures, methodologies and criteria in Latin America**

Some countries in Latin America are considering introducing new criteria in their energy planning that take into account renewable energy sources and their contribution to system stability.

The Peruvian electricity market regulator, Osinergmin, recently conducted studies on strengthening implementation of the planning of electricity generation. The main objective is to enhance the regulatory mechanisms to effectively implement the development plans for the electricity sector and, in particular, to guarantee reliable electricity supply. So far, variable renewable generation is considered to have a firm energy equal to zero. While this assumption is conservative in nature, it tends to underestimate renewables' contribution to the system.

The study proposes a new approach to correct this distortion, based on the idea that even if a certain wind or solar plant has large periods with zero generation, a cluster of projects of the same technology that are geographically separated would be able to ensure a certain level of generation at all times. Therefore, this cluster can guarantee a certain firm capacity in the system, which would

be proportionally distributed to each of the plants (CIER, 2013; AF Mercados & Deloitte, 2015).

In Brazil, the Ministry of Mines and Energy is conducting a study that analyses the technical and regulatory impacts of high shares of wind energy in the country's electricity system, which is highly reliant on hydropower. The study, funded by the World Bank, analyses the seasonal climate complementarity among energy sources, and it assesses the contribution of wind power generation to the system's reliability (Brazilian Ministry of Mines and Energy, 2014).

Another example is the ongoing reform of the Chilean transmission planning approach. As part of the approach proposed in a bill currently under evaluation by the Chilean congress (MINENERGIA, 2015), the methodology designed for the transmission expansion planning is based on identification of potential generation hubs, including renewable generation. The transmission networks are planned proactively not only to allow renewable generation to reach demand, but also to bestow the system with enough power transmission capacity to make it possible to take advantage of complementarities between different renewable energy resources.

Naturally, the modernisation of methodologies and criteria for system expansion planning is valuable not only for *generation*, but also for *transmission*, as the network is a key asset for integrating both hydropower plants and other renewable energy technologies into the system. Regional co-operation and co-ordination in transmission planning also would benefit from a clear valuation of complementarities between hydropower and other renewable technology resources in different countries (see box 5.10).

**Procurement****■ Valuation of complementarities in capacity adequacy mechanisms**

Several Latin American countries have implemented procurement processes categorised as *capacity adequacy mechanisms*. Auctions for long-term supply contracts are key elements of these mechanisms in several countries in the region. Policy makers have an important role in the design of these mechanisms, and should ensure that the procurement process includes mecha-

nisms to *internalise the value* of the complementarities between hydropower and other renewable energy technologies, thus sending the right economic signals to power plant developers. This is important when comparing competing projects in generation auctions.

The necessary condition to achieve this is to ensure that the amount of firm capacity that each project can offer in the competitive procurement process is defined properly. On the one hand, it is important to consider the vulnerability of hydropower to droughts caused by the ENSO and other climate-related phenomena, the short-term variability in the availability of primary energy resources for wind or solar plants, and any seasonality in the output of either hydropower plants or other renewable energy technologies. Ignoring these phenomena would result in an over-evaluation of the firm capacity that can be offered by these technologies. On the other hand, properly evaluating the contributions of each project to long-term supply reliability (its firm capacity) requires explicitly quantifying the complementar-

**Box 5.10** Transmission interconnections in Central and South America**Central America**

Central America's dependence on hydropower raises concerns about energy security, especially given the extreme dry events that have resulted in electricity shortages. Therefore, Central American countries engaged in the creation of a regional grid – named SIEPAC – aimed at enabling international power exchanges. The creation of SIEPAC resulted in the establishment of a regional electricity market, a regional system operator and a regional regulator.

SIEPAC provides greater reliability and enhanced security of supply for each member country by enabling energy exchanges. This regional co-operation and co-ordination in transmission planning also would benefit from a clear valuation of complementarities between hydropower and other renewable energy technologies. By strengthening the role of renewables in a larger, more widespread grid, their variable generation and overcapacity can be transmitted across borders. For example, Costa Rica – reliant on hydropower capacity – will be able to import wind power from Nicaragua, when its hydropower generation decreases (Dolezal *et al.*, 2013). Thanks to the interconnection of SIEPAC, Central American countries are better positioned to face droughts; the system experienced a notable decrease in hydroelectric production between 2013 and 2015, without rationing electricity.

**South America**

In South America, recent studies have indicated that a larger participation of wind power in Uruguay could be facilitated by increasing energy exchanges with Brazil and Argentina (Hristova, 2015). Other studies have indicated that an increase not only in interconnection capacity, but also in the flexibility of the commercial model for exchange agreements with Argentina and Brazil would be highly beneficial for the value of the wind farms in Uruguay, especially when the amount of wind capacity in the country is increased (EnergyNet DK, 2012).

Claims that electricity exchanges in the Southern Cone and southern Brazil could benefit from a modernisation of commercial models are common. Many of the exchanges in the region are based on almost *ad hoc* arrangements, limited largely to scarcity conditions. Recent examples from Argentina illustrate this. In 2015, Argentina exported energy to Brazil as part of measures to cope with poor hydrological conditions in the latter country, with the state-run Brazilian company Petrobras managing the imports commercially. In January 2016, Brazil exported to Argentina close to 3,700 MWh in an emergency supply arrangement to help cope with the surge of summer demand, tied to a prolonged heat wave in Buenos Aires.

There also are ongoing discussions about a number of other interconnections in Latin America. Peru has been one of the most active countries in this sense, having entered bilateral or multilateral agreements about the execution of studies and the future implementation of new transmission interconnections (or reinforcement of existing ones) and integration with other Andean Countries (Ministros de Energía y Minas de las Repúblicas de Colombia, Ecuador y Perú, 2001) and with Brazil (Gobierno de la República del Perú y Governo da República Federativa do Brasil, 2010).

Although the agreements have moved at different paces, according to specific technical, economic and social-environmental factors, Peru has diligently incorporated the analysis of the possible benefits resulting from interconnections in its transmission system expansion planning studies (COES, 2014). These studies include analyses of possible benefits of an interconnection with Chile (COES, 2014), for which no underlying bilateral agreement has been signed as of this writing. Such benefits could include the complementarity between Peruvian hydropower and Chilean solar power.

ities between hydropower and other renewable energy technologies (see box 5.11).

■ **Valuation of flexibility in competitive procurement processes**

When discussing the internalisation of the value of complementarities between hydropower and other renewable energy technologies within ca-

capacity adequacy mechanisms, the focus was on synergies related to climate seasonal patterns of both types of resources. Yet, the cost-effectiveness of using hydropower generators with reservoirs to counteract the short-term variability of other renewable energy technologies also should be valued in competitive procurement processes.

**Box 5.11 The reliability mechanism allows wind energy participation in Colombia**

With a power mix based 80% on hydropower, the Colombian government's primary concern is assuring reliability of supply. A key reason why the government is starting to value wind generation is the observed production complementarity with hydropower energy resources (Batlle & Barroso, 2011). This led to the introduction of wind plants in the country's reliability mechanism. Since 2011, wind installations are allowed to participate in the reliability payment auctions in Colombia.

The maximum quantity of firm power that a generator can offer in a firm electricity auction is known as its ENFICC (*Energía Firme para el Cargo por Confiabilidad*, i.e., firm energy for the reliability payment). ENFICC represents the amount of energy that a generator can reliably and continually produce during periods when hydropower generating capacity is at a minimum, particularly during the ENSO. Table 5.4 shows the typical ENFICCs for different generation technologies in Colombia as a percentage

**Table 5.4** ENFICC for different generation technologies in Colombia, as established by CREG

Technology	Maximum ENFICC (% of the plant's total generation capacity in a year)
Hydropower with / without storage	55% / 30%
Coal	97%
Natural gas	93%
Fuel oil	88%
Wind	6%

Source: Robinson, Riascos & Harbord, 2012

of a plant's effective net capacity, as established by the Colombian Energy Regulator (CREG).

As it can be observed, CREG assigns a value of 6% firm energy to wind. A common methodology for assessing the contribution of variable technologies (such as wind) to system reliability is to average their generation over the relevant shortage periods. An alternative methodology is to order the observed wind generation (or an estimation based on wind speed) and then to adopt a threshold percentile limit. For instance, it is common to set the

capacity factor to the level of wind generation that has occurred at least 85% of the time. However, this wrongly implies that all generation below that threshold makes zero contribution to the system reliability.

CREG's approach is especially conservative because it ignores the contribution of all generators that cannot be guaranteed 100% of the time; this is why it assigns a (relatively low) 6% value to wind. Using a similar methodology as CREG, and based on the hourly generation data from the Jepirachi wind plant from April 2004 to April 2011,

**Table 5.5** Estimated values of ENFICC considering the contribution over all periods of the year, and just during periods affected by El Niño, for three different thresholds

ENFICCs	El Niño periods	All periods
ENFICC with 100% percentile limit	15%	6%
ENFICC with 95% percentile limit	18%	13%
ENFICC with 75% percentile limit	29%	25%

Source: Robinson, Riascos and Harbord, 2012

ENFICC values were calculated considering only El Niño periods, and considering lower percentile levels (Robinson, Riascos and Harbord, 2012), as shown in table 5.5 (the 6% value can be observed). The table conveys two main messages. First, the ENFICCs on the El Niño periods are higher than the ones based on all periods. This is evidence that wind power has the potential to complement the hydropower generation in dry periods in Colombia,

and increase the system's reliability. However, this higher contribution during the critical hydrological periods affected by the El Niño has not been considered while setting the current *maximum ENFICC* for wind power plants in Colombia. The second message is that considering a less conservative threshold, the wind contribution to the systems' reliability increases significantly.

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As already mentioned, hydropower plants with reservoirs have notable operational flexibility in the short term, which is a valuable attribute in a system with a high share of non-hydropower renewable energy technologies. Policy makers interested in ensuring that power system expansion develops optimally within a market environment therefore should instruct technical bodies to create methodologies for internalising the value of the storage of hydropower plants with reservoirs and pumping while procuring new generation capacity. This will ensure that adequate price signals are sent to project developers. This ultimately also would add an economic element to the social and environmental cost-benefit analysis when discussing the impacts of building new hydropower plants with storage capacity. The impact that increasing flexibility could bring to the Chilean system is detailed in box 5.12.

**Box 5.12 Relevance of flexibility in Chile**

In the framework of the definition of its energy policy to 2050 (MINENERGIA, 2015), the Chilean Ministry of Energy, supported by projects financed by the German Ministry for the Environment (implemented by GIZ), established a round-table with technical sector experts of all types in order to find a common standing regarding the inclusion of variable renewable energy in the Chilean grids. The key result is that in a conservative scenario where no new technologies (such as storage) are considered, Chile could integrate around 20% of variable renewables generation cost-efficiently. However, only by increasing flexibility of the system this share can be increased up to 30%. A key element here is the flexibility of thermal generation units, followed by efficient management of reserves and generation forecasting.

Source: MINENERGIA, 2015

Another option is to establish the guidelines for the creation of the procurement mechanisms to meet the demand not only for *firm capacity*, but also for *flexibility* in the power system. The cost-effectiveness of existing hydropower plants in providing this flexibility could allow them to capture a significant share of the market for such a *flexibility product* and therefore capture revenues compatible with their actual value for the

power system. In summary, the incorporation of the economic value of hydropower as storage is an important issue.

**Financing**

Since financing of renewable energy in Latin America is analysed extensively in chapter 4 of this report, this section is limited to topics relevant to access to financing as a potential barrier to harnessing the complementarities between hydropower and other renewable energy technologies.

A crucial aspect is whether – when determining the *economic viability* of the power generation projects, *i.e.*, their ability to produce enough cash to pay back the loans – financing institutions take into account complementarity mechanisms that reduce the exposure of projects to cash flow risks. For non-hydropower renewable energy technologies, the seasonal and climate complementarity with hydropower is of a great importance when assessing their cash flow; their increased generation in these occasions might allow them to capture revenues from the spot market. If financing institutions fail to consider this aspect when evaluating the economic viability of renewable energy technologies, they may deny loans to these projects and introduce barriers to their entry in the market. This becomes more important as the financing of portfolios of projects (instead of financing on a project-by-project basis) emerges as an alternative financing modality in the region.

In order to avoid these failures and correctly value the complementarities between hydropower and other renewables when assessing new projects, financiers may need to develop fairly sophisticated technical know-how. Policy makers can have a direct role in enabling the development of the technical know-how that financiers may need to appropriately value complementarities. They can provide funds for capacity-building programmes or establish guidelines for evaluating the feasibility of hydropower and other renewable energy technologies.

Another way for financing institutions to create adequate conditions to harness the complementarities between hydropower and other renewable energy technologies relates to the diversification of asset ownership. As discussed in section 5.2, the smaller scale of non-hydropower renew-

able energy technologies represents an opportunity for ownership diversification and reduction of structural concentration in electricity markets that can be particularly relevant in hydropower-dominated countries. However, some state-owned public financing institutions in the region have been criticised for a lending policy oriented largely to the creation of “national champions”, reducing the funds available for smaller firms. Policy makers can have an important role in removing these barriers.

### Implementation

Once a project is procured and its financing is secured, development begins. Complementarities in generation infrastructure between large hydropower and modular non-hydropower renewable energy technologies should be fully harnessed at this stage. The quick implementation of modular non-hydropower renewable energy technologies can be used to cope with unforeseen delays in large hydropower development and mitigate mid-term imbalances between supply and demand. By creating mechanisms for monitoring the implementation of such projects, policy makers can enable the early identification of conditions that could lead to delays in the start of commercial operation.

To take advantage of this complementarity, it is necessary to avoid delays in the start of commercial operations of the modular non-hydropower renewable energy technologies. The delay risks may be reduced via a careful design of the mechanism for procuring these technologies. For example, in the design of an auction, participation could be limited to only those generators that are able to connect to the grid without requiring any development of new transmission infrastructure.

It can be argued that auctions for non-hydropower renewable energy technologies have been used in an *ad hoc* manner in Latin America to mitigate mid-term structural imbalances between supply and demand resulting from such events, such as the case described in box 5.13. Also, some recent auction design choices suggest that countries in the region are looking into modular renewables as a means of coping with such mid-term imbalances. For instance, Brazil has, since 2013, limited the participation of wind and solar projects in its

### Box 5.13 Complementarity in the construction phase of large hydropower plants and other renewable energy technologies in Brazil

In Brazil, hydropower projects usually display the highest delays. Table 5.6 shows a yearly measure of delays of such projects, given by the share of firm energy installed out of the planned firm energy to be installed in 2012 and 2013.

**Table 5.6** Planned and installed firm energy certificates of hydropower in Brazil

	2012	2013
Planned firm energy certificate [MW average]	959	1749
Installed firm energy certificate [MW average]	804	550
Completion rate	84%	31%

Source: ANEEL, 2015b

Due to the substantial delays in implementation of hydropower plants and other generation technologies, and considering the demand growth rates projected for the near future, Brazilian authorities called two auctions in the second semester of 2013. In order to make sure that the new capacity will come online quickly, the auctions involved very tight implementation schedules –in some cases, there were only 26 months between the auction and the contractual date of delivery of the energy purchased. Modular non-hydropower renewable energy technologies, notably wind, were among the few generation technologies that could be implemented in such short lead times.

In addition, an up-to-then unprecedented requirement was introduced in the 2013 auctions: only the generators that could be connected to the existing grid, without demanding any expansion of the network capacity, were allowed to participate. This aimed at tackling the main cause of previous delays in the start of commercial operations of non-hydropower renewable energy technologies in the country, which was the implementation of transmission infrastructure.

These auctions highlight how wind plants’ fast implementation schedules can play an important role in adjusting generation expansion plans to circumstantial imbalances between supply and demand, caused by delays in the implementation of hydropower plants.

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*reserve energy* auctions only to generators that do not require transmission expansion in order to be incorporated to the grid.

However, as of now, there are no formal mechanisms in place to monitor structural imbalances between supply and demand due to delays in the implementation of large projects or to systematically contract (modular) renewable generation capacity.

#### 5.4 HARNESSING COMPLEMENTARITIES IN ELECTRICITY SYSTEM OPERATION

This section presents recommendations for creating a policy environment that allows for exploring synergies between hydropower and other renewable energy technologies, focusing on power system and market operation in Latin America.

##### Operating procedures

When considering power system and market operation in countries with high shares of hydropower, it is useful to differentiate between *long- to mid-term* and *short-term* operation.

Operation decisions of the *long- to mid-term horizon* include hydropower reservoir management. Determining the optimal amount of energy production from hydropower plants with reservoirs requires an examination of inter-temporal opportunity costs. Higher levels of hydropower generation at any point in time will reduce the amount of complementary thermal generation at that moment, but will result in less water stored in the reservoirs and therefore potentially higher costs of complementary thermal generation in the future. Several physical phenomena are taken into account for this decision-making process: the seasonal behaviour of hydrology and of renewable resources affected by climate, such as wind speeds and solar irradiation; the uncertainty about the long-term availability of these resources; the occurrence of semi-periodic climate phenomena such as severe droughts associated with the ENSO, etc.

Latin American countries with a large share of hydropower in their electricity mix have been dealing with these aspects for a long time. As a result,

they have developed sophisticated procedures, methodologies and criteria that allow for optimal long- to mid-term operation, considering complementarity mechanisms between hydropower and other renewable energy technologies (box 5.14 describes the example of Uruguay). Yet, the experience with the valuation of climate change vulnerability has been more limited, and this may demand capacity building in the region.

#### Box 5.14 Operational procedures changes in Uruguay with the introduction of large wind penetration

With the Wind Energy Program in place, 500 MW of wind capacity had been installed in Uruguay by the beginning of 2015, and another 700 MW is planned to come online by the end of 2016. With the new energy mix, Uruguay has been able to minimise the impact of the drought in early 2015 thanks to supplies from its wind farms, as declared the state-run utility UTE (Hristova, 2015). The methodologies and tools used for system operation planning in Uruguay already allow for optimisation of the dispatch of hydropower and thermal plants, considering the uncertainty in hydrology and in the production of wind power plants, on weekly time ranges for a time frame of 20 years.

These legacy methodologies and tools were developed in a context where hydrology was the main source of uncertainty for long- and mid-term system operation (Cornalino, Coppes & Chaer, 2012). However, as the participation of wind power increased, the Uruguayan authorities reported that it was critical for methodologies and tools to better reflect short-term dynamics and the uncertainty associated with generation from non-hydropower renewable energy technologies, aspects currently not fully represented (EnergyNet DK, 2012). These modifications are already being implemented.

Unlike long- to mid-term operations, *short-term* procedures have received comparatively less attention in several Latin American countries, due mainly to the high shares of hydropower, which historically has supplied all the short-term flexibility and ancillary services that the system needs at low costs. Thus, short-term operation proce-



dures and methodologies need improvements in some countries, in order to value these complementarities. The required improvements may include the improvement of existing computational models to represent the short-term behaviour of non-hydropower renewable energy technologies, with special attention to the variability and the uncertainty of the production of these resources, as well as improvements in their generation forecasting. The technologies and methods used for generation forecasting for variable renewable energy are of crucial importance: the better the temporal and spatial resolution and the shorter the actualisation period, the more reliable and efficient the system operation. Incentives and/or obligations for all market participants to count with more flexibility measures also can be crucial.

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***The economic value of the complementarities should be internalised by all agents in all stages of the power system management.***

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Policy makers can catalyse the improvement of operating procedures by issuing guidelines for system operators, making funds available for capacity building programmes or acquiring modern software tools. Ideally, the efforts to improve operating procedures should be co-ordinated with the modernisation of power system expansion planning capabilities, in order to allow a harmonious co-ordination of power system expansion and operation functions. Some of the examples of programmes recently implemented in Latin America mentioned in section 5.3 address both topics.

### **Short-term markets**

In power systems with competition in the generation segment, the price signals from short-term markets are of chief importance to drive efficient generation behaviour. As such, the possibility of exploring complementarities between hydropower and other renewable energy technologies is influenced by the design of these markets. Most of the Latin American countries with liberalised electricity industries and with a significant share

of hydropower have already developed pricing and market clearing rules that result in the proper treatment of hydrological seasonality and the impact of climate events such as the ENSO. This results in adequate incentives for market agents to harness the corresponding synergies between hydropower and other renewable energy technologies in the long- to medium-term.

This section focuses on possible improvements to harness the complementarities between hydropower and other renewable energy technologies that relate to short-term phenomena – particularly, the ability of hydropower plants to cost-effectively counteract the short-term variability of renewable technologies and to provide needed ancillary services to the system. Policy makers should issue guidelines for the design of market rules that allow this complementarity mechanism to be internalised in the remuneration of flexible generators – including hydropower plants with reservoirs and even thermal plants running on natural gas. When issuing these guidelines, policy makers should give special attention to three topics briefly discussed below: *ex post pricing*, *temporal resolution of trading and pricing intervals* and adequate design of *procurement of ancillary services*.

#### **■ Ex post pricing**

Short-term electricity prices can be calculated *ex ante* (before the dispatch of generation in real time, based on forecasted demand and supply) or *ex post* (after the real time dispatch and with basis on actual demand and supply conditions). Differences between *ex ante* and *ex post* pricing become less relevant when the frequency of price calculations is high. In Latin America, hourly trading intervals currently predominate. Introducing *ex post pricing* schemes can help to internalise the value of complementarities between hydropower and other renewable energy technologies.

Since there is uncertainty about the actual production of non-hydropower renewable energy technologies, even a single hour ahead of the real-time dispatch of the system might result in differences between the forecasted production of these plants and their actual output. Under a low penetration of non-hydropower renewable ener-

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gy technologies, this difference may not be high enough to materially affect prices. But the difference becomes more important as the share of non-hydropower renewable energy technologies in the power system increases. Therefore, an *ex post* price scheme that better reflects the actual supply and demand conditions may more accurately remunerate hydropower plants with reservoirs for their ability to quickly adjust their energy output in response to short-term fluctuations in the production of non-hydropower renewable energy technologies.

*Ex post* pricing is used in some Latin America countries with liberalised electricity markets – e.g., Colombia and Panama. Other countries employ *ex ante* prices – e.g., Brazil.

#### ■ Temporal resolution of trading and pricing intervals

The *instant* supply-and-demand equilibrium in power systems must be kept at all times. Thus, short-term variability of non-hydropower renewable energy technologies must be constantly counteracted by generators with high operational flexibility, capable of quickly increasing their output when the production of these non-hydropower renewable energy technologies decreases, and vice-versa.

The more reflective that prices are of the short-term demand-and-supply conditions, the better are the price signals sent to generators that can quickly and flexibly alter their output when needed by the system. Also, flexible generation technologies such as hydropower plants with reservoirs or gas turbines can capture higher revenues when shorter time intervals are used. For this reason, using shorter time intervals is beneficial for internalising the value of this flexibility. Hourly trading intervals, and therefore hourly energy prices, are commonly used in Latin American countries with liberalised generation markets. Peru is one exception, having quarter-hourly trading intervals. Brazil goes in the opposite direction, employing weekly prices calculated for three load blocks. There are countries with more complex pricing rules that allow for *partially* capturing the value of short-term flexibility of generation assets – such as Panama (see box 5.15).

#### Box 5.15 The Panamanian energy spot pricing rule

Panama uses hourly prices in its short-term electricity market, called *Mercado Ocasional*. Yet, the pricing rules are complex and allow for capturing some information on the variation of supply-and-demand conditions within each hour. According to the rules of the Panamanian spot market (ASEP, 2014), the system and market operator calculates marginal production costs for all four 15-minute intervals within each hour. If none of the marginal production costs of each of the four 15-minute intervals is more than twice that of any other interval, the homologated spot energy price used for the corresponding hour will be the highest of the four marginal production costs. Otherwise, the homologated hourly energy price will be calculated as the weighted average of the marginal production costs over all four 15-minute intervals, with weights corresponding to the total energy supplied in each 15-minute interval (ASEP, 2014).

#### ■ Procurement models for ancillary services

*Ancillary services* aims at maintaining the security of supply, delivering *flexibility* – rather than energy – to the power system (see box 5.6). Sometimes, the provision of these services is mandated by regulations (e.g., grid codes), while on other occasions, they are provided through markets. It is important that the commercial model for the procurement of ancillary services result in appropriate incentives for both long- and short-term decisions. It should incentivise the construction of generators which are able to provide flexibility to the system; and the efficient short-term operation and remuneration of these assets.

In many Latin American countries, ancillary services are subject to cost-of-service regulation, meaning that each agent providing the services is reimbursed solely with basis on incurred costs. A procurement model based on the reimbursement of costs provides weaker incentives than a model based on *establishing prices for ancillary services with basis on competitive processes*.

Policy makers should analyse whether benefits could be achieved by modernising procurement models for ancillary services, preferably with the

adoption of competitive processes. This can be critical to ensure that the amount of these services will evolve in accordance with the long-term needs of the power system. Since an increased participation of non-hydropower renewable energy technologies can increase the demand for ancillary services, the modernisation of procurement methods in countries which currently rely on a cost-reimbursement model can facilitate the increased participation of these generation technologies in Latin America. Moreover, it represents a further opportunity to harness the complementarity of hydropower, which can cost-effectively provide the flexible ancillary services, and other renewable energy technologies.

## CONCLUSIONS

As discussed in this chapter, hydropower and other renewable energy technologies are complementary rather than competing technologies, and exploiting their complementarity is a leveraging factor to enhance the penetration of renewables in Latin America. Taking full advantage of the synergies to create a win-win situation for these technologies, and the energy system as a whole, requires pro-active policy planning. A first challenge is to identify which of the synergies are of relevance for each country. Uruguay is a good example where such identification is being explicitly made (Chaer *et al.*, 2014).

Once the complementarity mechanisms relevant for each country are identified, policy makers can proceed with the design of a policy environment that allows for taking full advantage of the synergies between hydropower and other renewable energy technologies. The main priority of such an environment is to ensure that the *economic value* of the complementarities is *internalised* (or priced-in) by all agents whose decisions affect power system management, and in all processes ranging from expansion planning to design of market rules. It is worth highlighting the importance of a *systematic approach* to the design of policies to harness complementarities.

The historical experience with the development of hydropower in the region has led to some specific mechanisms conducive to harnessing synergies between hydropower and other renew-

able energy technologies which already are part of the policy repertoire of some countries. This is generally the case of measures required to take advantage of seasonal synergies and those related to the occurrence of the ENSO.

Several Latin American countries that have significant shares of hydropower plants with large reservoirs – including Brazil, Colombia, Panama and Uruguay – are experienced in internalising the value of different generation technologies regarding seasonal climate effects and climate variability impacts such as those of the ENSO, as well as of the storage capability of these plants. These countries can arguably proceed with the full valuation of these complementarities after making relatively minor, but nonetheless important, changes in expansion planning procedures, procurement processes and market design.

Also, the first initiatives from Latin American policy makers seeking an adjustment of some expansion and operation procedures and methodologies are emerging. Yet, the same is not generally true for measures required to internalise complementarity mechanisms in all stages of the power system management hierarchy. For specific links of the power system management chain, there are isolated positive experiences in the region –e.g., quarter-hourly trading intervals are currently used only in Peru. In other cases, experiences are not only isolated, but also implemented as *ad hoc* responses to individual challenges that became transparent as the participation of renewables in the market increased, rather than as part of a systematic effort to adapt policy environments to leverage on complementarities between hydropower and other renewable energy technologies.

A more structured approach to harnessing complementarities may require the commitment of policy makers to roll out comprehensive programmes combining the thorough adjustment of procurement instruments, technical capacity building in financing institutions, market design and commercial model improvements, etc. In some cases, adjustments to mechanisms that have been used for a long time in the systems and that were conceived exactly due to the large participation of hydropower in the electricity sys-

## 05

tem are needed. Whenever this is the case, the need to alter solutions deeply rooted not only in the text of regulatory instruments and operational procedures, but also in the personal experience and technical repertoire of individuals that participate in power system management, may represent key challenges.

Transmission grid strengthening is a crucial measure to leverage the synergies between hydropower and other renewables. First, a well-developed transmission grid, which spreads through different geographical regions, allows for capturing the geographical diversity of resources, enabling the joint operation of different renewable generation technologies in the same physical system and in the same market. Second, sufficient transmission capacity is necessary to accommodate changes in the electricity flows –either sudden changes associated with short-term variability of generation, or seasonal changes. Also, strong interconnections between countries allow cross-border electricity exchanges, enabling more flexibility by integrating markets.

Complementarities between hydropower and other renewable energy technologies exist at every stage of the power system's *expansion* and *operation*. There are, however, challenges in valuing them, and sometimes the right incentives are not in place. Even though many Latin American countries are uniquely positioned to exploit these complementarities, there are still opportunities to improve and adapt policy and regulatory conditions. Policy makers can take a number of key actions to obtain a truer valuation of the complementarities between hydropower and other renewable energy technologies.

The main action from the point of view of *system expansion* is to fully internalise the value of these complementarities when deciding which projects will be implemented. This applies irrespective of whether a central planning agency makes this decision, or if it is made by agents in the market. The system expansion model, the rules for new capacity procurement processes, and the evaluation of a project's economic viability by financing institutions should all take into account the value that these complementarities can bring to the system's reliability and efficiency. In many of the

countries, the value of structural flexibility in the system as a means to deal with short-term events, such as the short-term fluctuations in the output of variable renewable energy technologies, is not fully assessed and quantified during the system expansion processes. Traditionally, the flexibility of hydropower plants with reservoirs made it possible to deal with these short-term events at low costs.

A key action for policy makers is the modernisation of planning methodologies for the expansion of both transmission and generation. Transmission, crucial for exploiting the complementarities of hydropower and other renewables, is centrally planned in almost all Latin American countries. With generation, the economic signals sent to power plant developers in a procurement process (e.g., auction) and the guidelines of the capacity adequacy mechanism should internalise the value of complementarities. Policy makers can ensure this through careful design of the mechanisms for comparing projects and choosing auction winners, or by correctly defining the rewards of reliable generation in the capacity adequacy mechanism, in order to take beneficial synergies into account.

In the project implementation stage, circumstantial imbalances between supply and demand caused by construction delays (e.g., in large hydropower plants) can be partly overcome by the fast implementation of modular renewable technologies. By creating mechanisms to monitor the implementation of large projects, policy makers and regulators can allow for early identification of the delays that ultimately result in system imbalances. Guidelines and standards to facilitate prompt procurement of modular non-hydropower renewable systems, as soon as the first signs of delay are observed, should be developed.

*System operation* also affects the proper internalisation of the value of complementarities. For instance, the value of flexibility, particularly the fact that hydropower plants with large reservoirs can cost-effectively counteract the short-term variability of other renewables, should be internalised not only in the expansion planning and procurement processes, but also during the op-

eration stage. It does not suffice to build power plants in such a way that bestows the market and the system with the ability to take advantage of this complementarity. It also is necessary to ensure that the operation procedures and the short-term market rules will incentivise hydropower plants to deliver this behaviour when the system needs it, in real time.

Policy makers can catalyse the improvement of operating procedures by issuing guidelines for system operators, making funds available for capacity building programmes or acquiring modern software tools, both for long- and short-term operation. In addition, policy makers can implement market rules that directly or indirectly incentivise power plants to fully exploit the complementari-

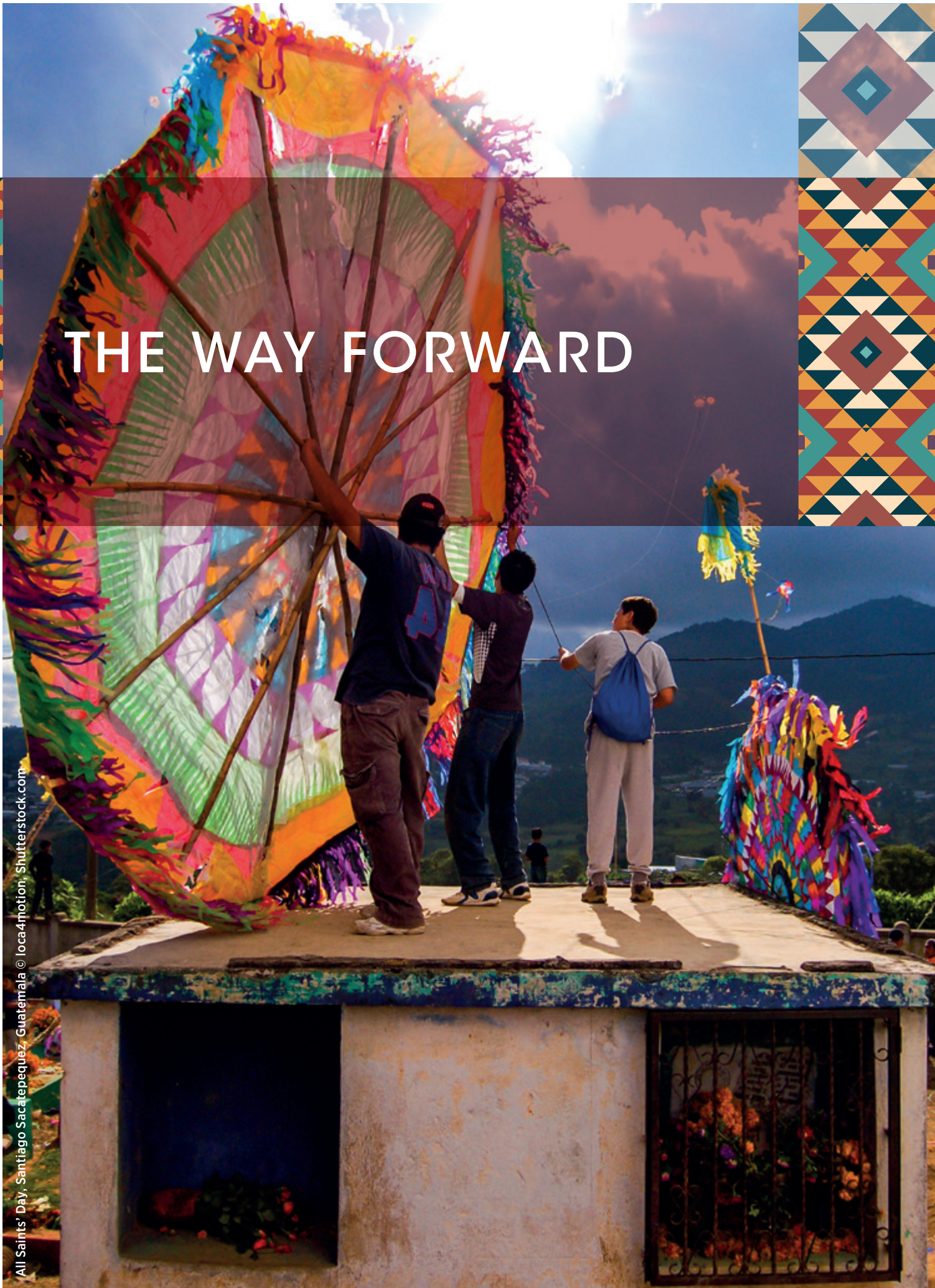
ties between technologies. For instance, *ex post* price schemes and shorter trading intervals better reflect the actual supply and demand conditions, helping to more accurately remunerate hydropower plants with reservoirs for their ability to quickly adjust their output in response to short-term supply-and-demand fluctuations in the system. The commercial model for the procurement of ancillary services should incentivise the construction of generators that are able to provide flexibility to the system. A competitive process to establish prices for ancillary services may provide stronger incentives than a model based on cost reimbursement. Figure 5.8 summarises the challenges and key actions for valuing complementarities at each stage.

**Figure 5.8** Hydropower and other renewable technologies in Latin America: taking advantage of complementarities

Stage	Challenges	Key actions from policymakers
EXPANSION	<p><b>Planning</b></p> <p>Ensure that expansion alternatives are compared and the best solutions are selected, under full internalisation of the value of complementarities of hydropower and other renewables.</p>	<p>Establish guidelines and methodologies for the development of planning procedures. Roll-on programs targeted at modernising methodologies and tools used by planners.</p>
	<p><b>Procurement</b></p> <p>Ensure that the rules for comparing candidate projects in competitive procurement processes result in the full internalisation of the value of complementarities.</p>	<p>Design procurement processes that include mechanisms to internalise the value of the complementarities, thus sending the right economic signals to power plant developers.</p>
	<p><b>Financing</b></p> <p>Ensure that financing institutions properly value complementarities while evaluating the economic viability of projects.</p>	<p>Roll out capacity building programs for public financing institutions. Establish guidelines for evaluating the viability of hydropower and other renewables, making such guidelines accessible to all financing institutions.</p>
	<p><b>Implementation</b></p> <p>Adjust the circumstantial imbalances between supply and demand, efficiently using modular non-hydropower renewables to do so.</p>	<p>Create mechanisms to allow early identification of implementation delays of large scale projects (including hydropower). Develop guidelines and standards for using modular non-hydropower renewables with short construction times to restore balance.</p>
OPERATION	<p><b>Op. procedures</b></p> <p>Ensure that system operators manage existing assets extracting as much value as possible from complementarities.</p>	<p>Issue guidelines for system operators in order to improve operation procedures, make funds available for capacity building programs and acquire modern software tools that better represent short-term dynamics and the uncertainty associated with the generation of variable renewables.</p>
	<p><b>Market rules</b></p> <p>Ensure that market prices provide the most efficient economic signals to developers of both hydropower and other renewables, to evoke efficient behaviour from these agents.</p>	<p>Implement market rules that result in the value of complementarities being internalised in price signals (e.g., <i>ex post</i> pricing, use of high-resolution trading intervals, adequate procurement of ancillary services).</p>

# THE WAY FORWARD

All Saints' Day, Santiago Sacatepequez, Guatemala © loca4motion, Shutterstock.com





**R**enewable energy investment in Latin America amounted to USD 16.4 billion in 2015, about 6% of the global total. The region is also home to 8% of the global population and contributes around 9% to global GDP. The most attractive renewable energy markets in the region demonstrate that beyond regulatory transparency and stability as critical pre-requisites for investment, there exists a diversity of market models. The region's top renewable energy investment destinations include Brazil and Chile, which display relatively high degrees of liberalisation in the power sector. Other strong performers include Mexico, in the midst of a liberalisation process, as well as Costa Rica and Uruguay, which have vertically integrated utilities and allow independent power producers.

Latin America's policies and achievements bring valuable insights for other renewable energy markets around the world. This report, like others in IRENA's regional market analysis series, has set out to consolidate knowledge on the region's decisive energy drivers and enabling frameworks for renewables. At the same time, it focuses on emerging themes intrinsic to the region's energy landscape, such as the potential for renewables in industrial heating applications and the complementarities between hydropower and other re-

newables. The analysis aims to help spread the best practices to accelerate the uptake of renewables, specifically in a region where linguistic unity and a shared history heighten the replicability of successful projects.

Looking ahead, certain themes will be central for the continued expansion of renewable energy in the region. These include catalysing public and private finance, adapting policies to dynamic market conditions, adopting a system-level approach in the power sector, harnessing complementarities across technologies, unlocking the potential for renewable sources in end-use sectors, and fully recognising the socio-economic benefits of renewable energy deployment.

### **CATALYSING PRIVATE FINANCE FOR INVESTMENT IN RENEWABLES**

Given limited public financial resources in Latin America (as in many regions), the ability to mobilize private investors will be crucial to scale up financing for renewable energy projects. While the exact characteristics of the framework for investment are country-specific, common attributes underlie successful experiences in the region. Chief among these is access to financing and the cost of finance.

■ Public domestic financing institutions, more than in other regions globally, play a crucial role in the large-scale deployment of renewable energy in key Latin American countries, offering low-interest loans and covering a large share of the demand from project developers for debt. Between 2013 and 2015, national development banks accounted for over one-third of new renewable energy project finance in the region. The roles of the Brazilian Development Bank (BNDES) and Mexico's NAFIN are remarkable in this regard, accounting for close to half of new-build renewable energy projects in those countries in 2014 and 2015, respectively. In other countries, foreign public finance institutions have played an important role. Surging investment in wind energy and bioenergy in Uruguay in 2013 was financed largely by public financing institutions from abroad, including multilateral development banks and export credit agencies, with total investment amounting to USD 1.1 billion.

■ At the global level, public investment in renewables is not expected to increase above the current level of 15%. To raise enough investment to

meet global climate goals, countries must reduce the cost of capital and catalyse large-scale private participation in renewable energy projects. From this perspective, the allocation of risks between the public and private sectors needs to be optimal. Risk mitigation instruments and other finance tools can facilitate this, helping to develop a strong pipeline of projects and to unlock private project financing and refinancing opportunities. Interesting examples exist in the region for geothermal projects, such as the Geothermal Development Facility.

■ Investment strategies need to be tailored to each phase of the renewable energy project cycle (planning, construction and operation). Project development is often overlooked when designing policies, with more emphasis usually given to the financing and operational phase, on the assumption that attractive projects will be developed anyway. Technical assistance and project development funding schemes play an important role in ensuring bankable projects.

■ Appropriate currency hedging strategies to unlock investment are similarly important, in partic-





ular to avoid short-term currency volatility that can harm nascent local industries. While dollar-denominated contracts have worked well to date (e.g., in Honduras or Peru), they do not eliminate currency risk, but simply transfer it to the public sector. For small countries, this can have a significant impact on the national budget.

- The success of any investment strategy relies on the active participation of a broad range of private and public actors, including development finance institutions, climate finance institutions, private equity funds, institutional investors, export credit agencies and green and commercial banks. One promising approach to leverage institutional investor finance and access to capital markets in Latin America would be to further develop the “financial value chain”, so that independent developers, IPPs, utilities and banks would have larger roles in construction-stage financing, allowing them to then refinance operative assets after reaching the operational stage. Examples in the region include the emergence of yieldco structures such as TerraForm Global, which holds projects in Brazil, Costa Rica, Honduras, Nicaragua, Peru and Uruguay.
- Looking ahead, climate finance, in particular the Green Climate Fund, can support the accelerated deployment of renewables in the region, both by increasing the volume of capital and offering specialised assistance to support the development of a pipeline of attractive renewable energy projects. Some activity is already taking place, such as the USD 49 million loan provided by the Green Climate Fund to a solar project in the Atacama Desert, Chile.

## ADAPTING POLICIES TO CHANGING MARKET CONDITIONS

Historically, Latin America’s renewable power policies have focused on hydropower development. Since the late 2000s, taking advantage of rapid cost declines, deployment policies have focused on non-hydropower sources. This has kick-started markets for new renewables, notably wind and, more recently, solar technologies. As deployment grows, policies in the region have gradually shift-

ed from price-based mechanisms towards greater use of quantity-based mechanisms. This better captures rapid cost declines and, increasingly, reflects the integration of growing shares of variable renewable (*i.e.*, solar and wind) power.

- FiTs have resulted in limited renewable energy development, either because they were set too low (e.g., Argentina), because the regulations to implement laws were lacking (e.g., Ecuador) or, more frequently, because an adequate enabling environment was not in place. To address such shortcomings, Latin American FiTs have become more limited in their scope, with tariffs implemented only for certain amounts of capacity with particular technologies (e.g., biomass in Uruguay and solar PV in Honduras), pre-defined price bands (e.g., Nicaragua) or specific project sizes (e.g., large-scale generation up to 200 MW in Uruguay).
- Power sector policies in the region remain dominated by auctions, with more than 54 renewable energy auctions in 12 countries as of 2015. The number of auctions has increased steadily over the past five years, pioneered by Brazil. While most auctions for renewables have been technology-specific, technology-neutral auctions have also emerged, with renewables standing up against competing technologies. Several countries in the region have developed new design features to increase the effectiveness of their auctions, both in terms of optimising cost reductions and to ensure the delivery of additional power generation, notably by taking into account connection costs. As part of this trend, many Latin American countries have started using combinations of policy instruments, including FiTs, grid access policies and clean energy certificates.
- Combinations of policy instruments reflect the unique conditions and policy goals of each country. Mexico, for example, has announced plans for its first auction, with 4 million to 6 million 20-year renewable energy certificates, in 2016. Uruguay has used an auction in 2013 for a total capacity of 206 MW to allocate small-scale solar projects (less than 1 MW or 1-5 MW), while large-scale solar projects (5-50 MW) benefit from a pre-determined FiT. Peru uses FiT design elements

in its auctions. Grid-access policies, currently in place in 13 Latin American countries, are increasingly linked with auctions. For example, Brazil has been addressing transmission issues by imposing grid access as a prequalification to bid, as seen in solar auctions in 2015.

- Increased policy attention is being devoted to decentralised applications, reflecting the region's widely distributed resource potential. Off-grid opportunities abound, for example, from the Mexican solar belt to the unequalled irradiation of the Atacama Desert. With declining costs, countries with net metering policies and high electricity retail prices, such as Chile and Brazil, are set for rapid deployment. A number of municipalities are "leading by example" on sustainability, while reducing municipal bills through the use of rooftop solar on public buildings. Policy makers and market players, closely monitoring the rapid uptake, have begun anticipating the impact of large-scale deployment of distributed energy on the region's electricity grids. The rapid adoption of net metering and distributed generation raises far-reaching issues, such as electricity rate design, cross-subsidies, income effects, reserve capacity and cost recovery.

To improve affordability and effectiveness, Latin America has also addressed structural issues related to power system design.

### APPLYING A SYSTEM-LEVEL APPROACH TO THE POWER SECTOR

As in other regions, growing shares of increasingly cost-competitive renewables call for a shift in policy priorities, from an exclusive focus on support and deployment policies towards ensuring the deeper integration of renewables with the overall design and functioning of the energy sector.

- Power sector integration could be enhanced at different levels, namely sub-national (*e.g.*, by interconnecting the northern and central Chilean power grids), bi-national (*e.g.*, the interconnection between Uruguay and Brazil, soon to start operation, or that between Colombia and Panama, currently under study), or even regional (*e.g.*,

by further strengthening the Central American integration system, SIEPAC, or developing the more recent SINEA integration initiative among Andean States). Among other benefits, increased levels of integration can allow for better incorporation of variable renewables into power systems while ensuring economies of scale for larger projects.

- In turn, market integration requires improved system operation and planning, along with expansion of transmission lines to new areas, which can also help tap into some of the best renewable resource locations. Interesting examples of improved system planning and expansion include Mexico's open-season processes, the inclusion of good-quality resource areas in Peru's grid-expansion plans, and enhanced co-ordination between transmission planning and renewable auctions in Brazil.

- A rethinking of energy infrastructure and markets is needed to foster storage and demand-side management, both of which can enhance flexibility and improve the operation of power systems with greater shares of variable renewables. Examples of storage include pumped hydropower plants in Argentina and batteries in Chile's solar thermal hybrid plant. Policy actions to foster demand-side management notably include improved pricing of electricity for consumers, reflecting all costs and more closely matching the temporal evolution of supply and demand (*e.g.*, real-time pricing).

A system-level approach to the energy sector is essential to harness complementarities between technologies and scale up all sources of renewable energy.

### HARNESSING THE COMPLEMENTARITY BETWEEN HYDROPOWER AND OTHER RENEWABLES

Ambitious deployment of renewable power generation across Latin America can leverage the multifaceted complementarities between hydropower and other renewables.

- The region already features prime examples of complementarity in renewable energy deployment. These include the use of large hydropower

plants to balance the variability of wind- and solar-based generation and increase power-system flexibility (e.g., Brazil and Costa Rica); the enhancement of technical rules for power market operation (e.g., Uruguay); and the use of shorter trading intervals to better reflect the real-time conditions of power supply and demand (as in Peru).

■ Looking ahead, a more robust, comprehensive approach to power sector management will be critical to achieving higher shares of renewable generation while improving the reliability and economic efficiency of the region's systems. Such an approach would systematically internalise the value that the complementarities between hydro-power and other renewables can bring across all stages of power system management, from expansion planning to short-term operation.

■ The main challenge from the point of view of system expansion is to fully account for the value of these complementarities when deciding which projects will be implemented, whether by a central planning agency or through the market. In system operation, existing complementarities should be internalised by all agents involved, including utilities, IPPs, system and market operators, and consumers. A well-developed electricity grid that ensures sufficient transmission capacity between distant locations and across neighbouring countries is key to harnessing these synergies in the region.

Latin America has one of the highest shares of renewables in electricity generation, which can be more widely used in end-use sectors (e.g., electric vehicles, heat pumps in the commercial and residential sectors). In addition, the region is a



leader in renewable transport fuels and holds significant potential for renewables as a source of heating and cooling in the industrial and residential sectors.

## UNLOCKING RENEWABLE ENERGY POTENTIAL IN END USES

**Industrial sector.** Given the region's existing high use of bioenergy for heat, higher shares of renewable energy can be unlocked through the direct use of renewables in high-energy consuming sectors, specifically in industry.

- The first driver for the adoption of renewable heat sources relates to competitiveness. Ensuring a constant supply of heat at a pre-defined price is essential to counter the price volatility associated with other energy sources. In particular, given the importance of the food processing, tobacco, and pulp and paper industries in Latin America, bioenergy residues from processes can be obtained with a predictable stream of supply and can be used for energy purposes. Using bioenergy residues also reduces the costs of disposing of them. This has been a driver of bagasse usage in the Brazilian sugarcane industry for years.
- A second driver is marketing, as green labelling can open new markets and add value to products. A number of Latin American companies have invested in the social and environmental sustainability of their operations and have received carbon neutrality certification for their products, allowing them to enter new international markets with a price premium on sales.
- The development of a market for renewable heat can be facilitated by a combination of appropriate business models (e.g., energy service companies) and access to specific financing solutions for industrial companies. Awareness-raising, access to information and capacity building also have an important role to play in expanding the market for renewable heat, especially for small and medium-size industrial companies that may not yet be aware of the renewable energy technologies available for heat uses. When an adequate enabling framework is in place, renewable heat can be competitive in a broad set of industries, with multiple benefits. A case in point is the Pam-

pa Elvira solar thermal plant supplying heat to a copper mine in Chile at a stable price.

**Residential/commercial sector.** Latin America also has considerable untapped potential for renewable energy heating and cooling applications in the residential and commercial sector.

- Policy support to promote renewable energy sources for heating purposes is still limited. Countries have started adopting solar thermal mandates, which are driving rapid market growth and have the potential to further unlock a significant market. Solar water heating mandates can be enacted at any level, from local to regional to national, and can be incorporated into building codes or social housing programmes. Replicability is already evident in Brazilian cities following São Paulo's Solar Ordinance, and similar municipal efforts have started in Mexico and Central America.
- Many Latin American countries are experiencing an increase in demand for space cooling. Solar air conditioning and solar thermal cooling technologies are gaining interest, with some projects already underway in new buildings in Central America and in the dairy processing industry in Mexico. This trend is likely to consolidate given the region's high urbanisation rate, with steadily rising temperatures and higher standards of living. As a result, higher electricity demand peaks can be expected, along with shifting patterns of seasonal residential demand.

The potential of renewables for heating and cooling in Latin America can be harnessed effectively through closer integration of renewable-oriented policies and energy efficiency measures, thereby developing a systemic approach for end-use sectors, *i.e.*, residential, commercial (both of which include buildings) and industry.

**Transport sector.** Latin America's growing populations and rising living standards are significantly increasing the demand for transport. Many countries could soon find themselves at a crossroads in scaling up renewables for transport: either opting for greater electrification or aggressively embracing second-generation biofuels.

- To limit reliance on imported fossil fuels, about half of Latin American countries have implement-

ed biofuel blending mandates. Although most of these focus on the private vehicle fleet, they could be expanded to other road vehicles introducing mandates for specific niches (e.g., for captive fleets such as buses or other professionally owned vehicles), or for modes other than road and sectors other than transportation. An example of the latter is the idea of introducing blending mandates for diesel used in electricity generation in remote parts of Brazil.

- However, the future trend of renewable fuels in the region is uncertain. In recent years, some countries have suspended or amended their blending mandates to prioritise food security. Several countries, including Ecuador and Costa Rica, have specific laws prioritising food over biofuel production, while Mexico restricts the use of corn for biofuel production only to those years with an official national surplus of corn.
- The potential electrification of the transport sector can open a vast market for renewable electricity and create a mechanism to mitigate the variability of some renewable technologies by absorbing power generation during periods of low demand. In Latin America, as in other regions, renewable energy policies need to prepare for future system transformation.

## INSTITUTIONAL AND HUMAN CAPACITIES

Beyond energy infrastructure and markets, a transition towards a renewables-based energy sector critically depends on sound institutions and adequate skills to ensure effective implementation.

- The 20 countries of Latin America together count at least 120 public institutions working on different aspects related to renewable energy. This multitude of institutions is a manifestation of the dynamism of the sector, as well as of the important role of the public sector in renewable energy development in the region.
- Clear institutional roles and responsibilities are an essential dimension to enable renewable energy investors to adequately assess the time and resources needed for project evaluation, permitting and licensing. Such clarity can reduce transaction costs and make projects more attractive.

An adequate institutional framework goes hand in hand with clear, transparent and streamlined administrative procedures for renewable energy projects. This encompasses a wide array of procurement formalities, environmental and social licensing, applications for land use and other permits, submissions for tax exemptions, and other procedures. Given the diversity of stakeholders involved (e.g., energy policy makers, regulators, utilities, investors and consumers), co-ordination is of utmost importance. Dedicated renewable energy institutions perform a key function in this regard.

- Institutions and other stakeholders require a growing number of trained renewable energy professionals. Human capacities, in terms of both quantity and competencies, can be developed through targeted capacity-building programmes and initiatives. From policy-making and regulatory design to project preparation, evaluation, financing, development and implementation, specific skills are essential in government ministries, regulatory agencies, financing institutions, utilities and other actors. Planning needs to integrate education and training policies within national renewable energy strategies, as some countries in Latin America have already demonstrated. Mexico's Strategic Programme for Human Resource Training in Energy provides one example.

- Looking ahead, Latin American countries, like many countries globally, need to anticipate skills gaps and devise renewable energy training and education strategies accordingly. These may include strategic planning to meet the demand for specific skills, fostering partnerships between academia and industry, integrating renewable energy into curricula and providing financial support for training programmes. Vocational training creates opportunities for people to obtain a specialisation and participate in the growing renewable energy job market.

## TAKING FULL ACCOUNT OF SOCIO-ECONOMIC BENEFITS

**Local value creation.** Investment in renewables brings a range of socio-economic benefits, including income generation, industrial development and job creation.

■ Renewable energy deployment can stimulate local industrial development and diversify economies, especially when synergistic industries already exist. Strengthening domestic capabilities and encouraging the development of local industries can help maximise the benefits of deploying renewables. As a result of increasing renewable energy deployment, new markets will emerge at the regional and sub-regional level, creating new trade flows while creating opportunities for countries to localise different segments of the value chain for various renewable energy types. Latin America already has full value chains for the most established technologies (liquid biofuels, biomass for both heat and power, and hydropower), and is actively developing wind and solar value chains.

■ In Brazil, the regulations and incentives established alongside renewable energy deployment policies have contributed to the creation of a domestic wind supply chain that now employs more than 40,000 people, thanks to the establishment of ten factories along the wind supply chain. Solar heating in the region also employs close to 40,000, mostly in Brazil, where the solar heating market has expanded strongly in the past decade. This sector is expected to grow considerably as solar heating policies are established in an increasing number of Latin American countries.

■ Looking ahead, cross-cutting policy interventions, aimed at creating an investment-friendly environment, foster industrial clusters, strengthen domestic firms and facilitate technology transfer, can underpin greater volumes of renewable energy equipment manufacturing in the region. This is an attractive proposition in those countries that have focused their economic development on exporting commodities, and where the contribution of manufacturing to GDP is below the level of similar countries around the world. In those countries with higher participation of manufacturing industries in their GDP, such as Mexico, renewable energy can create opportunities for diversification and the establishment of new, innovative firms and activities.

## Off-grid renewables

The socio-economic benefits of renewables are not limited to the large-scale developments normally located in or serving urban areas; similar benefits occur in the rural context. Latin America is close to achieving universal energy access, with 95% electricity access (99% urban and 82% rural) and 85% of the population using modern fuels for cooking. Yet across the region, 56 million people still rely on traditional uses of biomass for cooking and heating, while more than 15 million lack access to electricity, most of them living in Andean or Central American countries.

■ Providing access to unserved communities in Latin America will require a combination of solutions, including grid extension and off-grid renewables, which include both mini-grids and stand-alone systems. Off-grid renewable solutions can be deployed rapidly and can be tailored to local needs, and are particularly relevant in Latin America's remote rural areas, where grid extension is not viable either technically or financially. Recent cost reductions make renewable energy technologies the most competitive option to expand electricity access in rural areas with high-quality resources. Examples include solar PV in the Andean highlands, and wind or micro- or mini-hydropower in mountainous areas, notably in the Andean sub-region or in the Amazon. Rural electrification strategies in the region increasingly integrate dedicated off-grid renewable policies.

■ Renewable energy-based off-grid electrification, when supported by adequate access policies, can stimulate small-scale economic activity and entrepreneurship. Looking ahead, the development of complete supply chains in some Latin American countries, in particular for solar PV, can benefit off-grid renewable development and can improve the sustainability and operational viability of systems by disseminating related technical skills for improved quality, operation and maintenance at the local level.

■ For households relying on the traditional use of solid biofuels for cooking, improved cookstoves represent a key solution to increase combustion efficiency, decreasing forage and reducing indoor

air pollution. Some countries, such as Mexico and Peru, have longstanding cookstove programmes, while in Central America several countries are developing such programmes. Looking ahead, more attention can be given to improved cookstoves as a simple, low-cost solution while taking into consideration fuel-switching policies to promote more efficient fuels.

Rapid cost reductions, maturing technologies and more advanced markets, as well as the rapid

evolution of policies, present a unique opportunity for Latin America to accelerate the uptake of all uses of renewables. High shares of renewables are already seen in the power, heating and transport sectors, and the transformative potential of new technologies is increasingly recognised. Latin America has begun, therefore, to rethink its energy mix. The opportunity is at hand to boost energy security, fuel economic growth in a sustainable manner, and drive economic development for future generations.



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## LATIN AMERICA



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