A Monte Carlo Simulation Framework to Track Panama NDC Target

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Abstract

The 2015 Paris Agreement represents a restarting point for combating climate change. The Agreement introduces the National Determined Contributions (NDC) to control greenhouse gas emissions. This paper provides a step-by-step framework to evaluate Panama's renewable energy contribution commitment in terms of CO2eq mitigation. Monte Carlo Simulations are used to compute dynamic scenarios of MtCO2eq emissions determining that the occurrence of delays in the entry into operation of specific projects combined with the presence of El Niño phenomenon could increase, up to 45%, the value of the CO2eq emissions compared against baseline scenario.

Introduction

The Paris Agreement represents a restarting point for combating climate change, for three reasons: it achieved the consensus and formal commitment of the countries almost twenty years after the last signed comprehensive arrangement, the Kyoto Protocol; it made a change to the mechanism used to control greenhouse gas emissions, confronting global warming through the definitions of National Determined Contributions (NDC); and it establishes a mechanism for periodic review of the NDC promoting the evaluation of progressive goals and the assessment of the measures implemented to reach those contributions.

International studies present that the committed pledges amounts defined by the countries would not keep the global average temperature increase below 2ºC (Rogeli et al., 2016; UNEP, 2016; Sokolov et al., 2016, and Jiang et al., 2019). Furthermore, several studies also conclude that countries are failing to meet their pledge to cut greenhouse gas emissions (Victor et al., 2017; CAN, 2018; and CAT, 2019). The failure of each country to meet its individual goals in terms of emissions reduction increases the likelihood of failing to reach a global goal reduction of GHG emissions. Additionally, when a country lacks studies that define and monitor measurable indicators to assess the effectiveness of compliance with its proposed goals, and it does not present an explanation of the process and the interaction among the variables that led to the calculation of its goals, the tracking capacity of the targets is limited.

IPCC (2014) indicates that economic and population growth remain as the main drivers of the increase in CO2 emissions. It also comments that extraction, conversion, storage, transmission, and distribution of energy remains as the most significant contributor to GHG emissions in the world. The report highlights the deployment of renewable energy as a reliable option to reduce greenhouse gas emissions produced by fossil fuel combustion. It comments that renewable energy technologies demonstrated considerable performance improvements and cost reductions. The document also remarks that decarbonising electricity generation, in combination with energy demand reduction, is a crucial instrument to achieve lower levels of CO2eq.

This paper is organised as follow: The first section presents Panama NDC. The second section shows the Monte Carlo Simulations Framework. It will explain how to transforms installed capacity to CO2eq emissions. It also explains how to simulate a delay in commercial operation of a project and the presence of El Niño using a binomial distribution. The third section shows the discussion of results. The last section provides conclusions.

Panama NDC

According to the Panama NDC (2016), the nation contributes only 0.02% to global greenhouse gas emissions and records a low 1.86 average global tCO2eq emissions per capita, excluding land-use change and forestry. The country defined as an objective of mitigation in the energy sector to increase installed capacity of other energy sources renewable (solar, wind and biomass) by 15% in 2030 and 30% in 2050 compares with 2014.

The updated National Energy Plan (SNE, 2017) recognises that emissions monitoring is essential to determine the activities that generate the most pollutants in the country. The implementation of public policies to reduce emissions and the evaluation of the effectiveness of measurements requires a continues follow up of emissions. For the energy sector, the document depicts the following indicators to display progress towards the achievement of the objective: installed capacity and total electricity generation, including the participation of renewables energies. The plan does not present a transparent calculation of equivalent CO2 reduction, neither alternative scenarios for the energy matrix showing different energy generations paths.

NDC commitment based on an increase in the installed capacity of (non-conventional) renewable energy sources can overestimate the expected CO2eq emissions reductions over a period. A target defined in terms of installed capacity that does not consider parameters changes in the capacity factor or delays in the construction of projects can undervalue total CO2eq emissions. For example, in the electricity sector, the greater use of thermal plants that operate with petroleum derivatives holds a more considerable amount of CO2eq emissions. Countries generally use thermal plants when there is a delay in the entrance into the operation of renewable energy projects to avoid blackouts. Also, countries trend to use thermal plant to guarantee energy security when there is a reduction in the generation of the installed hydroelectric plants because of the scarcity of rainwater.

MiAmbiente (2018) remarks that transforming the contribution of Panama in tCO2eq requires an exercise that depends on the composition of the energy matrix. These calculations are difficult to quantify with precision because the emissions of the sector are directly as associated with generation and not to the installed capacity of the different plants.

Monte Carlo Simulations Framework

The Monte Carlo Simulation Framework first requires building a CO2eq emissions baseline scenario and second to make random variations on the inputs to generate alternative outputs (see Figure 1).

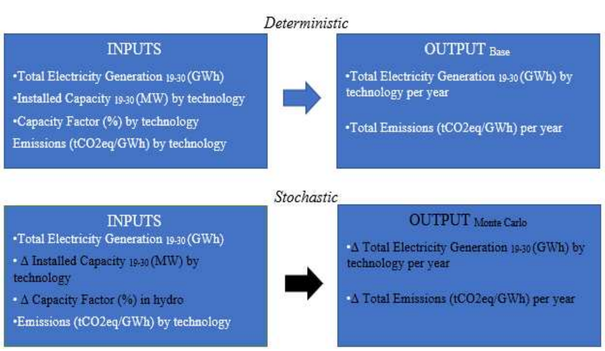

Figure 1. The Monte Carlo Simulations Framework

Generation (GWh) is calculated multiplying the installed capacity (MW) by the capacity factor (%) times 8,76.

CO2eq emissions[++] are calculated multiplying the generation by electricity generation technology type by its life-cycle emissions (see Figure 2). Annex III of IPCC (2014) provides the median life-cycle emissions for pulverised coal=820, gas combined cycle=490, dedicated energy crops biomass=230, utility-scale solar photovoltaic=48, onshore wind=11, and hydropower=24. WNA (2011) provides the median life-cycle emissions for oil=735.

	A	B	C=A*B
Technology	tCO2eq/GWh	GWh	tCO2eq
Coal	820	483	396,273
Oil	735	1,389	1,021,040
Gas	490	623	305,403
Biomass	230	18	4,054
Solar	48	233	11,167
Hydropower	24	7,855	188,524
Wind	11	588	6,467
Total:		11,189	1,932,927

Figure 2. CO2eq emissions calculations at 2018

a) CO2eq Emissions Baseline Scenario

The deterministic estimations of CO2eq emissions for the 2019-2030 period define the Baseline Scenario. Calculation of the Baseline Scenario follows the next procedure (see Tables in Exhibits section):

• To estimate the total installed capacity of the country per electricity generation technology per year for the period 2019-2030 (Table 3). It starts with the most recent information available (Table 1) and then subtracts projects that will stop operating and adding projects that will begin operating in a given year (Table 2).

• To estimate the total electricity generation of the country per year for the period 2019-2030 (Table 4). In this case, the maximum energy demand of the country was used to forecasts energy generation. It is also assumed that the country is self-sufficient, so it should not incur energy importation during that period (SNE, 2016, p. 196).

• To estimate the total electricity generation of the country by technology per year, applying a conversion factor for each energy source (Table 5). In this case 50% for coal and natural gas using expert criteria, 25% for biomass, 14% for solar, and 25% for wind using

[++] CO2eq emissions in terms of gCO2eq/kWh, kgCO2eq /MWh or tCO2eq /GWh are equivalent ratios.

the real capacity factor registered in 2018, and 45% for hydro using the real average capacity factor registered for the period 2015-2018, averaging wet and dry years. The electricity generation from oil derivatives plants is estimated as the amount required to reach the projected annual generation minus the generation generated by the other energy sources.

• To estimate the total CO2eq emissions per year for the period 2019-2030 (Table 6).

b) Building Simulations

The Monte Carlo Simulations will be executed using the Oracle Crystal Ball software. Simulations represent an original exploration to estimate the impact of two specific random events (Delay and El Niño) in terms of change in the expected CO2eq emissions per year for the period 2019-2030. Simulations were executed through 10,000 trials and using the 99.9% percentile to present the simulation graphs.

The first simulation evaluates a delay in the entry date of operation of any of the "big four" projects: Viento Sur 115 MW, Chan II 228 MW, Martano 458 MW, and NG Power 670 MW. This simulation incorporates the use of a binomial distribution with parameters n=1 and probability 50% (it happened, or it did not happen). It is assumed a value of 1 if the project was implemented in a year and a value of 0 if not. In case the project is implemented in a specific year recording a value of 1, then it will be computed a value of 0 for the remaining years. A delay in any of these projects will increase CO2eq emissions because the energy demand must be satisfied with electricity generation from thermal plants.

The second simulation evaluates the phenomenon of El Niño. In Panama El Niño, on average, produces a decrease in rainfall in regions located in the Pacific climate, and it repeats between every 2 to 7 years (ETESA, 2015, p. 3). This simulation also incorporates the use of a binomial distribution with parameters n=1 and probability 50%. In this case, the value of 1 represents the presence of a dry year, so the capacity factor uses 35% in the hydro plants. The capacity factor of 35% was recorded in 2014 when this natural phenomenon took place in the recent years. The value of 0 represents the presence of an average year, so the capacity factor keeps 45% in the hydro plants.

The third simulation evaluates the delay and El Niño cases at the same time. These random events are independent ones, so there is not needed to assume a correlation value for the variables.

c) Limitations

The following sections present the main limitations found in the simulation process:

• Energy exchange: There is an Electric Regional Market (MER) that regulates the energy sold, in the contract market and the opportunity market, among Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, and Panama. Although SNE (2016) did not project energy exchanges between Panama and the MER's member countries, there is a daily export and import of energy flows. The National Dispatch Centre (CND) of Panama maintains monthly statistics of the MER, for instance in 2018 Panama exported 327 GWh and imported almost 15 GWh. Energy exchange estimations could be used to fine-tune the electricity generation projections and their associated tCO2eq emissions.

• Accurateness of the capacity factor: Historical recorded values were used to define the inputs of the capacity factors of each electricity generation technology. However, the capacity factor is specific to the availability of the resource on the site and to the technical specifications of the generation equipment to be purchased from the manufacturing company. Ideally, each proposed expansion project should have its evaluation of the capacity factor.

• Exactness of the life-cycle emissions: The lack of information on CO2eq emissions by source of energy for the specific type of plants that the national energy system expansion plan depicted, constitutes a weakness. It would have been pertinent, if there was knowledge of how to perform the harmonisation of parameters, to make the appropriate adjustments between each specific project. For example, to adjust the CO2eq emissions for the Chan II hydroelectric project that constitutes a (large) hydro with reservoir and it is not a (small) run-of-river hydro. Equally, to adjust the CO2eq emissions from the thermal plants that produce with light diesel vs those that produce with bunker-C.

• Strictness of the probabilities: The random events simulations assumed that the probability of occurrence is determined by a 50%/50% chance. Nevertheless, researchers can use criteria with greater statistical depth, even incorporating conditional probabilities. For example, based on methodological studies, it is possible to determine the likelihood that the El Niño phenomenon will occur in one year and the year after.

Discussion of Results

a) Baseline Scenario

During the period 2019-2030, the estimated installed capacity in the baseline scenario will increase 62.7%, from 3,487 MW to 5,674 MW. That increase (+2,188 MW) is supported in a 51.6% by the integration to the system of two natural gas plant planned to enter at 2023 (+1,128 MW) and a 48.4% by the development of several new renewable projects (+1,060 MW). The renewable sources will have a participation in the total installed capacity of the country of 64.8% in 2019 and 58.5% in 2030.

Figure 3 presents the projected gap in MW between the installed capacity defined by SNE in the National Energy Plan and the one estimated in the baseline scenario. At 2020 it is determined a gap of 1,383 MW of installed capacity in the country. The delay in the execution of 381 MW in natural gas, 366 MW in hydro, and 338 MW in wind projects, and the difference in the assumption of exit of bunker and diesel plants justified the gap. By 2030 it is estimated that the gap in the total projected installed capacity will be 208 MW. Thus, in 2030 the deficit of wind, hydro and oil derivatives is partially compensated by the surplus of natural gas and solar.

Installed Capacity (MW)						
Technology	2020[a]	2020[b]	Gap	2030[a]	2030[b]	Gap
Coal	320	420	100	420	420	-
Oil	866	428	- 438	866	428	- 438
Gas	762	381	- 381	1,362	1,509	147
Biomass	8	8	- 0	8	8	- 0
Solar	250	291	41	250	611	361
Hydropower	2,190	1,824	- 366	2,308	2,189	- 119
Wind	668	330	- 338	668	509	- 159
Total:	5,064	3,681	- 1,383	5,882	5,674	- 208

Leyend (a) SNE (2016) (b) Baseline Scenario

Figure 3. Installed Capacity Gap 2020 & 2030

A natural gas plant, a hydroelectric plant, and a wind project has a construction period of at least three years, between two and three years, and at least two years, respectively. Therefore, the lethargy recorded at the start of works of these types of projects will raise the tCO2eq emissions that the country could achieve. Particular concern should generate the fact that since 2016 no wind project has been integrated into the national grid. Additionally, it should worry that NG Power gas plant registers until now a delay of at least six years. Finally, it should also draw attention that the Panamanian energy matrix did not incorporate 366 MW hydroelectric projects as planned.

Figure 4 presents the projected gap in CO2 emissions. Given the gap in the installed capacity, the estimated generation by type of technology will produce an increase of 1.4 MtCO2eq in 2020 between la emissions expected in the National Plan and the baseline scenario. In the year 2030, the estimated values produce an emissions' gap of almost zero.

MtCO2eq						
Technology	2020[a]	2020[b]	Gap	2030[a]	2030[b]	Gap
Coal	1.1	1.5	0.4	1.5	1.5	0.0
Oil	0.0	0.8	0.8	2.4	2.2	- 0.2
Gas	0.5	0.8	0.3	2.9	3.2	0.3
Biomass	0.0	0.0	0.0	0.0	0.0	0.0
Solar	0.0	0.0	0.0	0.0	0.0	0.0
Hydropower	0.2	0.2	- 0.0	0.2	0.2	- 0.0
Wind	0.0	0.0	- 0.0	0.0	0.0	- 0.0
Total:	1.9	3.3	1.4	7.1	7.2	0.1

Leyend (a) SNE (2016) (b) Base Model

Figure 4. CO2eq Emissions Gap 2020 & 2030

The government has a critical role in providing an appropriate environment to maintain investment flows in the energy sector (IPCC, 2007, p. 21).

ETESA (2018) estimated in its expansion plan a total investment of $1,5 billion (864 MW), $0.9 billion (907 MW), $1.5 billion (485 MW) for the next twelve years in wind, solar, and hydro projects, respectively. That amount of investment will keep requiring the participation of the private sector under a satisfactory regulatory framework.

The presence of long-term energy contracts facilitates obtaining financing for projects (Junfeng et al., 2002; Mirza et al., 2009; and Wiser and Pickle, 1998). ETESA awarded the last long-term PPAs auction for renewable projects between 2013 and 2014, specifically, wind and hydro in 2013, and solar in 2014.

It is also known that the promotion of incentives contributes to the development of a renewable project (Islam et al., 2008; Lidula et al., 2007; Martin and Rice, 2012; Painuly and Fenhann, 2002; and Yaqoot et al., 2016). The last supports instruments were formulated in 2004 for hydroelectric plants through the Law. No. 45, in 2011 for wind projects through the Law No. 44, and in 2013 for solar installations through the Law No. 37.

Furthermore, the perception of adverse environmental impacts by local communities has slowed the development of hydroelectric projects in Panama. Mainly, the opposition to hydro led to the cancellation of 21 hydro concessions in 2015 (Lorenzo, 2016). Hydropower projects may require multi-party collaborations to address energy and water needs (IPCC, 2011, p. 13). Thus, the government should promote awareness and information about the benefices of the hydro projects and contribute to reach agreements between the parties.

b) Monte Carlo Simulations

The Monte Carlo Simulations detail that all random events simulated affect emissions by increasing the amount estimated of MtCO2eq that the country can reach (see Figure 5). The joint effect of El Niño and the delay (see Figure 6) is the event with a more considerable increase in emissions.

The effect of dry years for the period 2019-2030 will increase the annual average MtCO2eq emissions by 25.0%. The average emissions will rise 1.1 MtCO2eq per year from 4.6 MtCO2eq to 5.7 MtCO2eq.

The effect of delays in the “big four” project represents an increase of 27.2% in the annual average MtCO2eq emissions for the period of analysis 2021-2030. The average emissions will growth 1.3 MtCO2eq per year from 4.8 MtCO2eq to 6.1 MtCO2eq.

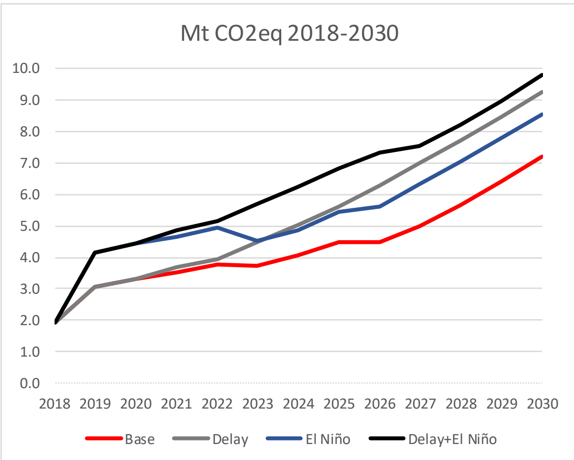

Figure 5. CO2eq emissions by the Monte Carlo Simulations

The joint effect of a delay and El Niño for the period 2019-2030 will increase the annual average MtCO2eq emissions by 44.9%. The average emissions will increase 2.0 MtCO2eq per year from 4.6 MtCO2eq to 6.6 MtCO2eq.

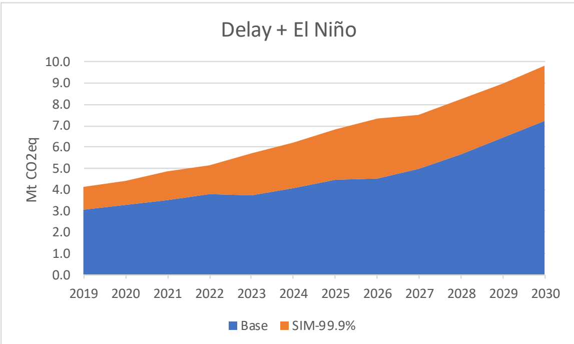

Figure 6. CO2eq emissions by the Monte Carlo Simulations

Conclusions

The Paris Agreement defined the year 2020 as the first year to communicate new updated NDCs. This study assessed that the country would fail to achieve the 2020 goal proposed in terms of installed capacity. The country will record a deficit of around 50% in wind and natural gas facilities not installed and approximately 20% in hydro projects not installed. Some instruments mentioned to accelerate the execution of missing installed capacity are: the issuance of new long-term PPA contracts, the reformulation of incentives for companies that develop and operate energy project, and the awareness of potential benefits hydroelectric projects,

Concerning the Panama NDC 2030 goal of reaching 15% of the country's installed capacity by wind and solar facilities, it is feasible. According to the projection made in the baseline scenario, the installed capacity of wind plants and solar installations would represent 19.7% for the year 2030. So, non-traditional renewable sources can have a participation greater than the target set.

However, the presence of a higher installed capacity in non-traditional renewable energy sources does not guarantee in advance lower CO2 emissions. When the electricity generated with wind or solar sources present a lower production, there will be a lower possibility to replace the emissions generated by the alternative thermal sources. Therefore, it is preferable to set targets in terms of MtCO2eq emissions for the energy supply sector. Various combinations of electricity generation by technology can produce the same amount of MtCO2eq emissions.

Furthermore, as was presented through a Monte Carlo Simulations Framework, the delay in the entry into operation of specific projects depicted in the National Energy Plan and the potential impact of El Niño phenomenon on the energy generation of the hydro projects will increase country’s CO2eq emissions. Therefore, it is also crucial to take measures that mitigate the impact of these simulated events.

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Exhibits

Project	MW	Project	MW	Project	MW	Project	MW
Minera Panama	300.0	Ikako	40.0	Chan I	222.5	Los Planetas 2	8.6
Celsia BLM	120.0	Pocrí	16.0	Estí	120.0	Mendre 2	8.3
Total Coal	***420.0***	Sol Real	10.8	Baitún	85.9	La Cuchilla	7.6
		Milton Solar	10.3	El Alto	69.0	La Yeguada	7.0
		Sol de David	10.0	ACP	60.0	Bajos del Totuma	6.3
Celsia BLM	160.0	Farallón Solar	10.0	Prudencia	56.2	Paso Ancho	6.0
Termo-Colón	150.0	Divisa Solar	9.9	Bajo de Mina	56.0	Macano	5.8
PANAM	144.0	Don Félix	9.9	Los Valles	54.8	El Fraile	5.3
ACP	134.0	Solar Los Angeles	9.5	Monte Lirio	51.6	Los Planetas 1	4.8
Barcaza Esperanza	92.0	Solar Chiriquí	9.0	La Estrella	47.2	ENESA	4.7
Celsia ATL	87.0	Solar Coclé	9.0	Lorena	35.7	Hidro-Panama	4.2
Estrella de Mar	72.0	Solar París	9.0	Bonyic	31.3	Bugaba 2	4.0
Jinro Power	57.8	El Espinal	8.5	Barro Blanco	28.8	Dolega	3.1
Pedregal Power	53.5	Vista Alegre	8.2	La Potra	27.9	Macho Monte	2.4
El Giral Power Station	50.4	Solar Caldera	5.5	Salsipuedes	27.9	Mini La Potra	2.1
Cerro Azul	44.1	Estrella Solar	5.0	Gualaca	25.0	Canopo	1.1
Sistemas Aislados	35.0	Solar Bugaba	2.6	Pedregalito 1	22.5	Candela	0.6
ACP	28.0	Sarigüa	2.4	Mendre 1	19.8	***Total Hydropower***	***1,776.7***
Total Oil (Bunker+Diesel)	***1,107.9***	La Mesa	1.0	Pedregalito 2	12.5		
		Bejuco Solar	1.0	Cochea	12.0		
		Coclé Solar	1.0	Concepción	10.0	Nuevo Chagres 2	62.5
Costa Norte	381.0	El Fraile Solar	0.5	Las Perlas Norte	10.0	Nuevo Chagres 1	55.0
Total Gas	***381.0***	***Total Solar***	***188.9***	Las Perlas Sur	10.0	Rosa de los Vientos 1	52.5
				RP490	10.0	Rosa de los Vientos 2	50.0
				Los Algarrobos	9.9	Portobelo Ballestillas	32.5
Cerro Patacón	8.1	Fortuna	300.0	Las Cruces	9.4	Marañón	17.5
Total Biomass	***8.1***	Bayano	260.0	San Lorenzo	9.0	***Total Wind***	***270.0***

Table 1. Detailed installed capacity 2018

Source: SNE Website. Capacidad Instalada, Firme, Generacion Bruta

Project	2019	Project	2021	Project	2023	Project	2026
Celsia BLM	-160.0	Solar Penonomé II	60.0	Panama NG Power	670.0	Chan II	228.5
Termo-Colón	-150.0	Solar Prudencia	21.4	Martano	458.1	***Total Hydropower***	***228.5***
El Giral Power Station	-144.0	Solar Gualaca	17.3	***Total Gas***	***1,128.1***		
Cerro Azul	-134.0	Jagüito	10.0	El Sindigo	10.0	Project	2028
ACP	-92.0	Farrallón Solar II	5.1	La Herradura	5.5	Tizingal	5
Total Oil (Bunker+Diesel)	***-680.0***	***Total Solar***	***113.8***	***Total Hydropower***	***15.5***	***Total Hydropower***	***5***
Providencia Solar	10.0	Chuspa	8.8			Toabre III	22.0
Pacora II	4.0	Colorado	6.7	Project	2024	***Total Wind***	***22.0***
Total Solar	***14.0***	***Total Hydropower***	***15.5***	Solar Coclé 04	9.0		
		Viento Sur	115.2	Solar Herrera 01	8.0	Project	2029
Project	2020	***Total Wind***	***115.2***	***Total Solar***	***17.0***	Solar Chiriquí 20	71.0
Solar Penonomé I	60.0			San Bartolo	20.4	***Total Solar***	***71.0***
Bajo Frío Solar	20.0	Project	2022	***Total Hydropower***	***20.4***		
Don Félix II	8.0	Solar Chiriquí 19	52.0	Toabre II	22.0	Project	2030
Total Solar	***87.9***	Solar Coclé 12	10.0	***Total Wind***	***22.0***	Solar Chiriquí 18	46.0
Pando	37.0	***Total Solar***	***62.0***			Solar Cocle 23	5.0
San Andres	9.9	Burica	65.3	Project	2025	Solar Cocle 09	5.0
Total Hydropower	***46.9***	Cotito	5.0	El Recodo	10	***Total Solar***	***56.0***
Toabré I	***60.0***	Barriles	1.0	***Total Hydropower***	***10***		
Total Wind	***60.0***	***Total Hydropower***	***71.3***			Plants in disuse (CF<0.5%)	
		Eólico Chiriquí 01	19.8			ETESA Alternative Scenario I	
		Total Wind	***19.8***			ASEP Resolutions	

Table 2. Detailed additional installed capacity 2019-2030

Installed Capacity (MW) 2019 - 2030												
Technology	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Coal	420	420	420	420	420	420	420	420	420	420	420	420
Oil	428	428	428	428	428	428	428	428	428	428	428	428
Gas	381	381	381	381	1,509	1,509	1,509	1,509	1,509	1,509	1,509	1,509
Biomass	8	8	8	8	8	8	8	8	8	8	8	8
Solar	203	291	405	467	467	484	484	484	484	484	555	611
Hydropower	1,777	1,824	1,839	1,910	1,926	1,946	1,956	2,185	2,185	2,189	2,189	2,189
Wind	270	330	445	465	465	487	487	487	487	509	509	509
Total:	3,487	3,681	3,926	4,079	5,223	5,282	5,292	5,521	5,521	5,547	5,618	5,674

Table 3. Installed capacity by technology 2019-2030

Year	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
GWh	12,091	12,840	13,587	14,301	15,104	15,956	16,831	17,736	18,695	19,706	20,817	21,988

Table 4. Electricity generation 2019-2030

Source: SNE Website. Transmision Electrica

Energy Generation (GWh) 2019 - 2030												
Technology	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Coal	1,840	1,840	1,840	1,840	1,840	1,840	1,840	1,840	1,840	1,840	1,840	1,840
Oil	721	1,046	1,340	1,654	-	-	-	-	-	900	1,924	3,027
Gas	1,669	1,669	1,669	1,669	4,065	4,767	5,602	5,607	6,565	6,610	6,610	6,610
Biomass	18	18	18	18	18	18	18	18	18	18	18	18
Solar	249	357	496	572	572	593	593	593	593	593	680	749
Hydropower	7,004	7,188	7,250	7,531	7,592	7,672	7,712	8,612	8,612	8,631	8,631	8,631
Wind	591	723	975	1,018	1,018	1,067	1,067	1,067	1,067	1,115	1,115	1,115
Total:	12,091	12,840	13,587	14,301	15,104	15,956	16,831	17,736	18,695	19,706	20,817	21,988

Table 5. Electricity generation by technology 2019-2030

tCO2eq Emissions 2019 - 2030												
Technology	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Coal	1,508,472	1,508,472	1,508,472	1,508,472	1,508,472	1,508,472	1,508,472	1,508,472	1,508,472	1,508,472	1,508,472	1,508,472
Oil	529,966	768,848	985,141	1,215,600	-	-	-	-	-	661,658	1,414,096	2,224,743
Gas	817,702	817,702	817,702	817,702	1,991,622	2,335,650	2,744,917	2,747,422	3,216,940	3,238,830	3,238,830	3,238,830
Biomass	4,080	4,080	4,080	4,080	4,080	4,080	4,080	4,080	4,080	4,080	4,080	4,080
Solar	11,946	17,123	23,822	27,472	27,472	28,472	28,472	28,472	28,472	28,472	32,652	35,948
Hydropower	168,086	172,522	173,992	180,738	182,202	184,136	185,083	206,697	206,697	207,137	207,137	207,137
Wind	6,504	7,950	10,725	11,202	11,202	11,732	11,732	11,732	11,732	12,262	12,262	12,262
Total:	3,046,755	3,296,696	3,523,935	3,765,265	3,725,050	4,072,541	4,482,756	4,506,875	4,976,393	5,660,911	6,417,529	7,231,473

Table 6. tCO2eq emissions by technology 2019-2030