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ECUADOR ENERGY SECTOR ASSESSMENT

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CONTENTS

ACRONYMS

AME	Association of Ecuadorian Municipalities
ARCH	Hydrocarbon Regulation and Control Agency
ARCONEL	Electricity Regulation and Control Agency
BOT	Build-Operate-Transfer
CAF	Development Bank of Latin America
CELEC	Electricity Corporation of Ecuador
CENACE	National Electricity Operator
CNEE	National Energy Efficiency Committee
CNEL	National Electricity Corporation
COMEX	Committee on Foreign Trade
CONELEC	National Electricity Council
EPC	Engineering, procurement, construction
ESCO	Energy Service Company
EV	Electric vehicle
GAD	Decentralized Autonomous Government
GHG	Greenhouse gas
GHI	Global Horizontal Irradiation
GIZ	German Society for International Cooperation
GoE	Government of Ecuador
HVAC	Heating, Ventilation, and Air Conditioning
ICE	Internal combustion engine
ICEE	Intersectoral Committee on Energy Efficiency
IDB	Inter-American Development Bank
IIGE	Geological and Energy Research Institute
INDC	Intended Nationally Determined Contribution
INEN	Ecuadorian Service for Standardization
JICA	Japan International Cooperation Agency
KIAT	Korean Institute for Advancement of Technology
LOSPEE	Organic Law of the Public Electric Power Service
LPG	Liquefied Petroleum Gas
MDUVI	Minister of Urban Development and Housing
MEER	Ministry of Electricity and Renewable Energy
MERNNR	Ministry of Energy and Non-renewable Resources
MICSE	Ministry of Coordination of Strategic Sectors
MW	Megawatts
NREL	National Renewable Energy Laboratory
NEC	Ecuadorian Construction Standard
OLADE	Latin American Energy Organization
OPEC	Organization of the Petroleum Exporting Countries
PLANEE	National Energy Efficiency Plan
PME	Electricity Sector Master Plan
PPA	Power Purchase Agreement
PV	Photovoltaic
REZ	Renewable energy zone
RTE	Technical Regulations for Energy Efficiency
SGEn	Energy Management System
SINEA	Andean Electrical Interconnection System
SINEE	National Energy Efficiency Indicators System
SNEE	National System of Energy Efficiency
SNI	National Interconnected System
SNT	National Transmission System
UNIDO	United Nations Industrial Development Organization
VERE	Expected Value of Energy Rationing
VEREC	Expected Value of Conditional Energy Rationing

EXECUTIVE SUMMARY

This energy assessment provides an overview of Ecuador's energy sector, with a focus on the electric power sector. It examines the current energy context, the current state of the electricity sector, and the role of energy efficiency and renewable energy in the sector. Considering this information, the assessment identifies potential opportunities for USAID to support the Government of Ecuador (GoE) in advancing the adoption of renewables and energy efficiency. ICF developed this document on behalf of USAID through a desk review of publicly available information.

KEY FINDINGS

Ecuador is a major producer and exporter of oil. Oil production revenue has been a major source of economic growth over the last decade. Recent disruptions in oil markets and impacts of the global COVID-19 pandemic have severely affected Ecuador. Revenue has plummeted due to collapse in oil prices and the lockdown. While global oil market conditions have allowed the GoE to reduce the country's substantial fuel subsidies on gasoline and diesel, the longer-term impact of these events on the GoE's energy sector developments is uncertain.

State actors dominate Ecuador's electricity landscape. Key players include the Ministry of Energy and Non-Renewable Energy (MERNNR), the agency responsible for developing energy policy and promoting renewables and energy efficiency and Electricity Regulation and Control Agency (ARCONEL), the regulatory agency. Several key laws govern the electricity sector including the 2008 Constitution, which tasks the government with providing electricity and calls for promoting alternative energy and energy efficiency; the 2015 Organic Law of the Public Electric Power Service (LOSPEE), which requires that MERNNR create an Electricity Sector Master Plan (PME) and a National Energy Efficiency Plan (PLANEE), and that MERNNR and ARCONEL promote renewable energy; and the 2019 Energy Efficiency Law, which reinforces LOSPEE's requirements that MERNNR create PLANEE and update the plan every two years.

Ecuador's electric power system has a net capacity of nearly 8,200 MW. Over 60% of this capacity is hydropower, approximately one-third of the capacity is fossil-fuel fired, and the remaining 2% comes from non-hydro renewables. The vast majority of capacity lies within the mainland National Interconnected System (SNI) and the remaining capacity is primarily located on the Galapagos Islands and in remote parts of the Amazon coupled with hydrocarbon installations. Ecuador anticipates a 7% average annual growth in electricity demand through 2027, with demand reaching a total of 44,715 GWh in 2027 (before considering recent economic impacts of COVID-19). The latest planning documents indicate that Ecuador plans to add 5,300 MW of capacity by 2027. Most of this capacity (80%) will be hydropower, 10% thermoelectric, and 10% non-conventional renewable energy. Recently, the country has moved to procure renewable resources using a competitive procurement system.

RENEWABLE ENERGY

Hydropower—both run-of-river and conventional—constitutes the vast majority of Ecuador's existing and planned renewable generation in the mainland SNI. In the Galapagos, MERNNR plans to expand non-hydro renewables and battery storage substantially, and reduce reliance on thermal generation. In the transport sector, as of 2019, Ecuador had the largest fleet of hybrid vehicles in South America, likely driven by favorable tax policies that have been in place since the late 2000s.

In the mainland SNI, MERNNR appears to have limited ongoing efforts and plans for integrating renewables into the grid or ramping up storage. However, the GoE has been holding power purchase agreement auctions to expand non-hydropower renewable energy in the country. Currently, the GoE is holding a Public Selection Process for solar, wind, and mini-hydro developments.

Barriers facing renewables expansion include a lack of capacity for procuring and integrating variable non-hydro renewables into the grid; a lack of renewables workforce training programs; and a lack of a national plan and capacity for expanding biofuel production and electric vehicle charging infrastructure. Historically, deep fossil fuel subsidies have also hindered renewables adoption, though recent subsidy reductions may diminish this barrier. Risks include those introduced from regional destabilization; unexpectedly high capital costs in hydropower developments; climate change-driven droughts and floods, social and environmental impacts, and cybersecurity risks.

ENERGY EFFICIENCY

Ecuador has various energy efficiency objectives and plans. For the residential, commercial, and public sector, PLANEE sets a target of reducing cumulative energy consumption by 88.8 Mboe by 2035, equivalent to 150,907 GWh from 2016 to 2035. The plan proposes several programs for achieving this target, including implementing a national energy efficiency emblem to identify and label highly efficiency appliances, creating an oversight and control mechanism for regional governments adopting energy efficiency, and others. In support of these goals, the GoE has already undertaken a range of energy efficiency initiatives, including establishing energy efficiency standards for buildings, equipment, and appliances, and implementing a program to replace inefficient appliances—namely refrigerators and light bulbs—with more efficient models. However, several barriers inhibit the GoE's energy efficiency gains, including misplaced incentives, a lack of access to financing, a lack of information and misinformation, flaws in market structure, regulations leading to mispricing, and customer behavior and decision.

OPPORTUNITIES

Ecuador's adoption of renewable energy and energy efficiency could be advanced by targeting the gaps in and the barriers facing the GoE's efforts with USAID support. Ensuring that long-range planning processes capture the full value of these resources, are integrated with transmission planning, and consider the risks and resilience of the energy system could improve the environment for clean energy resources. Assisting Ecuador in reducing and eliminating fossil fuel subsidies would also create market conditions that support the development of clean energy resources.

Additional activities that would address barriers to renewable energy include:

- Supporting the continued development of Ecuador's competitive procurement processes;
- Accelerating the adoption of clean energy resources through an improved enabling environment created by grid integration strategies studies, improved operations including forecasting, and smart grid best practices;
- Assessing the role of battery storage in support of variable energy resources;
- Integrating transmission system buildout consistent with renewable expansion plans; and
- Building out the renewable energy value chain to assure financing.

In the energy efficiency sector, USAID could

- Supporting the development of a skilled workforce to ensure an effective network of trained energy efficiency professionals;
- Supporting the development of standards and codes that set a floor for technologies, buildings and practices;
- Supporting the development of efficient technologies including infrastructure for research, for testing and labeling, and showcasing applications;
- Supporting the development of financial mechanisms to support energy efficiency.

INTRODUCTION

The Government of Ecuador (GoE) recently re-opened discussions with USAID about a development assistance program to create a strategic energy modernization program to produce significant, sustainable, and transformational change in the sector. This document provides an energy assessment of Ecuador in order to help USAID better understand the country's energy sector, including the challenges facing the sector and opportunities for USAID to provide support focusing on renewable energy and energy efficiency.

This desk study is based on publicly available data and information on the country and its energy systems. This effort therefore excluded in-country research or discussions with key stakeholders. Further research and in-country engagement with key stakeholders and local authorities will potentially provide a more current, more detailed, and more complete set of perspectives.

The review focuses on renewable energy and energy efficiency in the power sector, and provides information on other energy resources and related information for context.

The remainder of this document is organized as follows:

- An overview of the Ecuadorian energy sector including its primary energy resources; information on its uses of energy; and background on the regulatory, legal and policy environment;
- An in-depth discussion of the electricity sector;
- A discussion of the state of renewable energy development;
- A review of the state of energy efficiency activities; and
- A review of donor engagement activities and discussion of gaps and opportunities to help the country increase the development of energy efficiency and renewable energy.

ECUADORIAN ENERGY SECTOR OVERVIEW

Ecuador is a constitutional republic of 17.5 million people and has a land area approximately the size of the U.S. state of Nevada (CIA World Factbook n.d., INEC n.d.). Within Ecuador, there are 24 provinces; seven regions (or zones) are two or more provinces that are combined and designed to decentralize the administrative functions at the national level. Decentralized Autonomous Government (GADs) are rural parish councils, municipal councils, metropolitan councils, provincial councils, and regional councils (Guía OSC 2017). They are the institutions that make up the territorial organization of the Ecuadorian state and have political, administrative, and financial autonomy; they are also responsible for some development projects (Guía OSC 2017).

In 2019, 25% of the population lived below the poverty line (defined as earning less than $85 per month) and 97% of the population had access to electricity (BCE 2020, MERNNR 2019, EIA 2017).

ECUADOR KEY DATA

Government: Constitutional Republic
Population: 17.5 million people
Land area: 106,900 square miles
GDP: $108 billion (2018)
GDP per capita: $6,300
GDP growth rate: 3.2% (2008–2018)
Population below the poverty line: 25% (2018)
Electricity access: 97.3%
Electricity consumption per capita: 1,200 kWh

As shown in Figure 1, below, the transport sector is a major energy user at nearly 50% of final consumption, predominantly in the form of gasoline and diesel fuel (MERNNR 2019). Industry and residential are the next two largest consumers at 15% and 13%, respectively (MERNNR 2019).

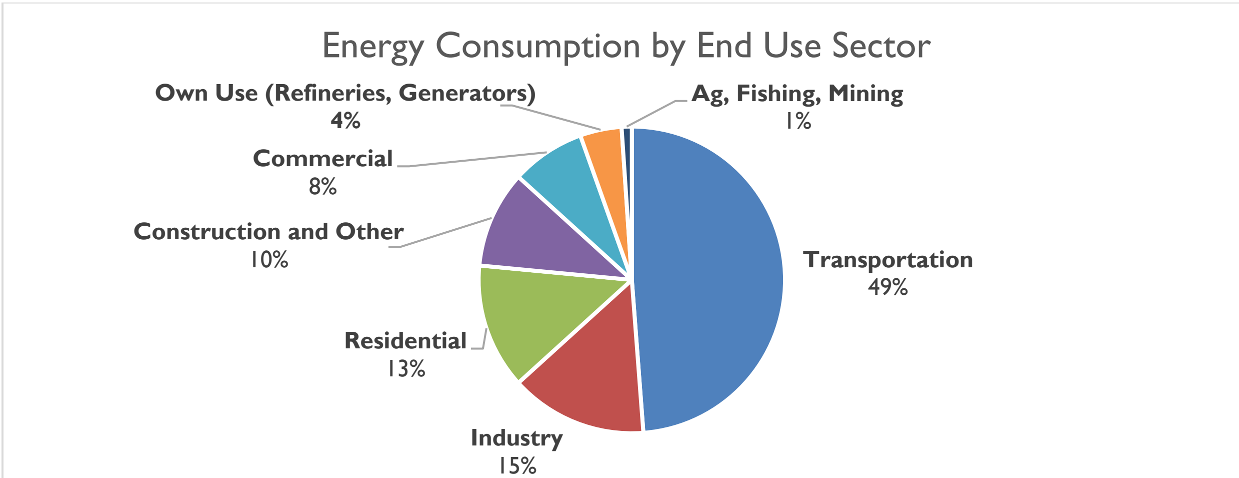


Figure 1. Energy consumption by end use sector. Source: (MERNNR 2019)

Ecuador has been severely affected by COVID-19 pandemic (New York Times 2020) and the disruptions in world oil markets created by the Russia-Saudi oil price wars and compounded by the global pandemic. Globally, lockdowns driven by the COVID-19 pandemic have had significant impacts on economies and, as a result, energy demands. The impacts on electricity demand in Latin American countries has been significant. Across a range of Latin America and Caribbean nations, demand has fallen between 4% and 28% as compared to the same time in 2019. (Tolmasquim 2010). The long-term effects on economies and electricity demand are uncertain, but the result could be lower levels of growth in the near and longer term. While the GoE has been proceeding with several energy sector developments to support future growth, this may not continue to be the case (Transformer Technology 2020). In the longer term, issues in neighboring countries and shifting alliances and national priorities may create delays or uncertainties in the government's plans.

An important and recent shift in how the country procures electricity has occurred. After several years of relying on public financing of the electricity sector, in 2019 the country opened the electricity sector to private investors (Escobar 2019). The country initially offered concessions on eight electricity generation projects with a combined capacity of 5,000 MW, requiring approximately $7.5 billion in investments (BNAmericas 2019).

Figure 2. Map of Ecuador, including mainland Ecuador and the Galapagos Islands

CURRENT ENERGY MIX

PRIMARY ENERGY RESOURCES

Ecuador has the third largest proven oil reserves in Central and South America at 8.3 billion barrels, behind Venezuela (303 billion) and Brazil (13 billion) (EIA n.d.). Ecuador's oil fields are primarily located in the Amazon region of the eastern part of the country. The country exports most of the crude that it produces, totaling 356,000 barrels per day (MERNNR 2019). Ecuador left the Organization of the Petroleum Exporting Countries (OPEC) in January of 2020 (Reuters 2019, S&P Global 2020). In addition to eliminating its OPEC membership fee, the departure allows the country to increase crude production beyond OPEC quota limits in an attempt to raise more government revenue (Reuters 2019). State-owned oil company Petroecuador accounts for the large majority of oil production—nearly 80% in 2018—with the rest attributed to privately-owned companies (MERNNR 2019).

ECUADOR PIPELINE INFRASTRUCTURE

- The 310-mile Trans-Ecuadorian Pipeline System (SOTE) is state-operated and can transport up to 360,000 barrels per day.
- The 300-mile Heavy Crude Pipeline (OCP) is operated by private oil producers and can transport up to 450,000 barrels per day.
- The 190-mile Oleoducto Transandino (OTA) transports 20,000 barrels per day from the Amazonian production region north to Colombia

Ecuador has two major crude oil pipelines that run parallel to each other and carry crude from production regions in the eastern part of the country to the northwest coast for export and refining (Reuters 2020, ARCONEL 2019). The country has one international pipeline which transports production from the Amazonian production region north to Colombia (EIA 2017). Other pipeline infrastructure carries product from production regions to refineries and export terminals along the southwestern coast (Petroecuador n.d.).

The country's pipeline infrastructure is old, and its capacity is not fully utilized (EIA 2017). This situation was exacerbated in early April of 2020 when sections of the SOTE and OCP pipelines in the country's Amazon region were badly damaged by a landslide (Reuters 2020). The event caused oil to spill into the Coca and Napo Rivers, polluting the food and water sources for local indigenous tribes (Wordley 2020). The pipelines were repaired by early May of 2020 and operations resumed (Spain News 2020).

The country has three major oil refineries and in 2018 refined an average of 169,000 barrels per day (MERNNR 2019). Despite large amounts of production, the country lacks adequate refining capacity, and imports approximately 48,000 kBOE of gasoline, diesel fuel, and other refined petroleum products (MERNNR 2019, EIA 2017).

Natural gas is extracted primarily in the Gulf of Guayaquil in the southern part of the country and as a coproduct of oil extraction (MERNNR 2019). The offshore Gulf of Guayaquil field is operated by the state-owned Petroamazonas and in 2018 produced 34 mcf/day (MERNNR 2019, EIA 2017). Total natural gas reserves in the country are estimated at 388 bcf (OPEC 2018).

The country has 31 GW of technically feasible hydropower potential, 22 GW of which is economically feasible to harness (MERNNR 2020). Current hydroelectric capacity stands at 5 GW, or approximately 23% of the economically feasible potential (MERNNR 2020). Since 2014, the share of the country's electricity generated from hydropower has increased from approximately 45% to 70% (MERNNR 2019).

ENERGY SUPPLY AND DEMAND BALANCE

As shown in Table 1, in 2018, domestic primary energy production in Ecuador totaled 217,000 kBOE, mostly in the form of crude oil (MERNNR 2019). In 2018 the country produced approximately 190 million barrels of oil, of which it exported 130 million, or 70% (MERNNR 2019). The United States is a major recipient of Ecuadorian oil exports and in 2018 received approximately 50% of the country's total oil exports (EIA 2017). According to EIA data, in 2018 Ecuador was the third-largest supplier of crude oil imports to the U.S. West Coast behind Saudi Arabia and Canada (EIA 2017). Regionally, crude oil exports flow to Colombia, Chile and Nicaragua (Simoes, Alexander n.d., EIA 2017). The country imported approximately 48,000 kBOE of refined petroleum products due to a lack of domestic refining capacity (MERNNR 2019).

After accounting for transmission losses, power plant use, and other adjustments, energy consumption at the end-use level was approximately 94,000 kBOE, as shown in Table 1 (MERNNR 2019). Final energy consumption in 2018 represented a 3.8% increase from 2017 (MERNNR 2019). Transportation accounted for 17% and 49% of primary fuel and end use consumption, respectively. As shown in the table, transportation demand was followed by industry at 14%, residential at 13% and commercial at 8% (MERNNR 2019). While the country historically imported electricity, in recent years it has become a net electricity exporter (MERNNR 2019). Between 2016 and 2018 the country exported an annual average of nearly 300 GWh to neighboring Colombia and Peru (MERNNR 2019, MERNNR 2020). The balance of primary energy inputs reflects crude exports, power exports, energy conversion losses, and T&D losses.

Table 2 illustrates electricity production inputs. Hydropower represents 5% of the country's primary input and 46% of input to electricity production. Fossil resources are 52% of primary inputs to electricity production in 2018, while solar, wind, and biomass are about 2% of primary energy inputs, all to electricity production.

TABLE 1. PRIMARY ENERGY PRODUCTION & END USE CONSUMPTION (MERNNR 2019)

SOURCES	KBOE	% TOTAL	END USES	KBOE	SHARE OF PRIMARY	SHARE OF FINAL
Crude	189,076	71%	Transportation	45,712	17%	49%
Hydro	12,812	5%	Industry	13,570	5%	14%
Natural Gas/NGLs	11,055	4%	Residential	12,386	5%	13%
Biomass	3,996	2%	Commercial	7,317	3%	8%
Wind/Solar	74	0%	Ag, Fishing, Mining	1,002	0%	1%
			Construction and Other	9,579	4%	10%
			Own Use (Refineries, Generators)	4,114	2%	4%
Total Production	217,013	82%	Total Consumption	93,680	35%	100%
Product Imports	47,677		Crude Exports	129,840		
Electricity Imports	66		Product Exports	21,187		
			Electricity Exports	158		
Total Imports	47,743	18%	Total Exports	151,185	57%	
			Electricity Conversion and T&D Losses	11,908		
			Flaring, Own Use/Gas, Inventory Changes	8,181		
			Own Use, Losses and Inventory Changes	20,089	8%	
Total Sources	264,756	100%	Total Uses	264,954	100%	

TABLE 2. ELECTRICITY INPUTS, USES, IMPORTS AND EXPORTS (MERNNR 2019)					
ELECTRICITY INPUTS	KBOE	% TOTAL	ELECTRICITY USES	KBOE	% TOTAL
Hydro	12,812	46%	Industry	6,195	39%
Refined Product	8,276	30%	Residential	4,585	29%
Natural Gas	3,423	12%	Commercial	4,299	27%
Crude	2,668	10%	Construction and Other	347	2%
Biomass	629	2%	Own Use (Refineries, Generators)	257	2%
Wind/Solar	74	0%	Transportation	7	0%
Net Exports	(224)	-1%	Ag, Fishing, Mining	-	0%
Total Inputs	27,658	100%	Total Consumption	15,690	100%
Conversion Losses	(9,560)	-35%			
T&D Losses	(2,348)	-8%			
Net Domestic Supply	15,750	57%			

MARKET, INSTITUTIONAL, POLICY, AND REGULATORY FRAMEWORKS

KEY ACTORS, ORGANIZATION, AND MARKET STRUCTURE

This section describes the key stakeholders within the energy and electricity markets, as well as information on how the market is structured.

Ministry of Energy and Non-Renewable Natural Resources (MERNNR) was created in 2018, by Executive Decree 399 by merging the Ministry of Electricity and Renewable Energy (MEER), the Ministry of Mining, and the Hydrocarbons Secretariat (The Business Year 2020). The Ministry is responsible for developing relevant policy and promoting the development and sustainable use of energy and mineral resources (MERNNR n.d.).

Electricity Regulation and Control Agency (ARCONEL) is housed under MERNNR and regulates all state-owned electricity operations and oversees the National Electricity Operator (CENACE) (ARCONEL n.d.). The Agency also maintains the country's statistical information system for the electric sector (INEC & ARCONEL n.d.).

Hydrocarbon Regulation and Control Agency (ARCH) regulates oil and gas activities in the country (ARCH n.d.).

National Electricity Operator (CENACE) is the grid operator of the electricity system on the mainland, the National Interconnected System (SNI) (CENACE 2014). It manages energy transactions and ensures adequate operation of the grid (CENACE 2014). It is attached to the MERNNR.

Electricity Corporation of Ecuador (CELEC) is the state-owned holding company responsible for generation, transmission, distribution, commercialization, and import and export of electrical energy. (CELEC n.d.) The company has 13 business units dedicated to thermal and renewable energy generation, in addition to one business unit, Transelectric, dedicated to transmission (CELEC n.d.) The transmission system associated with the SNI is referred to as the National Transmission System (CELEC n.d., CELEC n.d.) CELEC also oversees generation assets of islanded systems (CELEC n.d.).

National Electricity Corporation (CNEL) is the state-owned distribution holding company with 12 business units who distribute energy to 50% of the population (CNEL n.d.). Nine provincial entities serve the remaining customers (MERNNR 2015).

Undersecretariat for Energy Distribution and Marketing has as its mission to "direct, coordinate and evaluate the expansion of electricity distribution, as well as the technical, operational, commercial, administrative and financial management of electricity distribution companies" (MERNNR n.d.).

Public Hydrocarbons Company of Ecuador (Petroecuador) is the state-owned oil company (U.S. DOJ 2020). Its subsidiary, Petroamazonas, deals with hydrocarbon exploration and exploitation and in 2018 accounted for 78% of all oil production in the country (Petroamazonas n.d., MERNNR n.d.).

Corruption in Ecuador is a major obstacle facing prospective investors. Ecuador's anti-corruption legal framework is designed to address corruption offenses, but these laws are poorly enforced, and government officials continue to accept bribes. The former president was recently found guilty of corruption. He and 19 others were recently were accused of accepting $7.5 million in bribes in exchange for public contracts. In January of 2020, an Ecuadorian businessman, pleaded guilty to a $4.4 million bribery and money laundering scheme in connection to public officials from Petroecuador (Department of Justice 2020). He stated that from 2012 to 2015, he and others conspired to bribe Petroecuador officials in order to receive and retain business (Department of Justice 2020). Various organizations have accused the GoE of corruption, citing the construction of eight hydroelectric plants that lacked sufficient technical oversight and future demand studies, resulting in an excess of electricity supply (Los Tiempos 2019).

The GoE is the major player in the energy sector; non-profit organizations have limited involvement. While local and regional agencies, such as GADs, are responsible for some development projects, including implementing the National System of Energy Efficiency (SNEE), there is limited published publicly available information regarding these institutions.

FOSSIL FUEL SUBSIDIES

The GoE has subsidized gasoline, diesel, liquefied petroleum gas (LPG), and electricity since the 1970s by up to 85%. The country ranked fifth globally and third in Latin America in energy subsidies when expressed as percentage share of GDP. (Schaffitzel, et al. 2019) In 2017 liquid fuel subsidies were estimated at 2% of the country's GDP (The World Bank 2020). These subsidies act as an indirect subsidy to electricity sector. One estimate indicates that fuel subsidies and subsidies to capital expenditures for state-owned hydroelectric plants reduce tariffs by as much as one-third of the full price (BNAmericas 2019). Reforms supported by the World Bank sought to dramatically reduce subsidies for gasoline and diesel and assigned ARCH to set fuel prices using a pre-determined cost-based formula (The World Bank 2020). Fossil fuel subsidies can be counterproductive to climate, health and social goals, and distort trade. Subsidies can also dampen clean energy development.

In October of 2019, the GoE announced that it would eliminate gasoline and diesel subsidies in order to cut costs; the GoE spends $1.4 billion annually on fuel subsidies (El Pais International 2019). However, after two weeks of violent and widespread protests, the GoE reversed the decision (The World Bank 2020). The GoE has attempted to withdraw subsidies on gasoline and diesel previously, including in 2015 when former President Correa reduced public spending by $300 million by eliminating aid to fuels from shipping companies, airlines, and international heavy cargo (El Pais International 2019). The World Bank stated that low oil prices as a result of the current COVID-19 crisis and the GoE's commitment to subsidy redesign provide an opportunity to reform fuel subsidies (The World Bank 2020). Similarly, in April of 2020, the country's Energy Minister indicated that the global drop in crude oil prices provides an opportunity to remove fuel subsidies without causing dramatic price increases (Reuters 2020).

In May 2020, the GoE announced a new market-based price band for gasoline and diesel, an effort to take advantage of the drop in oil prices and reduce fuel subsidies (Argus 2020). This pricing system is part of the GoE's COVID-19 response and an energy measures package to restructure debt and reduce public spending.

LEGAL, POLICY, & REGULATORY CONTEXT

Constitution

The most recent Ecuadorian constitution, adopted in 2008, addresses energy and sustainability issues, in addition to specifying government responsibility for the provision of electricity (Georgetown University 2011). Specifically, Article 413 calls for the promotion of alternative energy and energy efficiency, while Article 414 calls for adopting measures to mitigate climate change (Georgetown University 2011). Article 314 calls for government provision of services, including electricity, that are universally accessible, equitable, and affordable (Georgetown University 2011)

Organic Law of the Public Electric Power Service (LOSPEE)

Passed in 2015, LOSPEE is intended to guarantee that the provision of electricity complies with various constitutional principles, including energy efficiency and renewable energy (LEXIS Finder 2019). LOSPEE requires that MERNNR[1] create an Electricity Sector Master Plan (PME) and National Energy Efficiency Plan (PLANEE). Furthermore, the law mandates that MERNNR and ARCONEL promote renewable energy (MEER 2017).

LOSPEE also determines that MERNNR may delegate to private companies in the following cases: (1) when it is necessary to satisfy the public, collective, or general interests; (2) when the service cannot be supplied by public or mixed companies; or (3) for renewable energies not identified in the PME (GoE 2015). LOSPEE establishes that when the GoE delegates to private companies, MERNNR must select the company through a Public Selection Process guided by national interests, but does not prescribe details for the process (GoE 2015, MERNNR 2019).

LOSPEE's precursor—the 1996 Electric Law—also promoted energy efficiency and renewable resources, and explicitly stated a desire to foster private sector investment and competitive markets (CONELEC 2002, IRENA 2015, GoE 2015).

Energy Efficiency Law

The 2019 Energy Efficiency Law reinforces LOSPEE's requirement that MERNNR create PLANEE and adds a requirement to update the plan every two years. (OLADE 2019, El Comercio 2019). The law also calls for moving away from nonrenewable energy sources (OLADE 2019).

[1] Referred to as MEER in LOSPEE, though in the intervening years, the GOE has replaced MEER with MERNNR

Climate Change Commitments

Ecuador's Intended Nationally Determined Contribution[2] (INDC) commits the country to reducing its energy sector greenhouse gas (GHG) emissions by 20–25% below the business as usual (BAU) scenario, and by 40% below BAU should the country receive international support by 2025, largely through changes in the energy sector (GoE 2015).

In addition, the INDC recognizes the need to identify and adapt to climate risks driven by extreme events and climate variability, including for electricity infrastructure and hydropower development.

NATIONAL ENERGY AGENDA

The National Energy Agenda is the government's comprehensive strategic planning framework for the energy sector (MCSE 2016). It is aligned with the United Nations' Sustainable Development Goals and the most recent version of the Agenda covers the timeframe 2016 through 2040 (MCSE 2016). It has the following five pillars:

1) An integrally planned, equitable, and inclusive energy sector
2) A diversified, renewable, and sustainable energy system
3) Sovereignty and energy security with a quality supply for the whole population
4) Energy efficiency
5) Regional energy integration and Ecuador's contribution to sustainable global energy development

ELECTRICITY SECTOR OVERVIEW

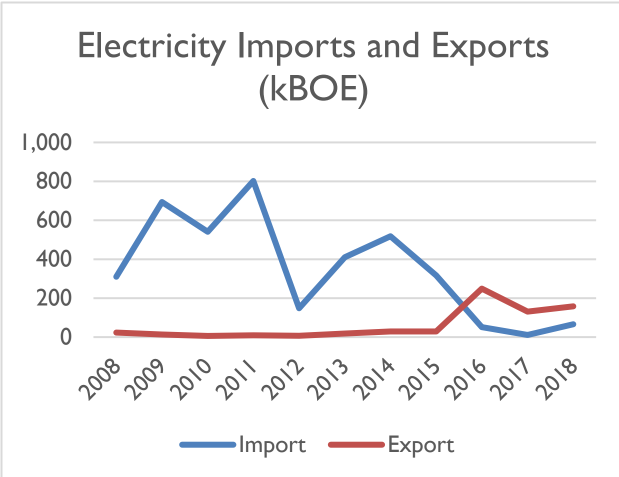
EXISTING GENERATION SYSTEM

The country has a total installed electricity generation capacity of 8,800 MW and a net capacity of nearly 8,200 MW (MERNNR 2020). Approximately 62% of this capacity is hydro, while 36% is thermal, and the remaining ~2% comes from non-hydro renewables (biomass, biogas, wind, and solar) (MERNNR 2020). Total generation in 2018 reached 29,350 GWh (including 106 GWh imported from neighboring Colombia) (MERNNR 2020). Of total domestic generation, 71% is derived from hydropower, 27% from thermal generation, 2% from other renewables, and 0.4% from imports (MERNNR 2020).

There is 1,300 MW of generation capacity that is not associated with the SNI (ARCONEL 2019). These installations are primarily located on the Galapagos Islands and in association with hydrocarbon installations in the remote Amazonian regions in the eastern part of the country. On the Galapagos, there is 27.6 MW of installed thermal capacity, 4.7 MW of installed wind capacity, and 2.6 MW of installed solar.

Prior to 2015, Ecuador was a significant importer of electricity. However, in recent years the trend has reversed, and Ecuador produces more electricity than it consumes, as shown in Figure 3 (MERNNR 2019, MERNNR 2020).

[2] INDCs describe countries' commitments to reduce national emissions and adapt to climate impacts. Countries submitted INDCs to the Intergovernmental Panel on Climate Change ahead of the 2015 Paris Conference of Parties.



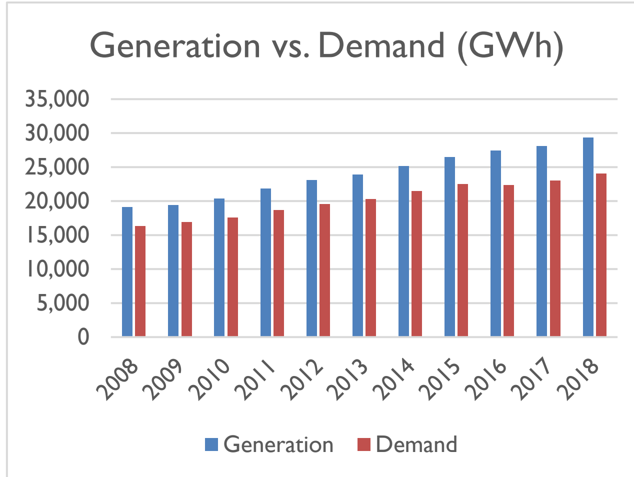


Figure 3. Left: Electricity imports and exports, 2008 – 2018 (MERNNR 2019). Right: Generation vs. demand, 2008-2018 (MERNNR 2019, MERNNR 2020).

PLANNED ADDITIONS

In 2017 and 2018, 700 MW of new capacity was added, 92% of which was hydropower and the rest of which was thermal (MERNNR 2020). As of 2019, 645 MW of new generation was under construction; 92% of this was hydropower, while the remainder is wind power (MERNNR 2020). These additions are part of MERNNR's 2018-2027 generation expansion plan, which calls for a total 5,300 MW of added capacity (MERNNR 2020). Of this, approximately 4,150 MW (78%) is hydropower, while nearly 600 MW (11%) is thermoelectric, 500 MW (9%) is non-conventional renewable energy, and 50 MW (<1%) is wind (MERNNR 2020). There is a "Productive" case that anticipates a higher growth in demand and calls for 6,600 MW of added capacity during the same time frame. Of this capacity, 4,400 MW (67%) is expected to come from planned hydropower projects, 1,200 MW (18%) comes from planned thermal projects, 950 MW (14%) comes from other renewable sources, and 50 MW (<1%) comes from geothermal (MERNNR 2020).

The country's grid infrastructure has been strained in some areas due to large increases in the amount of hydropower on the system in recent years (MERNNR 2020). However, the Transmission Expansion Plan calls for spending $1.8 billion on transmission system improvements and expansions through 2027 (MERNNR 2020). Detailed expansion plans are discussed in the Renewable Energy section (p. 10).

ELECTRICITY DEMAND AND FORECASTS

Ecuador anticipates a 7.1% average growth in electricity demand between 2018 and 2027, reaching a total of 44,715 GWh (MERNNR 2020). This projection only considers demand within the SNI, which accounts for 82% of all generation in the country and does not include the Galapagos Islands. Electricity consumption within the residential sector is expected to increase on average by 4% annually, in the commercial sector by 6% annually, and in the industrial sector by 8% annually (MERNNR 2020). More information regarding electricity demand and future projections are discussed in the Energy Efficiency section (p. 26).

EXISTING TRANSMISSION AND DISTRIBUTION SYSTEM

The country has 3,800 miles of 500 kV, 230 kV, and 138 kV transmission lines within the mainland National Transmission System, including interconnection with neighboring Colombia and Peru. Increased hydropower on the system has strained transmission and the country expects increases in demand, including from the steel, copper, and aluminum industries.

NATIONAL PLANS AND OBJECTIVES

The GoE has developed various national plans that outline electricity sector objectives, including the:

- **Electricity Sector Master Plan (PME).** As mandated by the Electric Law of 1996 and later by the 2015 LOSPEE, the GoE has published 11 PMEs since 1998; MERNNR published the latest PME in 2020 (ARCONEL 2020, MERNNR 2020). This latest PME, which covers 2019–2027, establishes objectives of expanding generation capacity by 6.6 GW by 2027, expanding the transmission system to accommodate new generation facilities, and expanding and modernizing the distribution system to increase electricity access to 98% by 2027 (MERNNR 2020). Additionally, Annex B of the PME focuses on sustainable development in the electric sector, and outlines nine key strategies for achieving sustainability, including strategies on advancing renewable generation (Strategy D) and energy efficiency (Strategy E) (MERNNR 2020). The PME is discussed in further detail in the Renewable Energy section (p. 10).
- **National Energy Efficiency Plan (PLANEE) 2016–2035**, which establishes goals for the plan's six key sectors/regions—Judicial, Institutional, and Access to Information; Residential, Commercial, and Public; Industrial; Transportation; Energy; and Galapagos. (MEER 2017) The Energy Efficiency section (p. 26) discusses this plan in further detail.
- **National Energy Agenda 2016–2040,** which establishes five strategic objectives, described in the section Legal, Policy, & Regulatory Context (p. 7) (MCSE 2016).
- **INDC of 2015,** which commits the GoE to (a) hydroelectricity making up 90% of Ecuador's electricity production by 2017, and (b) introducing 2,828 MW of hydropower generation capacity (scenario without external funding) and 4,382 MW of hydropower generation capacity (scenario with external funding) by 2025
- **National Plan for Good Living 2013–2022**, which establishes the goal of sourcing 60% of energy generation from renewables by 2017 (IRENA 2015).
- **Executive Order 1303 of 2013** mandates that transportation diesel fuel be blended through 2025 (IRENA 2015, MEER 2017).
- **Executive Order 1681 of 2009** requires that government institutions form and Energy Efficiency Committee that implements energy saving measures (World Bank, IADB, & SEM 2010).

In general, Ecuador appears to be on track for achieving its renewable electricity targets, so long as conventional hydropower is counted as a renewable energy.[3] For example, the GoE achieved the National Plan for Good Living target of sourcing 60% of electricity from renewable sources by 2017 (IRENA 2015, MERNNR 2020). Similarly, the GoE has already met its INDC commitment for the scenario without external funding of installing 2,828 MW of hydropower by 2025, and is on track to nearly meet its commitment for the scenario with external funding of installing 4,382 MW of hydropower by 2025 (GoE 2015, MERNNR 2020). However, the GoE did not meet its INDC estimate of sourcing 90% of electricity from renewable sources by 2017 (GoE 2015, MERNNR 2020). In the transport sector, the GoE may not be on track to meet its bioethanol blend 2025 target (USDA 2018).

TARIFFS

The Organic Law of the Public Electric Power Service (LOSPEE) empowers ARCONEL to set tariffs for electricity (ARCONEL 2020), and the president has the authority to set subsidy prices as needed (The

[3] In other cases, larger conventional hydropower is not considered a renewable energy source due to GHG emissions, environmental impact, and the technology's maturity, among other factors.

World Bank 2020). In April of 2019, ARCONEL and MERNNR announced they would not raise electrical rates for any part of the country (Ecuador TV 2019).

In April of 2020, the GoE announced that electric services would not be suspended due to missed payments, and that a discounted rate for residential low-income customers would remain in place in response to the COVID-19 crisis (MERNNR 2020, ARCONEL n.d.). Additionally, energy bills from March and April 2020 will be deferred for dignity rate customers, small business, and artisanal industries (MERNNR 2020).

RENEWABLE ENERGY

GOVERNMENT OF ECUADOR POLICY INITIATIVES

Over the past several decades, the GoE has adopted a range of policies, plans, laws, and regulations to promote renewable energy (IRENA 2015). In particular, over the past several years, the GoE has been transitioning toward implementing policies and actions to procure renewable energy. This desk review indicates that the GoE has focused on advancing renewables in the electricity and transport sectors.

In the electricity sector, the Electric Law of 1996 and the LOSPEE of 2015 aim to promote renewable resources (CONELEC 2002, IRENA 2015, GoE 2015). For example, the 1996 law required that the now disbanded CONELEC promote renewable electricity through dispatch regulations (IRENA 2015). In 2015, the LOSPEE mandated that MERNNR promote renewable energy (GoE 2015). The law also mandates that ARCONEL regulate electricity from renewable sources in a preferential manner, and allows the agency to set rates that favor renewable energy (GoE 2015). In 2018, ARCONEL passed Regulation No. 003/18, which incentivizes solar PV distributed generation (MERNNR 2020). In 2018, the GoE issued a regulation allowing the private sector to propose distributed renewable energy projects to reinforce distribution and subtransmission networks (The Dialogue 2019). This aligns with the global trend of variable energy resource projects or distributed energy resources, capable of such reinforcement by responding quickly to grid disturbances, participating in ancillary services markets (IRENA 2019).

Several national plans also foster renewables growth. In 2013, the National Plan for Good Living established objectives of promoting sustainability and diversifying the energy mix with renewables (Senplades 2013). Similarly, the PMEs establish goals around expanding renewables. The most recent PME (2019–2027) includes plans to expand renewable generation, as well as several strategies to advance sustainable development, one of which focuses on promoting renewable energy projects (MERNNR 2020).

From 2000 until at least 2015, a feed-in-tariff system supported renewable electricity deployment and mandated preferential renewables dispatch (IRENA 2015). In 2000, CONELEC established a 10-year feed-in tariff for wind, solar PV, biomass, biogas, and geothermal for projects smaller than 15 MW. Over the course of the 2000s and 2010s, CONELEC extended the tariff, adjusted rates, and modified technologies covered by the tariff including (IRENA 2015):

- In 2004, expanding the tariff to include small hydropower of up to 10 MW;
- In 2011, expanding the tariff to include hydropower up to 50 MW;
- In 2012, expanding the tariff to include ocean energy and concentrated solar power;
- In 2013, eliminating the tariff for solar PV and setting additional capacity limits for the other technologies covered by the tariff;
- In 2014, maintaining the tariff only for biomass and biogas and hydropower smaller than 30 MW.

While one source seems to indicate that the latest iteration of the renewables feed-in tariffs will be in place through 2027 (Bustamante & Bustamante 2018) another source seems to indicate that these tariffs ended in 2015 (IRENA 2015).

Over the past several years, the GoE has also begun transitioning away from feed-in tariffs and toward power auctions to procure renewable generation, particularly in the Galapagos (PV Magazine 2019).In the transport sector, policies promote both biofuels and electric vehicles (EVs). Issued in 2013, Ecuador's Executive Order 1303 mandates that transportation diesel fuel be a 5% biodiesel blend (B5) (IRENA 2015). This mandate requires an increase to a 10% bioethanol blend by 2025 (IRENA 2015, MEER 2017).

Since 2008, GoE has incentivized hybrid and EV purchases through import tariff exemptions (MEER 2017). In 2015, the GoE Foreign Trade Committee (COMEX) eliminated import taxes on EVs that cost less than $40,000, and eliminated Value Add Tax and Tax on Special Items on EVs that cost less than $35,000 (Enriquez 2015, UEMI Secretariat 2018). Additionally, since 2018, ARCONEL established preferential rates for fast charging at public charging stations, EV owners who install smart meters, and private EV charging stations (Isla, et al. 2019).

CURRENT CONTEXT AND EXPECTED TRENDS

EXISTING RESOURCES

In mainland Ecuador's SNI electricity system, renewables make up the majority (64%; 5,232 MW) of Ecuador's net dependable generation capacity (MERNNR 2020). Of this 5,232 MW, most (63%) comes from run-of-river hydropower, followed by conventional hydropower (i.e., hydropower with reservoir storage) (34%), while biomass, solar, wind, and biogas make up the remaining 4% (MERNNR 2020). Table 3 describes the net dependable capacity for each of these renewable generation types.

TABLE 3. NET DEPENDABLE CAPACITY IN THE SNI IN 2018 (MERNNR 2020)

GENERATION TYPE	UNITS	NET DEPENDABLE CAPACITY (MW)	PERCENT OF CAPACITY (%)
Biogas	2	6.5	0.1%
Biomass	3	136.4	2.6%
Wind	3	21.2	0.4%
Hydropower: Conventional	71	1,754.0	33.5%
Hydropower: Run-of-river		3,286.9	62.8%
Solar	34	26.7	0.5%
Total	113	5,231.7	100%

Between 2008 and 2018, Ecuador expanded the SNI's renewable energy net dependable generation capacity from 2.1 GW to 5.2 GW (MERNNR 2020). Hydropower made up the vast majority (97%; 3 GW) of that growth (MERNNR 2020). The remaining growth came from biomass (1.4%; 42 MW), solar (0.8%, 24 MW), wind (0.5%, 17 MW), and biogas (0.2%, 7 MW) (MERNNR 2020). Table 4 depicts this change in generation capacity.

TABLE 4. SNI NET DEPENDABLE GENERATION CAPACITY FROM RENEWABLE SOURCES 2008–2018 (MERNNR 2020)

GENERATION TYPE	NET DEPENDABLE GENERATION CAPACITY (MW)										
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Biomass	95	95	93	93	93	93	136	136	136	136	136
Solar	-	-	-	-	-	3	24	24	24	24	24
Hydropower	2,028	2,029	2,212	2,204	2,233	2,233	2,237	2,398	4,413	4,481	5,035
Wind	-	-	-	-	-	17	17	17	17	17	17
Biogas	-	-	-	-	-	-	-	-	2	7	7
Total	2,123	2,123	2,305	2,297	2,326	2,346	2,415	2,574	4,591	4,664	5,218

In 2007, the GoE established the initiative Zero Fossil Fuels in the Galapagos Islands, aiming to reduce the use of fossil fuels (MERNNR 2020). Since then, MERNNR and the Galapagos Province Electric Enterprise S.A. have developed projects to replace existing thermal generation with renewable resources (MERNNR 2020). As of 2018, the Galapagos electricity system was comprised of 7.2 MW of renewables, with 4.7 MW from wind and 2.6 MW from solar (MERNNR 2020).

Looking at renewable energy in transport, as of 2019, Ecuador had the largest fleet of hybrid vehicles in South America, likely driven by favorable tax policies that have been in place since the late 2000s (Isla, et al. 2019). The automobile companies that dominate the EV market in Ecuador, BYD and KIA, have installed much of the existing publicly available charging infrastructure (Isla, et al. 2019). As of 2018, an estimated 15 chargers were publicly available in Ecuador (Isla, et al. 2019).

CURRENT AND PLANNED DEVELOPMENTS

In the SNI, MERNNR (2020) plans to double its renewable generation capacity over the next decade, reaching 10.5 GW in 2028. Conventional storage hydropower is expected to make up around 70% of the growth; because of this growth, conventional hydropower capacity will begin to exceed run-of-river capacity toward the end of the planning term (MERNNR 2020). Run-of-river hydropower, solar PV, wind, geothermal, and other renewable projects where the generation type has not yet been defined are also expected to contribute to growth (MERNNR 2020). MERNNR has one main planned solar development (El Aromo at 200 MW), and one planned wind development (Villonaco II and III at 110 MW). Many of these projects have been or will be procured through a Public Selection Process (MERNNR 2020). Figure 4 summarizes these projections.

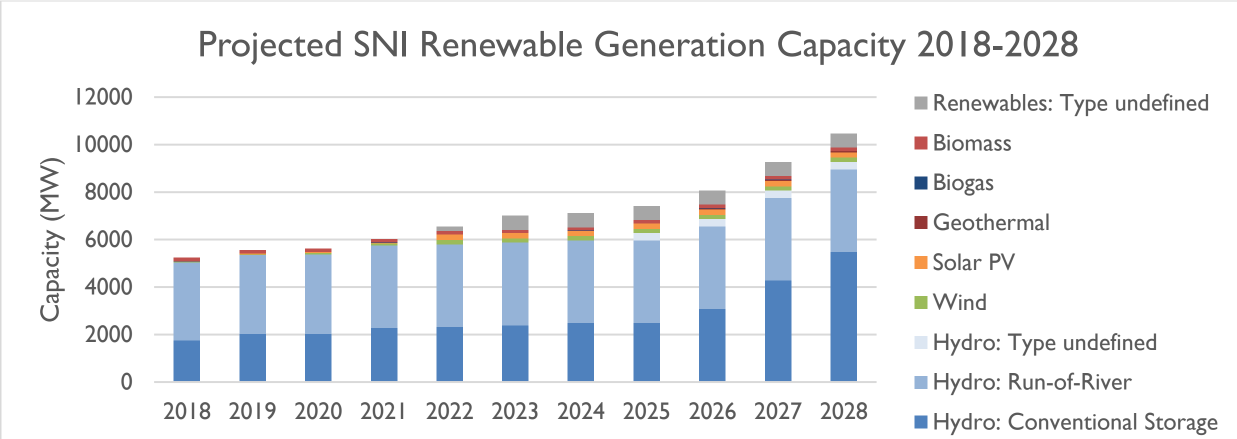


Figure 4. Projected renewable generation capacity in the SNI under the productive matrix case, 2018–2027. Source: MERNNR 2020.

MERNNR is also expanding the transmission system to connect these new projects to the grid. Table 5 summarizes expansion plans for major transmission lines and substations (Transformer Technology 2020, MERNNR 2020, Sanchez 2012).

TABLE 5. TRANSMISSION AND SUBSTATION EXPANSIONS PLANNED TO ACCOMMODATE NEW RENEWABLES (MERNNR 2020)

YEAR	PROJECT	PURPOSE
2019	230 kV Milagro-Esclusas line (second circuit)	Various generation projects including the 275 MW Minas San Francisco hydropower plant
2020	138/69 kV 150 MVA Rayo Loma substation (expansion)	180 MW Delsitanisagua hydropower plant
2020	138 kV Cuenca-Yanacocha line (expansion)	180 MW Delsitanisagua hydropower plant
2021	230 kV Delsitanisagua–Cumbaratza–Bomboiza line (new)	180 MW Delsitanisagua hydropower plant
2022	230 kV El Aromo-San Juan de Manta line (new)	200 MW El Aromo solar PV development
2022	34.5/69 kV Villonaco Substation; Sub-transmission line from Villonaco Substation to Loja Substation (new)	110 MW Villonaco wind farm
2025	230 kV Zhoray – Sinincay line (new)	180 MW Delsitanisagua hydropower plant
2025	230 kV line (new)	596 MW Paute - Cardenillo hydropower plant
2026	500 kV Santiago line (new)	2,400 MW Santiago hydropower plant
2026	Chorrillos Taday and Pasaje substations (expansions)	500 kV Santiago line

In the Galapagos system, MERNNR (2020) plans to nearly quadruple renewable generation capacity, reaching 33.3 MW in 2025. This increase will largely be driven by wind (15 MW) and solar photovoltaic (solar PV) (11 MW) (MERNNR 2020). MERNNR (2020) also plans to substantially increase storage capacity, reaching 61 MW in 2025. MERNNR plans to hold Public Selection Processes, or auctions, for at least some of these planned renewable generation and storage projects (PV Magazine 2019). Figure 5 summarizes these changes.

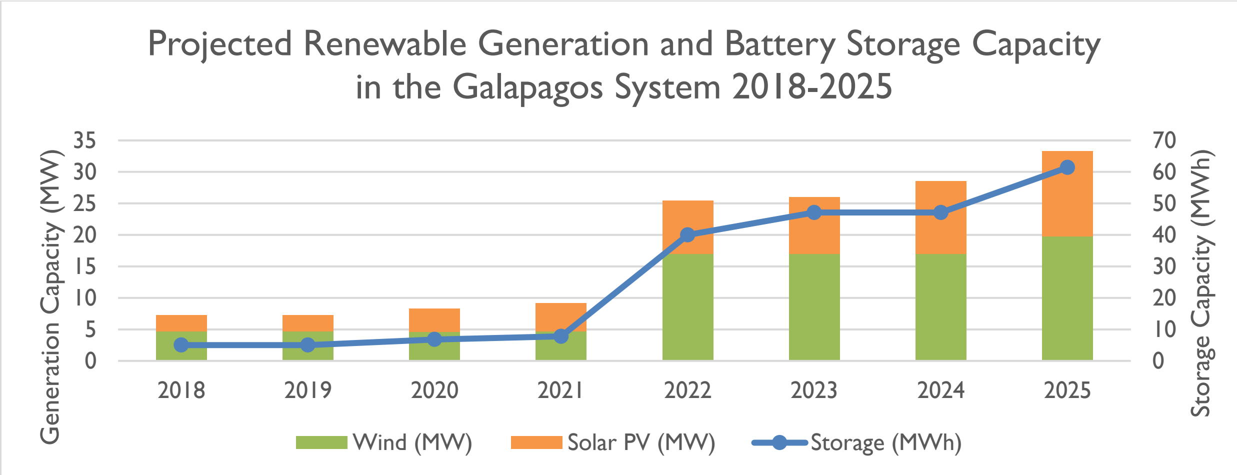


Figure 5. Projected renewable generation capacity (primary y-axis) and battery storage capacity (secondary y-axis) in the Galapagos system 2018–2025. Source: MERNNR 2020.

Furthermore, the GoE is working to modernize distribution systems through strategic management, updating the distribution system, improved grid management through automation, improved customer service systems, a new Enterprise Resource Management System (intended to improve project management, human resources, asset inventories, finance, accounting, etc.), and information technology and communication management (MERNNR 2020). These developments have the potential to help integrate small scale renewables into the grid.

In the transport sector, there are several ongoing biofuels projects. In 2010, the Eco País Biofuel Production Project launched a pilot program to make 5% bioethanol blend gasoline available in the cities of Guayaquil and Durán (USDA 2018). The project is now nationwide, though ethanol is primarily used in lowland areas due to concerns around performance in high altitudes (USDA 2018). Similarly, the GoE Biofuel and Agroenergy Programme aimed to establish 80,000 hectares of sugarcane plantation for bioethanol by 2018 (IRENA 2015).

While the GoE lacks national plans and programs for advancing EVs, there are several efforts at the municipal level. For example, in 2019, the City of Guayaquil converted its bus fleet to electric, purchasing 20 EV buses from the company BYD (Field 2018). Similarly, in 2019, BYD built Ecuador's largest electric charging station on land that the federal government loaned to the company in Guayaquil (Xinhua 2019). The City of Cuenca also launched a pilot project where EV owners pay reduced municipal taxes and parking fees (UEMI Secretariat 2018).

PRICE AND TECHNOLOGY TRENDS DRIVING OR HINDERING RENEWABLE GENERATION AT THE ENTERPRISE LEVEL

Price trends can be difficult to compare between different resources because the capital, fuel and operating cost profiles over time tend to look very different. For example, upfront capital costs are lower for thermal relative to hydropower, while ongoing operational costs for thermal are similar to or greater than hydropower, and thermal plants require fuel costs to operate, while hydropower plants do not. Wind and solar generation technologies have had declining capital costs, no fuel costs, and relatively low operational costs but produce intermittent generation on diurnal or seasonal cycles. Over time, hydro, wind, and solar can provide the highest value on a levelized cost[4] basis.

Renewable energy prices are falling globally, including in Latin America. The region's levelized cost of electricity is rapidly dropping due to increased renewables deployment and it is expected that in South America onshore wind development will drive renewable resource growth in the coming years. Onshore wind efficiency improvements have driven price reductions. The region also boasts a highly competitive environment, with many development firms competing in a market which lacks dominant players, further driving down costs (Mordor Intelligence 2018).

In the transport sector, the GoE's heavy fuel subsidies have facilitated ownership of private ICE vehicles (UEMI Secretariat 2018, Valencia 2019).

Some facilities in Ecuador that utilize processes with large amounts of waste heat have been approved for cogeneration plants (OLADE 2006). As Ecuador begins to allow concessions contracts and private ownership of utility scale solar and wind facilities, there may be increased interest in distributed generation in the commercial and industrial sectors.

EXPECTED TRENDS

Renewable Generation: Grid Integration

Variable renewable generation (e.g., wind, solar PV, run-of-river hydropower) introduces uncertainty into the bulk power system due to its variable and intermittent nature. While expensive transmission upgrades and expansion, as well as integration of storage capacity can solve this uncertainty, several lower cost solutions can potentially help operators maintain system balance.

Improvements in short-term solar forecasting can reduce curtailment and reduce ramping costs for all power plants on the system (Brancucci Martinez-Anido, et al. 2016). Sub-hourly wind forecast improvements also have the potential to address uncertainty on a grid with high wind energy penetration (Hodge, et al. 2015). Other methods of operational flexibility, such as faster scheduling and demand response, can be low cost options for integrating renewables (NREL 2015).

Energy Storage

Energy storage facilitates renewables integration by mitigating the volatility of the renewable resource. Energy storage can charge (or absorb power) when renewable generation exceeds demand, and discharge to meet the deficiency when generation falls. Energy storage is characterized by the charging period (time required to fully charge a battery or fill a reservoir), the discharge period (how quickly the battery or reservoir can drain and provide power to the grid), and its efficiency (how much energy it can discharge as a fraction of the energy supplied).

Conventional hydropower can be used as a dispatchable resource to balance intermittency. However, large scale hydro and wind or solar facilities may be installed in different regions, limiting the viability. In some South American countries, developments have explored co-location of renewable electricity generation sources and pumped hydropower. In this case, during low load periods, excess electricity generation can be used to pump water into an upper reservoir and discharged through a turbine during high load and/or low solar or wind generation. Renewable energy developers have begun deploying batteries, especially lithium ion chemistries, which can be available to discharge in as little as a minute

[4] Levelized cost is the average net present cost of electricity generation over the lifetime of a generation plant

and more easily co-located with intermittent generation sources, giving it an advantage over hydropower that could take hours (EESI 2019).

Throughout the early 2010s, lithium-ion batteries typically provided short discharge durations, often less than an hour, and were most frequently deployed to provide time shift services on renewable energy projects (Hary and Sarkissian 2016). Starting in approximately 2015, declining prices and longer duration technologies (with 4-hour durations becoming common) began to allow system operators more flexibility in matching of supply and demand (Patel 2020). With falling costs, favorable policies globally, and more developed supply chains, in the 2020s, lithium-ion manufacturers are optimistic for cheaper prices and longer durations (Finn-Foley 2020). In addition to lithium ion batteries, which have dominated the battery industry due to deployment across the bulk electricity system and EV sectors, other storage technology solutions are nearing potential for wide scale commercialization including flow batteries (which can provide a greater than 4-hour duration), fuel cells, and hydrogen storage. Furthermore, seasonality does not play a significant role in Ecuadorian energy demand, allowing Ecuador to satisfy much of their needs with the mid-duration battery storage that will be more rapidly developed (BNAmericas 2020).

Renewable Generation: Curtailment

Power that cannot be stored must be disposed of via curtailment or reducing generation output. Variable renewable generators and grid operators will have to handle the risk of economic curtailment as more variable resources come online. The bearer of this risk varies based on local market rules. In Uruguay, generators are compensated for any power that they supply which is then curtailed, while in Chile, generators must bear the market risk of curtailment (Darez 2018). With diligent planning and operation, the flexibility of hydropower could serve to complement variable resources and somewhat diminish curtailment. The high level of existing and planned conventional hydroelectric storage in Ecuador's generation mix may allow for higher penetration of variable generation sources.

The ENEL Foundation's 2019 report on renewables grid integration in the Colombia-Ecuador-Peru region found that overgeneration risk was high in Ecuador. However, renewable generation facilities with curtailment are still expected to be economically optimal as compared to thermal generation (ENEL Foundation & CESI 2019). Additionally, Ecuador's grid interconnections with its neighbors allow it to export excess power of 110 MW to Peru and 525 MW to Colombia (MERNNR 2020). ENEL's reference case modeling indicates that in Ecuador, 61 GWh are curtailed annually due to instantaneous power surplus, with an additional 10 GWh curtailed due to transmission line overload (ENEL Foundation & CESI 2019).

Renewable Energy Procurement

Over the past decade, the GoE procured many of Ecuador's large hydropower plants through engineering, procurement, construction (EPC) contracts—also called turnkey contracts—where the GoE pays developers to design the project, procure equipment and materials, and construct the project to deliver a functioning facility (Kirchherr and Matthews 2018). The GoE then operates the hydropower plants (Kirchherr and Matthews 2018). Chinese banks—namely China Development Bank, China Exim Bank, and the Bank of China—funded many of these plants (Kirchherr and Matthews 2018).[5] For example, the Chinese Sinohydro dam developer built the 1500 MW Coca Codo Sinclaire, plant and CELEC now operates the project (Kirchherr and Matthews 2018).

[5] China benefits from assisting Ecuador by gaining access to oil, including pre-sales to the Chinese state-owned oil and gas company.

MERNNR is holding a procurement procedure for 500 MW of renewable energy projects, including the 200 MW El Aromo solar PV project in the Manabí province on the Pacific coast, the 110 MW Villonaco II and III onshore wind projects in the Andean region of the Loja province in the south, and two dozen smaller wind, solar, and mini-hydro projects with a combined capacity of 200 MW (PV Magazine 2019). El Aromo will be sited at a location originally intended for an oil refinery. MERNNR is expecting all 500 MW to come online by 2022.

MERNNR is using a Public Selection Process, to select the winning company for the El Aromo PV project, as required by LOSPEE (PV Magazine 2019). MERNNR will select the bid with the lowest offer rate, with reckless bids disqualified. The winning company will then be awarded a concession contract to design, finance, construct, operate, and maintain the facility, as well as deliver electric power to the grid. The plant owner will be compensated with multiple tax credits and a 20-year Power Purchase Agreement (PPA), after which the GoE will assume ownership of the plant (MERNNR 2019).

The Villonaco II and III projects is being procured similarly, with a public bidding process awarding the contract to design, finance, construct, operate, maintain the project, and deliver electric power to the grid. The owner will be compensated with multiple tax credits and a 25-year PPA, after which time possession of the plant will be transferred to the Ecuadorian government.

In the El Aromo project, after an initial application pool of 19 developers, MERNNR selected eight finalists based on their legal, technical, and financial qualifications to bid. These eight finalists hail from a combined four countries—China, France, Qatar, and Spain—representing a global procurement effort. Six of these eight firms have also been selected as finalists for the Villonaco II and III projects (Martín 2019). Although contracts for both projects were originally scheduled to be awarded in April 2020, the procurement process has been extended to allow developers more time to submit their final bids due to the COVID-19 pandemic (Renewables Now 2020). It is estimated that each will bring in $200 million worth of investment and capital expenditure during development, including the building of transmission lines and step-up transformers required for interconnection (MERNNR 2019).

One of the smaller projects that makes up part of the remaining 190 MW is Conolophus, located in the Galapagos Islands. A similar procurement procedure and 20-year PPA are in place for this 14.8 MW solar PV project, which is to be built with 40.9 MWh of lithium-ion battery storage (MERNNR 2019).

With the GoE's international GHG reduction commitments, Ecuador's generation mix is expected to become less GHG-intensive. Regional and global trends are also expected to impact the Ecuadorian energy system. Technological advancements, like bifacial modules in solar (producing power from both sides of the panel) and larger onshore wind turbines that can operate at lower wind speeds, are allowing more power to be generated by wind and solar at a lower cost.

Transportation

The transportation sector is also expected to experience changes influenced both by Ecuadorian policy and global trends. GoE goals of 10% bio-ethanol gasoline by 2025 will provide GHG reductions for fleets or personal internal combustion engine (ICE) vehicles that are difficult to electrify (IRENA 2015, MEER 2017). Bioethanol gasoline made from sugarcane has been largely successful for Latin American economies, most notably Brazil, although it is worth noting that sugarcane has traditionally not grown very well in the Amazon and Ecuador may need to look for arable land in other regions of the country.

Sugarcane as a bio-ethanol feedstock leads to GHG savings of approximately 50% as compared to conventional petroleum gasoline (Wang, et al. 2012). These GHG savings can help Ecuador meet their internal policy targets, but also importantly serve to hedge the price of their bioethanol in international markets. In many regions globally, including Europe and California, local decarbonization targets have led to GHG markets, which will allow biofuel to realize multiple value streams; the value that it has as a physical fuel and the value of the GHG reduction within these markets.

Bioethanol production may also be important politically and economically for Ecuador, moving it to national energy independence and a net exporter of energy while creating jobs. In 2019, it is estimated that only about 1% of global renewable energy investment dollars went towards biofuel projects (Frankfort School-UNEP Centre/BNEF 2019). Based on data throughout the 2010s however, the global biofuels industry employed between 20% and 30% of all those employed in the renewable energy sector (IRENA 2019).

In addition to bioethanol, EVs are attractive solutions for replacing many of the ICE vehicles on Ecuador's streets today. Several public and private owners in Ecuador have already transitioned their ICE fleets to electric. Local governments in Guayaquil and Loja have operational fleets of electric busses and taxis and heavy-duty transport company Transcarsell became the first to purchase a fleet of electric trucks in Ecuador, acquiring 20 trucks from Chinese firm BYD that will be delivered in late 2020 and early 2021 (BYD 2020).

As the wealth of Ecuador's population rises and the number of personal vehicles on the road increases, a higher fraction of EVs may put a strain on electricity demand. MERNNR (2020) expects continued growth in EV adoption, with EV energy demand growing from 1GWh in 2018 to 63 GWh by 2027. Frost & Sullivan (2018) estimate that by 2025, Ecuador's EV penetration will be the highest within the region, with EVs making up 9.9% of total vehicle sales in the country. Grid modernization will be necessary to accommodate this additional load.

CAPACITY FOR RENEWABLES EXPANSION & INTEGRATION

CAPACITY FOR GRID INTEGRATION OF VARIABLE RENEWABLE ENERGY

Existing transmission line congestion and equipment sizing may create constraints or "choke-points" at nodes along the grid that will influence where the grid has the capacity to integrate renewables. ENEL Foundation & CESI (2019) found that in their optimized future case of 3.8 GW of combined solar wind installations in Ecuador, this constraint would only cause about 10 GWh of curtailment annually out of about 464 GWh of electricity production from solar and wind resources. While curtailment is estimated to be low, reducing system constraints would allow space for even more renewable energy on the grid. Additionally, increasing the sizes of interconnections with neighboring Colombia and Peru could allow for more energy exports and manage the intermittency of renewable resources (ENEL Foundation & CESI 2019).

For the PME, MERNNR (2020) performs various analyses that can help prepare for integrating renewables into the grid, including modeling:

- **Annual demand by distributor.** For the demand forecast, MERNNR uses a macroeconomic model and demographic data, and models low, base case, and high demand scenarios.
- **Generation and transmission expansion.** MERNNR uses OPTGEN, a generation and regional interconnections expansion planning model which uses the demand forecast and asset inventory to determine a path for minimum cost expansion.
- **Generation output and economic dispatch.** MERNNR uses SDDP, a stochastic hydrothermal dispatch model which accounts for grid restrictions. The model uses hydrologic scenarios to characterize future generation output in a probabilistic manner. SDDP also models economic dispatch, or optimal output by generation facility to meet demand at the lowest possible cost, considering grid constraints.
- **Complying with reliability requirements.** After running these models, MERNNR verifies that the plan complies with reserve margin requirements and two reliability criteria, being VERE (expected value of energy rationing) and VEREC (expected value of conditional energy rationing).

Separate from the PME, MERNNR also performs load flow analysis using their Advanced Distribution Management System, which can support renewables integration efforts (MERNNR 2020). As renewable penetration increases, MERNNR will need to perform system stability studies and studies to assess ramping needs and adequacy of operating reserves. From the desk review, it is unclear whether MERNNR already performs these studies.

In the mainland SNI, likely as a result of its plans to rely heavily on hydropower and only minimally expand wind and solar PV capacity, MERNNR (2020) seems to have few efforts aimed at managing the variability that comes with wind and solar, based on the desk review. Throughout the latest PME planning period (2019–2028), wind and solar PV combined are projected to make up no more than 5% of the entire generation mix (MERNNR 2020).

Within the Galapagos system, MERNNR (2020) is expanding battery storage and smart grids to better cope with the intermittent nature of wind and solar as the archipelago becomes more reliant on these technologies. According to MERNNR (2020), as of 2019, wind and solar PV are quickly becoming major components of the energy mix in the Galapagos, growing from 21% in 2020, to 32% in 2021, to 53% in 2022, and remaining in the 52%–56% range through 2026. As a result, renewables integration strategies will be increasingly crucial to this system.

EXISTING TRANSMISSION PLANNING FOR RENEWABLES INTEGRATION

The renewable energy zone (REZ), supported by USAID and implemented by the National Renewable Energy Library (NREL) as part of the Greening the Grid platform, is a concept in transmission planning that promotes future-proofing buildout by building to areas of high renewable resource concentration. Then, developers can build in these areas and have the benefit of easily connecting to the electric grid. Resource maps of annual Global Horizontal Irradiation (GHI) and mean wind speeds at 100 m within Ecuador are shown in Figure 6 and Figure 7, respectively.

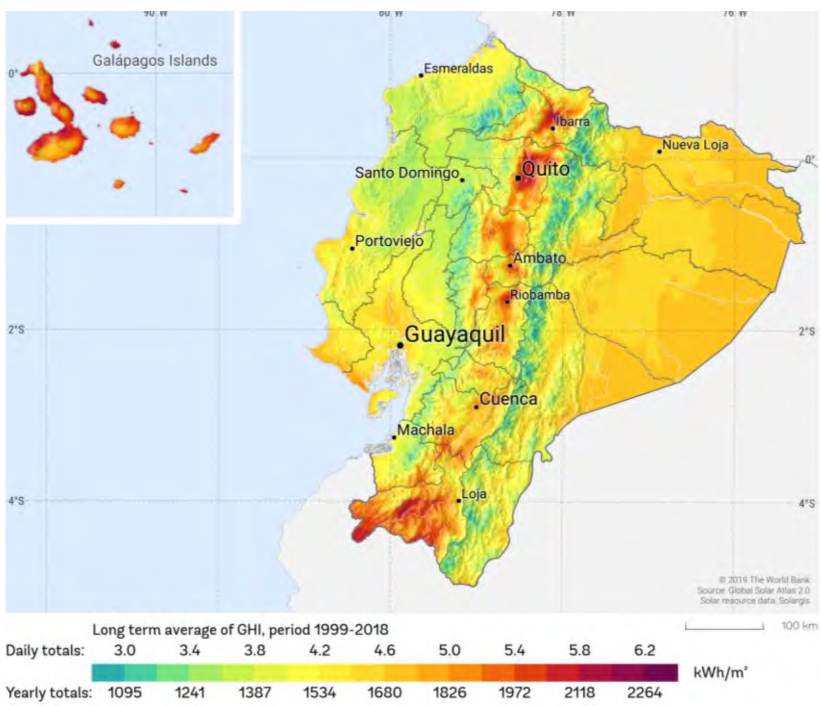


Figure 6. Long term average GHI map of Ecuador. Map obtained from the Global Solar Atlas 2.0, a free, web-based application is developed and operated by the company Solargis s.r.o. on behalf of the World Bank Group, utilizing Solargis data, with funding provided by the Energy Sector Management Assistance Program (ESMAP). For additional information: https://globalsolaratlas.info. Source: (Solargis 2019)

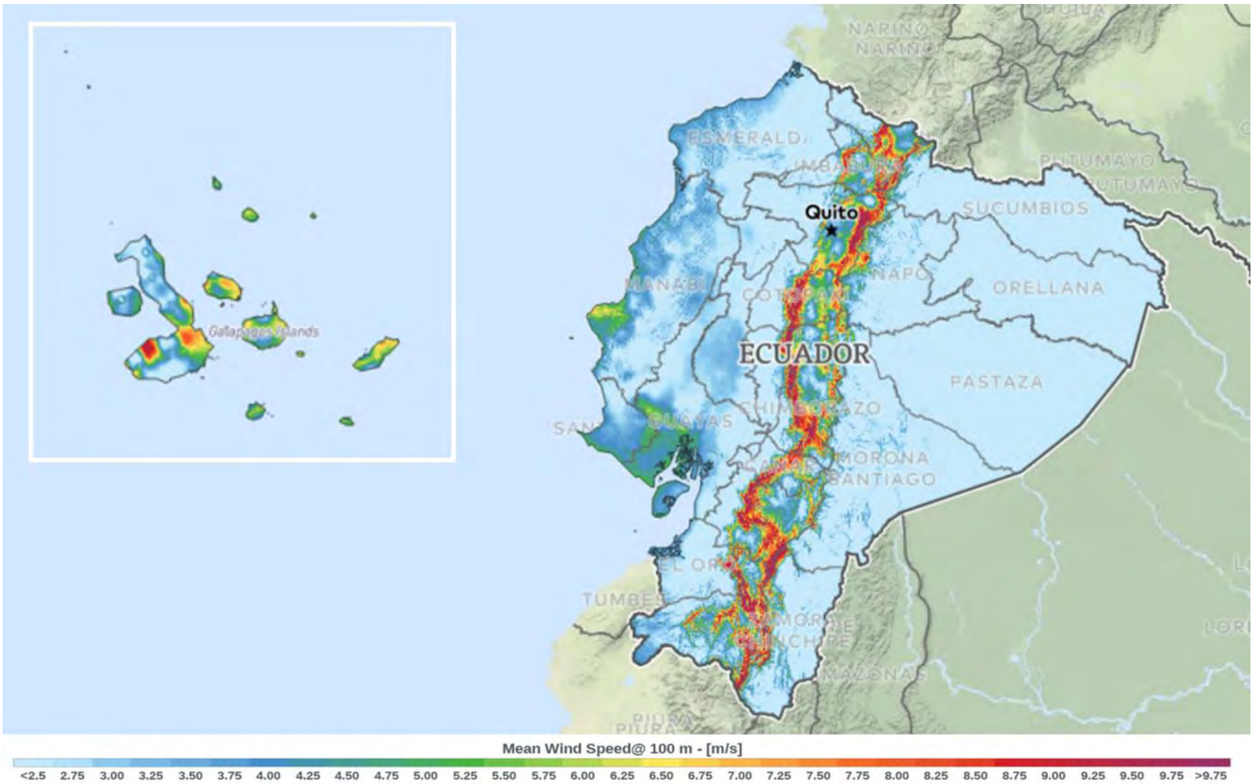


Figure 7. Wind speed map of Ecuador at 100 meters. Map obtained from Global Wind Atlas 3.0, a free, web-based application developed, owned and operated by the Technical University of Denmark (DTU). The Global Wind Atlas 3.0 is released in partnership with the World Bank Group, utilizing data provided by Vortex, using funding provided by the Energy Sector Management Assistance Program (ESMAP). For additional information: https://globalwindatlas.info. Source: (Technical University of Denmark 2019)

Ecuador boasts high solar resource throughout the country, particularly in the mountainous Andean region located in the middle third of the country. Similarly, high wind speeds are found in this region. While there is no evidence of formal REZ planning in Ecuador, some planned transmission buildouts account for the addition of renewable energy resources. The 7 km, 230 kV El Aromo-San Juan de Manta line is being built to connect the El Aromo solar PV facility to the grid and the 138 kV Ducal Membrillo-Loja line is being built for the Villonaco II and III wind projects (Transformer Technology 2020). Each project is being built in areas with abundant solar and wind resource, respectively. El Aromo's location was selected to take advantage of infrastructure built out to accommodate a bankrupt oil refinery, while Villonaco II and III will be sited alongside the 16.5 MW Villonaco I wind turbine facility built in 2013. By building lines prior to projects even being developed and basing siting decisions on available transmission, Ecuador can best shape the grid to take advantage of its abundant solar and wind resources. As described within the Current Developments section (p. 13), MERNNR (2020) plans to expand transmission capacity in order to integrate new renewable generation sources—namely new hydropower—into the grid.

EXISTING PLANNING FOR INTEGRATING MORE ADVANCED TECHNOLOGIES

While MERNNR (2020) has developed plans for building and integrating battery storage in the Galapagos, the agency does not appear to have plans for doing the same within the mainland SNI. The GoE also lacks plans that promote EVs and associated infrastructure and electric needs.

BARRIERS TO ACHIEVING GOE RENEWABLE ENERGY TARGETS

POLICY, LEGAL, & REGULATORY BARRIERS

In the transport sector, according to USDA (2018) the GoE must significantly increase ethanol production to meet the 10% diesel blending goal, including implementing policies to incentivize domestic industry to increase biofuel production. Biofuel production may in part be limited by the Organic Law of Food Sovereignty of 2010, which mandates that the government prioritize food production and limit the use of food crops as biofuel feedstock (IRENA 2015) Similarly, the GoE lacks a national plan for expanding EVs and charging infrastructure, which Isla et al. (2019) consider a major challenge to expanding EV use.

INSTITUTIONAL & SECTORAL CAPACITY

The GoE has faced various capacity challenges around developing wind, solar PV, biomass, and biogas. For example, during a competitive public procurement process in 2013, MEER failed to provide transparency in the approval process, failed to define technical norms and standards, and failed to take into account capital costs, access to the transmission grid in the mountainous terrain, and the lack of bank financing available (St. James 2016). Seventeen solar projects were awarded, and were scheduled to begin operating in 2015, but none were built due to these challenges (St. James 2016). According to St. James (2016), this process damaged the GoE's credibility with investors.

USDA (2018) identifies a need to significantly increase capacity for biofuel production through expanding sugarcane fields, refinery and storage capacity, and adopt new technologies and management practices. In the same vein, Isla et al. (2019) note that the supply of alternative vehicles and charging infrastructure is limited, and that just one or two companies dominate the market.

TECHNOLOGICAL

Workforce Development

A workforce of trained technicians will be required to install and maintain renewable energy equipment. While much of this work can be performed by individuals already employed in power or electrical fields, workforce retraining may be necessary to ensure that renewable energy facilities operate properly.

Based on the desk review, there do not seem to be significant workforce training efforts underway in Ecuador. Partnerships with local universities or existing workforce development programs could provide opportunities to meet this need. Additionally, the Latin American Energy Organization (OLADE) has developed renewable energy workforce programs for some of its other member nations, and taping into this network would allow Ecuador to benefit from their lessons learned.

FINANCIAL BARRIERS

Trade

The renewable energy industry has a global supply chain. Solar array modules are primarily sourced from China and Southeast Asia and inverters from Europe, China, and Japan. Wind manufacturers are located primarily in Europe, North America, and China. Meanwhile, battery technology for potential future storage is being manufactured in China, Japan, and South Korea.

Ecuador maintains a healthy international trading relationship that includes the nations of many of these high-quality suppliers (OEC n.d.). Changes or risks to this relationship could inhibit Ecuador's ability to procure Tier I equipment.

Taxes

Ecuador can incentivize behavior to meet their policy goals through their tax structure. At present, developers of renewable energy projects can receive exemption from import taxes on their equipment, as well as a five-year income tax waiver. These developers also have the option to apply for a 20-year income tax exemption with the government, which is granted on a discretionary basis (Bustamante 2019).

International Market

As mentioned above, Ecuador currently sells exported power to other countries, primarily Colombia, via international grid interconnections as part of the Andean Electrical Interconnection System (SINEA). If these other countries were to stop buying Ecuadorian power, it would present a barrier to building out the electrical system to include more renewable energy resources. However, this market also presents an opportunity to sell power generated from renewables that would ordinarily be curtailed; the transmission capacity to Colombia totals 525 MW, while capacity to Peru is 110 MW (MERNNR 2020).

Transport

In the transport sector, several financial factors may inhibit EV adoption. For example, the GoE's provides deep diesel fuel subsidies that encourage consumers to select ICE vehicles over EVs (UEMI Secretariat 2018). Additionally, EV prices are not competitive with ICE vehicles, even when accounting for tax incentives (Isla, et al. 2019). Experts believe that EVs are set to reach cost parity by 2025 (Eggert and Gopal 2019). However, if this cost curve does not decrease at the rate expected, these transportation policies could impact Ecuador's ability to meet their expected increase in EVs.

POTENTIAL RISKS

Regional Destabilization

Ecuador has experienced one of the worst death tolls during the COVID-19 outbreak, and the outbreak has the potential to exacerbate the GoE's already high public debt and reduce government spending, including in the energy sector (New York Times 2020, Bloomberg 2020, Deloitte 2020). While the GoE has been proceeding with some energy sector developments, this may not continue to be the case (Transformer Technology 2020). In the longer term, issues in neighboring countries and shifting alliances and national priorities may prevent the GoE from meeting their goals.

Financial Risks

Capital cost overruns also pose a risk to hydropower development, especially large-scale hydro (Carvajal and Li 2019). Hydropower developments can experience substantial cost overruns, driven by challenges in accurately assessing geotechnical conditions prior to the project, and potential for unforeseen excavations and construction obstacles (Carvajal and Li 2019). Carvajal and Li (2019) find that over the past decade, Ecuadorian hydropower projects have incurred cost overruns, with one 2,800 MW project experience a $1,520 million cost overrun, leading to a 26% increase in the initial budget.

Climate-driven Risks

Ecuador's heavy dependence on hydropower leaves the country highly vulnerable to rainfall variability and drought-driven electricity shortages (Carvajal and Li 2019, The Dialogue 2019). Drought already threatens Ecuador's electricity reliability. In 2009, a prolonged drought caused severe water shortages at the Paute hydropower plant, and led to electricity rationing and blackouts (BBC 2009, Carvajal and Li 2019). Looking forward, climate change is projected to drive greater variability in annual rainfall and more frequent, intense, and extended droughts, threatening water available for hydropower generation (World Bank 2011, Carvajal and Li 2019). In addition, climate change could alter seasonal flow, increasing hydropower generation in in the wet season and decreasing hydropower generation in the dry season which could result in power shortages during the dry season (Hasan and Wyseure 2018). Neighboring countries, such as Colombia, Chile, Brazil, and Argentina, face similar risks from heavy reliance on hydropower and rainfall variability, indicating that changes in climate may threaten electricity reliability at the regional scale (Campos do Prado, Logan and Flores-Espino 2019).

Intensifying drought may increase competition between hydropower and other end uses (e.g., agricultural, drinking water) (Zhang, et al. 2017). Furthermore, due to intertwined nature of the water, energy, and food sectors (i.e., the water-energy-food) climate risks to a given sector may lead to risks in another sector.

On the other end of the spectrum, climate change is also projected to drive more frequent and intense extreme rain events, which may alter the extent of current floodplains, introducing risk into project siting decisions (World Bank 2011). Extreme rain may also lead to dam overtopping and downstream flooding, creating risks to the downstream communities. Finally, climate variability and change can negatively or positively impact renewable energy production by affecting fuel (e.g., water availability, wind speed, and radiation).

Under the build-operate-transfer model where governments assume asset ownership after 20 years, these risks will be greatest under government ownership. Additionally, this model does not incentivize operators to design hydropower plants such that they account for climate change risks.

Social & Environmental Risks

Transmission buildout will require light deforestation. Building into the more remote areas of the country will heighten risk of electric lines igniting wildfires without proper tree and branch maintenance, which can threaten surrounding communities and ecosystems.

There is also a risk of upsetting and harming local communities. Communities have historically opposed hydropower developments (Terry 2007). For example, communities surrounding the Coca Codo Sinclair construction site opposed the project during the planning period, though the federal administration approved the project despite this opposition (Nathanson 2017). Similarly, communities surrounding the Hidrotambo plant opposed the development for at least ten years (Pskowski 2016). The plant reduced water access for upstream communities, reduced fish populations which were a key food source, and caused flooding and erosion; a flood even in 2015 destroyed housing and cultivation areas and killed three people (Pskowski 2016). Hydropower developments can also substantially alter and damage ecosystems, and can adversely impact communities required to relocate or whose water resources become stressed due to competition with the hydropower plant (Carvajal and Li 2019).

Solar PV waste creates environmental challenges due to the toxic nature of some of the materials (IRENA 2016). In Ecuador, IRENA (2016) projects that PV waste volume will grow by several orders of magnitude through 2050.

Cybersecurity Risks

As renewables and advanced technologies (e.g., EVs, battery storage, smart end use devices) integrate into the grid, the number of interconnections increases and the connectivity of control systems with other networks increases, heightening cybersecurity risks (Stamp n.d.).

ANALYSIS OF PAST AND CURRENT RENEWABLE ENERGY PROGRAMS

CHARACTERISTICS AND ISSUES THAT LEAD TO THE SUCCESS/FAILURE OF ACTIVITIES

Policies & Economic Incentives

National subsidies can drive adoption or lack of adoption of renewable energy options. Electricity and fuel subsidies are major barriers to expanding renewable energy use (and energy efficiency programs). For instance, the GoE runs a national program aimed at increasing the adoption of electric induction stoves and reducing the use of LPG and biomass for home cooking. However, the program was relatively ineffective due to a persistent LPG subsidy (Gould, et al. 2018).

Similarly, high electricity prices have driven Chilean mining companies to adopt wind and solar, while low residential gas and electricity prices have prevented adoption of distributed solar and solar thermal elsewhere (e.g., Argentina) (IRENA 2016).

Access to Finance

IRENA (2016) found that access to adequate financing is key to successful renewable energy developments. Specifically banks offering credit lines designed for renewable energy projects, and that split risks between the public and private sectors, is key to financing developments (IRENA 2016). IRENA (2016) suggest developing the financial value chain where independent developers, independent power producers, utilities, and banks take on larger roles in financing the construction stage, enabling them to refinance assets after reaching the operational stage.

St. James (2016) asserts that in Ecuador, MEER's 2013 solar public procurement process, a lack of appropriate bank financing prevented projects from coming to fruition.

Procurement Process

As described above, challenges in executing an effective procurement process have prevented the installation of non-hydro renewable developments in Ecuador. These included a lack of transparency in the approval process, clear technical norms and standards, consideration of capital costs, consideration of ability to connect to the transmission system, and ability to instill and retain investor confidence (St. James 2016). IRENA (2016) also found that establishing minimum quality and performance standards for solar developments is key. Based on the desk review, it is unclear whether the GoE has overcome these challenges in the latest Public Selection Process with the El Aromo and Villonaco projects. However, the answer may become clear as the GoE moves toward awarding a contract and initiating construction.

ENERGY EFFICIENCY

ENERGY EFFICIENCY POLICY INITIATIVES IN ECUADOR

The 2015 LOSPEE established MERNNR as the governing body in charge of Ecuador's energy efficiency policy (GoE 2015). LOSPEE requires that MEER develop a National Energy Efficiency Plan (PLANEE) and grants the Ministry authority to create institutions to advance energy efficiency (GoE 2015). LOSPEE also requires that electricity providers comply with various constitutional principles, including advancing energy efficiency (LEXIS Finder 2019).

More recently, the 2019 Energy Efficiency Law provides specific legislation to support development of energy efficiency in the country (OLADE 2019). The law aims to promote energy savings, favor citizens' financial wellbeing, promote competition, encourage environmentally friendly practices and technologies, and move away from non-renewable resources (OLADE 2019). Additionally, the law requires that MERNNR update the PLANEE every two years (El Comercio 2019).

PLANEE establishes energy efficiency projects, plans, and objectives across six sectors. The latest plan covers the period 2016–2035, and focuses on the Residential, Commercial, Public, and Industrial Sectors. PLANEE creates requirements for the public sector and provides guidance for the private sector (Perez Bustamante & Ponce 2019). Table 6 summarizes the programs and projects identified in the latest PLANEE for the residential, commercial, and public, and industrial sectors.

TABLE 6. NATIONAL ENERGY EFFICIENCY PROGRAMS AND PROJECTS (MEER 2017)

SECTOR	PROJECT/PROGRAM ID	PROJECT/PROGRAM DESCRIPTION
Residential, Commercial and Public Sector	PLANEE-CANV-05	Project to Identify Final Uses of Energy in Residential, Commercial and Public Sectors
	PLANEE-CANV-06	Program for the Standardization and Labeling of Energy Consumption Equipment
	PLANEE-CANV-07	Program for Replacement of Equipment of Residential Use of Greater Energy Consumption.
	PLANEE-CANV-08	Project to Define Control and Oversight Mechanisms for the Implementation and Continuous Improvement of the NEC Standard - Energy Efficiency, Air Conditioning and Renewable Energy
Industrial Sector	PLANEE-CANV-09	Program for the Implementation of the ISO 50001 Standard in Energy-Intensive Industries
	PLANEE-CANV-10	Cogeneration program in the industry
	PLANEE-CANV-11	Replacement Program for Engines, Pumps, Boilers and Heaters in Industries.
	PLANEE-CANV-12	Program for the Development and Promotion of an ESCOs Market in Ecuador

The Ministry of Coordination of Strategic Sectors (MICSE), responsible for directing the policies and actions of Ecuadorian institutions, developed the National Energy Agenda. This national plan identifies energy efficiency as one of the key objectives and establishes the followings actions items related to energy efficiency (MCSE 2016):

1. **Maintain a solid institutional framework for energy efficiency to guarantee its transferability.** MERNNR will work with an Inter-sectoral Committee on Energy Efficiency (ICEE) to monitor and evaluate policies and energy efficiency guidelines.
2. **Ensure the implementation of energy efficiency with proper planning.** MERNNR and the ICEE will promote the implementation of energy efficiency measures in all sectors of the country. This will include creating PLANEE, which will focus on sectors with the highest energy consumption.
3. **Increase the quality and optimize the management of information on energy use.** MERNNR will consolidate and update technical statistics on the use of energy, economic information, and social/demographic information to create indicators. These indicators will be used to monitor the success or failure of initiatives.
4. **Sustain energy efficiency on a sound regulatory framework.** MERNNR and the ICEE will encourage the development of technical regulations to have high standards of energy efficiency for goods, infrastructure, machinery and other equipment.
5. **Encourage the creation of market mechanisms and promote the management of financing schemes for energy efficiency.** MERNNR and the ICEE will encourage different initiatives and fundraising projects to finance energy efficiency initiatives. Additionally, MERNNR will encourage behavioral changes for end consumers and promote the creation of Energy Service Companies (ESCOs).
6. **Promote energy efficiency behavioral changes.** MERNNR will develop mechanisms to raise awareness of the benefits of energy efficiency and promote the rational use of energy to the general public.
7. **Train and certify experts in energy efficiency.** MERNNR will encourage trainings, certifications, and accreditations for energy efficiency and energy management experts.

INSTITUTIONAL FRAMEWORK

This section describes those entities that are focused on energy efficiency policies, standards, and implementation in Ecuador.

National Energy Efficiency Committee (CNEE)

To promote the efficient, rational and sustainable use of energy in Ecuador, the 2019 Energy Efficiency Law creates a National Fund for Development and Investment in energy efficiency and establishes a National System of Energy Efficiency (SNEE) (OLADE 2019). The law also forms the CNEE to create energy efficiency policies, programs and projects (El Comercio 2019). CNEE will be the technical body that monitors the SNEE (Perez Bustamante & Ponce 2019). The law requires that GADs implement the regulation of the SNEE (Perez Bustamante & Ponce 2019). GADs are rural parish councils, municipal councils, metropolitan councils, provincial councils, and regional councils (Guía OSC 2017). They are the institutions that make up the territorial organization of the Ecuadorian state and have political, administrative, and financial autonomy (Guía OSC 2017).

Ecuadorian Service for Standardization (INEN)

Established in 1970, the Ecuadorian Service for Standardization (INEN) is responsible for the establishing, publishing, and advancing of technical standards and conformity assessments for appliances and equipment (INEN n.d.). Through these actions, INEN "promotes standardization in Ecuador in order to contribute to the national economy, support sustainable development, promote the health, safety and welfare of workers and the public, protect consumers, and facilitate domestic and international trade," (ISO n.d.). The 2019 Energy Efficiency Law mandates that INEN and the Ministry of Urban Development and Housing issue policies and regulations for industrial, commercial, recreational, residential, and equipment use in buildings (El Comercio 2019). INEN is responsible for the preparation, adoption, and application of Ecuador's Energy Efficiency standards and the Technical Regulations for Energy Efficiency (RTEs) (INEN n.d.).

Geological and Energy Research Institute (IIGE)

Established in 2018, the Geological and Energy Research Institute (IIGE) is attached to MERNNR and focuses on earth science research aimed at improving institutional capacities (IIGE 2018). The Laboratory of Thermal Tests and Energy Efficiency is an extension of IIGE and the Center for Renewable and Alternative Energies. This laboratory conducts research to better inform and design efficient buildings (ESPOL 2020).

GOVERNMENT OF ECUADOR PRIORITIES, TARGETS, & COMMITMENTS

Understanding how electricity is currently used in the country is the first step in understating the government's priorities, targets, and commitments to energy efficiency. Ecuador's electricity consumption reached 25,310 GWh in 2019, representing an increase 4.5% over 2018 levels (MERNNR 2020). Consumption reflects five sectors: residential, commercial, industrial, public, and other (e.g., water pumping, sports venue). Table 7 shows the total net electricity demand between 2011 and 2017 (Luis Rivera-González 2019). Demand grew by over 30% from 15,249 GWh in 2011 to 20,204 GWh in 2017 (Luis Rivera-González 2019).

TABLE 7. ELECTRICITY DEMAND FOR KEY SECTORS 2011-2017 (GWH) (LUIS RIVERA-GONZÁLEZ 2019)

SECTOR	2011	2012	2013	2014	2015	2016	2017
Residential	5351	5629	5881	6364	6928	7105	7298
Commercial	2955	3209	3486	3786	3981	3838	3844
Industrial	4481	4686	4684	4975	4973	4778	5700
Public	883	913	964	1023	1081	1127	1214
Others **	1579	1738	2058	1835	2043	2019	2149
Total	15,249	16,175	17,073	17,983	19,006	18,867	20,205

** Unusual subscribers, social assistance, water pumping, official entities, sports venues, and EVs

The country anticipates a 7.1% average annual growth in electricity demand between 2018 and 2027, reaching a total of 44,715 GWh in 2027 (MERNNR 2020). Residential demand is expected to increase on average by 3.7% annually, while the commercial sector is expected to show an average 5.7% increase annually (MERNNR 2020). Demand is anticipated to grow fastest in the industrial sector, at an annual average increase of 8.4% annually (MERNNR 2020).

The residential sector is the largest consumer of electricity with 36% of consumption, followed by industrial at 28%, and commercial at 19% of the total, as shown in Figure 8 (Luis Rivera-González 2019). The key end use technologies that consume electricity in these sectors are lighting, refrigeration, water heating, HVAC, and cooking.

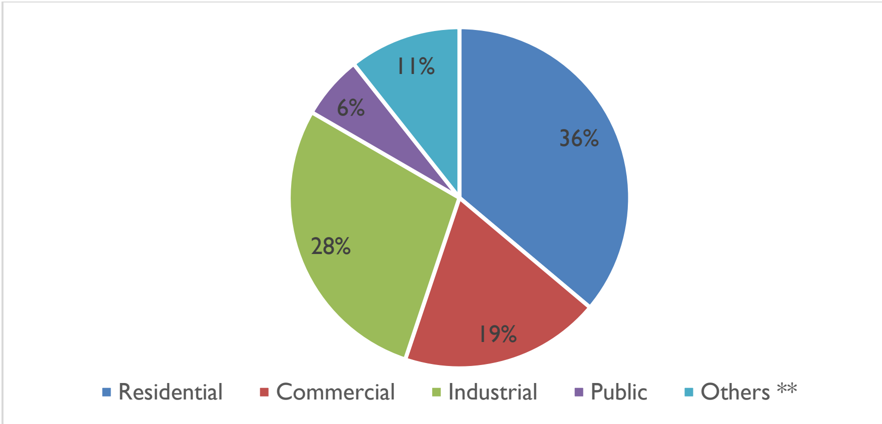


Figure 8. Electricity consumption in key sectors of the Ecuadorian economy (Luis Rivera-González 2019)

The PLANEE reinforces the GoE's is commitment to advance energy efficiency in residential, commercial, and public buildings (MEER 2017). The Plan set a target to reduce cumulative energy consumption in the residential, commercial and public sectors by at least 88.8 Mboe by 2035 through implementing energy efficiency measures (MEER 2017). If implemented solely in the electricity sector, this would amount to the cumulative reduction of 150,907 GWh between 2016 and 2035. The plan also proposes to implement a national energy efficiency emblem (DMEE) to identify and label high efficiency appliances and promote the replacement of inefficient products with efficient ones (MEER 2017). These initiatives are expected to achieve energy savings of 150,907 GWh by 2035 (MEER 2017). The plan proposes creating an oversight and control mechanism to support GADs in adopting the Ecuadorian Construction Standard (NEC) chapter on energy efficiency, air conditioning and renewable energy (MEER 2017). They will have a target of 20% of GADs having successfully implemented and applied the NEC by 2020 (MEER 2017).

The PLANEE targets energy savings of at least 50,812 GWh by 2035 in the industrial sector through implementing energy efficiency measures (MEER 2017). This includes implementing energy management systems, cogeneration, and replacement of inefficient equipment in the energy intensive industries (MEER 2017). The PLANEE also requires that industries report their energy consumption to the National Energy Efficiency Indicators System (SINEE) (MEER 2017). Another objective of the plan to promote energy efficiency in industries through ESCOs (MEER 2017). The PLANEE aims to develop an energy efficiency market and have implemented at least 80% energy efficiency projects through ESCOs (MEER 2017).

CURRENT CONTEXT AND EXPECTED TRENDS

EXISTING INITIATIVES AND DEVEVLOPMENTS IN KEY SECTORS

In addition to future projects and plans, Ecuador has existing initiatives to help promote energy efficiency. This includes "limitations on the sale of inefficient equipment, replacement plans for residential appliances, and mandatory technical regulations, etc.," (MEER 2017). Other initiatives include the regulatory instruments, especially energy efficiency standards. These standards are widely used in Latin America and around the world to promote the efficient use of electricity in appliances, equipment, and building construction. In Ecuador, INEN has developed 11 Energy Efficiency Standards to promote energy efficiency and efficient construction of buildings and 23 RTEs to set minimum energy performance requirements of equipment and appliances sold for household, commercial, and industrial sectors (MEER 2017).

The GoE implemented the Program to Replace Inefficient Energy Consumption Equipment between 2012 and 2016, which focused on substituting inefficient appliances—specifically refrigerators—with new and efficient equipment. By December 2016, the program replaced 95,625 refrigerators nationwide through the Electricity Distribution Companies, resulting in a reduction of electricity generation equivalent to 38,200 MWh/year of electricity and 5.53MW of power capacity (MEER 2017). MEER also implemented a program to replace 16 million incandescent light bulbs with energy saving light bulbs between 2008 and 2014, which reached an estimated 3 million beneficiaries (MEER 2017). This initiative prompted a COMEX resolution, suspending imports of incandescent light bulbs for residential use, ranging from 25 to 100 W, beginning in January 2010. This measure achieved an estimated reduction of 287,000 MWh/year and 263 MW of power capacity (MEER 2017).

Other existing initiatives include Efficient Public Lighting, Energy Efficiency Program for Electrical Induction Cooking and Electrical Water Heating, Ensuring Energy Efficiency in the Public and Residential Sectors of Ecuador, and the Maximum Energy Efficiency Badge (PNUD Ecuador 2017).

Residential, Commercial, and Public Sector Developments

One of the PLANEE's first objectives for the Residential, Commercial, and Public Sector is "…to strengthen programs for replacement and labeling of high energy consuming home appliances and equipment." (MEER 2017) Electrical equipment and home appliance use make up most of the energy consumption across these sectors (MEER 2017). The PLANEE details several key projects and programs for achieving this objective, including the as described below.

The *Project to Identify End-Use of Energy in Residential, Commercial and Public Sectors* will develop statistics on energy use and consolidate this information on a regular basis. This consolidation will include economic data and social/demographic information to create indicators to monitor and analyze the success of new energy efficiency initiatives. Planned actions include applying final-use energy surveys, gathering statistics, and feeding statistics into the SNEE.

The *Program for Standardization of Labeling of Energy Consuming Equipment* will require the strengthening of infrastructure (energy efficiency laboratories, conformity of assessment bodies, etc.) to update and develop standards and technical specifications of energy consuming equipment. Action items for this project are as follows: (MEER 2017)

1. Review and update the regulations.
2. Strengthen the quality and structure of national testing laboratories.
3. Strengthen the quality of evaluation agencies.
4. Implement the energy labeling program (DMEE).
5. Coordinate the incorporation of energy labeling in goods purchasing within the public sector, through corresponding government offices.
6. Perform market surveillance.
7. Develop a training program on standards and labeling.
8. Coordinate trainings with the corresponding authorities. (MEER 2017)

The *Program to Replace High Energy Use Residential Appliances* will aim to replace appliance that do not operate at acceptable levels of energy efficiency, as determined by technical assessments. Voluntary replacement programs for refrigerators, stoves, lights, and other appliances will continue to be encouraged and the scope of replacement programs will be broadened (MEER 2017).

The second specific objective for the Residential, Commercial, and Public Sector is to establish oversight and control mechanisms to implement and apply NEC chapters on energy efficiency. To achieve this objective, PLANEE details *Project to Define Control and Oversight Mechanisms for the Implementation and Continuous Improvement of the NEC Standard - Energy Efficiency, Air Conditioning and Renewable Energy.* To complete this project, the Association of Ecuadorian Municipalities (AME), the Minister of Urban Development and Housing (MDUVI), and MERNNR must coordinate and establish oversight and control mechanisms to promote or require compliance with the rules (MEER 2017). Actions items for this project, as detailed in PLANEE, are as follows:

1. Create and apply control and oversight mechanisms to aid GADs in adopting the NEC.
2. Carry out campaigns to inform the public about the mechanisms.
3. Put together a catalog of thermal, and other characteristics/properties of building materials used in Ecuador (under development by INEN).
4. Create a country climate zone map.

For further detail, see the Annex (p. 1) Table 8 titled "Specific objectives, lines of action and indicators in the Residential, Commercial and Public Sector" (MEER 2017).

Industrial Sector Developments

Energy efficiency developments in the industrial sector are focused on improving productivity and efficient use of natural resources. The first specific objective for the Industrial Sector is to replace inefficient equipment, apply cogeneration systems, and adopt ISO 50001 in energy intensive industries. ISO 50001 was developed to provide guidance on efficient ways to use energy through energy management system (SGEn) (ISO n.d.). An energy management system is a structured program that helps organizations better manage their energy resources by developing organization-wide programs, creating achievable energy use targets, designing actions plans, and implementing new energy-efficient technologies, all with the goal of improving efficiency across all end uses and processes (ISO 2018). PLANEE discuses a partnership between SGEns and the SINEE (MEER 2017). PLANEE details action items required to accomplish this program (MEER 2017):

1. Identify energy-intensive industries to implement the ISO 50001 standard.
2. Develop a training and certification program in energy efficiency and best practices.
3. Coordinate SGEn training and optimization of systems.
4. Follow up on SGEn implementation in energy-intensive industries.
5. Monitor and prepare a SGEn report for SINEE to manage energy efficiency programs.
6. Create a network of professionals trained in SGEn and systems optimization.
7. Prepare a database of professionals trained in SGEn and systems optimization, which will
8. be widely communicated. (MEER 2017)

The *Cogeneration program in industry* aims to accomplish the Industrial Sector's first objective. This program is designed to motivate industries to install cogeneration (also known as combined heat and power) systems. To accomplish this, PLANEE details a list of required action items, including evaluation of nationwide potential for cogeneration systems, pilot projects and case studies, promoting the implementation of cogeneration systems, and monitoring and communication of best practices.

The third program in response to the Industrial Sector's first objective is the *Program to replace engines, pumps, boilers and water heaters in industries*. The program's goal is to replace inefficient equipment, including pumps, motors, boilers, and water heaters. The government will accomplish this by providing incentives that will be implemented by the private sector. The private sector will benefit from energy savings generated after equipment replacement (MEER 2017). PLANEE details the following required action items (MEER 2017):

1. Conduct an information survey about inefficient equipment in the industries participating in the program.
2. Evaluate the selection criteria of participating equipment/industries.
3. Define incentives to promote private sector participation.
4. Implement inefficient equipment replacement.
5. Follow-up on, monitor and communicate best practices. (MEER 2017)

The second specific objective related to the Industrial Sector includes the development of Energy Savings Companies (ESCOs). ESCOs function to "…optimize the use of energy and implement savings solutions through the reengineering of processes and management of energy resources in the industry." (El Telegrafo 2018) Creating ESCOs will develop an energy efficiency services market, in which ESCOs will be responsible for implementing improvement measures in the Industrial Sector. In turn, ESCOs will be compensated based on the monetary savings produced by reducing energy consumption (MEER 2017). To create ESCOs, PLANEE details the *Program for the development and promotion of an ESCOs market in Ecuador.* This program will help create ESCOs by developing prerequisites, training financial institutions, and providing technical assistance to aid in energy diagnostics (MEER 2017). Defining incentives for ESCOs and creating an ESCOs database make up the actions items still required for this program (MEER 2017).

For further detail, see the Annex (p. 1) Table 9 titled "Specific objectives, lines of action and indicators in the Industrial Sector" (MEER 2017).

BARRIERS TO ENERGY EFFICIENCY IN ECUADOR

Energy efficiency remains the lowest-cost option to meet Ecuador's national energy goals and thus should be prioritized before all other energy options. But despite the enormous potential, energy efficiency continues to be underutilized in Ecuador and other developing countries because of persistent policy, technical, informational, and financial barriers. Generally, the barriers to energy efficiency can be divided into six groups: (1) misplaced incentives, (2) lack of access to financing, (3) flaws in market structure, (4) mis-pricing imposed by regulation, (5) decisions influenced by customer, and (6) lack of information or misinformation (MERNNR n.d., Golove and Eto 1996). In this report, two of the most obvious barriers (1) lack of incentives and financing, and (2) lack of information or misinformation, are discussed.

LACK OF INCETIVES AND FINANCING FOR ENERGY EFFICIENCY

Lack of incentives to overcome the high upfront cost of energy efficient products is one of the biggest barriers to the adoption of energy efficient technologies. For low-income households, this barrier is difficult to overcome until substantial subsidies, rebates, or discounts are provided for the purchase of more efficient appliances. Incentives, such as rebates, tax credits, or appliance trade-in programs, can be offered to encourage the purchase and installation of energy-efficient products or the purchase of a service to promote efficiency, such as a building energy audit. Incentives are particularly effective when promoting new or unfamiliar technologies and related services. Such smart incentives can influence skeptical customers to try out products and services, and then be phased out as those technologies and strategies become more accepted and consumers have a greater understanding of their value.

In past, the government has implemented a refrigerator and lighting replacement program to encourage customers to trade-in inefficient appliances for rebates on new efficient models. The government also provides large energy subsidies for low income, senior citizens, and customers with disability. For example, as per the Executive Decree No. 451-A, 2009, the tariff subsidy is provided to consumers of low economic resources in the residential sectors with lower electricity bills, if they do not consume more than a predetermined amount of electricity. However, low energy tariffs due to subsidy also acted as disincentive to energy efficiency (UNIDO 2016). Utilities can look to provide smart incentives as an alternative strategy to lowering their total system costs. Converting some of those subsidy payments into energy efficiency smart incentives could facilitate a decrease in the monthly subsidy resulting from decreased energy demand.

INFORMATIONAL BARRIERS

Due to the diverse ways in which energy efficiency is implemented in the market, public acceptance of the associated costs and benefits is fundamental to scaling up efficiency. Consumers must not only be aware of the economic and environmental benefits that efficiency provides, but also of the best strategies to make improvements and maximize the co-benefits provided by energy-efficient products (e.g., improved comfort, usable space, improved acoustics). The Ecuadorian government successfully implemented energy efficiency programs for lighting and refrigerator replacement but could not sustain those benefits for other products. This could be because of limited awareness creation among consumer towards energy efficiency. Sustained marketing programs or other methods of information dissemination can be ways to encourage a population to adopt energy efficiency methods or promote the purchase of energy efficient or certified products.

For example, in the United States, the ENERGY STAR program has been very successful in building awareness and consumer confidence in buying energy efficient products and services. The program's label and consumer education activities enable the public to make informed buying decisions based on energy performance. In 2018, U.S. EPA counted over 300 million ENERGY STAR products (ENERGY STAR n.d.) purchased in more than 70 product categories (ENERGY STAR n.d.). Household recognition of the ENERGY STAR label is estimated at more than 90% (ENERGY STAR 2017). Awareness campaigns can also be incorporated into incentive and technical assistance programs to increase participation and successful adoption of efficiency technologies and practices.

DONOR ENGAGEMENT, GAPS AND OPPORTUNITIES

In this section, we identify select ongoing and recent donor engagements, and opportunities to support the GoE by addressing the gaps in and barriers facing energy efficiency and renewable energy investments. These gaps and opportunities reflect the results of the desk review and experience in other countries. Future in-country engagement would allow for a more complete assessment of needs and requirements.

DONOR ENGAGEMENT

Ecuador has received international support for energy projects from a variety of sources, including the World Bank, the Japan International Cooperation Agency (JICA), German Society for International Cooperation (GIZ), the Korean Institute for Advancement of Technology (KIAT), and China, as well as organizations including the United Nations Industrial Development Organization (UNIDO), the Inter-American Development Bank (IDB), and the Development Bank of Latin America (CAF). Funding has gone toward improving and modernizing the transmission and distribution grids, promoting renewable energy and energy efficiency, and decreasing dependence on fossil fuels. Selected activities related to the energy sector include the following:

- In January of 2020, JICA and the Ecuadorian government signed a loan agreement that would provide up to $70 million for a Project for Supporting the Advancement of Energy Matrix Transition. This project's objectives are to promote: (i) access to renewable energy, (ii) stabilization of the energy supply, (iii) energy efficiency through expanding and reinforcing the National Transmission System and the National Distribution System, and improving the operational efficiency of the electrical system to promote the Energy Matrix Transition. (JICA 2020)
- The German Development Bank financed a $14 million 2.5 MW of solar and biofuel installation on the Galapagos Islands as part of Ecuador's "Zero Fossil Fuels for the Galapagos" initiative (OLADE 2019). As part of the same initiative, in 2019 the GOE signed a Memorandum of

Understanding with KIAT to fund a $5 million 2.5 MW combined solar and storage installation on the Galapagos Island of San Cristobal (OLADE 2019).

- Between 2012 and 2016, the IDB approved $1.3 billion in loans to Ecuador focused on improving and modernizing the country's transmission and distribution systems, as well as increasing access to electricity (IDB 2017). In 2017, the CAF provided a $150 million loan to support Ecuador's energy sector and promote sustainable diversification of the country's grid (CAF 2017).
- From 2012 to 2015, Ecuador and GIZ were partnered in a project—*Climate protection through the use of renewable energies on the Galapagos Islands, with special focus on power generation using jatropha oil (ENERGAL)* (GIZ n.d.). The project was commissioned by the German Federal Ministry for the Environment, Nature Conservation and the Building and Nuclear Safety (BMU) and its objective was to generate renewable energy on the island and use the oil of the Hatropha Curcas plant as a biofuel (GIZ n.d.).
- From 2011-2015, UNIDO participated in a $2.65 million Efficiency for Industry project to promote energy efficiency in Ecuador's industrial sector (UNIDO 2016).
- Since 2010, China has provided more than $6 billion in funding for energy projects, including for the 1,500 MW Coca Codo Sinclair hydro project completed in 2016, the 487 MW Sopladora hydro project completed in 2016, and the 270 MW Minas San Francisco hydro project completed in 2019 (Castro 2014, MERNNR n.d., The Dialogue n.d.).

GAPS AND OPPORTUNITIES

Several opportunities would benefit both renewable energy and energy efficiency.

Improved Long-range Energy Planning Processes. One potential area of improvement is supporting improved planning processes. While this desk review has not included a detailed review of the power sector planning in Ecuador, there may be aspects of the process that could be improved that would benefit the development of clean energy resources. Without a comprehensive review of the planning processes in Ecuador it is difficult to make precise recommendations as to areas of focus for improvement. However, in their Statement of Interest, the GoE noted that they are particularly interested in best practices for energy planning, including risk management.

USAID could support the GoE in integrating energy resilience and risk management best practices into their existing planning processes, such as the PME updates. This might involve helping the GoE determine the appropriate resource mix based on performance objectives and risk considerations; improved integration of generation, transmission and distribution planning; improved demand forecasting to match investments to demand; and integration of energy efficiency into the long-range plan.

This may be especially beneficial given that Ecuador is investing heavily in hydropower and may not be considering how projected changes in climate—namely more frequent and intense drought—might introduce risk. USAID could consider supporting an Integrated Resource and Resilience Planning (IRRP) process where the country evaluates the resilience of potential future energy mixes against a range of future scenarios and identifies the one that performs best against key performance objectives. These efforts would improve the environment for both renewable energy and energy efficiency, build support for future plans, and improve the confidence of potential private sector investors.

Fossil Fuel Subsidy Reform. Indirect subsidies to electricity via fossil fuel subsidies result in tariffs that are not cost reflective. As a result, opportunities for energy efficiency and renewable energy are undervalued. The COVID-19 pandemic in combination with a Russian-Saudi oil price conflict has resulted in a period of historic low oil prices and excess supply. Such a time provides countries with an opportunity for reform of their fossil fuel subsidies. Low oil prices mean countries can establish fuel prices based on market conditions without triggering any price change to consumers. Ultimately, eliminating subsidies generate savings that can be used to address pandemic relieve, improve social protection systems and encourage more efficient and cleaner energy systems. Ecuador has recognized this as indicated by its recent announcement to introduce market-based price band for gasoline and diesel.

USAID could help the GoE develop a strategy to maintain these and further phase out remaining fossil fuel subsidies in a politically feasible manner (USAID 2018). Over 50 countries have undergone similar reforms over the past decade. (IEA-OECD 2019) Many took the opportunity of the low oil price to link their energy prices to world prices. This improves the financial stability of the energy sector and increase confidence of private investors. Success will be improved if these measures are accompanied by policies designed to protect poor and vulnerable groups from the impact caused by rising energy prices.

RENEWABLE ENERGY

In the electricity sector, Ecuador lacks substantial development of non-hydro renewables, namely solar, wind, biogas, biomass, and geothermal in the mainland SNI system. By 2028, MERNNR (2020) projects that non-hydro renewables will make up less than 5% of installed capacity in the SNI. It is unclear whether since the unsuccessful procurement process in 2013, MERNNR has refined its procurement process sufficiently to successfully procure non-hydro renewable power for the SNI. As described above, MERNNR is currently working to procure wind and solar PV for the Villonaco and El Aromo projects, but it is still to be seen whether MERNNR will be able to successfully bring the projects to construction and completion. It is also unclear whether private companies have adequate access to financing for renewable energy developments (i.e., banks offering credit lines designed for renewable energy projects); as mentioned above, inadequate access to financing posed a key challenge to bidders in the 2013 procurement (St. James 2016).

Ecuador also lacks plans to integrate more advanced technologies into the system, such as battery storage and smart grids, and new demands such as EVs. In the transport sector, there is a lack of a national plan or program for expanding EV adoption. Ecuador also lacks efforts to ensure that biofuel production expands sufficiently to meet the 2025 10% blend mandate (IRENA 2015, MEER 2017, USDA 2018). Based on the desk review, it is unclear whether Ecuador has taken steps to fill these gaps and address the barriers associated with some of these gaps.

These gaps present several opportunities.

Renewable Energy Procurement Processes. USAID could provide support in the area of competitive procurement. While Ecuador is engaged in a procurement process now, additional support may improve the transparency and effectiveness of the process. For example, USAID might help MERNNR determine the appropriate technical specifications and standards to release to the prospective bidders, determine how to allocate risk between private and public entities, and help create an environment that attracts bidders. In their Statement of Interest, the GoE identified a need for technical assistance in risk management.

Accelerating Adoption of Technologies and Resources. USAID could support the GoE in adopting renewable energy and energy efficiency technologies. Support might include:

- <u>Preparing the grid for integrating variable renewable energies and other new technologies.</u> This could involve helping MERNNR identify both operational and infrastructure strategies for integrating solar, wind, and battery storage. For example, USAID could support the GoE in:
    - Conducting studies on how reserve requirements may change with increased renewable penetration and conducting studies to determine whether the appropriate resources are available in the appropriate locations.
    - Improving forecasting, speeding up dispatch, and/or identifying ideal locations for microgrids or transmission line connections.

- Identifying best practices for smart grids, which the GoE identified as a technical assistance need.
    - Assessing battery storage needs under different variable renewable energy penetration scenarios.
    - Deploying battery storage to provide ancillary services and enhance the stability of the transmission and distribution system.
    - Implementing transmission expansion models, such as the NREL tool ENGAGE[6].
    - Developing REZs and/or conducting studies to identify locations with high renewable energy potential and determine transmission infrastructure needs to enable delivery to load centers.
- Developing programs to implement distributed generation and microgrids in remote communities. There is high potential for mini-hydro and microgrids in remote communities with limited access to electricity. USAID could work with the GoE to set up auctions for developments in these types of communities.
- Developing a national electric mobility plan and program. USAID could also support the GoE in developing a plan for promoting EV adoption, including expanding EV charging and preparing the electricity system for EVs. The GoE identifies electric mobility as a technical assistance need.
- Designing and implementing a biogas program. As described above, Ecuador faces challenges in expanding its biofuel production and meeting the target of a 10% blend by 2025. USAID could support the GoE's promotion of agricultural, livestock, and timber waste for electric generation.

Building Out the Renewable Energy Financial Value Chain. This could involve engaging key stakeholders (e.g., banks, developers) to create lines of credit or other financing sources that companies can pursue to implement renewables projects. This could also involve determining strategies for distributing risk across private and public entities, given the GoE's interest in risk management approaches. It could also involve developing a framework to engage international donors. The GoE's INDC identifies opportunities to further advance renewable energy development and climate adaptation efforts should the country receive financial support from the international community (GoE 2015). USAID might also support the GoE in jointly studying power system operations and potential changes in price setting and dispatch practices.

ENERGY EFFICIENCY

Ecuador, like other countries in the region, is in the process of strengthening and expanding energy efficiency policies and programs to realize untapped energy savings potential. One estimate indicates that the country has an opportunity to save 1,846 GWh annually by just transitioning to efficient refrigerators, air conditioners, and fans (UNEP 2014). To implement the National Energy Efficiency Plan 2016-2035 (PLANEE) that targets to achieve 150,907 GWh in savings between 2016 and 2035 and expand existing energy efficiency initiatives, Ecuador requires additional support in developing local capacity for program implementation. Investments are needed to increase public awareness and provide incentives to overcome financial barriers and realize the potential market opportunity. Implementation of energy efficiency in residential, commercial, public, and industrial sectors is possible under existing regulations and plans. These could be in the form of developing new building energy codes, expanding the scope of products and appliances standards and labeling program, energy audit requirements in industries, utility regulatory reform to encourage utility investment in efficiency, and supporting energy

[6] The NREL Engage Energy Modeling Tool is available at: https://www.nrel.gov/state-local-tribal/engage-energy-modeling-tool.html

services companies for implementation of energy management programs. Some of these are discussed in the sections below.

Skilled Workforce Development. Scaling up adoption of energy efficiency technologies and practices requires an effective network of trained professionals, which is not present today in the country. The skilled workforce is required to perform energy assessments and other analyses for residential, commercial, and industrial buildings and infrastructure, as well as technicians to install and service energy-efficient equipment and building components (e.g., energy management systems, lighting, windows, and insulation). The National Energy Agenda has given the mandate to MERNNR to encourage trainings, certifications, and accreditations for energy efficiency and energy management experts, but not much has been achieved so far.

The workforce can be developed through partnerships with universities and professional trade organizations, and should include mechanisms to provide skills training (e.g., credentialed energy auditor) and certifications (e.g., Certified Energy Manager) that help the service and professional industries keep pace with technical and strategic advances in energy efficiency. USAID can support the MERNNR in developing local capacity of skilled workforce through several activities such as curriculum development, workshops and study tours, technical training and developments, and conferences.

Standards and Building Codes Development. Standards set a baseline that establishes minimum efficiency requirements for products and places a "floor" under the market to drive efficient technologies, building designs, and operating practices. Although codes and standards, such as building energy codes, require their own set of market supports that may include local adoption, enforcement, and training, they have the potential to achieve significant energy savings. The National Plan has identified the development of a labeling program, DMEE, as a priority activity in its objectives, but further details of implementation are not available. The continued development of efficiency standards for products available in Ecuador and the design of a new building energy code are opportunities for USAID to further influence the market. Once standards and codes are in place, the country can focus on improving compliance to realize the full savings potential.

Support deployment of energy efficient technology. For energy-efficient appliances and equipment to be widely purchased, they must be affordable, easily identifiable, deliver consistent energy performance, and readily accessible. Infrastructure for researching, producing, testing, and labeling quality products needs to be in place for this to be ensured. This can include in-country or regional research, testing and labeling protocols and programs. Promoting the resulting energy-efficient technologies and labels, and showcasing country-specific application of technologies, are also important. USAID is well positioned to support this through regional initiatives in Latin America or through bi-lateral cooperation.

Energy Efficiency Financing Support. Financing Support refers to recognition among banks and other lenders of the need for, and the potential return on investment from energy efficiency. Financing can be an essential in helping overcome the capital-cost barrier associated with higher-cost/greater-savings energy efficiency investments. Public policies and lending practices that enable energy efficiency project finance can be key to increasing initial consumer investment in efficiency, and thus delivering the many associated economic and environmental benefits. PLANEE and the Energy Efficiency law discuss developing an energy efficiency guarantee fund and a national fund for energy efficiency, respectively. USAID could support these energy efficiency funds for the residential, commercial, and industrial sectors.

Support Green Recovery Efforts. USAID may consider supporting Green Recovery efforts as they employ many individuals and enable customers to save on monthly energy bills. This may be especially well suited for cold, mountainous regions in Ecuador.

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ANNEX

TABLE 8. SPECIFIC OBJECTIVES, LINES OF ACTION AND INDICATORS IN THE RESIDENTIAL, COMMERCIAL AND PUBLIC SECTOR," OF ECUADOR NATIONAL ENERGY EFFICIENCY PLAN 2016-2035 (MEER 2017)

SECTORAL OBJECTIVE	RESIDENTIAL, COMMERCIAL AND PUBLIC BUILDINGS, AND ESTABLISH A REGULATION ON BUILDING HABITABILITY.	
INDICATORS	PERCENTAGE OF REDUCTION IN ENERGY CONSUMPTION WITH RESPECT TO THE BASELINE.	
GOAL	IN THE YEAR 2035, THE CUMULATIVE ENERGY CONSUMPTION OF THE RESIDENTIAL, COMMERCIAL AND PUBLIC SECTOR WILL BE REDUCED BY AT LEAST **150,907.29 GWH**, DUE TO THE ENERGY EFFICIENCY MEASURES IMPLEMENTED.	
SPECIFIC OBJECTIVE	BASE LINE	ESTIMATE OF REDUCTION IN ENERGY CONSUMPTION
To strengthen programs for the replacement and labeling of electric appliances and high energy consumption equipment.	Project for the identification of final uses of energy in the Residential, Commercial and Public sectors.	Not quantifiable.
	Program for the standardization and labeling of energy consuming equipment.	Reduction of **120.38 GWh**, from 2016 to 2035. Estimated reduction from 25% by 2035, of energy intensity; however, because the growth of electrical appliances is very similar to the reduction of energy intensity, the final result is that there is no reduction of Boe.
	Replacement program of greater energetic consumption equipment for residential use.	Reduction of **150,907.29 GWh**, from 2016 to 2035. Improvement of energy efficiency in residential equipment. Replacement in the commercial sector to achieve a reduction of 10% of energy intensity by 2035. Continuation of the massive introduction of induction stoves
To establish oversight and control mechanisms for the implementation and application of the NEC (chapters of energy efficiency, air conditioning and renewable energy) at the GAD level.	Project for the definition of oversight and control mechanisms for the implementation and continuous improvement of the NEC standard - Energy Efficiency, Air Conditioning and Renewable Energy.	Not quantifiable.

TABLE 9. SPECIFIC OBJECTIVES, LINES OF ACTION AND INDICATORS IN THE INDUSTRIAL SECTOR (MEER 2017)

SECTORAL OBJECTIVE	TO REDUCE ENERGY CONSUMPTION PER UNIT OF PHYSICAL PRODUCTION IN THE SUB SECTORS OF THE INDUSTRY.	
INDICATORS	ENERGY CONSUMPTION IN EACH INDUSTRIAL SUB SECTOR INDEXED TO PHYSICAL PRODUCTION UNITS FOR INDUSTRIES IMPLEMENTING ENERGY EFFICIENCY MEASURES.	
GOAL	BY 2035, THERE WILL BE A SAVING OF AT LEAST 50,812.25 GWH, THANKS TO THE ENERGY EFFICIENCY ACTIONS IMPLEMENTED IN THE SECTOR.	
SPECIFIC OBJECTIVE	BASE LINE	ESTIMATE OF REDUCTION IN ENERGY CONSUMPTION
Replace inefficient equipment, apply cogeneration systems and adopt ISO 50001 in energy-intensive industries	Program for the implementation of the ISO 50001 standard in energy intensive industries	Reduction of **12575.6 GWh**, from 2007 to 2035. Reduction of energy intensity considering 100 energy intensive industries.
	Cogeneration program in the industry.	Reduction of **13,170.4**, from 2007 to 2035. Improvement of energy efficiency by 10%.
	Replacement program for engines, pumps, boilers and heaters in industries.	Reduction of **24,981.27**, from 2007 to 2035. Estimated reduction of 10% of energy intensity by 2035.
Promote the development of a Market of Companies of Energy Services (ESCOs) in the country	Program for the development and promotion of an ESCO market in Ecuador.	Not quantifiable.