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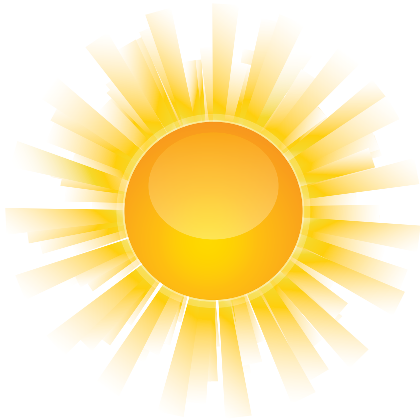
International Renewable Energy Agency

RENEWABLES
READINESS
ASSESSMENT

PANAMA



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About IRENA

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

Acknowledgements

This report was prepared by IRENA in close collaboration with the Government of Panama, as represented by the National Energy Secretariat (SNE). Special thanks are due to numerous other officials from Panama, especially from the Electricity Transmission Company (ETESA), the National Dispatch Centre (CND) and the National Authority of Public Services (ASEP), This report benefited from the inputs of various experts, notably including Fernando Diaz (SNE), Francisco Gafaro (formerly IRENA), Cletus Springer (OAS) and Hugo Ventura (ECLAC). IRENA colleagues including Vanessa Interiano, Tomas Jil, Mohammed Nababa, Hameed Safiullah and Dennis Volk also provided valuable guidance and input.

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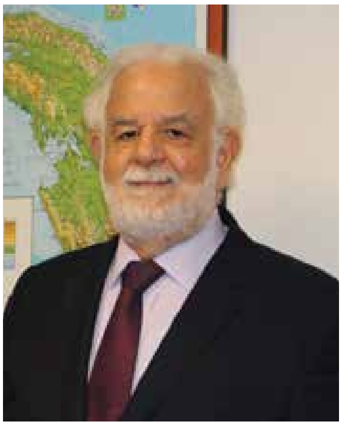
FOREWORD
from the Secretary of Energy



Hydropower is the main source of renewable energy in Panama, based on capacity first put in place by a vertically integrated state-owned utility. In the last 20 years, we have developed a market characterised by competition, whose actors have invested more than 6 billion balboas to move the power sector forward. The results have been satisfactory, and the electric power supply adequately supports our growing economy.

In recent years, our energy matrix has been reinforced by the deployment of other, newer renewable energy technologies. Since 2014, investments in solar and wind energy have grown markedly.

Today, more than two-thirds of Panama's electricity generation comes from clean sources, primarily through the contribution of hydropower. The country also has the largest wind farm in the region, and solar power generation – although still modest – has begun to take off rapidly. A key factor behind this trend has been the decrease in the prices of such technologies. The rise of solar and wind power challenges us to ensure adequate sector-wide planning, particularly so that they can compete on even terms with conventional technologies.

Given this scenario, there is no doubt about the way forward for Panama's energy system. The country is dedicated to fulfilling the commitments made in the Paris Agreement and aims to play a meaningful part in the global fight against climate change.

Panama, therefore, has enthusiastically joined with the International Renewable Energy Agency (IRENA) in the preparation of this Renewable Readiness Assessment, which can help us to determine the adjustments needed to effectively incorporate these technologies.

The objective is to keep up the pace of development in the power sector in a competitive and transparent environment. This includes scaling up private investment, under sound policies, without subsidies, and avoiding any action that causes distortion in the market price.

Panama has been an active participant in IRENA's work from the beginning. This is because we are convinced that such international co-operation can help to point the way for future energy development.

We thank all of our national and international collaborators for their support in the preparation and revision of this document, which we are sure will benefit the entire region.

Victor Carlos Urrutia
National Secretary of Energy
Republic of Panama

FOREWORD
from the IRENA Director-General

Like many countries in Central America, Panama faces the challenges of a growing population and rising energy demand to power its economic growth. Oil and oil products account for around two-thirds of primary energy supply, making Panama vulnerable to global price volatility and rising costs for fuel imports. At the same time, the growing impact of climate change has led to droughts and disrupted the country's hydropower resources.

To address these challenges, Panama's National Energy Plan 2015-2050 has started moving the energy sector decisively towards a more diverse energy mix that takes full advantage of the country's significant renewable energy resource potential. At the core of the plan is a massive scale-up of solar photovoltaic and wind energy. These sources, combined with hydropower, would account for 77% of installed power capacity by 2050.

Furthermore, with the ambitious goal of supplying 70% of the national energy mix through renewables by 2050, the plan serves as a long-term roadmap for the transition to a sustainable energy future.

This Renewables Readiness Assessment (RRA), undertaken by the International Renewable Energy Agency (IRENA) in close co-operation with the Government of Panama, examines the energy sector holistically. The study identifies key actions to expand renewable energy development in the short to medium-term.

Panama is also the pilot country for IRENA's Clean Energy Corridor of Central America (CECCA) initiative, which supports the accelerated deployment of renewable power at the regional level. For this reason, the RRA examines Panama's power-system planning and operational procedures, along with the existing regulatory and financial incentives to develop variable renewable energy for the national and regional electricity market.

Since 2011, the RRA process has been undertaken in over 30 countries across Africa, the Caribbean, Latin America, the Middle East and the Asia-Pacific region. This has led to increased knowledge exchange and support for international co-operation to promote clean, indigenous renewable energy technologies.

I wish to thank the Energy Secretary, Dr. Urrutia, and his staff at the National Energy Secretariat of Panama for their support in the preparation of this study. Insights from other governmental agencies and a wide range of other stakeholders have further enriched the findings. IRENA looks forward to working with all of them, as well as with regional institutions and development partners, to translate these recommendations into practical on-the-ground initiatives that promote renewables as a key element in sustainable, equitable socio-economic development.

I sincerely hope the RRA process and its recommendations will strengthen Panama's pursuit of renewable energy solutions. IRENA stands ready to assist in the country's transition to a sustainable energy future.

Adnan Z. Amin
Director-General
International Renewable Energy Agency

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ABBREVIATIONS

ASEP	National Authority of Public Services (Autoridad Nacional de los Servicios Públicos)
CDMER	Steering Committee of the Regional Electricity Market (Consejo Director del MER)
CECCA	Clean Energy Corridor of Central America
CMS	system marginal cost
CND	National Dispatch Centre (Centro Nacional de Despacho)
CO^2	carbon dioxide
CRIE	Regional Commission for Electrical Interconnection (Comisión Regional de Interconexión Eléctrica)
DC	direct current
DT	transmission right (derecho de transmisión)
EDECHI	Chiriqui Distribution Company
EDEMET	Metro-West Distribution Company
EGESA	Electricity Generation Company (Empresa de Generación Eléctrica, S.A.)
ENSA	Northeast Distribution Company
EOR	Regional Operator Entity (Ente Operador Regional)
EPR	Regional Operations Entity
ETESA	Electricity Transmission Company (Empresa de Transmisión Eléctrica, S.A.)
GDP	gross domestic product
GHG	greenhouse gas
GW	gigawatt
GWh	gigawatt hour
ICP	Colombia-Panama Electric Interconnection
IRENA	International Renewable Energy Agency
kboe	thousand barrels of oil equivalent
km	kilometre
km^2	square kilometre
kV	kilovolt
kW	kilowatt
kWh	kilowatt hour
LPG	liquefied petroleum gas
m	metre
m/s	metres per second
MEN	National Electricity Market (Mercado Eléctrico Nacional)
MER	Regional Electricity Market (Mercado Eléctrico Regional)
MW	megawatt
MWh	megawatt hour
NDC	Nationally Determined Contribution
PEN 2015-2050	National Energy Plan 2015-2050 (Plan Energético Nacional 2015-2050)
PIMUS	Comprehensive Plan for Sustainable Urban Mobility
PPA	power purchase agreement
PSSE	Power System Simulation for Engineering
RRA	Renewables Readiness Assessment
SIEPAC	Central American Electric Interconnection System (Sistema de Interconexión Eléctrica de los Países de América Central)
SIN	National Interconnected System (Sistema Interconectado Nacional)
SNE	National Energy Secretariat (Secretaría Nacional de Energía)
T&D	transmission and distribution
UTP	Technological University of Panama
UP	University of Panama
V	volt
VRE	Variable Renewable Energy

The Penonomé I and II wind projects located on Panama's southern coast
Photograph: Shutterstock

EXECUTIVE SUMMARY

Panama depends heavily on fossil fuels, which have historically accounted for roughly two-thirds of total primary energy supply. The country's transport sector has until recently relied almost entirely on oil and oil products. At the same time, electricity demand in the country has continued to increase, reaching a peak demand of over 1 600 megawatts (MW) in 2015.

To meet this growth, Panama introduced wind and solar photovoltaic (PV) energy in 2013, which reached 270 MW and 90 MW of installed capacity by 2016, respectively. However, fossil-fuelled generation from coal, oil and oil products still accounted for nearly one-third of power production in 2016, and plans are in place to bring natural gas-fired capacity on line in the years ahead. These developments make Panama's transition to a sustainable energy future uncertain.

However, in March 2016, the Government of Panama approved the National Energy Plan 2015-2050 (PEN 2015-2050) to serve as a long-term roadmap for diversifying the energy sector and advancing energy access, energy efficiency, energy security and the overall decarbonisation of the energy system. The plan compares a "business-as-usual" reference-case scenario with an alternative, ambitious scenario, and finds that under the reference-case scenario, Panama's demand growth trajectory would lead to a higher share of coal in the power mix by 2050. The ambitious scenario, in contrast, suggests that renewable energy could reach 70% of the power supply in the next 35 years, while at the same time meeting growth in demand. Furthermore, under the ambitious scenario, a solar photovoltaic (PV) and wind energy scale-up, combined with hydropower, would account for 77% of installed power capacity by 2050.

Reaching this desired energy future would require exploitation of Panama's vast renewable energy potential, which includes resources such as hydropower, wind, solar, geothermal, marine and biomass (bagasse, husk, firewood, charcoal, peat and bioethanol). Despite abundant renewable energy resources, solar and wind companies in Panama face economic challenges, given that the current power market model is based on conventional sources such as thermal and hydropower generation and does not recognise the unique operating characteristics of variable renewable energy (VRE) generation. As such, adjustments to electricity sector regulation are needed to ensure that variable renewables compete on a level playing field with conventional generation sources.

The high shares of solar and wind in the electricity network, as envisaged in the PEN 2015-2050, will require significant flexibility mechanisms in the power system. Combined with updated power system planning and operational practices, these measures can help ensure the reliable integration of VRE in a cost-effective manner.

This Renewables Readiness Assessment (RRA) finds that several key challenges would need to be effectively addressed to further exploit indigenous renewable energy resources and integrate growing shares of solar and wind energy in Panama's power system. To this end, the recommendations that follow are provided to the Government of Panama for its consideration in the development of policy and regulation for its energy system.

RECOMMENDED ACTIONS

1. Assess the regulatory and financial incentives for VRE development

Panama's power market has been structured around the operation of its hydropower and thermal generation fleet, where generators are rewarded on the basis of an outdated definition of firm power. To allow renewables to compete on a level playing field vis-à-vis conventional generation, particularly in the competitive wholesale market, the current regulatory framework conditions must be adjusted to adequately capture the unique operating characteristics of VRE, and in doing so, incentivise new development of wind and solar PV.

By undertaking a robust assessment of the investment incentives for wind and solar PV projects, both under the current and expected market conditions, Panama can identify factors with a negative influence on investment behaviour and their required regulatory responses. Given the importance of power purchase agreements (PPAs) for solar and wind energy, the assessment should take into account possible adjustments to the compensation for curtailment of renewable generators, a new calculation of PPA-related remuneration levels and an updated definition of firm power that incorporates variable renewable generation output. The assessment should culminate in a set of implementable solutions that can help lead to a strengthened investment environment without compromising the efficient functioning of the Panamanian electricity market.

2. Develop a national strategy to improve power system planning and modelling with higher penetrations of VRE

Looking ahead, power system planning will continue to be a critical element of Panama's evolving energy sector, as planners must cope with rising variability from the envisaged high penetration of solar and wind generation through to 2050. Without strong sets of quantitative techno-economic analyses to guide such planning, however, generation expansion can be delayed, grid infrastructure development costs can be allocated inefficiently, and the overall reliable operation of the power system can be compromised.

In response to these challenges, Panama should develop a comprehensive plan to define long-term transition scenarios and near-term actions. This will help align the development of the electricity grid with the development of new VRE generation. Moreover, it can help rationalise the management of connection queues, reduce or avoid interrupting renewables generation, support the efficient use of the SIEPAC (Central American Electrical Interconnection System) regional line, and cut overall costs of the electricity system.

3. Identify new operational practices to increase the flexibility and reliability of a grid with growing shares of VRE

Panama's power system operations still largely reflect an "old paradigm" of centralised, dispatchable generation units. Yet, due to the unique physical conditions of variable renewables, reliably integrating solar and wind sources into the electricity network requires modifications to the National Dispatch Centre (CND) operational procedures, in addition to increased flexibility measures. These include enhanced forecasting techniques, improved ancillary services, more flexible scheduling of generation and load dispatch practices, and improved management of reserves, among other areas.

A comprehensive evaluation of new operational practices would further identify the necessary flexibility options for the reliable operation of the power system with a higher penetration of solar and wind.

The International Renewable Energy Agency (IRENA), through its work with CND under the Clean Energy Corridor of Central America (CECCA) initiative,[1] identified additional potential updates related to power system operations in Panama. These include: automation of system security analysis using power system software to allow closer real-time system security checks, with the aim of reducing VRE curtailment due to network congestion; calculation of transmission capacities closer to real time and considering forecasts for wind and solar production in these calculations to minimise curtailment; and training on the impacts of VRE on transient and frequency stability analyses.

4. Assess the regulatory interfaces between the National Electricity Market (MEN) and Regional Electricity Market (MER)

With its connection to the SIEPAC, Panama participates in the MER with five other countries in Central America. However, due to a lack of

1 IRENA created the Clean Energy Corridor of Central America (CECCA) to promote the accelerated development and cross-border trade of renewable power in Central America, in line with the call made in 2015 in the Abu Dhabi Communiqué on Accelerating Renewable Energy Uptake in Latin America.

harmonisation among rules and methodologies, such as grid codes, the MER does not function in a fully efficient manner and is underutilised. Moreover, institutional gaps exist between single jurisdictions and the regional market. In this respect, more flexible market rules, including the allocation of transmission rights, are needed to ensure firmness through the multiple resources of the MER, instead of the current approach which allows limited short-term transactions.

By undertaking an assessment of the regulatory interfaces between the MEN and the MER, Panama can advise on potential solutions to current challenges, such as energy transfer problems on the MER, grid design values, and the suboptimal regional dispatch that occurs when energy is "trapped" on national markets due to transmission constraints.

Key issues that need to be further analysed include: the definition of firm energy and its equivalence to firm capacity at national level; the authorisation of the right of transmission and of the long-term firm contract; the creation of an intraday market to adjust the volumes of variable renewables; the concept of interruptible service under firm contracts at the national level; and verification of the capacity limits of the SIEPAC line, as designed.

5. Examine the skills development needs of Panama's workforce to support efforts towards reaching the 2050 renewable energy goal

In order to achieve a 70% renewable energy share in Panama's power supply by the year 2050, as envisaged in the PEN 2015-2050, a robust workforce will be essential to underpin the growing solar PV and wind energy market in the country. An examination of the current national workforce in the field of renewables and the projected future needs can help to adjust existing and new education and training programmes to develop the necessary renewables workforce.

To comprehensively evaluate workforce needs, the assessment should, at a minimum, include a survey of: current education and training for renewables in Panama; the range of jobs available in Panama's renewable energy sector; and the types of renewable energy training and certifications that employers prefer. This would then lead to the development of new or expanded education and training programmes in line with the goals of the PEN 2015-2050.

6. Develop a long-term plan for electric mobility and sector-coupling

Panama's transport sector has traditionally relied entirely on fossil fuels; however, with the growth of the Panama Metro, the electrification of transport in the country has begun. To adapt Panama's energy system to this evolving paradigm, a comprehensive plan is needed that considers a sector-coupling approach between power and transport, and considers the introduction of expanded metro lines, electric passenger vehicles and electric buses.

Developing a comprehensive Urban Mobility Plan for Panama based on the electrification of transport would help speed up the use of renewable energy in the electricity mix, reduce the transport problems that currently affect Panama (such as high levels of congestion, urban planning, limited availability of public transport), support the reduction of CO^2 emissions, and eliminate the current dependence of the sector on fossil fuels.

At the same time, the generalised subsidy of liquefied petroleum gas (LPG) for cooking acts as a disincentive to deployment of electric stoves and thus the shift in residential and commercial energy demand from the fossil-fuel sector to the electricity sector. Shifting this demand profile would provide an opportunity to meet increased demand in the end-use sectors with solar and wind generation, aligning with the goals of the PEN 2015-2050 alternative scenario.

Therefore, in the residential and commercial sectors, policy options should be examined that can alter or eliminate subsidies for LPG. This process should compare the true costs of cooking with LPG and using electric cook stoves that are deployed in concert with high shares of renewable power.

Panama City skyline
Photograph: Shutterstock

I. INTRODUCTION

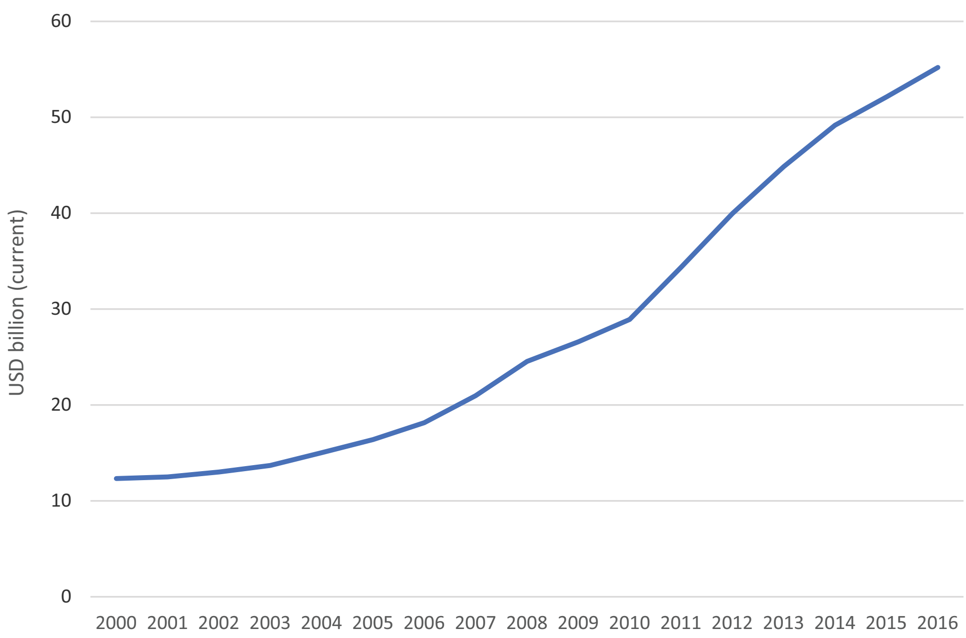
1.1 COUNTRY BACKGROUND

Panama is the southernmost country in Central America. As the link between Central and South America, it borders Colombia to the east and Costa Rica to the west. To its north is the Caribbean Sea, and to its south the Pacific Ocean.

Panama has a surface area of 75 320 square kilometres (km^2), and its population sits at just over 4 million (2017). The capital, Panama City, is located in the centre of the country and is home to roughly 1.6 million people (UN, 2017).

Panama's economy operates without a central bank, and uses the US dollar as legal tender. Its official currency, the balboa, is tied to the US dollar: one dollar equals one balboa. Since the 1990s, when the Panamanian economy was liberalised, the country's banking sector has become one of the most globalised in Latin America. Gross domestic product (GDP) growth in Panama has been stable in recent years (Figure 1). In 2016, the country's GDP reached USD 55 billion, and it is forecast to grow at around 5.4% in 2018 (World Bank, 2017a).

Figure 1: **GDP in Panama (2000-2016)**



Based on World Bank (2017b), The World Bank in Panama, www.worldbank.org/en/country/panama/overview.

Between 2007 and 2013, the service sector accounted for the largest share of the country's total GDP, at 74% (World Bank, 2017a). This is largely due to the Panama Canal, a 77 kilometre (km) artificial waterway that cuts across the country and connects the Atlantic Ocean with the Pacific Ocean. Completed in 1914 and expanded in 2014, the canal underpins Panama's trade, transport and tourism industries (SNE, 2015).

Climate change is a concern for Panama, which has a tropical climate and both a rainy and dry season. The country experiences various extreme weather events, such as El Niño-La Niña events, floods, droughts, tropical cyclones and windstorms, among others (Adaptation Fund, 2017). Further climate risks for Panama relate to rising sea levels, altered agriculture and food production, and changes to its ecosystems and biodiversity.

To help mitigate these impacts, Panama's Ministry of Environment developed the "Estrategia Nacional de Cambio Climático de Panamá" (National Climate Change Strategy of Panama), which outlines actions and strategies for adaptation and cross-sectoral greenhouse gas (GHG) emissions reduction (Ministry of Environment, 2015).

Central to the country's action on climate is the decarbonisation of its energy system, with the National Energy Plan 2015-2050 (PEN 2015-2050) aiming to reduce energy sector emissions by 60.6% by 2050, compared to a reference case scenario (SNE, 2015). These efforts are also reflected in the country's Nationally Determined Contribution (NDC), which sets a goal of a 15% increase in non-hydropower renewable energy capacity by 2030, and 30% by 2050,[1] compared to base year 2014 (Government of Panama, 2016).

1.2 RENEWABLES READINESS ASSESSMENT IN PANAMA

The International Renewable Energy Agency (IRENA) developed the Renewables Readiness Assessment (RRA) as a tool to carry out a comprehensive evaluation of the conditions for renewable energy deployment in specific countries. The RRA is a country-led, consultative process that leverages broad, multi-stakeholder dialogue to identify barriers and solutions to renewables deployment in a country.

Following the official request of the Government of Panama to IRENA, the RRA process was initiated. It has been led by Panama's National Energy Secretariat (SNE), with IRENA facilitating the process. The RRA has been undertaken in conjunction with the national-level projects of IRENA's Clean Energy Corridor of Central America (CECCA) initiative, given that Panama was later chosen as the pilot country of the initiative in 2016.[2]

The completed RRA process for Panama includes a background paper, an identification of stakeholders and strategic partners, a set of service-resource pairs, an RRA Expert Workshop and a Validation Workshop.

In October 2016, the government hosted an RRA Technical Consultation Workshop in Panama where national, regional and international stakeholders exchanged and validated the findings of the RRA Background Paper. Discussions focused on the overall status of renewable energy development in Panama, and identified key barriers to accelerating deployment.

Based on this, priority actions were then developed to form a set of recommendations. The group discussions were divided into four areas:

- National Energy Plan 2015-2050: Institutional, policy and regulatory frameworks, and their national and regional implications.
- Renewable energy targets: Assessing renewable energy resources for stronger planning.
- National and regional market interaction, and private-sector renewable energy financing.
- Large-scale and small-scale distributed renewable energy integration.

The workshops shaped the focus of the RRA. For instance, the electricity sector was identified early on as a key focus area, since immediate adaptations to power system operations can help integrate higher shares of variable renewable energy (VRE), such as wind and solar. This also has important implications for Panama's end-use sectors, as the growing power demand resulting from the electrification of transport and residential appliances could be met by scaling up variable renewables in the power mix.

The Validation Workshop, co organised by SNE and IRENA, was held in June 2017. The recommendations in Section 4 of this report were discussed and validated by the government and all relevant stakeholders.

2 These values refer to modern renewable energy and do not include traditional biomass.

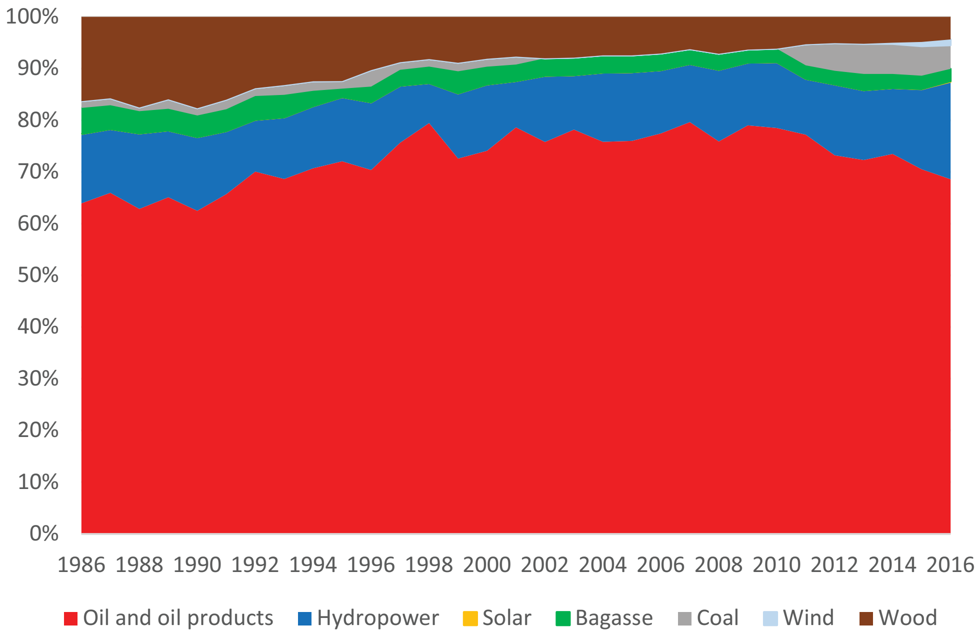
3 IRENA created CECCA to promote the accelerated development and cross-border trade of renewable power in Central America, in line with the call made in 2015 in the Abu Dhabi Communiqué on Accelerating Renewable Energy Uptake in Latin America.

II. ENERGY CONTEXT

2.1 ENERGY SUPPLY AND DEMAND

Panama's total primary energy supply has historically had a high dependence on oil and oil products. Figure 2 shows the evolution of the country's primary energy sources, with oil generally accounting for over 60%, and reaching nearly 80% at certain points.

Figure 2: **Panama's total primary energy supply (% per source, 1986-2016)**



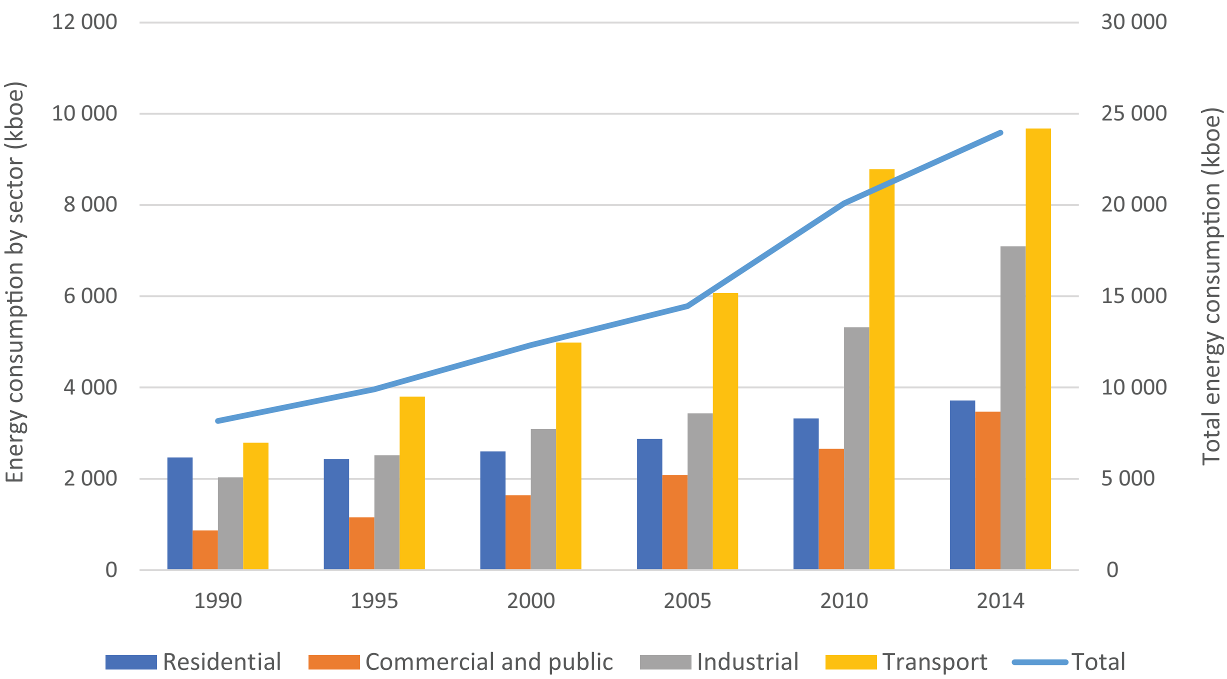
Based on SNE (2015), Plan Energético Nacional (2015-2050).

Panama's energy demand can be divided into four main sectors: residential; commercial and public; industrial; and transport. Figure 3 shows the evolution of total final energy consumption in each of these sectors. The transport sector is the largest energy consumer, followed by the industrial sector. The transport and industrial sectors are the main consumers of oil and oil products, while the commercial and public and residential sectors account for the highest electricity share.

The share of electricity in total energy supply has remained at around 20% for the last 15 years (Figure 4), while the final electricity consumption rate has witnessed a steep growth rate of approximately 5.8% annually.

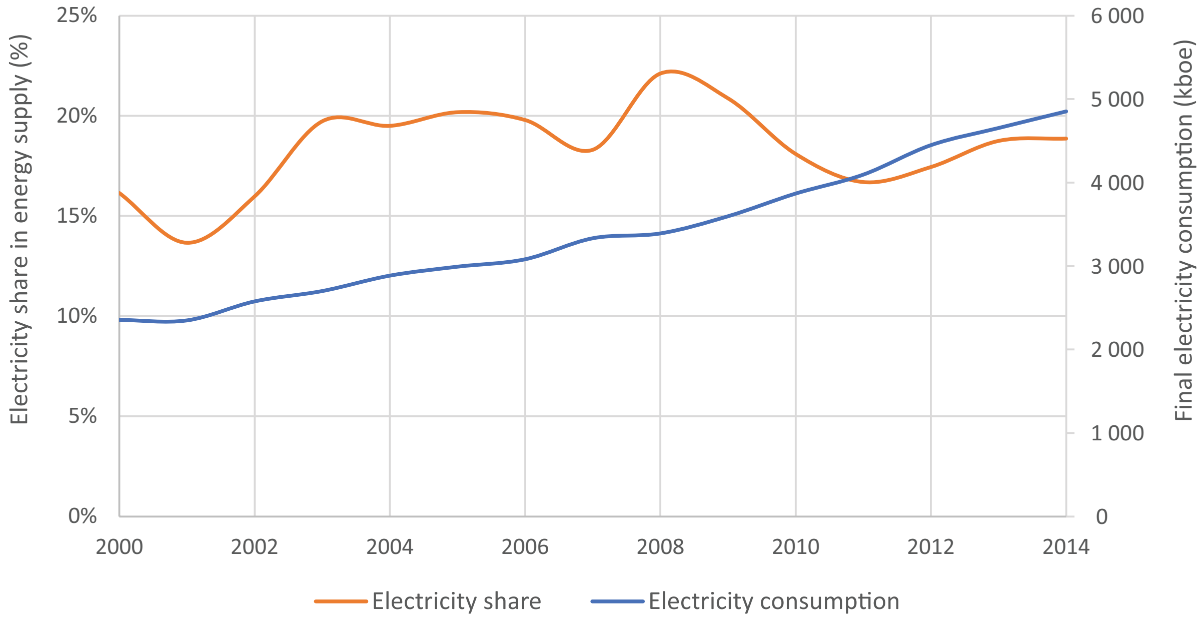

Wind turbines in Panama
Photograph: Shutterstock

Figure 3: **Total final energy consumption by sector (1990-2014)**



Note: kboe = thousand barrels of oil equivalent.
Based on SNE (2015), Plan Energético Nacional (2015-2050).

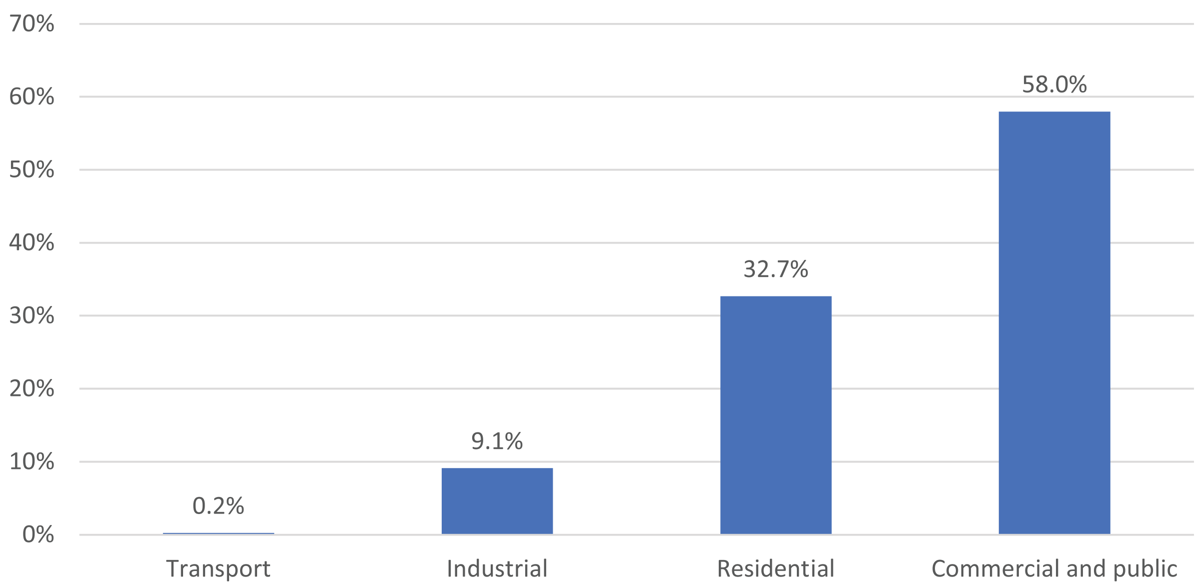
Figure 4: **Total final electricity consumption and electricity share in the total energy supply (1998-2014)**



Based on SNE (2015), Plan Energético Nacional (2015-2050).

As stated above, the commercial and public sector is the main consumer of electricity, followed by the residential sector and industrial sector. Given its high dependence upon oil products, the transport sector consumes the least electricity among sectors (Figure 5). The following paragraphs provide further detail on the energy profile of each end-use sector.

Figure 5: **Electricity consumption share by sector (2014)**



Based on SNE (2015), Plan Energético Nacional (2015-2050).

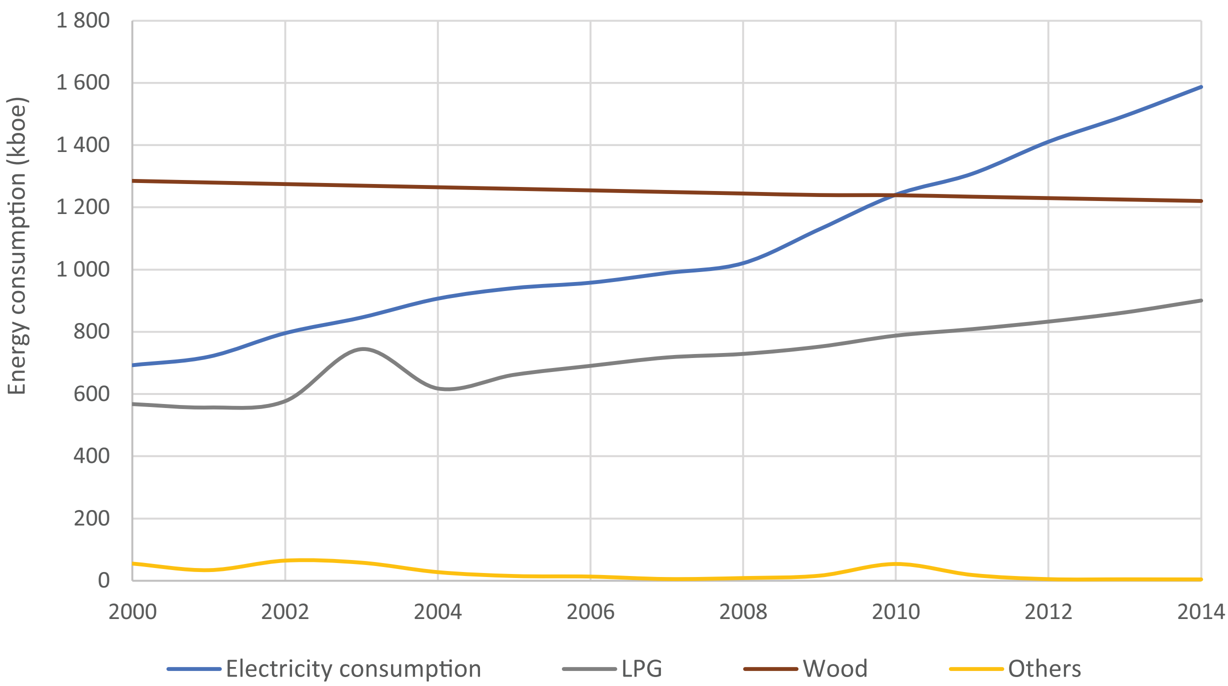
1. RESIDENTIAL SECTOR:

Household energy requirements are supplied by electricity, wood and liquefied petroleum gas (LPG) for cooking and heating. As Figure 6 shows, electricity consumption has expanded rapidly in households, particularly over the last 10 years, which has in turn boosted total final electricity consumption (Figure 4). The residential sector also relies on wood for cooking and heating, an estimated 13% of Panamanian households using wood (SNE, 2015).

LPG also maintains a high share of the energy used in the sector, and correlates with growth in total energy consumption. The 25-pound LPG tank has been subsidised since 1992, following an executive decision by the government, and this decision was later endorsed by a sequence of Cabinet decrees. In 2009, an official decree for price regulation of LPG used in households was created (Ministry of Industries and Commerce, 2009), and by 2014, annual LPG subsidies in Panama had reached USD 96 million (SNE, 2015).

The PEN 2015-2050 recognises the need to increase the use of electric cooking stoves in Panamanian households, which could support government efforts to increase electricity access while at the same time reducing the use of LPG and wood for cooking and heating.

Figure 6: **Final energy consumption – residential sector (2000-2014)**



Based on SNE (2015), Plan Energético Nacional (2015-2050).

2. TRANSPORT SECTOR:

The transport sector includes both cargo and passenger transport, and is the largest consumer in Panama's total final energy consumption, at around 45% (Figure 3). The number of vehicles on the road in Panama has accelerated in recent years, from 564 155 in 2012 to 718 518 in 2015 (Figure 7).

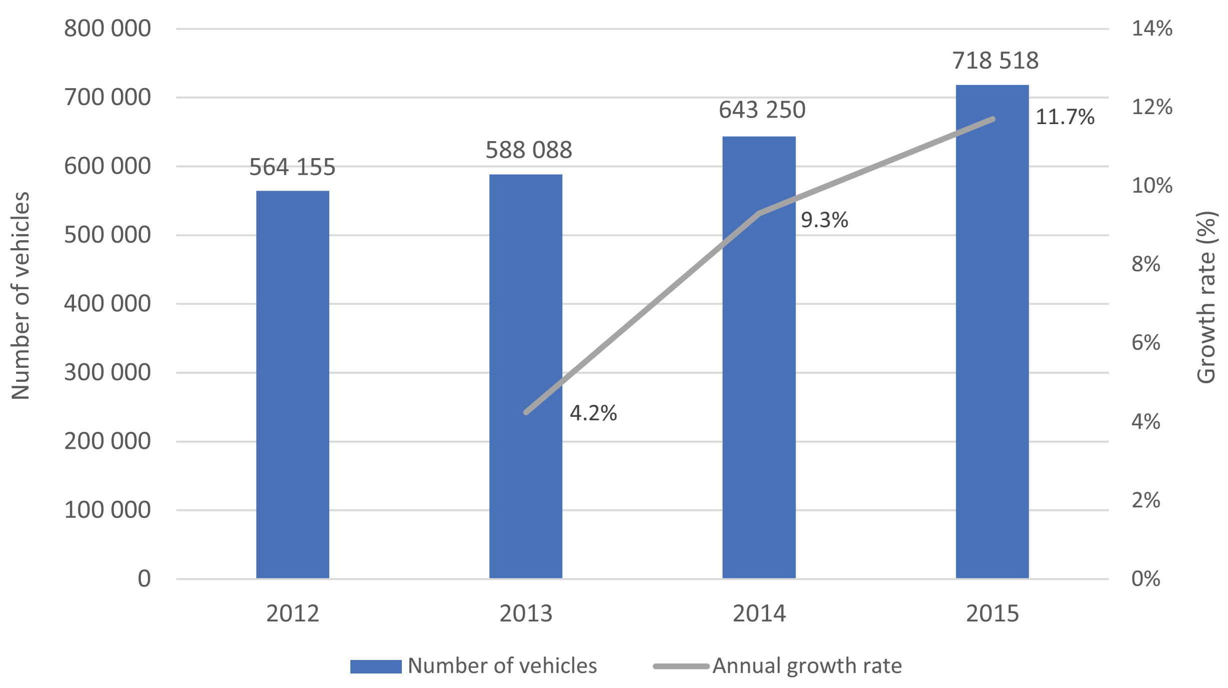
Between 2012 and 2014, gasoline in Panama was blended with 5% ethanol, until the mixing plant ceased operations due to economic challenges. However, this blending initiative is expected to return. While still a nascent market, hybrid vehicles have begun to increase their sales in the country, while electric vehicles have yet to be deployed on a large scale in Panama.

The PEN 2015-2050 will require significant flexibility mechanisms in the power system

An increase in the use of electrified public transport has begun to take place following the creation of Line 1 of Metro de Panamá (the Panama Metro), which provides a range of benefits to the population including reduced journey times. In the year to February 2018, the metro system was already carrying between 5 and 7 million riders each month, having started operations in 2014 (The Panama Metro, 2018).

A second line is currently under construction, with a third line under development and an eventual fourth and fifth line being planned. The growing use of electrified transport (public and private) could represent a moderate increase in electricity demand, which could in turn be used as an opportunity to expand the use of renewable power generation to meet this new demand (sector coupling).

Figure 7: **Vehicle fleet growth rate in Panama (2012-2015)**



Based on INEC (2018), "Automóviles en circulación en la República según distrito y tipo: años 2012-2016".

The Ministry of Environment, in co ordination with the Panama Metro, has developed the Comprehensive Plan for Sustainable Urban Mobility (PIMUS) for the transport sector. The plan is intended to serve as a framework for sustainable mobility policy in the Metropolitan Area of Panama, with an emphasis on capitalising on the investment in the expansion of the metro system. In addition, it identifies the best international practices for the reduction of GHG emissions in urban mobility (CCAP, 2016).
The plan suggests five key action areas:

1. Strengthening institutional capacity.

2. Establishing an integrated public transport system.

3. Mitigating the impact of the use of the private vehicle.

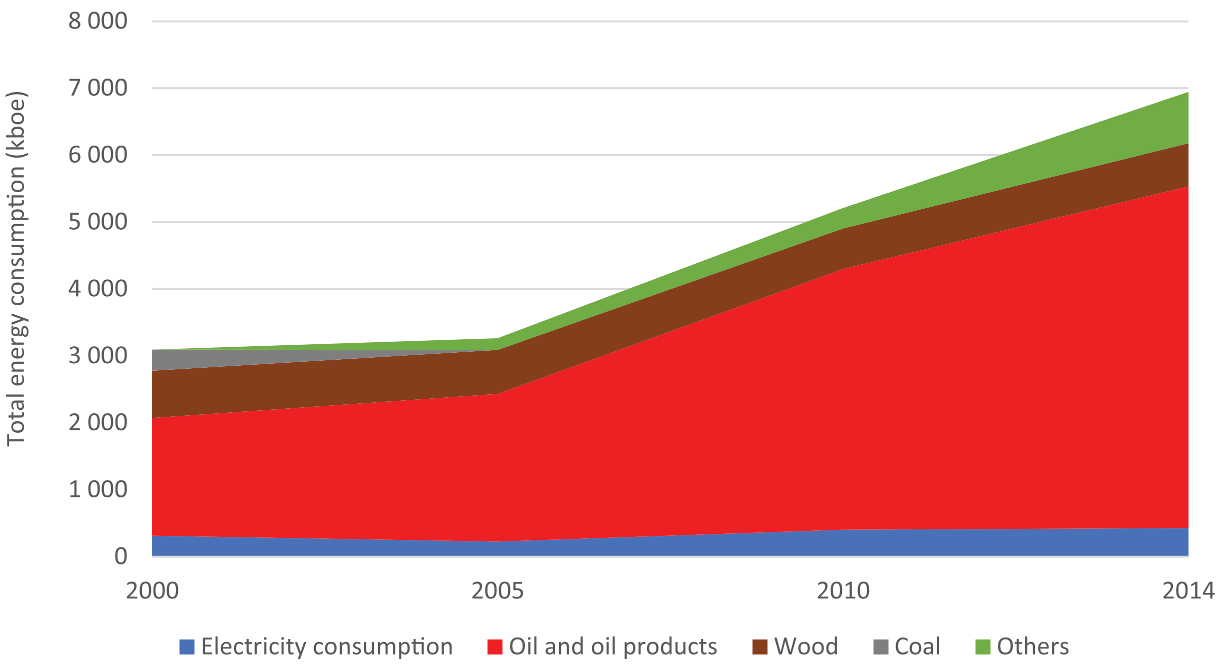
4. Generating an investment programme in road infrastructure for mobility.

5. Promoting citizen participation in the management of mobility.

3. INDUSTRIAL SECTOR:

Industry has seen moderate growth in energy demand, with total energy consumption in the sector reaching nearly 7 000 kboe in 2014, from 5 209 kboe in 2010 (Figure 8). Buildings in Panama use electricity for lighting, cooling, heating and motive power, while bunker fuel and diesel are used in boilers and furnaces to produce heat, and petroleum coke is used in cement plants. The use of oil products corresponds to more than 80% of the industrial sector's total energy consumption (Figure 8). Energy-intensive industries in Panama include food, tobacco, cement and paper production.

Figure 8: **Energy consumption in the industrial sector, Panama (2000-2014)**



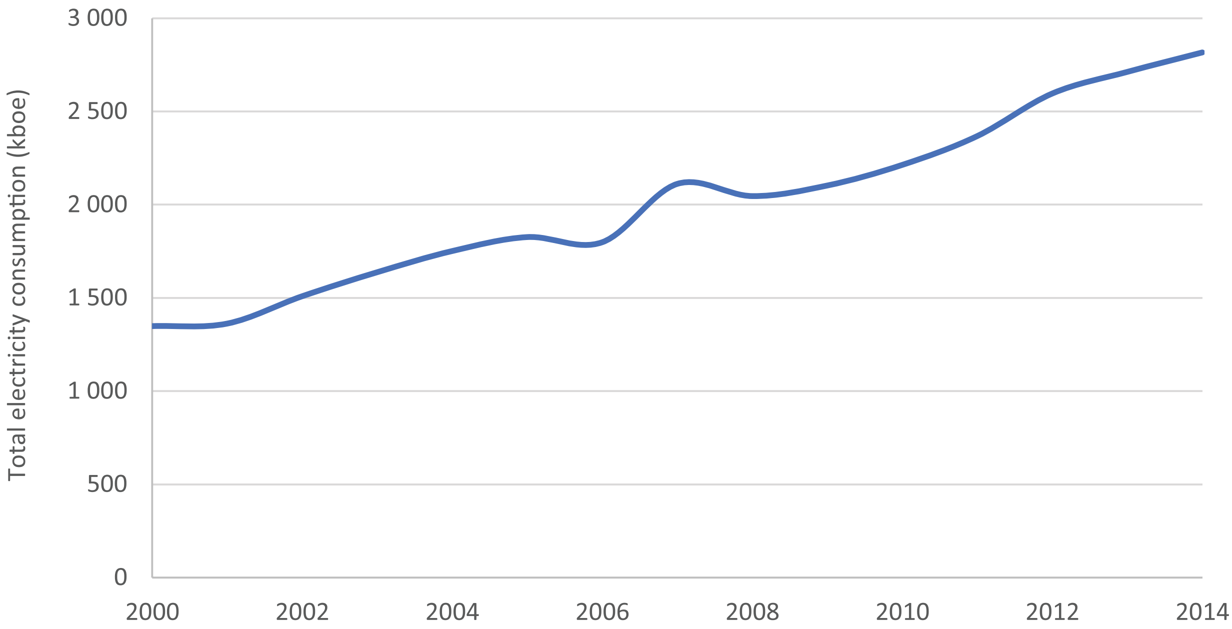
Based on SNE (2015), Plan Energético Nacional (2015-2050).

4. COMMERCIAL AND PUBLIC SECTOR:

The commercial and public sector is the largest consumer of electricity among the four sectors. Consumption reached 2 816 kboe in 2014 (Figure 5). Since 2010, the sector has accounted for about 15% of total final energy consumption in Panama, and its electricity consumption has maintained an annual average growth rate of 6.2% (Figure 9).

As services are the primary activity in this sector, it can be expected that information technology will play an important role in efficiency measures and energy savings in the future.

Figure 9: **Electricity consumption in the commercial and public sector (2000-2014)**



Based on SNE (2015), Plan Energético Nacional (2015-2050).

Panama has 270 MW of installed wind power capacity
Photograph: Shutterstock

2.2 KEY INSTITUTIONS IN THE ENERGY SECTOR

The government institutions involved in energy policy and regulation include the following:

1. The National Energy Secretariat (SNE) oversees the development and implementation of national energy policy to promote a diversified energy supply, with an aim to reduce costs and avoid adverse social and environmental impacts. SNE is also responsible for promoting a competitive energy market, as well as a regulatory framework that facilitates a modern and efficient electricity system. In addition, SNE may propose changes to laws, including policy support mechanisms.

2. The National Authority of Public Services (ASEP) is the regulator of the National Electricity Market (MEN). It monitors compliance with market rules, issues regulations, facilitates dispute resolution between market actors, and grants licences and concessions for new market agents.

3. The Ministry of Environment was created in 2015 and is charged with formulating national environmental policy and promoting the sustainable use of natural resources. It is also responsible for approving the Environmental Impact Assessment of energy projects and granting use of a natural resources.

4. The National Science and Technology Secretariat is an autonomous agency that promotes sustainable development in Panama through science and technology, and works with the public and private sectors, as well as academia. In this context, the secretariat supports renewable energy and sustainable development forums in Panama.

In 1997, the state-owned, vertically integrated electricity company, Hydraulic Resources and Electrification Institute, was unbundled into separate business units. Following this process, four generation units, one transmission unit and three distribution units were created. The generation and distribution units were partially privatised, with the government still maintaining minority ownership in them, while the transmission unit remained completely state-owned.

Since then, the power generation market in Panama has steadily grown through mostly private capital, while some power plants still belong to the public sector or have taken the form of public-private partnerships (Annex I). In 2006, the state-owned Electricity Generation Company (EGESA) was created by the government to develop projects and compete in the generation market with the private sector.

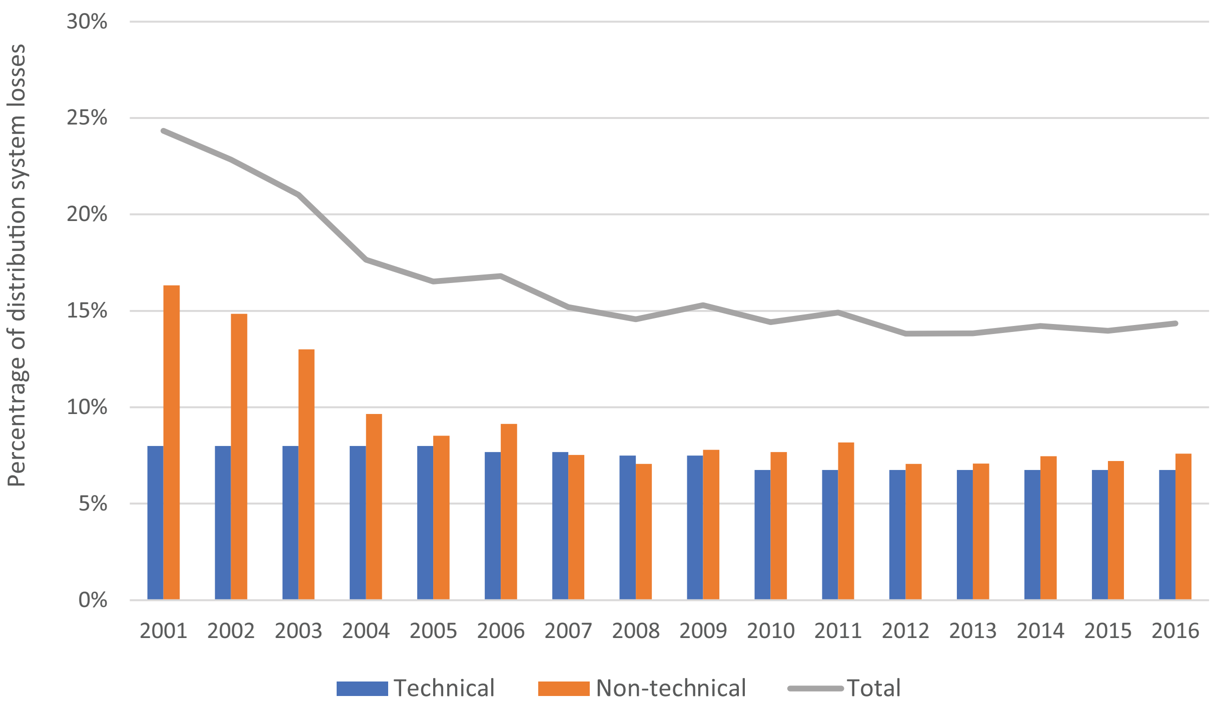
Panama also has self-generators, which are defined as companies that generate their own electricity and can sell the surplus and buy any deficiency on the national or regional market. A co-generator is defined as a company that generates electricity as a by-product of its main activity and can sell its surplus and buy its deficiency on the national or regional market. An example is a sugar mill that produces high-pressure steam by burning the bagasse in a boiler. This steam moves the turbines for the various equipment of the sugar manufacturing process, while also being used to generate electricity for the mill, with surplus energy sold on the market.

Panama's transmission and distribution infrastructure is managed by several key actors, including:

1. The Electricity Transmission Company, ETESA, maintains responsibility for developing and operating the transmission system, providing feasibility of connection to new actors and conducting energy and power tendering in accordance with the policies and procedures established by the SNE and ASEP. It also arranges auctions on behalf of Panama's distribution companies, and concludes power purchase agreements (PPAs) with distributors and generating actors.

2. The Metro-West Distribution Company, EDEMET, the Chiriquí Distribution Company, EDECHI, and the Northeast Distribution Company, ENSA, are three main distribution companies in Panama. The companies are regulated, and their profit is linked to a rate on their net assets and their efficiency (distribution grid infrastructure), as an economic method to improve the quality of their service. They are also allowed to provide 15% of their demand with their own generation assets. Following the privatisation of the Hydraulic Resources and Electrification Institute, distribution losses were reduced considerably due to improved management and increased investment in the distribution system (Figure 10).

Figure 10: **Annual distribution losses (2001-2016)**



Based on ETESA (2017a), Plan de Expansión del Sistema Interconectado Nacional 2017-2031: Tomo I.

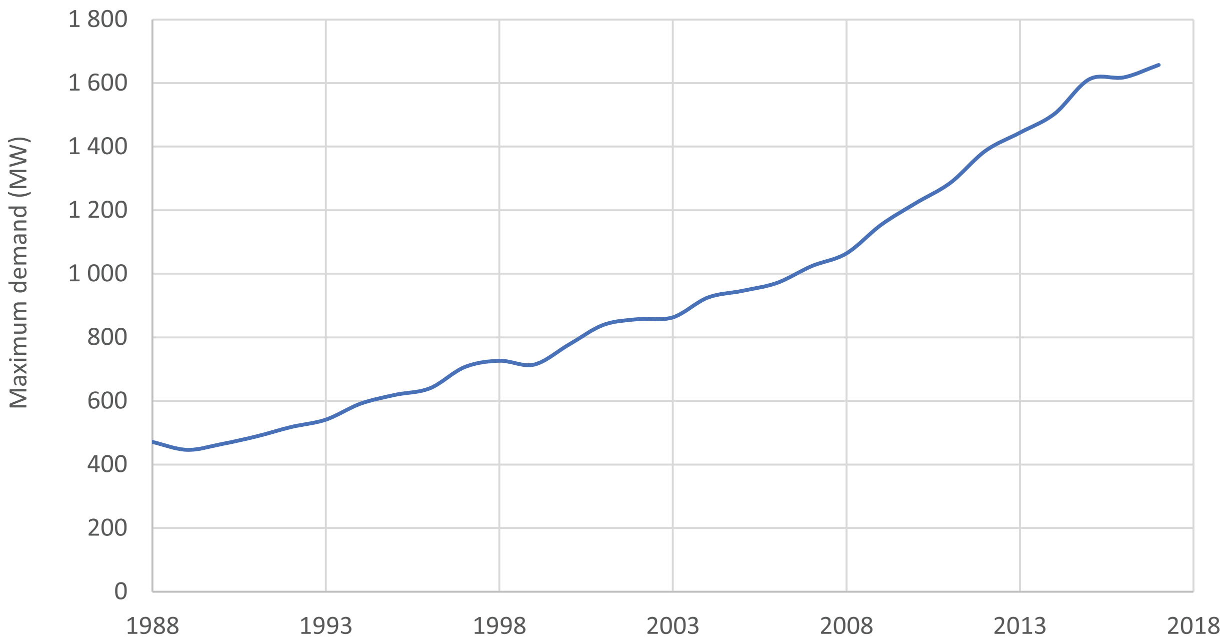
2.3 POWER SECTOR OVERVIEW

Since the 1980s, electricity demand in Panama's Nationally Interconnected System (SIN) (Figure 14) has continued to increase, reaching peak demand of over 1 600 megawatts (MW) in 2015 (Figure 11). Installed power capacity has also continued to grow, reaching 3 379 MW in 2016. The largest source in the electricity mix is hydropower, followed by thermal generation (oil products and coal).

Wind and solar power came on line in 2013, and by 2016 Panama had 270 MW of installed wind power capacity and 90 MW of installed solar power capacity (SNE, 2015). In addition, biogas was deployed in 2016, with an installed capacity of 8.1 MW (Figure 12).

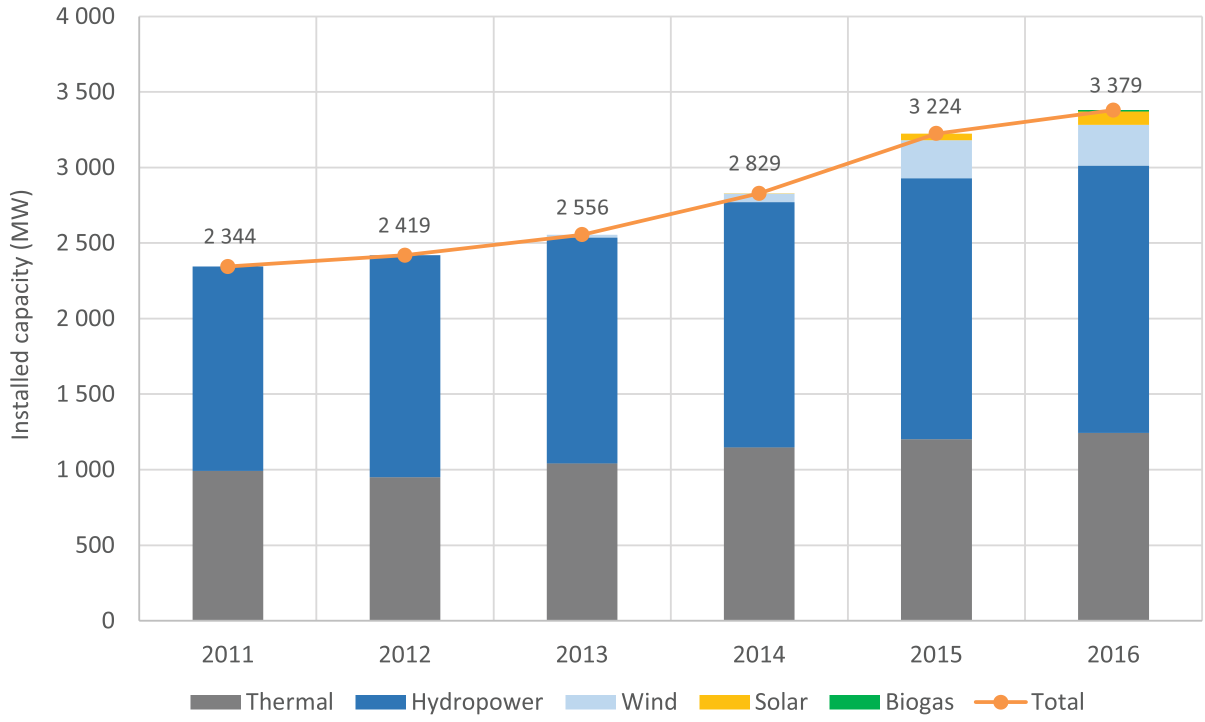
Updated power system planning and operational practices can help to ensure reliable integration of VRE in a cost-effective manner

Figure 11: **Maximum electricity demand in Panama (1988-2017)**



Based on SNE (2015), Plan Energético Nacional (2015-2050).

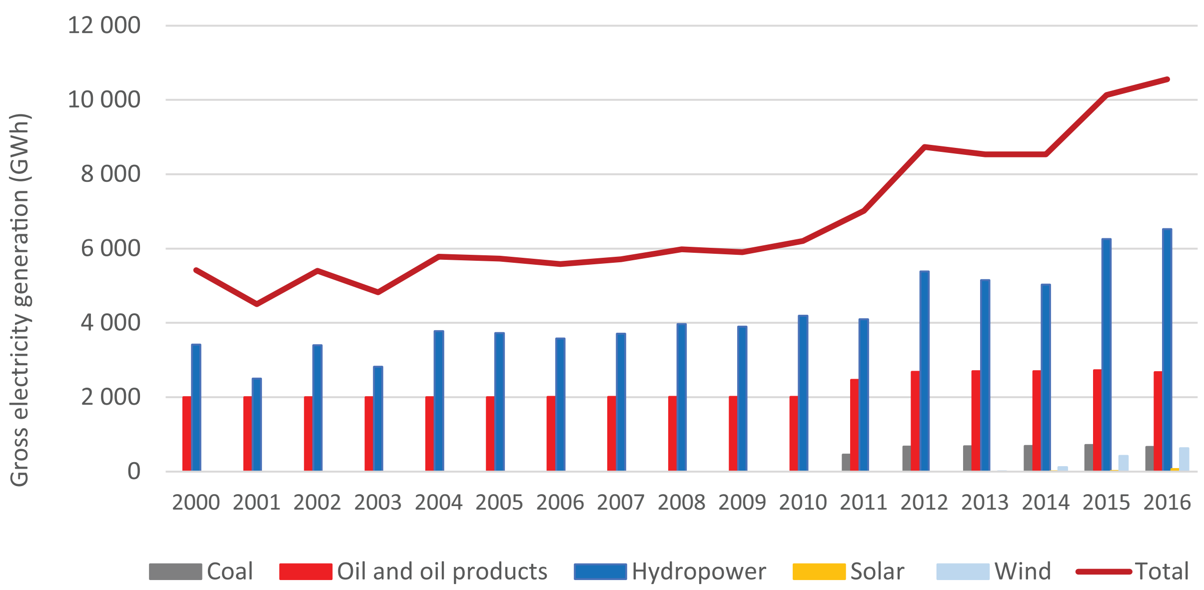
Figure 12: **Installed power capacity in Panama (2011-2016)**



Based on SNE (2015), Plan Energético Nacional (2015-2050).

As shown in Figure 13, electricity generation in Panama has been dominated by hydropower. Wind and solar generation began in 2013, and reached 625.2 gigawatt hours (GWh) of onshore wind and 71.4 (GWh) of solar PV in 2016 (SNE, 2017a). Gross electricity generation saw an annual growth rate of around 6.7% between 2010 and 2016, reaching a total of 10.8 gigawatt hours (GWh) in 2016, compared to 4.8 GWh in 2000. Coal has only been used since 2011, corresponding to an average of 7% of gross electricity generation from 2011 to 2016 (Figure 13). The share of oil and oil products in the generation mix has reduced from 37% in 2014 to 27% in 2016, but is still the second-largest electricity generation source after hydro.

Figure 13: **Gross electricity generation in Panama per energy source (2000-2016)**



Source: SNE (2017a), Capacidad Instalada por Tipo de Central, años 1970-2016, www.energia.gob.pa/tmp/file/303/Generaci%C3%B3n%20El%C3%A9ctrica%202016.xls.

POWER SYSTEM REGULATION

The desire to maintain adequate generation resources to meet demand at all times is reflected in Panama's current reserve margin, which has fluctuated between 15% and 20% in recent years (ETESA, 2017a). The current reserve margin appears to be in line with the high end of margins applied in other jurisdictions, and no immediate generation scarcity can be identified. Should low utilisation rates of conventional generators be experienced in the future, their impact on the power market and declining reserve margins would likely need to be monitored closely.

Wind and solar PV in Panama have been assigned a value of zero with regard to their firm capacity (Table 1). This has led ASEP to undertake an in-depth assessment to better understand the true value of firm capacity from wind and solar PV in the power market. A refined approach in calculating the reserve margin, taking into account the true contributions of VRE, is likely to help avoid situations of over- or under-capacity in Panama.

Wholesale electricity prices in Panama are impacted heavily by weather patterns. El Niño produces dry seasons that reduce water resources and thus hydropower output, raising the marginal cost of electricity as more thermal generation is needed. Conversely, La Niña causes strong storms and increases water resources, causing a reduction in the average marginal cost of electricity.

Box 1: Panama's definition of firm capacity for VRE

The concept of firm capacity was introduced with the creation of the MEN in Panama, and is calculated and periodically revised by the National Dispatch Centre (CND). It refers to the actual amount of power that a generator (electricity supplier) can guarantee to make available under maximum operating conditions. Firm capacity is a commitment assumed by the generator, and is used by regulators to ensure that the standards governing the reliability of the grid are met.

In Panama, the firm capacity for VRE (solar and wind energy) is attributed a value of zero, given the intermittent nature of their output and non-dispatchability. Wind and solar generators have expressed several concerns regarding this practice, especially as the zero-attribution is likely to be below the real contribution of these technologies. The attribution of zero firm capacity can result in an artificially reduced revenue stream for wind and solar PV generators, as the Panamanian market remunerates firmness. Furthermore, as Panamanian transmission capacity can be a constraining factor at specific locations and times, the zero firm capacity attribution may require curtailment of wind and solar PV as only firm capacity resources are considered when scheduling generators ahead of time.

The Panamanian market rules compensate curtailment at the level of wholesale market prices, which can be volatile and often lower than PPA prices for the cheapest solar PV and wind generation facilities. This linkage between curtailment and wholesale market prices then adds price volatility and the risk of reduced remuneration levels to wind and solar investors.

Table 1: **Installed and firm generation capacity by type**

National Interconnected System (SIN) capacities in MW (as of 30 June 2017)				
	Installed		Firm capacity	
Total	**3 386**		**2 189**	
Thermal	**1 203**	**35.5%**	**1 090**	**49.8%**
Bunker	691	20.4%	657	30.0%
Coal	120	3.5%	108	4.9%
Diesel	392	11.6%	325	14.8%
Renewable	**2 182**	**64.5%**	**1 099**	**50.2%**
Biogas	8	0.2%	5	0.2%
Wind	270	8.0%	0	0.0%
Hydropower	1 777	52.5%	1 094	50.0%
Solar	127	3.8%	0	0.0%

Source: SNE (2017b), El Mercado Eléctrico de la República de Panamá, www.energia.gob.pa/tmp/file/311/Sector%20Electrico%20-%20Panama,%20170630.pdf.

In 1997, Panama restructured its electricity sector and developed a wholesale market. This included the hourly energy spot market and the daily generation capacity spot market. In addition, the contract market serves as a third market, where bilateral PPAs between producers and off-takers are organised. These PPAs help to limit risk and stabilise prices for end customers, while creating greater cash flow certainty for investors. The use of three markets provides investors with opportunities to find a balance between their investment risk and their expected rate on return, as participation in the contract market is not obligatory.

Box 2: Electricity sector investment and the role of PPAs

Panama uses auctions to determine capacities and prices within the contract market, including for renewable energy. ASEP sets auction guidelines, and ETESA arranges the auctions on behalf of off-takers – Panama's three distribution companies. Panama held its first wind auction in 2011, followed by a second wind auction in 2013. In 2014, Panama undertook its first solar PV auction. As of May 2018, no further auctions for VRE have been held.

The wind auctions resulted in the award of projects with a total capacity of 158 MW and 125 MW respectively, at prices between USD 95 per MWh and USD 110 per MWh in 2011, and between USD 92 per MWh and USD 97.5 per MWh in 2013. The majority of wind capacity operational in Panama has been built under the use of PPAs, with the exception of a 25.5 MW wind project which was commissioned in 2012.

The solar PV auction resulted in five companies being awarded a total estimated generation capacity of around 60 MW, with prices between USD 86 per MWh and USD 94.9 per MWh. However, as of April 2016, ETESA had only signed PPAs with two out of the five companies, representing around 24 MW of capacity, with none of the projects being commissioned yet (BNEF, 2017).

These results indicate that PPA contracts have a high degree of relevance in facilitating wind investment, and less so for solar PV investment. As such, the merchant solar PV development that has taken place can be explained by the sufficiently high wholesale market prices for solar PV installations in recent years. However, Panama's wholesale electricity market prices are expected to decline in the future, beginning in 2018. In its 2016 assessments, ETESA expected market prices to drop by some 15% to USD 61.3 per MWh until 2019, and despite growing electricity demand, anticipates prices to remain below USD 70 per MWh in the next decade. At the same time, Panama intends to expand fossil generation in the short term, with a 380 MW combined-cycle gas facility in Costa Norte planned to come on line in 2018 (ETESA, 2017b).

This development is likely to reduce the number of hours with very high market prices, as expensive oil facilities and inefficient plants may be replaced by the new less expensive natural gas generation, which has a higher firm capacity value than solar and wind energy under Panama's current wholesale market regulation.

Looking ahead, price uncertainty and the attribution of zero firm capacity to solar is likely to influence investment decisions, making the role of PPAs even more important. This could negatively affect the business case for planned solar PV plants that would rely on the wholesale markets alone, creating conditions that do not fully support a renewable energy scale-up in line with the PEN 2015-2050.

Sources: BNEF (2017), Climatescope 2017: Panama Description,
http://global-climatescope.org/en/country/panama/#/enabling-framework;
ETESA (2017b), Plan de Expansión del Sistema Interconectado Nacional 2017-2031: Tomo II.

To meet the future targets for wind and solar PV, the reliance on PPAs is likely to grow for both technologies. However, during IRENA's RRA consultations, stakeholders highlighted structural challenges with current PPAs that may negatively influence investment behaviour. While such an assessment is outside the scope of this RRA, several factors appear to be particularly relevant: the technology-neutrality of current remuneration schemes in combination with an assigned zero capacity factor for wind and solar PV; assignment of delivery points; curtailment rules, especially in combination with transmission constraints; and the time resolution for calculating energy supply requirements and energy supply remuneration.

Based on feedback obtained in the course of RRA consultations, which highlighted PPAs as a key area for further assessment, IRENA initiated a technical assistance project under the CECCA initiative. This project aims to support the Government of Panama in addressing one of the recommendations of this RRA (Section 4.1).

TRANSMISSION AND DISTRIBUTION SYSTEM

ETESA's transmission system consists mainly of 10 sections of 230 kilovolt (kV) lines that stretch from the Bayano Hydroelectric power station to the east of Panama City, to the Progreso substation on the border with Costa Rica. It also has 115 kV lines from the Bahía Las Minas thermal power station in Colón to the Panama I substation, and another section from the Caldera substation to the La Estrella and Los Valles hydroelectric plants. A 400 kV direct current (DC) interconnection with Colombia is also under development. The lower-voltage distribution system is divided into three main service territories, each served by its own distribution company.

Figure 14: **Transmission and distribution system in Panama**

Source: ETESA (2018), Mapa del Sistema Interconectado Nacional, www.etesa.com.pa/Mapas/Mapa_Interconectado/interconectado.html.

POWER SYSTEM OPERATION

The National Dispatch Centre (CND) is responsible for carrying out the centralised operation of the national electricity system. In this capacity, it undertakes the planning of generation resources needed to satisfy energy demand on a weekly basis, over a planning period of two years. This is implemented in accordance with market rules and is based on the updated information provided by generators, verified by the CND when necessary. The CND's planning also takes into account a range of factors, including rainfall and wind forecasts, fuel costs, demand, regional exchanges, availability and maintenance of plants and equipment.

Once the results are verified to be consistent, the CND issues the official weekly stochastic study, which includes 104 weeks of power dispatching and the calculation of water cost from reservoirs that have values equal to or higher than USD 0/MWh. Based on these results, the CND performs weekly pre-dispatch on an hourly basis, taking the first week of the stochastic study and detailing the energy dispatching of the 168 hours of the week. This is then used as the basis for the daily pre-dispatch the following day, updating certain data such as generator availability, regional electricity market (MER) transactions and resources.

The daily and weekly pre-dispatches reflect the increasing economic merit order of the units. Run-of-river hydro units, solar and wind power plants are dispatched first with zero variable cost. Thermal generators are dispatched with a variable cost associated with their efficiency, declared fuel price and their variable maintenance and operation. Hydro reservoir plants are dispatched with their variable cost calculated when the weekly dispatch is made.

In the real-time dispatch, the CND takes the daily pre-dispatch as a guide to make its real-time decisions, giving instructions to all power plants on how to operate, when to be cycled on or off, and when to be ramped up or down. VRE generation, such as solar and wind energy, are dispatched per their resource availability and under close communication between the system controllers and plant operators.

Power system planning will remain critical in Panama's evolving energy sector

The CND maintains sufficient spinning reserves, as well as storage in the form of hydropower reservoirs, to ensure the system is balanced and mitigate the risk of sharp supply variations. In addition, the MER also contributes spinning and non-spinning reserves in real time.

POWER SYSTEM OPERATIONAL PLANNING

The operational planning of the power system is undertaken by the CND, which conducts technical and economic assessments across different time horizons and at varying time scales (CND, 2018a):

1. **Midterm operational planning:** This is a forward-looking assessment of the operation of the power system over a two-year time horizon,[4] which aims to provide a forecast of the expected generation resources necessary to supply demand (future cost function of water, expected values for utilisation of available generation resources, marginal operating costs, level of the reservoirs and potential non-served load). The assessment is updated every six months.

2. **Midterm transmission network constraint assessment:** This is a technical assessment of the constraints in the operation of the transmission network with a forward-looking two-year time horizon. It aims to identify system constraints, as well as the operational measures necessary to guarantee the security of system operation. The study is updated every year.

3. **One-year-ahead transmission network security assessment:** This is a technical assessment of the constraints of the operation of the transmission network with a one-year-ahead time horizon. Similar to the two-year forward-looking study, it aims to identify the constraints of the transmission system and the need for operational measures to guarantee security of system operation. The study is updated every year and includes assessments similar to the midterm assessment, with a focus on priority operational issues for the shorter time horizon.

Besides the CND's operational planning assessments described above, the operational code requires the conduct of technical interconnection studies for new generating units, including VRE sources, to ensure that the integration of the new resources will not affect the system's stability (CND, 2018a).

4 A five-year time horizon is also included.

INFRASTRUCURE PLANNING

ETESA oversees the annual update of generation and transmission expansion plans. These plans are based on techno-economic studies that assess the performance of the system under different scenarios. As the development of new power plants is, in principle, carried out by private investors (with ASEP providing permissions), the generation expansion plan is only indicative in character. It aims to provide policy makers and market stakeholders with appropriate signals for policy development or investment decisions. However, in the past the majority of bids for the construction of new power plants have been carried out at the request of the regulator, bearing in mind the indicative plan.

The Generation Expansion Plan looks at a 15-year time horizon. The first five years assume the commissioning of new plants based on projects with licence-holders and concessions. For the following ten years, an optimal generation expansion mix is calculated under different scenarios using optimisation and simulation-of-operation software tools. Currently the assessments for the plan consider a co ordinated, but not integrated, operation with other countries participating in the MER.

The Transmission Expansion Plan is a ten-year optimal investment plan, aiming to eliminate existing and projected system constraints. The plan looks at operational costs, losses and the overall reliability of the system, and is based on techno-economic assessments of system performance. The studies use scenarios from the Generation Expansion Plan and are based on detailed steady-state and dynamic simulations of the transmission network, with a model implemented in Power System Simulation for Engineering (PSSE) to evaluate the performance of the system. Once approved by ASEP, the Transmission Expansion Plan must be implemented by ETESA.

The infrastructure planning process could be strengthened for better integration of VRE. This includes improving the modelling and forecasting of VRE technologies, and their complementarity with baseload hydropower. More detailed infrastructure and operational planning processes, which include higher shares of VRE penetration, will require the evaluation of system flexibility and a VRE generation forecast system, among other operational considerations.

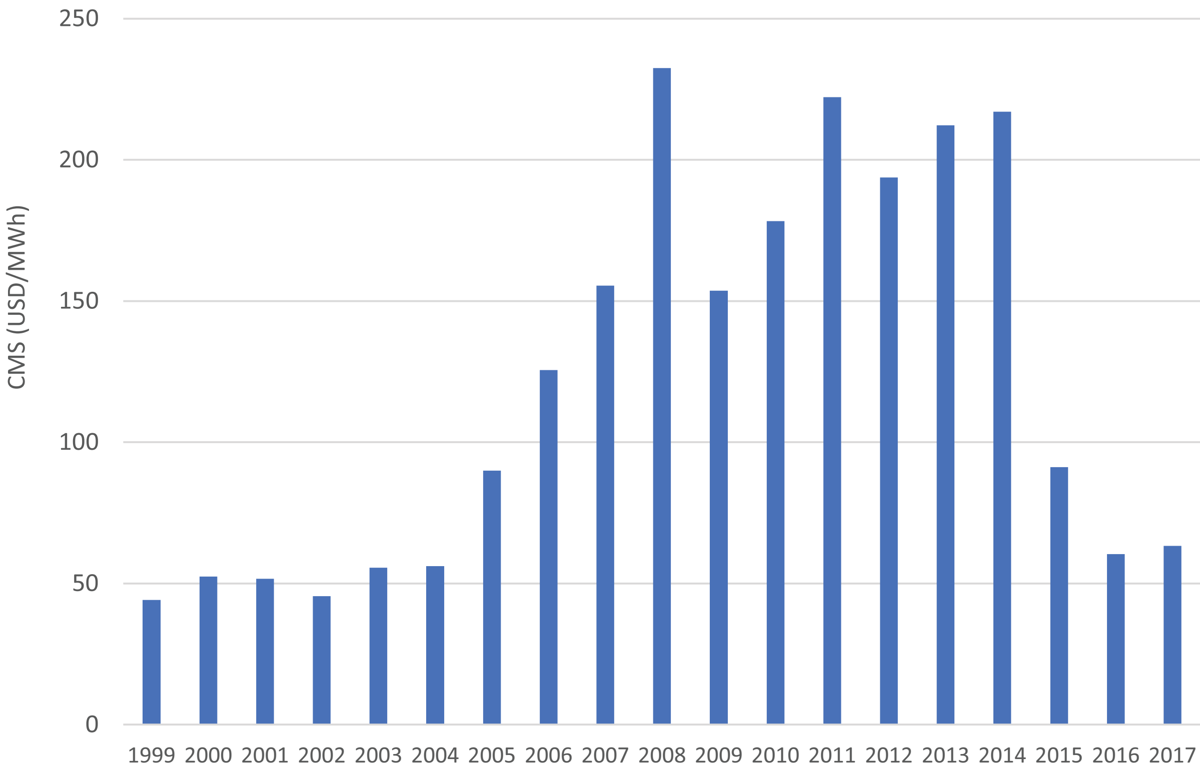
ELECTRICITY MARKET TRANSACTIONS

Electricity market transactions are directly linked with power system operations. Once the CND finishes the daily dispatch of the generation units, it performs the post-dispatch preparation for the following day. This is a document similar to pre-dispatch except that it contains data on real demand, exports or imports, and generation from power plants, as well as the generation that was estimated in the pre-dispatch but which faced disruption to supply.

This method ensures that any malfunctioning power plants do not affect the calculated hourly price or the system marginal cost (CMS). The CMS is marked hourly by the variable cost of the last generation unit required to meet the demand. In this calculation, the units that are on line for reasons other than supplying load (such as those subject to operational restrictions or providing operational safety) are not considered.

Figure 15 shows the historical yearly average of the CMS since 1999. At first the CMS was low, but then began to increase sharply between 2006 and 2014 mainly due to increases in fuel costs, as well as a failure to organise tenders for new investment to meet demand growth on time. In 2015, it began to decrease following a drop in fuel prices and the growth of VRE generation.

Figure 15: **Historical yearly average of the CMS (1999-2017)**



Based on CND (2018b), Oficial Historico Costo Marginal, www.cnd.com.pa/descargar_archivo.php?nombre=Oficial_Historico_Costo_Marginal.zip&tipo_informe=38&ano=2018.

With the post-dispatch prepared, the CND undertakes the preliminary market liquidation for the day and considers the PPAs from the different market actors. If an actor does not have a PPA, it sells or buys all the generated energy on the spot market or at the CMS price. If another actor has a commitment to supply a volume of energy under a PPA and its power units generate a surplus, the difference between these volumes of energy is sold on the spot market. If the supplier did not generate enough energy to fulfil the PPA requirement, it must buy the deficit on the spot market. The CND organises these assignments of sales and purchases for the spot market hourly.

At the end of the month, the CND prepares and distributes to all market actors a report called an economic transactions document that is a summary of the hourly transactions for the month. A schedule of activities is attached to the document, indicating the deadlines for depositing the amounts due and the time when the liquidating bank will transfer the registered credits on each account.

The liquidating bank is responsible for verifying that all actors have transferred the funds registered in the economic transactions document. If there are any missing deposits, they will be reported to the CND, which will then order the bank to execute the compliance guarantee to that actor.

The CND conducts a weekly verification of the actors' firm capacity. First, the average weekly capacity is calculated for each power plant, considering the firm capacity included in any contracts. These values are then compared with the committed energy, which should be less than the calculated weekly capacity of the power plant. If this is not the case, the actor is penalised.

The CND records all market statistics, which are publicly accessible online. The liquidating bank oversees the spot market transactions, while the transactions that are part of PPAs are settled between the actors involved in such contracts.

Panama's installed solar power capacity has exceeded 100 MW
Photograph: Shutterstock

ELECTRICITY TARIFFS

The electricity tariff structure is developed by the distribution companies and approved by the ASEP. The electricity tariff comprises four elements: generation; transmission; distribution; and commercialisation. Transmission and distribution costs are regulated and have historically been about USD 0.01 per kilowatt hour (kWh) for transmission and USD 0.05/kWh for distribution. Generation costs are determined on the wholesale market with the purchase of energy and firm power by the final user through PPAs, and/or the purchase of energy on the spot market. If PPAs are insufficient to cover all demand of final users at any hour, the CND will then assign a distribution company to purchase this difference in the spot market.

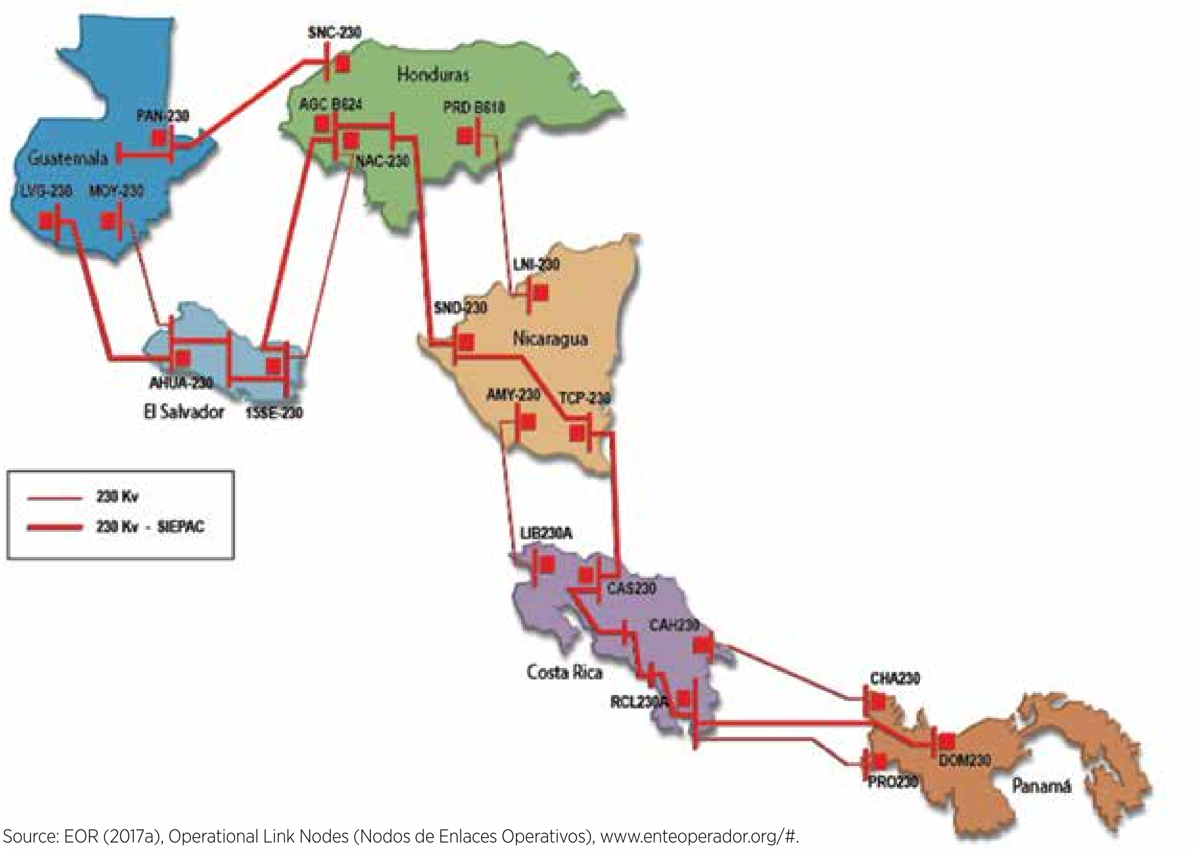
Tariff details are published every six months by the ASEP. The values in force until 30 June 2018 are shown in Annex II.

The end-user tariffs determined by distribution companies, which were previously classified only based on consumer type (residential, commercial, industrial and government customers), also vary according to the consumer's level of consumption and voltage:

- Rates for customers connected to low-voltage grids (equal to or under 600 volts):
  - Simple Rate for customers with demand equal to or under 15 kilowatts (kW) per month
  - Maximum Demand Rate for customers with demand over 15 kW per month
  - Time Block Rate for customers upon their request, which allows for a range of prices depending on the electricity supply schedule (peak or off-peak periods).
- Rates for customers connected to medium-voltage grids (over 600 volts and under 115 kV) or high-voltage grids (over 115 kV):
  - Maximum Demand Rate available to customers upon their request
  - Time Block Rate providing a range of prices depending on the electricity supply schedule (peak or off-peak periods).

The rates include adjustments for changes in fuel prices, rebates for unused energy costs and actor penalties, as well as subsidies for final consumers with very low consumption levels.

Figure 16: **Geographic localisation of SIEPAC line**



Source: EOR (2017a), Operational Link Nodes (Nodos de Enlaces Operativos), www.enteoperador.org/#.

2.4 CROSS-BORDER POWER TRADE

Panama currently has three 230 kV cross-border transmission lines:

- from the Progreso substation in Panama to the Rio Claro substation in Costa Rica
- the Central American Electric Interconnection System (SIEPAC) line section from the Veladero substation in Panama to the Rio Claro substation in Costa Rica
- from the Changuinola substation in Panama to the Cahuita substation in Costa Rica (ETESA, 2017a).

Panama and Colombia are also jointly developing a 400 kV DC interconnection, which would connect the MER with South America. The Colombia-Panama Electric Interconnection (ICP) is the owner of the project and is leading its development. Interconexiones Eléctricas S.A., Colombia's electricity transmission company, and ETESA have equal ownership of the project.

The interconnection of Central American countries began with bilateral transmission interconnections between neighbouring countries. Early on, energy transfers were only carried out in blocks of between 5 MW and 50 MW, under specific arrangements. The bilateral connections have evolved into a regional transmission line linking six Central American countries, which is conceived as the SIEPAC (Figure 16).

In light of the strong political support for the regional project by Central American countries, the Marco Treaty of the Electricity Market of Central America was signed in 1996, which gave rise to the creation of the MER that relies on the SIEPAC infrastructure. Presently, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama are part of the MER.

THE MARCO TREATY

Signed by the six governments in 1996 and coming into force in 1999, the Marco Treaty of the Electricity Market of Central America established the Regional Operations Entity (EPR), which owns the SIEPAC line. Furthermore, the treaty led to the creation of a regional regulator, the Regional Commission for Electrical Interconnection (CRIE), and a regional market operator, Regional Operator Entity (EOR) (World Bank, 2011).[5]

Located in Guatemala, the CRIE started operations in 2000 as the regulatory authority of the regional market with its legitimacy recognised by all parties to the Marco Treaty. It has an Executive Secretary and a Board of Commissioners consisting of one representative from each country, which is often a member of the national regulator.

The EOR was created in 2001 and as its own legal entity that is applicable to SIEPAC countries (Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama). It has an Executive Director and a Board of Directors, which consists of two representatives from each country, who are typically the director of the national system operator and a representative of the national market actors. The EOR is headquartered in El Salvador, together with the Regional Dispatch Centre (World Bank, 2011).

The Second Protocol to the Marco Treaty established the Steering Committee of the Regional Electricity Market (CDMER), which is located in Costa Rica. The CDMER is responsible for promoting the development of the EOR, and taking decisions to achieve the objectives of the Marco Treaty and its protocols. To this end, it set up co ordination mechanisms with the CRIE and the EOR.

Under the CRIE's regulation of the MER, each member country is allowed to operate per their own national rules; however, there must be effective co ordination at the regional level. The MER is a day-to-day trading market, itemised by the hour. All actors of the member countries are also members of the MER, and can undertake contracts and transactions with actors from different countries.

REGIONAL ELECTRICITY TRANSACTIONS

Transactions in the MER are made between actors from different countries, which can be through firm contracts, non-firm contracts or spot transactions. Firm contracts can be made monthly or annually and include a fee to obtain transmission rights (Derecho de Transmisión [DT]), which guarantees the right to transmit contracted energy between the actors. The fee is paid to the EOR monthly and is distributed among the transmission companies that participate in the DT (World Bank, 2011).

Non-firm contracts can be agreed between two actors on a daily basis. One of the actors is responsible for the regional transmission charges, known as Transmission Variable Costs, which are calculated hourly as the cost difference between the injection and withdrawal point in the system (nodal pricing).

The third option is spot transactions, which can be imported by the CND, or opportunity offers, which can be exported by actors. In Panama, opportunity offers to purchase imports or withdrawals from the regional transmission network are only made by the CND on behalf of the market. The CND makes an offer to purchase energy for each hour of the following day from the MER, using a price lower than the variable cost of the last dispatched unit in the national market, creating the ability to replace a more expensive generator in the national market.

For export opportunity offers, the CND publishes daily on its website an hourly template listing all national energy surplus not dispatched (surplus available for export), also indicating the variable cost of each generator. The regional market actors that wish to buy fill out a template indicating the amount of power in MWh and the price of their offer, which must be equal to or greater than the corresponding variable cost, and upload it to the CND website before 13:30. The CND sends all the offers to the EOR, which allocates the purchasing/selling intentions of the actors. Every day, it issues the regional pre-dispatch where the allocated and non-allocated purchases and sales appear.

At the end of the month, the EOR develops a Regional Economic Transactions Document, which shows the summary of all transactions settled in the month. This information also includes a calendar of actions where actors who have debts must transfer the credits into the account of the regional liquidating bank in a specific period. To participate in the MER, all agents must have guarantees of payment at the liquidating bank. The EOR deducts the amount of credits from the value of the guarantee in the daily transactions, thus validating that no transactions will take place without a guarantee.

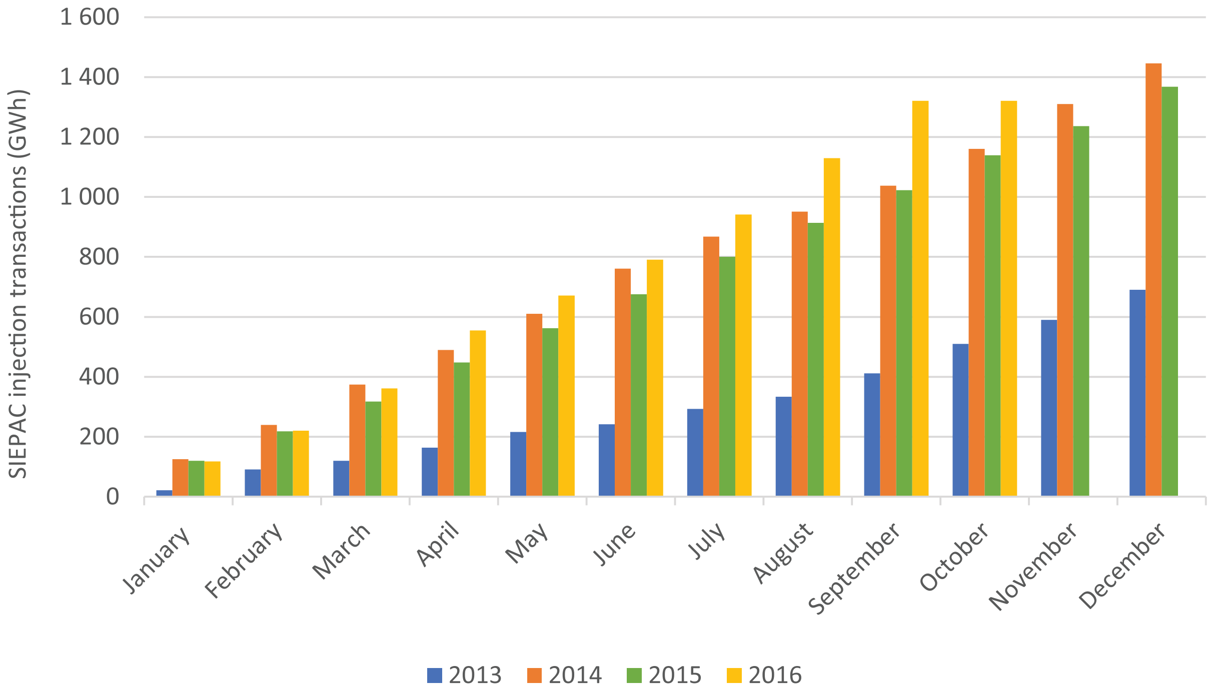
Figure 17 displays SIEPAC injection transactions from 2013 to October 2016, which show upward growth over the years.

5 Transmission rights (DT) is a system of trading the rights to using transmission lines.

The transmission entity (EOR in this case) will issue rights to use the regional line (SIEPAC) and make it available to buyers and sellers of electricity in the region. The regional energy buyer/seller will then buy these transmission rights in order to use the line to transmit/transport the energy across the region for their needs.

The regional transmission line is often constrained and transmission entities are required to plan ahead of time to manage the system. The transmission rights system allows them to plan ahead and offers a transparent pricing system for the users.

Figure 17: **SIEPAC monthly injection transactions (2013-2016)**

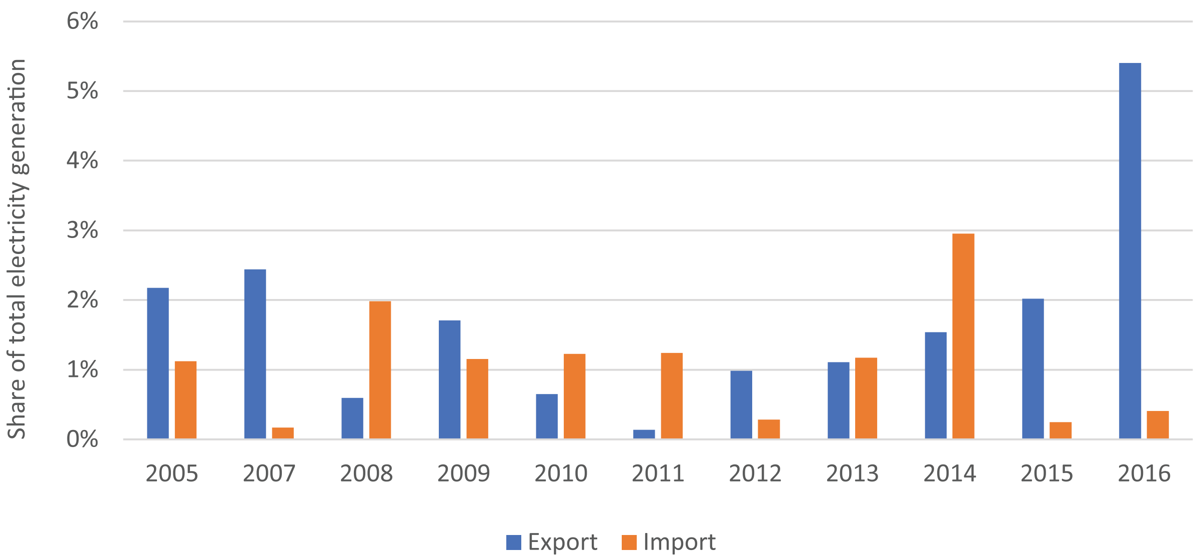


Based on EOR (2017b), Transaction information (Informe de Transacciones), www.enteoperador.org/#.

Panama has considerably increased its electricity exports since 2010, reaching 5.4% of total electricity generation in 2016. Meanwhile electricity imports have varied over the years, but due to the high exports in recent years, imports have seen values of less than 1% of total electricity generation (Figure 18).

A robust workforce will be essential to underpin Panama's growing solar PV and wind energy market

Figure 18: **Share of export and import of electricity as a proportion of total electricity generation in Panama (2005-2016)**



Based on CEPAL (2017), Estadísticas del Subsector Eléctrico de los Países del Sistema de la Integración Centroamericana (SICA).

2.5 ENERGY POLICY AND REGULATORY FRAMEWORK

NATIONAL ENERGY POLICY

The SNE is responsible for establishing national energy policy and strategy, and developing a long-term plan to assure the reliability of the energy system and security of supply. It entails policy, economic and regulatory aspects of energy, and aims to:

1. Provide the entire population with a modern and reliable energy system
2. Reduce the carbon content of the energy supply
3. Make rational and efficient use of energy resources
4. Ensure uninterrupted national energy supply.

Panama's national energy policy considers eight actions in line with the sustainable development of the energy sector:

1. Drafting of a long-term plan for the country's energy sector development
2. Comprehensive management of water basins
3. Spatial planning
4. Development of pricing for the carbon content of energy
5. Implementation of the Law on the Rational and Efficient use of Energy
6. Reorganisation of the laws on renewable sources
7. Sustainable cities
8. Energy and education programme.

NATIONAL ENERGY PLAN 2015-2050

In March 2016, the Government of Panama approved the PEN 2015-2050. The plan was undertaken by the SNE and was developed following country-wide public forums involving the government and more than 800 people from civil society, the public and private sectors, and indigenous communities.

The plan outlines the general and conceptual guidelines for Panama's energy sector over the next 35 years, and serves as a roadmap for diversifying the energy sector and advancing energy access, energy efficiency, energy security and the decarbonisation of the energy system. It is divided into five parts:

1. Conceptual guidelines for the sustainable development of the sector
2. The 2015-2019 Short-Term Operational Plan
3. Scenarios (reference and alternative)
4. Proposal for a long-term energy policy (2015-2050)
5. Report of the consultative process.

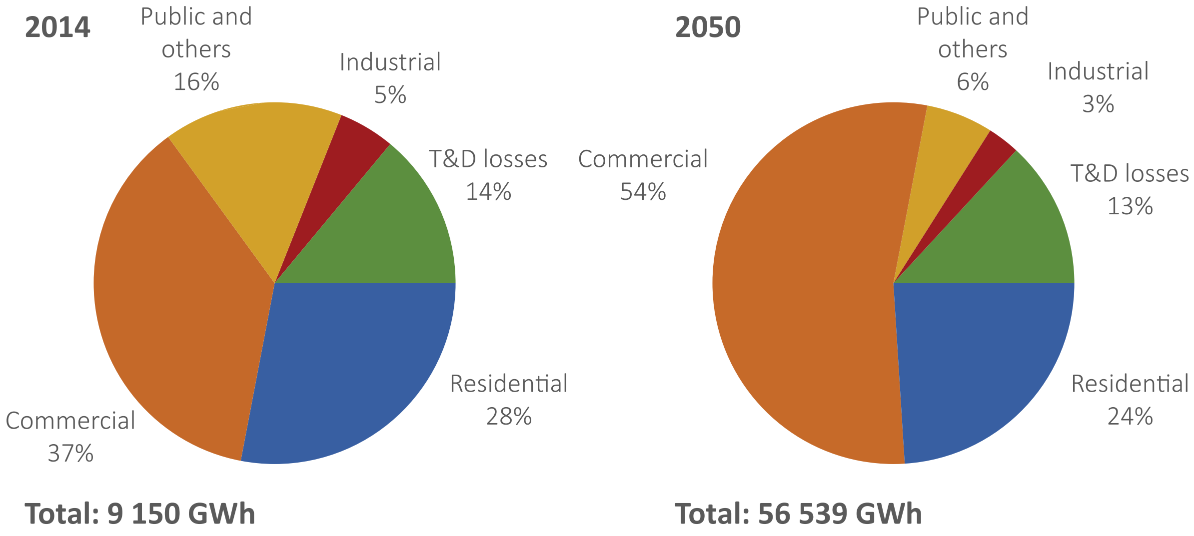
The plan analyses two possible scenarios (reference and alternative) and compares them to identify main actions to enable the achievement of the national energy sector goals as described through the alternative scenario.

The plan analyses a base case (reference scenario), which assumes historical projected growth without the implementation of any regulations intending to curb demand, and contrasts it with other alternatives that consider both consumption efficiency and responsibility (for example, through the expansion of mass-transit solutions and high-efficiency refrigeration and other home appliances) and the incorporation of renewable energy and less carbon-intensive fuels (such as solar, wind and liquefied natural gas generation) in order to decarbonise the Panamanian energy supply.

Concerning electricity, the reference case shows that Panama's demand growth trajectory would lead to a higher share of coal in the power mix by 2050. The ambitious scenario, however, suggests that renewable energy could reach 70% of supply in the next 35 years, while meeting growth in demand (SNE, 2015).

According to the reference scenario, which establishes a baseline assuming a "business-as-usual" scenario, the distribution of electricity consumption shows a marked increase between 2014 and 2050 in the commercial sector, with the losses to the system remaining in the range of 13-14%. At the same time, annual consumption would increase from 9 000 GWh today to 56 000 GWh in 2050 (Figure 19).

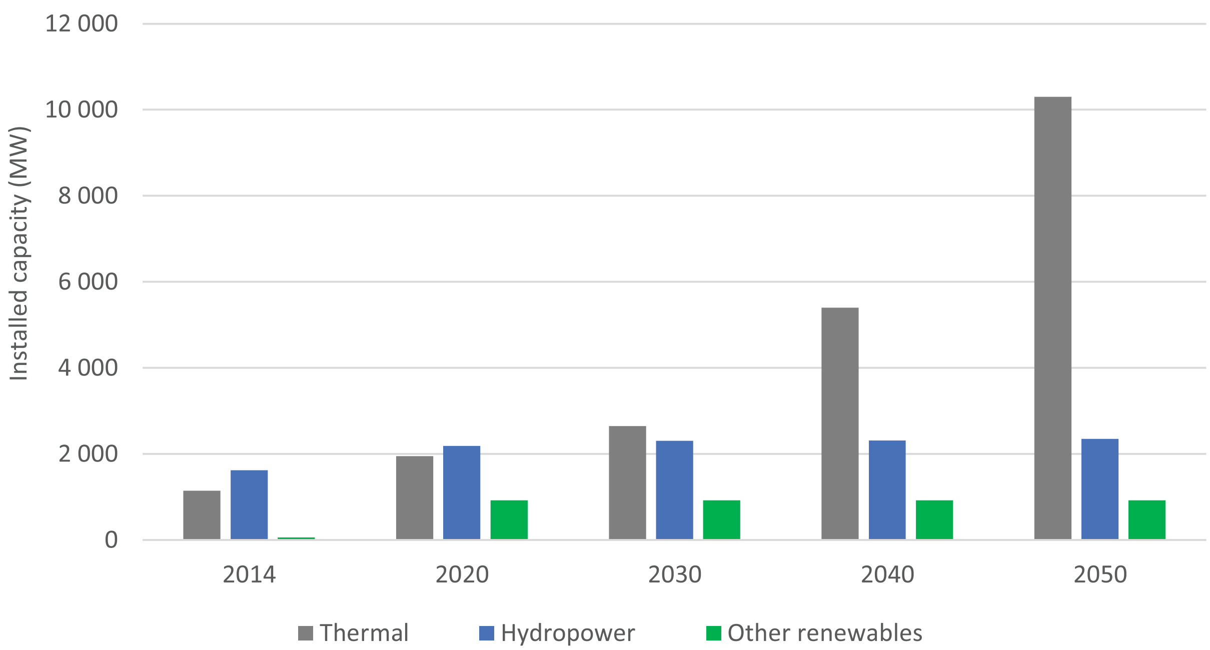
Figure 19: **Reference scenario: distribution of electricity consumption (2014 vs 2050)**



Based on SNE (2015), Plan Energético Nacional (2015-2050).

The reference scenario suggests steady growth in thermal generation, with around 10 000 MW of installed capacity by 2050, and a stagnation of renewables and hydropower capacity after 2020. Thermal sources account for 76% of the electricity mix, while renewables (hydro, solar and wind) only cover 24% (Figure 20).

Figure 20: **Reference scenario: installed electricity capacity (2014-2050)**

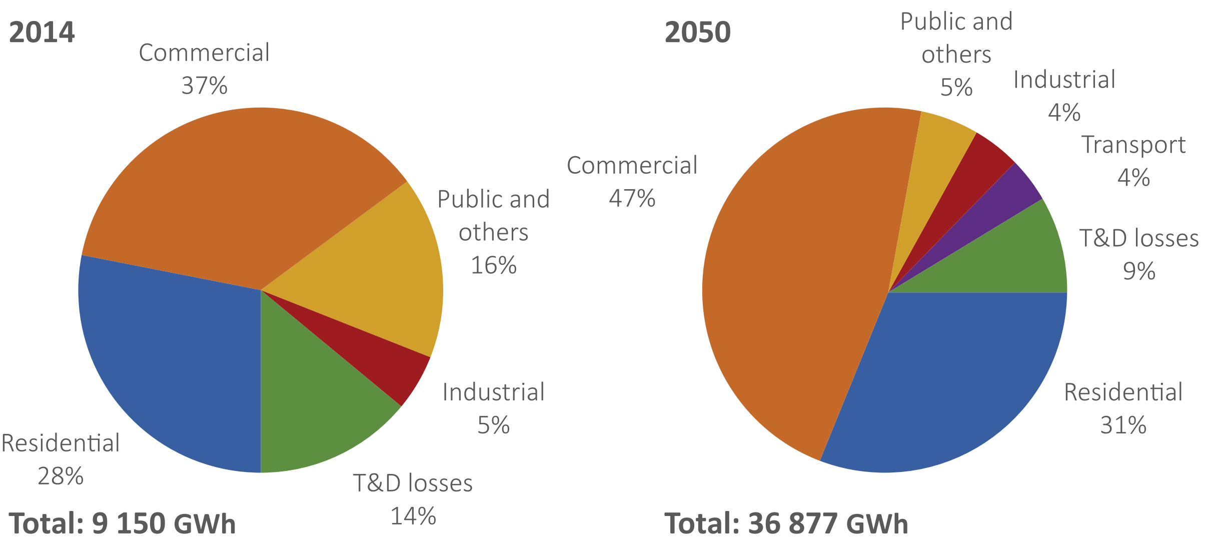


Based on SNE (2015), Plan Energético Nacional (2015-2050).

Panama reached 1 769 MW of installed hydropower capacity in 2016
Photograph: Shutterstock

The alternative scenario seeks to change the current paradigm and reach a desired energy future. In this scenario, energy efficiency measures have been expanded from their current low application so that annual consumption is reduced to 36 877 GWh, while transmission and distribution losses drop from 14% to 9% (Figure 21).

Figure 21: **Alternative scenario: distribution of electricity consumption (2014 vs 2050)**



Based on SNE (2015), Plan Energético Nacional (2015-2050).

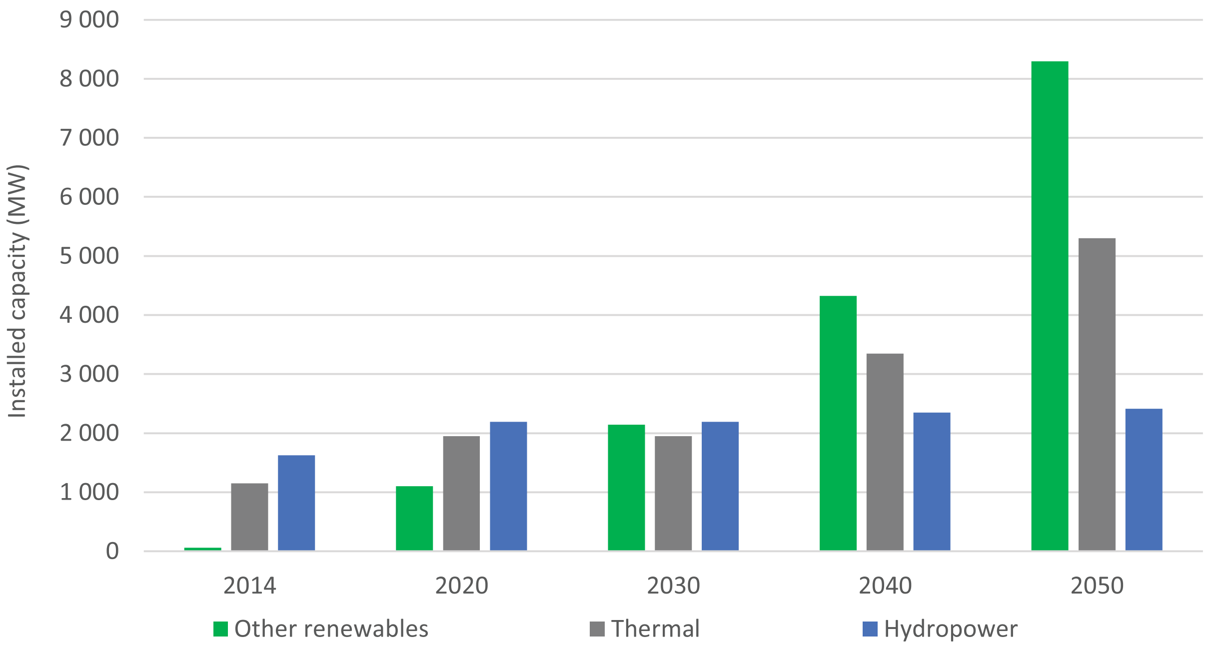
Renewables hold a significantly larger share of the electricity mix than thermal sources in the alternative scenario. By 2050, with the implementation of adequate policies, non-conventional renewables (solar and wind energy) would exceed an installed capacity of 8 000 MW, and when accounting for hydro, renewables take a 77% share of the power mix (Figure 21).

Thermal sources, meanwhile, would only reach an installed capacity of just over 5 000 MW by 2050, around half of the thermal capacity under the reference scenario (Figure 20).

Achieving the alternative scenario of the PEN 2015-2050 would have significant implications across the energy sector (SNE, 2015):

- **Electricity demand:** A reduction in electricity demand through increased energy efficiency (including better building design) and reduced transmission and distribution losses. Compared to the reference case, electricity demand drops by 35%.
- **Electricity supply:** Total installed capacity in the alternative scenario is 18% higher than the reference case. Increased solar and wind capacity, together with hydropower and biomass, accounts for around 77% of installed capacity.
- **Fossil fuel consumption**: Gasoline and diesel consumption is reduced by 42% and 29%, respectively. This is due to a more electrified transport sector, including through a greater use of the Panama metro and increased adoption of electric vehicles. LPG consumption is reduced by 31% due to its substitution by electric stoves in households, resulting in an increase in electricity demand in the residential sector of 7.2%.
- **Carbon dioxide (CO^2) emissions:** A 61% reduction in CO^2 emissions compared to the reference case.

Figure 22: **Alternative scenario: installed electricity capacity (2014-2050)**



Based on SNE (2015), Plan Energético Nacional (2015-2050).

III. RENEWABLE ENERGY DEVELOPMENT

3.1 RENEWABLE ENERGY RESOURCE POTENTIAL AND DEVELOPMENT

The renewable energy potential of Panama is abundant and diverse, and includes resources such as hydro, wind, solar, geothermal, marine and biomass (bagasse, husk, wood, charcoal, peat, biogas and bioethanol). Despite its vast untapped potential, Panama's energy needs are largely met with fossil fuel resources.

The potential and status of development of renewable energy resources in Panama are discussed below.

HYDROPOWER

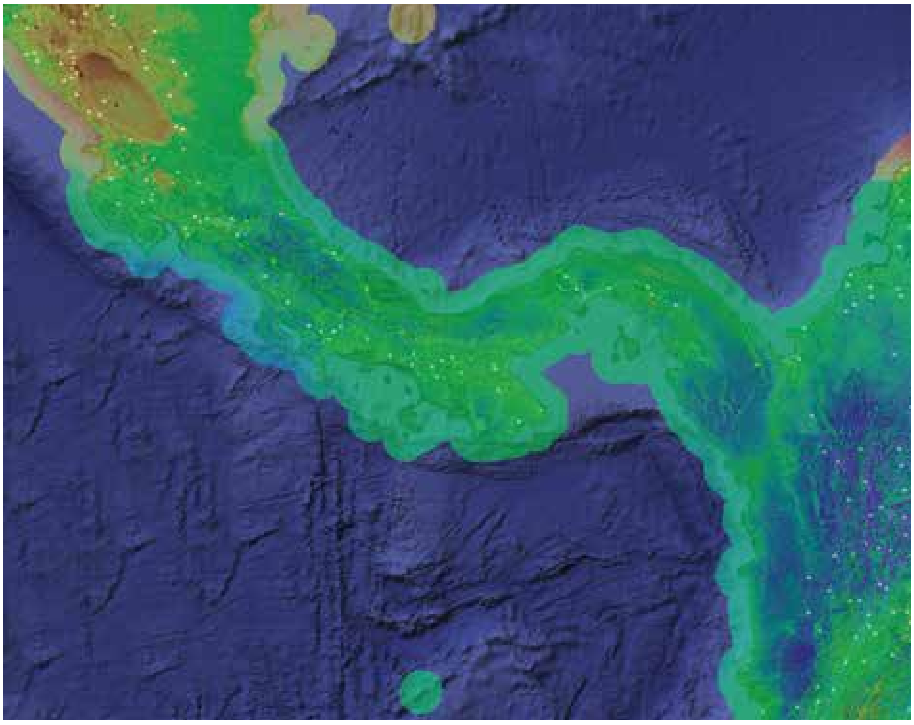
Hydropower is the largest electricity source in the country, with an installed capacity of 1769 MW in 2016, corresponding to a 53% share of the total installed capacity (Figure 11). Hydro potential has been extensively studied, revealing an estimated potential of approximately 11 879 GWh/year (translating to an installed capacity of 2 389 MW, with an average net capacity factor of 0.57) (SNE, 2015). A total of 42 sites have been identified for plants with a capacity under 1 MW, and 53 sites for plants over 1 MW. The potential for large plants over 100 MW has been exhausted, with the latest being the 220 MW Changuinola II project, planned by EGESA (SNE, 2015).

WIND ENERGY

Panama's wind resources are spread throughout the country, and improve along the Caribbean coast and at several wind passages on mountain ranges. IRENA's Global Atlas shows average wind speed estimates of 5-7 metres per second (m/s) at a height of 200 metres (m) (Figure 23). According to the PEN 2015-2050, measurements undertaken for ETESA at 40 m high have identified sites with average speeds of between 6 m/s and 11 m/s together with a capacity factor of 35% (SNE, 2015). Offshore wind energy potential has yet to be assessed.

Panama has 270 MW of installed wind power capacity, located entirely in the municipality of Penonomé, in the province of Coclé (SNE, 2015). As of February 2017, ASEP had granted 662 MW of permanent wind licences for the future development of projects that would allow developers to begin construction; these licences required guarantees from the applicants, which would be executed should the project not be completed, especially under PPA obligations. Provisional licences for an amount of 870 MW were also granted for future development of wind.

Figure 23: **Wind resource assessment in Panama**



Source: IRENA (n.d.), Global Atlas for Renewable Energy, www.irena.org/globalatlas; map data: DTU 2015; base map: Google 2016.

Furthermore, IRENA's suitability maps show potentially viable areas for the development of decentralised wind power systems (systems that are not connected to the distribution or transmission grid) and for systems connected to the grid. The maps indicate the potential wind resource for developing wind projects through a range of yellow-red colours (yellow being less suitable, and dark red being the most suitable). To verify this, existing wind power plants and those under construction are marked on the map, corroborating the reliability of the analysis for the two wind farms to the south. The suitability analysis for grid-connected wind power shows that Panama's wind generation facilities correspond to the areas with higher resource (Figure 24), while the areas suitable for decentralised wind remain distant from the main transmission system but within strong resource areas (Figure 25).

Figure 24: **Suitability analysis for grid-connected wind power (1 km resolution)**

Source: IRENA (n.d.), Global Atlas for Renewable Energy, www.irena.org/globalatlas; map data: DTU 2015; base map: Google 2016.

Figure 25: Suitability analysis for decentralised wind power (1 km resolution)

Off-grid wind 75km grid distance 1km resolution IRENA 2015

- 60% - 70% sustainability
- 70% - 80% sustainability
- 80% - 90% sustainability
- 90% - 100% sustainability
- Existing wind farms - thewindpower.net April 2016
- OSM power lines

Source: IRENA (n.d.), Global Atlas for Renewable Energy, www.irena.org/globalatlas; map data: DTU 2015; base map: Google 2016.

Box 3: Global Atlas for Renewable Energy

As part of IRENA's project facilitation support to its Members, the Agency's renewables assessment includes publication of resource maps through the publicly available Global Renewable Energy Atlas. The tool holds over 2 000 maps and zonal suitability assessments, and integrates maps with key local information such as distance to transmission infrastructure, population and topography, which can help identify zones suitable for development.

In 2017, Global Atlas 3.0 was launched, which now includes solar and wind resource maps with a 1 km spatial resolution that are extensively validated. Through the zoning methodology, IRENA has supported regional market analysis for Latin America to identify suitable zones for both utility-scale and decentralised solar and wind development, which provide an indicative technical potential.

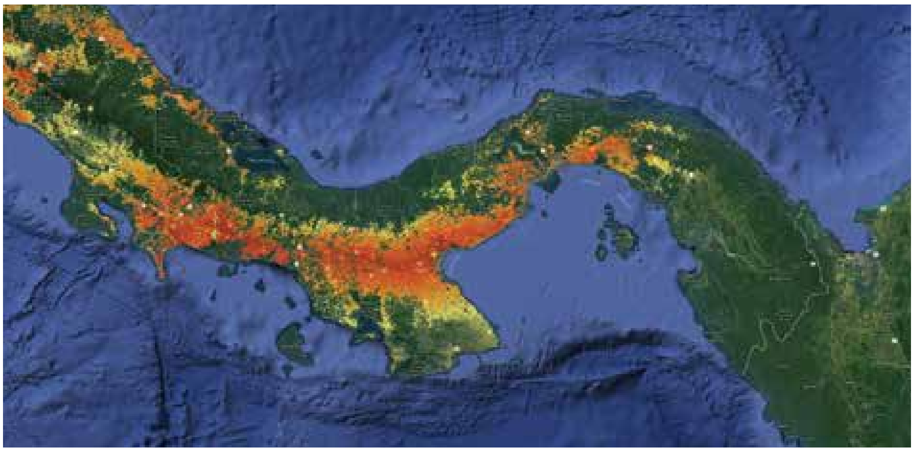
SOLAR ENERGY

Panama receives an average irradiance of 4.8 kWh/m^2/day, with the strongest resource being identified at the south of the provinces of Chiriquí and Veraguas, with an average of over 5 kWh/m^2/day (SNE, 2015). Solar has been exploited in the country to a very limited extent, primarily in rural areas and isolated industrial applications, such as communication systems, lighting on marine buoys, and drying processes in agriculture.

Solar power plants started to be installed in the country in 2013 and the installed capacity of solar power reached 90 MW in 2016, and 127 MW as of June 2017 (Table 1). As of February 2017, ASEP had granted permanent solar licences for future development of 345 MW, and provisional licences for 376 MW.

Highly suitable areas for the location of solar PV plants are quite wide-ranging and offer a significant opportunity. Figures 26 and 27 show IRENA's suitability maps displaying solar resources throughout the country, both for grid-connected and decentralised generation facilities. The maps reveal higher solar potential throughout most of the country than for wind, with the most suitable areas being in the south and west regions of Panama given the proximity to grid infrastructure.

Figure 26: **Suitability analysis for grid-connected solar power (1 km resolution)**



Grid connected solar PV 75km grid distance 1km resolution IRENA 2015

- 60% - 70% sustainability
- 70% - 80% sustainability
- 80% - 90% sustainability
- 90% - 100% sustainability

Source: IRENA (n.d.), Global Atlas for Renewable Energy, www.irena.org/globalatlas; map data: 3TIER 2015; base map: Google 2016.

Figure 27: **Suitability analysis for decentralised solar power (1 km resolution)**

Off-grid solar PV 75km grid distance 1km resolution IRENA 2015

- 60% - 70% sustainability
- 70% - 80% sustainability
- 80% - 90% sustainability
- 90% - 100% sustainability
- OSM power lines

Source: IRENA (n.d.), Global Atlas for Renewable Energy, www.irena.org/globalatlas; map data: 3TIER 2015; base map: Google 2016.

GEOTHERMAL ENERGY

Preliminary geothermal potential assessments began in Panama in the 1970s. However, further site-specific studies and evaluation have not taken place since, leaving resource estimates to vary widely. The preliminary studies identified 23 areas as sources of hot water in the country, and three of these sources have the technical potential for geothermal energy exploitation: Calobre in the province of Veraguas; Cerro Colorado in the province of Chiriquí; and El Valle de Antón in the province of Coclé. Other locations with geothermal potential were also located, including Tonosí in the province of Los Santos, and Coiba Island (SNE, 2015).

Panama has sought to exploit its geothermal resources. In early 2017, the Technical University of Panama organised its first geothermal expedition to identify possible new sources of geothermal energy in the country (Richter, 2017). Plans were also announced for a possible 5 MW geothermal project in the Chiriquí province that would become the country's first geothermal generating unit (Richter, 2013).

Barriers including high upfront costs and investment risks, particularly in the exploration phase, must be overcome for Panama's successful geothermal development. The primary cause of the high investment risk is the lack of resource studies in Panama that can differentiate the availability of high, medium and low enthalpy geothermal resources.

BIOMASS

Biomass potential varies greatly depending on human activity. Cane bagasse has been used traditionally in sugar mills as a source of energy for sugar processing and to produce electricity, and it has an estimated annual electricity generation potential of about 28 GWh (SNE, 2015). The drying process of coffee and rice crops generates coffee and rice husks, which are also used as fuel to produce heat. Wood and charcoal have traditionally been used in cooking in rural and small industrial areas, such as bakeries and grain drying.

A peat deposit of 80 km^2 by 8 m of thickness has been identified in the province of Bocas del Toro, with an estimated mass of 118 million tonnes, sufficient to feed a 30 MW steam plant for 30 years. Bioethanol is a by-product of biomass, and between 2013 and 2014 a plant supplied this fuel product that was then mixed with gasoline at a rate of 5%. The plant ceased operations recently, although this activity is expected to resume in the future. Panama's electricity market has an 8.1 MW diesel-based back-up plant (Urbalia Cerro Patacón), which uses methane as a by-product of waste. Additionally, the Project CADASA, a 30 MW capacity generator using bagasse, rice husks and other organic products is currently under construction (SNE, 2015).

MARINE ENERGY

Panama has almost 3 000 km of coastline with the Pacific and Atlantic Oceans, and could take advantage of the differences between high and low tides – over 5 m in the Pacific Ocean. Both oceans have waves of varying intensities, frequencies and sizes that could be exploited. There are also offshore winds that could potentially be exploited along the Caribbean coast (Atlantic Ocean). Despite having vast marine energy resources, its potential has not been assessed yet. The SNE has considered studies in line with its future plans.

3.2 RENEWABLE ENERGY POLICY AND SUPPORT SCHEMES

With the liberalisation of the electricity sector in 1997-1998, private investment began steadily pouring into the construction of new thermal generation facilities. At the same time, Panama had limited policies in place to support renewable energy deployment. An exception was Law 6 of 1997, which established Panama's regulatory and institutional framework for the electricity sector, mandating a 5% price premium on renewable energy sources bidding in auctions (ASEP, 1997).

In 2004, Panama sought to diversify its electricity mix by advancing a range of tax incentives for renewable energy project development through the adoption of Law 45, which allows renewable projects (less than or equal to 10 MW) to enter into a PPA with its respective electric distribution company, so long as electricity sales do not surpass 15% of the utility's maximum demand (ASEP, 2004). In addition, the law exempts renewable generators from all imported equipment tax, and provides an income tax credit of up to 25% of project investment,[6] which can be utilised up to 10 years from the date of commissioning. The law also exempts renewable energy projects under 10 MW from transmission or distribution fees, while projects of between 10 MW and 20 MW pay no transmission or distribution fees for the first 10 MW for 10 years (ASEP, 2004).

More recently, Panama established tax incentives for wind and solar energy. Law 44 of 2011 created wind-specific auctions, as well as accelerated depreciation on wind equipment and tax exemption for up to 15 years for wind equipment producers based in Panama. Law 37 of 2013 established solar-specific auctions in Panama, along with accelerated depreciation on solar energy equipment (ASEP, 2017).

Panama also maintains a net-metering scheme. Resolution AN No. 5399-Elec allows retail consumers with renewable generating units up to 500 kW to connect to the distribution grid and sell their excess generation. This surplus electricity is reimbursed by the consumer's distribution company, at the average per kWh price that it charged retail customers in that year (ASEP, 2012).

Through Law 42 of 2011, Panama developed an ethanol blending mandate of 10% in gasoline that was set to take effect in 2016. This law also established a 20% subsidy for feedstock costs in the first five years of operation of biofuel plants that process local biomass. Due to a lack of ethanol supply, the mandate was later suspended in 2014. However, the government still offers a tax credit of USD 0.159/litre to fuel blenders for the purchase of biofuels (IEA and IRENA, 2017).

A prolonged drought in 2014 significantly reduced Panama's hydropower generation, forcing the country to rely heavily on thermoelectric generation and electricity imports. As a result, the government announced its intent to continue developing non-hydro renewable sources to diversify the country's energy supply.

Panama should develop a long-term plan for electric mobility and sector-coupling

6 The tax break amount is measured by the amount of CO^2 emissions that are abated by the project annually. ASEP calculates this for each project, in co ordination with the Ministry of Economy and Finance and the National Environment Authority.

3.3 RESEARCH AND DEVELOPMENT OF RENEWABLE ENERGY

Research and development of renewable energy technology in Panama began in the 1970s. Today, universities in the country offer a wide range of engineering and technical courses to prepare students for work in the energy sector, including programmes in electromechanical engineering, electrical engineering, electronic engineering, civil engineering, industrial engineering and mechatronics engineering. Despite this, more emphasis is needed on equipping students with the technical, economic and institutional knowledge of renewable energy, particularly as it relates to growing shares of VRE in power systems, as proposed in the PEN 2015-2050. Moreover, training on planning with short- and long-term software programmes, operational forecasts for renewables, and the needs of control centres are still limited in Panama's higher education.

In response to this need, universities in Panama are beginning to tailor their programmes to suit the growing demand for renewable energy professionals. These include the energy and environmental engineering course offered by the Technological University of Panama (UTP) at the undergraduate, master's and doctoral levels, and upcoming degrees at the University of Panama (UP) in electricity and renewable energy engineering. Furthermore, options are increasing at private universities to study geophysical engineering for the development of geothermal technology.

The Gatun hydropower station in Panama
Photograph: Shutterstock

In addition to universities, Panama's main institutions involved in the study and evaluation of renewable energy include the following:

A. **The Hydro and Hydrotechnical Research Centre** was created in 1980, and undertakes research related to water resources and the environment.

B. **The Centre for Research and Innovation in Electrical and Mechanical Industry** was created in 2011 as an Energy Savings Unit, a Department of Research and Development, and a Department of Production Services. Within this structure, it hosts three decentralised units: the Centre for Training in Renewable Energies, the Innovation and Technology Transfer Centre, and the Astronomical Observatory of Panama.

C. **The City of Knowledge** is a development of more than 200 buildings and was established for the purpose of promoting sustainable development through international collaboration in the fields of business, academia and science. The city hosts several renewable energy companies, and its Vice Presidency for Business is responsible for identifying, attracting and recruiting companies, academic programmes, and research and training centres.

D. **ETESA's Hydrometeorology** Unit undertakes the planning, expansion, operation and maintenance of Panama's national network of meteorological and hydrological observation stations and water quality monitoring stations, per the international standards established by the World Meteorological Organization (WMO).

E. **The Panama Canal Authority** was established as an autonomous legal unit, and is charged with overseeing the operation, administration, management, preservation, maintenance and modernisation of the canal. The authority has installed an experimental floating solar plant of 22 kW, and will build further installations if the initial project is successful (Panama Today, 2017). This new solar generation would help displace fuel consumption, reduce the growth of aquatic vegetation in the lakes of the channel and reduce evaporation of the water of the lakes, while avoiding challenges related to land use.


The Panama Canal
Photograph: Shutterstock

IV. CHALLENGES AND RECOMMENDATIONS

4.1 OVERVIEW

In the 15 years following the privatisation of Panama's electricity sector, more than 1 500 MW of conventional hydro and thermal projects were awarded tenders with PPAs and enjoyed certain regulatory benefits,[7] such as fiscal incentives and tax exemptions. Against this background, the SIN has traditionally relied on baseload hydropower and thermal generation assets since its inception, with generating units enjoying the recognition of payment for their capacity, energy and ancillary services, such as spinning reserve, secondary regulation, quick start, and others.

Sarigua plant, the first solar plant in Panama with a capacity of 2 MW, was installed in 2013. After this milestone, new solar and wind projects have slowly emerged, all of which added up to 397 MW in June 2017. It has been difficult for these projects to compete effectively within a market that is geared towards conventional hydro and thermal power generation, as they are not offered payments for firm capacity.[8, 9]

The implementation of renewables has impacted the national market by lowering energy costs in the spot market, guaranteeing security of supply through the large volume of installed power and displacing thermal generation, thus reducing the country's carbon footprint, generating skilled labour and lessening dependence on volatile oil prices.

The system's marginal costs have reduced since 2014 due to dropping fuel prices and the large volume of renewable energy injected since 2011, including VRE since 2013. The use of these technologies can push prices to zero in off-peak periods, due to their marginal cost allocation being zero.

Table 2 shows how the number of hours when the CMS falls to zero has increased in recent years, which reduces prices in the spot market and can be threatening for actors who operate without a PPA.

7 Actors with thermal plants can index the price of energy according to the variation of the price of fuel, while the selling price for hydropower is fixed.

8 The current firm power definition requires resource availability for 95% of hours per year.

9 In the rainy season, a CMS that is equal to zero often causes energy to be sold at a price of zero.

Table 2: **Yearly hours with CMS values of less than USD 10**

	CMS=USD 0	CMS< USD 10
2010	0	7
2011	25	55
2012	2	13
2013	37	37
2014	174	174
2015	280	281
2016	780	931
2017	1 508	2 071

Source: CND (2018b), Oficial Historico Costo Marginal, www.cnd.com.pa/descargar_archivo.php?nombre=Oficial_Historico_Costo_Marginal.zip&tipo_informe=38&ano=2018.

At the same time, the increasing amount of new renewables generation has helped Panama export its excess power in the regional market. However, these benefits are at risk because VRE companies face economic challenges stemming from the current market model, which is based on more conventional sources such as hydropower and thermal generation, and does not recognise the unique operating characteristics of VRE generation.

The government, seeking to improve these conditions, developed a series of special laws and grid connection codes for VRE to incentivise renewable energy development. However, further regulatory adjustments could be undertaken to ensure that renewables can operate on a level playing field with fossil generators, as opposed to the current regulatory environment that favours conventional hydropower and thermal generation.

4.2 KEY CHALLENGES AND RECOMMENDATIONS

Variable renewable power, including wind and solar energy, are the main technologies outlined in the PEN 2015-2050 to diversify and decarbonise Panama's energy sector. At the same time, technological advances in other technologies, such as marine energy, also have the potential to make important contributions to the future energy mix.

The following recommended actions can help overcome barriers to enable an accelerated deployment of higher shares of renewables in an optimal way that supports the country's transition to a sustainable energy future.

REGULATORY AND FINANCIAL INCENTIVES FOR VARIABLE RENEWABLES

Challenge: Considering the government's ambition for a transition to 70% renewable energy in the national electricity mix by 2050, revised regulatory rules that provide a level playing field for renewables vis-à-vis conventional generation are required, especially in a competitive wholesale market with a medium-term outlook of low prices and transmission capacity constraints. The current regulatory framework conditions, and specifically the PPAs, are designed for dispatchable technologies such as coal, gas, oil and hydroelectricity, and do not incentivise new wind and solar PV projects.

Recommended Action: Assess the investment incentives for wind and solar PV projects under current and expected market conditions, with a specific focus on PPAs. Identify factors with a negative influence on investment behaviour and the required regulatory responses. Determine a set of implementable solutions leading to a strengthened investment environment without compromising the efficient functioning of the Panamanian wholesale market. These could include an adjustment to the compensation for curtailment, a new calculation of PPA-related remuneration levels and a new definition of firm power that takes into account the operating characteristics of VRE.

POWER SYSTEM PLANNING WITH HIGH SHARES OF VARIABLE RENEWABLES

Challenge: Planning will remain an important cross-cutting area for Panama's energy sector, as planners must cope with rising variability and uncertainty from the envisaged high penetration of solar and wind generation through to 2050. Without strong sets of quantitative techno-economic analyses to guide these planning efforts, however, generation expansion could be delayed, grid infrastructure development costs may be allocated inefficiently, and the overall reliable operation of the power system could be compromised.

Recommended Action: Develop a national strategy to improve power system planning and modelling with higher penetrations of VRE.

This will support Panama's power sector planning by defining long-term transition scenarios and near-term actions that can link the development of the grid with the development of renewable energy generation, while aligning with periodic updates to the PEN 2015-2050. Moreover, it could rationalise the management of connection queues, reduce or avoid interrupting renewables generation, support the efficient use of the SIEPAC regional line, and cut overall costs of the electricity system.

NEW OPERATIONAL PRACTICES FOR THE POWER SYSTEM

Challenge: Power system operations in Panama still reflect the "old paradigm" of centralised, dispatchable generation units. Given the unique physical conditions of VRE sources, challenges emerge for system operation with high shares of variable renewables. These can largely be classified as: flexibility, system adequacy and system stability challenges. As such, reliably integrating large shares of wind and solar generation requires modifications to the CND's operational practices as well as the identification of the necessary flexibility mechanisms.

Recommended Action: Conduct a comprehensive assessment to identify new operational practices that can provide adequate flexibility and robustness for the reliable operation of the power system with higher shares of VRE. These include enhanced forecasting techniques, improved ancillary services, more flexible scheduling of generation and load dispatch practices, and improved management of stocks, among other areas. If implemented widely, this recommendation will help ensure the reliability of the system in a more cost-effective way as it integrates large numbers of variable renewables into the system.

As part of IRENA's work with CND through the technical component of the CECCA initiative, the following issues were also identified as possible updates to power system operation in Panama:

- Provide training on the impacts of VRE on transient and frequency stability analyses, considering the impact of VRE.
- Automate system security analysis tasks using power system software analysis to allow closer real-time system security checks, with the aim of reducing VRE curtailment due to network congestion.
- Calculate transmission capacities closer to real time for better congestion management and consider forecasts for wind and solar production in these calculations to minimise curtailment.

DEVELOPING A RENEWABLE ENERGY WORKFORCE

Challenge: A robust workforce is essential for the growth of national solar and wind power implementation capabilities. An appropriate evaluation would allow better understanding of the current national workforce in the field of renewables, the projected needs for the future, and how existing and new education and training programmes can meet future needs.

Recommended Action: Undertake an assessment of the skills development needs in Panama's workforce to support efforts towards the 2050 renewable energy goal.

The assessment would entail, among other actions:

- Conducting a survey of current education and training programmes on renewables in Panamanian schools and universities.
- Determining the jobs that are currently available in the renewable energy sector and what types of training employers prefer.
- Identifying the need for new or expanded education and training programmes focused on renewables to achieve the goals.

LONG-TERM PLAN FOR ELECTRIC MOBILITY AND SECTOR-COUPLING

Challenge: Achieving the alternative scenario of the PEN would lead to a 61% reduction in CO^2 emissions from the energy sector, of which the majority comes from end-use sectors, led by transport. But so far, the deployment rate of low-carbon technologies in these sectors has been slow to achieve significant results, with transport in Panama depending 100% on fossil fuels. With the newly operating Line 1 of the Panama Metro, however, the electrification of transport in the country has begun.

To adapt Panama's energy system to this evolving paradigm, a comprehensive plan is needed that considers a rapid growth in demand from the electrification of transport, including from the introduction of expanded metro lines, electric passenger vehicles and electric buses.

At the same time, the generalised subsidy of LPG for cooking acts as a disincentive to deployment of electric stoves, and thus the shift in residential and commercial energy demand from the fossil-fuel sector to the electricity sector. Shifting this demand profile would provide important opportunities to meet increased demand in the end-use sectors with VRE generation, aligning with the goals of the PEN alternative scenario.

Recommended Action: Develop a long-term urban mobility plan based on the electrification of transport (metro system and vehicles), with this new demand powered by renewable energy. This recommendation can help speed up the use of renewable energy in the electricity mix, reduce transport problems that currently affect Panama (such as high levels of traffic congestion, urban planning, and low availability of public transport, among others), support the reduction of CO^2 emissions, and eliminate the current dependence of the sector on fossil fuels. The plan could also detail a more active role for electricity distributors in promoting electric mobility, possibly through schemes to facilitate the installation of electric vehicle charging stations.

In the commercial and residential sectors, examine the feasibility of a policy that can alter or eliminate subsidies for LPG. This should be underpinned by a study that details the social benefits of reducing LPG subsidies, and compares the societal costs of cooking with LPG against electric stove use deployed in concert with higher shares of renewable power.

INTERFACE BETWEEN THE NATIONAL AND REGIONAL ELECTRICITY MARKETS

Challenge: The Marco Treaty aims to promote gradual growth of a competitive regional market, the MER, by regional authorities (CDMER, CRIE and EOR) in co ordination with national authorities. However, there currently exists a lack of harmonisation among rules and methodologies, such as grid codes, relevant to the efficient functioning of the MER. Moreover, institutional gaps exist between single jurisdictions and the regional market. In this respect, more flexible market rules, including those governing the allocation of transmission rights, are needed to ensure firmness through the multiple resources of the MER, instead of the current approach which allows limited short-term transactions.

Recommended Action: Support regional efforts to assess and advise on improvements to regulatory interface between national and regional electricity markets.

While this recommendation is longer term and more regional in scale, it can help accelerate efforts at the regional level to find solutions to energy transfer problems on the MER, specifically grid design values and the sub-optimisation of regional dispatch that occurs when energy is "trapped" on the national markets. This is due to transmission constraints, such as the rigid dispatch processes. In addition, the great inertia made available via the MER helps to optimise the operational stocks needed to connect large volumes of variable renewables at a minimum cost.

Among the critical issues that need to be further analysed are: the definition of firm energy and its equivalence to firm capacity at national level; the authorisation of transmission rights and of long-term firm contracts; the creation of an intraday market to allow adjustment of the volume of variable renewables; reviewing the concept of interruptible service in firm contracts at the national level; and verifying the limited capacity of SIEPAC lines in terms of their design capacity.

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ANNEXES

ANNEX I: POWER PLANTS IN OPERATION IN PANAMA (2017)

COMPANY	PLANT NAME	NUMBER OF UNITS	TYPE	DATE ENTERED OPERATION	PRIVATE CAPITAL	MW
ENEL FORTUNA	Fortuna	3	Hydropower	Oct-84	51%	300
AES PANAMÁ	Bayano	3	Hydropower	1976: #1 & #2, 2002: #3	51%	260
AES PANAMÁ	La Estrella - Los Valles - Esti	6	Hydropower	1979, 2003	51%	222.0
AES CHANGUINOLA	Changuinola	3	Hydropower	Nov-11	100%	222.5
AES	Estrella De Mar	6	Bunker oil	Apr-2014	100%	72
CELSIA	Blm - cc	3	Diesel	1998 TG, 2000 CC	51%	160
CELSIA	Blm- Carbón	3	Coal	Mar-11	51%	120
PAN-AM GENERATING	Panam	9	Bunker oil	2000:1-6, 2016: 7-9	100%	156
PEDREGAL	Pacora	3	Bunker oil	Jan-2003	100%	54
GRUPO MELO	Canopo	1	Hydropower	Jan-2006	100%	1.133
CAFÉ DE ELETA	Hidrocandela	1	Hydropower	Jan-2006	100%	0.54
ESEPSA (GAS NATURAL-FENOSA)	La Yeg., Dolega, M.Monte	8	Hydropower	Aug-2006	100%	12.14
ESEPSA (GAS NATURAL-FENOSA)	Algarrobos	2	Hydropower	Jun-09	100%	9.86
ACP (Canal de Panamá)	Miraflores #1,2,5,6,7,8,9,10,11,12	10	Bunker oil	1963, 1976, 2002, 2008, 2014	0%	173.62
ACP (Canal de Panamá)	Gatún, Madden - Cogeneración	9	Hydropower	1912, 1934	0%	60.000
GENERADORA DEL ATLÁNTICO	Gena - cc	3	Diesel	2010	100%	157.75
HIDROPANAMÁ	Antón	18	Hydropower	May-009	100%	4.3
VALLEY RISE	El Giral	8	Bunker oil	2009	100%	50.4
CALDERA ENERGY CORP.	Mendre I	2	Hydropower	Sep-10	100%	19.76
HIDROBOQUERÓN	Macano	2	Hydropower	Dec-2010	100%	3.42
PASO ANCHO	Paso Ancho	2	Hydropower	Nov-10	100%	6.12
SALTOS DE FRANCOLI	Los Planetas i & i	5	Hydropower	2011 & 2017	100%	13.75
PEDREGALITO	Pedregalito i	2	Hydropower	Dec-2011	100%	20
RIO CHICO	Pedregalito ii	2	Hydropower	Dec-2011	100%	12.52
IDEAL PANAMA, S.A.	Bajo De Mina/Baitun	4	Hydropower	2012	100%	145.0
HIDRO IBÉRICA	El Fraile	2	Hydropower	Jan-2012	100%	5.35
CELSIA – BONTEX	Gualaca	2	Hydropower	Jun-12	100%	25.2
CELSIA – ALTERNEGY	Lorena/Pruedencia	4	Hydropower	2012	100%	89.98
CELSIA – ALTERNEGY	Cativá	10	Bunker oil	Feb-13	100%	87
HIDROPIEDRA	Hidropiedra	2	Hydropower	Sep-12	100%	13.14
ALTO VALLE	Cochea	2	Hydropower	Jan-2013	100%	14.93
HIDROTENENCIAS, S.A.	Concepción, Las Perlas Norte & Sur	6	Hydropower	2008, 2013, 2013	100%	30

ANNEX I: **CONTINUED**

COMPANY	PLANT NAME	NUMBER OF UNITS	TYPE	DATE ENTERED OPERATION	PRIVATE CAPITAL	MW
ELECTROGENERADORA DEL ISTMO	Mendre 2 G1, G2	2	Hydropower	Nov-13	100%	7.8
UEP PENONOMÉ I, S.A.	Nuevo Chagre I	22	Onshore wind	2014	100%	55.0
UEP PENONOMÉ II, S.A.	4 parks	86	Onshore wind	2014	100%	215.0
EMNADESA	Bugaba	3	Hydropower	Jan-2014	100%	3.278
ELECTRON INVESTMENT	Monte Lirio	3	Hydropower	Oct-14	100%	51.65
SAN LORENZO	San Lorenzo	2	Hydropower	Sep-14	100%	8.12
HIDRO CAISÁN	El Alto	1	Hydropower	Oct-14	100%	69.486
HIDROECOLÓGICA DEL TERIBE	Bonyic	3	Hydropower	May-15	100%	30
ENEL GREEN POWER	Solar Chiriquí	7	Solar PV	Jun-15	100%	9.3
CEISA	Las Cruces	3	Hydropower	Dec-2015	100%	21
DIVISA SOLAR 10 MW	Divisa Solar	8	Solar PV	Jan-2016	100%	9.9
KANAN	Santa Inés, Estrella Del Norte	17	Bunker oil	Apr-2016	100%	93
JINRO	Jinro	34	Bunker oil	Mar-2016.	100%	57.8
FOUNTAIN	La Potra/Salsipuedes	7	Hydropower	Aug-2016.	100%	57.9
FARALLÓN SOLAR	Farallon Solar 2	1	Solar PV	Dec-2016	100%	0.96
ENERGYST	Cerro Azul	27	Diesel	Jan-2017	100%	44.135
AZUCARERA NACIONAL	Cocle Solar 1	16	Solar PV	Jan-2017	100%	0.96
GENERACIÓN SOLAR	Zona Franca Albrook	2	Solar PV	Feb-17	100%	0.1
HIDROIBÉRICA	El Fraile Solar 1	8	Solar PV	Mar-17	100%	0.48
SOLAR COCLE VENTURE	Solar Coclé, Paris, Los Angeles	3	Solar PV	Mar-17	100%	27.50
EGESA	Sarigua	1	Solar PV	2013	0%	2.00
EMNADESA	Solar Bugaba	1	Solar PV	2017	100%	2.56
LLANO SANCHEZ SOLAR POWER, S.A.	Don Felix, Milton, Sol Real, Vista Alegre	4	Solar PV	2017	100%	31.70
PSZ1 S.A.	El Espinal	1	Solar PV	2017	100%	8.50
SOL REAL ISTMO, S.A.	Sol De David	1	Solar PV	2017	100%	9.90
SOL REAL UNO, S.A.	Solar Caldera	1	Solar PV	2017	100%	5.50
URBALIA PANAMA, S.A.	Cerro Patacón		Biogas	2017	100%	8.10
GENERADORA DEL ISTMO	Barro Blanco	3	Hydropower	Apr-2017	100%	28.5
		413			**TOTAL ......**	**3382.54**

Source: Based on CND (2018c), Capacidad Instalada, http://cnd.com.pa/informes.php?cat=5.

ANNEX II: SEMI-ANNUAL ELECTRICITY TARIFFS FOR REGULATED CUSTOMERS (UNTIL 30 JUNE 2018)

		EDEMET	ENSA	EDECHI
TARIFAS DE BAJA TENSIÓN				
Tarifa Simple BTS 1		*	*	*
Cargo fijo, por los primeros 10 kWh	B/. Cliente mes	2.53	2.17	2.44
Cargo por energía (siguientes kWh)	B/. kWh	0.14341	0.15229	0.17681
Tarifa Simple BTS 2				
Cargo fijo, por los primeros 10 kWh	B/. Cliente mes	2.53	2.17	2.44
Cargo por energía (siguientes kWh)	B/. kWh	0.17749	0.18509	0.20574
Tarifa Simple BTS 3				
Cargo fijo, por los primeros 10 kWh	B/. Cliente mes	2.53	2.17	2.44
Cargo por energía (siguientes kWh)	B/. kWh	0.19558	0.21359	0.23826
Tarifa con Demanda Máxima (BTD)				
Cargo Fijo	B/. Cliente mes	4.59	4.68	4.56
Cargo por energía hasta 10,000 kWh	B/. kWh	0.13756	0.17945	0.13545
Cargo por energía, siguientes kWh de 10,001 a 30,000	B/. kWh	0.14323	0.18544	0.14337
Cargo por energía, siguientes kWh de 30,001 a 50,000	B/. kWh	0.15421	0.19308	0.14891
Cargo por energía, siguientes kWh desde 50,001	B/. kWh	0.16494	0.19969	0.17425
Cargo por Demanda Máxima	B/. kW/mes	9.95	11.06	20.4
Tarifa por Bloque Horario (BTH)				
Cargo Fijo	B/. Cliente mes	4.6	4.68	4.56
Cargo por Energía en Punta	B/. kWh	0.20397	0.17157	0.21968
Cargo por Energía Fuera de Punta	B/. kWh	0.1412	0.1653	0.15453
Cargo por Demanda Máxima en Período de Punta	B/. kW/mes	12.84	18.4	20.9
Cargo por Demanda Máxima Fuera de Punta	B/. kW/mes	1.3	1.9	2.26
TARIFAS DE MEDIA TENSIÓN				
Tarifa con Demanda Máxima (MTD)				
Cargo fijo	B/. Cliente mes	11.56	8.38	11.41
Cargo por Energía	B/. kWh	0.14806	0.14544	0.1507
Cargo por Demanda Máxima	B/. kW/mes	9.96	9.83	19.54
Tarifa por Bloque Horario (MTH)				
Cargo fijo	B/. Cliente mes	11.61	8.38	11.41
Cargo por energía en Punta	B/. kWh	0.18947	0.11432	0.16401
Cargo por energía Fuera de Punta	B/. kWh	0.14206	0.10093	0.12862
Cargo por Demanda Máxima en Período de Punta	B/. kW/mes	11.32	17.03	18.97
Cargo por Demanda Máxima Fuera de Punta	B/. kW/mes	1.43	1.8	2.65
TARIFAS DE ALTA TENSIÓN				
Tarifa con Demanda Máxima (ATD)				
Cargo fijo	B/. Cliente mes	11.61	8.38	11.41
Cargo por Energía	B/. kWh	0.10769	0.10801	0.13854
Cargo por Demanda Máxima	B/. kW/mes	13.37	11.99	13.36
Tarifa por Bloque Horario (ATH)				
Cargo fijo	B/. Cliente mes	11.61	8.38	11.41
Cargo por energía en Punta	B/. kWh	0.14143	0.10751	0.15185
Cargo por energía Fuera de Punta	B/. kWh	0.10194	0.10157	0.11446
Cargo por Demanda Máxima en Período de Punta	B/. kW/mes	14.25	13.74	12.81
Cargo por Demanda Máxima Fuera de Punta	B/. kW/mes	2.58	1.42	2.63

Source: ASEP (2018), "Tarifas de Electricidad para Clientes Regulados", asep.gob.pa/images/electricidad/tarifas_new/01_tarifas_clientes_regulados/02_tarifas_sector_electrico_2014-2017/ano_2018/abril/I_semestre_tarifas_2018.pdf.

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