Antigua and Barbuda public building climate adaptation upgrade programme

Feasibility study final report 16 July 2019

EXECUTIVE SUMMARY

This document is the final report for a feasibility study, on a proposed upgrade to the existing public building portfolio of the Government of Antigua and Barbuda (GovAB). The portfolio extends to over 200 buildings. If it can secure the financing, the GovAB plans to upgrade the buildings to adapt to climate change and for other reasons over the period 2020 to 2025.

The GovAB proposes to both develop and launch the upgrade programme via an initial climate adaptation project that is co-financed by the GovAB and international donors, including the Green Climate Fund (GCF). The scope of this project is expected to include i) policy support, ii) capacity building and iii) the discussed investments in physical infrastructure upgrades.

A first pass concept note for this project has been submitted to the GCF, who responded with formal and informal feedback, including recommendations that co-financing is needed and the entire project should cost US$40M or less.

This feasibility study has delivered the fundamental information required to design the upgrade programme and identified the two major challenges as a) affordability for GovAB and b) the difficulty of securing sufficient adaptation finance.

In this context, a comprehensive building upgrade programme was identified that would cost US$90M and deliver multiple adaptation benefits. The economic analysis indicates however, that this is probably not feasible to co-finance, and also unlikely to be secured via adaptation grant funding alone.

To resolve this serious problem, an alternative more basic programme costing US$28M has been outlined. This would deliver less benefits but is considered feasible to finance. The critical benefit delivered by the basic programme would be financial risk reduction: forecast significant avoided losses and damages from hurricanes and storms. The basic programme would also still allow for up to US$7M in GCF sourced adaptation grant funding to be redirected to linked soft investments such as policy development and capacity building.

The core recommendation delivered by this study is to progress the basic upgrade programme as soon as practical and to develop the full programme in parallel as more grant based climate finance is secured.

The temporary and potentially permanent loss of some benefits due to this phased approach is regrettable, but less regrettable than either having no upgrade at all or significantly increasing the debt burden of GovAB.

The short term way forward is presented as a set of more detailed recommendations for GovAB and its selected GCF accredited partner.

1 INTRODUCTION

1.1 Report context

This document is the final report for a feasibility study, on a proposed upgrade to the existing public building portfolio of the Government of Antigua and Barbuda (GovAB). The portfolio extends to over 200 buildings. If it can secure the financing, the GovAB plans to upgrade the buildings to adapt to climate change and for other reasons over the period 2020 to 2025.

The planned upgrades are presented in this report as a proposed programme: an interlinked set of projects with a common goal. As yet, this programme does not exist in practical or policy terms. It is already clear however, that a comprehensive response to the noted needs of GovAB will need to be framed as a long term programme rather than a single discrete project.

The GovAB proposes to both develop and launch the programme via an initial project that is co-financed by the GovAB and international donors, including the Green Climate Fund (GCF). This project would focus on climate adaptation and would have a broader scope than just upgrading the existing public building portfolio. This broader scope is however outside of the scope of this feasibility report – which focuses only on the upgrade.

1.2 Goal and objectives of the feasibility study

The study is framed as a feasibility study in the language of the GCF proposal process. However, the term "feasibility" in this case needs some further definition.

The need for GovAB to invest both in climate change adaptation and adequate maintenance of its building portfolio is not in question – the evidence is overwhelming. The technical feasibility of upgrading a relatively small portfolio of public buildings is also completely clear. In principle, if the GovAB cannot immediately pay for the programme it could in theory decide to take a public sector loan – so the pure financing feasibility is also clear.

The key remaining feasibility concerns are linked to access to international aid and national affordability, which are partly political issues:

- If GovAB cannot access large scale international grant aid for this programme, all indications are that it will not be economically feasible. This is a circular issue, as the design, scale and presentation of the feasibility study will influence but not control the decision of donors to support the programme. There is never sufficient donor funding to cover all adaptation and general development needs.
- Even if grant aid is secured, all indications are that key donors will only cover adaptation costs and will also request significant co-financing. The programme can therefore only progress if GovAB finds and allocates finance via its current own resources or via a public sector loan.

This infers that the "feasibility" of the programme is in the large part based on both national and donor political decisions on funding priorities and willingness to take on public sector debt. The central goal of this feasibility study is therefore to inform these decisions.

In this context, the detailed objectives of the feasibility study are:

- To inform the GovAB and other key stakeholders including the GCF, of the potential overall scope and estimated cost of the upgrades to the existing building portfolio.
- To develop and present an expert judgement on what scope and percentage of the overall upgrade cost could reasonably be classed as investments in adaptation.
- To provide recommendations on financing and mobilizing the upgrade programme.
- To form part of the technical submission for a potential formal GCF grant or grant and loan proposal.

1.3 Report status and associated detailed material

This is a public-non-confidential document; however, it is designed for a professional audience and to fit into a larger family of planning and funding proposal documents. As such it has a technical and economic focus on the existing building portfolio and provides only a summary of the context.

Detailed information on the climate and policy context of Antigua is available from the AB Department of Environment. A comprehensive list of references is provided in the current draft GCF concept note linked to this report.

This final report is linked to the following detailed technical reports and files:

- The UN Environment generated detailed Excel master spreadsheet of project scope and cost: AB Pub Bldg Adaptation Cost File 311221018.
- The ECMC generated package V 2.0 of 32 individual Detailed Work Package Word files, one for each building assessed in detail.

1.4 The study team and financing

The study was developed and implemented by a multi-national team.

- The GovAB Department of Environment acted as client for the work and also contributed substantially through the participation of its in-house team of engineers, specialists and project managers.
- UN Environment provided a senior engineer who undertook the core planning, interpretation, design and reporting work.
- The private consultancy ECMC, provided focused input on the structural and civil components of the programme, including the development of a large part of the detailed scope of work for the Phase I buildings
- A range of GovAB departments and organizations occupy the Phase I buildings and contributed to the site inspections and assessment of the needs.

The UN hosted Climate Technology Centre & Network (CTCN) supported the work of UN Environment and ECMC at the request of the GovAB Department of Environment, as part of its technical assistance service.

1.5 Study activities and calendar

The principle activities of the study were as follows:

- A preliminary UN Environment scoping mission in January 2018, including a start to the building inspections.
- Procurement of UN Environment and ECMC technical expertise in April 2018.
- Initial analysis, planning and design, to inform detailed inspections and data collection for 34 representative buildings from the portfolio of over 200.
- Two further missions by UN Environment and ECMC, focused on building inspections
- Further analysis, design, costing and consultation draft reporting
- Draft report circulation, consultation and finalization.

The study formally commenced in June 2018, was effectively completed in February 2019 and fully completed in June 2019. This was six months later than initially planned, in part due to the initial results, which indicated a significant affordability issue. This has not been completely resolved and recommendations to mitigate the issue are included in this report.

2 NATIONAL CONTEXT

2.1 Antigua Barbuda geography and climate

The nation of Antigua Barbuda consists of the two major islands and several smaller inhabited and uninhabited isles. Antigua has a surface area of 280km2 and a population of approximately 100,000. Barbuda has a surface area of 160km2 and a population of approximately 2,500.

Antigua is composed primarily of low lying coral and limestone rock and sediment, with several small hilly areas of extinct volcanic rock. Virtually all original vegetation has been cleared for agriculture and timber. Barbuda is flat with a large coastal lagoon. It still retains significant areas of original scrubland.

The AB climate is tropical but drier than much of the West Indies. The wet season is from May to November. Average annual rainfall is 1200mm, although this can be greatly distorted by both periodic drought and individual hurricanes and tropical storms, with a recorded annual minimum and maximum of 574mm and 1940mm respectively. The average annual temperature is 27 ^{o}C, ranging from 23 ^{o}C in January to 30 ^{o}C in August.

2.2 Natural hazards

AB has three distinct and important natural hazards: hurricanes and tropical storms, drought and earthquakes.

Hurricanes and tropical storms Antigua Barbuda are located within the Atlantic hurricane belt and so experience the full spectrum of severe weather, classified in ascending scale as tropical depressions, tropical storms, hurricanes and major hurricanes, the latter begin further divided into Categories 3, 4 and 5.

In the absence of climate change, the average return period or frequency of hurricanes can be extrapolated from historical data. The historical data indicates the following return period table (1 event per period) for hurricane centers passing within 30km (effectively a direct strike- labeled landfall in meteorological terminology).

Extreme weather event historical average return periods for AB[1]

Tropical storm or stronger: 6-7 years

Hurricane: 8 years

Major hurricane: 15 – 16 years

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[1] NOAA. National Hurricane Center NHC Archive.

The hurricane watch season is 1st June to 30th November and the peak hurricane frequency month is August. The last hurricane to strike Antigua Barbuda was Irma, which directly struck Barbuda on 6th September at Category 5 strength.

Drought Antigua Barbuda experiences frequent droughts. The most recent severe drought lasted from 2013 to 2016 and 32 droughts rated Severe or Serious have been experienced since detailed records began in 1928[2]. The short return periods of droughts means that Antigua in particular is now chronically short of water and relies heavily on seawater desalination for potable water.

Earthquakes Antigua Barbuda are located in an earthquake with relatively frequent tremors in the MMs 2-4 range. The strongest recorded earthquake was an MM7.4 recorded 40km east of Antigua in 1974. A MM7.3 earthquake was recorded in the region in 2007.

2.3 Climate change

The current and forecast climate change events and trends for Antigua Barbuda are:

- Increased intensity of hurricane and storm winds and floods.
- Increased average and peak temperatures and associated increased soil evaporation.
- Increased drought frequency and intensity and a long term decline in average rainfall.[3]

The significance of these climate trends is linked to the baseline: Antigua Barbuda is already suffering significantly and has limited economic resources. As such it is highly vulnerable to the economic and other impacts of climate change, so even slight increases in event severity will cause significant further harm.

Rising sea levels are an issue for both Antigua and Barbuda. Nearly 70% of Barbuda lies less than 3m above sea level, so the island is highly vulnerable to sea level rise, particularly when combined with hurricane induced storm surges.

The single most important climate issue of relevance to the upgrade programme is the impact of climate change on hurricane intensity and frequency. The Antigua and Barbuda Country Paper on National Climate Change Issues reported that from 1990–1999, the number of hurricanes per year and the number of named storms[4] increased[5].

Between 1990 and 1994, the country experienced 4 hurricanes annually and a total of 8 named storms. This increased to 8 hurricanes per year and 13 named storms between 1995 and 1999. Note that “experienced” hurricanes does not equate to direct hits, it instead means that the islands experienced higher than average winds and/or rainfall events linked to their passage.

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[2] Antigua and Barbuda Meteorological Service, Climate Section. Drought and precipitation statement for March 2017.

[3] FAO 2016. Drought characteristics and management in the Caribbean.

3 THE AB PUBLIC BUILDING BASELINE

3.1 Introduction

AB is a small island nation with a long settlement history and a recent history of multiple recessions. Antigua and Barbuda have population densities of 360/km2 and 15/km2, respectively. The public building portfolio reflects this history and demographics: it is in general quite dispersed and generally low rise, aging and in overall moderate to poor condition. Over 90% of the buildings are small: less than 1000m2 and 1 or 2 storeys.

This chapter provides a snapshot of the AB public building baseline. It covers the applicable building codes, the structures themselves, the utilities and infrastructure that service the buildings, how the buildings are ventilated and cooled, and building related lessons learned from past hurricanes.

3.2 AB building codes

Building codes in Antigua have been gradually developed and enforced in stages since 1985. Antigua Barbuda completed and legislated the detailed Antigua and Barbuda Building Code in 1996 and issued further guidelines thereafter. The code was closely based on a common standard (Caribbean Uniform Building Code – CUBiC) proposed by the Organization of Eastern Caribbean States.

The key climate issue linked to the building code is the concept of a design peak wind, which is the absolute maximum foreseen wind velocity that buildings need to withstand. For Antigua the peak wind is 168 miles per hour for the most critical public building types (such as hurricane shelters), equating to a modeled 700 year return period.

The CUBiC code is in the process of being superseded by another Caribbean joint effort. The Association of Caribbean States has sponsored the development of Model Building Codes for Winds and Earthquakes. These are under consideration by GovAB. The main difference between the existing and potential code is a slight increase in the design peak wind and extra detail on building design features, such as window, doors and shutters.

3.3 Building construction types

There are three main types of building construction in AB:

- Small masonry and mortared rock wall
- Timber framed construction
- Reinforced concrete

In addition, a minority of the industrial and commercial building fleet is of steel frame construction, usually combined with masonry and reinforced concrete. Virtually all buildings in AB are roofed in galvanized steel sheet, with a minority of reinforced concrete flat roofs and tiled pitched gable and hip roofs.

Masonry and mortared rock wall construction This is the commonest building type in AB and the dominant construction type for residential and other small buildings, including most of the public sector building portfolio. It is based on a colonial era design – pre 1950s. Key features of this type of building include:

- Generally, one and sometimes two storeys in height.
- Shallow pad and footing foundations and no basements.
- Walls of hollow masonry (concrete brick) and solid stone in the oldest buildings.
- Mixed levels of wall reinforcement, dependent largely upon age and construction quality control:
    - Better built and newer buildings have reinforced concrete column and beam wall structures with masonry brick infill.
    - Older and poorer quality buildings are completely masonry built with limited or no reinforcing bar inserts.
    - The oldest buildings have concreted but non-reinforced rockwall construction for outer and load bearing walls.
- Low angle pitched timber framed roofs with sheet metal coverings.
- The roof structure-wall connection typically consists of timber rafters embedded in slots within a traverse poured concrete beam or topline of masonry. Physical connections vary in strength and quality:
    - In the oldest and poorest buildings, the connection is only gravity and friction based.
    - In many buildings the rafters are tied into the mortar of the topline or the traverse beam via a single horizontal steel reinforcing rod.
    - In building built to code over the last 20 years, the horizontal rod is also vertically tied into the wall via steel tie bars concreted into the underlying masonry rows.
    - Hurricane straps drilled into the rafters and the masonry rows are retrofitted in many but not all buildings of all ages.
- Extensive time framed and metal roofed balconies, often light built.
- Storm shutters are rare in the non-renovated buildings.

Bolans health clinic

A typical small building of mortar block construction

Clearvue psychiatric hospital

Note the typical wood framed and sheet metal pitched roof

Timber framed construction Timber framed buildings are still relatively common in AB. Many of the oldest small buildings and homes are fully timber framed and timber clad. Outbuildings and annexes are generally timber framed and clad in board of timber, cement fiber or metal.

Reinforced concrete construction Full concrete construction is common for in post 1970s commercial and industrial buildings. Roofs are of two general types: a) flat exposed concrete with a waterproofing membrane and metal framed and metal sheet covered flat and pitched roofs.

Note that concrete degradation was noted in all but the most recent buildings. The most common problem noted was water infiltration via exposed reinforcing and poor quality casts. This in turn results in reinforcement corrosion and expansion and concrete spalling.

Barbuda hospital

Concrete construction including reinforced concrete roofing

3.4 The assessed buildings

A total of 34 buildings on 25 sites on Antigua island were assessed in detail to provide a representative sample for programme design and costing. The buildings were selected by the Department of Environment in conjunction with the facility managers and the Department of Public Works.

In total the sample is considered to represent 20% of the total portfolio of buildings of public interest and 50% of the higher priority buildings for climate adaptation, with a particular focus on disaster preparedness.

AB 2018 detailed building assessment list

1. All Saints Clinic
2. All Saints Fire Station
3. All Saint’s Police Station
4. Analytical services 1
5. Analytical services 2
6. Antigua State College 1
7. Antigua State College 2
8. Bendals health clinic
9. Bolans health clinic
10. Clareview Psychiatric Hospital 1
11. Clareview Psychiatric Hospital 2
12. Clareview Psychiatric Hospital 3
13. Clareview Psychiatric Hospital 4
14. High Court of Justice
15. Defence Force Building 1
16. Defence Force Building T
17. Department of Environment 1
18. Department of Environment 2
19. Fiennes Building 1
20. Fiennes Building 2
21. Good Shepherd Children’s Home
22. MET office (airport terminal),
23. Ministry of Finance
24. Ministry of Tourism
25. National Archives
26. National Office of Disaster Services
27. Parham health clinic
28. Police Headquarters
29. Potters health clinic
30. Prison Block
31. St John’s Fire Station
32. Swetes health clinic
33. Victory Centre
34. Nyabinghi School

Detailed inspection reports and photo records from this process are stored by the AB Department of Environment, within the Health and Environment Ministry.

Note that the detailed assessment sample excludes the largest and most important single public building in Antigua Barbuda: the Mount St Johns Medical Centre. This five storey reinforced concrete building was effectively completed in 2009. It has multiple construction and operational issues linked to its initial design, construction quality and insufficient maintenance.

However, it does have relatively strong windows and doors, with internally controlled storm shutters and an existing emergency power supply. Its roof is industrial steel sheet firmly fixed to a steel frame. Hence no adaptation linked structural investment is foreseen for hurricane resilience.

3.5 Electricity supply

All of the assessed public buildings and practically all of the public building portfolio are connected to the public utility grid on each island.

Electricity in Antigua is currently supplied by 3 heavy fuel oil powered plants and a modest investment in grid-connected wind power is ongoing.

Electricity in Barbuda is supplied by diesel generator and a significant solar PV project is ongoing, in the context of a major reconstruction effort after Hurricane Irma in 2017.

The availability of grid electricity is relatively high, but no public statistics were found. Blackouts do occur due to grid instability and occasional generator mechanical problems. A full grid restart in Antigua can take up to 30 minutes.

The distribution grid in AB is currently 100% above ground. Power lines are generally mounted on concrete and steel poles. Selected distribution trunk lines on Antigua are being buried alongside main roads as part of a climate change adaptation project.

The distribution grid on Barbuda was effectively 100% destroyed by Hurricane Irma and is being rebuilt, above ground.

3.6 Telecommunications

Effectively all of Antigua is covered by 3G networks, although there are some weak spots in coverage due to the hilly topography. Coverage in Barbuda is reliable within the Codrington region and variable elsewhere.

3.7 Water supply and use

Potable water in AB is supplied by government controlled wells and desalination of seawater. The desalination plants are a large scale consumer of electricity.

Both Antigua and Barbuda have municipal water networks, however coverage is not universal. In Antigua water supply cuts are apparently relatively frequent, due to a combination of power cuts and insufficient potable water. Supply shortages are particularly acute in the annual dry season and the frequent droughts.

The government of AB has been campaigning and investing in rainwater harvesting as a partial solution. Most systems are relatively basic, and the harvested water is simply filtered and used for gardens and sometimes for flushing toilets and cleaning.

3.8 Wastewater treatment and stormwater drainage

There is no universal sewage network or central wastewater treatment plant on either Antigua or Barbuda. This is problematic, as the density of development now makes such an investment difficult.

The universal solution is septic tanks with soakaways and holding tanks. Tank contents are removed by vacuum trucks and discharged to landfill. Incomplete treatment of wastewater by septic systems is widespread, resulting in thousands of small scale pollution point sources. As a result, many urban and peri-urban waterways on Antigua are contaminated. The problem is much less intense in Barbuda due to the low population and even lower population density.

Stormwater drainage is a constant challenge for AB, principally due to the sudden and heavy loads from tropical storms and hurricanes and the lack of a gradient to aid rapid drainage. Drainage systems are universal, but frequently overwhelmed for short periods, resulting in localized damage.

3.9 Building ventilation and cooling

The temperature profile of AB is tropical but also relatively stable and benign. Annual daily average temperatures range from 25.4 to 28.3 ^{o}C, with annual maximum and minimum temperatures of 31 C and 22 ^{o}C respectively.

The traditional buildings are well adapted to this temperature range and are typically very open, providing shade but not sealing off the external air. Freestanding and ceiling fans are the most common form of cooling, with air conditioners installed in higher income homes and some commercial and public buildings.

3.10 2017 hurricane damage and lessons learned

The Category 5 Major Hurricane Irma struck Barbuda on September 6th 2017, causing massive damage and forcing the evacuation of the island for some time. Reconstruction is ongoing as of January 2019. The lessons learned from the hurricane relevant to this programme include the following:

- Most public and private buildings were clearly not prepared for a Level 5 hurricane, with the levels of damage ranging from modest to total destruction.
- Short term flash flooding and standing water caused widespread damage in all areas, particularly to building contents.
- All of the anticipated roofing failures modes were visible in the damaged buildings:
    - Lifted roof sheets due to sheared and lifted nails and tearing of sheet metal.
    - Lifted ceiling battens and traverse boarding, still attached to the sheet metal.
    - Roofs lifted in section and entirely, via pullout of the rafters from the masonry wall sockets, in walls without any roof-wall connection.

    - Roofs lifted in sections, via pullout of the rafters and the top concrete beam and/or row of masonry, due to a lack of hurricane straps or other forms of wall connections
- The Codrington hospital was moderately damaged. The concrete flat roofed structures retained their integrity, but damage was caused by window and door failures and standing water. Lighter weight annexes were badly damaged or destroyed.
- The recently installed solar PV array at the Codrington power station was 95% destroyed. The most common modes of failure were:
    - Shearing and buckling of the relatively lightweight fastening systems connecting the panels to the very sturdy ground mounts.
    - Flying debris damage, including loose panels.
- The small Codrington power station, which housed two diesel generators to service 2000 people, was deroofed and massively damaged. This type of building is normally considered critical infrastructure, warranting a significant investment in hurricane proofing.
- The electrical distribution grid was completely knocked down. Reconstruction in total took 6 months, using equipment and teams from Antigua and contracted in from the region.
- Flying and shifting debris, including empty shipping containers, caused extensive damage.
- The town water network was only marginally damaged, but the pumping and desalination station was severely damaged. The damaged power station resulted in no town water for months. A shortage of potable water and sanitation issues was an important consideration in the initial evacuation of the island.

Barbuda fire station, showing multiple modes of roof failure

Codrington power station, Barbuda January 2017

4 THE UPGRADE DESIGN AND SCOPING PROCESS

4.1 The upgrade design goal and objectives

The selected overarching **goal** of the GovAB upgrade programme is: Increasing the **resilience** and **sustainability** of the portfolio of app. 200 existing public buildings.

The selected programme **objectives** are to deliver an upgraded portfolio that will:

- Deliver cost effective services during normal conditions, for several decades.
- Minimize the environmental impact of their routine operations.
- Operate largely unaffected by predicted frequent droughts.
- Survive multiple hurricane and storm direct hits and at least one earthquake.
- Restart post-disaster operations immediately and reliably contribute to local and national scale recovery efforts.

4.2 The rationale for a pragmatic vs. a compliance based design process

The selected design process is labeled as pragmatic rather than code compliance based.

Building code compliance upgrade programmes are simple to scope. They typically follow a two stage process, as follows:

- A detailed inspection and assessment of facilities determines what is fully compliant with the desired code and what is not. This may entail stripping back interior building surfaces to access structures. A robust code is primarily designed for new builds and includes very extensive details on the required standards of design, materials and build quality. As a result, the assessment process may be time-intensive but can deliver very detailed and defensible findings.
- A scope of work is developed, based on renovating or replacing non-compliant components or whole buildings if the latter offers better value. Upgrades are not partial – the end result is compliance. The expense of these works is not considered in the initial design process.

This process was not fully used in this case, which is somewhat unusual. The rationale for this is:

A) The limited connection of many building code provisions to climate risks. Issues such as space, light, damp proofing, ventilation, fire, electrical and earthquake safety and plumbing quality are important – but not strongly linked to climate adaptation.

B) The moderate to poor state of much of the existing portfolio.

C) The limited economic resources of the GovAB at this time, including access to debt finance.

All indications are that the outcome of a completely strict compliance based design process would be a massive renovation, demolition and new build programme. Such a programme is both completely unaffordable in the short to medium term (2-5 years) and of questionable value in adaptation terms.

It is possible that a full building code compliance based upgrade programme may be affordable in the long term (5-30 years) as both the economics of replacement (of aging buildings) and the ABGov financial status improves. However, in the long term, the buildings will have further degraded, unit costs will have increased, the climate and scenarios will have changed. In addition, the building codes may have also changed. In this context, any 10 year old building upgrade design work (via whatever process) would be obsolete and need to be redone.

Note that for new buildings, the recommended (and legal) approach is full code compliance as the minimum, with additional features as desired by the building owners/clients.

4.3 The pragmatic design process

The goal and objectives help frame the programme, but a lot more detail is required to accurately design and plan and estimate costs, whilst dealing with both the uncertainties and the financial constraints.

There is no standard or recognized best approach for developing a pragmatic programme such as this. The approach used has been to use several well-established individual design aids and processes to work through the uncertainties and issues and arrive at a defensible design, plan and cost estimate.

These aids and processes are listed and described in turn below:

A. Selecting a standard design life for the buildings (50 years).
B. Developing a 50-year scenario to help envision the operational and disaster settings.
C. Developing a table of uniform building operational states.
D. Developing a set of performance criteria – including reference to the wind load and water proofing components of the existing building code.
E. Developing an investment and operational plan to achieve each individual criterion, without undue impacts on other criteria.
F. Scoping and costing the resultant works programme.
G. The final step, linked to funding the programme, is attempted classification of the works and costs into two financial categories:
    - Those that should/could qualify for international climate adaptation or mitigation financial support
    - All other costs.

Unfortunately, even this process resulted in a programme scope and cost estimate that was assessed as beyond the current financing limits of GovAB and international climate finance. In response, a second round of analysis was undertaken to see what could still be achieved with a significantly reduced scope and budget.

4.4 Building design life and project investment period

The design life of the planned rotating mechanical and electronic equipment will vary on a case to case basis but will generally be 5-20 years. The design life of the building fabric investments (roof, walls, doors and windows) and general plumbing and electrical systems will range from 20 -50+ years. The project investment payback period for infrastructure is commonly set at 20 years, as high discount rates greatly diminish their value after 20 years. In practice however buildings last much longer, and so such investments can continue to deliver for generations.

The proposed remaining useful life of the buildings is arbitrarily set at 50 years for project planning purposes. This is not exceptionally long, as most of the structures inspected have a potential lifespan of over 100 years, if adequately maintained.

4.5 Developing a 50-year scenario

A scenario in this context is defined as a package of predictions and assumptions that can be used as design and planning input. A well-informed scenario can supplement but does not replace the use of single point codes and criteria such as load bearing, wind resistance or energy efficiency standards. It provides a pragmatic framework that illustrates the timing, scale and form of the challenges the building users, owners and the environment will present over its likely useful life.

For simplicity a single and relatively basic scenario has been developed and is presented below. In-depth scenario modelling involves changing components individually and collectively to generate multiple scenarios, that are then reviewed for credibility and impact. In this case however, scenario modelling was assessed as unlikely to generate a different design result compared to a single scenario – and is more expensive to undertake.

The single scenario presented is considered to be balanced: neither optimistic or pessimistic. Numerical estimates are used to provide a general idea of scale and frequency and should not be regarded as solid predictions.

The AB Build 50-year lifespan disaster scenario

Building use demand and lifespan The demand for use of the buildings is expected to grow over time with population and GDP. Buildings will be used until they are no longer economic to maintain or fit for purpose. The remaining building lifespan will vary significantly based on the materials used and current condition. For this scenario, the assumed average lifespan is 50 years.

Climate change over the building lifespan A broad base of scientific assessments have developed their own scenarios for the climate of the Caribbean over the next 50 years. They can be divided into two general groups: a) incremental but major changes in line with current climate phenomena and b) highly unpredictable, drastic and fundamental changes driven by runaway effects, particularly after 2050. This scenario will only use a basic summation of the first group of scenarios.

Hurricanes and tropical storms Climate modelling at present can only provide very broad and speculative forecasts of hurricane frequency and force for specific islands in the Caribbean. Any forecast with very specific numbers is little more than a guess, but this can still assist planning.

Assessing the difference that climate change has made and will make is also very difficult – trends are noted but are difficult to quantify and have wide ranges of uncertainty.

Based on a modest intensification of prior climate history (expressed in return periods), this scenario has the following frequency of direct hit events for the projected 50-year lifespan. Note that the number of direct hits is much lower than the number of experienced (combined hits and near misses) hurricanes and storms.

Direct hits – events that cause significant damage

Category 5 hurricane: At least 3

Category 4: At least 6

Category 3: Over 9

Tropical storm: Over 15

Experienced - events that trigger a hurricane warning and partial or full shutdown

Hurricanes and storms – 8 per annum

Earthquake Seismic modelling can predict the likely maximum energy of an earthquake in a specific area and can vaguely forecast its frequency on a century scale but cannot predict a specific location or a specific event in a specific period. Given the projected 50-year lifespan of the portfolio and the AB setting, this scenario has an earthquake frequency of at least 1 event of MMS 7.5 (major)and at least 5 events of MMS 6 or more (moderate), noting that an epicenter directly on either island has a much lower probability, due to the small size of both islands.

Drought Drought is already a significant issue for Antigua Barbuda. The frequency, duration and intensity of future droughts in the Caribbean is impossible to accurately predict, even without climate change. In addition to seasonal and 1-3 year droughts, the strong potential exists for an effectively permanent and/or incremental change in the annual average precipitation over the next 50 years. For this scenario, droughts are forecast annually and severe droughts every five years. In parallel, water demand is expected to increase with population and GDP.

Post disaster evacuation Any post disaster evacuation off the island will be limited due to the logistical challenge and the unwillingness of the population. People will move temporarily to relief centers and temporary housing on the islands but will return to their homes as soon as practicable. For the public building portfolio, this translates to a need for continuous operation. There will be no post-disaster break in demand to simplify reconstruction.

Isolation - Post disaster road access and telecommunications The need for building autonomy is linked to the likelihood of disasters that cutoff centralized access and support systems, and the duration of the resultant isolation. This has a practical and significant impact on design issues such as water and energy reserves. The Caribbean countries have very extensive experience with this challenge. In this context, the scenario has the following setting for isolation:

- Total road cutoff for 48 hours after a major hurricane or earthquake
- Complete loss of mobile phone service for 2 weeks after a major hurricane or earthquake
- Communication and access difficulties for 6 months after a major hurricane or earthquake

Electrical grid availability The APUA electrical grid is currently a critical service for all of the building portfolio. Its current availability is over 98%, with occasional blackouts due to technical issues. Its performance in a hurricane has been tested on Barbuda in 2017 and the performance of APUA in recovery has been tested at the same time. The 2017 hurricane season provided other relevant examples of grid damage and recovery, particularly in Dominica and Puerto Rico. In this context, the scenario has the following electrical availability:

- Normal conditions, 98% availability
- Deliberate shutdown 2-6 hours prior to hurricanes and major storms
- Recovery of services after major storms & Category 4 hurricanes: 1 – 60 days
- Recovery of services after Category 5 hurricane (Antigua): 3-24 months
- Recovery of services after a major earthquake: 3-24 months

Town water supply availability The APUA water network is currently stressed by chronic leakages, each drought event and technical issues. Climate change and aging infrastructure is expected to worsen this issue, whilst planned/hoped for investments are expected to improve performance. Extensive investments in reverse osmosis plants will improve reliability but push up the unit cost of water. The APUA water network has yet to be tested in an earthquake but was tested on Barbuda in the 2017 hurricane. In this context, the scenario has the following town water supply availability:

- Normal conditions: 95% availability
- Extended drought conditions: 50 – 90% availability, with breaks of 1 hour to 7 days
- Recovery of services after major storms & Category 4 hurricanes: 1 – 60 days
- Recovery of services after Category 5 hurricane (Antigua): 3-24 months
- Recovery of services after a major earthquake: 3-24 months

Drinking water container availability Water for drinking in AB is generally supplied by dedicated water stands, which use 20 litre containers delivered to site. Some larger facilities purify their own water to fill their own containers. Contractors buy RO purified water from APUA and deliver the containers by truck. In a disaster scenario, timely delivery of drinking water containers is definitely not assured. The break in supply is difficult to predict, with the following used in this scenario:

Drinking water delivery disruption period:

- Major disaster 1 month
- Minor disaster 1 week

The scenario above may look pessimistic, but it is considered realistic as a basis for long term planning for the GovAB building portfolio. The most challenging aspect of the scenario is **the high**

frequency and cumulative impact of all possible events and the very high number of partial and full shutdowns due to hurricane and storm warnings.

4.6 Building operational states

A table of building operational states was developed as an additional design aid used to develop the upgrade scope. It provides more detail on the timing and settings, with a focus on the disaster onset and recovery cycle.

ABGov building operational states

Routine operations. Electrical grid and town water supply operational. No disaster warnings

Drought operations. Town water supply shortages, otherwise routine

Hurricane warning 2-72 hours. Normal operations cease. Electricity grid and town water shutdown. Building protection activities continue for 1-6 hours.

Hurricane strike 6-24 hrs. No activities. No communications. Electricity grid and town water shutdown Some buildings will be occupied.

Hurricane-earthquake immediate relief period: 1-5 days. Heavy and/or unpredictable service demand. No communications or road access. Electricity grid and town water shutdown.

Hurricane-earthquake early recovery period: 5 days – 3 months. High service demand. Difficult communications and road access. Fuel and some food shortages. Electricity grid and town water shutdown.

Hurricane-earthquake extended recovery and reconstruction period 3-24 months. High service demand. Improving communications and road access. Improving electricity grid and town water supplies.

The scenarios and building states are combined to provide an operational concept for the portfolio over the next 50 years:

- Major disasters: 2-3
- Minor to moderate disasters/incidents: 5-10
- Cumulative time spent in one of the disaster related operational modes (warning, strike, early recovery, reconstruction): approximately 5 years or 10% of the total period. Most of this time is spent in recovery and reconstruction.
- Cumulative time spent in drought mode: 10 years or 20% of the total period.

All of the above work is acknowledged as highly speculative and the individual numbers presented have a low level of confidence. Nonetheless it is considered useful as infrastructure planned support. In particular, it shows what a truly resilient public building portfolio will need to withstand to deliver benefits over the next 50 years – not just one disaster, but a repetitive cycle of preparation, events and recovery.

4.7 Performance criteria

The generic objectives have been broken down into 12 detailed performance criteria, Note that in many cases the criteria are interlinked, but also in some cases compete rather than complement. They are listed and described in turn below.

Crosscutting criteria

- Compliance with national building legislation and standards
- Affordable repairs and maintenance
- Heritage protection
- Reduced operating costs
- Reduced environmental and climate impacts

Thematic criteria

- Wind loading and debris risk management
- Flood security
- Earthquake resistance
- Low electricity consumption
- Increased electricity supply autonomy
- Low water consumption and increased water autonomy
- Reduced wastewater pollution

4.8 Crosscutting criteria

The crosscutting criteria are:

- Compliance with national building legislation and standards
- Affordable repairs and maintenance
- Heritage protection
- Reduced operating costs
- Reduced environmental and climate impacts

These criteria are self-evident in most cases; however the detail is important. This is particularly the case with conflicting criteria and for controlling the cost of the upgrade. Each criterion is briefly discussed in turn below.

Compliance with national building legislation and standards

The majority of buildings inspected failed the wind load and waterproofing standards of the existing and proposed national building codes, principally in the quality and state of repair of roofs, windows, doors and shutters.

The approach taken in the study was to incorporate a full upgrade to comply with the wind and waterproofing standards. This has resulted in substantial scope and costs, presented in the detailed files in the cost category of “extreme weather resistance”.

Affordable repairs and maintenance

Many of the AB Gov buildings are old, with basic electrics and plumbing and have degraded structures and fittings. They need repair and in some cases renovation. In several cases, renovation may not be a good investment and the preferred option will be demolition and a new build.

These routine investments are needed, irrespective of climate adaptation, earthquake risks and other emerging challenges. It is however very difficult to determine an appropriate division in cost and activities between general portfolio management work (renovation, repair, maintenance) and upgrading for resilience and sustainability.

The approach taken in this study is to incorporate only limited routine investment work within the upgrade scope for resilience and adaptation. Essentially only critical accompanying or prerequisite activities are included.

Heritage protection

The portfolio includes several buildings of importance to the national heritage. Investments in disaster resilience and energy efficiency need to be sensitive to avoid permanent loss of heritage. In some cases, this will translate to much higher unit costs for building strengthening and/or a compromise on modern structural standards, which cannot be achieved in full if restricted to some heritage materials, such as stonework.

On the positive side, well targeted investments in disaster resilience or climate adaptation may provide opportunities for rehabilitation of heritage structures, which otherwise would remain neglected and continue to degrade.

The proposal with respect to heritage, is to preferentially select heritage buildings for multi-purpose upgrades, to take advantage of the investment opportunity. Upgrading a stonewall and timber heritage building offers better overall long-term value for GovAB than upgrading a generic concrete-masonry building with poor inherent earthquake resilience and a very finite lifespan.

Reduced operating costs

The main operational costs of the GovAB portfolio are the provision of utilities (electricity, communications, water, waste removal and wastewater treatment). Most of these utilities are charged on a unit rate basis, hence reductions in consumption will translate into lower operating costs. Operational cost savings are therefore actually an important driver for many of the proposed sustainability investments.

Reduced environmental and climate impacts

The principle environmental and climate impacts of the existing building portfolio will come from operations for a further 50 years. The impacts of construction are historical, and the impacts of demolition are predicted to be minor and deferred. The main components of the operational footprint are:

- Energy use.
- Water consumption and wastewater generation and discharge.
- Solid and hazardous waste generation.

Reductions in these operational inputs and outputs will reduce the overall environmental and climate impact. In general, they will also reduce the operating cost.

4.9 Wind loading and debris risk management

Context Both a quantitative and qualitative-common sense approach is needed for developing resilience against hurricane winds. Recent hurricane experience indicates two areas where GovAB will need to focus:

- Ensuring overall integrity, whereby investments are made in a balanced manner to reduce weaknesses. For example, heavy investments in main building roofing reinforcement cannot fully mitigate highly vulnerable designs, such as lightweight broad balconies. Particular attention is also required for doors, windows and shutters.
- Debris risk management, to avoid building integrity being compromised by surrounding structures and objects. These objects include trees, power poles, utility buildings (garages, sheds etc..) and even vehicles and shipping containers.

Approach The proposed plan has two parts:

A. Invest in accordance with the current and planned national standards for resilient buildings. In practice this entails works on roofs, walls, windows and doors. The scale and complexity of works is building dependent and can range from basic roof sheet strengthening through to comprehensive refits of roofs, windows and doors. Some buildings have either substandard or damaged walls and foundations and these need repair or upgrading as a prerequisite to investments in the upper structure.

B. Conduct assessments of the building surrounds and invest in reducing the risk of tree and major debris strikes on the upgraded buildings. In some cases, this may entail the repair, demolition or moving of adjacent utility structures.

4.10 Flood security

Context The majority of buildings inspected were sited in areas of relatively low risk from large scale, catchment related flooding. Many however appeared vulnerable to very localized flooding from stormwater, due to limited or very shallow perimeter drains and unfavorable slopes. For example, several buildings have door sills at ground level that invite flash flooding.

Approach The proposed plan is to focus on improved stormwater drainage in the immediate vicinity of the buildings. Selected sites also warrant investment in larger evacuation drains to transport and divert water further away from the buildings.

4.11 Earthquake resistance

Context The details of earthquake resistant design are provided in the formal standards. These standards however cannot fully accommodate the practicalities of a post-earthquake recovery process.

Following an earthquake, concerns over building safety have to compete with the imperative to provide shelter and emergency services. Detailed building inspections and repairs can take 3-24 months. The most relevant experience in the Caribbean can be drawn from the Haiti 2010 earthquake. Following the earthquake, the condition and utility of the building stock in Haiti was divided by inspection into four main types:

A. Well-constructed near-new buildings, with limited or negligible structural damage, that could be quickly inspected, cleaned up and put back into productive use (rare).
B. Traditional 1-3 storey wood structures that in general suffered limited structural damage, that could be quickly inspected, cleaned up, timber braced and put back into productive use.
C. Heritage buildings with heavy stone walls, with a highly variable performance. Some heritage structures suffered catastrophic collapse, whilst others were barely cracked. The lack of reinforcement and old roofs meant that their safe ongoing use could not be certified and so use post-earthquake was often very limited.
D. Lower quality reinforced concrete and masonry structures, that suffered extensive damage and required either extensive repairs or full demolition.

The ABGov building portfolio has all four of the above building types and so a similar performance profile is to be expected.

Approach The proposed programme does not have any investments focused only on improved earthquake resistance. However much of the proposed structural work for increased wind resistance and general structural safety will also improve performance and safety in earthquakes.

In particular, wall repairs and reinforcements and wall-roof fastenings in the low-rise buildings will help in reducing wall and roof catastrophic collapses in the event of an earthquake. Tensile glass in new windows will reduce broken glass risks. In summary, the plan is to include improved earthquake resistance as a co-benefit at no extra cost.

4.12 Low electricity consumption

Context The efficient use of electricity within the building portfolio will generate three benefits:

- It will reduce operational costs
- It will increase building autonomy (see below)
- It will support the reduction of emissions from AB due to electricity generation.

A detailed electrical load assessment was not undertaken for this project; however, the building energy profiles are expected to match that seen in similar buildings worldwide in tropical environments. For investment planning purposes the following load breakdown is used:

- HVAC – Heating, Ventilation and Air Conditioning 50%. For AB, space heating is not significant and air conditioners and cooling fans form over 90% of the HVAC load.
- Lighting 15%
- Other (office equipment, water heaters, refrigeration, workshops etc..) 35%

The priority for investment in electrical efficiency is based both on its scale and its payback period. The investments may be either structural (e.g. insulation and double-glazed windows.) or electrical-mechanical: e.g. AC units and fans).

Some potential energy investments generate conflicts with the other upgrade objectives. For example, external shading of building walls and windows via balconies and verandahs is very effective in reducing the cooling load, but these structures are vulnerable to hurricane winds.

Approach The proposed strategy for upgrading the energy efficiency of the buildings has four main components, described further in the scope of works:

- **Installation of hurricane resistant doors and windows that are also well insulated**. For windows, it is important that they can be opened and include insect screens, in order to maximize the use of natural cooling and ventilation.
- **Installation of high-efficiency ceiling fans**. These fans can largely replace low-efficiency desk and standing fans. They also partly replace and defer the need for air conditioning units. A typical daily cycle for many of the smaller buildings will be open windows and the use of natural ventilation and fans in the morning and evenings. The buildings are closed up and the AC turned on only once the outside temperatures and the heat gain from the roof increase the internal temperatures beyond comfortable limits.
- **Replacement of older air conditioners** with high efficiency units.
- **Installation of solar augmented water heaters**, to reduce the water heating load.
- **Upgrade all lighting to LEDs.**

4.13 Increased electricity supply autonomy

Context Disaster resilience is the principle driver for increasing the electricity supply autonomy of the portfolio. In the context of the 50-year scenario, the buildings will need to maintain operations for up to 10% of their lifespan without grid electricity. In particular, the whole portfolio needs a viable solution for electricity in operational states for hurricane warning, hurricane strike and post disaster relief and early recovery. The default assumption is that grid electricity will not be available during these operation critical periods.

The historical default solution for the provision of emergency and short-term electrical power has been diesel powered standby generators positioned at each facility. However, generators have a number of drawbacks:

- They cannot be easily financed via climate linked funds, which commonly veto investment in any form of fossil fuel power system (see Chapter 5)
- A high operational cost, with all-in per kilowatt hour costs typically three to four times the cost of power from the electrical grid.

- Local equipment housing and security issues. Generators need to be housed against the elements and the fuel tanks needs to be secured against theft.
- Local pollution and greenhouse gas emissions from the diesel exhaust.
- Operational noise.
- Ongoing maintenance issues.
- The difficulty in ensuring fuel deliveries in a post-disaster setting.

For all these reasons, the ABGov has decided not to install standby generators in the majority of the public building portfolio. An alternate solution is required.

Approach The proposed approach is based on combining a standard off-grid hybrid solar power system with extra battery storage and a backup portable generator fleet. The five key system components are as follows:

A. **Onsite lithium battery banks**, which play multiple roles:

    - Providing 3-5 working days of highly reliable emergency power for the building, when operated in building low energy mode.
    - Enabling the utilization of high penetration rooftop PV systems (penetration in this case is the ratio of annual renewable energy production to total annual energy consumption of both on-site renewable energy and grid production). Power stability limits constrain PV penetration in the absence of batteries or excess PV energy dumping.
    - Load shifting rooftop PV electricity production to evening and early morning use. The planned operational autonomy is 2 working days in building normal energy mode.
    - Improving the fuel efficiency of emergency generators by up to 40%. This works by operating the generator at full power for short periods only to charge the batteries. Full load operation is much more fuel efficient than extended operation at low and variable loads.

B. **Rooftop mounted PV arrays**, which will supply daytime power to the building during routine operations. In addition, the arrays may supply power in the post disaster relief and early recovery periods – if they survive the hurricane or earthquake. Strong and well-designed installations can improve the PV panel survival rate, however the planning assumption is that many rooftop systems will suffer damage – hence the need for the strategic stock as per below.

C. **Bi-directional invertors, smart meters and power management systems**, installed at each site to enable efficient grid connected and off-grid operation of the hybrid systems.

D. **A strategic warehouse stock of RE equipment**, combined with in-house technical capacity and retainer contracts with local engineering companies. The purpose of the stock and contracts is to enable the rapid repair and restart of systems damaged by natural disasters.

    A detailed analysis of the size and type of stock will be undertaken at the detailed design stage of the GCF project. It is anticipated that all types of spares will be stocked, with an emphasis on PV panels and racks: the equipment most likely to be damaged in a hurricane. The stock needs to be of exactly the same brand and type as that deployed, to enable rapid and simple changeout work in a post-disaster setting. Hence the plan is to procure and build the strategic stock in parallel with the building installation projects, using the same contractors.

The strategic stock must be matched with local (on island) technical capacity to rapidly respond in a post-disaster setting. The required capacity includes system inspection, diagnosis, spot repairs, major repairs and recommissioning. This capacity will be secured through a) maintaining some ABGov in-house capacity for system maintenance and b) maintenance of retainer contracts with 2 local solar PV installation companies.

E. **A back-up fleet of trailer mounted small diesel-powered generators with integrated fuel tanks**. These can be stored centrally and only deployed after a disaster, for the minority of anticipated sites which cannot be rapidly repaired and restarted with the strategic RE stock.

It is important to note that the primary purpose of the rooftop PV arrays and battery systems is to increase building autonomy and NOT to reduce the routine cost of electricity for ABGov. This distinction is due to the deployment model rather than the base technology of solar PV.

The unit cost of produced electricity from many small and relatively complex rooftop installations with off-grid operational capacity is approximately twice the cost of production from large scale PV farms. If multi-day battery storage is added, the unit cost escalates to four times that achievable with large scale PV farms. In summary, full PV and battery based energy autonomy is very expensive compared to grid supplied renewable energy.

Hence, large PV farms coupled with electricity trading would be the better investment, if the ABGov only wishes to reduce the overall cost of electricity for its 200+ building portfolio. The general business case for a grid-connected PV farm (in addition to the small systems) is expected to be strong, however this is outside the scope of the ABGov building portfolio upgrade programme.

4.14 Low water consumption and increased water autonomy

Context The largest single use of water in general public buildings is toilet flushing. Handwashing and dishwashing are the next most important. Drinking water in AB is mainly supplied by portable water dispensers. Purification of town water and water from rainwater tanks is generally via basic filtration followed by chlorination.

The ABGov has emphasized rainwater harvesting as one solution to its water shortages, however the standard of tanks and plumbing seen to date indicates that this source will remain below drinking water standards in most cases. This is an important weakness in terms of post-disaster resilience. Heavy chlorination of on-site storage tanks is not a complete solution, due to problems with disinfecting tank and line sediment and chlorine-sediment reactions.

Approach The plan is to focus on expanding and upgrading on-site water storage capacity and in parallel invest in demand reduction and on-site water purification. In practice this means rainwater harvesting piping systems, aboveground storage tanks, dual flush toilets, under-sink water filters, and spring valve taps.

4.15 Reduced wastewater pollution

Context Virtually all of the ABGov building portfolio relies on on-site septic systems for wastewater treatment. Many of these systems are space constrained or under-sized and so result in the uncontrolled discharge of partially treated wastewater. ABGov does not have plans in place for a centralized sewage system, so the portfolio will remain dependent on on-site systems.

Approach The plan is to invest in basic upgrades of the existing systems wherever needed. This may entail enlarging septic tanks or the follow-on infiltration galleries. Some sites are very space constrained and so space efficient semi-mechanized treatment plants are the only viable upgrade option.

Note that investments in wastewater are considered important for reducing the environmental impact and for public health reasons. They are however, not considered investments in climate adaptation.

5 UPGRADE SCOPE

5.1 Upgrade scope breakdown

The results of the building inspections have been compared against the design criteria to develop the potential full scope of work for the upgrade programme. This has been broken down in a series of tables by categories and by building. The full tables are provided separately as Excel sheets in a bill of quantities format.

The generic full scope of work list template is presented below, noting of course that the actual selected scope varied significantly between buildings.

Upgrade scope and cost categories

GENERAL STRUCTURAL
Concrete - major structural repairs - slabs, columns, beams
External walls - minor crack repair
External walls - major crack repair
Foundation work
Other structural work
EXTREME WEATHER RESISTANCE
Roof structural upgrades
Roof cover and fastening upgrades
Replace windows and frames
Replace doors and frames
GENERAL BUILDING REPAIRS
Internal walls - repair
Parapets and railings repair
Stairways and ramps repair
False ceiling repair or replacement inc. insulation
Flooring repair or replacement
GENERAL ELECTRICAL
General wiring repair and upgrade
Install sensors and timers
Replace FLs with LEDs
Install ceiling fans
Install or replace split unit ACs
Install or replace multi-split ACs
Install or replace central HVAC system
Perform major repairs and maintenance
ON-SITE POWER SUPPLY AND STORAGE
Rooftop or local ground mount PV
Li battery bank
OFF-SITE EMERGENCY RE STRATEGIC STOCK
PV panel, racking and BOS strategic stock
Warehouse space allocation
OFF-SITE EMERGENCY DG BACK-UP POWER
Trailer mounted generators with tanks
WATER SUPPLY
Potable water reserve tanks
Solar hot water units

Electric water heater
Install or upgrade rainwater tanks
Install water saving taps, toilets and fixtures
Install dual source internal plumbing and fix pipe leaks
Install or upgrade water and rainwater tank pumps
STORMWATER DRAINAGE
Stormwater drainage upgrade
Roof guttering repair or replacement
WASTEWATER TREATMENT
Septic tank cleaning and upgrade
Other WW treatment infrastructure

Table 5.1 Upgrade scope and cost categories

5.2 Cost estimates

The cost estimates provided in the tables are all-in estimates, covering project development, management and implementation with a 10% engineering contingency. Detailed cost estimates have been developed for the representative sample of 34 buildings. These estimates are considered to be in the accuracy range of -10 to + 20% for 2018 prices. These prices are however based on a low paced and standard building scenario. A fast track or post disaster scenario will increase all prices by up to 30%.

Cost estimate summaries – for the full upgrade scope for the 34 assessed buildings

Estimated cost of all upgrade works: **US$ 18.1M**

Total building footprint: 18,860m^2

Average cost per building: US$ 555,000

Average cost per m^2: US$ 960.

Cost categorization

General structural repairs	1.23M
General building repairs	1.63M
Extreme weather resistance (roofs, doors and windows)	3.03M
General electrical	3.21M
On-site power supply and storage	5.47M
Off-site emergency RE strategic stocks	0.44M
Off-site emergency DG back up supply	0.47M
Water supply	1.96M
Stormwater drainage	0.53M
Wastewater treatment	0.10M

The 34 buildings are considered to represent 50% (by surface area) of the priority buildings and 20% of all public buildings in AB. Low quality outline cost estimates (+/-30%) for the entire portfolio are provided by extrapolation.

Estimated cost of full upgrades for the priority buildings: **US$ 36M**.

Estimated cost of full upgrades for all 200 public buildings: **US$ 90M**.

The economic importance of these costs can be assessed by a comparison to the national Gross Domestic Product (GDP). The 2017 GDP of Antigua Barbuda was approximately USD 1,500 million, so the estimated cost of fully upgrading the existing building portfolio is in the order of 6% of GDP.

5.3 Upgrading vs new builds

An average cost of US$960 per m^2 is relatively high compared to the speculated value of many of the buildings assessed. The GovAB portfolio has not been commercially assessed and no insurance figures were provided, so it is not possible to provide accurate estimates of the value. Nonetheless, it is clear that this is a significant economic and strategic issue.

A brief online survey of real estate prices in the eastern Caribbean was used to provide a rough benchmark-snapshot. Multiple relatively new luxury homes in Antigua are listed in the region of US$3500 per m^2 and several industrial commercial buildings in the eastern Caribbean are listed in the region of US$1000 per m^2. The quality and features of the majority GovAB building portfolio is considered to fall somewhere in between these two extremes – in the order of US$2000 per m^2.

This first pass review indicates the average full upgrade cost per m^2 is in the range of 40 – 50% of a complete rebuild. However, these upgrades cannot always resolve fundamental design and material deficiencies that may result in a residual vulnerability to disasters. For example, an upgraded building in a low lying area will still be vulnerable to flooding and a weak-walled building with a strong roof will still be vulnerable to an earthquake.

These figures and issues indicate the economic rationale for upgrading many of the older and more degraded buildings is highly questionable and full replacement/relocation or demolition and rebuilding may be more appropriate.

6 CLIMATE ADAPTATION COST ALLOCATION

6.1 Climate adaptation related scope and cost classification

Each of the 39 potential interventions listed in Table 5.1 has been screened for eligibility for adaptation financing. The first pass classification of eligibility is limited to three levels Yes:100%, No: 0%, Partial: 50%.

In summary of the classification results, **56% of the estimated costs of a full upgrade are considered potentially eligible for adaptation financing**. The important exceptions are:

- General structural repairs – not at all eligible.
- General building repairs – not at all eligible.
- Wastewater treatment – not at all eligible.
- Off-grid and emergency renewable energy systems are considered only 50% eligible. Part of the investment is for increased autonomy (adaptation linked) and part is for increased renewable energy penetration (mitigation linked).
- General upgrades of building wiring and control panels are considered only 50% eligible, as substantial work is also needed for general safety and maintenance reasons, irrespective of the upgrade in power supplies for the PV and battery units and/or emergency generator connections.

6.2 Technical limitations to adaptation cost allocations

It is acknowledged that the above system of adaptation cost allocation is relatively basic. However, it is not considered technically possible to provide a more robust allocation within the scope of the UN Environment & ECMC appointment – there are simply too many uncertainties.

It is also considered unlikely that further investments in local data collection will significantly improve the quality of any such estimate. This is because the largest uncertainties are not linked to the condition of the buildings. Instead they are linked to inherent limitations on the process of determining the climate rationale: dividing investments between those required for adaptation, and those required for other reasons.

Two examples indicate the intractability of this issue and the need for both engineering judgement and an inherently political decision on an aggressive vs permissive approach to climate rationale assessments, including conflicts between adaptation and mitigation investments.

Windows, doors and roofs all degrade over time and often do not meet building codes developed after their installation. Those new building codes may or may not fully factor in climate change in their determination of risk and the associated additional design features. It is assumed that the replacement of windows, doors and roofs that are no longer functional due to age is a routine process that is not eligible for adaptation financing. However earlier replacement of such infrastructure may be warranted, based on the cumulative impact of three factors:

- Degradation from exposure and wear and tear
- Obsolescence/non-compliance due to evolving codes
- Increased loss and damage risk due to the climate change induced increased intensity of hurricanes.

It is considered practically impossible to accurately divide the costs of replacement of such infrastructure into these three categories on a portfolio scale. It may be possible on a component level, but the cost of such detailed analysis would far exceed the benefits – an overspend on problem analysis vs. problem resolution.

In this study, 100% of the replacement/upgrade cost has been allocated to adaptation – which is a permissive approach. An aggressive approach in this case would potentially reduce the allocation to 50%, cutting the total costs eligible for adaptation financing by approximately 12%.

On-site diesel generators are the default emergency power supply solution worldwide. Purchasing a fleet of such generators will improve disaster preparedness, which is part of climate change adaptation. However as fossil fueled systems they are not favored by climate funds, such as the GCF. This funding disconnect is regrettable but does not change the utility of generators for climate emergency response.

6.3 Adaptation cost estimates

Given all of the caveats above, the following are the adaptation cost estimates considered justifiable in the full upgrade case.

Adaptation cost estimate summaries – 34 buildings

Estimated cost of all adaptation works: **US$ 10.1M**

Total building footprint: 18,860m^2

Average adaptation cost per building: US$ 336,000

Average adaptation cost per m^2: US$ 535.

Adaptation cost estimate summaries – 200 buildings

Estimated cost of all adaptation works required for the priority buildings: **US$ 20M**.

Estimated cost of all works required for all 200 public buildings: **US$ 50M**.

7 FINANCING

7.1 Financing options and risks

The estimated combined general repair and adaptation cost estimate for the AB public building portfolio is US$90 million. This sum is well beyond the short term financing capacity of the AB government, particularly at limited notice.

If the works are limited to the priority buildings the total cost estimate is reduced to US$ 36 million. If the assessed 56% of eligible costs can be financed by climate adaptation funds, then the balance for the priority buildings is only US$15.8 million.

However, the advice provided by the GovAB Department of Environment is that even this sum is also unaffordable at present, due to the poor economic situation of the government. **So, at present, the recommended full upgrade works for either the full portfolio or just the priority buildings, are unfortunately both unaffordable, if financed only through tightly classified adaptation grant funds such as the GCF, together with the GovAB regular budget.**

A second and important issue is financing the operation and maintenance of the upgraded buildings. The current state of the inspected building portfolio indicates that O&M funding is very scarce in AB.

The investments are to provide continuation of existing public services and will not generate additional revenue or significant operational savings. If the GovAB takes on a development loan for the balance of the upgrade costs, then the principal and interest on the loan will have to be found somewhere else.

This indicates a significant risk that a major (US$20-50M) loan for fully upgrading the public building portfolio will exacerbate rather than relieve the economic stress on GovAB.

AB only recently cleared its long standing arrears with Paris Club creditors. Hence, the risk of excessive debt should not be taken lightly. This risk however, needs to be balanced against the other real risk of substantial avoidable damage and losses in the event of a hurricane.

7.2 Programme scope and phasing options: The Basic and Full Programme options

Given the above negative results, a second round of analysis was conducted to search for a lower cost approach that still delivered most of the desired outcomes.

The categorization of costs indicates three potential options for reducing the cost of the upgrade programme.

- The calculated costs of the electrical and energy upgrades are very high and comprise 53% of the total cost. In addition, these costs are considered to be only 50% eligible for adaptation financing, increasing the burden on GovAB. Finally, building electrical equipment in general has higher O& M costs and a shorter lifespan than the building fabric.
- The calculated costs of the structural and general repairs are also high and comprise 16% of the total cost. They are also assessed as not at all eligible for adaptation financing.

- Wastewater treatment is an important issue, but the required works are not assessed as eligible for adaptation funding.

If these upgrade components are removed, the remaining components are:

- Extreme weather resistance (roofs, doors and windows)
- Water supply
- Stormwater drainage

This greatly reduced scope is labeled the **Basic Programme** and the cost estimates are presented below. **Note that this drastic reduction in scope would also drastically reduce the benefits of the programme**. However, it would deliver two key economic benefits:

- A major reduction in the anticipated damages and losses from hurricanes and storms. It is these anticipated costs that present the greatest economic risk to GovAB. Hence this reduced scope is strongly targeted towards risk reduction.
- 100% of the scope is considered eligible for climate adaptation funding.

Estimated cost for basic adaptation works for the 34 buildings: **US$5.5M**

Estimate cost for the priority buildings: **US$ 11M**.

Estimated cost for all 200 buildings: **US$28M**.

Average cost per building: US$ 162,000

Average cost per m^2: US$ 290.

8 KEY FINDINGS AND RECOMMENDATIONS

8.1 Key findings

The public building portfolio of Antigua Barbuda consists of over 200 buildings in variable states of repair. A significant investment is needed to ensure the buildings can continue to adequately host the AB public authorities and support the provision of public services. Additional investments are required for the portfolio to continue to perform in the face of climate change.

Antigua Barbuda has a valid case for requesting international support for both covering these adaptation specific costs and the technical and management challenge of implementing the upgrade programme. At present there is no single unified international support mechanism capable or suitable to providing all of the finance, however there are several instruments that can provide some funding. GovAB consider the GCF to be the most important potential donor at this stage.

A comprehensive scope of work has been developed based on a series of site inspections and the communicated needs and priorities of GovAB. This comprehensive scope is labeled the **Full Programme.** The all-in estimated cost of the upgrade for the entire portfolio of 200 buildings is US$90M.

The primary concern on the feasibility of the Full Programme is its affordability for GovAB. Approximately 56% or US$50M is assessed as eligible for adaptation financing, leaving a co-financing requirement of US$40M. This is assessed as unaffordable for the GovAB at this time. It also considered unlikely that GovAB would be able to secure the full US$50M in adaptation grants.

A second round of analysis was undertaken to strip out all but the truly vital scope and anything that would not qualify for adaptation financing. The resultant scope is labeled the **Basic Programme** and focuses tightly on extreme weather resistance, water supply and stormwater drainage. The cost estimate for this basic scope for all 200 buildings is US$28M – all of which should qualify for adaptation financing.

US$28M is considered feasible in scale terms to secure via adaptation grants; however, it is anticipated that all adaptation donors including the GCF will demand some co-financing, if only to provide evidence of GovAB ownership of the issue and appropriate plans for operations and maintenance. Hence the affordability of this basic programme will be dictated by the required level of co-financing by GovAB.

A linked issue was the economic rationale for upgrading some of the older and lower value buildings. General repair and adaptation costs combined reach over 50% of the asset value in some cases, indicating that replacement or a demolition and rebuild would be more logical. This approach however would demand more co-financing from GovAB.

8.2 Recommendations

Programme planning

- GovAB should immediately progress the Basic Programme as a loss prevention investment, irrespective of the source(s) of financing. It should aim to apply this to the entire 200 building portfolio, except for those buildings it further assesses as uneconomic to upgrade and scheduled for replacement.
- Fundraising work should progress in parallel for the Full Programme.

GCF proposal development and co-financing

- A single GCF proposal should be developed which combines:
    - The Basic Programme
    - Low cost soft investments such as policy development and capacity building.
    - Elements of the Full programme, up to practical cost limits (Early advice from the GCF and UN Environment indicate that the total cost of the GCF co-financed project should not exceed US$40M.)
- The accredited entity for the GCF proposal could be either GovAB itself or an international partner such as UN Environment. GovAB and/or its accredited partner should open up enquiries directly to confirm the appropriate level of co-financing that needs to be confirmed to unlock the GCF funding.
- GovAB then needs to produce confirmation in writing or at least a letter of intent that they will secure the co-financing in the event of GCF funding. US$3-5M is considered an appropriate co-financing range for a GCF submission in the range of US$32 - 35M.
- Co-financing by GovAB should be directed first and foremost to general and structural repairs on buildings targeted for adaptation upgrades. This will deliver the largest economic benefit per co-financed dollar, as it will help increase the useful life of the buildings. Once this is complete, any savings generated during the project can be directed later to other components, such as wastewater treatment and energy.

Public sector debt

- If the GovAB proposes to take a public sector loan for the financing, it needs to note that the basic upgrades will generate public benefits and avoid future losses but will not generate operational savings. Hence such a loan will not be freestanding or self-financing and will instead add to the general debt burden for GovAB. Hence GovAB needs to include the impact of such sovereign debt on its overall economic position.

Project management

- The GovAB will need to develop or appoint an implementation team capable of managing an infrastructure works programme on the USD 30 – 90M scale to the standards demanded by GCF and other donors. The typical solution for projects of this type is for the government to develop/appoint a dedicated Project Management Unit, attached to an appropriate ministry or department. The PMU delivers the project and then hands over operation and maintenance to the host ministry or department.