Centro Nacional de Despacho

SECRETARÍA NACIONAL DE ENERGÍA

ETESA

IRENA
International Renewable Energy Agency

PANAMA POWER SYSTEM FLEXIBILITY ASSESSMENT

IRENA FLEXTOOL CASE STUDY

DECEMBER 2018

FlexTool Engagement Process

The FlexTool engagement process for Panama started in October 2017, with a set of discussions during training on power grid studies with large shares of solar and wind. During that session, an expert from the International Renewable Energy Agency (IRENA) informed representatives from the Electricity Transmission Company (Empresa de Transmisión Eléctrica, ETESA), the state-owned organisation in charge of system operation and transmission planning, about FlexTool development. They then discussed the possibility of carrying out a flexibility analysis for the power system of Panama.

After confirming the country's interest, IRENA collaborated with a group of experts from ETESA, while the National Energy Secretariat (Secretaría Nacional de Energía, SNE) supported the engagement process and the exchange of data and information. IRENA began the data collection process using publicly available sources, obtaining data on demand, internal transmission, installed generation capacity and variable renewable energy (VRE) from ETESA (2018a), and information about interconnectors from the Central American Electrical Interconnection System (Sistema de Interconexión Eléctrica para Países de América Central, SIEPAC) (SIEPAC, 2018). After consolidating this information, IRENA requested additional missing information from SNE and ETESA. The generation mix for future scenarios (2030) was taken from the ETESA generation expansion plan (ETESA, 2018b).

IRENA then created a consolidated dataset that was checked by SNE and ETESA to confirm the accuracy of the data. Following this, the FlexTool model and its input files were built, and the flexibility analysis was performed. The FlexTool model, the study results and a slide deck explaining the main findings were shared with experts from SNE, ETESA and the National Dispatch Centre (Centro Nacional de Despacho, CND) for review, discussion and validation of the model and results.

This brochure summarises the main results and findings from the flexibility assessment of Panama's power system using the FlexTool. Figure 1 shows the main challenges identified before starting the assessment, as well as the analyses undertaken to cope with these.

Figure 1: Main challenges of Panama's power system and FlexTool analysis done

Country challenges

» High reliance on hydropower
» Low energy storage capacity
» Weak interconnection

Analysis undertaken

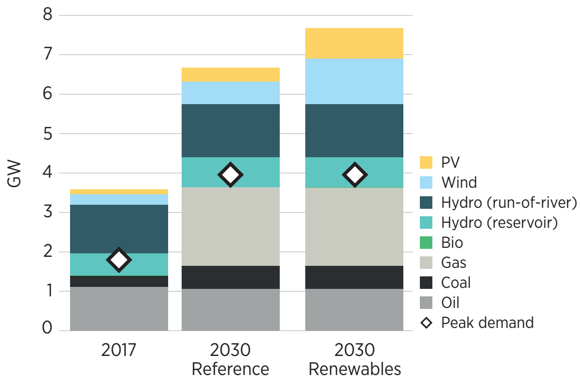
» Simulation of different VRE penetration scenarios according to national plans
» Assessment of the optimal generation capacity mix (including storage)
» Consideration of VRE share increase in long-term planning (mostly solar PV)

PANAMA'S POWER SYSTEM

In 2017, Panama's power system had very large installed hydropower capacity (54% of total capacity) and substantial VRE capacity (45.3%). The generation breakdown was 64% renewable energy (36% run-of-river hydro, 18% reservoir hydro, 8% wind, 2% solar photovoltaics (PV)) and 36% thermal generation (29% oil and 7% coal).

ETESA's 2018 energy plan (2018b) considers two scenarios for 2030. In the reference scenario, the wind and solar installed capacities remain the same as in 2017, but an additional 2 gigawatts (GW) of natural gas-fired generation is installed. In the renewables scenario, wind capacity increases from 270 megawatts (MW) to 1 156 MW, and solar PV capacity increases from 131 MW to 782 MW. Panama expects total energy demand to more than double between 2017 and 2030 (+113%), with peak demand growing from 1.6 GW to 3.5 GW.

Figure 2: Expected evolution of the generation capacity mix in Panama's power system, 2017-2030

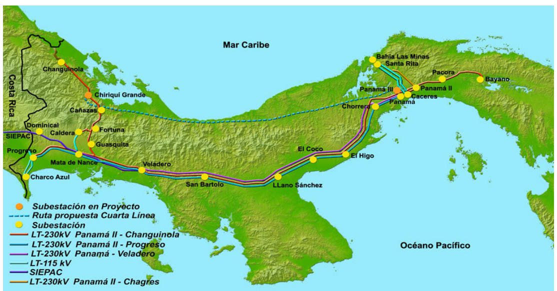


In both years installed capacity significantly exceeds peak demand (3.6 GW in 2017 and 4.6 GW in 2030), so generation adequacy issues are not expected (see Figure 2).[1]

Panama is currently connected to Costa Rica via a 300 MW transmission line. A 400 MW high-voltage direct current (HVDC) interconnector with Colombia is expected to be commissioned by 2022. In the absence of a cross-border electricity market, this interconnection was modelled assuming that Panama imports energy from Colombia at the high price of USD 200 per megawatt-hour (MWh). Because imports are likely the most expensive source of electricity, they will be required only if Panama's internal generation mix is unable to meet demand. Regarding internal transmission, ETESA agreed with IRENA on using a single-node model for the analysis.

Table 1 shows key enablers of flexibility in Panama's power system, based on historical data and the latest generation expansion plans.

Figure 3: Panama's transmission network



Source: ETESA
Disclaimer: Boundaries and names shown on this map do not imply any official endorsement or acceptance by IRENA.

Table 1: Flexibility enablers in Panama's power system*

Flexibility enablers	High	Medium	Low
Interconnection capacity vs. average demand		●	
Generator ramping capabilities	●		
Matching of demand with VRE generation	●		
Hydro inflow stability	●		
Strength of internal grid		N/A	
Storage vs. annual demand (MWh)			●
Geographical dispersion of VRE generation and demand		N/A	
Minimum demand vs. VRE capacity	●		

* These flexibility enablers are defined in in IRENA (2018b).

Note: Flexibility enablers' levels are an indication of: very good enabling conditions when level/value is "High"; normal enabling condition when "Medium"; bad enabling conditions when "Low". N/A (not applicable) due to the fact that the system was modelled as a single node.

1 In the simulations, generation adequacy issues might be identified. This is because VRE sources does not have 100% firm capacity and hydro resources have limited energy, therefore issues could appear if VRE production is low and the year of analysis is dry. However, the flexibility assessment can be performed also for specific cases where low rainfall or low wind might create adequacy challenges, and the tool is capable of addressing them by investing in a least-cost mix of technologies.

Highlights from the Analysis

Flexibility analysis in Panama´s 2030 power system

The 2017 power system was simulated to calibrate the FlexTool model and no flexibility issues were identified. After calibration, both the reference and renewables scenarios for 2030 were simulated, again indicating no flexibility issues (see Table 2).

Figure 4 shows the annual generation and the optimal dispatch for a week with the highest VRE penetration for both scenarios, and Table 2 shows the main flexibility indicators.

Figure 4 also highlights a key difference between the reference and renewables scenarios. In the latter, the share of VRE, and therefore the share of renewable energy in the system, is higher. The ramping requirement is higher in the renewables scenario as well.

However, Panama's hydropower and natural gas-fired generation can cope with it. Analyses of the simulation results indicated that the renewables scenario has 5% lower annual costs and 20% lower carbon dioxide emissions.

Besides this, no flexibility issues were identified in either scenario (see "zero" values in Table 2). This is mainly because Panama, according to ETESA projections, plans to increase its supply-side flexibility and prevent adequacy issues.

Investments to achieve this include:

- Installation of 2 GW of natural gas-fired capacity, characterised by high ramping capability and low start-up time;
- Installation of 194 MW of hydropower capacity with reservoir.

Figure 4: Power generation (annual share) and hourly dispatch over a week in 2030 with the highest VRE penetration: Reference and renewables scenarios

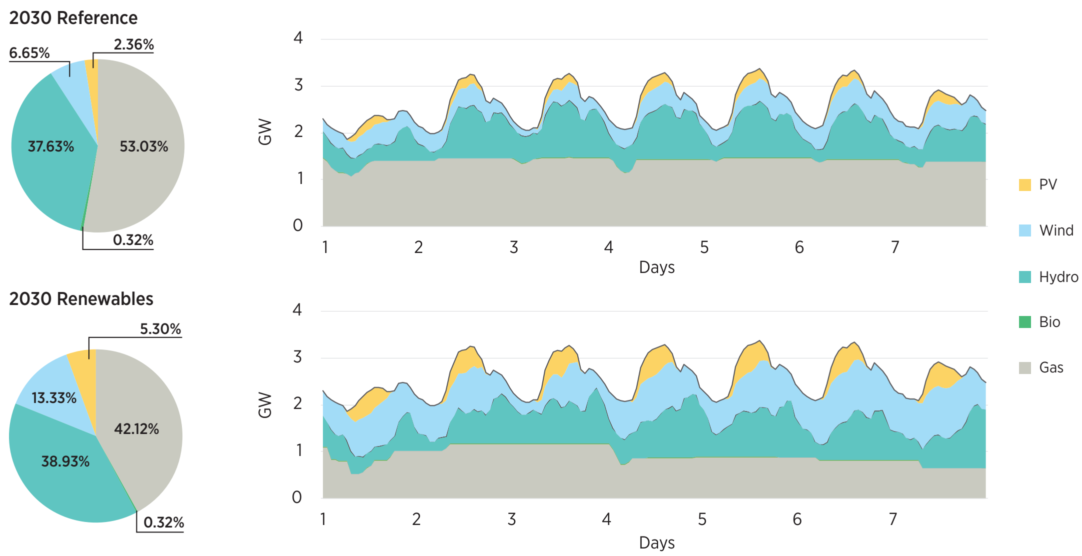


Table 2: Main flexibility indicators in Panama's power system in 2030 reference and renewables scenarios: No flexibility issues identified

	2030 Reference		2030 Renewables	
	Total (GWh)	Peak (MW)	Total (GWh)	Peak (MW)
Curtailment	0	0	0	0
Loss of load	0	0	0	0
Spillage	0	0	0	0
Reserves inadequacy	0	0	0	0

Note: These flexibility indicators are defined in IRENA (2018b).

Evaluating additional investments for optimal capacity mix

Since no flexibility issues were identified in the 2030 reference and renewables scenarios, a sensitivity analysis was performed to check whether additional cost-efficient investments are available and worthwhile for Panama to consider. [2] The FlexTool's investment mode was run for the renewables scenario, producing the results illustrated in Figure 5 (investments in new generation capacity) and Figure 6 (total system cost).

In the 2030 renewables scenario, the FlexTool finds it cost-efficient to invest in 1.7 GW of additional solar PV capacity and 164 MW (82 MWh) of battery storage, increasing the renewable energy share from 58% to 69%.

Figure 5: Generation capacity in 2030 renewables scenario with and without investments for optimised system costs

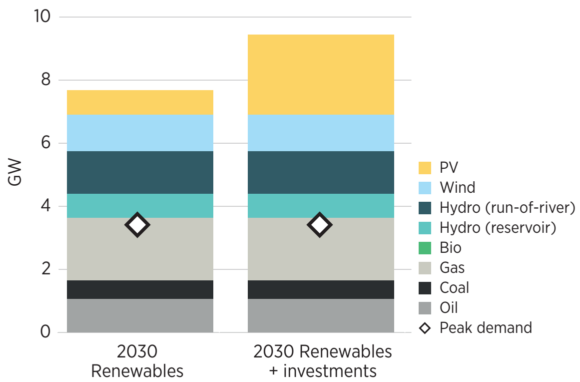
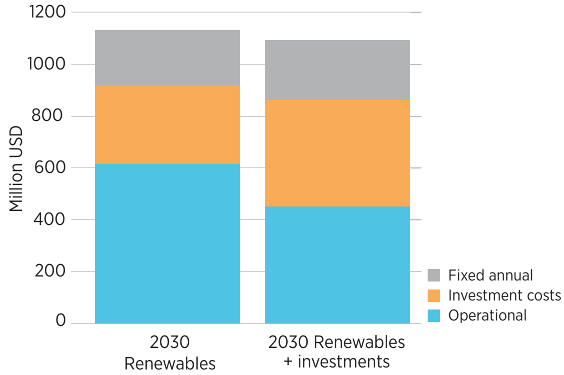


Figure 6: Annualised cost comparison between 2030 renewables scenario with and without investments for optimised system costs



The investment costs of installing additional PV and storage are covered by a reduction in operational costs due to lower fossil-fuelled generation.

A set of flexibility indicators was calculated to measure the remaining flexibility in the system. Table 3 presents the values of these indicators for the 2030 renewables scenario with an optimised generation capacity mix.

Panama's power system would still have enough flexibility to handle even higher penetration of VRE, as seen in the 2030 renewables scenario with investments. However, investing in more VRE under the current assumptions would increase the total system cost.

Table 3: Remaining flexibility indicators for the 2030 renewables scenario with optimised investments: Annual average and most critical period*

	Average	Most critical
Residual ramping capability (MW/min)	69.5 MW/min	45.5 MW/min
Share of time when transmission is not congested (%)**	N/A	N/A
Remaining interconnection capacity (%)***	100%	100%
Unused hydro reservoirs capacity (%)	80.8%	56.8%

* Most critical represents the worst conditions for each indicator under the modelled scenario. The period, or time interval, is one hour in the Panamanian FlexTool model.

** N/A (not applicable) because the system was modelled as a single node.

*** The model does not use interconnection. Lower prices or a liquid market would make the use of interconnection more attractive.

Note: These remaining flexibility indicators are defined in IRENA (2018b).

2 In the case of Panama, the expansion includes solar PV and wind capacity and battery storage. Domestic transmission capacity expansion is not relevant in this case given that it is a single-node model.

Gradually integrating additional VRE into the system

As a sensitivity, additional solar PV and wind were added to the system until curtailment emerged. Fifty-six scenarios were analysed, starting from the 2030 renewables scenario. Figure 7 shows how VRE curtailment grows with increasing shares of VRE.

In the 2030 reference scenario, the renewable energy share is around 48% (with 34% VRE), while in the renewables scenario this share reaches 58% (with 44% VRE). Neither scenario shows VRE curtailment. When optimal investments are added to the renewables scenario, the renewable energy share reaches 69% (with 56% VRE). Here VRE curtailment appears, although it is limited at less than 1%, which is part of the economically optimal solution.

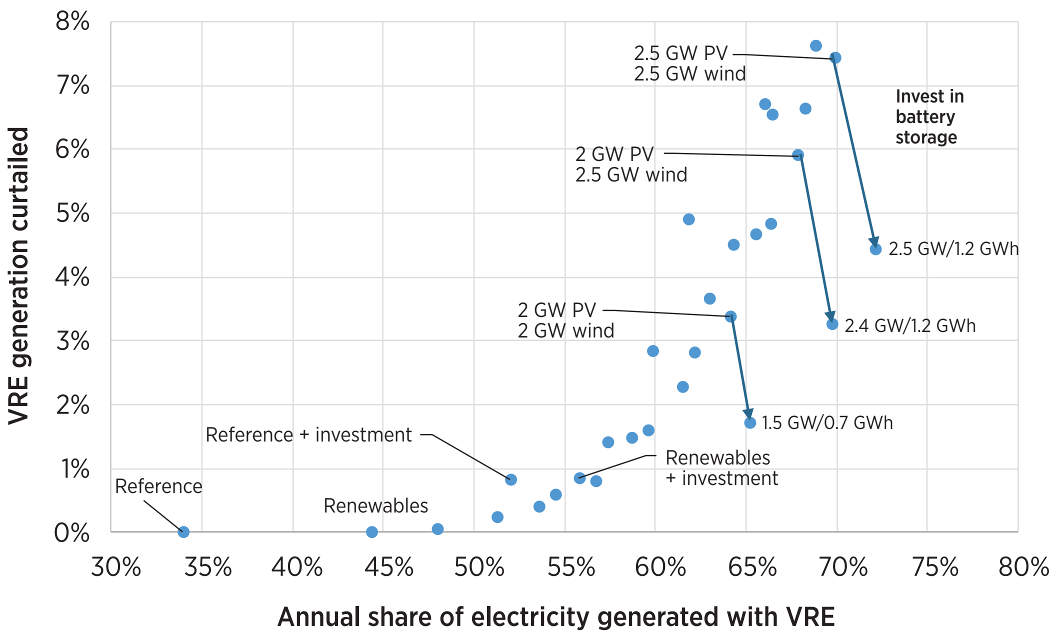
The system, therefore, can accommodate more VRE; however, the model does not invest in additional capacity as this would increase total system cost, making the marginal investment uneconomical. From this point on, curtailment increases further with VRE deployment.

Curtailment becomes and issue and starts to increase rapidly when both solar PV and wind capacity reach 2 GW. By then VRE curtailment is around 3%, and flexibility solutions should be analysed to further integrate VRE into the system.

The investment mode was run considering energy storage systems as a candidate for investment. Figure 7 shows that by investing in 1.5 GW (0.7 gigawatt-hours) of energy storage, curtailment decreases to less than 2%, while the VRE share increases from 64% to 66% and the renewable energy share increases from 76% to 78%.

If installed solar PV and wind capacity keep increasing, the FlexTool shows that the integration of additional VRE can be facilitated by investing in battery storage. Another flexibility option could be to couple the power sector with other energy sectors (e.g., power-to-heat, power-to-gas or power-to-electric vehicles) via "sector coupling", providing a significant source of additional flexibility and demand for the power system.

Figure 7: VRE curtailment at different levels of solar PV and wind penetration in 2030



Conclusions and Recommendations

In 2017, the power system in Panama was characterised by a high share of hydropower (mostly run-of-river) and no flexibility issues. In 2030, VRE installed capacity should remain the same as today in the reference scenario while growing to 3.28 GW (including run-of-river) in the renewables scenario; under both scenarios, however, flexibility will be sufficient. This is mostly because of the plan to further increase reservoir hydropower, the main source of supply-side flexibility in the system, and to add 2 GW of natural gas-fired generation to displace coal and oil.

Based on the results of the analysis, the IRENA FlexTool suggests investing in additional solar PV and battery storage in 2030, reducing total system costs and further decreasing carbon dioxide emissions.

In the renewables scenario, an additional 1.7 GW of solar PV and 164 MW (82 MWh) of battery storage are identified as optimal under current assumptions (reaching a 69% renewable energy share), while no further cost-efficient investments in wind power have been identified.

Additional investments beyond the identified optimum were also analysed. Here, the solar PV and wind capacity can go beyond the identified optimal; however, if the VRE share is to be further increased (e.g., to reach a 100% renewable energy), investment is needed in flexibility options such as energy storage systems. Another option could be to investigate solutions based on sector coupling, a line of work that could be investigated in the future.

Impact

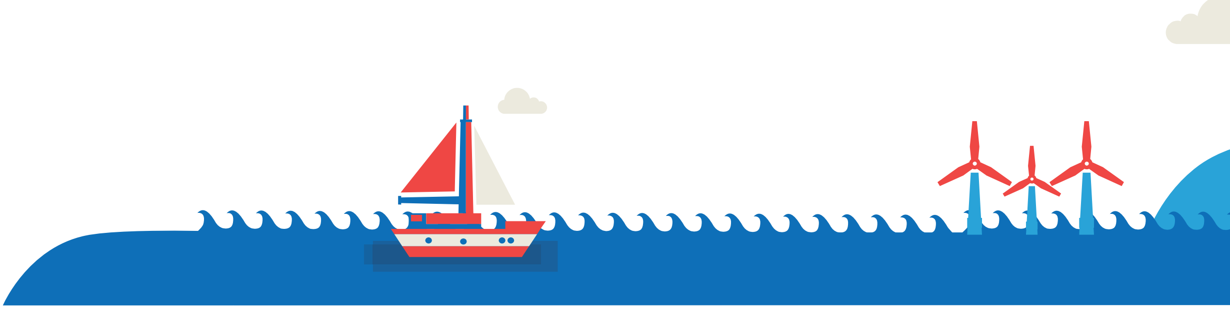
Panama has taken part in power sector activities under the Clean Energy Corridor Central America (CECCA), for which it is a pilot country. Country experts expect to use the FlexTool in scenarios and studies by ETESA, CND and SNE.

- ETESA is responsible by law for the Expansion Plan of the National Integrated System of the Electrical Sector (PESIN), which is divided into a generation plan (indicative) and a transmission plan (mandatory).
- CND models the system for economic dispatch purposes at regular intervals: daily, weekly and others.
- SNE performs the annual revision and update of the National Energy Plan (SNE, 2016), which takes into account all forms of energy with long-term projections.

The IRENA FlexTool could support Panama in short-, medium- and long-term transmission and generation capacity planning, by identifying the technologies needed to reach higher VRE penetration.

Adding this tool into the planning process could help the country design effective energy policies, particularly to develop a flexible power sector that is compatible with the decarbonisation needs implied by the Paris Agreement.

The increased deployment and cost-effective integration of renewables in the electricity mix are important for Panama to fulfill the emissions reductions outlined in its Nationally Determined Contribution while also enabling the power sector to maintain reliability and economic performance.



Further Reading

- **ETESA (2018a)**, National Dispatch Centre (Centro Nacional de Despacho) – Electricity Transmission Company (Empresa de Transmisión Eléctrica), Panama. www.cnd.com.pa/.
- **ETESA (2018b)**, *Expansion Plan of the Interconnected Power System 2017-2031 (Plan de Expansión del Sistema Interconectado Nacional 2017-2031).* Electricity Transmission Company (Empresa de Transmisión Eléctrica), Panama.
- **SIEPAC (2018)**, Interconnection Panama-Colombia (Interconexión Panamá-Colombia). Central American Electrical Interconnection System (Sistema de Interconexión Eléctrica para Países de América Central), Panama. www.eprsiepac.com/contenido/interconexion-panama-colombia/.
- **SNE (2016)**, National Energy Plan (Plan Energético Nacional). National Energy Secretariat (Secretaría Nacional de Energía), Panama.
- **IRENA (2018a)**, *Power System Flexibility for the Energy Transition. Part I: Overview for policy makers*. International Renewable Energy Agency, Abu Dhabi.
- **IRENA (2018b)**, *Power System Flexibility for the Energy Transition. Part II: IRENA FlexTool methodology.* International Renewable Energy Agency, Abu Dhabi.

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Contributing authors: Emanuele Taibi, Carlos Fernández and Laura Gutiérrez (IRENA), with Tomi J. Lindroos and Juha Kiviluoma (VTT).