GREEN CITY KIGALI

GREEN CITY KIGALI: A NEW MODEL FOR URBAN DEVELOPMENT IN RWANDA

ANNEX 3: ECONOMIC AND FINANCIAL ANALYSIS

Narrative Summary

Produced by Sweco UK

3rd Floor, Eldon House

2 Eldon Street

London EC2M 7LS

+44 (0)20 7422 7800

www.sweco.co.uk

ACKNOWLEDGEMENTS

Table of Contents

ABBREVIATIONS

CAPEX	Capital cost
CoK	City of Kigali
DEVEX	Development cost
EIRR	Economic internal rate of return
EU	The European Union
FIRR	Financial internal rate of return
FONERWA	Rwanda Environment and Climate Change Fund / Rwanda Green Fund
FS	Feasibility Study
GAP	Gender Action Plan
GCF	Green Climate Fund
GCK	Green City Kigali
GGGI	Global Green Growth Institute
GoR	Government of Rwanda
Ha	Hectares
LDP	Land Development Plan
LGI	Local Government Institute
NPV	Net present value
NST 1	National Strategy for Transformation (2017-2024)
OPEX	Operating cost
PAP	Project Affected Person
PAH	Project Affected Household
PMU	Programme Management Unit
PPF	GCF's Project Preparation Facility
RAP	Resettlement Action Plan
RFP	Request for Proposal
RPF	Resettlement Policy Framework
REMA	Rwanda Environment Management Authority
RIBA	Royal Institute of British Architects
RHA	Rwanda Housing Authority
RSSB	Rwanda Social Security Board

RwaGBO	Rwanda Green Building Organization
ToR	Terms of Reference
TVET	Technical and Vocational Education and Training Centre
USD	United States Dollars
VfM	Value for Money
WB	The World Bank

LIST OF TABLES

LIST OF FIGURES

1 Introduction

1.1 Purpose of this document

The purpose of this Annex is to provide evidence of the potential financial and economic impact of the proposed project, which includes the upgrade of an existing informal settlement (Ngaruyinka at Kinyinya Hill) with low emission infrastructure that is resilient to climate change and supports the use of renewable energy in the planned Green City Kigali (GCK) pilot development. The informal settlement focal area extends over 18ha on Kinyinya Hill, and the pilot is located nearby and extends over 16ha. The project comprises two components identified through a participatory process: 1) climate responsive investments to upgrade an informal settlement, provide critical transport links, and support renewable energy investments in a nearby pilot project and 2) increased awareness and capacity for inclusive climate responsive upgrades and enabling environment for climate resilient, low emission investment. The objective of the project is to create a climate responsive model which can be scaled up and replicated across Rwanda and the region. To promote the scale up and replication, the project will include activities to build awareness and develop institutional capacity.

The Kinyinya Hill site extends over approximately 600ha with a population of 37,238 and is a typical 'hillcrest to wetland' landscape commonly found across Rwanda. There are several existing settlements on the hill with several more under development or consideration. There are a number of informal settlements on Kinyinya Hill and the intention is to upgrade these via densification, greater land use efficiency and connection to infrastructure. **In a business as usual (BAU) scenario, densification will be achieved through conventional development practices which rely on carbon intensive construction materials and housing and infrastructure investments that fail to take account of the increased risk of flooding, landslides and prolonged dry periods**.

Our analysis of the project's potential impacts aims to understand the net economic, environmental and social impacts, by establishing the project's additionality. The estimation of the BAU constitutes a key determinant of the extent to which any of the proposed interventions from the project can be classed as 'additional', i.e. would not have been delivered in the absence of the project.

As outlined above, the key objective of the project is to upgrade the existing informal settlement, overcoming the initial financial barriers at the most risky stages of climate-linked resilience and adaptation, allowing communities to eventually scale up and replicate these improvements. In addition, given the time and resources involved in setting up climate responsive infrastructure upgrades, the economic, environmental and social benefits of such projects are typically only realised once the interventions are at scale and in full operation.

The upgrade of the site will serve as a model for community-based resilience strengthening that can be scaled-up to other parts of Kigali and secondary cities in Rwanda. The design was guided by the National Informal Urban Settlement Upgrading Strategy and aims to increase resilience to climate change while also minimising resettlement, land acquisition and social disruption. Low-cost interventions were prioritised in order to increase the scope for scale up and replication.

There are two layers of economic analysis typically delivered as part of the supporting evidence base in development plans. For this infrastructure upgrade, an economic model with a comparison to the BAU (what would happen in the absence of the upgrade) is supplemented by a financial cost-effectiveness analysis (value for money analysis). This approach was deemed most appropriate as a supporting evidence base for the proposed upgrade. This Annex estimates the local financial and economic impact, providing:

- Quantitative estimation of direct economic and financial impacts from the 5-year development period and for an additional 35 years of operation (a total project lifetime of 40 years), and
- Qualitative description of additional impacts, including
    - Qualitative review of impact on the local economy, and

- Impact on improvements to local well-being.

1.2 How to identify and quantify direct impacts for a project

Technical and financial assessments are strictly limited to the direct impacts of a project; that is, they cover the technical and financial viability of a project, including an assessment of any constraints which could prevent the project from going ahead. Such constraints could include road access issues faced by the project developer, or limits to potential building fabric improvements due to a building's existing construction. Economic assessments, by contrast, consider wider impacts from the perspective of society as a whole, including costs and benefits which affect those outside the direct participants in a project, e.g. the impact on neighbours or the wider local community. In many cases, these additional costs and benefits can be intangible or difficult to quantify or monetise.

Financial and economic analysis can be used to compare various options in order to determine not only whether they provide net benefits, but also which option offers the best benefit-cost ratio. Detailed financial and economic analysis, e.g. in accordance with best practice principles for cost benefit analysis, is only feasible and useful when most significant costs and benefits can be quantified and monetised, and when there is a certain degree of choice as regards the extent to which objectives should be met (as a function of the costs associated with the proposed measures).

For this annex, the economic and financial analysis is undertaken in alignment with international best practice, which incorporates the following key steps:

1. Determine key objectives: These are the main intended impacts that will ultimately determine the effectiveness of the proposed interventions. Where several such objectives exist, they need to be prioritised in order to make an analysis possible.

2. Define costs: The (budgetary) costs should be calculated in accordance with the basic rules of CBA, taking into account direct financial outlays, human resource implications and administrative costs. Generally speaking, only direct resources that have a well-defined monetary value are included. These are included in Annex 4.

3. Estimate the impacts: The benefits (in terms of the level of achievement of the previously defined interventions, measured in physical terms) need to be estimated. This can be the trickiest part of the analysis and can be done using primary and/or secondary data to arrive at a robust estimate of effectiveness.

4. Calculate cost-effectiveness ratio: This is simply the ratio of costs to effects (e.g. number of lives saved per dollar invested, or, expressed the other way round, cost per life saved). The best way to use this ratio for comparing options depends on whether or not a target for the desired level of benefits has been set. For the project assessed in this appendix there were no set targets for any of the interventions identified ex ante.

The technical and financial assessments carried out for the proposed project will be the source of the direct impact data (initial investment, maintenance and operation, and fuel costs). Cost data for the direct impacts for the counterfactual can be sourced from the Bill of Quantities.

In addition to the direct financial impacts, non-financial impacts are estimated, e.g. from carbon savings and a change in land use (saving forest cover) resulting from the replacement of the use of charcoal with the use of biogas for cooking. Carbon savings are more fully explored in Annex 22.

1.3 Project activities included in the proposed upgrade of the site

Project activities included in the upgrade for resilient infrastructure, household energy solutions and community buildings in an informal settlement on Kinyinya hill - Ngaruyinka, to serve as a model for a resilient, low emission upgrade. This would include:

- creating a green, permeable network of swales, gullies and detention-filtration-percolation areas to increase retention of water on the hill, improve stormwater management and reduce the risk of flooding and landslides;
- establishing community composting, neighbourhood collection points, recycling centres to improve solid waste management, reducing emissions, increasing the productivity of urban agriculture and reducing the blockage of drains with solid waste;
- expanding the central water supply (including connections), rainwater harvesting, point of use household water treatment technologies to improve the water supply and enhance water security during dry spells;
- creating green rights of way network to improve transport and mobility, safety and security, using green construction methods and materials to minimize emissions;
- establishing toilets with biogas recovery and providing training on sanitation improvements to improve health and reduce emissions;
- installing solar PV and solar water heaters (SWH) and promoting the use of clean cooking technology, energy efficient lighting and appliances to reduce emissions; and
- establishing a technical and vocational education and training (TVET) centre, community focal points and market squares to enhance green skills and livelihoods development in new value chains.

Provision of Technical Assistance (TA) to support the scale up and replication of resilient, low emission approaches through:

- developing training programs for building the capacity of construction sector workers and professionals to adopt best practices in green construction;
- assess and select best practices in green construction that can be replicable in Rwanda
- developing training events to enhance the institutional capacity of GoR agencies to support inclusive, green city development;
- providing support relating to the planning and regulatory environment in order to develop an enabling environment that fosters increased investment in the green upgrade of informal settlements;
- conducting several types of events, including through social media, briefs, meetings, exchange visits, for raising awareness, and engaging citizens to increase their active participation in resilient, low emission initiatives; and
- developing a design template and blueprinting the GCK and the planning code for the GoR so that it can be easily and cost effectively replicated.

1.4 Structure of the report

The structure of the report is illustrated in the below sections:

- Section 1: Introduction of the objectives of the study.
- Section 2: Summary of financial evaluation, including overview of DEVEX, CAPEX, OPEX and Reinvestment.
- Section 3: provides a breakdown of the economic analysis of the evaluated measures.

1.4.1 Scope and objective

Annex 3 of the GCF funding proposal package describes the methodology, assumptions and results of the Economic and Financial Analysis of:

- Output 1.1 Public infrastructure is upgraded to increase resilience to flooding, landslides and prolonged dry spells and household energy and water use is efficient.
- Output 1.2 Increased awareness and capacity
- Output 2.1 Increased capacity of GoR Agencies and Recycling Sector
- Output 2.2 Enabling environment for climate resilient, low emission investment
- Cross-cutting project management component from the first 5 years of implementation.

The full breakdown of spend against each activity is provided in Section 2.3.

1.5 Methodology

This document sets out the approach and methodology proposed for delivery of Annex 3 of the Kigali GCF application.

The GCF Application Form includes a mandatory requirement for economic and financial modelling contained in Annex 3, including spreadsheets and drafting.

Economic and financial modelling are broadly based on the same input assumptions but differ in terms of calculation approach and outputs. Notably, economic analysis incorporates quantifiable non-financial impacts on a like-for-like basis with financial costs and revenues but doesn't include key financing assumptions or the impact of financial and governance structures.

Economic analysis requires assessment against a counterfactual, in this instance a business as usual scenario of based on minimal changes to current development, also known as a Do-Minimum scenario.

1.5.1 Economic and financial modelling inputs and assumptions

Both economic and financial modelling will be based on a 40-year time period.

Similar to the carbon modelling, the economic and financial modelling is based on the Bill of Quantities in the first instance. Additional assumptions around non-financial costs and benefits and investment assumptions, respectively, are captured below.

Economic	Financial
Upgrade investment costs	Financial discount rate based on regional/national bank loan interest rates
Residual values of assets	Upgrade investment costs
Value of change in land use	Savings from solar streetlighting
Value of increased local water harvesting	
Value per tonne of carbon equivalent saved	

Benefit to residents from solar PV and solar hot water	

As there are limited financial revenues associated with the identified upgrades, it is recommended that the financial analysis is based on cost effectiveness analysis rather than cost benefit analysis. This will allow for an estimate of value-added relative to the cost of the upgrade. This cost-effectiveness analysis will include estimates of the savings expected from certain upgrades, e.g. solar street lighting, relative to a business as usual counterfactual.

1.5.2 <u>Direct economic and financial impacts</u>

The technical and financial assessments carried out for the proposed project will be the source of the direct impact data (initial investment, maintenance and operation, and fuel costs). Capital cost data for the direct impacts for the counterfactual can be sourced from the Bill of Quantities.

The distinction between economic and financial impacts is based on the parties involved in a transaction. For this project, funding for capital costs is provided by the GCF with ongoing operational costs for e.g. streetlighting and road maintenance paid for by the local government. Beneficiaries of the project range from the community as a whole to individual households (depending on the proposed intervention). The benefits of the projects are primarily through cost-saving measures, time-saving measures and health benefits rather than any defined revenue streams. This precludes the use of a conventional financial assessment where the funder would recoup capital investment over the lifetime of the project through usage tariffs or tolls. The main quantifiable financial benefit to the local government is the upgrade of local streetlighting infrastructure to use solar power, thus reducing lifetime operational costs.

The economic analysis looks at the benefits accrued to householders benefiting from the interventions financed by GCK. These include time and cost savings from increased water harvesting at the household level, cost savings from use of solar PV and solar water heating, changes in land use from a reduction of charcoal use and carbon savings from a change in fuel consumption. As the upfront capital costs are paid for by EE but the benefits accrue to individual households and there is no repayment plan, these benefits are considered economic rather than financial. Note that carbon savings are more fully explored in Annex 22.

Direct impacts will be estimated for:

- Upgrade of the settlement street lights to solar street lights
- Improvements to infrastructure resilience, in particular for stormwater damage
- Improvements to mobility within the settlement as well as the surrounding area
- Development of the Technical and Vocational Education and Training Centre (TVET)
- Changes to water, electricity and charcoal sources and consumption in the affected community.

Adaptation impacts will be assessed qualitatively in the first instance and supplemented with quantitative and monetary analysis where feasible.

The methodology consists of the three steps presented below:

- **Step 1.** Assess financial and economic net zero carbon upgrade impacts on the city. This first step requires developing a baseline assuming a "without project" Business as Usual (BAU) scenario - (i.e. with climate change but without any project measures to reduce vulnerability and build resilience). This scenario provides the counterfactual estimates for the project based on the findings of the Feasibility Study (Annex 2), which has analysed data on past climate change trends and future scenarios and climate risks.

- **Step 2**. Develop cost parameters and assumptions for a portfolio of adaptation and mitigation measures: The second step requires developing the intervention scenario by gathering cost and benefit parameters for the identified prioritised adaptation measures and consulting with key stakeholders to verify underlying assumptions. These parameters are also used to develop the bottom-up project budget presented in Annex 4.
- **Step 3**. Prepare an economic and financial analysis of costs and benefits of proposed adaptation and mitigation measures: The third step involves calculating the net financial and economic costs and benefits incurred by implementing the proposed adaptation and mitigation measures.

The models are constructed over a 40-year basis, with Years 1-5 being part of the duration of the Programme Management Unit (PMU). Constructions costs primarily occur in Year 3, leaving a total of 37 years of operation across the financial and economic timelines.

2 Financial evaluation

2.1 Overview of the financial costs and benefits of the project

Investing in the upgrade of an informal settlement to form a climate-responsive blueprint for upscaling and replication is a significant departure from a conventional financial model. Typically speaking, any significant infrastructure upgrade would be planned and financed by local government across a 40-60 year horizon or - as in the case of significant road infrastructure - financed as a stand-alone project through user tolls, general taxation or government borrowing.

Infrastructure upgrades are typically accompanied by increases in property value with follow-on increases in tax income which help pay for the original infrastructure upgrades. This may have the detrimental effect of pushing out the existing local occupants from homes they can no longer afford, who will then create new informal settlements elsewhere.

The proposed project for climate-responsive upgrades is therefore not only important in creating a scaleable, replicable model which can be deployed elsewhere but also needs to carefully consider wider socioeconomic impacts affecting the existing population. To facilitate this, the adaptation and mitigation measures for the project have been proposed on the basis of providing long-term cost-savings, allowing local residents to boost their household wealth in parallel with the expected increases in local property value, reducing the risk of financially-induced eviction and/or migration.

From a financial perspective, the project is a subsidy-based model where initial capital cost investment is offset by long-term improvements in the health and wealth for local households, minimising detrimental impacts on local residents (formally known as economic displacement[1] and economic deadweight[2]). Only one (solar streetlighting) of the proposed interventions was monetisable at a scale benefiting the community as a whole outside of individually impacted households. The upgrade of streetlighting from conventional to solar-powered would typically be a cost burden borne by local government and financed through tax revenues. Due to data limitations and because the upgrade would be financed by GCF, the financial analysis is based on a BAU comparison with conventional streetlighting and is presented in Section 2.4.

In terms of replicability and scalability, any departure from the subsidy-based model should be accompanied by a detailed assessment of distributional impacts to ensure that existing households are not "priced out" of their current homes from the impacts of infrastructure improvements.

2.2 Total direct costs of the project

This section provides a breakdown of development, construction and operational costs estimated for all of the activities of the project. While some of the interventions can be split out and assessed separately either in financial or economic terms, not all of the interventions were quantifiable or monetisable. The total costs provide an overview of the requested funding from the GCF and are linked to the spend profile in the first five years of the project.

Note that all values are undiscounted, presented in real terms (i.e. excluding inflationary impacts).

- **Development costs** (DEVEX) include four categories from the Action column linked to each Activity of works from the Annex 4 breakdown; Local consultants, International consultants, Travel and Professional/Contractual Services.
- **Construction costs** (CAPEX) include two categories from the Action column; Equipment and Construction cost.

[1] Economic displacement is when policy intervention which causes the expansion of one economic activity or activity in one location also has the effect of bringing about some degree of reduction in economic activity elsewhere
[2] Economic deadweight cost to society created by market inefficiency, which occurs when supply and demand are out of equilibrium

- **Operational costs** (OPEX) include the remaining two categories from the Action column; Staff cost and Training, workshops and conference.

A summary of the breakdown of cost for each cost category is provided in the table below.

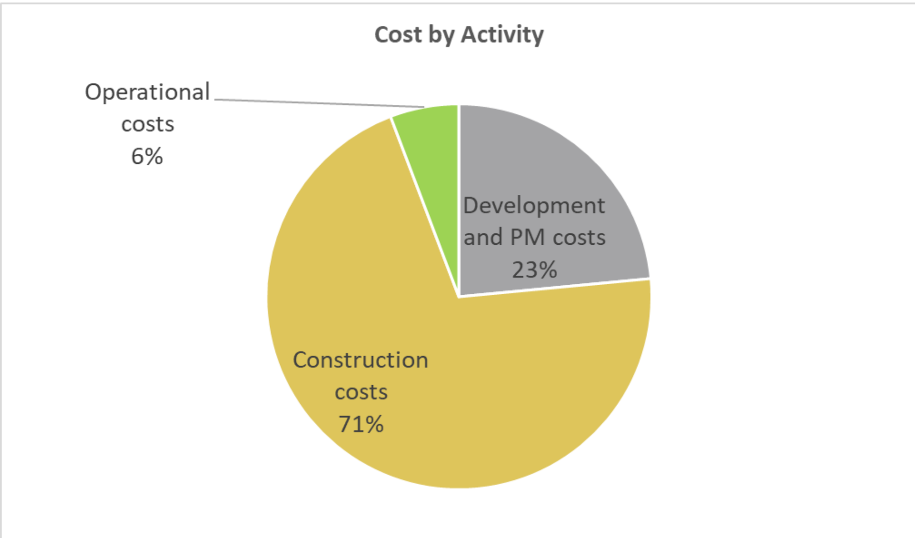
Table 1: Summary of cost breakdown across cost categories

Cost breakdown (2021 USD) across 40-year timeframe (excl. tax and land compensation costs)	**Development and PM costs**	**Construction costs**	**Operational costs**
Total costs per category	$4,361,524	$13,133,204	$1,070,950
Total costs	**$18,565,678**		

Note that no additional operational costs outside of the 5-year PMU activity have been included in the analysis. It is assumed that infrastructure will be handed over to relevant utilities and municipality to operate and maintain and as indicated in the project FS, as well as trainings on use of home-based systems for homeowners during the implementation period. Additionally, any fuel or electricity consumption which may be needed during the lifetime have been excluded from this summary of costs.

The lifetime cost breakdown including and excluding the replacement costs are illustrated in the figure below:

Figure 1: Breakdown of 40-year lifetime costs by activity, with and without replacement costs



Construction costs clearly represent the bulk of the financial costs. Note that operational costs here include costs dedicated to training, workshops, and conference activities as well as staff costs.

2.3 Activity cost breakdown

The table below provides a full breakdown of costs identified in Annex 4 divided into Development, Construction and Operational costs. The provided split across the three cost categories are all costs which are incurred in the first five years, during the operation of the PMU.

Table 2: Cost breakdown across DEVEX, CAPEX and OPEX categories (excl. tax support and land compensation costs)

Capital Costs	Activity no.	Development costs	Construction costs	Operational costs
Activity 1.1.1 Transport and mobility	1.1.1	$ 615,658	$ 4,382,635	$ -
Activity 1.1.2 Stormwater management	1.1.2	$ 404,110	$ 1,334,007	$ 15,000
Activity 1.1.3 Water supply	1.1.3	$ 243,518	$ 532,182	$ 24,000
Activity 1.1.4 Sanitation	1.1.4	$ 79,220	$ 88,000	$ 23,250
Activity 1.1.5 Energy	1.1.5	$ 536,527	$ 6,052,989	$ 6,300
Activity 1.1.6 Solid waste	1.1.6	$ 171,363	$ 130,983	$ 6,500
Activity 1.1.7 Community buildings	1.1.7	$ 344,777	$ 582,409	$ -
Activity 1.2.1 Community ownership, gender equality and sustainability	1.2.1	$ 428,000	$ -	$ 32,200
Activity 1.2.2 TVET operationalised to serve as a learning and innovation centre for climate responsive upgrades	1.2.2	$ 381,200	$ -	$ 77,500
Activity 1.2.3 Awareness raising and citizen engagement in climate responsive regeneration	1.2.3	$ 97,500	$ -	$ 20,000
Activity 2.1.1 Institutional capacity development of GoR agencies	2.1.1	$ 105,000	$ -	$ 3,200
Activity 2.1.2 Blueprinting the GCK and Planning code for GoR	2.1.2	$ 212,900	$ -	$ 1,500
Activity 2.1.3 Development of recycling value chains	2.1.3	$ 154,500	$ -	$ 2,000
Activity 2.2.1 Policy support for an enabling environment and mainstreaming green city development standards and approaches into regulatory and planning frameworks	2.2.1	$ 166,000	$ -	$ -
Activity 2.2.2 Knowledge management system developed on climate responsive regeneration	2.2.2	$ 199,500	$ -	$ -
Project Management Component	PM	$ 221,750	$ 30,000	$ 859,500
	Total	**$ 4,361,524**	**$ 13,133,204**	**$ 1,070,950**
	Grand total	**$ 18,565,678**		

2.4 Costs and revenues for streetlighting upgrade

As set out in Section 2.1, as this is a subsidy-based financial model with limited ability to recoup initial capital costs without adversely affecting the existing population and limited availability of financial beneficiaries of all the proposed activities, a full financial model covering the whole of the project is not feasible.

Due to the absence of clear revenue streams, traditional calculation methods for calculating net present value and internal rate of return are not viable metrics for measuring financial benefits of the proposed upgrade. Instead, this section provides a summary of the costs and savings linked to the streetlighting upgrade, providing a payback period range reflection low and high assumptions for the cost of electricity.

Key assumptions are shown below.

Table 3 Assumptions used for streetlight financial case

Description	Value	Units
Cost of standard non-solar streetlight	$ 1,815	*USD*
Number of standard street lights	653	*#*
Total cost of standard street lights	$ 1,185,195	*USD*
Cost of solar street light	$ 6,316	*USD*
Number of solar street lights	526	*#*
Total cost of solar street lights	$ 3,322,321	*USD*
Traditional street lighting electricity requirement	115,909	*kWh/year*
Cost of electricity (high)	255	*RWF/kWh*
Cost of electricity (low)	89	*RWF/kWh*

The full list of assumptions is included in the accompanying financial model.

An additional assumption applied to the financial case is expected annual increase in electricity costs. This is set at 7%, based on historic pricing for the region. Without expected increases to annual electricity costs, there is no financial case for solar streetlighting relative to conventional streetlighting based on avoided electricity consumption.

Based on an increasing electricity costs assumption, the discounted financial case for solar streetlighting is 21.4 years for the high electricity cost scenario and is not repayable across 40 years for the low electricity cost scenario. This is based on discounted annualised capital costs and operating costs using the Rwanda Central Bank real interest rate value of 7.5% (extracted from the World Bank database for the most recent year, 2020). In the high electricity cost scenario, annual savings from the difference in annualised capital and operating costs become positive from year 10 onwards while this only happens in year 40 for the low electricity cost scenario.

The primary driver for the lack of financial viability for solar street lighting in the constant electricity cost assumptions and the low but increasing electricity cost assumption is due to the significant cost uplift for solar streetlight investment, which is more than double the capital investment for conventional streetlighting. If the cost for a solar streetlight could be halved (from the modelled cost of USD 6,316), then the financial case for solar streetlighting would be viable across all scenarios except the constant low electricity cost scenario.

3 Economic evaluation

Separate from a financial evaluation which only considers direct financial impacts from any proposed project or intervention, an economic evaluation views all potential benefits and costs, both direct and indirect, seen from both the local perspective and a regional/national perspective. Where these costs and benefits cannot be quantified, they are assessed on a qualitative basis. As set out in Section 2.1, the economic evaluation contains the monetisable and quantifiable adaptation and mitigation measures for the project directly affecting a subset of households benefitting from the project. These have been estimated on the basis of providing long-term cost-savings, allowing local residents to boost their household wealth in parallel with the expected increases in local property value, reducing the risk of financially-induced eviction and/or migration.

Quantified benefits have initially focussed on the following mitigation measures:

- Water harvesting on existing homes - additional hours available for working and savings from reduction in purchase of water*
- Savings from generation of power by solar PV*
- Savings from use of solar water heating*
- Carbon savings
- Savings expected from the change in land use

*Note in this report the benefits for water harvesting, solar PV and solar water heating have been quantified on a per household level.

The main benefit, improvement to local quality of life, could not be quantified at the present time so is not included in this analysis. Additionally, adaptation measures at a societal level could not be quantified at this time due to a lack of data for quantification and monetisation of the specific planned interventions, e.g. those improving transport and waste activities.

Core assumptions are explained in the sections below, and sources are provided in the Assumption tabs in the Annex 3 spreadsheets.

3.1 Water harvesting in existing households

Due to the absence of clear revenue streams, traditional calculation methods for calculating net present value and internal rate of return are not viable metrics for measuring the economic benefits of the proposed upgrade at a household level. Instead, this section provides a summary of the costs and savings linked to the proposed installation of water harvesting in existing households, providing a payback period both from the additional hours available for working and the potential cost savings from a reduction in purchased water.

Core assumptions used for the calculation of the benefit of installed water harvesting measures per household are provided below.

Table 4: Assumptions used for payback for water harvesting in terms of additional income

Description	Value	Units
Annual living wage in Rwanda	187,633	(RWF/month)
Exchange rate RWF to USD	0.001	
Annual living wage in Rwanda	$187.59	(USD$/month)
Equivalent hourly wage	$1.13	(USD$/hr)
Percentage of male wage female receives	88%	
Female wage per hour	$0.99	(USD$/hr)
Cost of water harvesting equipment	$747	(USD$)
Number of hours required for payback	754	(hours)
Number of hours a day water collecting	2	(hours/day)
Years for payback (non-discounted)	**1.0**	**(years)**

In terms of the support provided to individual households to increase household revenue in parallel with the expected increases in property values from the overall infrastructure improvements, the additional time freed for revenue generation activity is a potentially significant contributor. Similarly, the cost reduction potential of using harvested rainwater rather than purchased water has a similarly positive impact on household finances. Core assumptions are shown in the table below.

Table 5 Core assumptions used for water harvesting cost reductions

Description	Value	Units
Water truck, per 25L jerry can	100	*(RWF/25L)*
Amount of water required per person per day	80	*(L/day)*
Cost of water purchased from truck per person	320	*(RWF/day)*
Volume of water captured per residential property (large)	40	*(m3/year)*
Volume of water required per person/year	29.2	*(m3/year)*
Volume per household (4.6 pp/hh avg.)	134.3	*(m3/year)*
Cost of 1m3 water from truck	4,000	*(RWF)*
Annual savings from water purchase	160,000	*(RWF)*
Annual savings from water purchase	160	*(USD)*
Exchange rate RWF to USD	0.001	
Cost of water harvesting equipment	$747	*(USD)*
Years for payback (non-discounted)	**4.67**	***(years)***

While the non-discounted payback period per household for reductions in water expenditure is slightly higher than payback period for additional household income from saved time linked to household water harvesting, the longer term impacts on household income are still significant.

3.2 Savings from generation of power by solar PV

Similar to the case for household water harvesting, household production of power from solar PV can support household income increases in line with wider property value increases from infrastructure upgrades. Core assumptions are provided in the table below.

Table 6: Core assumptions for household benefits from solar PV

Description	Value	Units
Energy generated by solar PV, residential, of total demand	25%	*(%)*
Electricity per person per year	79	*(kWh/year)*
Electricity per household	30.3	*(kWh/month)*
Energy generated by Solar PV	7.57	*(kWh/month)*
Residual electricity requirement from grid	22,713	*(kWh/month)*
Electricity cost at 0-15 kWh/month rates	212	*(RWF/kWh)*
Exchange rate RWF to USD	0.00100	
Electricity cost at 0-15 kWh/month rates	$0.21	*($/kWh)*
Total monthly cost of residual electricity from grid	$4.81	*($/month)*
Total monthly solar PV saving per household	$1.6	*($/month)*
Total yearly solar PV saving per household	$19.26	*($/year)*

From the above table, it is estimated that households can save up to a third of their annual electricity bill, assuming their demand remains constant. Alternatively, if households increase their electricity consumption due to the lower prices (rebound effect) they are able to increase their electricity consumption at no extra cost to the household, but with additional benefits in terms of household wealth and/or health improvements. The simple payback based on money saved is 30 years.

3.3 Savings from use of solar water heating

The final quantifiable benefit at a household level is through the installation of solar water heating. This measure provides necessary hot water used for the household, in some instances being the first source of hot water available. Core assumptions are provided in the table below.

Description	Value	Units
Hot water generated by solar heating as percentage of total demand	100%	
Solar water heater capacity	200	(litres)
Electricity required per day	13,460	(kJ/day)
Electricity required per day	3.74	(kWh/day)
Temperature difference of water required	35	(°C)
Daily quantity of water needed	92	(kg)
Specific heat capacity of water	4.18	(kJ/kg °C)
Cost of solar water heater	$ 1,198	($)
Electricity cost at 0-15 kWh/month rates	249	(RWF/kWh)
Exchange rate RWF to USD	0.001	
Electricity cost at 0-15 kWh/month rates	$0.25	($/kWh)
Cost of electricity per day for electric water heater	$ 0.93	($)
Years for payback	3.5	(years)

As with the other household improvement measures, the installation of solar hot water provides a net benefit relative to a BAU electric hot water unit. As per the solar PV calculation, it is likely that some of the household installing solar hot water technologies would not have access to hot water at all in the BAU, which implies that the net benefit to the household is likely higher than what has been estimated here.

3.4 Value of carbon savings

The value of carbon has been estimated for both a BAU scenario and implementation scenario across three categories:

- Improvements to existing structures and infrastructure to water, electricity and gas consumption.
- Improvements to residential structures to water, electricity and charcoal consumption.
- Improvements to streetlighting consumption from electricity consumption.

Further analysis of the carbon calculations is provided in Annex 22.

The value of a tonne of carbon has been taken from the World Bank Shadow Price of Carbon Guidance Note published in 2017, using 2020 values as a base and increased (in real terms) by 2.25% per year. Both a low and high cost have been included. Indicative values for 2025 and 2040 are provided in the table below. Note all values are provided undiscounted and in real terms (2021 USD).

Table 7: Estimates of the value of emitted carbon

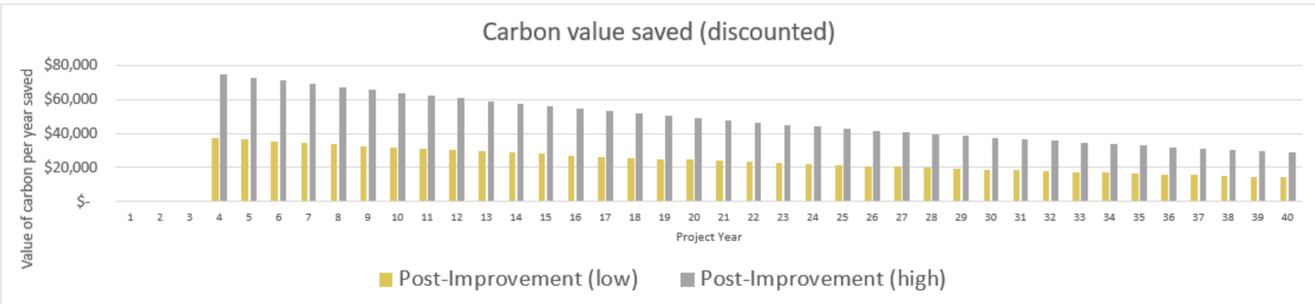
Value of annual carbon savings against BAU (2021 USD, undiscounted)	**2026**	**2040**
Post-Improvement (low)	$45,500	$62,129
Post-Improvement (high)	$90,999	$124,258

There is a significant difference between low and high valuations of carbon emissions, dependent on the value assigned to a tonne of carbon. Given the ongoing climate emergency, it is likely that the value of a tonne of carbon will increase further but for the purpose of this analysis the range is deemed sufficient.

There is a modest increase in the value of carbon emitted between 2025 and 2040 based on the annual proposed uplift of 2.25% recommended by the World Bank. More significant is the difference between the value of carbon emitted in the BAU scenario relative to the proposed infrastructure improvements. The net carbon savings per year are illustrated in the figure below. Note the start date of Year 4 to reflect construction taking place in Year 3. All values are in 2021 USD and presented in undiscounted, real terms.

Using a 5% real discount rate extracted from the 2021 IMF Third Review Report for Rwanda (source available in the Economic Model) provides 40-year values of USD 0.9 million and USD 1.8 million for the low and high improvements scenarios respectively.

Figure 2 Annual carbon savings relative to business as usual



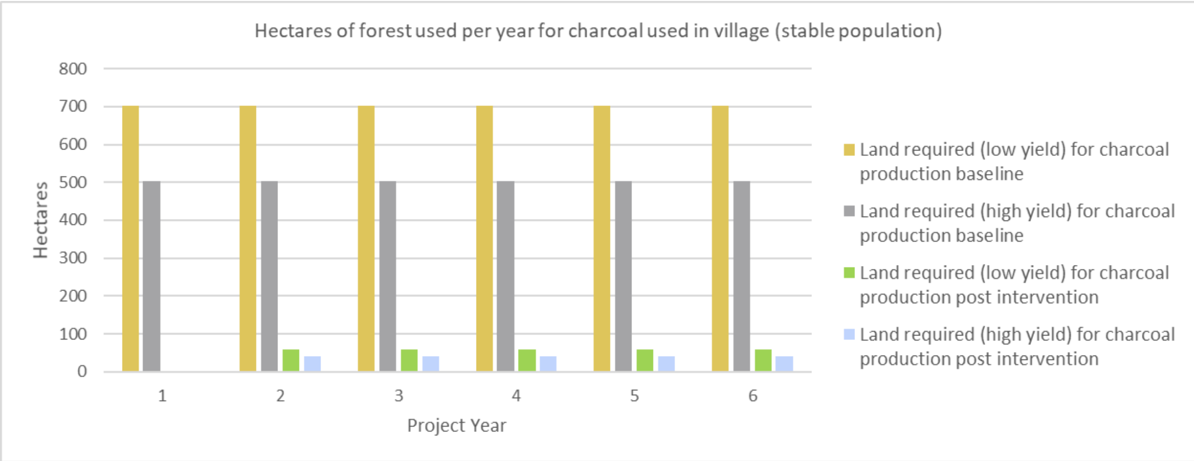
In both the low and high carbon value scenario, the value of carbon savings increases over time driven by the annual uplift in carbon value. Note that these values are based on no further increases to the population - if population increases are included, and additional funding sourced for necessary infrastructure upgrades, this would increase expected carbon savings further.

3.5 Value of savings to the forest

In the BAU scenario, residents are heavily dependent on the use of charcoal for domestic purposes. Under the proposed infrastructure upgrades, there would be a use of biogas instead of charcoal at the TVET and there will be education and promotion of improved cooking stoves, which use less charcoal. The value of this shift is captured in the carbon savings valuation above but there is a further benefit from increased forestry cover, which has benefits in the form of a carbon sink, improvements to biodiversity, improvements in local water retention/climate impacts, air quality impacts and potential alternate revenue streams for sustainable forestry. It was not possible to fully value these benefits in financial terms but quantification of the impact on increased forestry from a change in land use is illustrated in the figure below.

As the change in land use remains constant over the course of the project lifetime, only the first 6 years are illustrated.

Figure 3 Land use change from savings in charcoal consumption



Note that the BAU scenario includes both a high-yield and low-yield scenario, which is replicated post intervention. There is a significant reduction in land use for charcoal production in both the high-yield and low-yield scenarios, implying a significant additional benefit above the value of carbon savings.

4 Conclusions

The financial and economic evaluation conducted for this site have identified the following high-level findings:

- For the financial evaluation, costs are clearly understood but due to the nature of the upgrades proposed there are limited options for capturing revenue. The main benefits from the proposed upgrades are captured through an uplift in the property value which could be capitalised by sales of the affected homes or through increased taxation, but both of these measures will heavily impact affordability for the residents the upgrades are being designed for and who would see the greatest uplift in terms of quality of life improvements. The wider societal benefit for the upgrade in streetlighting has been estimated and has a relatively long payback period even when assuming significant year-on-year electricity cost increases.
- For the economic evaluation, benefits have been captured at a household level to illustrate the distributional economic improvement per household from improvements in water and electricity access/cost. Carbon value has been used as a proxy to capture the benefits from the proposed overall upgrades overall to translate the impacts into wider economic impact. Additional benefits in terms of the change of local land use from reduced household consumption of charcoal and the associated co-benefits linked to increased forestry cover has not been translated into monetised values due to a lack of shadow pricing mechanism but has been quantified to illustrated the magnitude of impacts. No significant additional costs from the upgrade have been identified outside of the financial costs assessed.