

Annex 21. Operations manual

The climate proofing of critical public buildings in Antigua and Barbuda will require ongoing maintenance over the lifespan of the proposed project to ensure the sustainability and optimal functioning of the proposed interventions. The lifespan of the project for the purpose of this manual is 50 years for building infrastructure and 20 years for solar PV infrastructure, including the implementation phase. Operation and Maintenance (O&M) activities should include the following:

- monitoring and post-construction inspection;
- regular, planned maintenance (annual or more frequent); and
- intermittent repair.

To ensure the sustainability of the proposed building and solar PV infrastructure, this document provides the overall framework for the operations and maintenance of the interventions. Detailed O&M plans will be developed for each of the interventions under the following project activities: i) implement climate-proofing measures on critical infrastructure (Activity 1.1.); ii) implement measures to secure uninterrupted power and water supply to critical public service buildings during and after extreme events (Activity 1.4.). These O&M plans will consider the technical aspects of each intervention, as well as the specific roles and responsibilities of the different stakeholders. The main stakeholders will be Antigua and Barbuda's Ministry of Finance (MoF), Ministry of Works (MoW), Ministry of Education Science and Technology (MoEST), and Ministry of Health, Wellness and the Environment (MoHWE). The Project Management Unit (PMU) will compile the O&M plans for the above-mentioned interventions into a detailed overarching O&M Plan for the project as a whole.

The first half of this operations manual will outline the importance, frequency, and maintenance costs for the proposed building infrastructure interventions. The second half of this manual will outline the importance, frequency, and intervention extent for the solar PV systems.

The main factors that will affect the maintenance costs of the proposed building infrastructure interventions and solar PV systems are as follows:

- type and frequency of maintenance required;
- costs of maintenance (materials, labour and equipment costs);
- availability of materials and disposal costs;
- site characteristics; and
- individuals/authorities responsible for maintenance procedures.

Building Infrastructure

Maintenance Frequency

The costs associated with maintenance will depend on the frequency of maintenance activities required. Table 1 highlights the required maintenance interventions and maintenance frequencies for the public buildings selected for climate adaptation upgrade. The importance of each maintenance interventions falls into four categories i) minimum requirement, ii) recommended, iii) according to manufacturer specification, and iv) site dependant. Assessment of the buildings and the associated maintenance should be carried out according to the stated frequency.

Table 1: Operation and maintenance works required for the climate adaptation upgrade of public buildings.

<i>Task</i>	<i>Importance</i>	<i>Frequency</i>
<i>General Building Repairs (Minor Repairs)</i>	Minimum Requirement	Yearly
<i>General Structural Repairs (Major Repairs)</i>	Recommended	Yearly
<i>Roof Structural Assessment/Repair</i>	Recommended	Yearly
<i>Windows, Doors and Shutters Maintenance</i>	Recommended	Yearly
<i>Electrical Infrastructure and Energy Efficiency Measures</i>	Recommended	Yearly
<i>Maintenance of On-Site Water Supply</i>	Recommended	6 Months
<i>Storm Water Maintenance and Cleaning</i>	Recommended	6 Months
<i>Waste Water Treatment</i>	Recommended	Yearly

Maintenance Cost

The estimates of annual O&M costs are represented as a percentage of replacement costs, ranging from 4-6%¹. Table 2 outlines the base costs for the routine maintenance of interventions per building, to be conducted during the 50 year project lifespan according to the frequency laid out in Table 1. Table 3 outlines the cost of maintenance of interventions if repairs are necessary beyond the scope of biannual and annual maintenance works.

Funding for the operations and maintenance of the buildings following project implementation will be covered by the Government of Antigua and Barbuda.

Table 2: Annual operations and maintenance costs per building.

<i>Task</i>	<i>Cost Per Frequency (USD)</i>	<i>Total Cost/50 Year Period (USD)</i>
<i>General Building Repairs (Minor Repairs)</i>	\$500.00	\$25,000.00
<i>General Structural Repairs (Major Repairs)</i>	\$200.00	\$10,000.00

¹ CIDB. Infrastructure Maintenance Budgeting Guideline. Retrieved from: <http://www.cidb.org.za/publications/Documents/Infrastructure%20Maintenance%20Budgeting%20Guideline.pdf>

<i>Roof Structural Assessment</i>	\$500.00	\$25,000.00
<i>Storm Shutter Maintenance</i>	\$500.00	\$25,000.00
<i>Electrical Infrastructure and Energy Efficiency Measures</i>	\$500.00	\$25,000.00
<i>Maintenance Of On-Site Water Supply</i>	\$200.00	\$20,000.00
<i>Storm Water Maintenance and Cleaning</i>	\$250.00	\$25,000.00
<i>Waste Water Treatment</i>	\$250.00	\$12,500.00

Table 3: Cost of additional repairs beyond the scope of biannual and annual maintenance works.

<i>Task</i>	<i>Cost of Additional Repairs (USD)</i>
<i>General Building Repairs (Minor Repairs)</i>	\$2,500.00
<i>General Structural Repairs (Major Repairs)</i>	\$5,000.00
<i>Roof Structural Assessment/Repair</i>	\$3,000.00
<i>Windows, Doors and Shutter Maintenance</i>	\$3,000.00
<i>Electrical Infrastructure and Energy Efficiency Measure</i>	\$4,500.00
<i>Maintenance of On-Site Water Supply</i>	\$2,500.00
<i>Storm Water Maintenance And Cleaning</i>	\$1,500.00
<i>Waste Water Treatment</i>	\$2,500.00

Solar PV Infrastructure

Maintenance frequency

The costs associated with maintenance will depend on the frequency of maintenance activities required, as well as the size of the solar PV systems installed on project buildings. Table 5 outlines indicative maintenance tasks and frequencies for each component of the solar PV system. The importance of each maintenance task falls into four categories i) minimum requirement, ii) recommended, iii) according to manufacturer specification, and iv) site dependant. Maintenance extent falls into two categories i) total system (T) and ii) random unit (R).

Table 4: Maintenance tasks and frequency for Solar PV arrays

<i>Equipment</i>	<i>Task</i>	<i>Importance</i>	<i>Frequency</i>	<i>Extent</i>
<i>Modules</i>	Integrity inspection and replacement	Minimum requirement	Yearly	T

<i>Electrical cabinets and switchboards</i>	Thermography inspection	Recommended	Yearly	T
	Check tightening of clamps and bolts	Minimum requirement	Quarterly or before any major storms	R
	Module cleaning	Site dependant	As required	T
	Internal inspection of junction boxes	Recommended	Yearly	T
	Integrity inspection and cleaning	Minimum requirement	Yearly	T
	Check labelling	Minimum requirement	Yearly	R
	Electrical protection inspection and test	minimum requirement	Yearly	T
	Check fuse status	minimum requirement	Yearly	T
	Check surge protection	minimum requirement	Yearly	T
	Check cables and terminals	minimum requirement	Yearly	T
	Sensor verification	recommended	Yearly	T
	Thermographic inspection	Recommended	Yearly	T
	Lubricate locks	minimum requirement	Yearly	T
	Check tightening	minimum requirement	Yearly	T
<i>Cables</i>	Integrity inspection and replacement	minimum requirement	Yearly	R
	Check labelling	minimum requirement	Yearly	R
	Check terminals	minimum requirement	Yearly	R
<i>Inverter</i>	Integrity inspection and replacement	minimum requirement	Yearly	T
	Check labelling	Minimum requirement	Yearly	T
	Electrical protection inspection and test	Minimum requirement	Yearly	R
	Check fuse status	minimum requirement	Yearly	T
	Check surge protection	Minimum requirement	Yearly	T
	Thermographic inspection	Recommended	Yearly	T
	Sensor verification	Minimum requirement	Yearly	R
	Check parameters	Minimum requirement	Yearly	T
	Test Ventilation system	Minimum requirement	Yearly	T

<i>Transformers</i>	Check/replace batteries	According to manufacturer specification	Yearly	T
	Replace fans	According to manufacture specification	Yearly	T
	Safety equipment inspection	Minimum requirement	Yearly	T
	Clean/replace filter	Minimum requirement	Yearly	T
	Integrity inspection and cleaning	Minimum requirement	Yearly	T
	Check labelling	Minimum requirement	Yearly	R
	Thermographic inspection	Recommended	Yearly	T
	Sensor verification	Minimum requirement	Yearly	T
	Check parameters	Minimum requirement	Yearly	T
	Check oil level	Minimum requirement	Yearly	T
<i>MV switchgear</i>	Check cooling system	Minimum requirement	Yearly	T
	Check MV surge discharge	minimum requirement	Yearly	T
	Integrity inspection and cleaning	Site dependant	Yearly	T
	Safety equipment inspection	Minimum requirement	Yearly	R
	Check labelling	Minimum requirement	Yearly	T
	Electrical protection inspection and test	Minimum requirement	Yearly	T
	Thermographic inspection	Recommended	Yearly	T
	Sensor verification	Minimum requirement	Yearly	T
	Check correct operation	Minimum requirement	Yearly	T
	Check fuse status	Minimum requirement	Yearly	T
	Check terminals	Minimum requirement	Yearly	T
	Check/replace batteries	According to manufacturer specification	Yearly	T
	Check lubrication	Minimum requirement	Yearly	T
	Check protection parameters	According to local code	Yearly	T

<i>Power Analyser</i>	Integrity inspection and cleaning	Minimum requirement	Yearly	T
	Check labelling	Minimum requirement	Yearly	R
	Software maintenance	Recommended	Yearly	T
	Monitoring operation test	Minimum requirement	Yearly	T
	Check parameters	Minimum requirement	Yearly	T
<i>Energy Meter</i>	Integrity inspection and cleaning	Minimum requirement	Yearly	T
	Check labelling	Minimum requirement	Yearly	R
	Check parameters	Recommended	Yearly	T
	Check communication devices	Recommended	Yearly	T
<i>UPS</i>	Integrity inspection and cleaning	Minimum requirement	Yearly	T
	Check/replace batteries	According to manufacturer specification	Yearly	T
	Test Ventilation system	Recommended	Yearly	T
<i>Lights</i>	Integrity inspection and cleaning	Minimum requirement	Yearly	T
	Check operation	Minimum requirement	3 years	T
<i>Lightning protection</i>	Integrity inspection and replacement	Recommended	Yearly	R
<i>Fences and Gates</i>	Integrity inspection	Minimum requirement	Yearly	T
	Lubrication of locks	Minimum requirement	Yearly	T
<i>Vegetation</i>	Clearing	Minimum requirement	Site dependant	t
<i>Safety Equipment</i>	Integrity check and replacement	Minimum requirement	Yearly	T
	Check operation	Minimum requirement	Yearly	T
<i>PV Support Structure</i>	Integrity check	Minimum requirement	Yearly	R
	Check tightening	Minimum requirement	Yearly or before major storms	R
	Check potential equalization	Minimum requirement	2 years	T
<i>Weather station</i>	Integrity check and replacement	According to manufacturer specification	Yearly	T

<i>Irradiation sensors</i>	Sensor verification	According to manufacturer specification	Yearly	T
	Check operation	According to manufacturer specification	Yearly	T
	Check/replace batteries	According to manufacturer specification	Yearly	T
	Monitoring operation test	According to manufacturer specification	Yearly	T
	Integrity check and replacement	According to manufacturer specification	Quarterly	T
	Calibration	According to manufacturer specification	2 years	T
	Monitoring operation test	According to manufacturer specification	Yearly	T
<i>Communication board</i>	Communications test	Minimum requirement	Yearly	T
<i>Stock of spare parts</i>	Inventory of stock	Minimum requirement	Yearly	T
	Inspection of stock	Minimum requirement	Yearly	T
	Test of stock	Minimum requirement	Yearly	R
	Stock replenishment	Minimum requirement	Monthly	T

Maintenance costs

The estimates of annual O&M costs are a direct function of solar PV system size and therefore cannot be accurately determined without knowledge of the system size per building. Annual operations and maintenance costs for arrays with capacities between 5kW to 200kW currently range from \$17-\$21 USD per kW². The largest portion of these costs are due to the need to replace system inverters once within the project lifetime. Current industry standard warranties for inverters vary between 10-15 years.

It should be noted that O&M costs continue to decrease as PV technology advances. For fixed, utility scale solar PV installations O&M costs fell from \$20/kW in 2017 to \$14/kW in 2018.

It should also be noted that not all of the maintenance tasks outlined in Table 5 may be necessary for each building selected for this project. For example, not all buildings will require transformers, weather stations, irradiance sensors, or power analysers. Similarly, required vegetation clearing can vary greatly per site. Ground mounted solar PV arrays will require

² Fu, R., Feldman, D., Margolis, R. 2018 *U.S. solar photovoltaic system cost benchmark: Q1 2018*. Golden, CO: National Renewable Energy Laboratory.

more regular vegetation clearing than rooftop arrays to prevent shading and/or system damage.