

# 1 EXECUTIVE SUMMARY

While renewable energy and energy efficiency are complementary alternatives to conventional generation, transitioning to them needs to be done in a thoughtful and iterative process that ensures that the core needs of the system – including stability, reliability, and financial viability, are met. The electrical system underpins the economic foundation of the Bahamas – so it is essential that it continue to operate as well as or better than the current operating system standard during and after the introduction of renewables if the uptake of renewable energy and energy efficiency is to be fully realized.

The Government of The Bahamas aims to achieve a significant renewable energy penetration by 2030 in order to replace expensive generation from fossil fuels and reduce dependency on fuel imports. According to the National Energy Plan, the target is to achieve 30% of electricity generation from renewable sources of the total generation portfolio. Given that the current renewable share is less than 1% of the overall generation, an ambitious and fast track programme is required to achieve this target.

In that respect, a 5-year Renewable Energy Plan for New Providence and the Family Islands has been developed. This plan shows a path for next 5 years to achieve the 2030 National Energy Plan Goals and outlines estimated level of investment that is needed to achieve these goals.

**Over the next 5 years The Bahamas should plan and pursue 119.08MW of solar PV in New Providence (73.7MW) and the Family Islands (45.38MW) supplemented with 10.96MW of 4-hour battery energy storage.**

It should be noted that these figures represent total amount of solar PV that should be installed, including ones that that will be procured through SSRG programme, as well as through BPL and IPP investment. The associated capital costs are **\$203.7 million** for solar PV and **\$25.3 million** for the battery storage. These investments result in an annual savings of **\$3.7 million** for BPL comparing to BAU (business as usual) case as shown in following table:

**Table 1 – NP+FI – Annual Cost Saving for proposed PV+BESS investments**

<i>NP + Family Islands</i>			2019	2020	2021	2022	2023
PV+BESS case	<b>Total cost</b>	<b>mil\$</b>	358.9	368.8	386.0	415.3	427.3
	<b>Total generation</b>	<b>GWh</b>	2,018.6	2,113.1	2,221.5	2,300.0	2,356.7
	<b>Levelized cost of electricity</b>	<b>\$/MWh</b>	177.80	174.54	173.74	180.59	181.29
Base case (BAU)	<b>Total cost</b>	<b>mil\$</b>	358.8	368.6	389.1	421.9	436.4
	<b>Total generation</b>	<b>GWh</b>	2,018.6	2,113.1	2,221.4	2,299.7	2,356.2
	<b>Levelized cost of electricity</b>	<b>\$/MWh</b>	177.75	174.45	175.18	183.46	185.21

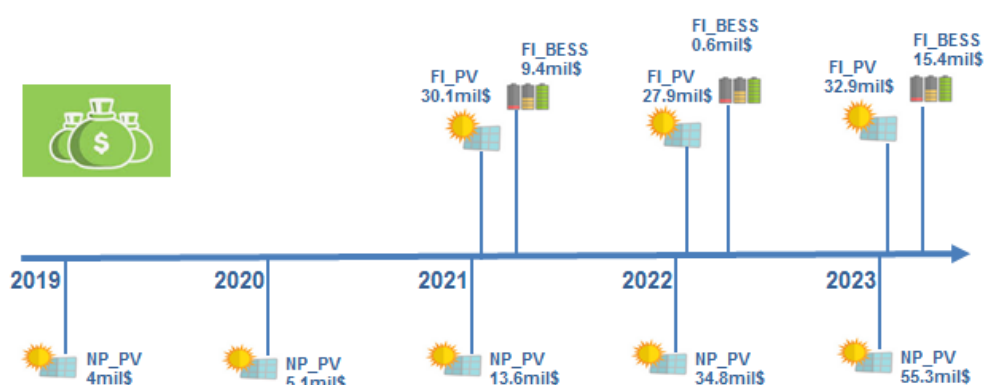
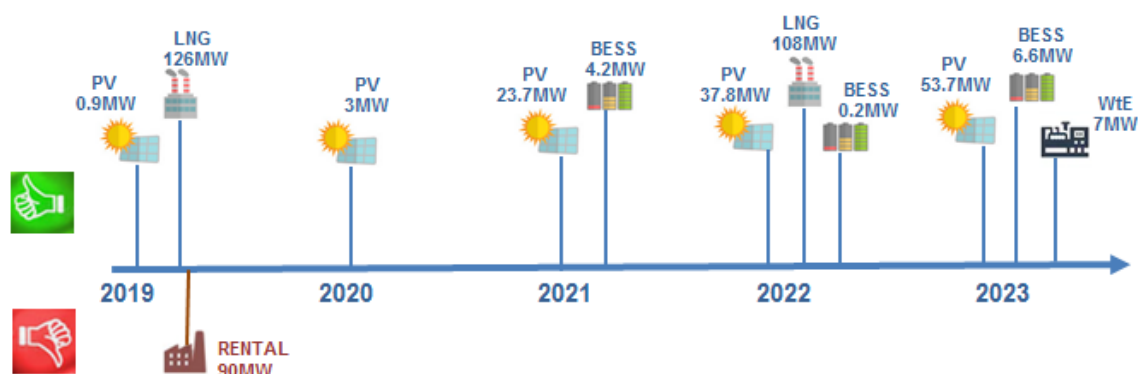
This plan provides details of the expected share of energy provided by renewable sources up to and including 2023 (in accordance with 2030 National Plan). The level of investments required to reach these targets has also been determined.

In the following table and figures review of recommended solar PV and battery energy storage facilities with associated costs for New Providence and Family Islands is given:

**Table 2 – NP+FI – Proposed PV and BESS investment**

Installed/Cost			2019	2020	2021	2022	2023	Total
NP	PV rooftop installed	MW	0.9	3.0	8.0	9.0	7.8	28.7
	CAPEX - PV rooftop	\$000	4,000	5,100	13,600	15,300	13,260	51,260
	PV Landfill installed	MW				15.0		15.0
	CAPEX - PV Landfill	\$000				19,500		19,500
	PV floating installed	MW					30.0	30.0
	CAPEX - PV floating	\$000					42,000	42,000
	BESS installed	MW						0
CAPEX - BESS	\$000						0	
FI	PV installed	MW			15.69	13.79	15.90	45.38
	CAPEX - PV	\$000			30,101	27,891	32,910	90,902
	BESS installed	MW			4.20	0.20	6.56	10.96
	CAPEX - BESS	\$000			9,360	560	15,368	25,288
NP + FI	PV installed	MW	0.9	3.00	23.69	37.79	53.70	119.08
	CAPEX - PV	\$000	4,000	5,100	43,701	62,691	88,170	203,662
	BESS installed	MW			4.20	0.20	6.56	10.96
	CAPEX - BESS	\$000			9,360	560	15,368	25,288

Timeline for these proposed capacities and investments is given graphically in the following figures.



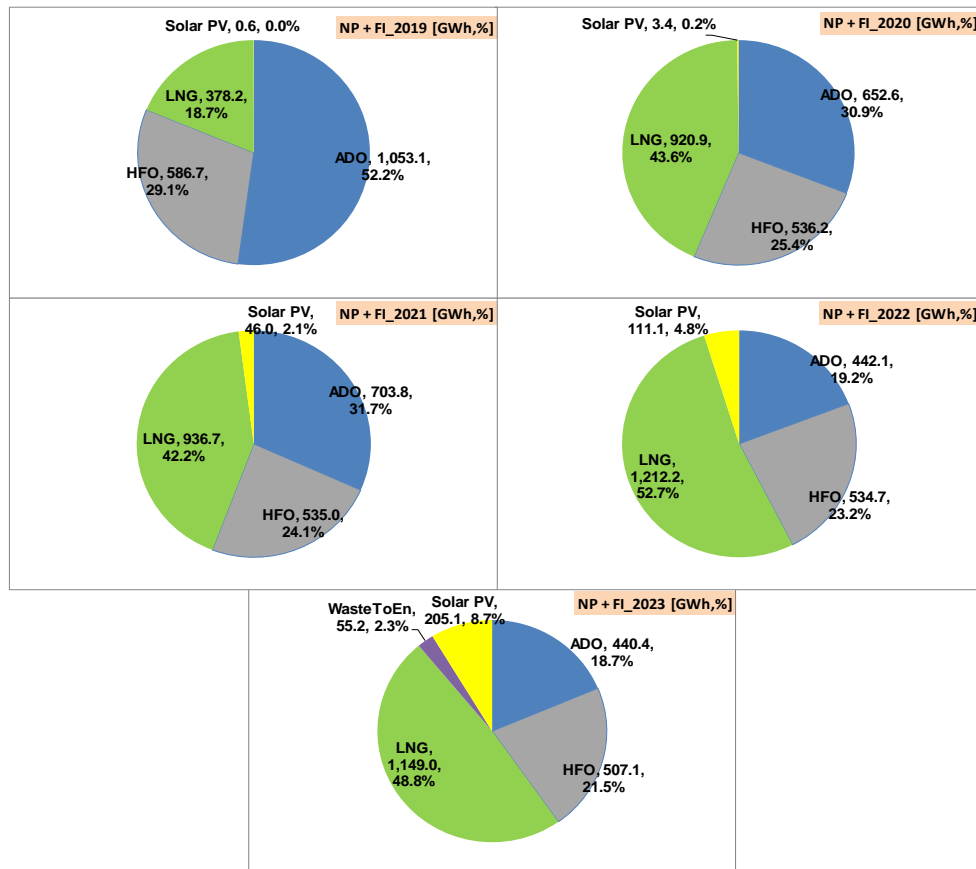


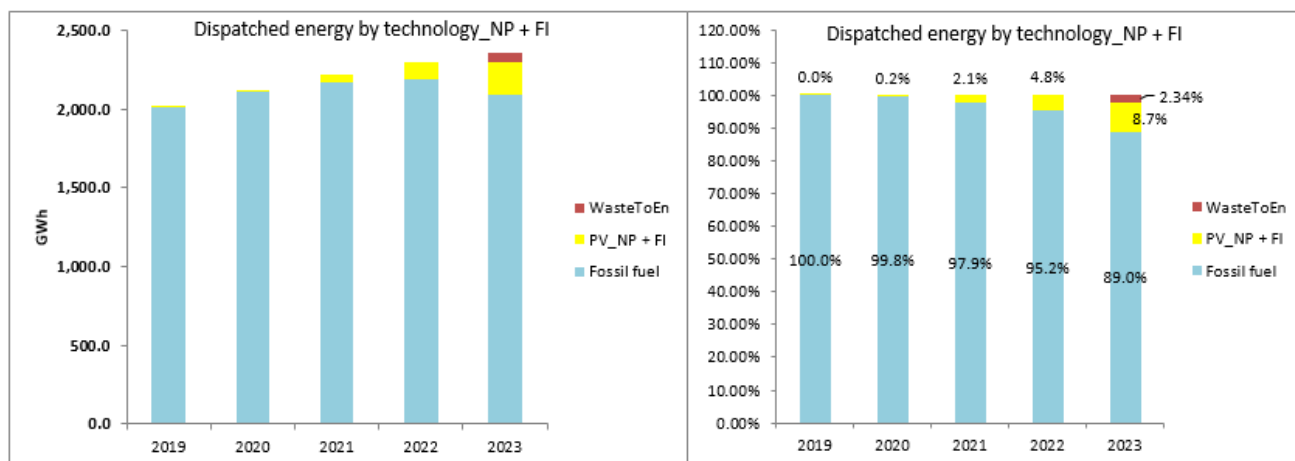
The first solar PV large scale facility, National Stadium (BPL/MOE/NSA) 900KW solar car park is envisaged to be online in June 2019. It is our assumption that all assessed potential rooftop PV facilities in New Providence would be installed just before the end of next 5-year period (in 2023). The amount of installed rooftop PV capacities in 2023 would be 28.7MW with annual production of 42.7GWh. Installation of 30MW of floating solar PV on Lake Killarney with annual production of 54.1GWh is envisaged in 2023. Further development of floating PV projects will be realized until 2030 year. Potential 15MW Landfill solar PV facility is assumed to be in operation in 2022. Installation of first ground mounted solar PV on Family Islands is planned for the beginning of 2021 year.

Due to the commercial arrangements and capacity factor for the planned LNG plant, PLEXOS analysis have shown that there is no incentive to invest in battery energy storage for provision of spinning reserve, as LNG units that have to be online will be providing sufficient reserve. However, there may be potential cases for battery storage such as backup for critical facilities, or to integrate additional renewable energy beyond 2023 targets.

On the other hand, investment in battery storage can be justified in Family Islands, as PV penetration level will reach 10-15% in 2023. When level of solar PV penetration reaches 10% of total annual demand (in 2023), shortages of spinning reserves as well as solar PV curtailments occur. Therefore, battery storage facilities with a 4-hour rating have been proposed to support normal system operation, provide spinning reserve, and avoid solar PV curtailment. The battery would be charged during daylight with excess PV generation and discharged during night hours, therefore would serve for regulation and load shaving. This battery storage will also support further integration of solar PV in following years up to 2030.

Considering recommended PV and BESS facilities and existing conventional generation fleet, calculated generation in next five years in New Providence and Family Island is provided in the next figures:





**Figure 1 – NP+FI – generation in next five years**

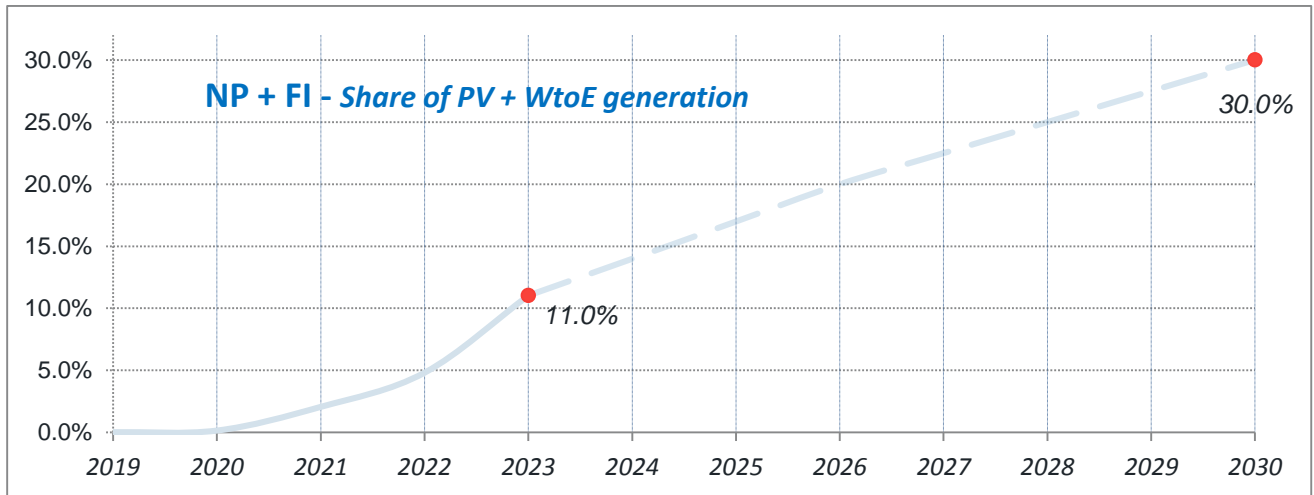
Total energy produced by generation type in GWh and % is summarized in table below:

Table 3 – NP+FI – generation in next five years

<i>NP + FI - generation</i>		2019	2020	2021	2022	2023
<b>Fossil fuel</b>	<b>GWh</b>	2,018.0	2,109.7	2,175.5	2,188.9	2,096.4
<b>PV (NP + FI)+WtoE</b>	<b>GWh</b>	0.615	3.395	46.003	111.063	260.262
<b>Total</b>	<b>GWh</b>	<b>2,018.6</b>	<b>2,113.1</b>	<b>2,221.5</b>	<b>2,300.0</b>	<b>2,356.7</b>

<i>NP + FI - generation</i>		2019	2020	2021	2022	2023
<b>Fossil fuel</b>	<b>%</b>	100.0%	99.8%	97.9%	95.2%	89.0%
<b>PV (NP + FI)+WtoE</b>	<b>%</b>	0.0%	0.2%	2.1%	4.8%	11.0%
<b>Total</b>	<b>%</b>	<b>100.0%</b>	<b>100.0%</b>	<b>100.0%</b>	<b>100.0%</b>	<b>100.0%</b>

In 2023, overall percentage of solar PV plus Waste to Energy generation share for New Providence and Family Island is 11%, which is in line with goal to reach 30% in 2030.



**Figure 2 – NP+FI – planned trend of PV + WtoE generation share up to 2030**

In period 2024-2030, larger quantities of PV facilities should be installed in New Providence and Family Islands to reach 30% target in 2030. That will require more batteries to support further integration of renewable sources.

## KEY ASSUMPTIONS

A summary of assumptions used to derive a 5 year plan for New Providence (NP) and Family Islands (FI) is outlined below:

### New Providence (NP)

- Installation of all assessed quantities of roof top solar PV till the end of next 5-year period. The amount of installed solar PV capacities in 2023 would be 28.7MW with annual production of 42.7GWh.
- Installation of 30MW of floating solar PV with annual production of 54.1GWh in 2023. Further development will continue until 2030.
- Installation of 15MW of landfill ground mounted solar PV with annual production of 27.1GWh in 2022.
- New LNG power plant project will be realized in two phases. As phase one, seven units of 18MW would be in operation in August 2019. In the following phase, another six 18MW units is planned to be in operation in 2022.
- After commissioning of LNG phase 1, Aggreko rental units (90MW in the sum) will be cancelled. In the PLEXOS model LNG phase 1 is set up in operation at 01<sup>st</sup> August 2019, with the rental units A, B and CP being set out of operation at the end of August 2019. In real operation, these rental units should operate until full operating performances of LNG phase 1 are granted.
- Commissioning of the 7MW Waste to Energy power plant in the landfill, in 2023.
- Units DA11 and DA12 in Clifton Pier are considered as decommissioned due to failure (fire accident).
- Maintenance activities are not performed from May to September.

Following scenarios have been studied:

- **PV scenario** – considers all abovementioned assumptions, that is **preferential scenario**
- **PV + BESS scenario** – that is PV scenario including battery
- **PV Zero-Cost scenario** – PV scenario without taking into account capital and operating costs of PV plant – scenario used to determine the avoided cost value of PV
- **Base scenario** – without PV installed

### Family Islands (FI)

- Level of solar PV penetration on each island in 2023 reaches 10-15% of the total annual demand, in line with goal to reach 30% of total demand in 2030 year.
- When level of solar PV penetration reaches 10% of total annual demand (in 2023), shortages of spinning down reserves as well as solar PV curtailments occur. Therefore, battery storage facilities with a 4-hour rating have been proposed to support normal system operation, provide spinning reserve, and avoid solar PV curtailment. Battery will be charged during daylight with excess of PV generation and discharged during night hours. This battery storage will also support further integration of solar PV in following years.
- Maintenance activities are not performed in the period May – September.

Following scenarios have been studied:

- **PV+BESS scenario** – considers all abovementioned assumptions, that is **preferential scenario**
- **PV ZeroCost+BESS scenario** – PV+BESS scenario without counting capital and operating costs of PV plant – scenario used to determine the avoided cost value of PV+BESS
- **Base scenario** – without PV installed

## QUANTIFICATION OF PV PPA CEILING PRICE BY AVOIDED COST

PV ZeroCost scenario and the Base scenario have been analysed in order to compare costs of the scenarios, in such a way to quantify cost savings after installing solar PV plants in the system.

The PV ZeroCost scenario is the PV scenario (considers all recommended solar PV plants, and in the Family Islands also includes the BESS) without the inclusion of PV capital and operational costs. The Base scenario is without any solar PV installed. The difference between the scenarios is the avoided costs.

With the principle of avoided costs, assuming the solar PV facility as an independent power producer (IPP), the value of electricity (\$/MWh) from the solar PV may be expressed as difference of the total costs between PV ZeroCost (or PV ZeroCost+BESS when there is a battery installed) and Base scenarios (avoided cost), divided by electricity produced from solar PV. In that way, avoided cost (\$/MWh) may be good reference to determine the electricity price ceiling in a Power Purchase Agreement (PPA).

As it can be seen from the table below, the value for possible electricity price in PPA varies from 130 to 160 \$/MWh which is considered attractive for this type of power plants in Caribbean region.

In the following tables calculated avoided costs in New Providence, Family Islands and overall in New Providence and Family Islands are given:

**Table 4 – NP+FI – review of avoided costs in New Providence**

<i>New Providence</i>			2019	2020	2021	2022	2023
Base case	<b>Total cost</b>	<b>mil\$</b>	254.118	258.891	272.633	296.099	303.716
PV ZeroCost case	<b>Total cost</b>	<b>mil\$</b>	254.033	258.423	270.267	289.350	289.482
Delta	<b>Avoided total cost</b>	<b>mil\$</b>	<b>0.084</b>	<b>0.468</b>	<b>2.366</b>	<b>6.749</b>	<b>14.234</b>
PV Zero+BESS case	<b>PV generation</b>	<b>GWh</b>	0.62	3.39	17.71	58.17	123.73
Delta	<b>Energy cost - avoided</b>	<b>\$/MWh</b>	<b>137.34</b>	<b>137.81</b>	<b>133.60</b>	<b>116.02</b>	<b>115.04</b>

**Table 5 – NP+FI – review of avoided costs in Family Islands**

<i>Family Island - Total</i>			2019	2020	2021	2022	2023
Base case	<b>Total cost</b>	<b>mil\$</b>	104.716	109.725	116.547	125.795	132.692
PV ZeroCost+BESS	<b>Total cost</b>	<b>mil\$</b>	104.716	109.725	110.413	114.250	116.348
Delta	<b>Avoided total cost</b>	<b>mil\$</b>	<b>0.000</b>	<b>0.000</b>	<b>6.134</b>	<b>11.545</b>	<b>16.344</b>
PV ZeroCost+BESS	<b>PV generation</b>	<b>GWh</b>	0.00	0.00	28.30	52.89	81.35
Delta	<b>Energy cost - avoided</b>	<b>\$/MWh</b>	-	-	<b>216.77</b>	<b>218.27</b>	<b>200.91</b>
	<b>Total PV installed</b>	<b>MW</b>	-	-	<b>15.69</b>	<b>29.48</b>	<b>45.38</b>
	<b>BESS installed</b>	<b>MW</b>	-	-	<b>4.20</b>	<b>4.40</b>	<b>10.96</b>

**Table 6 – NP+FI – review of avoided costs in the Bahamas (New Providence and Family Islands)**

<i>New Providence + Family Island - Total</i>			2019	2020	2021	2022	2023
Base case	<b>Total cost</b>	<b>mil\$</b>	358.834	368.616	389.180	421.894	436.408
PV ZeroCost+BESS	<b>Total cost</b>	<b>mil\$</b>	358.749	368.148	380.680	403.600	405.830
Delta	<b>Avoided total cost</b>	<b>mil\$</b>	<b>0.084</b>	<b>0.468</b>	<b>8.499</b>	<b>18.294</b>	<b>30.578</b>
PV ZeroCost+BESS	<b>PV generation</b>	<b>GWh</b>	0.62	3.39	46.00	111.06	205.08
Delta	<b>Energy cost - avoided</b>	<b>\$/MWh</b>	<b>137.3</b>	<b>137.81</b>	<b>184.76</b>	<b>164.72</b>	<b>149.10</b>
	<b>Total PV installed</b>	<b>MW</b>	<b>0.9</b>	<b>3.9</b>	<b>27.59</b>	<b>65.38</b>	<b>119.08</b>
	<b>BESS installed</b>	<b>MW</b>	-	-	<b>4.20</b>	<b>4.40</b>	<b>10.96</b>