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DOCUMENT OF THE INTER-AMERICAN DEVELOPMENT BANK

ENERGY SECTOR FRAMEWORK DOCUMENT

ENERGY DIVISION

OCTOBER 2018

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ABBREVIATIONS AND ACRONYMS

AFOLU	Agriculture, Forestry and Other Land Use
bcm	Billion Cubic Meters
BEV	Electric Vehicles with Batteries
BNEF	Bloomberg New Energy Finance
BoS	Balance of System
C2F	Canadian Climate Fund for the Private Sector in the Americas
CAF	*Banco de Desarrollo de América Latina* (Development Bank of Latin America)
CCS	Carbon Capture and Sequestration
CO_2	Carbon Dioxide
CRGs	Contingent Recovery Grants
CTF	Clean Technology Fund
DEM	Development Effectiveness Matrix
ECC	Eastern Caribbean Countries
ECLAC	Economic Commission for Latin America and the Caribbean
EE	Energy Efficiency
EER	Energy Efficiency Requirements
EIA	Energy Information Administration, Department of Energy, USA
EPC	Engineering Procurement and Construction
ESCO	Energy Services Company
ESPC	Energy Services Performance Contract
EU	European Union
FAO	Food and Agricultural Organization
FM	Fund Manager
GE	Geothermal Energy
GEI	Global Energy Institute
GHG	Greenhouse Gas
GWh	Gigawatt hour
ICE	Internal Combustion Engine
ICT	Information and Communications Technologies
IDB	Inter-American Development Bank
IDBG	Inter-American Development Bank Group
IEA	International Energy Agency
IET	Institute of Engineering and Technology
IFC	International Finance Corporation
IHA	International Hydropower Association
IISD	International Institute for Sustainable Development
IPCC	Inter-Governmental Panel on Climate Change
IPPs	Independent Power Producers
IRENA	International Renewable Energy Agency
Km	Kilometer
kWh	Kilowatt hour
LAC	Latin America and the Caribbean
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
MIF	Multilateral Investment Fund
MVA	Mega-Volt-Ampere
MWh	Mega Watt hour

NCRE	Non-Conventional Renewable Energy
NDC	Nationally Defined Contributions
NDCs	Nationally Determined Contributions
NOx	Nitrogen Oxides
NSG	Non-Sovereign Guarantee
O&M	Operations and Maintenance
OECD	Organization for Economic Co-operation and Development
OLADE	*Organización Latinoamericana de Energía* (Latin American Energy Organization)
PM	Particulate Matter
PNESER	National Program for Sustainable Electrification and Renewable Energy
PPA	Power Purchase Agreement
PPP	Public-Private Partnerships
PV	Photovoltaic
RBI	Results Based Incentive
RE	Renewable Energy
REN21	Renewable Energy Policy Network for the 21st Century
SE4All	Sustainable Energy for All
SFD	Sector Framework Document
SEF	Sustainable Energy Facility
SG	Sovereign Guarantee
SIEPAC	Central American Electrical Interconnection System
SINEA	Andean Countries Interconnection
SO_2	Sulfur Dioxide
SPVs	Special Purpose Vehicles
TC	Technical Cooperation
TCG	Total Credit Guarantee (TCG)
UN	United Nations
UNDP	United Nations Development Programme
UNIDO	United Nations Industrial Development Organization
US	United States
US$	United States Dollars
WB	World Bank
WEF	World Economic Forum
WHO	World Health Organization

EXECUTIVE SUMMARY

Radical technological changes are taking place in the Latin America and the Caribbean (LAC) region's energy sector, affecting the way we produce and consume energy, the type and amount of fuels we use, the infrastructure needed to have it available, and the interactions among actors in the different value chains involved. All these changes are creating multiple opportunities, but also posing many challenges. This update of the Inter-American Development Bank's (IDB) Energy Sector Framework Document maintains the structure of the original document, with its four pillars: (i) energy access –coverage, quality, reliability, and affordability in the provision of energy services; (ii) energy sustainability –energy efficiency (EE), renewable energy (RE), climate change mitigation and adaptation, and reduction of environmental impacts in the long term; (iii) energy security –energy infrastructure and regional energy integration for the provision of reliable services; and (iv) energy governance –institutions, regulation, policies, and information enabling the sector's long-term economic and financial sustainability. The treatment given to each of the pillars is based on the causes and consequences of these changes.

Access. Access has two dimensions: to electricity and to modern cooking fuels. LAC has increased its level of access to electricity in a very significant way. Between 2000 and 2016, the proportion of the population with access to electricity went from 88% to 97%, getting closer to achieving universal service by 2030. In the past, moving beyond 95% was more difficult and expensive because the favored mechanism, grid extension, had very significant costs to connect dispersed populations. New technologies allow renewable energy to serve remote users with mini-grids and individual solutions, with backup from diesel generation. The use of clean cooking, however, still lags. In spite of significant progress –the ratio of kerosene or solid biomass use has decreased from 19% to 12%, between 2000 and 2015– 59 million people still depend on them. Progressive electrification is one solution, as electric stoves could replace firewood, charcoal and animal dung, but they are relatively expensive. Alternatively, efficient cookstoves could reduce the negative impacts of the use of unsustainable biomass, but there are social habits that limit their use.

Sustainability. Non-Conventional Renewable Energy (NCRE) has seen a dramatic drop in the costs of wind and solar photovoltaic (PV) generation, lowering the economic scale of projects. Similarly, information and communication technologies allow for better coordination and greater flow of information and are available everywhere across a variety of platforms. Together, they create more opportunities to consumers to have an active role in managing their own consumption and production of energy. These opportunities will continue to expand with electricity storage. Wind and solar PV technologies are becoming more mature, and cost reductions will be more nuanced, but continued drops in the cost of electric batteries can modify the generation landscape, mitigating the largest drawback of non-conventional sources, that of output variability.

The continued reduction in the cost to generate electricity from renewable sources has an additional benefit –fewer greenhouse gas emissions. The electricity sector has traditionally been a significant contributor to emissions, accounting for about one-third of total global emissions. Yet, electricity is increasingly replacing other fuels– electric heat pumps are replacing fossil fuels for heating purposes, and electric vehicles are expected to become dominant within a few years, providing opportunities to achieve greater emission reductions. With greater EE, both from the supply and demand sides, and technological adaptations to shift loads, consumption and emissions could be reduced simultaneously without compromising comfort and productivity.

Security. Demand in LAC is expected to continue to grow, among other factors because more people are joining the middle class and the global trend in the electrification of energy is taking hold in the region. Infrastructure needs to keep pace with this growth, with larger requirements from higher quality in energy services. The participation of distributed generation will put additional pressure on the grids –an indication that the "cable business" will continue to have a very important, although different role. In a system with a large penetration of distributed renewable generation, where substantial amounts of power flow in multiple directions, the exchanges will occur at the grid. The cable business model needs to be sustainable, but the current payment by volume sales methodology might no longer be appropriate. New regulatory and even institutional models need to be developed far in advance to allow for a smooth transition to a high-penetration of renewables. The importance of regional energy integration will also grow, as many opportunities to reduce costs from greater efficiencies arise from the diversity of loads, patterns of consumption, and country endowments. NCRE will only boost these opportunities, becoming critical to the efficiency, stability and reliability of the electricity systems. In addition to traditional electricity interconnections between neighboring countries, small island nations in the Caribbean can link themselves with undersea links, as well as spook-and-hub Liquefied Natural Gas (LNG) delivery.

Governance. For the energy sector to be economically, socially and environmentally sustainable, the regulatory, legal and institutional frameworks need to adapt to the new technologies and business models, endorse greater private participation, and promote innovation Regulations should be drawn based on desired objectives, not on currently available technologies. As technologies age, so will regulations which, if not updated, could lead to inefficiencies. A new regulatory framework needs to incorporate approaches such as: (i) behavior tools to nudge players toward a better performance; (ii) regulatory impact assessment; and (iii) ex post evaluation to keep track of the effects of policies and regulations in a context of constant technological change. The current business model may become unsustainable within the next ten years, but there are some steps that electricity companies can take to adapt to the new situation. Incentives for renewables need to be carefully re-evaluated periodically, considering externalities, costs curves, and market distortions. Additionally, public and private utilities need to adapt to the new technologies, offer innovative hardware and software resources and offer innovative services to the new *"prosumer"*.

How is LAC affected? Energy-wise, LAC is the cleanest region in the world, but the participation of renewables in its energy matrix has been falling in recent years. Non-conventional renewables provide an opportunity to boost the participation of green technologies and provide access to energy services in a more environmentally, economically and socially sustainable way. Many countries in the region need to strengthen their electricity infrastructure not only to boost service quality but also to cope with additional demand from new services and new loads, such as transport and heating. Although electricity access is relatively high, there are opportunities to technological leapfrogging, in particular to off-grid systems in rural and remote areas.

What is the IDB role in LAC's Energy Sector? To provide knowledge-based support to countries, via Technical Cooperation (TC), policy dialogue, or with policy-based financial products; to assist countries in the identification of weaknesses in their energy grids; to provide advice on state-of-the-art technologies, best practices, and experiences from other countries in the region; and to engage in regional and in-country policy dialogue with policymakers, regulators, and other industry participants, fostering consensus on policy options.

What does the IDB need to do to better serve its member countries? Strengthen multisector work and multiagency work with other institutions both in knowledge and financing services, bring best practices to the region together with other multilateral agencies, disseminate and support new regulations more consistent with technological changes, and adopt innovative models to promote energy access in isolated areas.

I. THE SECTOR FRAMEWORK DOCUMENT IN THE CONTEXT OF CURRENT REGULATIONS AND THE INSTITUTIONAL STRATEGY 2010-2020

A. The Energy Sector Framework Document as part of existing regulations

1.1 This document supersedes the Energy Sector Framework Document (GN-2830-3), approved by the Operations Policy Committee in 2015, in accordance with the provisions outlined in the document "Strategies, Policies, Sector Frameworks and Guidelines at the IDB" (GN-2670-1), paragraph 1.20, that indicates that the Sector Framework Documents (SFD) shall be updated every three years.[1]

1.2 This SFD places more emphasis on areas where significant changes have happened since the previous version of the document: (i) technological changes occurring with non-conventional renewable generation, in particular in the areas of solar photovoltaic (PV) and wind; (ii) very significant reductions in the cost of these technologies, as well as electricity storage, which is reaching parity with conventional technologies; (iii) information and communication technologies that are allowing a dramatic increase in the generation, digitalization, transport, processing of information and automation of decision making processes; (iv) the urgent need to address climate change, including expanding the use of adaptation and mitigation strategies, and creating new approaches; (v) the relevance of the sector in terms of its contribution to productivity and well-being; (vi) an integrated planning to achieve an orderly transition from the current state of the industry; and (vii) given the very long period of time between the initial stages of planning and the final outcomes, there is a certain urgency in starting to incorporate these concepts in the different links of the industry's value chain. These changes are having, and will continue to have, implications on the behavior of the sector's main actors. The institutional and regulatory environments, therefore, will need to be adjusted at a faster pace; knowledge generated elsewhere will need to be adapted, and new knowledge will need to be generated to face these challenges.

1.3 This document is one of the 20 SFDs prepared within the scope of document GN-2670-1, together, they provide a comprehensive vision of the region's development challenges. Energy[2] has a cross-cutting impact on many IDB activities, and in turn, depends on the products and knowledge from other sectors. This SFD complements other SFDs including: (i) Agriculture and Natural Resources Management; (ii) Integration and Trade; (iii) Urban

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[1] To update the previous Energy SFD, consultations were made internally at the Inter-American Development Bank Group (IDBG) with specialists from the Energy Division, IDB Invest, and Climate Change and Sustainability. Our own experience in the continuous dialogue with our counterparts, the multiple training opportunities, the extensive research that we do as part of our work and our involvement in the operations distilled what are the greatest challenges that the region faces and how they should be addressed. Externally, consultations with multiple experts from Europe, the United States and the region acquainted us with the latest trends and with what might happen in the short and medium term. We concluded that most of the recommendations made in the previous SFD are still valid, as much of the evidence gathered and analysis made continue to be relevant and therefore should be treated as complementary.

[2] For purposes of this document, the energy sector is understood as the set of economic activities related to the use of resources (both from renewable and non-renewable sources) for the production, delivery, consumption and optimization of energy use (i.e. through measures of Energy Efficiency [EE] and conservation) in its various forms (i.e. as electricity, heat, or in the form of fuels for further processing). It is recognized that coverage, quality, sustainability, reliability and affordability of energy systems and services for cooking and heating, lighting, transportation, communications and other productive and residential uses, are critical factors for economic growth, social inclusiveness and quality of life. While a great amount of energy is used in transport, this document does not address this sector, except as its reference to the infrastructure needed to facilitate electric mobility.

Development and Housing; (iv) Tourism; (v) Transportation; (vi) Water and Sanitation; (vii) Innovation, Science and Technology; (viii) Environment and Biodiversity; (ix) Climate Change; and (x) Gender and Diversity with respect to integrated management of resources for climate change mitigation and adaptation, behavioral changes, multisector approach, tourism activities, technological change, incorporation of gender in both supply and demand as a specific area of focus, integrated water resource management, and the importance of safeguards for energy operations. The Policy and Fiscal Management SFD also complements this SFD, especially as it refers to the fiscal impact of subsidies.

1.4 The Energy SFD is aligned within the Strategy for Sustainable Infrastructure for Competitiveness and Inclusive Growth (GN-2710-5). It requires the provision of basic efficient and sustainable services and the development of infrastructure that contributes to economic growth through universal access to energy services, innovative financing mechanisms, and promotion of private sector involvement. Also, energy sustainability requires quality services. Therefore, infrastructure needs to be planned, built, and maintained within an environmentally, economically and socially sustainable framework, with better governance, greater efficiency, and more multisector interventions. Under this strategy, infrastructure is the means to provide quality services that foster sustainability and inclusive growth in the countries, reduce income gaps, and contribute to the mitigation of climate change.

1.5 The Energy SFD is aligned with the Integrated Strategy for Climate Change Adaptation and Mitigation, and Sustainable and Renewable Energy (RE) (GN-2609-1), as it seeks to contribute to the institutional priority of protecting the environment, adapting to climate change and promoting the reduction of Greenhouse Gas (GHG) emissions. The document is also aligned with the Public Utilities Policy (GN-2716-6) goals in that it: (i) promotes access to electricity and modern cooking fuels for the entire population; (ii) encourages service efficiency; (iii) fosters continuous improvements in the sector's governance; and (iv) promotes innovation and financial and environmental sustainability.

1.6 The SFD is indicative rather than normative. Its application, both in the design and in the execution of operations, will consider each country's specific circumstances and needs, as well as the goals of key regional energy integration initiatives. The Energy SFD is also consistent with: (i) the Sector Strategy for Institutions for Growth and Social Welfare (GN-2587-2), particularly with regards to management and financing of the public sector, since the provision of public services, in terms of quality and quantity, depends largely on the capacity of the public sector to mobilize resources and ensure they are used with maximum efficiency while reducing transaction costs; and (ii) the Sector Strategy to Support Competitive Global and Regional Integration (GN-2565-4) through the development of regional platforms for market integration of services: (a) interconnection of national electricity systems; (b) development of regional pipelines; and (c) the planning and project financing of joint bi-national or regional energy projects.

1.7 This SFD establishes that Bank actions will strengthen the region's energy sector, enabling its efficient, accessible, inclusive, sustainable, and secure operation. All IDB actions will promote poverty reduction, improvements in the quality of life of the region's population, economic development, and regional integration.

B. The Energy Sector Framework Document and the IDB Institutional Strategy

1.8 The Energy SFD is consistent with the Update to the Institutional Strategy 2010-2020 (AB-3008) that recognizes social inclusion, equality, productivity, innovation, and the impacts of the effects on climate change as challenges for structural and emerging development in the region. The Institutional Strategy also raises three crosscutting development issues that the interventions can potentially address such as: (i) gender equality and diversity; (ii) climate change and sustainability; and (iii) institutional capacity.

II. INTERNATIONAL EVIDENCE ON THE EFFECTIVENESS OF ENERGY POLICIES AND PROGRAMS AND THEIR IMPLICATIONS FOR THE IDB'S WORK

2.1 The United Nations (UN) General Assembly unanimously recognized that energy is the golden thread that connects economic growth, increases social equity, and an environment that allows the world to thrive. It has declared 2014-2024 as the decade of Sustainable Energy for All (SE4All). SE4All has the following three objectives by 2030: (i) reach universal access to modern energy services;[3] (ii) improve EE at double the current global rate;[4] and (iii) double the share of RE in the global energy mix (UN General Assembly, 2013). To achieve these goals in a financial, social, economic and environmental way, a solid set of norms, regulations, procedures, and methodologies, supported by a highly qualified group of people and well-endowed institutions is needed. This Energy SFD is based on these three objectives and adds a fourth one, requiring that institutional resources and necessary capacities are in place to plan and execute the actions required to achieve an efficient, effective and sustainable energy sector.

2.2 The actions are presented along the following thematic lines, or pillars, which are of relevance for the IDB's energy sector work. These pillars have been determined based on the region's energy challenges, are inter-related, and have different relevance to each country:

a. **Energy access** – coverage, quality, reliability, and affordability in the provision of energy services.

b. **Energy sustainability** – EE, RE, climate change mitigation and adaptation, and reduction of environmental impacts in the long term.

c. **Energy security –** energy infrastructure and regional energy integration for the provision of reliable services.

d. **Energy governance** – institutions, regulations, policies, and information to foster the sector's long-term economic and financial sustainability.

2.3 This section presents the major issues in the energy sector and available international evidence regarding the effectiveness of energy policies and interventions, as well as their

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[3] Access to modern energy is defined as access to electricity and cleaner and improved cooking facilities and fuels (International Energy Agency-IEA, 2010).

[4] According to the IEA, EE is a way of managing and restraining the growth in energy consumption. Something is more EE if it delivers more services for the same energy input or the same services for less energy input (see EE).

impact on economic and social development. At the same time, this section discusses the transitions and innovations under way in the sector, where evidence is limited.

A. Energy Access – Coverage, Reliability, and Affordability

2.4 Access to energy is essential to economic and social development. Access has two dimensions: to electricity and to modern cooking fuels. The LAC region has dramatically increased its level of access to electricity. Between 2000-2016, the proportion of the population with electric service went from 88% to 97%, getting closer to achieving universal service by 2030.[5] In the past, moving beyond 95% was more difficult and expensive because the favored mechanism, grid extension, had very significant costs to connect dispersed populations. New technologies allow RE to serve remote users with mini-grids and individual solutions, with back-up from diesel generation, and in the not so distant future, with batteries. The use of clean cooking, however, still lags. In spite of significant progress –the ratio of kerosene or solid biomass use has decreased from 19% to 12%, between 2000 and 2015– 59 million people still depend on them. Progressive electrification is one solution, as electric stoves could replace firewood, charcoal and animal dung, but they are relatively expensive. Alternatively, efficient cookstoves could reduce the negative impacts of the use of unsustainable biomass, but there are social behaviors that limit their use.

2.5 **Access to electricity.** Very significant advances have been made in access to electricity services around the world. Between 2000-2016, the number of people without access to electricity fell to 1.1 billion from 1.7 billion. If this trend continues, it could drop a further 40% by 2030. In the period 2012-2016, more than 100 million people per year started receiving electricity service, a significant improvement from 62 million people per year in the period 2000-2012 (International Energy Agency-IEA, 2017a). The access deficit worldwide is overwhelmingly rural, where 87% of people had no electricity in 2012 (World Bank-WB and IEA, 2015).

2.6 Most of the new access to electricity was through new grid connections, but with the power generated using fossil fuels. In the last five years, however, 34% of new connections were made with RE through off-grid and mini-grid systems, and this shift is expected to accelerate. By 2030, it is expected that 60% of the new connections will be with non-conventional renewable energy (NCRE), and almost half will be connected with off-grid and mini-grid systems. To achieve these results, more than US$50 billion must be invested annually throughout the world (IEA, 2017a).

2.7 People lacking electricity live in rural areas, are more dispersed, and have lower incomes (Jiménez, 2016). According to the Global Tracking Framework Report, these gains were made almost totally through the provision of electricity services to rural communities, (WB, 2017; *Organización Latinoamericana de Energía-OLADE* database). These advances will continue, and LAC will achieve 99% electricity coverage by 2030 according to the IEA (2017). These gains will be achieved by the traditional means of grid extension, but increasingly by off-grid and mini-grid connections based on hybrid systems combining diesel plants and solar PV panels. As storage costs continue to drop, integrated PV-battery systems will substitute diesel and PV-diesel hybrid generations.

2.8 LAC countries have raised electricity coverage substantially through both grid extension and isolated or off-grid renewable technology programs, reaching 97% in 2016 from

[5] Data from World Bank Development Indicators and Global Tracking Framework.

88% in 2000. Still, 22 million people lack electricity access. Brazil's *Luz para Todos* Program has provided electricity to 15 million people since 2003, reaching almost 100% coverage, while Peru increased national coverage from 64% to 95% from 2000 to 2016, although 1.5 million people still remain without access to power (OLADE, 2017).

2.9 There is a trade-off between off-grid systems and grid extensions. While the former is often less costly, they also tend to be less reliable and with a limited amount of available power. Selection of one over the other will depend on multiple variables, including the availability of roads, geographical conditions and the availability and seasonality of renewable resources, particularly small hydro or plants that use agricultural waste, as well as the level of demand, and the distance to and the architecture of the existing grid.[6] A solution that has often been used in the past is the installation of hybrid systems, combining RE with diesel generation (International Renewable Energy Agency-IRENA, 2016). While these systems tend to be more reliable, they have their downsides too: they require hauling diesel fuel over long distances. Also, when diesel for off-grid systems is subsidized, there is a risk of it being deviated to other uses.

2.10 Off-grid systems can provide distinct levels of service, ranging from an individual solution of a solar lantern that can charge a cellphone, to small- and medium-sized systems serving production facilities, such as for wood and fish processing and small clinics and schools. Basic services such as lighting, heating, cooling and cooking, and running small appliances are already being served by grids based exclusively on renewable generation. Services can be expanded with high-efficiency equipment, such as light-emitting diode lighting or with the increasingly available direct current appliances. For full-service grids, however, diesel plants will still be necessary until the costs of solar PV and batteries reach parity in performance (IRENA, 2015, 2016). IRENA (2016) forecasts that by 2025, with the expected continued drop in solar panels costs, advanced control systems, and energy storage, PV will replace diesel plants. Currently, mini-grids providing service 24 hours a day include both diesel and renewable generation. In these designs, the optimal fraction of renewable energy is 60% renewable and 40% diesel, having a production cost of US$0.45/kWh in 2015. In 2025, the proportion could grow to 90/10%, with a cost of US$0.30/kWh, depending on the quality of the resource, diesel transport costs, and the price of the battery and the PV system.

2.11 A close technical and institutional coordination between on-grid and off-grid electrification is needed. On one hand, uncertainty over where and when the grid will extend, is a powerful disincentive to private entrepreneurship for individual stand-alone and mini-grid supply (Fairley, 2017). On the other, future connection of mini-grid and distributed generation investments with the expanding grid must be carefully analyzed and planned for, and adequate institutional capacity and coordination are needed to perform this function. A long-term, comprehensive national policy with dedicated institutional structures would be better equipped to address the trade-offs between both modes to either accelerate a connection or to boost power supply quality. As the national grid tends to increase its coverage, the off-grid systems might provide interim solutions, so they need to be designed to allow their connection to the national grid. Both modes of electrification have strengths, and through the course of a nation's economic development and upgrading of infrastructure, except in the most remote locations, the goal is that the connection is made through the national grid. Rural electrification should incorporate detailed cost estimates, household level spatial data, and rapid comparison of available

[6] In some countries existing grids have been overextended, affecting service quality. To prevent this, it is advisable to upgrade the grid before it is extended. To this end, off-grid solutions are the only available option.

technologies to help decide whether grid expansion or off-grid options is more appropriate. This in turn requires a significant amount of data that might not be readily available.

2.12 **Social and economic benefits of electricity.** Evaluations of rural electrification programs worldwide have identified and quantified private welfare gains, including more hours for indoor activities, a higher educational attainment conducive to higher earnings, better levels of employment, information benefits from watching television, and higher productivity in business activities (Jiménez, 2017). Assessments have consistently shown that willingness to pay for lighting alone is higher than the costs to supply the service. Public benefits that have been identified, albeit not quantified, include an increased sense of security, greater opportunities for social activities, and improved health and education facilities (Feron, 2016).

2.13 Benefits of electricity access identified by beneficiaries in poor urban and peri-urban areas include: (i) reduced expenditures from paying lower prices for energy; (ii) health benefits from reduced indoor pollution from wood, charcoal and kerosene use; (iii) improved household safety because of fewer fires and better light at night; (iv) better security from street lighting; and (v) more investment in housing improvements as security improves. The benefits are not limited to households only, but also include significant impacts to the communities (van de Walle, 2017). Additional investments have been shown to be necessary to capture the development benefits of rural electrification. Productive-use programs can help increase income generation (e.g., the processing of agricultural goods or crafts for sale), thus giving communities a means to pay for energy (Valencia and Caspary, 2008).

2.14 **Affordability of electricity**. To improve the economic well-being and quality of life of lower income populations, assistance is required to ensure an affordable and reliable electricity service. When extending the grid, significant connection costs are often incurred to connect households. Absent government support, the connection can represent a major barrier to poor households. In the case of off-grid RE-based systems, equipment and installation account for the largest share of the costs. For individual and mini-grid systems, therefore, financing the consumer is a critical component of expansion programs (Bhatia and Angelou, 2015). In addition, Operation and Maintenance (O&M) costs are not negligible. Every four to six years, batteries need to be replaced, and old batteries must be disposed of properly. Less often, solar panels need to be substituted as well. The tariff for off-grid systems must include a component for O&M to ensure service sustainability. Alignment of payments with capital recovery and ongoing O&M should follow the same pattern of the costs of the energy sources replaced, such as batteries, candles, kerosene, and biomass (Bloomberg, 2015).

2.15 There are three mechanisms to make electricity more affordable: (i) enhancing the sector's competitiveness, which is the best solution; (ii) subsidizing power bills; and (iii) transferring cash to users so they can pay full price. Concerning to the first mechanism, one of the main goals of this SFD is to promote, as stated above, a financially sustainable sector with electricity that is affordable to consumers and profitable to providers. During events that caused price shocks, for example when the price of oil increased (Yepez-García and Dana, 2012), governments cushioned the impact on bills by transferring funds to the sector, limiting providers' ability to transfer costs, or a combination of the two. These subsidies, however, may become permanent in many cases. Therefore, subsidies should be carefully designed and implemented to avoid a heavy burden on governments and society. Access to rural areas, especially to isolated systems, may also require some level of subsidies, which should be designed and implemented in a manner that allows the system to be sustainable. A third alternative is the transfer of resources to lower income groups based on well-defined criteria. In the Dominican Republic, for example, electricity subsidies are part of the conditional cash transfers to low-income populations (Carrasco et al., 2016).

2.16 Innovative financing can improve both the affordability and scalability of rural electrification projects. Since off-grid generation is decentralized by nature, entrepreneurs do not benefit from economies of scale in their operations, making it difficult for them to make a profit in the absence of subsidies. The likely results are higher rates and inability to reach the poorest communities (Haanyika, 2006). Public funding is usually required to remove these pricing biases and resolve the tension between electricity as a market commodity and a social service. For example, the Chilean government has provided one-off support to private utilities to cover their initial investments. Producers then went on to recover the rest of their costs through much more affordable charges. The government administered the subsidy through regional governments based on their electrification performance (Haanyika, 2006).

2.17 **Access to modern energy for cooking**. There has been considerable progress in the number of people having access to clean cooking fuels, such as natural gas, Liquefied Petroleum Gas (LPG) or electricity for cooking. Plenty still needs to be done. Some 2.8 billion people, more than one-third of the world population, lack access to clean cooking fuel, relying on coal, charcoal, kerosene, firewood or other solid biomass fuels, about the same number today as it was in 2000 (IEA, 2017b). Although some countries, like China, have seen large drops, these declines have been offset by increases in other parts of the world. The IEA expects that by 2030, still 2.3 billion people will continue cooking mostly with charcoal and firewood, but also with kerosene. Helping them gain access to other fuels such as electricity, LPG or biogas should be a top priority. A solution could be the deployment of efficient stoves (Ahmed et al., 2005; Duflo et al., 2008), but they also have limitations (Hanna et al., 2016). To close the gap, annual investments of US$5 billion would be necessary for clean cooking facilities (IEA, 2017b). As of 2015, only US$1.8 billion were invested, leaving without clean cooking fuels the equivalent of Africa, the Americas and Europe combined (see Table 1).

2.18 Lack of access to modern cooking fuels has significant impacts on health (Jagger & Shively, 2014; McCracken & Smith, 1998). Households without modern cooking fuels or advanced biomass stoves, cook with traditional open fires using solid biomass fuels such as firewood, charcoal, agricultural waste and animal manure. Incomplete combustion of these solid biomass fuels accounted for 90% of all Particulate Matter (PM) emissions in households in 2015 using biomass. PM is linked to lung cancer, pneumonia, chronic obstructive pulmonary disease, low birth weight, tuberculosis, cataracts, throat cancer, asthma and heart disease (Smith et al., 2013; Smith et al., 2011; Smith-Sivertsen et al., 2009). When emissions occur in an enclosed space with poor ventilation, health impacts are more severe. For example, indoor smoke can contain small particles at levels 100 times higher than the acceptable level (World Health Organization-WHO, 2016; García-Frapolli et al., 2010). Together with lighting using kerosene, the WHO has estimated that in low- and middle-income countries, household air pollution was the cause of some 4.3 million premature deaths in 2012, particularly affecting lower-income populations, children under five years of age, and the elderly (WHO, 2016; Lambe & Ochieng, 2015).

Table 1. Access to Clean Cooking - Regional Summary

	People without access to clean cooking (as % of the global population/each region)				Without access (million)*	Relying on biomass (million)
	2000	2005	2010	2015	2015	2015
WORLD	46%	44%	42%	38%	2,792	2,500
Developing Countries	61%	57%	54%	49%	2,792	2,500
Africa	76%	75%	72%	71%	848	784
North Africa	9%	3%	1%	1%	2	1
Sub-Saharan Africa	91%	89%	86%	84%	846	783
Developing Asia	65%	60%	57%	49%	1,874	1,648
China	52%	48%	45%	33%	457	307
India	71%	66%	68%	64%	834	780
Indonesia	88%	88%	53%	32%	83	67
Southeast Asia (other)	61%	58%	54%	50%	188	185
Developing Asia (other)	76%	68%	64%	63%	312	309
Central and South America**	19%	18%	15%	12%	59	57
Middle East	9%	9%	6%	5%	12	10

Source: IEA, 2017a; and own calculations.
* Kerosene and biomass (or charcoal, wood, agricultural waste, and animal dung).
** Mexico is not included.

2.19 Mostly women and children spend many hours every year collecting firewood, time that could be better spent on income generation, education, or other activities. Women, however, are left out of the decision-making processes regarding the design, execution, monitoring, and operation of energy projects. This leads to services and infrastructure that do not necessarily meet their needs and that are consequently not as effective or sustainable over time. The number of women living in energy poverty shows that energy policies and projects have not yet considered their situation, with many projects simply assuming that women and men will be equally impacted. Yet these women tend to be the main household caretakers, have a better understanding of the energy needs, and therefore their enhanced participation could boost project effectiveness. Unfortunately, they are not alone –the infrastructure and energy services deficit also affect other vulnerable groups, such as indigenous and Afro-descendant communities, which tend to live farther away from the centers of economic activity (UN, 2015).

2.20 **Energy, gender, and indigenous populations**. **Gender and vulnerable communities' approach.** There is a need for a differentiated energy approach to the lack of access to safe, reliable, modern energy for women, indigenous people, Afro-descendants and other minorities. Lack of energy access has a key gender component, since more women than men live in poverty (UN, 2015) and households headed by women are less likely to have access to energy than those headed by men.

2.21 Indigenous people are less than 5% of the world's population but represent 15% of the poor of the world. The indigenous population of Latin America is estimated at 28 million, and nearly 80% of it lives in poverty. This figure did not change much from the early 1990s to the 2000s (Patrinos and Skoufias, 2007).

2.22 Boosting women and indigenous populations participation in energy programs requires integrating gender and cultural elements into government policymaking and planning; supporting civil society organizations working on energy, gender and indigenous population issues; training them on the design, installation, operation, and maintenance of energy technologies; and incorporating gender aspects in the design and implementation of sustainable energy programs and projects (IDB, 2013-2014). Training people and developing local capabilities and resources on the design, installation, and maintenance of energy technologies, including RE, could help reduce costs in rural areas and urban peripheries, create jobs and increase coverage. Women can become active change agents and play a vital role in scaling up energy access. As household energy managers and through their networks, they are in a unique position to connect with their peers, increase awareness and deliver energy products and services (United Nations Development Programme-UNDP, 2016; United Nations Industrial Development Organization-UNIDO, 2013).

2.23 **Energy and synergies with other sectors**. Studies suggest that the simultaneous provision of services like electricity, transportation, water, sanitation, health, and education, has led to major benefits for local populations (Toman and Jemelkova, 2009; UN, 2013). For example, a study in Peru examined the importance of various infrastructure services for poverty alleviation and social development; it showed that access to two or more infrastructure services simultaneously appeared to have greater-than-proportional impacts on household income (WB, 2009). Opportunities exist to deliver modern energy services to underserved populations, leveraging the growing telecommunication networks and mobile device ownership among populations, for example, with the use of telecom tower infrastructure and use of mobile payments and mobile services (Nique and Jain, 2014).

2.24 The Food and Agricultural Organization (FAO) and the International Institute for Sustainable Development (IISD), among others, have been working on approaches for managing the important nexus among interventions in water, energy and food to improve the effectiveness of interventions (Bizikova et al., 2014; FAO, 2014; Hoff, 2011). This nascent approach requires effective coordination mechanisms and joint planning between water, agriculture and energy authorities; improved and coordinated water and energy regulatory frameworks; integrated water resource management; conflict prevention and resolution systems, and protection of watershed ecosystems and environmental flows (Canales, 2014).

B. Energy Sustainability – EE, RE, and Climate Change Adaptation

2.25 NCRE has seen a dramatic drop in the cost of wind and solar PV generation, lowering the economic scale of projects. Similarly, information and communication technologies allow for better coordination and greater flow of information and are available everywhere across a variety of platforms. Together, they created more opportunities for people to have an active role in managing their own energy consumption and production. These opportunities will continue to expand with electricity storage. Wind and solar PV technologies are becoming more mature, and cost reductions will be more nuanced, but continued drops in the cost of electric batteries can modify the generation landscape, mitigating the largest drawback of non-conventional sources, that of the variability in their output.

2.26 The continued reduction in the cost to generate electricity from renewable sources has another benefit, that of the reduction in greenhouse gas emissions. Although the electricity sector is lowering its level of emissions, it is still a significant contributor. It globally accounts for about a third of the total. Electricity, however, is substituting other fuels. There is a tendency to replace heating with fossil fuels to heating with electricity, using heat pumps. In addition, it is expected that in the next few years, electric vehicles will become dominant, providing opportunities to achieve greater emission reductions. Together with greater EE both from the supply and demand sides, consumption and emissions could be reduced simultaneously without compromising comfort and productivity.

2.27 Ensuring that energy is supplied in an environmentally, socially and economically sustainable manner while meeting social and economic objectives is a vital challenge in the region as well as globally. Two primary concerns in the energy sector are: (i) reducing its impact on climate change; and (ii) urban air pollution. The 2014 Synthesis Report of the Inter-Governmental Panel on Climate Change (IPCC) stated that continued GHG emissions would have severe, pervasive and long-lasting impacts on the climate system (IPCC, 2014a). It called for reducing energy use, decarbonizing energy supply, reducing net emissions, and enhancing carbon sinks. Since global energy use accounts for two-thirds of all GHG emissions (IEA, 2017), reducing the sector's emissions is key. The IPCC report concluded that ambitious mitigation would cut global economic growth by only 0.06% annually.

2.28 **Decarbonization of society**. The IPCC, on its Fifth Assessment Report–AR5 (IPCC, 2014b), performs an integrated analysis of sector-dependent, cost-effective emission reductions. Since there are multiple options for reducing GHG emissions, the IPCC AR5 models those that contribute to reductions in the most efficient way. It argues that most of these options fall into three groups: (i) energy supply; (ii) energy end-use; and (iii) agriculture, forestry and other land use (AFOLU). The primary focus of energy supply options is to provide energy from low or zero-carbon energy sources; that is, to decarbonize energy supply.[7] On the demand side, options include reducing the use of energy in buildings, transport and industry, using energy produced from low-carbon sources, including electricity generated from NCRE, or a combination of both. Options in AFOLU require storing carbon in land systems, for example through reforestation of logged areas. It also includes the substitution of crops to produce bioenergy. Options to reduce non-Carbon Dioxide (CO_2) emissions[8] exist across all these sectors, but most notably in agriculture, energy supply, and industry.

2.29 The 2015 Paris Agreement, with a clear objective for stabilizing the concentration of GHGs, is an important milestone for climate change policies and actions. Direct emissions of CO_2 and non-CO_2 GHGs across sectors in mitigation scenarios should be such that the atmospheric concentration of GHG remains below 450 parts per million of CO_2eq concentrations in 2100. This is consistent with the objective to limit the increase in temperature to significantly less than 2 ºC. According to the IPCC, the electricity sector is the largest contributor to GHGs emissions reduction to reach this objective for three reasons: (i) reductions in energy consumption, through EE, have the largest cost-effectiveness; (ii) it has the biggest potential for GHGs emissions reductions though the use of renewables; and (iii) electricity is expected to replace other energy sources under the so-called electrification of energy. These include, for example, providing heating with electricity and the electrification of transport, replacing the direct use of fossil fuels.

2.30 Ever since the industrial revolution, economic output and energy consumption have been strongly linked, that is, increased economic output has been correlated with enhanced energy use. In recent decades, however, this link has been weakened, as economic output can occur without proportional growth in energy use. This has been referred to as energy-economic growth decoupling. From 2000 to 2016, for example, global gross domestic product grew by 80%, whereas energy consumption rose by 40%. It is expected that this decoupling will deepen between 2030 and 2040, when economic growth is also expected to reach 80%, but energy growth would only be 20% (IEA, 2017).

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7 For an in-depth strategy to achieve decarbonization in developing countries, see Fay et al. (2015).

8 16% of non-CO_2 emissions come from methane, 6.2% from nitrous oxide, and 2% from fluorinated gases. Annually, since 1970, about 25% of anthropogenic GHG emissions have been in the form of non-CO_2 gases. (IPCC, 2014a).

2.31 Air pollution is another consequence of the use of fossil and solid biomass fuels. In 2012, 6.5 million premature deaths were attributed to air pollution (both household and outdoor), or more than one out of every nine deaths worldwide (WHO, 2016). Energy production and use, through the combustion of fossil and solid biomass fuels, are the single largest source of air pollutants. Energy is the source of more than 99% of sulfur dioxide (SO_2) and nitrogen oxides (NO_x) and 85% of PM emissions. Power generation with coal is the main source of SO_2 and NO_x in the electricity sector (IEA, 2016). Natural gas-fired plants emit fewer air pollutants than coal and oil-fired power plants. In 2015, gas-fired generation emitted close to 20% of the NO_X from coal-fired power generation and barely any SO_2 or PM electricity. It is, however, just a fraction of the emissions of SO_2 and NO_x in the energy sector. Just one-third of SO_2 comes from the power sector, and 45% comes from industry. Moreover, transport accounts for more than 50% of the NO_x emission in the energy sector, followed by industry (26%) and the power sector (14%) (IEA, 2016).

2.32 Over the last decade, global SO_2 emissions, and to a lesser extent NO_X and PM emissions, have decoupled from the increase in coal-fired generation. From 2005 to 2015, coal-fired power generation grew by 34%, while total power sector emissions of $SO_{2,}$ $NO_{X,}$ and PM decreased by 55%, 34%, and 32%, respectively. This decoupling is the result of the introduction of emission standards for coal-fired power plants that require the use of coal with a lower sulfur content or the installation of pollution control technologies. Regulation for PM, SO_2 and NO_X emissions from coal-fired plants has been introduced in many countries. Governments in Europe and Japan have been regulating air pollution from coal plants since the 1970s, as have many emerging economies since 2000. Even though emission standards have been adopted throughout the world, there are significant differences in their stringency from country to country. China, Korea, Japan, and the European Union (EU) currently have the most stringent emission standards (IEA, 2016).

2.33 Even with additional US$9 trillion investments in emission reduction technologies, the estimated CO_2 emissions are projected to increase slightly before the growth curve levels out. According to the IEA's 2017 Outlook, projected emissions in 2040 under the new policies scenario (or the scenario where all currently announced policies are fully implemented) will be 600 million tons less than in 2016.

2.34 These investments, however, might not be enough. According to the Global Carbon Project (2017), this level of investments would lead to a 3 ºC increase in global temperature, way beyond the consensus reached in the Paris Agreements of a 1.5 ºC to 2.0 ºC increase in global temperature, or at least less than 2 ºC. Moreover, the business as usual scenario under the IPCC projections would lead to an average temperature increase of between 3.7 ºC and 4.8 ºC from pre-industrial levels by 2100 (IPCC, 2014a).

2.35 In anticipation of the IPCC's Sixth Assessment Report, the Global Carbon Project has prepared new scenarios exploring multiple future socioeconomic developments. These scenarios have been drawn on what is called Shared Socioeconomic Pathways. To determine the global impacts of adaptation and mitigation policies on climate change, multiple scenarios are created with plausible alternative trajectories of society's behavior.[9]

[9] About 1,200 long-term scenarios are aggregated based on different assumptions on how many important human systems (e. g., energy, agriculture and land use, economy) with physical processes associated with climate change (e. g., the carbon cycle) are related. They were generated primarily by large-scale, integrated models that project many key characteristics of mitigation pathways to mid-century and beyond, determining the resulting concentration of GHG and the ensuing temperature increase. The models approximate cost-effective solutions that minimize the aggregate economic costs of achieving mitigation outcomes, unless they are specifically constrained to behave otherwise. Since each scenario is a simplified, stylized model of highly-complex, real-world processes, and the scenarios they produce are based on uncertain projections about key events and drivers over very long timescales (Global Carbon Project, 2017).

The work of the Carbon Global Project shows that achieving the goal of below 2 ºC global temperature increase, by 2100, requires lower emission levels than today's, even needing to fall below zero, that is, to achieve negative emissions. According to the IEA, to achieve an increase in temperature of 1.75 ºC, net GHG emissions from energy systems should be zero by the year 2060 (IEA, 2017e). Since emission generation has a certain level of inertia, given that the design and implementation of policies are not immediate, and compliance is not perfect, emissions might not drop in the amounts required or might even continue to grow, as happened in 2015 and 2016 when global economic growth picked up.

2.36 The level of inertia in the early years (or overshoot, as the IPCC Report calls it) will define the amount of negative GHG emissions required to reach the 2 ºC goal. In the energy sector, negative emissions are achieved by capturing and storing CO_2 emissions from energy production using hydrocarbons. A technology, generically called Carbon Capture and Sequestration (CCS), can capture safely up to 90% of the CO_2 emissions produced from electricity generation with carbon, preventing the CO_2 to reach the atmosphere. Using CCS with renewable biomass is one of the few carbon abatement technologies that can be used to achieve negative emissions. The U.S. National Energy Technology Laboratory has shown that a combination of 100% short rotation biomass from woody crops with CCS could absorb about one ton of CO_{2e}/Megawatt-hour (MWh) from the atmosphere.

2.37 CCS technology could prove useful for power generation in industrial sectors. According to the IEA (2015), CCS could deliver 13% of the cumulative emissions reductions needed by 2050 to prevent the 2 ºC rise in temperature needed to avoid the worst effects of global warming. There are limitations to CCS technologies, including elevated costs, lack of availability of storage sites, difficulties to obtain rights-of-way and high costs to transport the CO_2 from the location it is generated to the site for disposition, etc. For CCS to gain traction and be implemented safely and responsibly, financial or policy support is needed from governments to encourage the development pipeline. Unless the cost of emitting CO_2 increases, or governments provide more support, CCS will not become a financially viable strategy.

2.38 **Energy Efficiency (EE).** EE, together with RE, accounts for close to 80% of emission savings under a sustainable development scenario, with EE being the leading source of reductions. Higher energy prices have a role in promoting EE, but other barriers need to be addressed. Studies focusing on technology adoption drivers have found that higher energy prices are associated with significantly greater adoption of EE equipment (Anderson and Newell, 2004). While experience shows that energy prices can motivate EE, high rates and prices alone are unlikely to overcome the well-documented barriers to cost-effective EE (IEA, 2017c). The IEA has found that most reductions in energy demand from EE have been achieved through government policies and measures, including mandatory EE regulations (such as minimum performance standards, fuel-economy standards, building energy codes, industry targets), public financing and the use of market-based instruments, including tradeable certificates linked to energy saving obligations on utilities (IEA, 2017c). Sixty-eight percent of global final energy consumption, however, remained uncovered by mandatory efficiency codes and standards in 2016. Policymakers and regulators, therefore, should examine rate and pricing approaches that encourage customer EE, as well as pursue non-price approaches.

2.39 In the electricity sector, standards are either focused on the equipment itself, such as lamps, air conditioning, and heating, motors, pumps, etc., or in integrated systems such as buildings. In the former, specific levels of consumption per unit of output are defined, and these have become more stringent with time. For example, for air conditioning in the

US, regulations mandated the minimum seasonal EE ratio to rise from ten in 1992 to 14 in 2015, representing a 40% increase in efficiency. In the building codes, regulations have evolved from establishing standards for each of the main individual components of a building to the performance of the complete facility, recognizing that not only its components but also location, the combination of design strategies and use of the building define its energy performance (see Table 2).

Table 2. Evolution of EE Regulations for Buildings

Decade	Type of regulation	Key Features
1970	Prescriptive-fixed	Energy Efficiency Requirements (EER) are set for each building part separately. Individual parts must comply with their specific targets. Most restrictive.
1980	Prescriptive-trade-off	EER are set for each building part separately. A trade-off can be made between energy performance of the envelope and those of heating, ventilation, and air conditioning systems. More flexibility, more complexity.
1990	Model building	EER are set as a trade-off. A model building with the same shape is calculated with those values. A calculation has to demonstrate that the actual building will be as good as the model building. Flexible, but costly in terms of design.
2000	Energy frame	The framework establishes maximum energy loss standards for a building. The calculation must show that this maximum is respected.
2010	Performance-based	Requirements of energy performance are based on a building consumption of energy or fossil fuel or the building's implied emissions of GHG.

Source: Mercado, 2015.

2.40 **Renewable Energy (RE)**. RE encompasses conventional hydropower and NCRE (including biomass, wind, geothermal, solar PV, solar thermal, and small hydropower). Renewables represented 32% of the total installed capacity in 2015, slightly more than coal. By far, the largest proportion corresponded to hydro, accounting for 58% of the renewable installed capacity, followed by wind with 22% and solar PV with 14% (IEA, 2017). In 2016, most of the world's power generation continued to come from fossil fuels combustion, accounting for 65%, of which coal represented 37%, followed by natural gas and oil products with 24% and 4%, respectively. On the other hand, renewables represented 24% of total energy production. Leading the group was hydro, with 16%, followed by wind with 4%, bioenergy with 2%, and solar PV with 1%. In many countries, the additions in RE have covered demand growth and substituted traditional generation sources reaching the end of their useful life.

2.41 In its 2017 World Energy Outlook, the IEA estimates that after a century of dominance, fossil-fueled power plants will no longer lead in additions, while renewables should account for more than 60% of total capacity additions to 2040. Net capacity additions in a coal-based generation, however, accounting for retirements, will still be positive IEA (2017). Thermal power, therefore, will be part of the matrix for an extended period, unless policies are targeted to the operating expenses (such as a carbon tax), require additional investments to existing plants (such as GHG scrubbers), or mandate its phase-out (such as nuclear power in Germany).

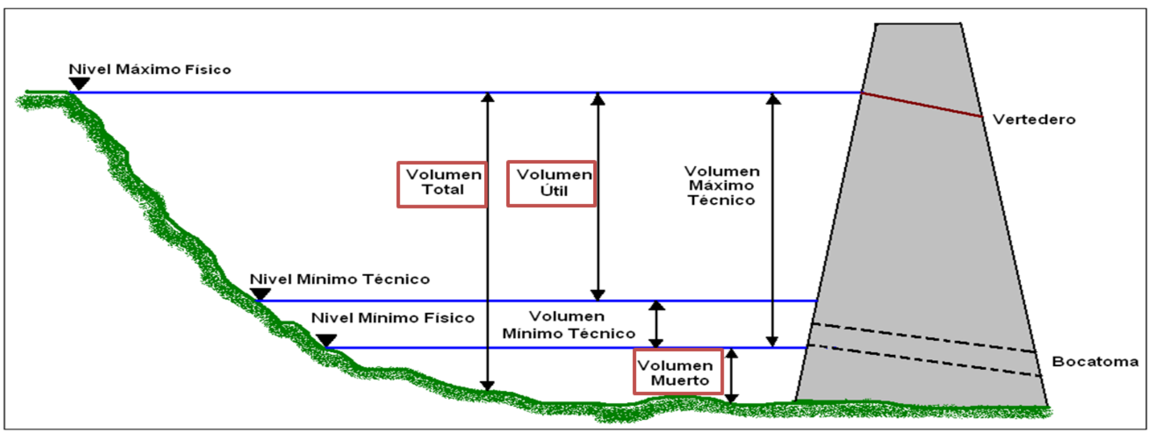
2.42 **Hydropower.** Hydropower is a mature, reliable and low-cost technology. Hydro plants with dams, as opposed to run-of-the-river, provide energy storage that, together with the digitalization of their control systems, can respond quickly to the fluctuations of demand

and the variability of non-conventional renewables. They also provide other benefits such as flood control, water for irrigation, and drinking water supply in urban and rural areas. About 12% of the hydropower installed capacity has pumped storage capabilities (International Hydropower Association-IHA, 2017), which provide additional flexibility to enable the system to incorporate a larger share of the variable non-conventional renewable generation.

2.43 Small hydroelectric plants with a capacity under 20MW and without storage capabilities could have advantages over large hydro- and fossil fuel-based generation, as no reservoirs are created, thus avoiding resettlements and reducing impacts on local ecosystems and agriculture. In addition, small hydro can be maintained at low cost by local communities (Caratori et al., 2015).

2.44 **Risks associated with hydropower**. Approximately 1% of the storage volume of the world's reservoir is lost annually due to sediment deposition (Samadi, 2012). In some developing countries, where watershed management measures are not conducted effectively, reservoir storage is being lost at much larger rates. Sediment accumulation is unavoidable, and dams are designed to manage them. However, when sediments are excessive, they have significant impacts on plants' operations, ranging from accelerated degradation of the turbines, penstocks, gates and valves to a lower capacity to regulate and produce energy. Deforestation and illegal mining in the basin are two of the main reasons that sediments increase, resulting in lower capacity to absorb floods, less energy output, higher impacts on local communities, and lower agricultural and fishing yields.

Figure 1. Components of a Dam for Hydroelectricity Production



Source: Acolgen

2.45 Affected communities and environmental groups increasingly oppose large-scale hydropower reservoirs, since they require resettlements and affect not only the reservoir area but also the flow and quality of water downstream, with impacts on the ecosystems and agriculture (Mekonnen and Hoekstra, 2012). Development of future projects will require continually advancing sustainability guidelines and criteria, innovative planning based on stakeholder consultation, and equitable benefit sharing with local communities.

2.46 **Rehabilitation of hydropower plants**. The electromechanical equipment of large hydropower plants has a useful life of 30 to 40 years, whereas civil works can last more than 100 years. Rehabilitation is usually the most profitable solution to increase energy and capacity systemwide (IHA, 2017). In a rehabilitation, modern designs, updated control technology, and a restoration of the storage capacity help cut O&M costs by reducing stoppage and boosting efficiency. When designing rehabilitation projects, it is important to consider the expected hydrology of the basins in the future, which will likely be modified by the combined effects of climate change and use changes in the watershed. It is also advisable to adjust the generation profile to support more variability in supply and demand, and to carry out watershed management interventions to reduce the sedimentation rate and extend the plant's life.

2.47 **NCRE**. NCRE has dramatically lowered its costs in the last several years, reaching parity with conventional sources in many places, depending on the quality of the resource, that is, wind intensity and regularity or sunshine radiation levels. The IEA (2016) estimates that the global average costs of installed utility-scale PV systems could fall by 57% between 2015 and 2025. Costs reductions would occur in the different components, including solar PV modules, inverters, and Balance of System (BoS) costs.[10] Several analyses carried out at global level indicate a transition towards 100% renewable-based electricity systems is viable (Jacobson et al., 2017; EnergyWatch Group, 2017). The single largest drawback of NCRE is its variability. Since it is impossible to control when the sun shines or the wind blows, and it is not efficient to curtail output or build transmission lines to accommodate the totality of the variable power flows, the transition should include measures to boost electricity systems' flexibility. This can be achieved through storage, changes in the operation of hydropower, demand management, and regional integration. It also needs to consider using RE sources for transportation and thermal applications in buildings and industry, including the substitution of fuels by electricity (e.g., electric vehicles with batteries, Renewable Energy Policy Network for the 21st Century-REN21, 2017).

2.48 **Electricity storage**. Energy storage technologies enable storing energy when available and releasing it when needed. They are one of the main ways to increase the flexibility of electricity systems and thus enable higher penetration of variable RE generation (IRENA, 2017).[11] Storage is vital to the energy transition, providing services in all the links of the value chain.[12] For example, it can reduce constraints in transmission and distribution by

[10] BoS costs include non-module hardware such as cabling, racking, mounting, infrastructure needed to connect to the grid, and monitoring and control systems; installation and supervision; and soft costs, including incentive applications, permits, design and financing costs. The IEA estimates that the largest cost reductions will come from soft costs and BoS.

[11] There are multiple ways to store energy, including pumped hydro, compressed air, thermal, flywheels and batteries with different chemistries. For a survey of different technologies see IRENA, 2017. The focus of the discussions will be batteries, as they are expected to be the technology with the greatest impact on the electricity sector.

[12] Services are required to provide reliability to energy generation, transmission and distribution with defined quality specifications. They include frequency regulation to maintain it within the maximum deviation established from 50 or 60 hertz; or, capacity reserves, to respond to unanticipated disconnections. It is expected that during the next decade, batteries will economically, efficiently and progressively replace services provided today by other means. IRENA (2017) provides a survey of the potential uses for batteries in the electricity sector, discriminating by support to variable RE, reliability, power quality and investment deferrals.

smoothing power flows, providing grid stability and lower equipment requirements, deferring major infrastructure investment. At the distribution level, it can have significant impacts on demand patterns observed from the grid. Behind-the-meter storage applications with residential and commercial customers would allow consumers to manage their bills, reducing peak demand charges and increasing self-consumption from rooftop PV panels. Batteries of electric vehicles could also be used for this purpose. For example, the owner of an electric vehicle could charge the battery during the day with energy produced by solar panels placed on the office rooftop, and release part of it at night at home.

2.49 Between 2010 and 2016, very significant progress has been made in storage technologies, with average costs plunging by 20% a year (Currie, 2017). In the future, the expected cost reductions will not originate in the electricity sector, as was the case with wind and solar technologies, but in the electric mobility sector. Bloomberg New Energy Finance (BNEF) estimates that by 2025, electric vehicles with batteries (BEV) will demand 408 Gigawatt hours (GWh) per year, with an additional 65 GWh from stationary applications, such as behind-the-meter and utility-sized batteries providing ancillary services. This capacity is the equivalent of 9.5 million Tesla Model 3 vehicles. BEVs would be cheaper than internal combustion engine (ICE) units and the demand for BEVs could explode, requiring close to 1,300 GWh of storage by 2030, when the price is expected to reach US$74/kWh. These costs reductions would then be transferred to the electricity sector, leading batteries to become ubiquitous.

2.50 On the other hand, BEVs[13] expansion can put heavy pressure on electricity networks. Each fast charging station, for example, requires the equivalent capacity of 20 houses, each consuming simultaneously at peak capacity. A very careful planning to place the stations within the distribution network needs to consider not only the parameters associated with the demand from the vehicles themselves -such as population and vehicle distribution, road networks, and traffic conditions–, but also power quality that is directly related to the electricity grid (Gong et al., 2016). Expansion of the grid to accommodate these new loads, particularly in urban settings, is complex, expensive and has long lead times.

2.51 **Electrification of energy**. The electricity sector accounts for about 40% of total emissions. Another third originates in the transport of people and merchandise, with most of the remainder coming from industry and land-use change. With the reduction in the cost of electricity from NCRE and the equipment using it, the deployment of technologies to add increased flexibility to demand, and the drop-in storage costs, replacement of other sources of energy is expected. Therefore, the electrification of transport and heating[14] will reduce the use of fossil fuels.[15] For this reason, there is a very significant

[13] Traditional vehicles (or vehicles with ICE) differ from BEVs in two respects: (i) the power train; and (ii) the battery size. All the rest is the same. In a BEV, the powertrain is an electric motor (or several), which is inexpensive. According to BNEF (Claire, 2017), in 2016 the battery pack represented close to half the vehicle cost. If ICE maintains its costs, BNEF calculates that battery prices need to drop by more than half before electric vehicles will be competitive with cars powered by ICE, reaching this threshold of US$100/kWh by 2026. They estimate that in 2017 it costs about US$160/kWh in the most efficient plant.

[14] In the case of heat pumps that provide cooling and heating, savings would occur in the investment phase, as one unit would provide both services. Emission reductions would be directly linked to the proportion of low-emitting fuels. The thermal efficiency of a furnace is similar to that of a heat pump. With cars, the contrast in efficiency is dramatic: about 25% for ICE vs more than 90% for electric motors.

[15] An alternative means to replace fossil fuel use is to convert electricity from renewable sources to gas or liquids and then use them in the current fleet, for example traditional vehicles for transport and boilers for heating. However, the conversion process is very inefficient compared to the direct use of electricity in electric vehicles or in heat pumps. See Germany’s Federal Ministry for Economic Affairs and Energy, 2017.

sector-dependency on the efforts to reduce GHG, and the bulk would fall on electricity use.

2.52 As was mentioned above, BEVs will progressively replace ICE vehicles. This trend will accelerate when BEV costs drop below those of ICE vehicles, which according to BNEF could happen in the mid-2020s (Currie, 2017). The result will be less consumption of gasoline and diesel and more consumption of electricity, with the expectation that it will come from low-carbon sources such as NCRE. Similarly, heating for the conditioning of spaces will use electricity feeding heat pumps, and heating in industrial processes will come from electric ovens, replacing natural gas, heating oil, heavy fuel oil, and to a lesser extent coal, diesel, and LPG. Major upgrades of the transmission grids to manage the extra loads, and of the distribution grids to cope with the additional flows will be required.

2.53 **Smart grids**. An electricity network is considered a smart grid when it uses advanced telecommunications and control technologies to coordinate all generators, grid operators, end-users, and electricity stakeholders efficiently. Smart grids have been shown to be powerful tools to achieve energy security, affordability, and sustainability. They have helped to: (i) manage the energy flowing from renewable distributed generation; (ii) improve EE and minimize costs by managing consumption using storage devices; (iii) improve system stability, resilience, and reliability by helping to regulate power flows; (iv) reduce transmission and distribution losses by optimizing system configuration; and (v) optimize the use of infrastructure to meet peak demand (Institute of Engineering and Technology, 2013 and 2013a; World Economic Forum, 2012; Covrig et al., 2014).[16] In countries where technical and non-technical losses are high, smart grids can reduce or even prevent them by quickly detecting when and where they occur.

2.54 While smart grids will yield full benefits only after full deployment, phased implementation can provide gradual benefits. The first step is to mount telecommunication-enabled meters, even if the telecom module installation is left for a later stage when links, software, and hardware for remote control of the grid and its elements are deployed.

2.55 Countries use smart grids for different purposes. While emerging economies may leapfrog directly to smart electricity infrastructure, industrial nations are more likely to invest in incremental improvements (IEA, 2011). There are two main challenges to the expansion of smart grids. One is policies and implementing regulations, including standardization and certification, system testing, and consumer participation. The other is financing. Substantial amounts of funding are needed throughout the lifecycle of smart grid development. In the US, a full smart grid could cost US$24 billion per year over 20 years (WEF, 2012).

C. Energy Security – Quality of Service Delivered, Energy Infrastructure and Regional Energy Integration

2.56 Demand in LAC is expected to continue to grow as more people join the middle class and the global energy electrification trend takes hold in the region. Infrastructure provision needs to keep pace with this growth as well as with demands for better quality services. The participation of distributed generation will create additional demands on the grids, suggesting that the “cable business” will continue to have a key, although different role. In

[16] Smart grids include advanced metering that relay real-time data to a control center to coordinate loads, switches that modify grid configuration to more efficiently serve customers, and sensors that evaluate network parameters to optimize energy flows and power production, both centralized and distributed. For a primer, see IET, 2013.

a system with a large penetration of distributed renewable generation, where large amounts of power flow in multiple directions, the exchanges will occur at the grid. It is crucial, therefore, that the “cable business” model be sustainable. In this scenario, the current remuneration by sales volume methodology might not be suitable. New regulatory and even institutional models need to be developed far in advance to allow for the smooth transition to a high penetration of renewables. Regional energy integration will increase in importance, as it provides many opportunities to reduce costs from greater efficiencies arising from the diversity of loads, patterns of consumption, and country endowments. NCRE will only boost those opportunities, becoming critical to the efficiency, stability and reliability of the electricity systems. In addition to the traditional electricity interconnections among neighboring countries, small island countries in the Caribbean may use undersea links as well as spook-and-hub LNG delivery.

2.57 Although conceptually energy security is a relatively simple notion, that is, how likely it is to have it when needed, its attainment is much more complex. Glachant et al. (2008), for example, focus on its temporality. They group energy security in potential levels of imbalance in the short and long run. Short-term disruptions are associated with unexpected transitory events (such as equipment failure, human error, weather events, crime, accidents); whereas long-term imbalance is caused by lack of investment generating a mismatch between demand and supply. The US Chamber of Commerce’s Global Energy Institute (GEI) takes a broader view, including geopolitical, economic, reliability and environmental factors (GEI, 2017). This SFD takes the more limited, service quality approach, centered on geographic and reliability variables where the action of the IDB can focus. These include both domestic and regional infrastructure levels. In the short term, efforts should focus on energy loss reduction as well as on the operation, maintenance, and rehabilitation of infrastructure, systems and processes to provide energy services economically and reliably. With a longer-term perspective, efficiency can be enhanced with strong regional integration to take advantage of the complementarities and differences in endowments in energy resources among countries. Also, institutional, regulatory and legal adjustments are required to incorporate technological advances and new business models to take advantage of the potential gains in efficiency arising from greater NCRE and information and communications technologies (ICT).

2.58 **Reduction of electricity losses.** Electricity losses are key measures of the efficiency and sustainability of the power sector (Jiménez, Serebrisky and Mercado, 2014). Transmission and distribution losses belong to two categories: (i) technical losses that occur in the electricity flows; and (ii) non-technical losses due to illegal connections, non-payment, or billing errors. Poorly designed and maintained transmission lines, as well as long distribution circuits with inappropriate cable sections and overloaded transformers, result in high technical losses. Metering, billing, and collection to prevent nontechnical losses are integral to the efficient management of an electric utility and its financial viability.

2.59 **Operation, maintenance, and rehabilitation.** Best practices include: (i) utilities must adopt asset management approaches prioritizing maintenance and rehabilitation; (ii) infrastructure maintenance must be predictive, rather than remedial or even preventive; (iii) asset management must be ongoing, with well-trained staff and adequate financial resources; (iv) its implementation should be based on a management system for the activity; and (v) it should consider not only the technical and economic aspects of the activity, but be performed with the highest safety and public security standards, minimizing social and environmental impacts. Advances in, and cost reduction of sensors, data transfer and processing capacity, justify their massive deployment, avoiding corrective maintenance or even asset destruction. Sensors can provide an early indication of future failure, allowing the improvement of the planning process and minimizing repair costs, and even could permit extending the useful life of the asset. It should be noted that maintenance requirements vary and are to be determined on a project by project basis (GN-2781-3).

2.60 **Regional energy integration.** Regional energy integration has been shown to create substantial benefits. Europe's experience in developing a well-integrated energy market resulted in the following benefits: (i) efficient operation of the power system by ensuring least-cost dispatch, and renewable integration over larger areas; (ii) consumers have a wider choice of energy suppliers, permitting competitive procurement with long-term contracts; (iii) a strong portfolio effect resulting in a more reliable and secure grid. Even though there is a strong seasonal effect on wind and solar PV generation, their joint production is much more stable, as the aggregation of generation from multiple sites with the same technology smooths the total output (Juergens et al., 2017); (iv) increased flexibility from all resources; (v) enhanced efficiency in pursuing security of electricity supply, as the increase in price due to its scarcity produce incentives to invest; and (vi) EU rules guarantee fair trading on wholesale markets and prevent price manipulation (Neuhoff et al., 2017). Similar efficiencies exist with the integration of natural gas networks, complementing the provision of piped gas with LNG. The international experience in integration raises the awareness for the benefits, challenges and the sequence of steps that are necessary for the energy integration. It requires investment in: (i) infrastructure to connect countries; (ii) institutional settings to ensure contracts; and (iii) the harmonization of regulation, to allow market development and economic efficiency.

2.61 As NCRE continues to reduce its costs and boost its market share, new challenges for grid infrastructure and system operations will appear. Conventional power plants will continue to offer security and reliability to the system, being increasingly valued for providing ancillary services and back-up capacity. As reserves, traditional generation plants would be required to produce an elevated level of minimal power. When there are restrictions in the transmission grid to transfer all the NCRE production, curtailment[17] might be required within the area with excess energy. On the zone with deficits, non-economic generation would be used, increasing the costs for congestion management.[18] Although these inefficiencies occur in the transmission networks with conventional systems, they may rise in NCRE-dominated systems, and therefore need to be taken into consideration when planning the expansion of the system.

2.62 The emergence of new loads from the electrification of energy consumption, such as electric vehicles or heat pumps, needs to be carefully considered. Electric cars will progressively replace vehicles with internal combustion engines. It is expected that this adoption will accelerate when the total cost of electric cars is below the cost of traditional vehicles. According to the BNEF, it is estimated that this will happen in the middle of 2020's. The result is a reduction in the consumption of gasoline and diesel, and an

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[17] Curtailment is the disconnection of variable renewable generation because the energy cannot be absorbed by a load. Since the additional (marginal) cost of production of a unit of energy is very close to zero, curtailment represents a very significant inefficiency of the system. Curtailment can be avoided by increasing the load in the unconstrained area, shifting loads to the moment when excess energy exists, store that energy to be used at another time, or expand the capacity of the grid to reach other loads. Each of these solutions requires a different type of investment and its selection will depend on a combination of economics, public policies and technology.

[18] Congestion arises when, in an economic dispatch of generation plants, the power flows would exceed the available transmission capacity, requiring the redispatch of less economic plants within the congested area. This difference in costs is what signals the need for the expansion of the transmission grid.

increase in the consumption of electricity, with the expectation that electricity generation will use fuel with low carbon emissions such as NCRE.

2.63 The electrical mobility is an important variable to think about not just in terms of demand, but also in terms of energy supply. The expansion of the stock of electric cars will create important requirements for capacity generation and the network use. The energy industry will have to upgrade the available infrastructure (and the regulation of its use) to adapt the need for the demand of electric cars (Gong et al., 2016). As a result, it is necessary to adapt the planning and expansion of the network to these new burdens. These changes in urbanization conditions are complex and expensive. This new demand is associated with delays in grid expansion and would increase congestion in the distribution systems.

D. Energy Sector Institutional Framework – Sectorial Organization, Regulatory Governance, and Policies

2.64 For the energy sector to be economically, socially and environmentally sustainable, the regulatory, legal and institutional frameworks need to adapt to the new technologies and business models, endorse greater private participation, and promote innovation. Regulations should be drawn based on desired objectives, not on currently available technologies. As technologies age, so will regulations which, if not updated, could lead to inefficiencies. A new regulatory framework needs to incorporate approaches such as: (i) behavior tools to nudge players toward a better performance; (ii) regulatory impact assessment; and (iii) ex post evaluation to keep track of the effects of policies and regulations in a context of constant technological change. The current business model may become unsustainable within the next ten years, but there are some steps that electricity companies can take to adapt to the new situation.

2.65 Incentives for renewables need to be carefully re-evaluated periodically, considering externalities, costs curves, and market distortions. Additionally, public and private utilities need to offer innovative hardware and software resources and strongly interact with and offer innovative services to the new *“prosumer”*.

2.66 **Governance.** The ways to generate, deliver, and use electricity evolved significantly over the past century and were reflected in the structure of the industry. For decades, scale economies associated with large centralized generation technologies encouraged vertical integration and drove down the cost of electricity, fostered access, and promoted one single provider by region. The combination of service area monopoly and tariff regulation was the main business model.

2.67 In the 1980s, the vertically integrated utility model was challenged. Surging energy costs, concerns about the environment, and experience with restructuring in other industries such as aviation and trucking, promoted the restructuring of the energy sector to introduce competition along the value chain. Chile pioneered an unbundled structure, where generation, transmission, and distribution were separated and performed by private companies, while the state controlled, planned and implemented policies and regulations, based on the notion that power generation and sales are not natural monopolies. In many countries, including in LAC, where the integrated utility was state-owned, separation was accompanied with assets privatization. The main objective was to introduce as much competition as possible, smoothing the insertion of private companies in the sector.

2.68 Unbundling became a key element of energy sector liberalization and market promotion, breaking the coordination mechanisms among these activities characteristic of vertically integrated utilities. This created the need to introduce new players in the industry, such as independent system operators and market administrators. The private sector participated in different roles, as market developers (i.e., where consumers can choose their electricity suppliers) to state-owned, vertically integrated firms that contract some services from private companies.

2.69 All around the world, the level of competition is highly heterogeneous and organized following five models: (i) vertically-integrated regulated monopoly; (ii) incorporation of independent power producers (IPPs) alongside the vertically integrated incumbent; (iii) unbundled industry with IPPs; (iv) wholesale market; and (v) wholesale market and retail competition (IEA, 2016). Even within these groups, there is diversity. For example, the wholesale market in Brazil consist of auctions with regulated demand, whereas that of Norway consists of a spot market with stack offers every half-hour from generators located in multiple countries. From the IEA (2016) database, we can observe that the most developed economies tend to adopt mechanisms allowing higher competition.

2.70 A well-functioning power system depends on the coherence of incentives created by the regulatory frameworks. There is no one-size-fits-all model. The best organizational model will depend on market size, resource availability, existing infrastructure and the institutional endowment. The academic literature on the subject is quite broad. Joskow (2008) summarizes lessons learned from 20 years of liberalization. He shows that one of the key challenges to assess liberalization reforms using traditional instruments is the absence of a counterfactual benchmark. Even if some methodologies may be useful ex post to policymakers, the best way to evaluate them is to use a comparative governance approach. And for that, it is key to consider the feasibility of different alternatives in the particular context of a country. He concludes that the reforms have significant potential benefits but also risks, especially when there is an incorrect or incomplete implementation. Considering some trade-offs of the key elements of market design, Wilson (2002) shows that it is crucial to assume that power markets are imperfect, and the adequate design must consider the potential of competition. In addition, the market design should evolve to adapt to new technologies. For instance, Vazquez et al. (2017) show how the renewables volatility impacts the costs and benefits of the day-ahead market design.

2.71 Even in the context of ample diversity of industrial organization, there is a tendency in most countries to introduce market mechanisms to allow efficient private participation. This tendency is reinforced by the innovation process: (i) innovation has decreased the economy of scale of generation, allowing new players to enter the market; (ii) even smaller markets have higher potential to introduce effective competition; (iii) innovation has been pushed by new players in the sector, including telecommunication and automobile industries; (iv) new business models offering service diversification may increase the value of competition to retail market; and (v) in innovative industries the cost associated with regulated monopoly is higher. In this context, innovation has fostered private participation even in previously reform-reticent energy industries (Zeng et al., 2016). As a result, 92% of investments in renewables in 2016 came from the private sector (IRENA, 2018).

2.72 In the late 2000s, the unbundled structure model started to change. Concerns about climate change led many European countries to actively promote RE. End consumers and small producers particularly adopted solar panels, exchanging energy with the grid. In some instances, they became net suppliers (also known as *"prosumer*s"). The sector reorganization is an ongoing process that has been strongly impacted by new technologies. Several elements are combining to drive changes in the electricity industry: (i) the competitiveness of wind and solar PV; (ii) the reduction in the cost of natural gas; (iii) the flexibility and efficiency of combined cycle plants; (iv) growing energy storage capabilities; and (v) demand response systems with progressively lower costs (Tuttle et al., 2016). Smaller scale systems (such as distributed energy) and the decrease of transaction costs (such as digitalization and blockchain) represent a higher potential for competition, including at the retail level.

2.73 **The governance in the Energy Sector**. The sector's industrial organization varies significantly among countries. In some, many institutions are involved, including public and private companies, regulatory and planning agencies, system operators, and energy, finance, or environment ministries. Institutional governance is central to have an efficient energy sector, with the legal framework providing the basis for its operation, including the definition and enforcement of property rights, private investor participation guidelines, and rules governing institutions that coordinate the sector.

2.74 **Energy information**. Data and information on the energy sector are essential for analysis and planning, policy design, and investment decisions.[19] Their availability varies strongly by country and by subject. Transparency is even more important in a sectorial organization where private companies play a leading role, as it promotes competition and regulatory oversight, boosting market reliability. Studies show that information on regulations, statistics, and general government services has a strong impact on private investment in energy infrastructure. Some authors point out, for instance, the importance of having in place tools such as well-developed e-government services that allow investors to access relevant information, apply for permits and licenses more efficiently, and interact with civl servants online (Mia, Estrada, and Geiger, 2007).

2.75 There are several areas in which data availability needs to be improved, such as production and use of traditional fuels for cooking, decentralized RE installations, unsatisfied energy demand, EE, energy prices, and infrastructure and service quality. In the era of big data, modern technologies connecting energy and telecommunications will produce enormous amounts of information that can help improve policies (such as EE and energy poverty policies) but also raise important questions about data regulation, ownership, and usage. This question has raised several challenges and government interest.[20]

2.76 In some countries, public investment and state-owned enterprises are still relevant in the energy sector. State-owned enterprises differ from their private counterparts in that they have multiple objectives, not only economic but also social, making their governance and performance assessment more challenging. In this context, one of the key elements to promote a superior performance is to achieve an effective corporate governance.[21] In

[19] To illustrate policies driven by data collection, we can point out the adoption of benchmarking and transparency policies in 24 US jurisdictions, which help promote EE measures by pointing out the opportunities for improvement in buildings through data collection and analysis (Mins N. et al., 2017).

[20] Policies in this direction include a public call from the European Commission for research proposals on big data solutions for energy for 2019, with a €30 million budget (DT-ICT-2019).

[21] Set of relationship between company and stakeholders based on three elements: (a) the companies' objectives, (b) the means to achieve the objective, and (c) the monitoring mechanism, including the fulfillment of the objectives, the means to achieve them and the results obtained. (OECD, 2004).

public utilities, the complexity of the stakeholders' interactions can substantially increase the challenges to develop a healthy corporate governance. Frequently, we can observe that the three elements of the corporate governance of energy utilities in LAC are unclear or ill-defined, negatively impacting their financial and operational results. Tariffs schemes that limit the recovery of the capital invested impact the quality of services, the introduction of innovation and the expansion of the system. Transparency in its execution is key for accountability and social oversight.

2.77 In the countries where private-public partnerships are relevant, transparency of the partnership, and the allocation process are central. Government intervention in the energy sector, independently of the institutional design, should be transparent and accountable. It should include the broad aspect of energy policies, from renewables policies to final consumer subsidies. As explained by Molina and Vieyra (2012), transparency creates channels for citizen participation (enhancing democracy) and detects deficiencies in both the public and private sectors, identifying entry points for corruption. In this context, to analyze the public resource efficiency allocation, it is important to implement a sound methodology assessing the government policy (goals, incentives, dynamic, and capacities) and design the transparency policy accordingly.

2.78 **Digitalization.**[22] There is another dimension of energy data for investment and policy decisions, and that is the availability of data and the technical, operational and financial processes that constantly flow among the different links in the sector's multiple value chains. Digitalization allows: (i) more efficient dispatch of distributed resources; (ii) enhanced demand control and consumer incentive for demand response; and (iii) overall better matching of supply and demand over all time periods. The internet has been a great enabler of the sector's transformation. Digitalization of information produced by a multitude of equipment and sensors and intelligent, autonomous systems that respond to certain predefined conditions permit the automation of a multitude of responses that greatly enhance speed and efficiency. Moreover, the internet of things, together with artificial intelligence, promises to automate operations further. There are, however, multiple risks associated with digitalization and automation, including cybersecurity, extended disruptions due to unanticipated feedback loops within systems (where the failure of one component can lead to cascading effects), and privacy and private information management issues.

2.79 **Regulatory agencies governance**. Regulatory agencies are key players in the energy market, so their proper governance is crucial. According to the Organization for Economic Co-operation and Development-OECD (2014) best practices for regulator's governance should include: (i) role clarity; (ii) preventing undue influence and maintaining trust; (iii) decision-making and governing body structure for independent regulators; (iv) accountability and transparency; (v) engagement with the stakeholders; (vi) a source of funding that enables the impartiality of the regulator; and (vii) performance evaluation.

2.80 Good regulatory governance should ensure that prices reflect efficient costs and companies comply with performance standards. While effective, independent regulation typically leads to significant improvements in utility performance even in the case of state-owned enterprises, the highest achievements have been reached through the combination of private sector participation and a regulatory agency that exhibits good governance (Andres et al., 2008; 2007). Regulatory agencies should be formally

[22] For a detailed analysis of what digitalization means to the energy sector, the benefits, costs and risks, see IEA, 2017d.

separated from ministries and have sufficient financial resources, preferably from sector levies. Accountability and staffing by competent professionals are essential (Fay and Morrison, 2007).

2.81 Harmonious collaboration among actors with different degrees of capacity and authority is decisive to produce coherent policies and regulations and to be capable of formulating adequate projects.

2.82 **Energy policies.** NCRE policies enacted during the current historical moment of transition could have impacts on the sustainability of energy systems for decades to come. Policymakers, particularly in Europe, incentivized alternative technologies, such as wind power. Governments implemented environmental regulations and tax credits, guaranteed selling prices, and required targets for renewable generation. Some states in the US implemented programs supporting solar installations in the late 2000s and early 2010s. Incentives included feed-in tariffs for electricity, auctions to contract renewable electricity at premium prices, RE portfolio standards, tradable green certificates, mandatory inclusion of net metering that permits self-producers to sell to the grid, and mandated blending of biofuels with fossil fuels as well as tax incentives, in combination with policy targets and support for training and research and development. European countries such as Germany and Spain promoted the adoption of NCRE that created economies of scale and competition that led to price reductions. However, they also created an enormous burden that has increased the cost of electricity for consumers still connected to the grid (National Renewable Energy Laboratory Technical Report, 2017). For example, in Germany, today, half the cost of the electricity bill of residential consumers goes to cover obligations generated by these mechanisms (Juergens et al., 2017). For both wind and solar, government support for deployment and manufacturing was critical (Tuttle et al., 2016).

2.83 Small-scale non-conventional renewable technologies, such as solar PV, enabled some customers to become *“prosumers”* by generating some of their own electricity, effectively competing with their local utility or large-scale generators. Some policies (such as feed-in tariffs) have incentivized the expansion of distributed generation and technological innovation, causing prices to drop. In addition, the potential of actual demand response transforms the consumer from passive player to a potentially key agent. This self-generation, however, threatens both the traditional utility business model and the competitive market structure.

2.84 The decline of new technologies costs is leading to a reevaluation of NCRE promotion policies. Germany, for one, in 2017 put an end to its onshore wind price support policy (Hubik, 2017), while Panama has served notice that it will not distinguish between technologies in future auction rounds (critica.com.pa, 2018).

2.85 Further NCRE cost reductions could create incentives to disconnect from the grid, putting pressure on the sector’s financial sustainability, as fewer customers pay for the fixed costs, potentially creating a vicious cycle of price increases and stronger incentives to cut the meter. The current business model that remunerates distribution utilities with energy sales may not be financially sustainable if there is a strong increase of distributed power under the current regulatory regime. In a scenario of falling revenues, utilities may lack the resources needed to upgrade their operations. For example, owners of rooftop PV systems pay grid costs as part of the price per kWh consumed. This has two consequences: (i) not all the consumption remunerates the grid, as behind-the-meter self-produced and consumed energy is not measured; and (ii) under a net metering scheme, the grid serves as a battery, storing the excess production for later consumption in the form of energy credits. That is, excess energy is absorbed by the grid, effectively using it. When those credits are consumed, the grid is used again. In none of these occasions the grid is remunerated. In addition, grid costs depend on the maximum –not the average– grid capacity needed. The result is that consumption of self-produced electricity rises costs for other grid users. The solution might be the implementation of gross metering, where the electricity produced and supplied into the grid is measured by separate meters and remunerated separately. This effect will persist as rooftop PV costs continue to fall. However, in the foreseeable future the cable business will continue to be important. Therefore, an alternative model might become necessary if the current revenue model based on volumetric sales does not produce enough income to pay for the grid upkeep, operation, maintenance and expansion.

2.86 Under the current regulatory framework, the threat to the existing natural monopoly business model would likely lead to defensive behavior and retrenchment on the part of utilities. A push to block legislation promoting distributed generation would slow down its development until it becomes cheaper to disconnect from the grid. The high-paying customers would likely leave first, forcing tariff increases on the remaining customers, leading more customers to leave and creating a vicious cycle that could lead to the destruction of the utility. Alternatively, a collaborative approach between policymakers, regulators, utilities, customers and industry would smooth the transition. Policymakers would consider alternative regulatory and electricity market structures, and electricity customers would pursue self-generation that relies on the grids of traditional utilities. More technologically driven new entrants, or the unregulated side of the existing utility would introduce further automation, creating greater efficiencies, leading to the separation of the cable and the energy management businesses (Energy Institute, 2017).

2.87 There is an interaction between the market organization and technological choices and evolvement.[23] There are alternative combinations of markets, regulations, and technologies, ranging from further separation of activities to the proliferation of self-sufficient mini-grids within national grids. Incorporating consumers as key players have the biggest transformation potential and the biggest challenges even for the most developed and liberalized countries. Careful planning needs to consider intra-sector variables such as resource endowment, state of the infrastructure, the industrial organization and the regulatory and legal environment, but also extra-sector variables such as the availability of financing, the level of entrepreneurship, and macroeconomic factors.

2.88 **EE policies.** EE policies and demand response have an immense potential to reduce demand and to shift peak loads, increasing the overall efficiency of the system. However, studies show the need to consider consumers behaviors when developing these policies, especially when the target of the policies are households, as shown by the review of Romero, 2017. In addition, policies should consider the potential of rebound effects, that is, other uses of energy may be found, bringing consumption to previous levels. Some studies, such as Liang et al. (2017), found that EE may impact households differently for different levels of income. Rebound effects are stronger in lower income households.

2.89 **Equilibrium between affordability and financial sustainability of the Energy Sector.** The financial and operational viability of electricity providers depends on the recovery of

[23] For instance, to deal with the increased volatility of the new energy sources, it is central to value flexibility services and tools, such as batteries and demand response.

the costs associated with: (i) their efficiently-run operations; (ii) adequate quality; and (iii) the affordability to consumers (IDB, 2013). If the utilities receive a revenue below costs of efficient operation, it will result in poor utility performance and a waste of electricity. Usually, tariffs must be adequate to allow service providers to recover fixed and operational costs. However, in some specific cases government subsidies may complement tariffs to recuperate the revenue required for utilities' cost recovery. In this context, the expected benefit from the subsidies, as well as the costs associated with the distortions generated by the subsidies need be carefully considered. Depending on the size, the duration and the targeting, subsidies may fail to meet their original objective (IISD, 2014).

2.90 **Financing energy investments**. Mobilization of funds will be key for the successful implementation of the 2030 agenda. To raise the financing needed to reach the sustainable development goals, in 2015 the Addis Ababa Agenda for Action called on the global community to move from billions to trillions in their funding efforts, demanding that they look to new, innovative schemes to finance the 2030 agenda (Development Committee Meeting, 2015).

III. MAIN CHALLENGES FOR THE REGION IN THE ENERGY SECTOR

3.1 Energy-wise, LAC is the cleanest region in the world, but the participation of renewables in its energy matrix has been decreasing in recent years. Non-conventional renewables provide an opportunity to boost the participation of green technologies and provide access to energy services in a more environmentally, economically and socially sustainable way. Many countries in the region need to strengthen their electricity infrastructure not only to boost service quality but also to cope with additional demand from new services and new loads, such as transport and heating. Although power access is relatively high, there are opportunities to technological leapfrogging, in particular to off-grid systems in rural and remote areas. This section will focus on the energy challenges in the region in relation to the main themes presented in the previous section, as well as actions required to meet those challenges. These areas will guide the work of the Bank in the region based on these four pillars: (i) energy access; (ii) sustainability; (iii) security; and (iv) governance.

A. Energy Access – Coverage, Reliability, and Affordability

3.2 The LAC region has made tremendous progress closing the access gaps since 2000. In electricity coverage, most countries have achieved universal service in urban settings and went beyond 80% coverage in total access. Moreover, the clear majority exceeded 90% coverage, when only a few in 2000 did. Improving the coverage, reliability, and affordability of modern energy, however, remains a major challenge throughout the region. Millions of people still lack electricity or suffer from poor-quality or unreliable service, while many more still use traditional biomass for cooking.

3.3 **Increasing electricity coverage**. Electricity coverage in LAC was estimated at 97% in 2016, with 22 million people lacking access (see Table 3). The region made impressive progress, but access is still an important challenge for some countries in LAC, such as Haiti (70% of the population does not have access to electricity), Honduras (26% of the population does not have access to electricity) and Nicaragua (10% of the population does not hmalave access to electricity). Except for a few countries with low coverage, most of the people without modern energy access in LAC live in poor urban areas and cities' peripheries, or in highly dispersed communities in rural or isolated zones. Issues of energy access affect particularly women and children, as well as indigenous people and Afro-Caribbean populations.

Table 3. Access to Electricity in the LAC Region

Population	National (%)			
	2000	2005	2010	2016
Latin America and Caribbean	**88**			**97**
Argentina	95	97	99	99
Barbados	96	98	99	100
Belize	82	82	89	93
Bolivia	55	65	79	88
Brazil	95	97	99	99
Chile	94	96	98	100
Colombia	87	92	95	97
Costa Rica	97	98	99	99
Cuba	92	94	96	100
Dominican Republic	89	92	95	97
Ecuador	85	88	92	97
El Salvador	63	74	82	96
Guatemala	65	77	80	92
Guyana	27	27	28	88
Haiti	43	52	64	30
Honduras[24]	88	92	93	74
Jamaica	95	96	98	98
Mexico	55	60	70	99
Nicaragua	84	86	90	90
Panama	82	98	99	92
Paraguay	64	71	79	99
Peru	82	84	89	95
Suriname	91	94	96	90
Trinidad and Tobago	96	97	99	99
Uruguay	94	96	98	100
Venezuela	95	97	99	99

Source: IEA, Energy Access Outlook 2017; OLADE SIER Database.

3.4 As indicated above, no other country in LAC has a lower level of access to electricity than Haiti due to its complex political, economic and legal environment. The IDB, together with other development organizations, has been heavily involved in institutional reforms, infrastructure development, and policy advice. Box 1 summarizes one of the many possible solutions to increase the level of access, showing options for possible interventions combining access to electricity with the innovative use of solar micro-grids and mobile phone payment mechanisms.

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24 Some effects of the access rates in Honduras from 2010 to 2016 can be explained by statistics effects. In May 2016 the National Energy Company (*Empresa Nacional de Energía Eléctrica*, ENEE) produced a report on the electricity coverage in Honduras during 2015 ("*Cobertura del Servicio de Energía Eléctrica en Honduras 2015*"). This report uses a new methodology, resulting in a national coverage of 73.9% (with 81.3% urban, 64.4% rural), and estimating that, the national coverage could be 77% (this estimation considers that there are some users that either are not registered in ENEE's billing system or do not have independent meters). This new methodology is based on the 2013 census data, which reported an increase in the number of households. According to the report, the National Statistics Institute indicates that 56.73% of households in Honduras are in urban areas (53.88% of population) and 46.27% are in rural areas (46.12% of the population). In addition, the new methodology applied by ENEE excludes homes with solar electricity systems. This information contradicts other electricity coverage reports produced by ENEE and other agencies. ENEE is aware of this and is in the process of revising the information.

Box 1. Haiti - Electrifying the Country with Community Solar Mini-Grids

The development of community solar mini-grids in Haiti could address the following challenges:

Low electrification rates and isolated high-density urban areas. Haiti is one of the least electrified countries in the world. It is reported that only between 25% and 30% of its eleven million inhabitants have access to electricity. There are seven million people, who can be grouped in 1,900 high density communities of more than 5,000 people each, with limited or no access to electricity.

High energy prices. Haiti has one of the highest costs of electricity in the world, challenging customers' ability to pay their bills.

Low economic retribution for electricity supply. Haiti has traditionally been a country with strong consumer resistance to pay the electricity bill, causing serious financial problems to utilities. The program is based on the principles that electrification increases income, the number of jobs, education and women´s empowerment. Through productivity, women in particular will be able to pay their bills. Hence, the program proposes the following steps:

Deploying mini-grids starting in high density areas. Deployment of community solar mini-grids in high-density communities would boost the country's electrification rate to over 70%. Funding could be centralized through a fund manager (FM) in charge of designing and developing the program. The FM would provide grants for power infrastructure. Other donors, including non-governmental organizations and religious groups supporting Haiti, may also provide funds for solar mini-grid developers.

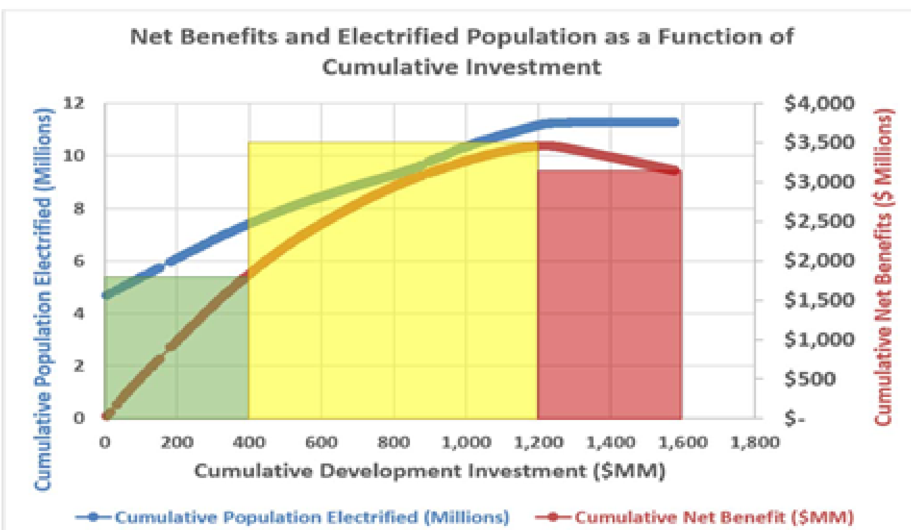
Empowering regulator. The current regulator could be empowered to establish rules governing financial contracts between developers and end users (price, quality of service and period of the operating license).

Mobile money payment. The proposed scheme establishes an easy and accessible mobile money payment option that would boost developer's ability to collect revenues and help users save time in the payment process. Haiti's mobile phones usage rate is close to 90%.

The figure in this box shows the cumulative investment needed to achieve increasing levels of electrification. US$400 million worth of investments would lead to 2.7 million people newly connected and US$1.8 billion in social benefits.

One feature of the program is the requirement that the mini-grids be compatible with the national grid for future interconnection. Also, the characteristics of the components will be standardized and tailored to favor climate change resilient facilities. Furthermore, mass purchases could allow procurement agreements and therefore lead to economies of scale in solar equipment and connections.

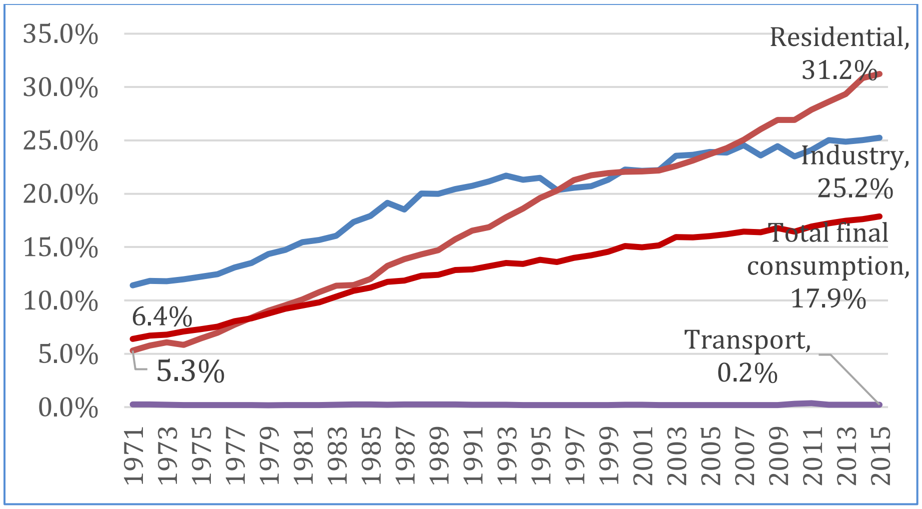
Cumulative Investment vs. Cumulative Population Electrified and Cumulative Net Benefit



Source: Navigant Consulting, 2017.

3.5 Whereas total energy consumption has risen one-sixth over four decades, residential participation has increased more than six-fold, reflecting a decline in the use of unsustainable biofuels, particularly wood and charcoal. There has been a progressive convergence towards universal service since the beginning of the century. Nicaragua, Bolivia, Honduras, Peru and Guatemala have made impressive gains. Once countries achieve about 95% coverage, reaching the remaining, more remote households becomes difficult, costly and slow, and therefore countries will need to redouble efforts to reach universal service.

Figure 2. Increase in Average Electricity Participation in LAC (1971-2015)



Source: IDB calculation based on data from CAIT Climate Data Explorer (World Resource Institute).

3.6 **Increasing access to modern fuels for cooking.** The region has experienced a steep decline in the use of unsustainable biomass for cooking since 2000, when 19% of the population depended on traditional fuels. Even though by 2015 that proportion dropped to 12%, the IEA has estimated that 59 million people still did not have access to clean fuels, whereas 57 million relied exclusively on solid biomass fuels (the rest is mostly kerosene). The WHO (2016) estimates that 90 million people in LAC use solid biomass fuels for cooking (including some that have access to clean fuels). The challenge remains to provide modern cooking fuels to the 87 million people who still use traditional solid fuels, including firewood and charcoal (see Table 4). The difficulties in penetration and adoption of clean and efficient cookstoves include a lack of consumer awareness and slow behavioral changes. Argentina, Bahamas, Barbados, Ecuador, Trinidad and Tobago, Uruguay, and Venezuela have reached 95% coverage. In contrast, the challenge remains in Haiti, where coverage is 7%, and Nicaragua, and Honduras, where it is less than 50%. In LAC, subsidies to LPG have substantially helped accelerate the transition from solid biomass fuels to clean fuels for cooking, showing that targeted subsidies should be considered as a policy option (Troncoso and da Silva, 2017).

3.7 Ideally, the replacement of traditional fuels should be done with electric stoves using RE. An alternative would be massification of natural gas, but the necessary capital investments are very significant, usually slow to deploy, and require a certain population density to be cost-effective. Another alternative is LPG, which is much more flexible and is already present in every country. Lastly, improved biomass cookstoves, despite providing better combustion and efficiency, still lead to levels of indoor air pollution that are higher than those recommended by the WHO. They are therefore only appropriate for regions without access to clean fuels.

Table 4. Access to Clean Cooking in Central and South America

	Without access to clean cooking				Without access (Million)	Relying on biomass (Million)
	2000	2005	2010	2015	2015	2015
Central and South America	**19%**	**18%**	**15%**	**12%**	**59**	**57**
Argentina	5%	4%	3%	-	-	-
Bolivia	33%	30%	19%	17%	2	2
Brazil	12%	10%	7%	5%	10	10
Colombia	20%	18%	14%	13%	6	6
Costa Rica	13%	9%	8%	6%	<1	<1
Cuba	9%	9%	9%	6%	<1	<1
Dominican Republic	14%	14%	15%	12%	1	<1
Ecuador	2%	7%	7%	6%	<1	<1
El Salvador	27%	27%	23%	20%	1	1
Guatemala	57%	57%	45%	30%	5	5
Haiti	>95%	>95%	94%	93%	10	10
Honduras	68%	58%	54%	52%	4	4
Jamaica	16%	15%	14%	13%	<1	<1
Nicaragua	62%	60%	55%	52%	3	3
Panama	19%	17%	16%	14%	<1	<1
Paraguay	55%	51%	43%	33%	2	2
Peru	46%	42%	36%	32%	10	10
Trinidad and Tobago	1%	1%	1%	1%	<1	<1
Uruguay	2%	4%	3%	1%	<1	<1
Venezuela	3%	2%	2%	2%	<1	<1

Source: IEA, Energy Access Outlook 2017

B. Energy Sustainability – EE, RE, and Climate Change

3.8 As part of a major transformation happening worldwide, LAC countries face the challenge of promoting the environmental, economic and social sustainability of energy systems -including through carbon emissions and local pollutants reductions–, a goal they can achieve by fostering the use of EE, RE, and supporting technologies such as smart grids.

3.9 In LAC, incorporation of a more sustainable use of energy has panned over decades. Early adopters Peru and Mexico enacted RE laws in the 1970s, and by 2015 most countries had followed suit. Mexico continued on this path, launching pilot projects to test EE measures and then incorporating the results into a law. It also adopted a carbon pricing mechanism, perhaps timidly, but creating the foundation for its expansion. More recently, almost all countries in the region acted on the science compiled by IPCC and the advice put forward by IEA.

3.10 They also signed the Paris Agreement, which urges countries to design and implement Nationally Determined Contributions (NDCs) and to investigate and report long-term emission reduction strategies. The Agreement also recognizes the need to reach zero net emissions by the end of the century. Most of LAC countries have NDCs targets. The type and the detail of the targets varies among countries. They can be broad and include different sectors, or they can have more specific targets in energy and electricity.

3.11 Fifteen countries in LAC have some NDCs targets, ten of them have specific objectives in energy or electricity, and four countries have specific goals for renewables. Therefore, there is an opportunity to support the inclusion of more specific targets in the design and implementation of strategies to achieve NDCs.

3.12 Although the relation between NDCs and renewables may not be straightforward, the efforts to achieve the NDCs are associated with the increased participation of renewables. For example, countries might not have renewable targets at the NDCs level but have established national goals (as we observe in Table 5).

Table 5. Countries with NDCs Goals and their National Plans to Renewable Energy (RE)

	NDC Target	National RE Plan	
Country	**Sector**	**Target Year**	**National RE target**
Argentina	Electricity	2025	20%
Brazil	Electricity	2030	28%
Chile	Electricity	2050	70%
Colombia	Electricity	2020	77%
Guatemala	Electricity	2030	80%
Haiti	Electricity	2030	50%
Honduras	Electricity	2034	80%
Mexico	Electricity	2035	60%
Nicaragua		2027	91%
Bolivia	Energy	2025	74%
Dominican Republic	Energy	2025	25%

Source: IDB's elaboration based on World Resources Institute, CAIT Data Explorer, Climatewatch, World Bank RISE Database, and IDB SER Database.

3.13 The policies to achieve the countries NDCs' objectives go beyond the energy sector. This includes the intersection between different sectors. For instance, efforts to drive big cities to decrease emissions (Salmeri et al., 2017), and the effort to increase EE and electromobility, which impacts energy and transport sectors.

3.14 **Increasing the efficiency of energy use.** The IEA forecasts that total primary energy demand in LAC in 2035 could be reduced by 4% in the new policy scenario compared to the business as usual scenario. With the implementation of all enacted EE measures, consumption could be reduced an additional 18% in the 2 ºC scenario (IEA, 2017). Investments needed were estimated to be US$315 billion through 2035 in the new policies scenario, or about 8% of total energy investments. To limit the global temperature rise to the 2 ºC goal, the contribution of LAC in EE investments would need to almost triple, to US$837 billion, which amounts to over 20% of sector investment (IEA, 2017). Mobilizing this level of investment will be a significant challenge for the region, especially because EE investments must be made by a multitude of users of energy rather than by large-scale energy suppliers.

3.15 Brazil, Chile, and Mexico have effective EE programs that include institutional frameworks, financing, and performance indicators, resulting in an effective reduction of the intensity in energy consumption (Economic Commission for Latina America and the

Caribbean-ECLAC, 2013). An ECLAC assessment has concluded that barriers remain in many of the region's 26 countries. These include: (i) lack of continuity of the institutions involved in EE; (ii) insufficient knowledge in all sectors about EE; (iii) inadequate regulations to encourage EE; (iv) in some countries, energy prices are too low to reflect costs; (v) reluctance of lending institutions to finance EE projects, resulting in high interest rates and/or more stringent requirements; (vi) the energy services company (ESCO) market is not yet fully established; and (vii) with the exception of Mexico and Brazil, countries have not developed indicators and monitoring systems to measure programs' results (ECLAC, 2013).

3.16 **Increasing the role of RE**. Many LAC countries have acted to increase the share of RE in the energy supply mix. By early 2015, 19 LAC countries had RE policies, and 14 had targets for electricity generation (see Table 6). However, policies and targets are not enough; many barriers to the adoption of RE need to be removed to ensure that targets are met.

Table 6. RE Targets for Electricity Generation in LAC

Country	Target of generation	2015% renewables	Country	Target of generation	2015% renewables
Argentina	8%, 2018 20%, 2025	2%	Guyana*	90%, no date	15%
Bahamas	15%, 2020; 30%, 2030	N.A.	Honduras*	60%, 2022; 80%, 2038	44%
Barbados	29%, 2029	3%	Jamaica	15% by 2020	5%
Belize	50%, no date	N.A.	Mexico*	35% by 2026	15%
Brazil	19.3 GW biomass, 8.8 GW small hydro, 15.6 GW wind by 2021	39.4%*	Nicaragua*	74% by 2018, 90% by 2020	43%
Chile*	20%, 2025	38%	Panama	18.3% by 2023	18%
Costa Rica*	100%, 2021	92%	St Lucia	5% by 2013, 15% by 2015, 30% by 2030	N.A.
Dominica	14%, no date	N.A.	St Vincent and the Grenadines	30% by 2015, 60% by 2020	17%
Dominican Republic	25%, 2025	14%	Uruguay*	90% by 2015 including 1GW wind	60%
Guatemala*	80%, 2027	31%			

* Includes conventional hydro. Sources: REN21 2017.

3.17 The need for price support is not one of those barriers anymore. Unconventional RE is increasingly competitive for electricity generation in LAC. In Argentina, wind projects won contracts ranging from US$37 to US$47 per MWh in an auction held in November 2017. Similar prices have been obtained in Brazil, Chile, and Uruguay, reflecting favorable conditions including good wind regimes, efficient planning procedures with little opposition, and backup from hydro storage. In many Caribbean countries, renewable generation can compete with fossil fuels. In Mexico, wind projects in Oaxaca are competitive with natural gas and are a useful alternative for large consumers (IDB Multilateral Investment Fund-MIF, BNEF, and United Kingdom Department for International Development, 2014).

3.18 Some countries are achieving notable results. Uruguay generated 96% of its electricity from renewables in 2014 using integrated dispatch where the wind is baseload and hydropower follows its variations (Rodo, 2015). Wind and solar PV has experienced very significant growth in the region, with Argentina awarding 1.5 GW of wind and 916 MW of solar PV; El Salvador 100 MW of solar PV and 50 MW of wind; and Mexico 8.9 GW of both (REN21, 2017). Solar PV, while important in off-grid and rural areas, has experienced a shift in focus from small domestic applications to large-scale power plants, including in Chile and Mexico (REN21, 2017).

3.19 Local RE development is a high priority in Caribbean nations since they are vulnerable to oil price volatility, but they face difficulties due to the small size of their markets. Many Caribbean islands are aiming to derive 15% to 30% of their electricity from RE by 2020-2029. A study of RE in island states identified particular needs to foster renewables: (i) institution building and training to create specialized skills; (ii) technology transfer and removal of import duties on technologies; and (iii) aggregation of projects to develop ownership between islands (Cottrell, Fortier and Schlegelmilch, 2015).

3.20 As was mentioned before, RE reached or is very close to reaching price parity with traditional fossil fuels. Special incentives such as feed-in tariffs or mandatory minimums might not be necessary (see Table 6). Their expansion needs to be coordinated to achieve appropriate levels of efficiency, that is, avoiding curtailment or degradation of service quality. Since the region has a very large endowment of hydropower, it can serve to absorb RE variability. However, hydropower services need to be remunerated to compensate for the reduction in energy production. Other risks need to be mitigated.

3.21 Other policy instruments are also needed or need to be revised to promote the adoption of clean energies, such as carbon pricing that monetizes negative externalities (Carlino et al., 2018); all-resource auctions (as opposed to technology-specific auctions), and net metering to promote distributed generation adoption.

3.22 The LAC region has been historically clean as consequence of the importance of hydroelectricity in its energy matrix. In 2015, hydropower plants produced 52% of LAC electricity, and hydroelectric installed capacity represented 47% of the total generation capacity in the region. These figures are well above the share of hydroelectricity in other regions' energy matrix: Europe 17%; Africa, 16%; Asia, 16%; and North America, 13% (Energy Information Administration, Department of Energy, USA-EIA, 2017). In 2016, the global average was 16.4%, which exemplifies the importance of this resource for the development of the electric sector and the economy in LAC. By 2015, LAC had 15% of the world's hydroelectric installed capacity, with just over 8% of the world's population. In the past few years, however, the participation has decreased for several reasons: (i) social and environmental constraints, including resettlement, loss of land, distance to load centers, are important challenges for hydroelectricity projects, especially large dams; (ii) the correlation of the hydrology between projects, and even countries, increases the risk of supply during droughts, and depresses prices during abundant periods (Levy, 2017); and (iii) long-lead times of construction, cost increases and capital intensity reduce the incentives to private investors (Alarcon, forthcoming).

3.23 **Geothermal Energy (GE)**. Among the NCRE, GE is considered a stable and unique resource to supply for baseload power generation. Latin America accounts for almost 34% (IRENA, 2017) of existing global geothermal capacity. Mexico and Central America, and Chile since 2017, have operating plants with a total installed capacity of more than 1.6 GW (IRENA, 2017). According to the GE Association, LAC has a geothermal potential of at least 70 GW. The main reasons why few of these projects have been developed are: (i) high upfront costs that can reach up to 30% of the total project costs must be invested during the assessment stage with no certainty that sufficient resources will be found to make the project economically viable, creating major risks for developers; (ii) a need for specific know-how ranging from geothermal exploration to drilling and reservoir engineering to plant operation and maintenance; (iii) lack of an enabling regulatory and legal framework, as well as fiscal and environmental policies that increase the perception of risk for the developers; and (iv) lack of available commercial financing, particularly at early stages of development.

3.24 Consistent with the risk profile of GE development, exploration risk mitigation, and technical assistance resources are expected to be funded by grants or by the developer's own equity provisions at an early stage. The next stage is exploratory drilling, which has a relatively elevated risk of failure. In this sense, facilities such as the Clean Technology Fund (CTF) and the Green Climate Fund provide contingent recovery grants (CRGs) which will remain as a grant in case of failure and transform into a concessional loan in case of success. Access to CRGs allows countries to fund their drilling programs and mitigate risks for GE developers until there is certainty as to the existence and quality of the geothermal resource. Only then can traditional loan resources be used for financing field development and plant construction phases. As such, geothermal development presents a unique opportunity to form Public Private Partnerships (PPP) between governments and private geothermal developers. The governments can access grants and CRGs which will constitute the governments equity and the developers will bring their experience and financial resources for plant development (Gischler et al., 2017).

3.25 The Sustainable Energy Facility (SEF) for the Eastern Caribbean (see Box 2) is a very good example of financing geothermal projects with limited capacity to absorb public debt and instead using grants and CRGs to build equity and therefore enhance the ability of governments to attract private sector investment through PPP.

Box 2. SEF - Example of Innovative Green and Blended Finance

The objective of the SEF for the Eastern Caribbean Program is to address the main barriers for GE development of the Eastern Caribbean Countries (ECC) by providing a range of financial products to public sector actors and/or PPP customized for each stage of geothermal development.

ECC have small and isolated electricity markets and economies. Each country independently does not have the financial strength to develop a geothermal project or the capacity to attract geothermal investors. Therefore, the SEF was created to give regional support to the six independent Eastern Caribbean states (Antigua and Barbuda, Dominica, Saint Vincent and the Grenadines, St. Kitts and Nevis, Grenada and St. Lucia), where all donors are centralized through the Caribbean Development Bank. SEF focus is to develop the countries geothermal potential by using an array of innovative financial instruments.

ECC have limited experience on the regulation, environmental aspects, management, construction and operation of geothermal projects. Through the SEF, governments receive technical assistance grants for capacity building as well as regulation improvement, environmental studies and early development assessments for geothermal development.

The six countries are small economies with considerable volatility and under strengthening processes. The ECC have a very tight fiscal situation where assuming more public debt is not an option. By using the SEF, ECC governments can achieve PPP with geothermal private developers to form Special Purpose Vehicles (SPVs). The SPVs assume the loans allowing countries to diversify their energy matrix without increasing their debt load or using their sovereign guarantee, hence allowing more fiscal space.

Regarding the technology particularities, geothermal exploration requires risky and high investments in early/stage site assessments and resource measurements. With the SEF, Geothermal SPVs receive CRG to proceed with the exploratory drilling. If the drilling is successful, the CRGs are transformed into a concessional loan; if not, they remain a grant.

Domestic electricity tariffs for most of the ECC are high due to their heavy dependence on expensive imported fossil fuels. To attend to this issue, SEF concessionality is reflected in the GE Power Purchase Agreement (PPA) prices and in the final tariff to end users. Also, GE will reduce the use of imported fossil fuels. Therefore, final users will be further benefited by additional electricity prices reduction.

3.26 **Smart grids**. The growing role of EE and renewables will increase variability and dispersion of generation, requiring that smart grids be deployed in the region to help maintain grid stability and reliability. A few countries in the region, including Brazil, Chile, Colombia, Costa Rica, Guatemala, and Panama have passed regulations on net metering. Its integration into the grid, however, has not reached the level that requires the use of smart meters beyond measuring power flows in and out of a customer premises.

C. Energy Security – Quality of Service Delivered, Energy Infrastructure and Regional Energy Integration

3.27 Ensuring a secure supply of sustainable energy to meet the energy demand reliably will be one of the greatest challenges for the region. This is a particularly challenging task given significant shifts in technology combined with a commitment to universal access and sustained if moderate economic growth. Four areas will be particularly important to the region's energy security: (i) improving electricity quality and reducing losses; (ii) developing natural gas production and transportation systems; (iii) achieving greater regional energy integration; and (iv) increasing energy infrastructure investments and their efficiency.

3.28 **Improving electricity quality and reducing losses.** Improving the quality and reliability of electricity is an important task that must be achieved in many LAC countries to improve competitiveness. The 2017-2018 World Competitiveness Report evaluated service quality through a survey of executives who rated electricity interruptions and voltage fluctuations. Measured on a scale of one to seven (with seven being very reliable), the LAC region weighted average rating was 4.2, compared to an OECD average of 6.2 (see Table 7). Quality problems are widespread in the region, with 16 out of 23 countries rated less than five, including major economies. Since these ratings reflect the opinions of executives, quality is likely to be worse in rural areas.

Table 7. Electricity Quality Ratings LAC Countries 2017/2018

Country	Rating	Country	Rating
Chile	6.1	Brazil	4.5
Uruguay	6.0	Nicaragua	4.4
Guatemala	5.7	Bolivia	3.9
Costa Rica	5.6	Honduras	3.5
Panama	5.2	Suriname	3.4
Peru	5.1	Argentina	3.0
Trinidad and Tobago	5.0	Guyana	2.7
Mexico	4.9	Paraguay	2.6
Ecuador	4.9	Dominican Republic	2.3
Colombia	4.8	Venezuela	2.1
El Salvador	4.8	Haiti	1.4
Jamaica	4.8		

Source: WEF 2018, Global Competitiveness Index Database 2017-2018.

3.29 Reducing elevated levels of electricity losses to improve efficiency and sustainability will be an additional challenge in many countries. Electricity losses in LAC averaged around 17% between 2007-2011, almost triple the OECD average of 6%. Eleven countries have losses above this average (see Table 8) After allowing for technical and non-technical losses, this ratio translates into 100 Terawatt-hours lost in 2012, representing revenue loss to the sector of US$11-US$17 billion. Despite their economic and environmental importance, there have been no reductions in the regional ratio over the last three decades. (Jiménez, Serebrisky, and Mercado, 2014). On the other hand, this study found that private utilities tend to have lower distribution losses.

3.30 Improving electricity quality and reducing losses in many LAC countries requires improved corporate utility governance, investments in transmission and distribution systems, and the introduction of advanced metering systems, as well as improvements in commercial systems and maintenance. In countries with significant non-payment and theft, creating a culture of payment is crucial to reinforce these advancements.

Table 8. Electricity Losses in Transmission and Distribution in LAC (in %)

Country	loss T&D*	Country	loss T&D
Argentina	15[b]	Guyana	32[c]
Bahamas	12[c]	Haiti	60[d]
Barbados	6[b]	Honduras	32[b]
Belize	12[b]	Jamaica	26[b]
Bolivia	14[c]	Mexico	16[c]
Brazil	15[b]	Nicaragua	21[a]
Chile	7[d]	Panama	12[b]
Colombia	20[c]	Paraguay	27[b]
Costa Rica	12[b]	Peru	7[b]
Dominican Republic	32[a]	Suriname	8[c]
Ecuador	16[a]	Trinidad and Tobago	5[c]
El Salvador	12[b]	Uruguay	19[b]
Guatemala	13[b]	Venezuela	33[c]
LAC **		**17**	
OECD		**6**	

* Latest available year: (a) 2014; (b) 2013; (c) 2012; (d) 2011.
** Excludes Haiti.
Sources: ENE calculations from government agencies, EIA and ECLAC.

3.31 **Developing natural gas production and transportation**. Venezuela has the largest proven natural gas reserves, accounting for 70% of LAC conventional gas reserves. However, such resources remain mostly unexploited. (Stipo, 2016). Brazil, Argentina, Trinidad and Tobago, and Peru follow, each with 5%. Conventional gas reserves increased by 10% in the last ten years while production increased at twice that rate, resulting in a declining reserves/production ratio (US Energy Information Administration, 2016). However, LAC, with only 4% of the world's conventional gas reserves, accounts for 26% of shale gas resources shared among Argentina at 11%, Mexico at 8 %, and Brazil at 3% (EIA, 2017). While promising, development of the region's high-cost shale resources is a daunting task. Potential investors will consider gas-pricing regimes, regulations and the rule of law, access to technology and capital, and infrastructure. There are environmental concerns as well, particularly with aquifer contamination from hydraulic fracturing using additives. The electrification of energy will also put pressure on gas demand.

3.32 Natural gas consumption reached 262 Billion Cubic Meters (bcm) in 2016, a 13.1% increase over demand in 2011. This has been a result of accelerated economic growth coupled with the need to switch to cleaner fuels. Mexico, Argentina, and Brazil have seen the strongest rise in natural gas consumption and this trend is expected to continue in the next 10-15 years. This robust growth in consumption is backed by high demand for natural gas in the electricity sector. The gap between supply and demand has risen in the last few years and is likely to continue unless LAC's natural gas resources are fully developed. In 2016, about 81 bcm excess demand of gas was met by LNG and pipeline imports. Of the total gas imported, LNG represented 31% (EIA, 2017). In Caribbean countries, the relatively low cost of natural gas compared with other liquids, together with floating barge technologies that reduce the cost of investments and the length of time required to deploy them, has progressively made LNG an economical solution. Examples include the Jamaica, Guyana and Suriname Integrated Resource Planning, the Barbados LNG importation project, and the Panama LNG terminal and thermal power plant.

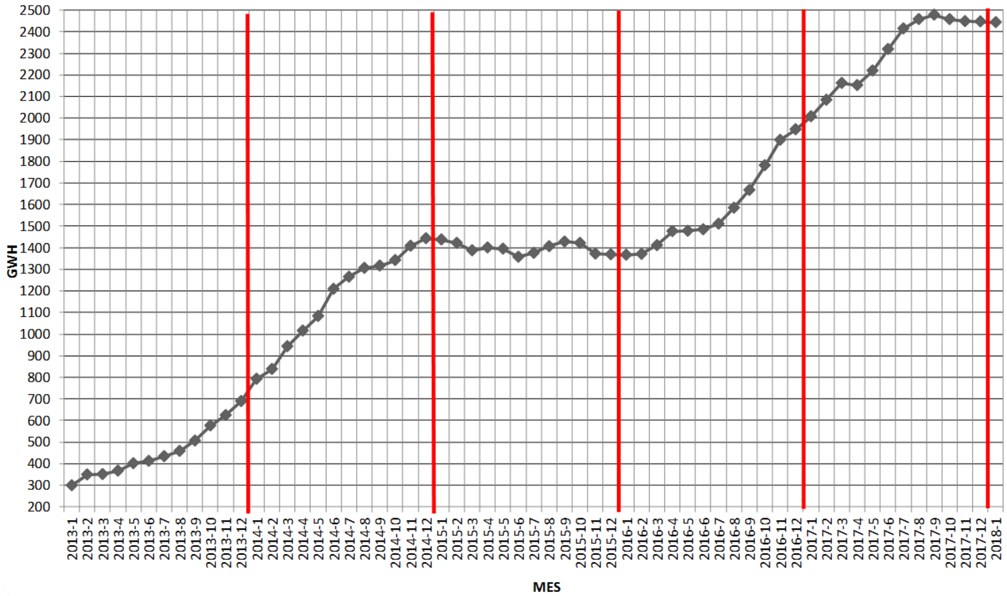
3.33 Meeting the rapidly increasing demand for gas in the region, especially for power generation, will be a further supply-side challenge. In 2016, total natural gas production rose by 1.8% to 235.8 bcm. Major contributors were Mexico, Argentina, Venezuela, and Trinidad and Tobago. Mexico is the largest natural gas producer, followed by Argentina, but it has seen a steep decline in recent years.

3.34 The IEA estimates that investments required for natural gas development in LAC for the next 20 years would range from US$537 billion in the new policies scenario to US$435 billion in the 2 ºC scenario. Expansion of gas markets will require additional domestic transportation capacity in countries like Mexico, gas pipelines that connect importing and exporting countries, and LNG terminals in countries like Chile, Colombia, and Uruguay and Central America.

3.35 **Greater regional energy integration**. LAC could realize substantial benefits by increasing regional energy integration, including lower energy prices, more system reliability, and improved competitiveness. Such integration could take advantage of the region's rich but unequally distributed resources, especially hydropower and natural gas. The energy mix diversification could strength energy security and the necessary balance for renewable generation. For this diversification, it is important to include supplies through regional gas pipelines, LNG or transmission power lines. Paredes (2017) shows that the capacity of Latin America to implement NCR at high percentages economically (potentially becoming 100% renewable) will depend on the integration of power markets. In the current state of the technologies, the required flexibility by the NCR cannot be efficiently managed at a national level. Thus, the lack of integration may prevent countries to advance in their sustainable agenda.

3.36 Regional energy integration has already showed some results in LAC. One notable example, supported by the IDB, is the Central American Electrical Interconnection System (SIEPAC) connecting Guatemala, El Salvador, Honduras, Costa Rica, Nicaragua, and Panama. SIEPAC has two components: (i) a treaty signed by member countries providing (a) the legal, institutional and political basis for a regional electricity market, based on a regional regulator, (b) a standard set of rules, and (c) a transmission operator; and (ii) a 1,800 Kilometers (km) transmission line. Begun in 1987, SIEPAC went into operation in 2013. Exchanges have increased tenfold between the start of SIEPAC in 2013 and 2017 (see Figure 3).

Figure 3. Evolution of the Exchanges in SIEPAC 2013-2017 (in GWh)



Source: Presentation of the Management Council of the Central America Regional Electricity Market for the Ministerial Meeting. February 2018.

3.37 Despite of SIEPAC remarkable advances in integration achievements, there are still some challenges. National market regulations still need to be harmonized with the regional regulations. Issues related to transmission rights, market structure and guarantees of capacity, are still being resolved limiting transactions to emergency exchanges (Echevarría et al., 2017) and resulting in a relatively low use of the line.

3.38 The IDB has supported other initiatives, such as the *Arco Norte* and Andean Countries Interconnection (SINEA). The latter contemplates investing US$850 million to build four transmission lines over a 1,310 km extension to connect Colombia with Chile through Ecuador and Peru, producing more than US$2.5 billion in savings. *Arco Norte* is the potential electrical interconnection of the power systems of Guyana, Suriname, French Guiana, and the states of Roraima and Amapa in Brazil. In the pre-feasibility study performed by the IDB, five interconnection alternatives with capacities from 300 MW to 4,500 MW were found to be economically viable, with net benefits ranging from about US$67 million to US$461 million (Larrea et al., 2016).

3.39 Regional integration of natural gas markets is another important issue in the region. There are different motivations for this integration: (i) it can be the only way to scale up and justify the inclusion of this resource in the energy matrix (displacing the more polluting and costly fuels); (ii) it can be the most economical way to buy natural gas; and (iii) it can be the best way to monetize some suppliers' reserves. From the infrastructure perspective, the integration of natural gas markets can be achieved by: (i) the construction of gas pipelines; or (ii) the development of LNG hubs, which, for instance, could allow the natural gas to reach small islands. Following the same lessons learned of power integration experiences, it is key to develop harmonized rules and market designs.

3.40 Integration leading to regional energy markets requires: (i) long-term availability of electricity and gas from countries with exportable surpluses; (ii) harmonization of power and natural gas regulatory regimes among countries; (iii) a regional accord to guarantee that energy supplies channeled through pipelines and transmission lines will not be arbitrarily cut, as well as protocols for short-term disconnections; (iv) stable energy policies and regulations that encourage both public and private investment; (v) a deep and liquid market, with availability of future contracts and hedge instruments; and (vi) long-term commitment to integration projects that extends beyond the life of particular governments. The opportunites and benefits of energy integration are important; however, the challenges go beyond the infrastructure requirements and they demand an appropriate institutional setting for the regional transactions and the harmonization of market designs.

3.41 **Increasing energy infrastructure investments and their efficiency.** It is estimated that by 2040, LAC will double its electricity demand. According to the projections calculated in the report The Energy Path of LAC (RG-E1520), we can estimate an annual average increase of 2.7% to 3.6% in the demand. As consequence, LAC is expected to be one of the regions with the greatest energy demand growth rates in the coming years.

3.42 The Energy Path of LAC report estimates that LAC countries must invest approximately 408 GW in new generation capacity. Assuming there are no changes in the historical tendency and the governments' formal expansion plans, we could expect that 138 GW would come from fossil sources and 270 GW from renewable sources. For this, we can estimate[25] that it would be necessary to invest approximately US$24 billion per year until 2040.[26] In addition, it is estimated that between 2016 and 2040, approximately 163 GW of installed capacity will reach the end of useful life, which will require effort and attention to replace. According to the report's estimates, a large part of this capacity is in the countries of the Southern Cone and Central America. It is estimated that around US$177 billion would be necessary for the replacement of these assets.[27]

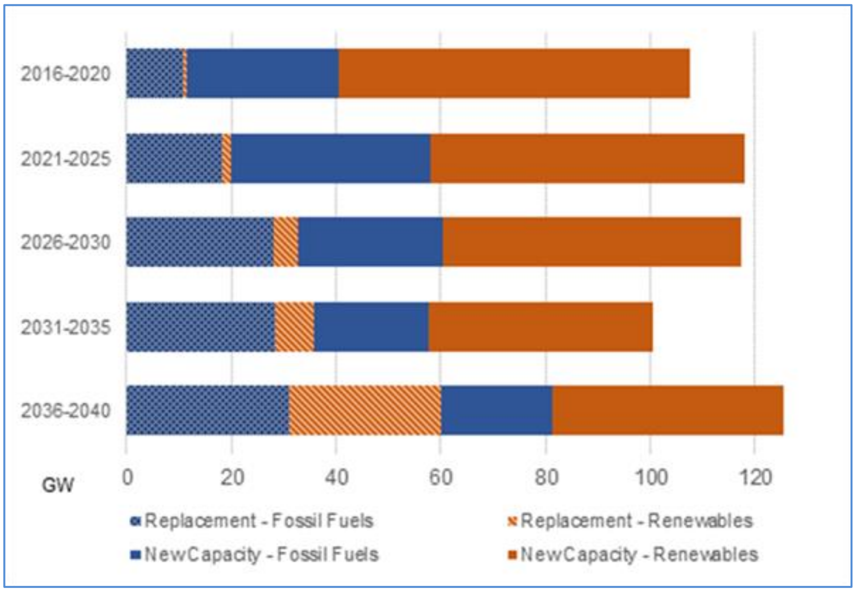
3.43 Figure 4 illustrates the expected investment in electricity generation in LAC, considering replacement and generation to face the increase of demand.

[25] The estimation uses historical costs, which does not consider future changes in costs.

[26] For its calculation, the public expansion plans of each of the countries and the electricity demand projections were considered, in those cases where there was not a plan of expansion or the planning horizon will not arrive until 2040 the last generation matrix was assumed constant. In doing so, the intentions declared by each of the governments in their expansion plans are respected. This is an estimate based on the information available, does not include projections of low costs, technological changes and changes to the matrix (which are not announced by governments).

[27] In order to calculate the useful life and the replacement date of each type of source, the historical generation matrices were taken as of 1971 and this year was assumed as the starting point for each of the technologies. When fulfilling its useful life, each asset must be replaced in its entirety, i.e. a natural gas plant with a useful life of 25 years at the beginning of its period in 1971 should be completely replaced in the year 1996. This calculation is a first approximation to the effort that the region must make in order to maintain good conditions in the current park of generation. More details can be found in the report Energy Path 2018.

Figure 4. Investment in Electricity /Generation in LAC (in GWh per five year)



Source: IDB Report to be published in 2018.

3.44 To summarize, it is estimated that all investment associated with the electricity sector chain (including generation, transmission, distribution and replacement of assets) will require around US$34 billion per year until 2040. This value can be considered a ceiling since it does not contemplate changes in costs and technologies, which is expected to decrease.[28]

3.45 The public sector will likely continue to be responsible for significant financing, since it remains an important actor in the energy sector in several LAC countries (Balza, Jiménez, and Mercado, 2013). A study conducted in seven regional nations found that governments could substantially improve infrastructure expenditure efficiency if the best practices of the most efficient countries were universally adopted. (Clements, Faircloth, and Verhoeven, 2007). When public financing is provided indirectly, for example by working closely with financial agents, adequate provisions to ensure close collaboration with energy authorities responsible for planning and regulation are imperative to ensure efficiency.

D. Energy Sector Governance – Institutional Framework, Sectorial Organization, and Policies

3.46 Countries in LAC have a variety of regulatory frameworks, institutional endowments and policies incentives. The way forward to improve the institutional setting for the energy industry depends on the quality of the sectoral organization, regulatory governance, and policies. This institutional setting should be able to deal with current market failures, to smooth the disruptive impact of recent technologies and to benefit from opportunities that innovations open to the energy sector.

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[28] In the last seven years, the Energy Division has invested an average of US$503 million per year in operations. Based on this, it is estimated that this amount corresponds to approximately 2% of the total investment of the electricity sector in the region. This estimation is based on the methodology and costs used in The Energy Path of LAC Report. In order to maintain this percentage, it is estimated an investment of approximately US$646 million per year up to 2040 is needed. However, the Bank's investment decisions are based on the demands and interests of the countries in the region.

3.47 To varying degrees, LAC countries need to build capacity in ministries, regulators, and local governments. Ministries must have the capacity to develop sector policy and shape and oversee the legal, financial, and technical aspects of the sector, concessions and contracts, and manage risk. Kaufman and Zulanty (2018) highlight the case of Chile, where the Energy Ministry's results-oriented management has brought about improvements.

3.48 Regional and municipal authorities also need strengthening, as they control a growing share of infrastructure as a result of decentralization. The importance of strong public institutions has only increased with the growth of Public-Private Partnerships (PPP), due to the more extensive conditions and obligations involved (Fay and Morrison, 2007). The institutions responsible for developing expansion plans are also key players in the organization of the energy sector.

3.49 Long-term energy plans need to be developed by those countries that do not have them. They provide roadmaps for realizing energy policies and making decisions on major energy infrastructure investments. The trend in LAC has been for governments to contract major energy infrastructure through the private sector or public-private financing or to make such investments directly through public-sector entities. In most cases, the decision to develop major infrastructure is made directly or indirectly by the state through a planning process or the application of specific rules that determine future needs (*Banco de Desarrollo de América Latina*-CAF, 2013). Such planning will become increasingly complex as EE and RE are incorporated into the process.

3.50 **Industrial organization.** Energy sector organization varies widely from country to country. Some LAC nations have advanced more in the separation of generation, transmission, distribution and commercialization activities, as well as in regulator independence and competitiveness (see Table 9). Availability of comparable data in LAC is limited. We can observe, however, that independent producers play a critical role throughout the region.

3.51 Limited unbundling and partial wholesale markets are frequent. The concentration of these markets is an important challenge for some countries, and the retail market, where it exists (such as Brazil, Chile, and Colombia) does not include households.

Table 9. Indicators on the Level of Completeness of Wholesale Markets in the Region

Indicator	Brazil	Chile	Colombia	Honduras	Mexico	Uruguay
Utility unbundling	Somewhat	Somewhat	Somewhat	Somewhat	Somewhat	Somewhat
Independent power transmission	Somewhat	Somewhat	No	No	Somewhat	Somewhat
Retail market liberalization	No	No	No	-	No	No
Wholesale power market	Yes	Yes	Yes	No	Yes	Yes
Concentration of generation market	Somewhat	Somewhat	Somewhat	Somewhat	High	Somewhat
Concentration of supply market	Low	Low	Somewhat	High	High	High

Source: IDB elaboration, data from BNEF, Climatescope, 2017.

3.52 **Building regulatory capacity.** Another necessary task in the region is to develop strong, independent regulators that operate under clear laws and regulations in countries where such regulators have not yet been established. This will be key to mobilize investments, especially private sector investment, as well as achieving policy goals such as affordable and sustainable energy supply. Effective and predictable regulation by an independent regulator is an important determinant of sector performance and its ability to attract investments. Reducing regulatory uncertainty is necessary to lower the cost of capital and increase returns, which can help boost private sector participation.

3.53 **The energy investment environment is improving, but private sector players still face structural challenges.** The region has some of the top performers in RE investment, but some countries still have market structures that hinder competition by limiting the entry for additional players, innovative business models, and new technologies that could improve energy infrastructure. Sustainable energy investors require regulatory environments that are stable and predictable, with a long-term vision of the sector to reduce risks and foster proper financing mechanisms. Availability and affordability of recent technologies are changing the marketplace faster than market regulation, creating investment opportunities. At the same time, recent technologies open the opportunity to renovate assets that are becoming obsolete, supported by policies and regulations that promote investment to renovate decommissioned capacity. New business models that provide energy services are thriving under more open markets, ranging from EE in housing and public lighting to distributed generation and demand response systems in the industry. Lastly, promotion of energy innovation is an area of opportunity that could address challenges of research and development, employment, and environmental sustainability. Thus, investment in more sustainable energy in the region requires more competition and regulation that is compatible with technological change, and with the lifespan of sustainable energy infrastructure.

3.54 **Improving sector information.** Data and energy sector analysis must be improved in LAC to provide a sound basis for energy policy and planning as well as for regulatory and corporate decisions. Analysis of the effectiveness and impact of energy policies and programs needs to improve. Sector studies have so far focused mainly on sector forecasts and planning as well as on project engineering rather than on the impact of interventions on development. This situation is aggravated by the lack of systematic and reliable data collection, especially in the Caribbean. The IDB will focus on improving the availability of results evaluation.

3.55 The region must also strengthen data generation and collection mechanisms (with disaggregated information, for example on income and gender). Although significant efforts have been made by organizations such as the IDB, ECLAC, OLADE, and the EIA to generate relevant data for energy supply and prices, challenges remain in obtaining standardized, comparable, and easily available data in key areas. Data are inadequate on quality of energy, energy prices, energy demand by sector, traditional and decentralized RE, consumers behavior, market design, auctions and procurement rules, regulations, and EE investments and results.

3.56 As the amount of information requirements, transparency, and data gathered and processed by the participants in the sector increases, so do the cybersecurity risks. According to Kaspersky Lab (2018), about 5% of attacks to industrial control systems for the first six months of 2017 occurred in the electricity sector, and 3% in natural gas and oil companies. In LAC, about 5 in every thousand computers were attacked, and the energy sector endured 2.3% of the attacks. The main attacks occurred via the Internet using malware and phishing, hidden in spam emails disguised as part of business communication, with malicious attachments or links to malware download programs.

3.57 This relatively low proportion, compared with more than half of the attacks targeting manufacturing companies, is due to the isolated nature of the communication and control systems in the energy sector. Recommendations to mitigate cyber-threats include: (i) make an inventory of the services that are executed in the network, with special emphasis on those that provide remote access to the objects of the file system; (ii) conduct an audit of the isolation of access to Industrial Control System components, the activity in the company's industrial network and its limits, the regulations and practices related to the use of removable media and portable devices; (iii) verify the security of remote access to the network as a minimum and reduce or eliminate completely the use of remote management tools at most; (iv) keep security solutions updated in the terminals; and (v) use advanced protection methods, implementing tools that provide network traffic monitoring and cyber-attacks detection.

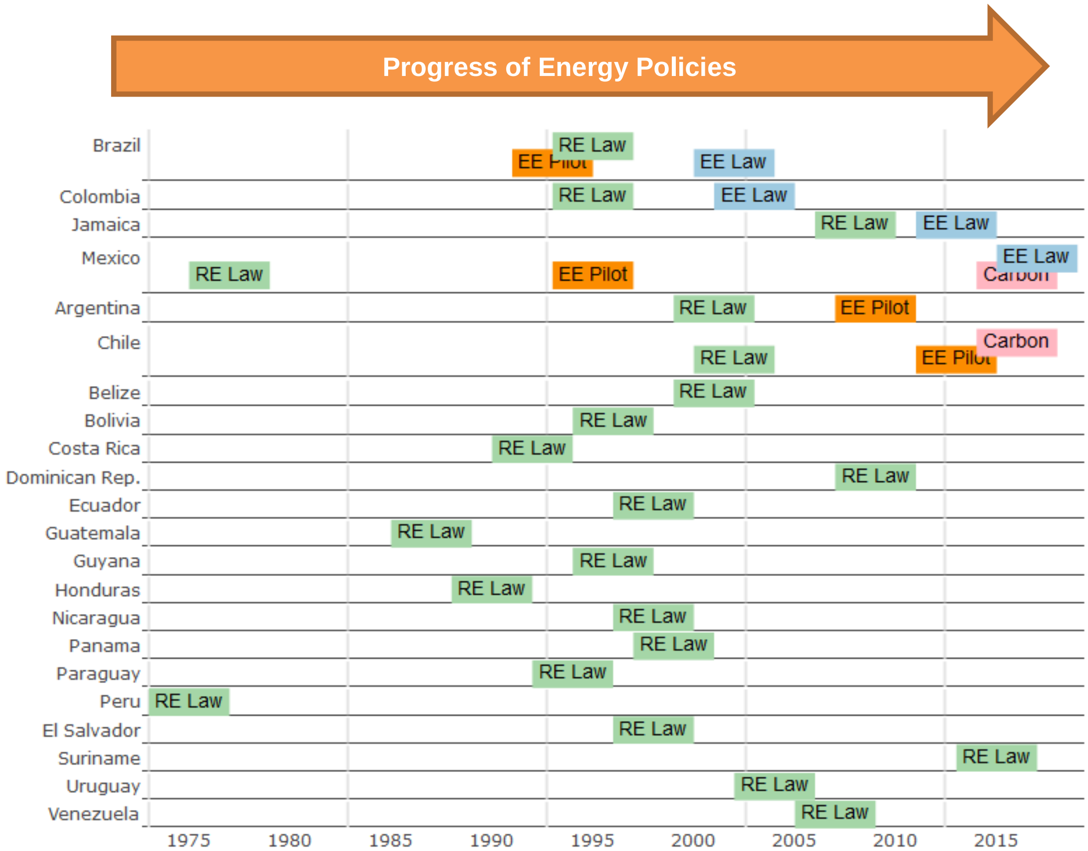
3.58 **Women in the energy sector labor market.** Women participation in the labor energy sector is low. According to the IDB's Labor Markets and Social Security Information System, women represent 19.7% of the total number of employees in the water, electricity and gas sector. The latest data on women in utilities and power shows that even though Latin America has the highest rate of female board executives globally, 9%, this number is still low (Ernst and Young, 2016). Women are still underrepresented in the sector, mainly in technical and managerial positions. This poses a challenge, not only because it limits women's economic opportunities, but also because it affects sector performance by missing out on the knowledge, skills, and perspective that women can contribute.

3.59 **Energy subsidies.** Energy subsidies may create significant distortions and unforeseen costs, such as: (i) environmental costs that lead to excessive energy consumption of high polluting fuels and harmful GHG emissions; (ii) macroeconomics costs, such as fiscal deficits and the use of important public funds from other sectors like health and education; (iii) social distortions where benefits flow disproportionately to consumers with higher incomes; and (iv) sectorial costs given that subsidies, if not compensated by government transfers, can create financial unbalances for the energy sector. Given these significant distortions, subsidies need to be eliminated or re-designed with the aim of guaranteeing an overall greater economic and social benefit and lowering negative distortions. In this context, a major policy issue is the urgent need to eliminate generalized fossil fuel subsidies (Bast et al., 2014; Galiana and Sopinka, 2014).

3.60 To decrease costs and distortions, untargeted energy subsidies could be replaced with explicit, well-targeted, and sustainable subsidies to poor and marginalized populations (Komives et al., 2005). For example, as an alternative to subsidies, conditional cash transfer programs could incorporate a specific component for energy. Together with social assistance and human capital development, this mechanism could help reduce poverty and avoid passing the trend from one generation to the next (Marchan et al., 2017; Stampini, 2012).

3.61 **Environmental sustainability policy.** Countries have been slower in adopting EE laws. As with RE laws, where a few early adopters served as an example to the rest of the region, it is expected that within the next few years every country in the region will adopt them. EE regulatory frameworks are complex, requiring many regulations specific to each type of use, application or appliance. Examples of the former are codes for residential, commercial or industrial buildings. There are also regulations for water pumping, or load carrying vehicles, and finally, there are regulations for refrigerators, or air conditioners of diverse types (for example wall units, heat pumps, central systems).

Figure 5. Incorporation of Energy Sustainability Policies in LAC



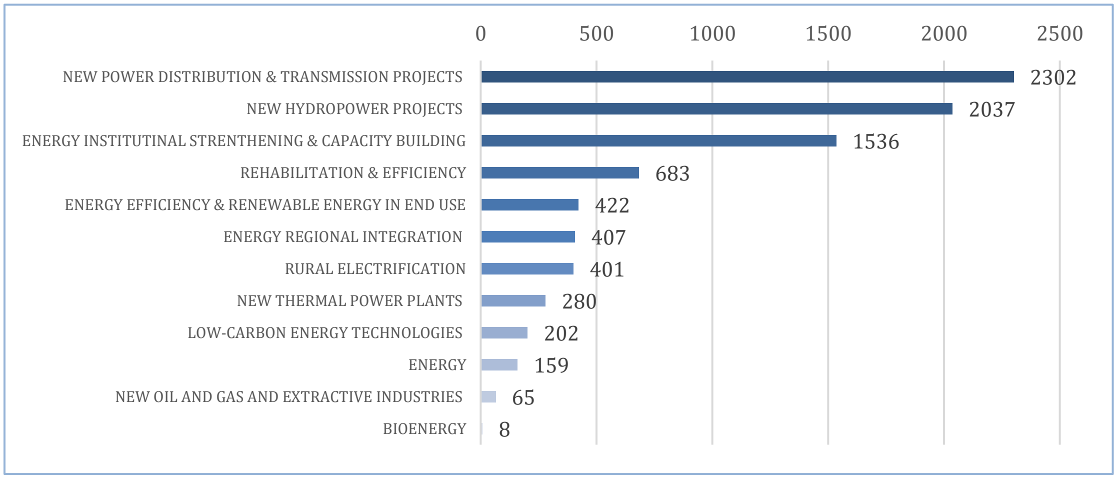
Source: IDB calculations based on IDB *Examen de Instrumentos Económicos para la Fijación de Precios al Carbono*, IEA/IRENA, BNEF; Carbon = carbon pricing instrument.

IV. LESSONS FROM THE BANK'S EXPERIENCE IN THE SECTOR

4.1 The IDB has been assisting countries for more than 50 years in the sustainable formulation and implementation of energy policies and regulations, and of infrastructure projects. The Bank has ample experience gathered in multiple countries, conditions, and energy technologies, both with sovereign and non-sovereign loans, other reimbursable instruments (guarantees and equity), investment grants, and Technical Cooperation (TC) grants. The extensive presence of the Bank in the field, the diversity of its members' backgrounds, the complementarity with climate change adaptation and mitigation, and the application of the environmental and social safeguards, guarantee high-quality results in the Bank's outcomes. This section reflects the lessons learned, the advantages and the areas that need to be strengthened to continue successfully supporting our member countries.

4.2 The accumulated financing in the 11 years from 2007 to 2017 totals US$8.5 billion in 425 projects. Slightly more than half of the funding was invested in transmission and distribution, and in hydropower projects. The rest was targeted to 10 categories, as can be seen in Figure 6. In the last three years, however, there was a qualitative change. While governance and sustainability together made up one-third of total investments, now each represents one-third of the total. The change reflects the importance of regional efforts in strengthening institutions, regulatory frameworks, and increasing operational efficiency, as well as in introducing low-carbon technologies, rehabilitating existing infrastructure and EE, and obtaining a balanced portfolio. It also reflects the impacts of the international climate funds. The effort in increasing access has remained steady. Energy-related operations have been carried out by the Energy Division, by IDB Invest, and by other divisions such as the Connectivity, Markets and Finance Division (IFD/CMF). The following sections focus on the experience of the Energy Division and IDB Invest.

Figure 6. Accumulated Investments by Energy Sub-Sector 2006-2017 (million US$)



Source: IDB calculation

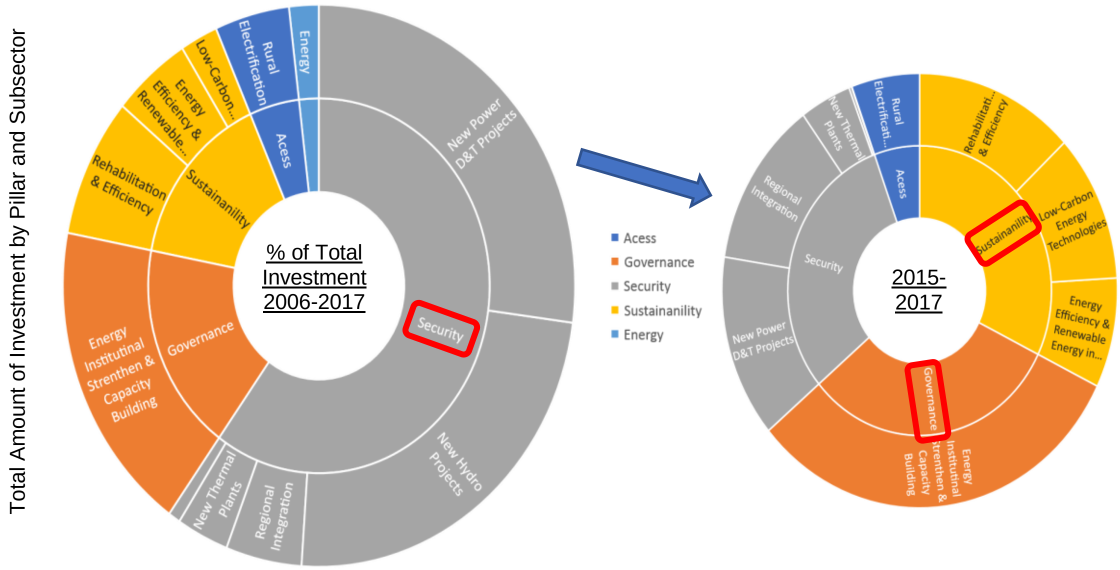
A. Lessons Learned from Completed or Final Stages of Execution

4.3 Building on the success of the previous Energy SFD, in force since 2015, we review the main lessons learned from operations led by the Energy Division through project completion reports, progress monitoring reports, loan proposals and other relevant documents. The lessons learned, described below, should be considered complementary to the previous SFD, as it still remains valid.

4.4 **Access to quality energy services**. The Bank has financed projects that: (i) expand energy coverage through systems connected to the grid or isolated systems; (ii) improve the quality of energy, reducing carbon consumption with the introduction of EE and RE measures; and (iii) boost the reliability and affordability of the connection, through infrastructure investment components for the reduction of total electricity losses. Some lessons learned from the projects for the Access Pillar are:

4.5 **Adequate framing of the projects.** The recognition of informal public networks allows to focus resources, design projects, and adjust the terms of the evaluation of benefits in energy loss reduction. Improving deficient electricity services requires a different approach depending on whether the homes have formal or informal connections, or no nearby network. Therefore, the impact on different stakeholders can vary.

Figure 7. Financing by Pillars



Source: IDB calculation.

4.6 **Definition of the operation scheme.** In the energy access projects, not only the initial investments are necessary. Even more important to guarantee service sustainability is to put in place a business model that will operate and maintain the goods and equipment in the medium- and long-term, to avoid their remaining in disuse at the end of their useful lives. In isolated systems or individual solutions, for example, the required batteries have a useful life of three to five years. Lack of an operation scheme that guarantees their replacement can result in beneficiaries losing service.

4.7 There are multiple system operation schemes that incorporate new clients both for network extensions and for isolated systems, including: (i) participation of the region's distributing company; (ii) granting new concessions to geographic regions or specific systems; (iii) hiring specialized private companies; (iv) adding new roles to entities operating in the area, such as granting functions of energy production and distribution to rural aqueducts; (v) creation of community organizations that provide the service; and (vi) a combination of some of the above. The program must ensure that a business model is defined during the design and an operator is hired during the implementation of the program. Rural electrification must be performed integrally to be successful (see Box 3).

4.8 **Selection of beneficiaries.** The identification and definition of the communities that will benefit at an early stage is crucial to: (i) promote their participation through workshops that educate them about the benefits and the requirements of the program in terms of human and financial resources; (ii) establish a baseline to quantify the impact of the program through contrasted methods, such as randomization; (iii) sign the agreements with the distributing companies when corresponding, to begin execution without delays; and (iv) ensure the communities' commitment to achieve medium and long-term financial viability and the future self-sustainability of the systems, without requiring economic contributions from the government.

Box 3. Nicaragua - National Program for Sustainable Electrification and Renewable Energy (PNESER)

The PNESER is a US$416 million program launched in 2010 by the Government of Nicaragua with a multi-year structure - three IDB loan operations - and with multiple participants: IDB, Central American Bank for Economic Integration, European Investment Bank, Export–Import Bank of Korea, the Organization of Petroleum Exporting Countries Fund for International Development, Japan International Cooperation Agency, EU / Latin America Investment Facility (LAIF), and the Fund for National Development. This comprehensive program covers numerous areas of the electricity sector: rural electrification, user standardization, reinforcement of the transmission system, expansion and sustainability of isolated systems, and pre-investment studies for RE and EE. The National Electricity Transmission Company coordinates and executes the program with the support of the Ministry of Energy and Mines and the Nicaraguan Electricity Company.

The program has extended coverage to 100,000 homes and normalized supply to 61,000 additional homes, which is equivalent to 13% of the country's population. It constitutes the single largest contribution to electrification, which in 2017 reached 90%. Although PNESER’s main goal was to increase access, it has had substantial impacts on the financial, economic and environmental sustainability of Nicaragua's electricity sector: pre-investment studies have been prepared for hydroelectric, wind and geothermal projects that together add 1,080MW, equivalent to the existing effective capacity in Nicaragua's electricity system, providing investment options to meet demand over the next 20 years.

In terms of EE, the sector has been transformed with the preparation and approval of the national program and EE law, the replacement of 2.1 million traditional bulbs with efficient luminaires in 500,000 homes, the replacement of 96,000 efficient street lighting lamps, and fitting 50,000 efficient light fixtures in public buildings. Finally, the transmission system is being reinforced with 600 km of new lines and 400 MVA in transformation capacity, equivalent to an increase of 30% in extension and capacity of the system.

Source: November 2017 Report - PNESER Follow-up Committee.

4.9 **Gender.** The energy sector offers opportunities to promote gender equality and the empowerment of women through the systematic implementation of a gender perspective in the operations. ENE has developed a plan that consists of proactive actions, transversally integrating the gender perspective and direct investment supporting it as an important part of the projects. ENE has reached its goal in the number of Sovereign Guaranteed (SG) loans strategically aligned with gender and diversity.

4.10 The Energy Division will continue to focus its operational work on promoting economic opportunities for women, adapting infrastructure and infrastructure services to address gender-differentiated needs, and strengthening women’s leadership and participation. The Gender Action Plan for the Energy Division[29] focuses on three main strategic lines of action: (i) energy access: (a) adapt energy access projects and projects related to the use of modern fuels for cooking, heating and others to address gender-differentiated needs; and (b) promote new habits/behaviors and technologies; (ii) data and information: (a) collect sex-disaggregated sectoral data; and (b) generate knowledge products for the design of energy policies and projects; and (iii) equal opportunities: (a) promote men’s and women’s ability to take advantage of the opportunities (mainly economic) generated by projects, and (b) promote women’s incorporation into non-traditional jobs within the sector (see Box 4).

[29] Energy Gender Action Plan 2018.

Box 4. IDB's Work with Clients to Promote Gender Issues and Transform the Energy Sector

In 2017, the IDB approved two programs that promote gender. The first was a loan for Brazil*, "CELESC Energy Infrastructure Program"*, with activities to foster greater gender equality. In the company, women account for 19% of 3,290 employees; nonetheless, they represent only 3% of all employees in technical positions. This situation prevents the company from taking advantage of the benefits of a more diversified labor force and the positive impacts it can have on women's professional development and on the company's operations and financial performance. Hence, the program includes the development of a gender promotion strategy and updating the Young Apprentice program implemented by the company.

The second operation was the *"Program to Support the Advancement of the transition of the Energy Matrix"* in Ecuador. The program will finance gender-related activities, including the development of a "Strategy to Promote Gender Equality in the Electric Sector". Ecuador has significant gender gaps regarding women's economic opportunities and contributions. Women are still a minority in the "electricity, gas, and mining" sector, at 28% of total employees. The program will contribute to: (i) reduce salary inequality between men and women; (ii) maximize the impact of energy policies and projects on women and girls; and (iii) incorporate a greater number of women into the labor force of the Energy Sector.

4.11 **Sustainability**. The Bank has financed projects to plan, design and update the regulatory framework, and developed projects to diversify the power matrix and enhance EE. The main lessons learned are:

4.12 **Diversification of the electricity matrix with more sustainable resources.** A technical and economically sustainable matrix requires: multiple studies to establish an accurate baseline; determine an inventory of energy resources; perform an analysis of possible policy options, timelines, and alternative strategies to achieve each policy goal; determine the resources needed; and assess the risks that the target matrix faces. The determination of energy resources should start with satellite data and proceed with ground-level measurements on the most attractive locations. The existence of: (i) an enabling legal and regulatory framework that establishes incentives to develop RE technologies; (ii) the government's solid commitment to development; and (iii) the availability of non-reimbursable support mechanisms and risk mitigation mechanisms, which are essential for the promotion of private investment and for the successful completion of projects in RE. Also, financial instruments need to be adapted to each and all stages of project development and include all relevant actors, including the public sector, and consider public-private alliances to complete the execution of RE projects.

4.13 **Engagement with the community in the construction of hydropower plants.** The Environmental and Social Safeguards policies, together with the continued and extensive involvement of ESG and energy specialists, have demonstrated to be successful in the reduction of conflicts with the community. Rigorous application of environmental and social safeguards policies to energy sector investments has allowed to effectively mitigate environmental and social impacts and risks related to those investments. ENE and ESG have continued reinforcing their collaboration, with early participation of ESG specialists in both pipeline decisions, particularly for the hydropower sector, and projects' design and preparation. Such application has permitted for the IDB: (i) to make complex and sensitive energy projects more sustainable (e.g. the *Reventazón Hydropower Plant*); (ii) to strengthen environmental and social management capacity of executing agencies to support long term safeguards compliance; and (iii) to identify opportunities for added value, such as leveraging investments to strengthen conservation and management of protected areas (e.g. in the geothermal sector), improving land tenure security, achieving greater natural resource efficiency, increasing opportunities for equal access, and promoting transparency.

4.14 **Adoption of EE measures.** The incorporation of EE objectives in policy-based programs and loans with specific policy measures are an effective way to circumvent the limitations of financial incentives to the massive replacement of inefficient equipment, including setting minimum efficiency standards in lighting, air conditioning, building envelope, variable-speed electric motors and water pumps.

4.15 **Programs on building retrofit for the efficient use of energy.** As EE technologies are very dynamic, operation manuals should be subject to periodic reviews. If discrepancies are detected, the executing agency should have sufficient flexibility to introduce any modifications required, for example, to ensure that the materials and technologies selected are the most suitable in terms of price and quality. The strategy to implement and supervise the reconditioning processes for EE must be shared with all relevant partners and stakeholders, including plant staff, to ensure their active participation.

4.16 Performing extensive energy audits at an early stage, including the building envelope, prevents errors in the preparation of budgets and of requests for proposals, leading to shorter procurement processes. Data collection must incorporate data recorders at least six months before the start of the reconditioning of the facilities; and analyze consumption comprehensively through the study of invoices and identify their relationship with the measurement systems. It is recommended that audits be performed before the approval of the loan contract. This allows to adjust with precision the scope of the works and avoid a scenario in which the reform may require larger investments than originally planned.

4.17 **Use of the ESCO business model and Energy Services Performance Contract (ESPC)**. The implementation of EE investment projects through the ESCO business model has proven to be commercially and economically viable in the region. These investments increase productivity and reduce operating costs and the carbon footprint. ESCOs are private firms that sign ESPCs with the beneficiary and invest in EE projects, being paid back from the savings generated by those investments. Those investments are made by the ESCOs at their own risk. To avoid difficulties in the process of measuring savings, agreements must be established on the measurement methodology, the areas of intervention and the prices to which the savings will be valued before actual audits. In addition, compliance with international standards should be ensured. To expand this model, guarantees to both parties are needed that could be funded by the government through a specific fund and with mezzanine financing. For example, in Mexico and Nicaragua, the Bank has promoted projects and TC to deepen the knowledge of the particularities of this system.

4.18 **Energy security and regional integration.** The Bank has supported programs for: (i) the rehabilitation and modernization of generation and transmission infrastructure; (ii) financing of new infrastructure to reduce the vulnerability of the electric system and guarantee a better supply to the region; (iii) reduction of fossil fuel consumption; and (iv) mitigation of the environmental impacts related to waste management and the use of diesel, focusing its actions on the improvement of environmental management and EE.

4.19 **Rehabilitation of infrastructure.** The Bank must accompany network rehabilitation projects during the complete development cycle, with measures such as extension of the measurement, updating of the beneficiaries, and development of complementary plans to guarantee the security of supply.

4.20 **Cost overruns vis-à-vis turnkey contracting.** The main causes in cost overruns are increases in work quantities, design modifications, and changes in the scope of the project. Per the contractual clauses in the Bank's loans, in such cases counterpart funding must be increased to complete execution, typically leading to project delays. Even through Engineering Procurement and Construction (EPC), turnkey tender costs tend to rise compared to the purchase of goods and hiring of work separately; these costs need to be compared with the loss of responsibility in the coordination of the purchase of goods and works, as cost overruns are more frequent when components are contracted separately. Unless the executing team, which assumes the risks of delays, has extensive experience in project integration, EPC contracting might be the preferable choice. During project preparation, it is necessary to assess the capabilities and resources of the executing agency, subnational governments and other institutions involved. The borrower's commitment to provide local counterpart resources in the required amounts and on time should also be evaluated.

4.21 **Adjudication processes.** In the design phase, sufficient time should be planned for the procurement processes. Executing agencies should be trained early in IDB's acquisition policies. If acquisition specialists are hired to strengthen the executing unit, it is advisable that the specialist also has a solid knowledge of similar projects and market characteristics. The creation of databases or repositories of information on contractors and consultants –both national and international– would facilitate the selection of the most suitable and reliable players. When market conditions lead an acquisition process to be declared void, the risk should be identified in the risk matrix, and the executing agency should be strengthened.

4.22 **Pre-investment studies.** Pre-investment studies, understood as technical designs and economic, financial and environmental feasibility evaluations, vary according to the type of project and the country or region. Correct allocation of resources for their preparation, monitoring, and closure, is key to achieving the required quality of a project. As a lesson learned, high-quality pre-investment studies incorporating the full scope of the project without underestimating its costs, allow for better project prioritization and budget allocation. Legalizing the land of project sites, obtaining permits and rights-of-way, authorizations or licenses, among others, can cause delays and affect the execution, and should be included in the timelines of the project, advancing in parallel to other activities, for example during the acquisition process. Several projects underline the need to strengthen team management capabilities, incorporate delay risks in the programming, determine their impact on a detailed schedule, and consider each of the steps to be taken by public entities. It is also crucial to ensure that the executing agency has a broad knowledge of the national regulatory framework, given its high impact on project execution timelines.

4.23 **Governance**. The Bank has accumulated extensive sector knowledge through its operational experience, presence in the countries, and preparation of programmatic loans, which are specially indicated instruments. The IDB has continued to accompany sector reforms, which involve a multiplicity of actors, with institutional strengthening components, implementation of solid legal and regulatory frameworks to encourage medium and long-term investments, financial sustainability and operational efficiency.

4.24 **Regulatory framework and governance.** Project success depends on: (i) adequate planning and management of expenditures; (ii) the capacity and effectiveness of the institutions that intervene in each stage, both at the national and subnational levels; and

(iii) coordination between agencies and institutions to align objectives, avoid redundancies, consider sensitivities and interests, and anticipate and resolve conflicts.

4.25 **Institutional capacity of the executing entity or government organizations.** Weak institutional capacity of public sector entities is a challenge in the implementation of projects to improve electricity service reliability. Evaluations point to the need to reinforce the following aspects: (i) system planning; (ii) project management; (iii) loss reduction; (iv) network design and operation; (v) service quality; and (vi) human resources. The IDB must offer a comprehensive solution that covers the corporate, technical and infrastructural challenges countries are facing. A Consultative Executive Committee that works with the executing agency supervising project execution and coordinating with other public-sector agencies can help solve strategic and organizational bottlenecks.

4.26 Most of the delays experienced in the execution phase are due to executing units with inadequate structures, lack of sufficient and well-trained staff, and weak institutional and technical capacity. Those units with sufficient budget to hire expert support in key functions, such as supervision and evaluation, environmental management, and compliance, have been able to reduce delays (see Box 5).

4.27 The IDB has supported the state-owned enterprises in three dimensions: (i) promoting best practices and restructuring to improve the corporate governance through TC and Policy-Based Loans; (ii) improving their effectiveness to achieve its economic and social objectives means by financing the investment needs coupled with institutional strengthening; and (iii) developing methodologies to evaluate their results.

4.28 **Aligning program objectives with stakeholders' priorities.** Objectives, intermediate program milestones, and execution plans must be consistent with the needs and interests of key stakeholders, including sizing of the programs, either in terms of amounts, components or execution periods. Operations should have flexible designs that can be adapted to the evolution of external factors, such as budget constraints.

Box 5. Actions to Promote Early Project Implementation in Ecuador

Since 2010, the Bank has invested US$1.28 billion in Ecuador to support the national initiative change in the energy matrix. Recently, there has been a very significant reduction in project execution time, from an average of seven years and five months to three years and eight months. This change comes from: (i) a deep knowledge of sector and country priorities; (ii) a thorough understanding of governments' project selection procedures; (iii) close coordination with authorities in the due diligence process; and (iv) the work to accelerate project implementation prior to the approval of the loans. Also, the Bank has made improvements in each of the three phases in which the execution is divided to ensure more expeditious management. The improvements implemented are:

- **Due Diligence for financing.** This process starts when the request for financing is received from the authorities of the country. The Bank's due diligence includes technical, socio-environmental, fiduciary, economic and financial analysis. The project team in Ecuador also performed early execution workshops, requiring the participation of all relevant institutions and suppliers. The scope of the workshops is technical and fiduciary and aims to produce annual operating plans, a multiyear plan, procurement plans, disbursements projections and tender documents.
- **Approval of the project, signature of the contract and eligibility for the first disbursement.** The average contract signing time has been cut from 113 to 66 days. Likewise, eligibility for the first disbursement has gone from 126 to 48 days. These improvements make it possible to reach the first disbursement in two months after approval and the case of disbursements, the amounts include retroactive financing and resources to ensure the advances of the contracts signed.
- **Project Implementation.** After eligibility, the Bank team is responsible for organizing kick-off workshops, in which the final review of the application instruments is facilitated, and any adjustment to the results matrix is recorded and justified. Once the first disbursement has been made, the executing agency launches the bidding processes. Implementation monitoring has improved through effective inter-agency communication during execution, and the review of information during the eligibility of each disbursement.

B. Lessons Learned from Non-Sovereign Guarantee (NSG) Loans

4.29 To identify separately lessons learned from the implementation of NSG projects, seven projects were analyzed: (i) Campos Novos Hydroelectric Plant (1567/OC-BR); (ii) Atlantic I Wind Farm (BR12009); (iii) Pirapora I Solar (BR-11924); (iv) Peru LNG (1946A/OC-PE; 1946B/OC-PE); (v) ISA Bolivia II - La Arboleda (BO-L1022); (vi) Eurus Wind Power (2275A/OC-ME); and (vii) Campo Palomas Wind Power (3663A/OC-UR). Their team leaders and members were also interviewed. Below are the most relevant lessons.

4.30 **The Bank's framework for social and environmental sustainability**. In addition to financing, private sector clients benefit from the Bank's technical, environmental, and social expertise (see Box 6). During a loan disbursement, the IDB provides technical know-how that helps mitigate operational and financial risks. Bank safeguards ensure that clients adequately address social and environmental risks that could threaten the long-term viability of projects. The Bank's policies generate confidence among private clients and their shareholders (sponsors), which is particularly important for politically sensitive projects.

4.31 **Coordination between SG and NSG operations**. Close coordination within the IDBG, between SG and NSG operations, improves energy projects´ quality and impact. Coordination between the IDB and IDB Invest improves regulatory frameworks and develops competitive private sector markets to support activities such as investment in RE. This coordination is also important for mitigating the risk of concession reversals and nationalization of private investments. For example, in Uruguay, early IDB involvement in and support of the legal and regulatory environment was essential in opening the door for IDB Invest to help shape the rules and legal agreements used in the first RE bidding processes. This early involvement ensured that the terms under which the RE projects were defined were acceptable to both developers and financiers. Furthermore, the value of a strong and stable public energy policy and legal framework and capable institutions supported by the IDB was key in developing the National Energy Policy in 2010. This policy laid out Uruguay's RE targets through 2020 as well as the procedures needed to achieve those targets –including fiscal incentives that were attractive to foreign investors. Facilitating the dialogue with IDB Invest and private sector actors was another contributing factor to the success of the RE program (see Box 7).

Box 6. Lessons Learned on Results-based Incentive Structures to Promote Gender Equality in Energy Investments

IDB Invest has used Results Based Incentive (RBI) structures to create economic opportunities for women on four RE loans. These structures were channeled through the Canadian Climate Fund for the Private Sector in the Americas (C2F), as a fund managed by IDB Invest focused on climate adaptation and mitigation where energy is a priority. RBI structures create employment opportunities through internships for female students of environmental engineering, industrial engineering and industrial design disciplines in the growing field of RE, encouraging companies to hire from a previously overlooked talent pool. In exchange for developing internship programs for these women, borrowers are offered concessional terms that offset their costs of implementing the gender component.

One of the lessons learned is that financial incentives can be attractive for the borrower to invest the needed time and resources. Substantial local client support and guidance is needed to implement gender actions, understanding the cultural, market, and regulatory context. Implementing RBI structures is costly due to the complexity of formalizing incentive arrangements. As more such projects are developed, however, legal costs could decline, and processes could become more expeditious as model language is developed. Finally, it is important to track the long-term impacts of gender programs (e.g., number of interns obtaining full time technical jobs and maintaining them over time), to measure their ultimate success.

IDB Invest, MIF, the governments of Germany and Japan and other partners are developing the Women's Empowerment Principles Gap Analysis Tool to quickly identify strengths and weaknesses in companies' gender equality operations to address corporate needs and create opportunities for women in the organizations, markets and communities where they operate. IDB Invest expects that the success of this model will lead to the incorporation of gender outcome incentives in operations beyond C2F, reaching gender outcomes from a broader set of operations without providing incentives.

4.32 **A forward-looking, innovative mobilization strategy in the energy sector.** In an integrated public-private strategic approach, the IDB Group is articulating different innovative financing tools that will respond to the 2030 agenda and be integrated as a core pillar of IDB's work. Innovative financing products will build on successful experiences of the IDB Group, and combine a mix of institutional, private and donor funding, allowing it to spearhead Official Development Assistance innovation and a new generation of mobilization vehicles to support the 2030 agenda in LAC. Innovative financing includes: (i) development of PPP in geothermal power, natural gas, and EE, among other interventions in partnership with IDB Invest; (ii) blended financing (combination of IDB loans, grants, and contingent grants as well as private sector funding); (iii) bonds for sustainable infrastructure and energy to fund projects with positive environmental and social returns crowding in institutional and non-traditional investors; and (iv) guarantees which may protect investors from a failure to be repaid, for example in honoring a PPA, or provide first-loss guarantee for institutional investors at a portfolio level to invest in new markets.

Box 7. Merchant Power Plants in LAC

Context. Merchant power plants emerged as an alternative to the traditional model of selling energy to regulated and retail customers via long-term power purchase agreements ("PPAs"). Merchant power plants, which are also known as independent power plants/producers, sell energy in a wholesale power market at prevailing spot prices. The model has been widely used in countries like the US, and, more recently, expanded to LAC. In the last few years, the IDB Group has financed half a dozen RE merchant deals, helping increase RE penetration in the region. However, where the influx of renewable merchant generators has helped bring down both wholesale and spot energy prices, experts are alerting that the low pricing is also a key risk factor in potentially rendering the merchant model "obsolete."

LAC regulatory models. While the regulatory environment in the region has generally helped facilitate the arrival and settlement of renewable merchant plants, there is a spectrum of policy measures available to each country. For instance, Uruguay, Nicaragua, Honduras, and Brazil, have experimented directly with feed-in tariffs, while other nations have implemented a spectrum of other policies, including fiscal incentives (which despite being implemented in much of Latin America, vary in scope and magnitude), premiums (for instance, Peru and Honduras), and preferential grid access and dispatch, which has been implemented in much of Latin America but where the impact in pricing is more acutely visible in countries with less regulation, like Chile.

Risks and issues. Merchant power plants may face financial sustainability risks due to falling energy prices. Simply stated, the energy prices that the merchant renewables themselves helped drive down are putting investors' returns at risk and even capital investments as such plants, in some cases, are not generating sufficient revenue to cover O&M costs. Falling natural gas prices and the rapidly falling costs of technology have further exacerbated the stress on renewable merchant plants and conventional generators, which, in turn, has resulted in lower prices. Thus, where in the United States the merchant model has been labeled obsolete as noted above, Latin America is entering a point of inflection that is causing key actors in the power space to reevaluate their long-term value-creation strategy in the region. Some of the considerations are whether: (i) to acquire a matrix of conventional and non-conventional generators to optimize across a portfolio of PPAs and clients; (ii) to increase activity in markets with more contract trading activity and, therefore, greater liquidity in the contracts/PPA space; (iii) to optimize generation with investment in the transmission space given the gap between grid capacities and demand for further investment in transmission infrastructure across the region; or (iv) to simply enter or exit certain markets, thereby potentially putting at risk the operational stability of certain grids.

Further to these strategic private-sector considerations, merchant power plants, especially in the solar space, are at increased risk of curtailments. Where solar power is concentrated during day-light hours, solar plants are at extreme risk of significant curtailments in cases where local demand is unable to absorb the spike in day-light production. Similarly, in the case of hydropower, with more precipitation than normal, power producers are curtailing production, leading to zero marginal costs and similar spot market prices. Curtailment also occurs when there is insufficient transmission capacity near the plant to dispatch the energy to a potential client beyond the local market. As reported by Wilkinson Barker Knauer LLP and the Power Research Group (WBK and PR Group), stagnant (flat) demand growth, increasing renewable generation and historically low gas prices have sent the merchant sector into a crisis. The bottom line is that generators' revenues are struggling to cover the all-in cost of supply, including cost of capital recovery and variable cost of operation.

Forward looking. As stated by the WBK and PR Group, markets relying on the merchant generation model risk increased costs and/or decreased reliability, which, in turn, imply important consequences for merchant generators, electric systems, policy makers, regulators, and customers alike. IDB Invest, researchers, and regulators are envisioning possible solutions to ameliorate the risks or prevent this from happening in other countries. In the US, there are talks of re-regulation, more like bilateral contracting instead of capacity markets, with longer fixed-term contracts, and regulations/pricing mechanisms focused on reliability. Similarly, it is envisioned that independent power producers try to balance out their balance sheets and portfolio of assets with regulated assets. Possible ideas and market changes that could also occur in LAC include: (i) securing long-term bilateral PPAs prior to approving financing, while also facilitating long, medium-term PPA/offtake contract trading; (ii) incentivizing developers to acquire and optimize a portfolio of assets; (iii) establishing prices on CO_2 emissions rather than RE subsidies; (iv) increasing investment in transmission capacity in line with increased generation; and (v) more radically, perhaps, developing a scheme to replace marginal cost pricing and scrutinize the practice of take-or-pay contracts to determine marginal costs.

4.33 Investment in sustainable energy in the region requires regulation that is compatible with technological change and aligned with the longer lifespan of sustainable energy infrastructure. In this context, the IDBG has been a catalyst in deploying cleaner and more secure energy systems by offering financial and non-financial products and creating enabling environments for public and private sector investment. Despite technological progress, perception and transition risks are still significant barriers, which requires a coordinated approach of the public and private sector sectors. Cleaner energy technology adoption could be boosted through the removal of structural challenges in the energy sector, as well as by supporting the deepening of capital markets, by providing long-term finance, as well as risk mitigation financial products, attracting a wider array of investors.

4.34 The Geothermal Promotion Fund in Nicaragua is an example of IDBG's intervention as a hotbed for private investments. The development of geothermal fields requires, in addition to surface investigations, the drilling of exploratory wells to determine the real potential. The international and local experience show the significant challenges faced by the developers, including the risks related to the uncertainty about the availability of the resource and the costs associated with its extraction. Future geothermal developments in Nicaragua are concentrated in new fields, therefore, it is necessary to establish financing mechanisms that mitigate exploration risk with the goal of confirming the real potential and making possible the implementation of generation projects. IDB, together with the Scaling up Renewable Energy Program (SREP) of the Climate Investment Fund, provides funding for the exploration of three fields with geothermal potential that already have preliminary surface investigations. Once the best option for commercial development is determined, a concession to the private sector will be bid and the amounts spent in the exploration will be replenished to the Fund, allowing it to perform additional exploration.

4.35 IDB Invest is promoting the entry for additional players, innovative business models, and new technologies that could improve energy infrastructure, while also reducing risks for project developers and investors. IDB Invest is working with the public sector in improving the regulatory environment towards energy markets that are stable and predictable, with a long-term vision of the sector to reduce risks and foster proper financing mechanisms, with the aim of facilitating investment in the emerging energy markets of the region.

4.36 **Innovation in financial products for the private sector.** IDB Invest is improving the business climate by supporting the transition to a cleaner energy infrastructure. It promotes technology innovation by providing private sector financing with value added services. IDB Invest is a catalyst in mobilization of private capital and blended finance, building a competitive advantage through financial products that are typically not available in domestic markets, such as long-term corporate and project financing between 15-25 years; credit enhancement products such as project completion, first loss guarantees, liquidity facilities; and use of local currency for long term financing in specific markets. IDB Invest supports the development of domestic capital markets with the A/B Bond Program. Further, IDB Invest provides services such as technical assistance for PPP, climate financing, corporate governance and gender initiatives, creating value added to clients, while also considering the development impact, as well as environmental and social of investments in the communities. In addition to the financial and non-financial services offered by IDB Invest, the deployment of a local presence and hubs are facilitating the contact with clients, but also improving the effectiveness of the IDBG by better coordinating the work between the public and private operations of the IDBG, both in HQ and its Country Offices, resulting in policies that better consider the perspectives of the private sector, and more competitive investment climates for the private sector due to more targeted upstream work by public sector operations (see Box 8).

Box 8. Lessons Learned from NSG Operations: Mexico's EURUS Wind Project

EURUS is a 250.5MW wind farm with 167 wind turbines. Located in Oaxaca, EURUS is one of the first wind farms in Mexico and the largest operating in Latin America. It sells energy primarily to CEMEX under a PPA at a fixed price; any excess is sold to the *Comisión Federal de Electricidad*, the national power utility.

Total project costs were financed with US$375 million debt comprised of IDB A and B loans and seven co-lenders, including the International Finance Corporation (IFC), CAF, DEG, ICO, Proparco, Bancomex, and NAFIN. The IDB lent to this project in 2009 when credit was scarce in the wake of the 2008 Global Financing Crisis, and at a time when the local banking sector was inexperienced in financing such technologies and private international lenders were not available.

The most important lessons learned are highlighted below:

- Understanding the legal and regulatory framework related to land. Despite recent progress, delays due to land registration continue to be a fundamental issue in Mexico and LAC. The IDB has to work with governments at the policy level, to improve land title and registration. This issue is extremely important for large infrastructure projects.
- Organizing to deal with social and legal issues. EURUS has set up a strong social and legal team at the local level. This group dealt with community and land issues at an early stage even helping with obtaining proof of ownership. This team has been critical to moving the process along.
- The importance of in-depth intelligence. The best sources of intelligence on land issues are local legal counsel opinions and a detailed parcel assessment by an independent engineer. EURUS received legal opinion on obtaining and assigning the Usufruct Agreements to the lenders. The engineers' report discussed the specifications of the turbines, wake effect and turbine placement so that the lenders had a solid understanding of the issues.

Sources: Project documents and interviews with project teams.

4.37 In 2017, IDB Invest approved two RE projects (PV and wind) in Brazil structured with an innovative full-wrap credit guarantee mechanism provided by IDB and IDB Invest. With total estimated costs of more than 2.2 billion reais, the financing of both projects is being made up of long-term debt together with issuance of infrastructure debentures in the local market. The innovative total credit guarantee provided by the IDBG to the debenture holders covers the full payment of principal and interest for the tenor of the debentures. The IDBG takes project risk and provides a AAA guarantee of payment to the debenture holders, thereby attracting a broader range of investors to the transactions, supporting the development of the local capital markets and increasing private sector investments in RE. Furthermore, this guarantee mechanism contributes to the mobilization of financing at a competitive price and longer tenors than would otherwise be available in Brazil. Also, the guarantee mitigates any concerns from investors regarding technology risk, as the PV project was the first of its type financed by Brazil's development bank, the Banco Nacional de *Desenvolvimento Econômico e Social.* Finally, the guarantee mechanism improves the liquidity of the debenture issuance, providing an additional benefit to potential investors.

4.38 **Lessons learned in applying new financial products.** A close relationship with rating agencies is critical considering their role in rating the debenture issuances. An investment grade rating is a mandatory requirement in making the issuance attractive to local investors. Hence, a lot of effort has been invested in making sure the agencies fully understand how the innovative Total Credit Guarantee (TCG) product functions; and similarly, early engagement with capital market participants is important in the structuring of the new credit guarantee product. In particular, some issues were faced in developing the TCG that required careful negotiation and education to make sure the product was acceptable from both the guarantor's and the debenture holders' perspectives. Both projects required local currency capacity, as the Brazilian investors buying the debentures expect payment in *reais*. By developing this innovative guarantee product, IDB Invest was able to circumvent its lack of *reais* and incentivize the participation of local capital markets in RE financing.

4.39 Link with climate-change mitigation strategies. RE operations financed by the private sector arm of the IDB aim to reduce GHG emissions. In addition to financing, project developers seek support in quantifying emission reductions and receiving emission reduction certificates. Moreover, the IDB is helping with concessional financing facilities (e.g., climate funds).

4.40 Value-added of NSG operations. NSG energy operations can add value to the sector by: (i) crowding in private sector investment; (ii) providing social and environmental safeguards; (iii) ensuring that operations properly mitigate engineering and financial risks; (iv) introducing new technologies and best practices, particularly in EE and RE; (v) providing access to concessional funds for green projects; and (vi) bringing together governments, civil society, and the private sector to address complex issues and help resolve differences between multiple actors.

C. Office of Evaluation and Oversight (OVE) Reports

4.41 Although there has not been a thematic evaluation conducted in the past three years by OVE relevant to the energy sector, there are reports on topics covered by this SFD.

4.42 **Public-Private Partnership (PPP)**. In the decade from 2006 to 2015, the LAC region had investments worth US$361.3 billion in around 1,000 PPP infrastructure projects, mostly in energy and transport. Of those, the IDB Group approved 145 PPP operations for US$5.8 billion. The interventions were successful in countries with solid PPP frameworks, but projects focusing on countries with weak PPP environments had more difficulties closing the financing. OVE recommends: (i) that specific country diagnostics be performed, including infrastructure needs at the sector level, the PPP environment, the fiscal constraints and risks, and the type of support governments are looking for; (ii) define priorities for intervention at the level of countries and sectors; (iii) explore the use and development of new financial and advisory products; (iv) design a specific PPP knowledge strategy; and (v) systematically incorporate lessons of experience.

D. Results from the Development Effectiveness Matrix (DEM)

4.43 A review of the scores listed in the DEM shows significant improvement in SG projects receiving evaluable scores. Evaluability is determined by assigning a score to the clarity of the program logic, monitoring and assessing the results to improve the execution of the operation and performing an economic analysis. The largest gains occurred in the monitoring and evaluation of projects approved between 2011-2016. This gain is reflective of a greater emphasis in designing the projects considering the potential risks, weaknesses and capabilities for an efficient execution, and assigning resources to strengthen the different actors participating in the project, mitigate the risks and developing or bringing in the capabilities needed. For example, in a rural electrification project, the focus was expanded from investments to incorporating the sustainability of the solutions, determining the capacity and capability of the executing agencies, or training to users. Within this period, the Project Management Report (PMR) was instituted, assisting teams in evaluating and monitoring project results during execution, complementing the evaluability analysis performed during preparation. Lastly, the contents of the project completion report were substantially modified to be able to obtain lessons learned from the execution. A next step would be to assure that these lessons learned are thoroughly incorporated in future operations.

4.44 The dimension under which operations have performed best in evaluability in recent years is the ex-ante economic analysis. All operations approved since 2012 have included ex-ante economic analysis using cost-benefit analysis. Evidence of effectiveness has been challenging to find due to the scarcity of rigorous evaluations, such as impact evaluations of comparable projects. Similarly, there have been challenges in selecting evaluation methods. Many projects are for power generation and transmission lines. In these projects, it is difficult to measure the direct impact on a population, given the difficulties in defining the control and treatment groups. For these reasons, the IDB has initiated a process of generating knowledge on evaluation, specifically from interventions with rural electrification components.

4.45 For unconventional RE projects, the main challenges in measuring development effectiveness are: (i) the small size of the projects compared to overall energy capacity; (ii) the difficulty of estimating and valuing emission reductions; and (iii) the impacts of low and fluctuating energy prices on profitability and economic value.

E. Comparative advantages of the IDB in the region

4.46 IDB operations have focused on transmission, hydropower, rural electrification, regulatory reforms and sector policies, and sustainable energy (including renewable energy and energy efficiency). In contrast, the WB has focused mainly on multisector projects, where a fraction of the project is for energy, and structural reforms. CAF has lent mainly for generation and transmission.

4.47 The IDB's public sector (SG) lending was directed at institutional strengthening and regulatory changes, transmission and distribution infrastructure, and supply and demand-side EE, while the private sector (NSG) portfolio focused on electricity generation with RE and EE. The IDB succeeded in channeling concessional resources from other sources of financing. In total, 53% of the funds invested in TC came from external sources that were managed by the IDB, and external concessional resources have been used as also for SG and NSG reimbursable operations (loans, guarantees and equity). The IDB's proven ability to mobilize resources from the Global Environment Facility, the Clean Development Mechanism, and the Climate Investment Funds (including the Clean Technology Fund–CTF, and the Scaling-Up Renewable Energy in Low-Income Countries Program–SREP) positions the IDB Group well in this sector.

4.48 In the energy sector, the Bank has been actively seeking co-financing resources to further leverage IDB financing and act as a catalyst for investment infrastructure in the region. Countries are limited in their fiscal capacity to borrow from the IDB (and IDB's lending capacity is also itself limited). Therefore, financing resources from co-financiers that would not fall under the same fiscal envelope are key to bridge the funding gap to make a project economically and financially viable. IDB's long term tenor and sovereign pricing, together with its implicit political umbrella, mitigates the perceived risk of other co-financiers of their potential lending to a LAC country. For example, in energy operations, under the JICA CORE (Cofinancing for Renewable Energy and Energy Efficiency) US$883 million were mobilized (for a total of US$408 million from IDB split into 5 separate projects); under Korea Infrastructure Fund (KIF) US$50 million (IDB financing of US$169.3 million for two separate projects) and most recently, the Agency Française de Development cofinanced a US$600 million IDB policy-based loan in Mexico for Euros 100 million. Lastly, cofinancing can be structured under various modalities such as parallel cofinancing (where cofinancing resources are directly disbursed to the recipient country) or joint cofinancing (where cofinancing resources are channeled through IDB) amongst others, and thus provide a significant additional source of funding for LAC governments to consider when prioritizing their investment plans.

4.49 The public and private sectors of the IDBG have distinct comparative advantages. They provide value to clients and the region by bringing the IDB's social and environmental safeguards to projects. The technical capacity of the staff has helped evaluate and structure technically and economically complex projects. They have mobilized additional private financing for energy investments and helped bring concessional funding to catalyze additional investments, both from the private sector and from other development and cooperation agencies, and to develop and apply innovative financial instruments, such as IDB Invest's energy efficiency investments securitization project in Mexico, and CMF's Energy Saving Insurance projects. Operations executed by the public and private sectors have financed recent technologies and best practice activities that have acted as demonstration projects. Finally, they have leveraged the Bank's convening power and image as an honest broker to address and resolve complex issues that involve governments, civil society, and the private sector.

4.50 The possibility of coordinated public-private work and access to concessional funding are regarded as the IDB's topmost comparative advantages. Both its public and private windows add value through their access to the government to discuss energy policy and markets. Clients appreciate having a partner in direct dialogue with governments. The joint intervention provides useful learning experiences for environmentally sensitive projects. One instance was an IDB operation (with IFC participation) where force majeure events reduced the amount of energy that could be delivered. The government renegotiated the feed-in tariff to ensure the sustainability of the project.

4.51 **Other sources of added value**. The IDBG adds technical value through its public and private sector window operations and policy dialogue. The experience of the IDB in reforming Chile's energy markets in the 1990s and 2000s was a precursor to the large expansion of private investment in recent years. Similarly, Uruguay's strategy to diversify its energy matrix by incorporating wind and solar power and the IDB's support to establish the conditions for bankable projects have expanded private investment. The IDBG also adds value by using private sector interventions to support a country's energy policies (see Box 9).

4.52 Alignment of the IDB's private sector portfolio with national policies also serves to mitigate important regulatory and country risks. Many of the risks of these operations have to do with sudden changes in the regulatory framework, including tariffs. Insofar as private sector investments fit into a coherent national policy, the likelihood of such changes is small. For the same reasons, aligning private sector investments with a long-term national strategy also makes the interventions more likely to be sustainable over time.

Box 9. The Value Proposition of IDB Invest in the Energy Sector of LAC

IDB Invest provides optimal financial solutions to the private sector and state-owned enterprises supporting energy-related projects in LAC by allocating its capital and mobilizing third-party resources. IDB Invest focus is on RE generation (PV solar, wind, large and small hydro, biomass, biogas, and waste to energy), natural gas generation, transport and distribution infrastructure, transmission and distribution networks, storage facilities, EE and street lighting, and rural electrification.

IDB value proposition addresses the region's specific needs in terms of rapid penetration of renewables and the required infrastructure, long-term, flexible financing, local currency treasuries, risk mitigation instruments, tackling the constraints of public and private financial institutions, and facing the challenges of climate change.

IDB Invest financial products include project finance debt (long-term senior and subordinated debt at project SPV level in local currency and US$ and mezzanine debt), guarantees (completion, first loss, and other long-term guarantees, as well as US$ and local currency to enhance issuances of project bonds), liquidity facilities to cover resource risk in renewables, construction in transmission lines, corporate and project loans at the developer/sponsor level, and equity investments. Other non-financial products that enhance this value proposition include access to blended and climate finance and TC funds with a focus on climate, corporate governance, and gender programs through advisory services.

4.53 These advantages are obtained from adaptability to clients needs and embedded in the preparation and execution of policies and procedures, including adequate integration of the teams (sector, fiduciary, legal, and safeguard specialists), a strong presence in the field that allows fast responses, multiple financing tools, and the availability of funds to develop knowledge products.

4.54 The IDB will work to address the region's main challenges in the sector and will use its comparative advantages, which are based mainly on its experience and knowledge of the strategic areas of energy infrastructure development in urban and rural areas; EE and RE; climate change; regional integration of electricity and natural gas infrastructure; strengthening public sector capacities for energy policy, planning, and regulation as well as the capacities of energy service providers; and supervision of contracts for high-risk or high-impact projects. Recognizing the IDBG's comparative advantages and the challenges concerning the environmental impact associated with certain energy sources, the IDB will not intervene on nuclear energy activities (as specified in documents DR-791 and GN-2609-2, both of 2011) and will give a lower priority to fossil fuel technologies, unless the investments make sense from an economic standpoint taking externalities into account, for example: in the rehabilitation of existing plants, substitution of solid or liquid fossil with cleaner gaseous fossil fuels; or to meet the demand for energy services.

4.55 The IDBG has a team of professionals with solid knowledge and experience in transmission and distribution, large hydro, rural electrification, EE and RE projects. The availability of professionals both at headquarters and in the field, adds to their value. However, projects in technologies such as geothermal, marine energy, waste-to-energy, and smart grids will also require strengthening the knowledge base through training and coordination with other institutions with experience in these areas to improve the capacity for dialogue with member countries.

V. Goals, Principles, Dimensions of Success, and Lines of Action That Will Guide the IDBG's Operational Activities and Research

5.1 **What is the role of IDBG in the Energy Sector of LAC?** The above chapters have shown the transition that the energy sector in LAC and around the world is undergoing. The IDB can help member nations navigate this transition and make it more responsive to its stakeholders, providing knowledge-based support via TC and policy dialogue, or with policy based financial products. The Bank can also assist countries in the detection of weaknesses in their energy systems; disseminate and promote new regulations more consistent with technological changes; and adopt innovative models to promote energy access in isolated areas. The IDBG will provide advice on state-of-the-art technologies, best practices, and experiences from other countries in the region; engage in regional and in-country policy dialogues with policymakers, regulators, and other industry participants; and promote consensus on policy options. In addition, there is a very significant role that multisector and multiagency work with other institutions can play, both in knowledge and financing services. In this chapter we summarize the goals that the IDBG has for the sector, their dimension of success, and the actions to be performed to achieve them.

A. Bank Goals and Principles in the Energy Sector

5.2 The goals of the IDBG in the energy sector are to help increase LAC countries access to efficient, sustainable, reliable, and affordable energy in a diversified and secure manner, while reducing poverty, promoting improved quality of life, and fostering competitiveness and economic growth and development. To achieve these goals, it is crucial to approach sector intervention integrally, both tackling current deficits and limitations, but with a view of the extraordinary changes that are likely to happen in the medium and long term.

5.3 Current deficits include, for example, major shortfalls in some countries' physical infrastructure and commercial systems. Medium and long-term goals should include the incorporation of RE and promote the participation of *"prosumers"*. When performing the required investments to reduce these shortcomings, opportunities will arise to upgrade multiple network components with the latest technologies, including meters that measure bidirectional flows, communication technologies that measure and relay information in real time, and commercial systems with the flexibility to operate under multiple regimes (for example with net-metered, time-of-day and regular customers). Careful and integrated planning, with a long-term vision of the system, is required to ensure that today's investments do not stifle tomorrow's innovation and growth options.

5.4 Regional countries face a wide variety of challenges in their energy sector, and IDBG's actions shall meet the particular needs of each, with technical notes diagnosing and analyzing each specific situation. The lines of detailed sectoral action will be analyzed together with other IDB sectors and will be established in the country strategies.

5.5 Investments and programs will be supported either through public funding, private sector participation, or PPP. Activities will follow general principles, since they are crosscutting and apply to all IDB activities irrespective of the particular analysis of each country and intervened sector.

a. **Develop economical and sustainable energy access**. The IDB will promote technically, economically, environmentally, and socially sustainable universal access to quality energy services. It will encourage the efficient and cost-effective expansion and strengthening of electricity networks and of power generation systems and will provide access to off-grid and isolated areas, using appropriate technologies and maximizing the participation of renewable energy. In addition, the systems should be designed to be potentially upgradeable to be connected to the national grid. Cost-effectiveness should consider not only whether to extend the grid or build an off-grid system, but also the number of hours of service to be provided, considering the actual or potential economic activities of the intervened area. Benefits evaluation should also include the potential to replace traditional fuels for cooking with electric stoves.

b. The IDB will promote efficient stoves and modern technologies for cooking, provide training on their use and maintenance, and support local production efforts. Emphasis will be placed on poverty reduction for the most marginalized and vulnerable sectors –incorporating persons with disabilities and indigenous populations– and on reducing gender inequalities. The Bank will search and evaluate innovative solutions to achieve sustainable energy access, including both new equipment and business models.

c. **Promote EE, RE and cleaner fuels for sustainable energy**. The IDB will promote demand and supply EE in all sectors (residential, commercial, industrial, and public), as well as RE production and cleaner fossil fuels such as natural gas to help reduce GHG emissions. When possible, the IDB will support raising power generation efficiency, for example by upgrading power plants or installing combined cycle generation in open cycle power plants. It will also promote the adoption of new technologies and concepts such as smart grids in the power sub-sector to strategically manage demand, enhance performance and security, and allow more distributed generation, advanced metering, and monitoring and control of electricity networks. The IDB will actively support policymakers, regulators, utilities, and customers in the transition to the electrification of the energy sector, implementation of distributed generation networks, and expansion of access based on RE. It will also support governments efforts at every stage, from defining a vision for the sector, to long-term planning, to investments.

d. **Stimulate energy security – maintaining and preserving infrastructure and promoting regional integration**. The IDB will support all efforts to improve and innovate on mechanisms to finance sustainable energy, improve infrastructure, and provide secure, reliable, quality services. Investments will be required to ensure adequate operation and timely predictive maintenance of energy facilities to improve their performance, enhancing power quality, extending their lifetime, and minimizing the need for investment in new facilities. IDB's Public Utilities Policy (GN-2716-6) serves as a reference for guidance on IDB operations having sufficient funds to meet financial commitments, and cover O&M costs. System protection of energy infrastructure through modern control systems, including an increase in the number of sensors, the use of artificial intelligence tools, and real time processing of information, will prevent damage to equipment and appliances due to abnormal currents and voltages. Investments in infrastructure and development of legal and regulatory frameworks for regional integration will also promote energy security, as the diversity of the systems will help absorb the variability of renewable generation. Emphasis will be placed not only on hardware but also on software and systems to enhance efficiency and performance. Bank lending to finance energy infrastructure will increase their financial viability by incorporating institutional, technical, environmental, and financial analysis of the O&M of the works during the project's lifetime. Private and public-sector financing will be designed to complement each other with the intent to leverage a high ratio of private sector funding. The IDB will support financing mechanisms and legal and regulatory frameworks that adequately balance risk and encourage private participation in energy markets and the financing, innovation, development, and operation of services in the sector.

e. **Promote good governance, increase financial sustainability, strengthen institutions, and encourage multisector collaboration.** Given the long lead times between planning and the start of operation of the infrastructure, the capital intensity of the investments, and the assets' extended useful life, the IDBG will focus on short-term moves needed to achieve the energy sector's long-term vision. The IDBG will assist countries in diagnosing the industry structure, multisector nexus, policies, and regulatory framework as well as with the necessary work to strengthen the government institutions in need of improved planning, decision making, accountability, and regulatory environment. This includes a review of subsidies for transparent and targeted allocation when used. It will also promote multisector and multi-institution collaboration to achieve common goals and maximize the use of resources. SG and NSG joint work will continue to be encouraged. In addition, the IDBG will support the modernization of the institutions, regulations and sector organization to incorporate new technologies, promote the adoption of innovation, and smooth potential disruption that these innovations could bring.

B. Dimensions of Success and their Lines of Action

5.6 **Dimension of Success 1. Countries progressively reach Universal Energy Access and provide High-Quality Energy Services.** The IDB will support countries' moves to improve quality, coverage, reliability, and affordability of the energy infrastructure with affordable prices while minimizing social/environmental impacts. It will uphold efforts to expand power generation and to extend grids when economically and environmentally viable or build sustainable isolated systems that can be upgraded, expanded and eventually connected to the national grid; reduce energy costs by promoting competition throughout the sector, including wholesale electricity markets; reduce energy losses and improve EE; and boost productivity and competitiveness by supporting service reliability. Through greater energy access, especially in isolated communities, the IDBG will endorse efforts to reduce poverty and increase equity. To achieve these objectives, the following lines of action are proposed:

5.7 **Lines of action:** (i) promote universal, reliable, and affordable access to energy services, reaching out to rural and low-income urban areas; (ii) encourage clean, high quality, and modern cooking facilities adapted to local conditions, with awareness raising, training, and monitoring on use of new technologies; (iii) include programs to promote productive uses of energy when providing energy services, including in off-grid areas; (iv) rehabilitate/reinforce power generation infrastructure and overloaded distribution networks and associated facilities; (v) upgrade backbone and regional transmission infrastructure capacity when operating over rated capacity and to allow new power generation capacity from variable RE sources; (vi) improve the resilience and adaptability of the infrastructure to natural phenomena and adverse effects of climate change; (vii) increase the reliability of energy systems by adding, strengthening, and sharing (for regional integration initiatives) ancillary services and capacity reserves; (viii) support governments in promoting private sector participation in infrastructure development and energy markets; (ix) develop micro-financing opportunities and programs to leverage private sector investments for rural energy access; (x) promote EE in providing access; and (xi) encourage planning for universal access at the national level. To pursue these lines of action, the following operational and knowledge activities will be implemented:

a. **Operational activities:** (i) investment programs in generation, transmission and distribution of electricity, including introduction of advanced metering systems, to reduce losses and improve efficiency; (ii) programs for off-grid provision of electricity, fuel substitution and/or efficient technologies for cooking; (iii) investment in transportation, storage, and distribution of natural gas and gas fuels; (iv) investment programs in the rehabilitation (or possible expansion) of energy infrastructure to extend its useful lifetime (and expand capacity); (v) promoting adequate operation and timely maintenance of systems (including supporting best practices in program operating regulations of projects financed by the IDB) and equipment to extend the useful life of infrastructure and reduce losses; (vi) investments in the improvement of energy systems reliability; and (vii) ancillary investments in energy markets that support the pricing and use of energy to reduce risks and improve market efficiency.

b. **Knowledge activities:** (i) result assessments of the improvements in energy infrastructure access in off-grid areas, including enhancements in the economic and social conditions of the population; (ii) studies determining causes of high costs and energy losses and how to reduce them; (iii) technology (along with implementation mechanisms) to reduce cost and losses, increase reliability, and reduce environmental and social impacts; (iv) supporting programs to create a culture of electricity payment (especially in countries with significant non-payment and theft rates); (v) impact assessment studies; (vi) best practices in the sector for institutional arrangements regarding access policies and stimulus, financial, social, and environmental sustainability; and (vii) data for planning and policy design.

5.8 **Dimension of Success 2. Countries Have Diversified Energy Portfolios**. Countries in the region combine legacy fossil fuels[30] with natural gas systems –that are mostly self-produced but also piped from neighboring countries– and LNG, EE, RE and other cleaner fuels.[31] On the other hand, NCRE are becoming a least-cost solution in most of our region. Given the state of technology progress in terms of cost and the sophistication of LAC countries energy markets, competitive solicitation is replacing the feed-in-tariff guaranteed access model, with some countries moving to technology-blind, all-source bids. The IDBG will help countries improve their policy and institutional profiles and migrate to specific competitive acquisition processes whenever possible, based on proven advantages in resource efficiency and declining RE costs, while at the same time clarifying criteria justifying continuing support for feed-in-tariffs in early stage marketplaces. A different approach is needed to perform long-term planning, incorporating *"prosumers,"* a greater role of ancillary services, and novel approaches to remunerate the activities of different actors in the value chain. The IDB can also assist in removing legal and regulatory

[30] Legacy equipment includes all the hardware and software deployed for conventional energy sources, ranging from generation stations and transport configurations, to control systems, protection devices and ancillary services that limit the incorporation of RE.

[31] Specific activities that apply to the energy and other relevant sectors are detailed in the Climate Change SFD.

barriers that diminish incentives to utilities, users, and other providers to install NCRE sources, incorporate demand-side management, adopt EE measures, and lower emissions. To achieve these objectives, the following lines of action are proposed:

5.9 **Lines of Action:** (i) utilization of advanced systems such as satellite data to assess the availability of renewable resources, including solar, wind, small hydro, and geothermal, and preparation of master plans, schedules and investment programs; (ii) devote efforts to promoting learning-by-doing by supporting, for example, large-scale pilots and commercial demonstrations of grid-integrated battery storage and parallel knowledge products that help valorize storage services at time scales ranging from miliseconds to hours; (iii) evaluation of energy conservation and efficiency potential, along with demand-side management; (iv) promotion of efficient and sustainable power generation; (v) analysis of technical and economic viability of substituting conventional generation with renewable sources; (vi) promotion of the *"prosumers"* models; (vii) analysis of the impacts of electric transportation on the grids; (viii) development of the institutional capacity to manage and coordinate public agencies (including different ministries and government agencies) and private actors involved in investment in RE and EE, including technical requirements and economic incentives for deployment and support to new energy companies entering monopolized markets; (ix) incorporation of training and capacity building in operations; (x) development of markets and the private sector to help install and provide distributed generation; and (xi) develop multisectoral approaches to basins management in areas such as hydropower, forest products, agriculture etc. One of the aims of such an approach would be to reduce waterways sedimentation. To pursue these lines of action, the following operational and knowledge activities will be implemented:

a. **Operational activities:** (i) investments in renewable power generation; (ii) investments in infrastructure to support the transport of utility-scale RE, including backbone and/or regional transmission lines; (iii) investments in EE projects in the residential, commercial, industrial, and public sectors; (iv) given that financial incentives alone will not achieve greater EE, the IDB could assist countries with knowledge sharing on best practices in other member countries or around the world, policy-based programs to create incentives to develop national policies furthering EE, and executing demonstration projects; (v) expand partnering with green funds to support RE and clean fuels; (vi) reforms to legal, policy, and regulatory frameworks to promote EE; (vii) programs for institutional strengthening in energy policy, reforms to level the playing field between fossil fuels and RE, the incorporation of *"prosumers"*, planning and inter-institutional coordination; (viii) programs for training people and developing local capabilities in the design, policymaking, installation, and O&M of RE options; (ix) engagement with the community for the successful implementation of hydroelectric power projects; and (x) programs to leverage private sector investments and support the private sector through TC, loans, investments, and guarantees to support the provision of energy services, expansion of public–private partnerships, development of EE markets, use of energy commodity markets, and promotion of new technologies and sustainable business practices.

b. **Knowledge activities:** (i) formulation of innovative methodologies to remunerate the "cable business" to reduce resistance to the expansion of distributed generation; (ii) formulation of business models to attract the private sector and provide services in rural settings, based on RE; (iii) national plans for the incorporation of RE and the expanded role of ancillary services to achieve higher quality standards; (iv) national plans for EE measures at the residential, commercial, industrial, and public level;

(v) institutional strengthening for the development of legal and regulatory frameworks promoting RE and EE; (vi) regulatory analysis to encourage effective participation of the private sector in RE through various measures, including PPP; (vii) diagnosis and proposal of suitable designs to address market failures linked to climate change (externalities, information asymmetries, lack of long-term finance); (viii) RE demonstration projects using innovative financial and risk coverage instruments, technologies, and regulations; (ix) technical, economic, and environmental analysis of scenarios with high penetration of RE; (x) tools for planning, design, and operation of infrastructure resilient to climate change impacts; (xi) create detailed action plans to implement nationally determined contributions that relate to the energy sector; and (xii) mechanisms and methodologies for multisector coordination and planning.

5.10 **Dimension of Success 3. Countries Reach Sufficient Level of Investment in Infrastructure and Prioritize the Integration of Energy Networks with other Countries.** The IDB will help countries identify their medium- and long-term investment needs. Clear rules and regulations should help attract private sector investments. The Bank will support the development of programs, projects, and regional institutions and governance mechanisms to connect the countries' electricity and natural gas networks, including small and island nations. The IDB will facilitate the development of hardware and software for greater regional integration. It will promote regional collective action, harmonization of domestic policy reforms and update regulatory frameworks, cross-border investment, and capture of cross-border externalities, resolution of coordination failures and other barriers in the implementation of regional projects. The value-added to projects of incorporating objectives and components of integration and regional cooperation will be emphasized. To achieve these goals, the following lines of action are proposed:

5.11 **Lines of action:** (i) continue supporting infrastructure planning and assessing investment needs for regional integration; (ii) assist countries in establishing regulations that give clarity to potential investors; (iii) promote PPP when there are adequate market conditions and foster reforms to achieve those conditions; (iv) assess gas and power interconnection alternatives among member countries; (v) develop physical interconnections between countries; (vi) strengthen participation in initiatives to facilitate the dialogue among countries on regional initiatives, promoting best practices; (vii) encourage more energy transactions on existing interconnections; and (viii) disseminate knowledge on effective arrangements to foster greater energy integration. To pursue these lines of action, the following operational and knowledge activities will be implemented:

a. **Operational activities:** (i) financing of planning and investments to improve national energy infrastructure that will also enable regional integration (e.g., construction of new energy infrastructure; rehabilitation of generation plants; and reinforcement of national electricity transmission lines and natural gas pipelines, LNG and gas fuel transportation, liquefaction, storage, and regasification facilities as well as subsea electricity transmission cables between Caribbean islands); (ii) promotion of institutional, commercial, and technical agreements, and regulatory support to extend the above interventions and ensure sustainability; and (iii) strengthening the IDBG's role as a neutral supporter and facilitator of cross-border and regional initiatives.

b. **Knowledge activities:** (i) analysis of infrastructure and investment requirements; (ii) sharing and diffusion of regional integration experiences that can provide lessons for LAC countries, including strategic alliances such as SIEPAC in Central America, NordPool in Europe, and other arrangements in the US; (iii) evaluation of regional impacts and benefits of infrastructure integration; (iv) analysis of mechanisms for compensating the asymmetric distribution of costs, benefits, and risks in integration projects; (v) development and applications of analytical tools to evaluate integration options and configurations; and (vi) capacity building on public–private partnership schemes.

5.12 **Dimension of Success 4. Countries Have Institutions Capable of Developing and Implementing Energy Policy, and of Planning, Supervising and Regulating Services**. The IDB will support the strengthening of countries' institutions and their governance to improve the management and effectiveness of interventions in the energy sector. The aim is to increase their technical and management capacities to more accurately identify sectorial needs, design policies, and plan and execute projects effectively. In addition, the IDB will encourage making institutional arrangements to ensure institutions and utilities are financially sustainable and have adequate human resources to ensure proper equipment operation and maintenance. Support will include expanding data collection and dissemination for better decision making, analyzing subsidy programs to determine if they are effective and transparent and support financial sustainability, as per guidance provided in the IDB's Public Utilities Policy (GN-2716-6). Additionally, the Bank will encourage the availability of data and knowledge of the sector to improve the ability to generate policies suited to the countries' needs and evaluate their results. To achieve these objectives, the following lines of action are proposed:

5.13 **Lines of action:** (i) building strategic planning capacity, policy formulation, monitoring, and evaluation; (ii) strengthening capacity to regulate and implement policy and projects; (iii) increasing capacity to manage and supervise concessions and private investments; (iv) ensuring financial sustainability of the sector; (v) reviewing subsidies to ensure that when these are used, the sources and beneficiaries are identified, progressively phasing out generalized and fossil-fuel subsidies; (vi) expanding sources, collecting, updating and publishing significant volumes of data to boost transparency and grease the wheels for adequate decision making; and (vii) building capacity to help adopt international standards. The IDB will improve the management and implementation of energy projects with high impacts and risks by financing institution strengthening activities in countries and generating knowledge of regional application in management and project contracting. To pursue these lines of action, the following operational and knowledge activities will be implemented:

a. **Operational activities:** (i) financing institutional assessments in order to identify areas of improvement; (ii) financing national plans and planning studies; (iii) financing technical, economic, environmental, and policy studies and regulatory changes to promote a more sustainable energy mix and needed regulatory reform; (iv) finance institutions to learn how to incorporate innovations; training government officials on policy, regulatory, operational, economic, environmental, and related consulting and recruitment of specific support; (v) facilitating adoption of energy-related international standards; and (vi) funding technical and information systems equipment.

b. **Knowledge activities:** (i) providing support at national and regional level to improve data collection, analysis, dissemination and regulation; (ii) developing results assessment tools to identify the effects of interventions; (iii) sharing best practices on managing and implementing large, high-impact projects; (iv) studying the interaction between sector rules and innovation; (v) implementing strategic planning to understand the water, energy, agriculture nexus; (vi) sharing best practices of sector organization and governance; and (vii) analyzing the regulatory and institutional interaction to deal with convergence of multiple industries.

5.14 Knowledge activities to prepare the IDBG for the future of the energy industry. The growing complexity and uncertainty of the energy industry and its institutions due to a more active role of end users and the dynamics of innovation (connecting energy with other sectors such as telecommunications, transportation and water) require new financing, policy and regulation tools. In this context regulators and the institutional framework need to be able to learn and respond fast, creating an important role for IDBG's support of LAC countries in their continuous process of reform and policy adaptation.

5.15 The IDBG will focus on developing new cutting-edge knowledge and tools to prepare the region for the future. We will concentrate on five areas: (i) understanding consumer behavior and the tools to achieve policy effectiveness; (ii) understanding the regulatory entities behavior and rules as well as their learning process to adapt to new technologies and social demands; (iii) monitoring new technology developments, helping countries understand their techno-economic characteristics and the potential benefits and disruptive effects they may have on their systems; (iv) understanding the best practices for industry convergence, such as the interaction between energy and telecommunications through digitalization; and (v) inclusion of uncertainty arising from technological, social and climate factors in the decision making processes of regulators, investors and policy makers to adapt them to the new context of the energy industry.

Bibliographical References

Ahmed, Kulsum; Awe, Yewande; Barnes, Douglas F.; Cropper, Maureen L.; and Kojima, Masami (2005). Environmental Health and Traditional Fuel Use in Guatemala. The World Bank.

Anderson, Soren T.; and Newell, Richard G. (2004). Information Programs for Technology Adoption: The Case of EE Audits. Resource and Energy Economics. Elsevier.

Andres, Luis; Guasch, José Luis; and Lopez Azumendi, Sebastián (2008). Regulatory Governance and Sector Performance: Methodology and Evaluation for Electricity Distribution in Latin America. Policy Research Working Paper 4494. The World Bank.

Andres, Luis; Guasch, José Luis; Diop, Makhtar; and Lopez Azumendi, Sebastián (2007). Assessing the Governance of Electricity Regulatory Agencies in the Latin American and Caribbean Region: A Benchmarking Analysis. Policy Research Working Paper 4380. The World Bank.

Balza, Lenin; Jiménez, Raul; and Mercado, Jorge (2013). Privatization, Institutional Reform, and Performance in the Latin American Electricity Sector. Technical Note IDB-TN-599. Inter-American Development Bank.

Baptiste, Brigitte; Pinedo-Vasquez, Miguel; Gutierrez-Velez, Victor H.; Andrade, Germán I.; Vieira, Pablo; Estupiñán-Suárez, Lina M.; Londoño, Maria C.; Laurance, William; and Lee, Tien Ming (2017). Greening Peace in Colombia. Nature Ecology and Evolution 1, Article Nr. 0102.

Barbero, José A. (2013). La Infraestructura en el Desarrollo Integral de América Latina. IDeAL 2013. Banco de Desarrollo de América Latina.

Bast, Elizabeth; Makhijani, Shakuntala; Pickard, Sam; and Whitley Shelagh (2014). The Fossil Fuel Bailout: G20 Subsidies for Oil, Gas and Coal Exploration. Overseas Development Institute and OilChange International.

Bhatia, Mikul; and Angelou, Nicolina (2015). Beyond Connections: Energy Access Redefined. Energy Sector Management Assistance Program. Technical Report 008/15. The World Bank.

Bizikova, Livia; Roy, Dimple; Venema, Henry; and McCandless, Matthew (2014). The Water-Energy-Food Nexus and Agricultural Investment: A Sustainable Development Guidebook. International Institute for Sustainable Development.

Bridle, Richard; and Kitson, Lucy (2014). The Impact of Fossil-Fuel Subsidies on Renewable Electricity Generation. Global Subsidies Initiative Report-GSI; and International Institute for Sustainable Development.

Butler, L., Neuhoff, K. (2006). Comparison of Feed in Tariff, Quota and Auction Mechanisms to Support Wind Power Development, Cambridge Working Papers in Economics, CWPE 0503, March.

Canales, C. (2014). Water and Energy Nexus in Latin America and the Caribbean. Economic Commission for Latin America and the Caribbean. Posted in Regional Perspectives in water conference 2014.

Caratori, Luciano; Carlino, Hernán; Gutman, Verónica; Levy, Alberto and Magnasco, Eugenia (2015). *Estudio sobre pequeños aprovechamientos hidroeléctricos (PAH). Proyecto de una NAMA. Nota Técnica IDB-TN-764*. Inter-American Development Bank.

Carrasco, Haydeeliz; García, Emma; Parodi, Sandro; and Vásquez, Madiery (2016). *¿Cómo se redistribuyen los recursos públicos en República Dominicana? Monografía 425. División de Protección Social y Salud.* Inter-American Development Bank.

Clements, Benedict; Faircloth, Christopher; and Verhoeven, Marijn (2007). Public Expenditure in Latin America: Trends and Key Policy Issues. Working Paper WP/07/21. International Monetary Fund.

Coady, David; Parry, Ian; Sears, Louis; and Shang, Baoping (2015). How Large are Global Energy Subsidies? Working Paper WP/15/105. International Monetary Fund.

Cottrell, Jacqueline; Fortier, Francois; and Schlegelmilch, Kai (2015). Fossil Fuel to Renewable Energy. Comparator Study of Subsidy Reforms and Energy Transitions in African and Indian Ocean Island States. United Nations Office for Sustainable Development.

Couture, Toby D.; Jacobs, David; Rickerson, Wilson; and Healey, Victoria (2015). The Next Generation of Renewable Electricity Policy. How Rapid Change is Breaking Down Conventional Policy Categories. Clean Energy Solutions Center.

Covrig, Catalin; Ardelean, Mircea; Vasiljevska, Julija; Mengolini, Anna; Fulli, Gianluca; and Amoiralis, Eleftherios (2014). Smart Grid Projects Outlook 2014. Joint Research Centre Science and Policy Reports. European Commission.

Curry, Claire. (2017). Lithium-Ion Battery Costs and Market. Bloomberg New Energy Finance. https://data.bloomberglp.com/bnef/sites/14/2017/07/BNEF-Lithium-ion-battery-costs-and-market.pdf

Del Río, Pablo; and Linares, Pedro. "Back to the future? Rethinking auctions for renewable electricity support." Renewable and Sustainable Energy Reviews 35 (2014): 42-56.

Development Committee Meeting (2015). From Billions to Trillions: Transforming Development Finance Post-2015 Financing for Development: Multilateral Development Finance. Prepared jointly by the African Development Bank, the Asian Development Bank, the European Bank for Reconstruction and Development, the European Investment Bank, the Inter-American Development Bank, the International Monetary Fund, and the World Bank Group.

Di Bella, Gabriel; Norton, Lawrence; Ntamatungiro, Joseph; Ogawa, Sumiko; Samaké, Issouf; and Santoro, Marika (2015). Energy Subsidies in Latin America and the Caribbean: Stocktaking and Policy Challenges. Working Paper WP/15/30. International Monetary Fund.

Dubois, Olivier; Faurès, Jean-Marc; Felix, Erika; Flammini, Alessandro; Hoogeveen, Jippe; Pluschke, Lucie; Puri, Manas; and Ünver, Olçay (2014). The Water-Energy-Food Nexus: A New Approach in Support of Food Security and Sustainable Agriculture. Food and Agriculture Organization of the United Nations.

Duflo, Esther; Greenstone, Michael; and Rema, Hanna; (2008). Indoor Air Pollution, Health, and Economic Well-Being. Surveys and Perspectives Integrating Environment and Society. 1, 1-9.

Echevarría, Carlos; Jesurun-Clements, Nancy; Mercado, Jorge; and Trujillo, Carlos (2017). Integración eléctrica centroamericana: Génesis, beneficios y prospectiva del Proyecto SIEPAC: Sistema de Interconexión Eléctrica de los Países de América Central. IDB-MG-524. Inter-American Development Bank.

Emamgholizadeh, S.; Samaadi Borojeni, H.; and Bina, M. **(**2005). The Flushing of the Sediments Near the Power Intakes in the Dez Reservoir. WIT Transactions on Ecology and the Environment, Vol 83 (ISSN 1743-3541). WIT Press.

Energy Institute (2017). A Comparison of New Electric Utility Business Models. Johnson, Lyndon B. School of Public Affairs, Policy Research Project Report 191. The University of Texas.

Fairley, Peter. (2017). Off-Grid Electricity Projects Are Starved for Funds. IEEE Spectrum. November, 2017

Fares, L., Robert; and King, Carey W. (2016). Trends in Transmission, Distribution, and Administration Costs for U.S. Investor-Owned Electric Utilities. White Paper. UTEI/2016-06-1. The University of Texas.

Faris, Stephan (2015). The Solar Company Making a Profit on Poor Africans. Bloomberg.

Fay, Marianne; and Morrison, Mary (2007). Infrastructure in Latin America and the Caribbean: Recent Developments and Key Challenges. The World Bank.

Fay, Marianne; Hallegatte, Stephane; Vogt-Schilb, Adrien; Rozenberg, Julie; Narloch, Ulf; and Kerr, Tom (2015). Decarbonizing Development: Three Steps to a Zero-Carbon Future. Climate Change and Development. The World Bank.

Federal Ministry for Economic Affairs and Energy (2017). Concluding Paper: Electricity 2030: Long-Term Trends – Tasks for the Coming Years.

Feron, Sarah (2016). Sustainability of Off-Grid PV Systems for Rural Electrification in Developing Countries: A Review. Sustainability. Vol. 8, 1326.

Fu, Ran; Feldman, David; Margolis, Robert; Woodhouse, Mike; and Ardani Kristen (2017). U.S. Solar Photovoltaic System Cost Benchmark: Q1 2017. National Renewable Energy laboratory.

Galiana, Isabel; and Sopinka, Amy (2014). Benefits and Costs of the Energy Targets for the Post-2015 Development Agenda. Post-2015 Consensus Energy Assessment Paper. Copenhagen Consensus Center.

García Frapolli, Eduardo; Schilmann, Astrid; Berrueta, Victor; Masera, Omar; Riojas-Rodríguez, Horacio; Edwards, Rufus D.; Johnson, Michael; Guevera, Alejandro; and Armendariz-Arnez, Cynthia (2010). Beyond Fuelwood Savings: Valuing the Economic Benefits of Introducing Improved Biomass Cookstoves in the Purépecha Region of Mexico. Ecological Economics, 69(12): 2598-2605.

Gischler, Christiaan; Janson, Nils; Gonzalez, Camila; Cordoba, Maria Jimena; and Santana, Scarlett (2017). Unlocking Geothermal Power: How the Eastern Caribbean Could Become a Geothermal Powerhouse. IDB Technical Note No IDB-TN-1256, Washington DC.

Global Alliance for Clean Cookstoves-GACC (2015). Gender and Livelihoods: Impacts of Clean Cookstoves in South Asia. Executive Summary.

Global Carbon Project (2017). Carbon Budget and Trends 2017.

Global Energy Institute (2017). Index of U.S. Energy Security Risk: Addressing America's Vulnerabilities in a Global Energy Market.

Gong, Lin; Fu, Yong; and Li, Zuyi (2016). Integrated Planning of BEV Public Fast-Charging Stations. The Electricity Journal: Volume 29; Issue 10; Pages: 62-77. Elsevier.

González, Ricardo (2018). No habrá licitaciones especiales para energías renovables. Crítica.com/pa

Haanyika, Charles Moonga (2006). Rural Electrification Policy and Institutional Linkages. Vol. 34; Issue 17; Pages:2977–2993. Energy Policy. Elsevier.

Habtezion, Senay. (2016). Gender and Climate Change: gender and sustainable energy. United Nations Development Programme. UNDP, New York.

Hanna, Rema; Duflo, Esther; and Greenstone, Michael (2016). Up in Smoke: The Influence of Household Behavior on the Long-Run Impact of Improved Cooking Stoves. Faculty Research Working Paper Series. RWP12-015. American Economic Journal: Economic Policy. Volume 8, No. 1, Pages: 80-114.

Hernández Oré, Marco Antonio; Sánchez, Luis Álvaro; Sousa, Liliana D.; and Tornarolli, Leopoldo (2017). Fiscal and Welfare Impacts of Electricity Subsidies in Central America. Directions in Development - Public Sector Governance. The World Bank.

Hoff, H. (2011). Understanding the Nexus. Background Paper for the Bonn2011 Nexus Conference. The Water, Energy and Food Security Nexus. Solutions for the Green Economy. Stockholm Environment Institute.

Hubik, Franz. Wind Energy In the Doldrums: Germany's windmill producers have hit a dangerous lull after a change in the law on subsidies. Handelsblatt Global. August 28, 2017.

Institution of Engineering and Technology (2013). What is a Smart Grid?

Inter-American Development Bank (2014). Promoting Geothermal Development.

Intergovernmental Panel on Climate Change (2014a). Climate Change 2014: Synthesis Report of the Intergovernmental Panel on Climate Change's Fifth Assessment Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

International Energy Agency (2011). Technology Roadmap: Smart Grids.

International Energy Agency (2014). Capturing the Multiple Benefits of Energy Efficiency.

International Energy Agency (2015). Energy and Climate Change. World Energy Outlook Special Report.

International Energy Agency (2016). World Energy Outlook Special Report 2016: Energy and Air Pollution. Organisation for Economic Co-operation and Development (OECD)/IEA.

International Energy Agency (2017a). Energy Access Outlook 2017.

International Energy Agency (2017b). World Energy Outlook 2017.

International Energy Agency (2017c). World Energy Investment 2017 Outlook.

International Energy Agency (2017d). Digitalization and Energy.

International Energy Agency (2017e). Energy Technologies Perspectives.

International Hydropower Association (2017). Hydropower Status Report 2017.

International Monetary Fund (2013). Energy Subsidy Reform: Lessons and Implications.

International Monetary Fund (2017). Latin America and the Caribbean: Stuck in Low Gear. Regional Economic Outlook Update. Western Hemisphere.

International Partnership for Energy Efficiency Cooperation (2012). Energy Efficiency Report: Brazil.

International Renewable Energy Agency (2016). Innovation Outlook: Renewable Mini-grids.

International Renewable Energy Agency (2017). Electricity Storage and Renewables: Costs and Markets to 2030.

IPCC (2014b). IPCC, 2014: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Izquierdo, Alejandro; and Manzano, Osmel (2012). *El mundo cambió: ¿Cambiará el crecimiento en Centroamérica?: Desafíos y oportunidades.*

Jacobson, Mark Z. et al. (2017). 100% Clean and Renewable Wind, Water, and Sunlight All-Sector Energy Roadmaps for 139 Countries of the World. Joule. Volume 1, Issue 1, Pages: 108-121.

Jagger, Pamela; and Shively, Gerald (2014). Land Use Change, Fuel Use and Respiratory Health in Uganda. Energy Policy, 67: 713-726.

Jiménez, Raúl (2016). Rural Electricity Access Penalty in Latin America: Income and Location. Policy Brief IDB-PB-253. Inter-American Development Bank.

Jiménez, Raúl (2017). Development Effects of Rural Electrification. Policy Brief IDB-PB-261. Inter-American Development Bank.

Jiménez, Raúl; Serebrisky, Tomás; and Mercado, Jorge (2014). Power Lost: Sizing Electricity Losses in Transmission and Distribution Systems in Latin America and the Caribbean. Inter-American Development Bank.

Joskow, Paul L. (2008) Lessons learned from the electricity market liberalization. The Energy Journal.

Juergens, Ingmar; May, Nils; and Neuhoff, Karsten (2017). From 2020 to 2030: Policies and Policy Learning Remain Key to Enable Cost-Efficient Renewable Energy Development. Inter-American Development Bank; IKEM Sustainable Energy Academy 2017. Internal Document.

Karpowicz, Izabela; Matheson, Troy; and Vtyurina, Svetlana (2016). Investing in Infrastructure in Latin America and the Caribbean. *Diálogo a Fondo.* International Monetary Fund.

Kaspersky Lab Industrial Control Systems Cyber Emergency Response Team. (2018). Threat landscape for industrial automation systems in H1 2017. Kaspersky Lab.

Kempener, Ruud; Lavagne d'Ortigue, Olivier; Saygin, Deger; Skeer, Jeffrey; Vinci, Salvatore; and Gielen, Dolf (2015). Off-Grid Renewable Energy Systems: Status and Methodological Issues. Working Paper. International Renewal Energy Agency.

Lambe, Fiona; and Ochieng, Caroline (2015). Improved Cookstoves in Central America: Health Impacts and Uptake. Energy Sector Management Assistance Program and Stockholm Environment Institute.

Lappeenranta University of Technology and EnergyWatchGroup (2017). Global Energy System based on 100% Renewable Energy – Power Sector.

Larrea, Sylvia; Binato, Silvio; Provenzano, Dario; and Jeifetz, Carlos (2016). Arco Norte Electrical Interconnection Study. Component I – Baseline Study. IDB-MG-453. Inter-American Development Bank.

Levy, Alberto; Anaya, Fernando; and Vieira de Carvalho, Arnaldo (2017). Sol, viento, fuego y agua: El futuro de las energías renovables no convencionales en Centroamérica. IDB-MG-547. Inter-American Development Bank.

Liang, Jing; Yueming Qiu; Timothy James; Benjamin L.Ruddell[c;] Michael Dalrymple; Stevan Earl; and Alex Castelazo (2017). Do energy retrofits work? Evidence from commercial and residential buildings in Phoenix. Journal of Environmental Economics and Management

Marchán, Estefanía; Espinasa, Ramón; and Yépez-García, Ariel (2017). The Other Side of the Boom: Energy Prices and Subsidies in Latin America and the Caribbean during the Super-Cycle. IDB- MG-567. Inter-American Development Bank.

McCracken, John P.; and Smith, Kirk R. (1998). Emissions and Efficiency of Improved Woodburning Cookstoves in Highland Guatemala. Environment International. Volume 24, Issue 7, Pages: 739-747. Elsevier.

Mekonnen, M.; and Hoekstra A. (2012). The Blue Water Footprint of Electricity from Hydropower. Hydrology and Earth System Sciences. Vol 16.

Mercado, José (2015): The Role of Energy Efficiency in the Private Housing Sector - The Case of Santiago de Chile.

Mia, I.; Estrada, J.; and Geiger, T. (2007). Benchmarking National Attractiveness for Private Investment in Latin American Infrastructure. World Economic Forum.

Michelitsch, Roland; Szwedzki, Roni; Sembler, Jose Ignacio; Haarsager, Ulrike; Carbajo, José; Murcia, Juan Felipe; Seiwald, Raphael; Oliveira, Patricia; Funes Aguilera, Rocio; Cabrera, Maria; and Sadeghi, Patricia (2017). Evaluation of Public-Private Partnerships in Infrastructure: Executive Summary. RE-504-4. Inter-American Development Bank.

Navigant Consulting. 2017. Haiti Minigrid Investment Governance Manual. Navigant Consulting, Inc. Burlington. Prepared for IDB. Internal document.

Neuhoff, Karsten; May, Nils; and Richstein, Jörn (2017). Incentives for the Long-Term Integration of Renewable Energies: A Plea for a Market Value Model. DIW Berlin. Economic Bulletin; Vol. 7, Issue 46/47, 467-476.

Nique, Michael; and Jain, Neha (2014). The Synergies between Mobile, Energy, and Water Access: Asia. GSMA. Mobile Enabled Community Services.

Olivares Gallardo, Alberto (2012). *Servicio público y sector eléctrico. Evolución en Europa desde la experiencia española. Revista de Derecho de la Pontificia Universidad Católica de Valparaíso XXXIX.* Pages: 437-471.

Paredes, Juan Roberto (2017). La Red Del Futuro. Desarrollo de una red eléctrica limpia y sostenible para América Latina. IDB – MG- 565.

Patrinos, Harry Anthony; and Skoufias, Emmanuel (2007). Economic Opportunities for Indigenous Peoples in Latin America: Conference Edition. The World Bank.

Renewable Energy Policy Network for the 21 Century (REN21). (2018). Renewables 2017 Global Status Report. Paris. ISBN 978-3-9818107-6-9

Rodo, J. (2015). Dejemos hablar al viento. Energía & Negocios 26: 8–9.

Romero D. (2017). From behavioral insights to practice. A content analysis of interventions to encourage reductions in energy demand. Master Dissertation EPEE. Energy Institute-University College London.

Rose, Jonathan; Huppi, Monika; Alonso, Pablo; Fryer, Michelle; Crespo, Ana; Anna Risi, Vianna; Carpanelli, María del Mar; Rivera, Johanan; Niembro, Rasec; and Jansson, Maya (2017). Approach Paper: Evaluation of the Bank's Support for Gender and Diversity. RE-518. Office of the Evaluation and Oversight. Inter-American Development Bank.

Salmeri Micol, Wedgwood Paul, Rugg Richard, Aiello Roberto (2017). Developing clean energy solutions in Latin America's major cities: an introduction for subnational energy policy decision-makers. Carbon Trust and IDB.

Samadi-Boroujeni, Hossein (2012). Sediment Management in Hydropower Dam (Case Study - Dez Dam Project).

Smith, Kirk R.; Frumkin, Howard; Balakrishnan, Kalpana; Butler, Colin D.; Chafe, Zoë A.; Fairlie, Ian; Kinney, Patrick; Kjellstrom, Tord; Mauzerall, Denise L.; McKone, Thomas E.; McMichael, Anthony J.; and Schneider, Mycle (2013). Energy and Human Health. Annual Review of Public Health. Volume 34: 159-188.

Smith, Kirk R.; McCracken, John P.; Weber, Martin W.; Hubbard, Alan; Jenny, Alisa; Thompson, Lisa M.; Balmes, John; Díaz, Anaité; Arana, Byron; and Nigel, Bruce (2011). Effect of Reduction in Household Air Pollution on Childhood Pneumonia in Guatemala (RESPIRE): A Randomised Controlled Trial. The Lancet. Volume 378, No. 9804, Pages: 1717-1726.

Smith-Sivertsen, Tone; Díaz, Esperanza; Pope, Dan; Lie, Rolv T.; Díaz, Anaite; McCracken, John; Bakke, Per; Arana, Byron; Smith, Kirk R.; and Nigel, Bruce (2009). Effect of Reducing Indoor Air Pollution on Women's Respiratory Symptoms and Lung Function: The RESPIRE Randomized Trial, Guatemala. American Journal of Epidemiology. Volume 170, Issue 2, Pages: 211-220.

Stampini, Marco; and Tornarolli, Leopoldo (2012). The Growth of Conditional Cash Transfers in Latin America and the Caribbean: Did They Go Too Far? Policy Brief IDB-PB-182. Inter-American Development Bank.

Stipo, Francesco (2016). Latin American Energy Outlook: Natural Gas Leads the Way.

Toman, Michael; and Jemelkova, Barbora (2003). Energy and Economic Development: An Assessment of the State of Knowledge. Discussion Paper 03-13. Resources for the Future.

Troncoso, Karin; and Soares da Silva, Agnes (2017). LPG Fuel Subsidies in Latin America and the Use of Solid Fuels to Cook. Energy Policy Volume 07, Pages: 188-196.

Tuttle, David P.; Gülen, Gürcan; Hebner, Robert; King, Carey W.; Spence, David B.; Andrade, Juan; Wible, Jason A.; Baldick, Ross; and Duncan, Roger (2016). The History and Evolution of the U.S. Electricity Industry. Part of a Series of White Papers. The University of Texas at Austin. UTEI/2016-05-2.

United Nations (2012). Sustainable Energy for All: A Framework for Action. The Secretary-General's High-Level Group on Sustainable Energy for All.

United Nations (2015). The World's Women 2015: Trends and Statistics. Department of Economic and Social Affairs.

United Nations Development Programme (2012). Gender and Climate Change Africa. Policy Brief 1. General Overview. Gender and Climate Change.

United Nations General Assembly (2013). Report of the Secretary-General, 2014-2024 United Nations Decade of Sustainable Energy for All.

United Nations Industrial Development Organization (2013). Sustainable Energy for All: The Gender Dimensions.

United States Energy Information Administration (2017). International Energy Outlook 2017

United States Energy Information Administration (2017). International Energy Statistics.

Valencia, Adriana (2008). New Energy Frontiers Expand Global Connections – Part I. YaleGlobal Online.

Van de Walle, Dominique; Ravallion, Martin; Mendiratta, Vibhuti; and Koolwal, Gayatri (2017). Long-term Gains from Electrification in Rural India. Economic Review Volume 31, Issue 2. Pages: 385 – 411. The World Bank.

Vazquez, Carlos; Hallack, Michelle; and Vazquez, Miguel. "Price computation in electricity auctions with complex rules: An analysis of investment signals." Energy Policy 105 (2017): 550-561.

Wilson, Robert. "Architecture of power markets." Econometrica 70.4 (2002): 1299-1340.

World Bank (2018). Open Data Databank.

World Bank and International Energy Agency (2015). Progress Toward Sustainable Energy. Global Tracking Framework 2015. Key Findings.

World Economic Forum (2018). The Global Competitiveness Report 2017-2018.

World Energy Council (2017). World Energy Trilemma: Changing Dynamics - Using Distributed Energy Resources to Meet the Trilemma Challenge.

World Health Organization (2016). Burning Opportunity: Clean Household Energy for Health, Sustainable Development, and Wellbeing of Women and Children.

Wyman, Oliver (2013). World Energy Trilemma 2013: Energy Sustainability Index. World Energy Council.

Yepez-Garcia, Rigoberto Ariel; and Dana, Julie (2012). Mitigating Vulnerability to High and Volatile Oil Prices: Power Sector Experience in Latin America and the Caribbean. The World Bank.

Zeng Ming; Yongqi Yang; Lihua Wang Jinghui Sun (2016). The Power Industry Reform in China 2015: Policies, Evaluations and Solutions. Renewable and Sustainable Energy Reviews Volume 57, May 2016, Pages 94-110.