Annex R

Greenhouse Gas Assessment

Zambezi River Authority (ZRA)

Greenhouse Gas (GHG) Assessment

Proposed Batoka Gorge Hydro-Electric Scheme (Zambia and Zimbabwe) on the Zambezi River

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Greenhouse Gas (GHG) Assessment

Proposed Batoka Gorge Hydro-Electric Scheme (Zambia and Zimbabwe) on the Zambezi River

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Acronyms and Abbreviations

Name	Description
AfDB	African Development Bank
BGHES	Batoka Gorge Hydro-Electric Scheme
CO_2e	Carbon Dioxide equivalent emissions
EBRD	European Bank for Reconstruction and Development Bank
EIB	European Investment Bank
GHG	Greenhouse Gas Emissions
GWP	Global Warming Potential
IFC	International Finance Corporation
IHA	International Hydropower Association
IPCC	Intergovernmental Panel on Climate Change
O&M	Operations and maintenance
SP	Studio Pietrangeli Consulting Engineers
UNFCCC	United Nation Framework Convention on Climate Change

OVERVIEW

This greenhouse gas (GHG) assessment estimates the emissions contributing to climate change from the proposed Batoka Gorge Hydro-Electric Scheme (hereafter known as the proposed Project or BGHES) during its construction and operation.

The construction of the proposed BGHES includes estimations for emissions associated with the combustion of fuel from the transportation of materials to site, transportation of excavated materials and use of construction plant; and emissions released from biogenic carbon contained within the vegetation that is cleared for the construction sites. The most significant source of GHG emissions during construction is associated with land use change from the clearance of vegetation for the construction sites.

The operation of the proposed BGHES includes estimations for emissions associated with the combustion of fuel from maintenance vehicles as well as from the decay of the remaining biomass submerged within the BGHES reservoir. The most significant source of GHG emissions during operation is associated with the decay of remaining biomass submerged within the BGHES reservoir, which contributes approximately 99.9% of the total emissions [(1)].

Mitigation proposed to reduce the most significant sources of GHG emissions includes utilising cleared vegetation (wood) for commercial timber and community fuelwood rather than clearance by fire during the construction period, and minimising the amount of biomass available to decay before the BGHES reservoir is inundated. It is suggested that a timber survey be carried out to estimate the amount of commercially viable timber, which could be recovered from the areas that will be cleared of vegetation during construction. It would then be possible to estimate the amount of biomass that would not release GHGs and reduce the impact from land use change emissions.

When the proposed BGHES is compared against fossil fuel electricity generation technologies over the 50 to 100 year Project lifetime, the GHG emissions associated are significantly lower per GWh of electricity generated. Although there is a high initial GHG impact primarily associated with the clearance of vegetation during construction and decay of vegetation from inundation, the emissions over the Project lifetime are significantly lower due to the minimal emissions associated with generating electricity once in operation. This means the BGHES will have a much lower contribution to climate change over its lifetime compared to any fossil fuel electricity generation technologies.

[(1)] Total emissions, during years 1-25 of BGHES operation have been calculated as 304,614 tCO_2e. Of this total, emissions associated with the decay of remaining biomass amounts to 304,594 tCO_2e (equating to 99.99% of the total).

1. INTRODUCTION

This greenhouse gas (GHG) assessment estimates the emissions contributing to climate change from the Batoka Gorge Hydro-Electric Scheme (BGHES), (hereafter known as the proposed Project or BGHES), during its construction and operation phases.

1.1 Assessment Objectives

The objectives for this assessment are:

- To undertake GHG modelling and calculation of the construction and operational carbon footprint of the BGHES through an impact assessment.
- To contextualise annual emissions against international and national thresholds.
- To determine whether expected GHG emissions are deemed to be 'significant'.
- To develop viable mitigation measures and management actions that are designed to reduce any significant GHG emissions.
- Assuming the implementation of the suggested mitigation measures and management actions, a residual impact assessment rating has being assigned.

1.2 Scope of the Assessment

The GHG assessment looks at the emissions associated with the BGHES during its construction and operation phases. These can be described as follows:

- During construction, GHG emissions are linked with the clearance of vegetation in the construction sites, as well as typical activities associated with construction such as the transportation of raw materials, use of heavy vehicles and on-site power generation [(1)].
- Emissions associated with the BGHES during its operation are related to the decay of biomass in the reservoir and additionally very limited vehicle transport and power generating requirements expected at and around the site.

1.3 Relevant Documents, Standards and Guidelines

1.3.1 Zambia GHG Documents, Standards and Guidelines

Zambia has various climate change-related policies, strategies, projects and programs in response to climate change impacts. These documents are aligned with the National Development Plans [(2)] and the Vision 2030, both of which support development of a low carbon and climate-resilient development pathway. In 2016, Zambia launched its National Climate Change Policy [(3)] aimed at stemming the impact of climate change, and introduces a well-structured and coordinated national strategy to effectively tackle the adverse effects of climate change. The policy is driven by the Ministry of National Development.

[(1)] Scope 3 emissions associated with the mining/manufacture of the raw materials used for construction of the BGHES (e.g. cement and steel) are considered to be outside the scope of this Assessment. Emissions associated with transportation of these raw materials to the project site have however been included within the scope of work.

[(2)] Zambia's latest National Development Plan for 2017-2021 is available at: http://extwprlegs1.fao.org/docs/pdf/zam170109.pdf

[(3)] http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/laws/8142.pdf

1.3.2 Zimbabwe GHG Documents, Standards and Guidelines

The Zimbabwean National Climate Change Response Strategy [1] provides a framework for the comprehensive and strategic approach to managing climate change. The response strategy includes climate change policies designed to make Zimbabwe more resistant to climate pressures and help it meet its international carbon-cutting pledges. Of particular note, the National Climate Policy [2] aims to help Zimbabwe put in place the legal structures needed to guide businesses on becoming greener.

1.3.3 IFC Performance Standards

Regarding resource efficiency, including the use of energy and other GHG-relevant activities, the IFC's Performance Standard 3: Resource Efficiency and Pollution Prevention [3] states that:

The client will implement technically and financially feasible and cost effective measures for improving efficiency in its consumption of energy, water, as well as other resources and material inputs, with a focus on areas that are considered core business activities. Such measures will integrate the principles of cleaner production into product design and production processes with the objective of conserving raw materials, energy, and water. Where benchmarking data are available, the client will make a comparison to establish the relative level of efficiency.

With specific reference to GHGs, the Standard states that:

The client will consider alternatives and implement technically and financially feasible and cost-effective options to reduce project-related GHG emissions during the design and operation of the project. These options may include, but are not limited to, alternative project locations, adoption of renewable or low carbon energy sources, sustainable agricultural, forestry and livestock management practices, the reduction of fugitive emissions and the reduction of gas flaring.

For projects that are expected to or currently produce more than 25,000 tonnes of CO_2-equivalent annually, the client will quantify direct emissions from the facilities owned or controlled within the physical project boundary, as well as indirect emissions associated with the off-site production of energy used by the project. Quantification of GHG emissions will be conducted by the client annually in accordance with internationally recognized methodologies and good practice.

As the BGHES is expected to produce more than 25,000 tonnes of CO_2-equivalent annually, the project is required to undertake consideration of the emissions associated with the BGHES during its initial design and later operational stages. "Project-related" should be considered to include any emissions related to the construction and operation of the BGHES.

1.3.4 African Development Bank (AfDB) Standards

The AfDB clearly sets out that the impact of climate change on the sustainability of investment projects, and the contribution of projects to global GHG emissions must be systematically considered.

This is outlined as an Operational Standard (OS 4) within its Integrated Safeguards System: "*Pollution Prevention and Control, Greenhouse Gases, Hazardous Materials and Resource Efficiency – This safeguard covers the range of impacts of pollution, waste, and hazardous materials for which there are agreed international conventions and comprehensive industry-specific standards that other multilateral development banks follow. It also introduces vulnerability analysis and monitoring of greenhouse gas emissions levels and provides a detailed analysis of the possible reduction or compensatory measures framework*" [4].

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(1) Government of Zimbabwe, Ministry of Environment, Water and Climate. Available online at: https://www.climatechange.org.zw/sites/default/files/National%20Climate%20Change%20Response%20Strategy.pdf

(2) http://newfour.ncuwash.org/wp-content/uploads/2017/08/Zimbabwe-Climate-Policy-2016.pdf

(3) International Finance Corporation, Performance Standard 3, 2012

(4) African Development Bank Group's Integrated Safeguards System, 2013

1.3.5 European Investment Bank (EIB) Standards

The EIB's Environmental and Social Handbook (1) has Climate Standards which require it's financing to be aligned with EU climate policy. Of particular note, the EIB is committed to: assessing and reporting the carbon footprint of EIB financed investment projects, their annual aggregate GHG emissions and savings. These are published in the EIB's Annual Report for each year of finance contract signature (2).

1.3.6 European Bank for Reconstruction and Development Bank (EBRD) Standards

The EBRD's Protocol for Assessment of GHG Emissions (3) sets out its methodology for how consultants should assess the GHG emissions from projects. The EBRD has assessed the impact on GHG emissions of its direct investments (loan and equity) since 2003. Summaries have been published in the Bank's annual Environmental or Sustainability Reports since that date. Although in most years all direct investment projects with emissions, or emissions savings, exceeding 20 kt CO_2e per annum have been assessed, the focus has been on large projects, i.e. those emitting > 100 kt per annum, mainly in the energy and industrial sectors, which dominate the portfolio GHG footprint.

1.3.7 Hydro-Electric Electricity Generation in Context

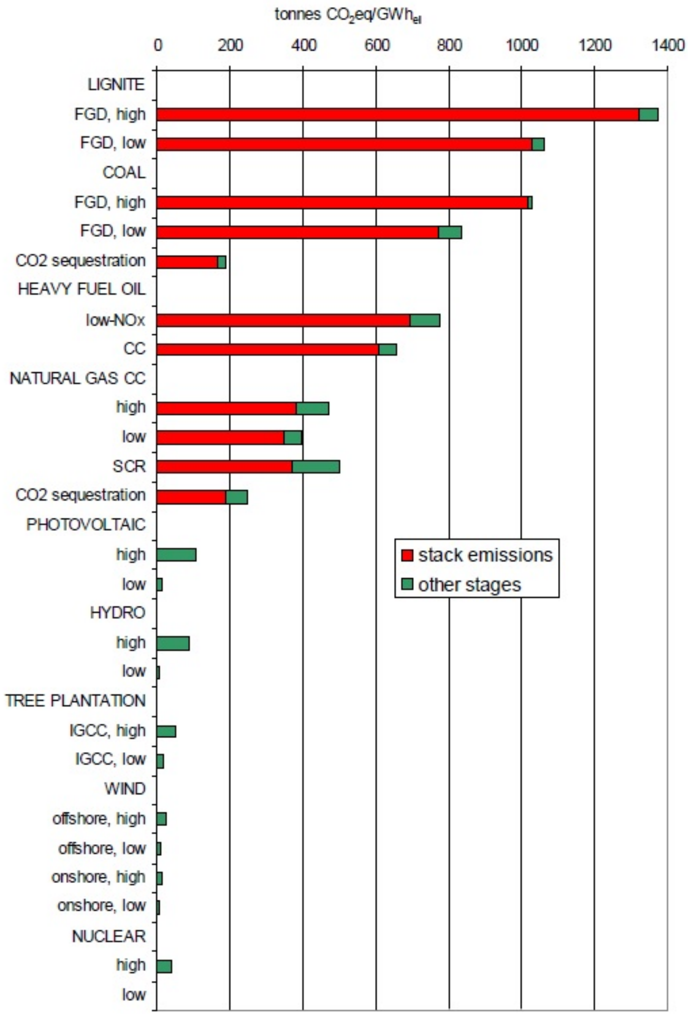
Figure 1.1 shows the relative contribution of GHG emissions from the different lifecycle stages over the lifetime of different power generation technologies, clearly showing the GHG benefit of power generation through hydro-electricity in comparison with other more GHG intensive technologies. *Figure 1.2* shows GHG emissions over the lifecycle of different hydropower technologies based on a literature review of studies since 1980 carried out by the Intergovernmental Panel on Climate Change (IPCC). *Figure 1.2* shows that GHGs (carbon dioxide and methane) associated with the construction and operation of hydro-electric projects are largely due to the decay of reservoir biomass (inundated areas). Moreover, *Figure 1.2* shows there is significant variation between schemes depending on the size of the inundated area and the vegetation type and extent of coverage within it.

(1) European Investment Bank, Environmental and Social Handbook, 2018

(2) European Investment Bank, Environmental and Social Handbook, 2013

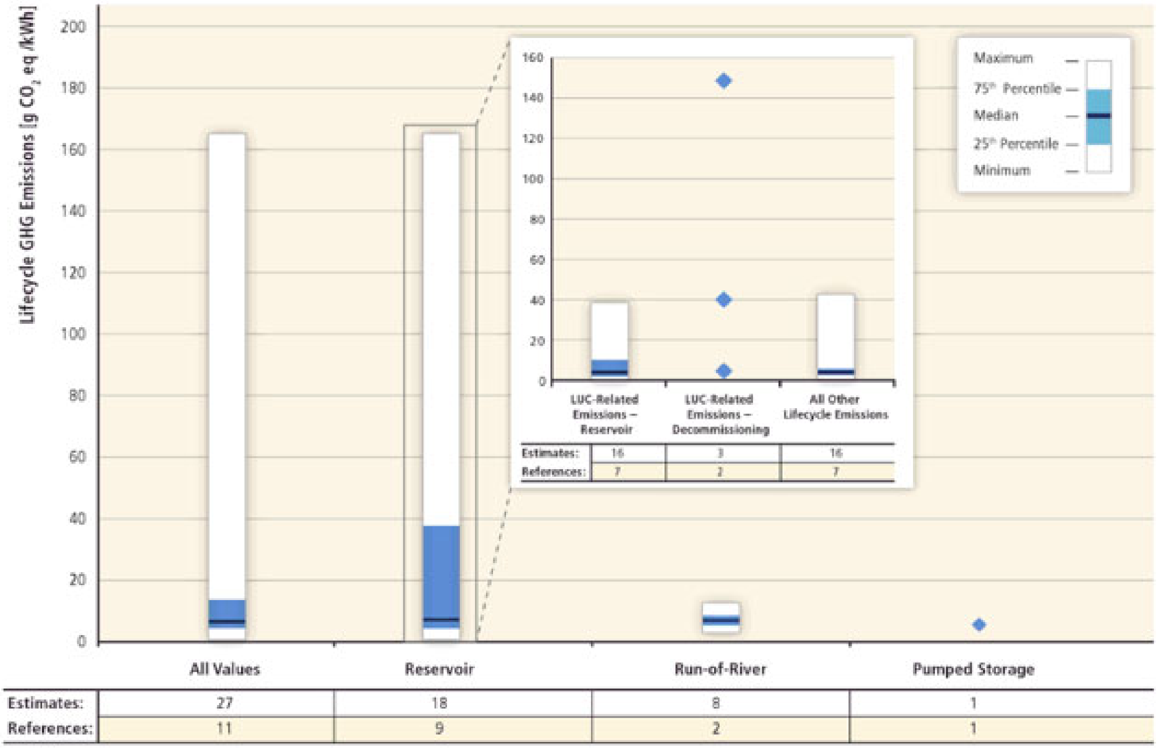
(3) European Bank for Reconstruction and Development Bank, Protocol for Assessment of Greenhouse Gas Emissions, 2010

Figure 1.1 Lifecycle Emissions from Operation of Power Generation Technologies [1]



[1] Source: World Energy Council, taken from http://www.worldenergy.org/wp-content/uploads/2012/10/PUB_Comparison_of_Energy_Systens_using_lifecycle_2004_WEC.pdf

Figure 1.2 Lifecycle GHG Emissions from Different Hydropower Technologies [(1)]



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(1) Source: Kumar, A., T. Schei, A. Ahenkorah, R. Caceres Rodriguez, J.-M. Devernay, M. Freitas, D. Hall, Å. Killingtveit, Z. Liu, 2011: Hydropower. In IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation [O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlömer, C. von Stechow (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

2. BASELINE

The baseline for GHG emissions prior to the development of the BGHES (i.e. – prior to the construction phase) is defined as zero for the purposes of this impact assessment, as it is understood that BGHES will provide additional capacity to meet energy demand rather than displacing existing grid capacity. Construction and operational activities will lead to incremental increases in GHG emissions, primarily due to the consumption of fuel and land use changes.

For context, the annual national emissions of Zimbabwe were 59.9 million tonnes of carbon dioxide equivalent ($MtCO_2e$) in 2010, whilst annual national emissions of Zambia were 396.4 million tonnes of carbon dioxide equivalent ($MtCO_2e$) in 2010. These figures represented 0.12% and 0.78% of global emissions in 2010 (global emissions amounted to 50,911 million tonnes of carbon dioxide equivalent ($MtCO_2e$) [(1)].

2.1 National GHG Inventories for Zimbabwe and Zambia

Zimbabwe submitted its Third National Communication Update Report (NC3) to the UN Framework Convention on Climate Change in 2017 [(2)]. NC3 includes information on Zimbabwe's greenhouse gas inventory for the year 2006, measures to reduce emissions (mitigation) and adaptation to climate change.

Zambia submitted its Second National Communication Update Report to the UN Framework Convention on Climate Change in 2014 [(3)]. NC2 summarises the national GHG inventory for the year 2000.

Given that the National Communication reports for Zimbabwe and Zambia only include GHG emissions data up to 2006 and 2000 (respectively), UNFCCC (United Nation Framework Convention on Climate Change) 2010 data has been used in this assessment [(4)].

Table 2.1 summarises Zimbabwe and Zambia's emissions from 1990 to 2012, compared with total global emissions. Zimbabwe and Zambia had an estimated 72.1 and 320 million tCO_2e (respectively) in 2012, excluding the emissions from land use, land use change and forestry. The countries were therefore responsible for 0.13% and 0.59% (respectively) of global emissions in 2012 and are considered to be low emitters. However, between 1990 and 2012, national emissions grew by 105% in Zimbabwe and 53% in Zambia, whilst global emissions increased by 41% over the same period.

The data available are not sufficiently detailed to show the sector emissions specifically associated with energy for Zimbabwe and Zambia.

[(1)] Source: Country information from UNFCCC (UNFCCC, 2010), data on current emissions and their share of global emissions including LULUCF from JRC/PBL (2012) (EDGAR 4.2 FT2010): http://edgar.jrc.ec.europa.eu/overview.php https://edgar.jrc.ec.europa.eu/overview.php?v=GHGts1990-2012

[(2)] Source https://unfccc.int/process-and-meetings/transparency-and-reporting/reporting-and-review-under-the-convention/national-communications-and-biennial-update-reports-non-annex-i-parties/national-communication-submissions-from-non-annex-i-parties

[(3)] Source: https://unfccc.int/process-and-meetings/transparency-and-reporting/reporting-and-review-under-the-convention/national-communications-and-biennial-update-reports-non-annex-i-parties/national-communication-submissions-from-non-annex-i-parties

[(4)] Country information from UNFCCC (UNFCCC, 2010), data on current emissions and their share of global emissions including LULUCF from JRC/PBL (2012) (EDGAR 4.2 FT2010): http://edgar.jrc.ec.europa.eu/overview.php https://edgar.jrc.ec.europa.eu/overview.php?v=GHGts1990-2012

Table 2.1 World, Zimbabwe and Zambia GHG Emissions [(1)]

		1990	2000	2010	2011	2012
World	Total Mt CO_2e, excluding LULUCF	38,232.0	40,563.0	50,911.0	53,197.0	53,937.0
Zimbabwe	Total Mt CO_2e, excluding LULUCF	35.1	51.4	71.0	71.6	72.1
	Relative to 1990 base %	-	46.5	102.3	1.309	105.3
Zambia	Total Mt CO_2e, excluding LULUCF	209.6	290.8	319.8	320.0	320.3
	Relative to 1990 base %	-	38.7	52.5	52.6	52.8

[(1)] Source: https://edgar.jrc.ec.europa.eu/overview.php?v=GHGts1990-2012&sort=asc1

3. METHODOLOGY

3.1 GHG Emissions Calculations

3.1.1 Introduction

The calculation of GHG emissions arising from the BGHES has been calculated using the design specifications provided by the design engineers for the BGHES (Studio Pietrangeli Consulting Engineers (SP)) and for a construction period of 7 years.

The carbon footprint for both the construction and operational phases have been estimated using the documents listed below:

- Greenhouse Gas (GHG) Protocol: Corporate Accounting & Reporting Standard (World Resources Institute/World Business Council for Sustainable Development [1];
- Intergovernmental Panel on Climate Change (IPCC) 2006 GHG Inventory guidelines [2];
- IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation [3];
- Green Investment Group - Green Impact Reporting Criteria [4];
- ACM0002 - Large-scale Consolidated Methodology Grid-connected electricity generation from renewable sources (v.19.0) [5];
- FAO Global Forest Resources Assessments (GFRA) [6];
- UK Government GHG Conversion Factors for Company Reporting [7];
- IFI (Interim) Dataset of Harmonized Grid Factors (v.1.016) [8]; and
- IGES List of Grid Emission Factors 2019 (v.10.4) [9]

The GHG Protocol Corporate Accounting & Reporting Standard divides emissions into three 'Scopes', which are defined as:

- **Scope 1** – direct emissions from sources owned or under the operational control of the company;
- **Scope 2** – indirect emissions from the consumption of purchased electricity; and
- **Scope 3** – indirect emissions an optional reporting category allowing for other indirect emissions associated with, but not controlled by the company.

Emission estimates for BGHES cover those which are under their direct operational control (scopes 1 & 2), with some limited coverage of indirect emissions (scope 3).

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(1) Available online at : https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf

(2) Available online at: https://www.ipcc-nggip.iges.or.jp/public/2006gl/

(3) IPCC, 2011 – Ottmar Edenhofer, Ramón Pichs-Madruga, Youba Sokona, Kristin Seyboth, Patrick Matschoss, Susanne Kadner, Timm Zwickel, Patrick Eickemeier, Gerrit Hansen, Steffen Schloemer, Christoph von Stechow (Eds.) Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1075 pp.Available from Cambridge University Press, The Edinburgh Building Shaftesbury Road, Cambridge CB2 2RU ENGLAND

(4) Available online at: http://greeninvestmentgroup.com/media/157426/gig_green_reporting_1017_02.pdf

(5) Available online at: https://cdm.unfccc.int/filestorage/5/8/I/58IAGB7SZUDEO2VN6LYM30K41HFPRQ/EB100_repan06_ACM0002.pdf?t=elJ8cHdqazN2fDBdFaeroak0uJq7GZc-_jUp

(6) Available online at: http://www.fao.org/forest-resources-assessment/en/

(7) 2018 emission factors available online at: https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2018

(8) Available online at: http://greeninvestmentgroup.com/media/185865/ifi_interim_dataset_of_harmonized_grid_factors_v1-0-with-cover.xlsx

(9) Available online at: https://pub.iges.or.jp/pub/iges-list-grid-emission-factors

Good practice dictates the use of actual activity data (e.g. litres of diesel consumed) for calculating a carbon footprint. Given that the BGHES involves an estimation of a future carbon footprint for activities yet to begin, a number of assumptions have been made in order to forecast the activity data required to undertake this GHG assessment. Calculation assumptions have been referenced within the relevant sections of this repot and are set out within the calculation spreadsheets (*Appendix A*). It should be noted that limited detail around BGHES construction and operation was available from SP at the time of this assessment. Calculations have therefore been undertaken on the basis of limited data, assumptions and experience of previous hydro-electric projects.

When assessing GHG emissions through the operational phase of BGHES, we have assumed full, normal operability.

3.1.2 Impact Assessment Methodology

A traditional impact assessment is conducted by determining how the proposed activities will affect the state of the environment described in the baseline (*Section 2*). In the case of GHG emissions, this process is complicated by the fact that the potential impact of GHG emissions on the environment cannot be quantified within a defined space and time.

As mentioned, the greenhouse effect occurs on a global basis and the specific source of GHG emissions cannot be linked directly to the future potential impact on the climate or on the BGHES geography. In the absence of such causal links, this *Section* presents a methodology that provides an appropriate and practical link between the GHG emissions of the BGHES and the impact assessment process adopted for this assessment.

The magnitude of GHG emissions from the BGHES has been compared to national and international (i.e. IFC) GHG emissions criteria [(1)].

Identifying Impact Magnitude

The magnitude of GHG emissions is defined as the tonnes of carbon dioxide equivalent (tCO_2e), emitted. GHG emissions which should be included in a GHG assessment, as stated by the GHG protocol Corporate Accounting & Reporting Standard (refer to *Section 3.1.1*), are the six greenhouse gases covered by the Kyoto Protocol. These are:

- Carbon dioxide (CO_2),
- Methane (CH_4),
- Nitrous oxide (N_2O),
- Hydrofluorocarbons (HFCs),
- Perfluorocarbons (PFCs), and;
- Sulphur hexafluoride (SF_6)

The quantity of these gases emitted must be multiplied by the gas' global warming potential (GWP) to convert this into tonnes CO_2e. *Table 3.1* shows the latest 100 year time horizon GWP's, relative to CO_2 are set out within the IPCC's Fifth Assessment Report, 2014 (AR5) [(2)].

[(1)] International Finance Corporation Performance Standard 3 – Resource Efficiency and Pollution Prevention (2012)

[(2)] IPCC's Fifth Assessment report, 2014 available online at https://www.ipcc.ch/assessment-report/ar5/

Table 3.1 Global Warming Potential Values

GHG	Fifth Assessment Report (AR5)
Carbon dioxide (CO_2)	1
Methane (CH_4)	28
Nitrous oxide (N_2O)	265
Hydrofluorocarbons (HFCs)	4 - 12,400
Perfluorocarbons (PFCs)	6,630 – 11,100
Sulphur hexafluoride (SF_6)	23,500

In the absence of national laws relating to the magnitude of GHG emissions from project developments, international standards are used to place project emissions into perspective.

Table 3.2 shows a potential magnitude scale for project-wide GHG emissions that is derived from, and in line with, reporting thresholds adopted by a number of current international lender organisations or groupings, such as the IFC Standards, the European Bank for Reconstruction and Development (EBRD) GHG assessment methodology (1) and the Equator Principles (2).

Table 3.2 Magnitude Scale for Project-Wide GHG Emissions

Project-Wide GHG Emissions / annum	Magnitude Rating
>1,000,000 tCO_2e	Very Large
100,000 – 1,000,000 tCO_2e	Large
25,000 – 100,000 tCO_2e	Medium
5,000 - 25,000 tCO_2e	Small
<5,000 tCO_2e	Negligible

The IFC's Performance Standard 3 defines a reporting threshold for annual GHG emissions of 25,000 tonnes of CO_2 equivalent (tCO_2e) and, as mentioned in *Section 1.3.3*, requires clients to "…*consider alternatives and implement technically and financially feasible and cost-effective options to reduce project-related GHG emissions during the design and operation of the project*".

An annual GHG emissions threshold of 25,000 tCO_2e has also been adopted by the EBRD within its Environmental and Social Policy (3). This updated policy reduces the GHG reporting threshold within projects that the EBRD supports from 100,000 to 25,000 tCO_2e / year and requires annual client quantification and reporting of these emissions. EBRD guidance on assessment of GHG emissions also defines a series of categories and thresholds for different project types (shown in Table 3.3). Hydroelectric power generation projects are considered likely to fall into the EBRD's 'Low' category.

(1) EBRD Methodology for Assessment of Greenhouse Gas Emissions (2010) http://www.ebrd.com/downloads/about/sustainability/ghgguide.pdf

(2) Available online at: http://www.equator-principles.com/index.php/ep3

(3) EBRD Environmental and Social Policy, 2014. Available online at: https://www.ebrd.com/downloads/research/policies/esp-final.pdf

Table 3.3 EBRD GHG Emissions Reporting Categories

GHG Emissions / annum	Magnitude Description
> 1,000,000 tCO_2e	High
100,000 – 1,000,000 tCO_2e	Medium-High
20,000 – 100,000 tCO_2e	Medium-Low
< 20,000 tCO_2e	Low
Not defined	Negligible

The Equator Principles require all projects, in all locations, to conduct an alternatives analysis to evaluate less GHG intensive alternatives when combined Scope 1 and Scope 2 operational emissions are expected to be more than 100,000 tCO_2e annually. In addition, the Equator Principles require that "*the client (should) report publicly on an annual basis on GHG emission levels (combined Scope 1 and Scope 2 emissions) during the operational phase for Projects emitting over 100,000 tonnes of CO_2 equivalent annually. Clients will be encouraged to report publicly on Projects emitting over 25,000 tonnes*."

Determining Significance

The receptor for GHG emissions is the global climate, and the natural and societal systems and infrastructure which the climate will influence.

In order to conclude whether the potential impact from GHG emissions is deemed significant or not, a risk classification approach is used. The approach is derived from classic risk assessment terminology, which involves the expression of risk as the consequence of the event multiplied by the probability of that event. The environmental assessment equivalent is the magnitude of the impact multiplied by the likelihood of the impact. Impact magnitude is a function of the potential intensity of the impact, moderated by the extent and duration of that impact. Expressed mathematically impact significance is:

Impact significance = (intensity + extent + duration) × likelihood

When considering GHGs, the extent and duration of the potential impact will always be the same. The extent is international as it is the total stock of world GHG emissions (leading to the greenhouse effect) that are directly increased due to the impact of a project. The greenhouse effect is transboundary and so global emissions and national emissions are both directly affected. The duration of the impact is regarded as permanent as the persistence of carbon dioxide in the atmosphere ranges between 100 and 300 years [(1)] and continues beyond the life of the project. Therefore, the magnitude of the potential impact is directly related to the intensity, or volume of emissions. Likelihood can be defined as 'Unlikely', 'Seldom/Occasional' or 'Likely' (see Table 3.4).

Table 3.4 Likelihood Definitions

Likelihood	Criteria
Unlikely	Reasonable to expect that the consequence will not occur at this facility during its lifetime.
Seldom/Occasional	Exceptional circumstances/conditions may allow the consequence to occur within the facility lifetime.
Likely	Consequence can reasonably be expected to occur within the life of the facility.

[(1)] Carbon Dioxide Information Analysis Centre (CDIAC) - http://cdiac.ornl.gov/pns/current_ghg.html Last accessed: 30/01/2015

The magnitude of a potential impact and the likelihood have been assessed in combination to evaluate whether a potential GHG impact is significant and if so, its degree of significance. This is illustrated in Table 3.5.

Table 3.5 GHG Impact Significance Rating

		LIKELIHOOD		
		Unlikely	**Seldom/ Occasional**	**Likely**
MAGNITUDE	**High**	**Major**	**Major**	**Major**
	Medium-High	**Moderate**	**Major**	**Major**
	Medium-Low	**Minor**	**Moderate**	**Major**
	Low	**Negligible**	**Minor**	**Minor**
	Negligible	**Negligible**	**Negligible**	**Negligible**

4. IMPACT ASSESSMENT

As discussed in *Section 3*, it is not possible to link emissions from a single source, such as the BGHES, to particular impacts in the broader study area. This study, therefore, looks at the potential impact of the BGHES on Zimbabwe and Zambia's National GHG Inventory and the likely implications of this rather than the potential physical impacts of climate change.

A full outline of data used and assumptions made is included in data supplied within the calculation spreadsheets (*Appendix A*). It should be noted that limited detail around BGHES construction and operation was available from SP at the time of this assessment. Calculations have therefore been undertaken on the basis of limited data, assumptions and experience of previous hydro-electric projects.

GHG sources associated with the construction and operation of the BGHES are listed within Table 4.1. Due to a number of factors, not all of the listed emission sources have been included within the assessment. Reasons for exclusion are also provided within Table 4.1.

Table 4.1 Emission Sources during Construction and Operation

Project Phase	Source	Included	Reason for Exclusion
Construction	Transport of materials (for the dam, access roads and transmission lines)	Yes	N/A
Construction	Transport of generation equipment	No	No data on equipment type, weight, volume, origin, mode of delivery transport, pre-assembly was available for ERM use at the time of the assessment.
Construction	On-site fuel use	Yes	N/A
Construction	Land use change of Project areas (including dam site, project townships, access roads and for transmission lines)	Yes	Land use change associated with the potential quarry sites excluded due to lack of available data and also uncertainty around whether these area(s) will be excavated.
Construction	Quarry emissions (quarrying and internal transportation)	No	Excluded due to uncertainty of the extent of the quarry areas. In addition lack of available data (e.g. quantity of aggregate required, machinery employed) meant that it was not possible to develop a proxy GHG figure for this activity.
Construction	Construction of two project townships	No	Constriction of the two project townships was excluded due to lack of available data around these activities. Land use change associated with the two project townships was included (see above).
Construction	Waste management activities	No	Given the uncertainty on exact details for waste management of the BGHES, emissions associated with BGHES construction waste is classified as scope 3 (indirect). It is understood that extracted materials (which will make up the majority of

Project Phase	Source	Included	Reason for Exclusion
			construction waste), will be diverted to form construction aggregate. As a result a significant proportion of the construction waste is reused onsite. Should any of the extracted material be sent for landfill, it is considered to be a low emitting material, so would likely have minimal GHG implications. No data was available on other construction wastes (quantity, composition, disposal route), however it is unlikely that these waste streams will be significant.
Operation	Decay of reservoir biomass (inundation)	Yes	N/A
Operation	On-site fuel use during site operation (Operations and Maintenance - vehicle movements)	Yes	N/A
Operation	Waste management activities:	No	Given the uncertainty on exact details for waste management of the BGHES, emissions associated with BGHES operational waste is classified as scope 3 (indirect). No data was available on operational wastes from BGHES or the two project townships (quantity, composition, disposal route), however it is unlikely that these waste streams will be significant. It is likely that the two project townships will not remain in the direct control of BGHES following construction. In this instance, domestic waste from the two project townships would not be part of the BGHES waste inventory.
Operation	Operation of the two project townships	No	Emissions associated with the operation of the project townships have been excluded from the assessment due available data. It is likely that the two project townships will not remain in the direct control of BGHES following construction, in which case all emissions associated with the townships will be categorised as scope 3 (indirect).
Operation	Sulphur hexafluoride (SF_6) and refrigerants, within electrical circuit	No	No data on the possible use of SF_6 within electrical circuit breakers or refrigerants within air cooling units was available and

Project Phase	Source	Included	Reason for Exclusion
	breakers/switchgear and air cooling units.		therefore potential fugitive emissions from these sources have been excluded from the assessment.

4.1 Construction Impacts

4.1.1 Transport of Materials Emissions

Emissions are associated with the transport required to deliver materials, predominantly cement, fly ash and steel to and around the BGHES construction areas. It has been assumed that the vehicles used for delivery of raw materials to and around the site will be owned and operated by BGHES and therefore sit within the scope 1 emissions category.

The base data provided by SP for undertaking the calculation estimates is shown in Table 4.2. According to SP, there will not be any aggregate transportation to the site, as it is intended that excavated material will be used as an aggregate in the concrete required for construction. If the aggregate is of insufficient quality, it is intended that alternative aggregate will be extracted from the on-site quarry. In the absence of certainty on data around the potential quarry sites, emissions associated with this activity (quarrying and transportation) have been excluded from the GHG assessment.

In the absence of data, transportation of materials associated with construction of the two project townships has been excluded from the assessment, as has emissions around transportation of generation equipment.

Table 4.2 Materials Requiring Transportation

Construction Location	Item	Volume	Unit
Dam and associated generation areas	Cement	65,143	tonnes
Dam and associated generation areas	Reinforcing Steel	8,571	tonnes
Transmission lines	Steel lattice towers	1,517	tonnes
Transmission lines	Cement	150	tonnes
Road	Construction material	67,168	tonnes

In the absence of data, a range of assumptions were made around the transportation vehicles used and distance travelled to the collection points. Based on estimated volumes (set out in Table 4.2), number of trips /total distance were calculated and the estimated tCO_2e calculated (set out in Table 4.3).

Table 4.3 Emissions Associated with Transportation of Materials

Part of Journey	Total Journeys (number)	Total Distance (km)	Conversion	Total
Full Leg	6,480	259,181	0.89125 kg CO_2e/km	231 tCO_2e
Empty (return) leg	6,480	259,181	0.67174 kg CO_2e/km	174 tCO_2e
Total				405 tCO_2e

Construction emissions associated with materials transport were estimated as an average 57.9 tonnes CO_2e per year over the construction period [(1)], equating to 405 tCO_2e over the whole construction period. On the basis of the estimations set out above, annual construction emissions associated with transport of materials therefore amount to less than 1% of Construction Activity Fuel Use Emissions.

Construction emissions associated with materials transport are classified as having a **Low** magnitude according to the EBRD GHG emission reporting categories (refer to *Table 3.3* in *Section 3.1.2*) and emissions likelihood is considered to be **Likely** (see *Table 3.4* likelihood definitions). As a result, the average annual emissions and are considered to be **Minor**, as set out within the GHG Impact Significance Rating matrix (*Table 3.5* in *Section 3.1.2*).

4.1.2 On-Site Fuel Use Emissions

There will be demand for fuel for excavation and construction machinery and on-site power generation (including power generation for the project townships). Table 4.4 shows fuel demands associated with the BGHES. The calculation is based on an estimated daily consumption of mineral diesel over a 7 day working week, provided by SP.

Table 4.4 On-Site Fuel Use for Construction Activities

Area	Item	Value	Conversion	Annual Emissions
Fuel use for excavation & construction machinery and on-site power generation	1,274,000 Mineral diesel	litres per year	2.688 kg CO2e/litre	3,424 tCO2e

Construction emissions associated with the excavation and construction machinery and on-site power generation have been estimated as 3,424 tCO_2e/year, equating to 23,970 tCO_2e over the whole construction period (7 years). On the basis of the estimations set out above, annual fuel use emissions are estimated to be less than 5% of average annual construction emissions.

Construction emissions associated with on-site fuel use are classified as having a **Low** magnitude according to the EBRD GHG emission reporting categories (refer to *Table 3.3* in *Section 3.1.2*) and emissions likelihood is considered to be **Likely** (see *Table 3.4* likelihood definitions). As a result, the average annual emissions and are considered to be **Minor**, as set out within the GHG Impact Significance Rating matrix (*Table 3.5* in *Section 3.1.2*).

4.1.3 Land Use Change Emissions

GHG emissions will result from land clearance in the areas required for construction of BGHES infrastructure and inundation following construction of the dam. GHGs resulting from clearance will be determined by the current use of the land, and how much carbon is estimated to be stored within it. The different land uses and their associated areas for BGHES are shown in Table 4.5. The area totals for each of the land use types has been calculated from data provided within the BGHES documentation or estimated, based on likely areas. It is understood that the reservoir area will not be cleared of vegetation extensively before inundation.

SP have indicated that in the first instance excavation materials from BGHES will be used as aggregate for the BGHES construction. Should this aggregate be of insufficient quality or quantity, it is understood that aggregate will be taken from the proposed quarry sites. According to SP, there is still uncertainty

[(1)] Distribution of materials transport within the construction period is unknown. In order to provide an average annual emissions figure, the total construction emissions associated with materials transport, it has been assumed that transport is spread evenly across the 7 year construction period.

on data around the potential quarry sites. As a result of this uncertainty, emissions associated with land use change across the potential quarry areas has been excluded from the calculations.

Table 4.5 Land Use Types and Total Areas of Land Use Change

Current land use	Area	Units	Existing land use	Conversion	Units
Transmission lines	0.44	ha	Wooded Grassland	165	tCO_2e/ha
Roads	178.00	ha	Wooded Grassland	165	tCO_2e/ha
Project townships	420.00	ha	Wooded Grassland	165	tCO_2e/ha
Impoundment area	2,200.00	ha	Wooded Grassland	165	tCO_2e/ha
Surface power plants, switch yards and batching areas	0.30	ha	Wooded Grassland	165	tCO_2e/ha
Total land area changed	**2,799.00**	**ha**	**Wooded Grassland**		
Converted totals	**461,835.00**	**tCO_2e**			

Construction emissions associated with the land use change have been estimated at 461,835 tCO_2e. The majority of emissions associated with land use change will occur at the time of the disturbance, which is likely to occur towards the beginning of the construction phase. In the absence of detailed information around construction schedules, land use change emissions have been spread across the 7 year construction period, equating to an estimated annual emission of 65,976 tCO_2e/year.

Whether land use change emissions occur within year 1 or split to provide an average annual emissions across the 7 year constriction period, these emissions account for 99% (emissions occurring within year 1) or 94.9% of average annual construction emissions.

Construction emissions associated with land use change are classified as having a **Medium-High** (emissions occurring within year 1) or **Medium-Low** magnitude (spread equally across the 7 year construction period) according to the EBRD GHG emission reporting categories (refer to *Table 3.3* in *Section 3.1.2*) and emissions likelihood is considered to be **Likely** (see *Table 3.4* likelihood definitions). As a result, the average annual emissions (years 1 to 7) are considered to be **Major** as set out within the GHG Impact Significance Rating matrix (*Table 3.5* in *Section 3.1.2*).

4.1.4 Impact Assessment Summary

The total expected GHG emissions for the 7 year BGHES construction period and associated GHG emission impact significance is summarised in Table 4.6.

Table 4.6 Total Expected Construction GHG Emissions

Item	Estimated annual emissions	Estimated total construction phase emissions	Magnitude Rating	Likelihood	GHG Impact Significance Rating
Transport of materials	57.90	405.1	Low	Likely	**Minor**

Item	Estimated annual emissions	Estimated total construction phase emissions	Magnitude Rating	Likelihood	GHG Impact Significance Rating
Excavation and construction activity	3,424.00	23,970	Low	Likely	**Minor**
Land use change	65,976.00 [1]	461,835	Medium-High to Medium-Low	Likely	**Major**
Total Construction	**69,459 tCO_2e**	**486,210 tCO2e**			**Major**

4.2 Operational Impacts

4.2.1 Decay of Reservoir Biomass Material

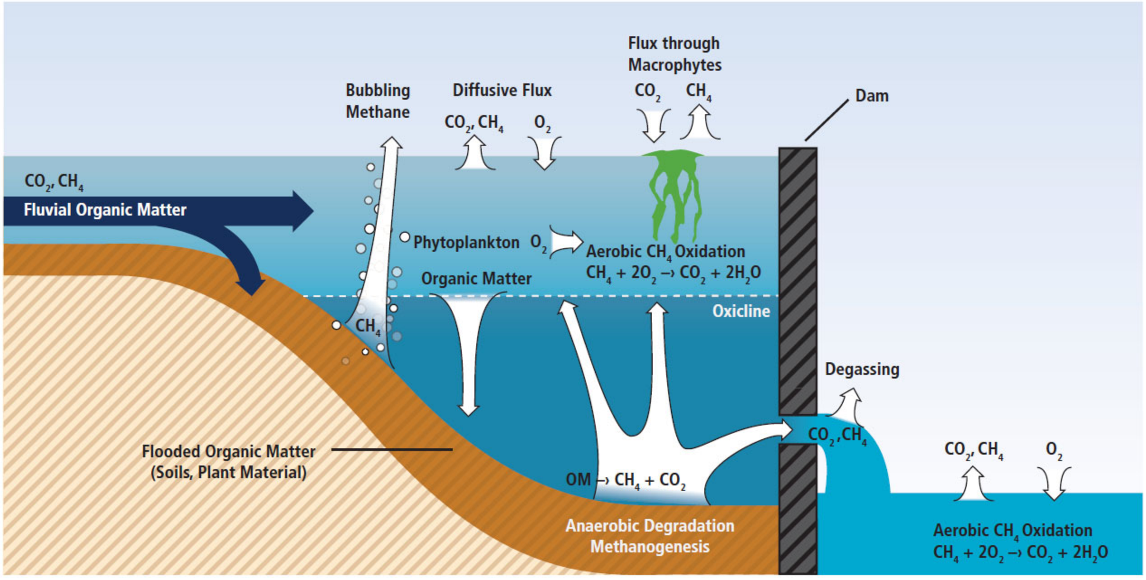
Best available research (IPCC) suggests that decay of biomass material in inundated reservoirs leads to emissions of both CO_2 and CH_4 with the main impact occurring during the first 10 years of relevant projects [2]. The IPCC has suggested an approach to calculating these emissions, which takes the total area to be inundated, the climate in which it is situated and multiplies it by estimated daily GHG emissions produced.

It should be noted that in 2017, the International Hydropower Association (IHA) and the UNESCO launched a web based tool (the GHG Reservoir (G-res) Tool) [3], to estimate and report net GHG emissions from planned and existing reservoirs.

In this instance, the IPCC approach was used because the data constraints from a proposed development allows for a high-level 'Tier-1' estimation of GHG emissions. This only accounts for the diffusive flux emissions across the air-water interface as shown in *Figure 4.1.*

[1] The majority of emissions associated with land use change will occur at the time of the disturbance, which is likely to occur towards the beginning of the construction phase. In the absence of detailed information around construction schedules, land use change emissions have been spread across the 7 year construction period.
[2] IPCC research indicates that emissions are associated with decay of organic matter in the first 10 years following inundation of a previously vegetated area. The best available research indicates that these emissions do not remain beyond this initial period. Source:http://www.ipccnggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_p_Ap2_WetlandsCO2.pdf
[3] Available online at: https://g-res.hydropower.org/

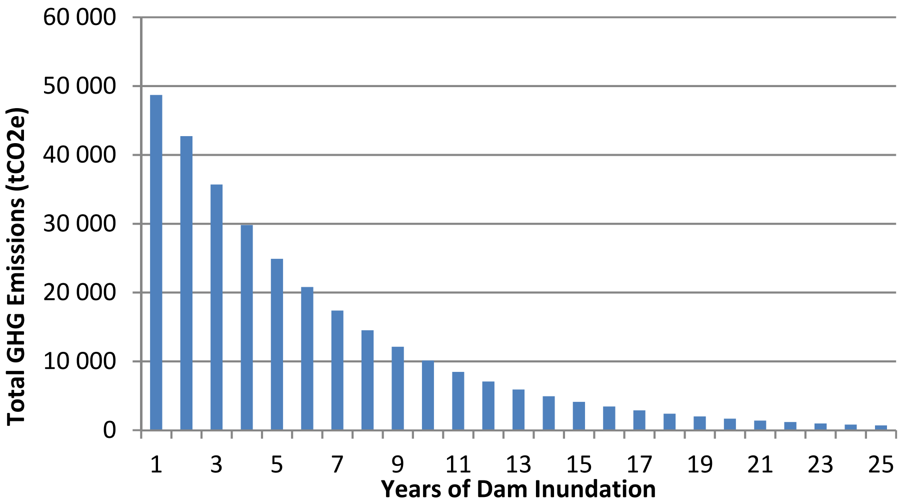
Figure 4.1 Carbon dioxide and Methane Pathways in a Freshwater Reservoir [(1)]



BGHES is expected to create an inundated area with a surface area of 2,200 ha. Inundation is expected to take approximately four months, leading to 100% inundation at the end of the four month period.

Figure 4.2 shows the estimated emissions throughout the whole 25 year period. Over 25 years, it is estimated that the total GHG emissions emitted from the decay of biomass is 304,594tCO_2e, of which 256,718 tCO_2e (84.3%) occurs during the first 10 years. This is primarily from CO_2 emissions, which account for approximately 74% of the total and 26% is from CH_4.

Figure 4.2 GHG Emissions from Decay of Biomass Material in the BGHES Reservoir



(1) Source: Figure 5.16, Chapter 5; Kumar, A., T. Schei, A. Ahenkorah, R. Caceres Rodriguez, J.-M. Devernay, M. Freitas, D. Hall, Å. Killingtveit, Z. Liu, 2011: Hydropower. In IPCC Special Report on Renewable Energy Sources and Climate Change

Research by the IHA [1] suggests that emissions will decrease in the years following full inundation, falling to 50% of peak emissions by year 8 following inundation; and less than 25% of peak emissions by Year 10 following inundation. The average annual operational emissions are equivalent to 12,184 tCO_2e over a 25 -year period. After 25 years annual operational emissions associated with decaying vegetation are approximately 2% of peak emissions and would continue to decline thereafter.

GHG emissions associated with the decay of biomass material in the BGHES reservoir over the 25 year period amounts to 304,594 tCO_2e, of which 256,718 tCO_2e (84.3%) occurs during the first 10 years.

Operational emissions associated with the decay of biomass material in the BGHES reservoir are classified as having a **Medium-Low** magnitude during the first 6 years of operation and a **Low** magnitude thereafter, according to the EBRD GHG emission reporting categories (refer to *Table 3.3* in *Section 3.1.2*) and emissions likelihood is considered to be **Likely** (see *Table 3.4* likelihood definitions). As a result, the average annual emissions and are considered to be **Major** during the first 6 years and **Minor** thereafter, as set out within the GHG Impact Significance Rating matrix (*Table 3.5* in *Section 3.1.2*).

4.2.2 BGHES Site Operation Emissions

SP were unable to provide any data around O&M (Operations and Maintenance) vehicle movements or on-site fuel consumption during the operational phase of the BGHES at the time of this assessment. As a result, vehicles emissions have been estimated based on an assumed number and length of on-site journeys, multiplied by GHG conversion factors for vehicle emissions per km. In the absence of data, it has been assumed that the O&M vehicle type is a 'van' [2]. Calculations are based on an average van [3]. A total of 75 return journeys, each covering a one-way distance of 10 km per year, (a total of 1,500 km per year) is assumed for the O&M vehicle emissions. On-site fuel consumption has been based on our experience of previous hydro-electric projects. Estimated annual operational emissions are set out in *Table 4.7.*

It is not clear whether the two project townships will remain in the direct control of BGHES following construction; however, in the absence of data, operational emissions associated with the two project townships (likely to comprise fuel and electricity consumption) has been excluded from the assessment.

Sulphur hexafluoride (SF_6) and many refrigerants, including Hydrofluorocarbons (HFCs) are potent GHG's (see *Table 3.1*). No information on the possible use SF_6 within electrical circuit breakers or refrigerants within air cooling units was available and therefore potential fugitive emissions from these sources have been excluded from the assessment.

Table 4.7 Annual Expected Emissions from Site Operations

Item	Estimated Annual Emissions (tCO_2e)
O&M vehicles	0.39
Operations activity, including machinery fuel use, on-site power generation (no imported electricity)	0.40
Total	**0.79**

Operational emissions associated with O&M vehicles and all other operational activity (excluding decay of biomass material) has been estimated as 0.79 tCO_2e/year.

[1] International Hydropower Association, 2010. 'GHG Measurement Guidelines for Freshwater Reservoirs'. Calculation Manual, pp121

[2] a van can be defined as a multipurpose, enclosed boxlike motor vehicle.

[3] Factor taken from UK Government GHG Conversion Factors for Company Reporting 2018 (version 1.01)

Construction emissions associated with site operations (excluding decay of biomass) are classified as having a **Low** magnitude according to the EBRD GHG emission reporting categories (refer to *Table 3.3* in *Section 3.1.2*) and emissions likelihood is considered to be **Likely** (see *Table 3.4* likelihood definitions). As a result, the average annual emissions and are considered to be **Minor**, as set out within the GHG Impact Significance Rating matrix (*Table 3.5* in *Section 3.1.2*).

4.2.3 Impact Assessment Summary

The GHG emission impact significance for during the operational phase of the BGHES is summarised in Table 4.7.

Table 4.7 Operational Phase Impact Rating

Operational Phase Annual Impact		Estimated annual emissions	Estimated total operational phase emissions (1)	Magnitude Rating	Likelihood	Significance
O1	Emissions associated with the decay of reservoir biomass material within the inundated area	Variable	304,594tCO_2e	Medium-Low	Likely	**Major**
O2	Emissions associated with onsite fuel or energy use (O&M transport and Operational Activity)	0.79 tCO_2e	19.75 tCO_2e	Low	Likely	**Minor**

(1) Note – this assumes a period of 25 years.

Based on the data in *Section 2.1*. Zimbabwe and Zambia emitted an estimated 72.1 and 320 million tCO_2e (respectively) in 2012, excluding the emissions from land use, land use change and forestry. The countries were therefore responsible for 0.13% and 0.59% (respectively) of global emissions in 2012, and are considered to be low emitters. However, between 1990 and 2012, national emissions grew by 105% in Zimbabwe and 53% in Zambia, whilst global emissions increased by 41% over the same period.

During the first year of operation, it is estimated that the BGHES emissions, including those from decay of biomass, will increase the national inventory of Zimbabwe (excluding LULUCF) by 0.03% and Zambia by 0.008%, based on 2012 emissions levels (assuming 50/50 split of BGHES emissions by country). It will gradually decrease down to 0.0005 and 0.0001% by year 25 (based on the assumption that BGHES emissions will split equally between the two countries).

The EBRD guidance on assessment of GHG emissions sets out that hydro-electric power generation projects are considered likely to fall into the EBRD's 'Low' category (i.e. <20,000 t CO_2e/year). In line with this assumption, the BGHES is expected to meet this criterial from year 7 of operation (refer to *Figure 4.2* in *Section 4.2.1*).

Based on the calculations undertaken through this assessment, it is identified that from year 5 of operation onwards, BGHES falls beneath the 25,000 tCO_2e significance threshold, set out within the IFC Performance Standard 3 (mirrored by EBRD's 2014 Environmental & Social Policy and the Equator Principle).

5. MITIGATION MEASURES AND RESIDUAL IMPACTS

5.1 Construction

Mitigation of GHG emissions during construction can be achieved through a series of measures that can be included within a Construction and Environment and Social Management Plan. These mitigation measures are split between the impacts, as follows and identified in *Table 5.1.*

1. **Emissions associated with transport of raw materials**:
    a. Type and quantity of raw material
    b. Distance the raw material is transported
    c. Type and efficiency of transportation vehicle
    d. Optimum working conditions for transportation vehicles
2. **Emissions associated with excavation transport**:
    a. Quantity of the subsurface material excavated
    b. Density of excavated subsurface material
3. **Emissions associated with construction activity**:
    a. Type and efficiency of construction vehicles
    b. Optimum working conditions for construction vehicles
    c. Source of on-site power generation
4. **Emissions associated with land use changes**:
    a. Current use of the land (quantity of carbon stored pre construction)

Table 5.1 Mitigation Measures

Impact		Mitigation Measures
C1	Emissions associated with transport of raw materials	■ Where possible, favour the use of raw materials that are easier to transport (lighter less volume) plus consideration for on-site assembly of parts. Where there are limited raw material options, focus should be on optimisation of transportation. ■ Reducing and / or optimising the quantities of construction material transported (dependant of the final dam design and its implementation). ■ Management of transport logistics to ensure efficient carriage of raw materials. ■ Management of voids and compaction of loads to ensure maximum safe payloads are transported. ■ Reducing vehicle idling times through focus on scheduling of construction operations. ■ Where possible, consideration for sourcing of materials from suppliers closest to the construction site. Where local suppliers are not available or their use feasible, focus should be on optimisation of transportation. ■ Prioritise the use of fuel efficient transportation vehicles and ensure regular maintenance of vehicles. ■ Consider using a less carbon intensive fuel (e.g. a biofuel blend), although this needs to be considered in the context of availability. ■ Provide efficient driving guidelines to transportation vehicle drivers, to promote fuel efficiency.
C2	Emissions associated with excavation	■ Prioritise the use of fuel efficient excavation machinery and ensure regular maintenance of machinery. ■ Provide efficient working guidelines to excavation machinery operators, to promote fuel efficiency. ■ Management of transport logistics to ensure efficient carriage of excavated materials. ■ Management of voids and compaction of loads to ensure maximum safe payloads are transported. ■ Reducing vehicle idling times through focus on scheduling of excavation operations. ■ Consider using a less carbon intensive fuel (e.g. a biofuel blend), although this needs to be considered in the context of availability.
C3	Emissions associated with construction activity	■ Prioritise the use of fuel efficient construction vehicles and ensure regular maintenance of vehicles. ■ Provide efficient working guidelines to construction vehicle drivers, to promote fuel efficiency. ■ Reducing vehicle idling times through focus on scheduling of construction operations. ■ Consider using less carbon intensive fuel (e.g. a biofuel blend), although this needs to be considered in the context of availability. ■ Ensuring that on-site power generation is designed, sized and operated for emissions performance as well as reliability. ■ Where possible, minimise the area of land clearance.

Impact		Mitigation Measures
C4	Emissions associated with land use change	■ Reduction in GHG releases through a thorough salvage of commercial timber and fuelwood. It is suggested that a timber survey be carried out to estimate the amount of commercially viable timber that could be recovered from the areas that will be cleared of vegetation during construction. It would then be possible to estimate the amount of biomass that would not release GHGs and reduce the impact from land use change emissions. It is also suggested that once an estimate of commercially viable timber is known, that markets for this are actively sought to make the proposed mitigation as commercially viable as possible. However, it is not believed that the reduction of GHG emissions from this would significantly change the conclusions of this impact assessment. ■ Productive utilisation of biomass material (wood) subsequent to land clearance. This will also serve to reduce the use of wood harvested away from the proposed inundation area for wood fuel for use by local communities, which is the current practice. ■ Consider planting/re-planting of suitable indigenous trees around the complex.

It should be noted that whilst each of these mitigation measures represents a small potential reduction in GHG, the reality of the BGHES and its location are likely to dictate whether the mitigation measures suggested are practical or feasible.

5.2 Operation

GHG emissions associated with the operation of BGHES are primarily linked to the decay of reservoir biomass material within the inundated area; however, some measures associated with on-site fuel or energy use have been identified, as set out in *Table 5.2*. An additional measure has been identified, relating to the potential use of SF6 and refrigerants during operation: Ensure management controls that minimise the potential for losses or leakage of these substances and track any emissions that occur during operation.

Table 5.2 Operational Mitigation Measures

Impact		Mitigation Measures
O1	Emissions associated with onsite fuel or energy use	■ Prioritise the use of fuel efficient on-site vehicles and ensure regular maintenance of vehicles.
O2	Emissions associated with the decay of reservoir biomass material within the inundated area	■ Reduction in GHG releases through a thorough salvage of commercial timber and fuelwood. ■ Consider planting/re-planting of suitably indigenous trees around the complex.

5.3 Residual Impacts

Table 5.3 identifies the residual impact significance ratings for both the construction and operation impacts. It should be noted that whilst improvements/reductions in GHG emissions can be achieved through identified mitigation measures, the emission sources identified cannot be completely removed from BGHES construction and operation activities, and therefore residual emissions will remain (likely falling within the identified significance category). Further in depth quantification of residual emissions would require a more detailed understanding of construction and operational activities alongside likely adoption of mitigation.

Table 5.3 Residual Impact Assessment Rating

Impact		Magnitude Rating (post-mitigation)	Likelihood	Significance (post-mitigation)
C1	Annual emissions associated with transport of raw materials	Low	Likely	**Minor**
C2/C3	Annual missions associated with excavation and construction activity	Low	Likely	**Minor**
C4	Emissions associated with land use change [(1)]	Medium-Low to Medium-High	Likely	**Major**
O1	Emissions associated with the decay of reservoir biomass material within the inundated area	Medium-Low	Likely	**Major**
O2	Emissions associated with onsite fuel or energy use (O&M transport and Operational Activity)	Low	Likely	**Minor**

Note: For further information detailing the methodological approach for the calculation of magnitude ratings refer to *Section 3*. These Tables present the magnitude scale categories for the BGHES wide GHG emissions and is in line with the EBRD GHG Emissions Reporting Categories.

[(1)] Whether considering land use change emissions occurring within year 1 of construction only or split to provide an average annual emissions across the 7 year constriction period.

APPENDIX A OVERVIEW OF EMISSION CALCULATION SHEETS

GHG Assessment of BGHES

Scope

For compatibility with the IFC standards and Equator Principles, a Greenhouse Gas (GHG) GHG emissions assessment of the BGHES Project will be carried out using established methods and principles and will:

- be carried out in conformity with the IFC Performance Standard 3 on Resource Efficiency and Pollution Prevention, and will follow internationally recognised methodologies and good practice (as provided by the IPCC, other international organisations, and any Zimbabwe/Zambia Governmental requirements);
- include a quantification of direct emissions from the construction and operation of the proposed Project, as well as any indirect emissions associated with the off-site production of energy used by the Project;
- use and present a robust, clear and defendable methodology;
- consider the magnitude of annual Project GHG emissions within the context of IFC Guidelines thresholds and Zimbabwe/Zambia's national GHG emissions;
- consider technically and financially feasible options for the reduction of GHG emissions in summary form.

Assessment Results

Construction Emissions	***Year***	*Materials Transport*	*Excavation Transport*	*Construction Activity*	*Land Use Change*	***Total***
(t CO2e)	1	57.87	0	3424	461835	465,317
	2	57.87	0	3424		3,482
	3	57.87	0	3424		3,482
	4	57.87	0	3424		3,482
	5	57.87	0	3424		3,482
	6	57.87	0	3424		3,482
	7	57.87	0	3424		3,482
Total Construction (years 1-7)		405.10	0.0	23,970	461,835	**486,210**
Total Annual emissions (equal distribution)		57.87	0.00	3,424	65,976	**69,459**
Total Annual emissions (100% LUC emissions in yr. 1)		57.87	0.00	3,424	461,835	**465,317**

Operational Emissions	***Year***	*O & M Transport*	*Operational Activity*	*Reservoir Emissions*		***Total***	
(t CO2e)	1	0.39	0.40	48,702		***48,703***	
	2	0.39	0.40	42,713		***42,714***	
	3	0.39	0.40	35,684		***35,684***	
	4	0.39	0.40	29,806		***29,807***	
	5	0.39	0.40	24,897		***24,898***	
	6	0.39	0.40	20,796		***20,796***	
	7	0.39	0.40	17,370		***17,371***	
	8	0.39	0.40	14,509		***14,509***	
	9	0.39	0.40	12,119		***12,119***	
	10	0.39	0.40	10,122		***10,123***	
	25	0.39	0.40	680		***681***	
Total years 1 to 25		9.75	10.00	304,594		***304,614***	
	%	0.00320077	0.003282841	99.99351639		100	%
Average annual emissions		0.39	0.4	12,183.8		12184.5664	

Context: Total life cycle emissions over 50 years dam lifetime

Annual generation (GWh)	10,046		
Lifetime generation (GWh)	502,300		**tCO2e per GWh (dam lifetime)**
Total construction emissions (tCO2e)		24,375	0.05
Total LUC emissions (tCO2e)		461,835	0.92
Total operational emission - excluding decay (tC		71	0.00014
Total decay emissions over 25 years (tCO2e)		304,594	0.61
Total tCO2e per GWh		2	

CONSTRUCTION ACTIVITY DATA							
Name	**Value**			**Unit**	**Fuel Type**	**Source**	**Notes**
	Year 1	Year 2	Year 3				
Construction Phase							
Materials Transport							
Dam, transmission lines and road: Aggregate	0			tonnes			Aggregate assumed to be taken from excavation volume
Dam and associated generation areas: Cement	65143			tonnes			The main bulk of cement is in the dam which has a volume 3,800,000 with a cement content of 120kg/m^3 which equates approximately to 456,000 tonnes. Assumed that this total volume will be split across the 7 year
Dam and associated generation areas: Reinforcing Steel	8571			tonnes			The current estimation for Steel is approximately 60,000 tonnes, excluding generators and other equipment. Assumed that this total volume will be split across the 7 year construction period
Transmission lines: Steel Lattice towers	1517			tonnes		Ratio of kV plus 50%	Total steel lattice towers 487 Assumed mass of steel in a single tower is 21,800kg
Transmission lines: cement (for concrete slab)	150			tonnes			*The foundation pad is constituted by a slab of reinforced concrete, located on the bottom of the trench to a depth of between 2-3m below ground level, according to the tower type. A chimney will be positioned*
Road: Construction material	67168			tonnes			TOTAL road construction material = 276,575m3 (see raw data below) Assumed that the average density of the construction material is 1700 kg/m³
Quarry: additional aggregate source	0						EXCLUDED AS QUARRY MAY NOT BE USED FOR AGGREGATE AND NO DATA AVAILABLE
Project township construction materials	0						EXCLUDED S NO DATA WAS AVAILABLE ABOUT THE PROJECT TOWNSHIPS
Project township goods deliveries	0						EXCLUDED S NO DATA WAS AVAILABLE ABOUT THE PROJECT TOWNSHIPS
Generation Equipment	0						UNKNOWN
Cons. material transport distance (one way)	40			km			No data available on source of construction materials. For the purpose of the calculations, it has been assumed that ALL materials are transported in from the nearest Township, Livingstone, located approximately 40km to the west. Distance from Livingstone to Batoka has therefore been assumed to be 80km (round trip). It should however be noted that the roads have not yet been constructed and therefore actual distance data is was not available at the time of completing these calculations.
Cons material vehicle - capacity	44			tonnes		https://www.gov.uk/government/publications/guide-to-lorry-types-and-weights	Assumed maximum (100%) load within HGV is 44 tonnes. However, capacity figure assumes 50% laden for all 'full leg' journeys, plus 0% laden for return 'empty leg' journeys). https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/211948/simplified-guide-to-lorry-types-and-weights.pdf
Cons. Material vehicle - number of journeys (full leg)	6,479.5			Number of vehicle journeys			Capacity figure assumes 50% laden for all 'full leg' NB *2 in calculation accounts for the assumption that each 'full leg' journey will be at an average 50% laden.
Cons. Material vehicle - number of journeys (empty leg)	6,479.5			Number of vehicle journeys			Number of 'emply leg' journeys assumed to match the number of 'full leg' journeys.
Cons. Material vehicle - total distance (full leg)	259,181.0			km		6,47,,,	Calculated by multiplying the estimated number of journeys by estimated length of a (one way) journey.
Cons. Material vehicle - total distance (empty leg)	259,181.0			km			Toal distance of 'empty leg' journeys assumed to match the total distance of 'full leg' journeys.
HGV Articulated (>33t) - 50% laden	0.89125			kg CO2e / km		UK Government GHG Conversion Factors for	In absence of actual data around construction logistics, it has been assumed that deliveries to the BGHES will be made by Articulated HGV (>33t) and assumed that the actual vehicle capacity will be 44 tonnes at 100% load (therefore 22 tonnes at the assumed 50% laden level).
HGV Articulated (>33t) - 0% laden	0.67174			kg CO2e / km		UK Government GHG Conversion Factors for Company Reporting 2018 (version 1.01)	
CO2e of Cons. Material vehicle - total distance (full leg)	231.0			tonnes CO2e			
CO2e of Cons. Material vehicle - total distance (empty leg)	174.1			tonnes CO2e			
Materials Transport Emissions		Breakdown of emissions over time not known					Does not allow for vehicle movements associated with construction of the project townships as NO DATA
Total construction materials transport	**405.10**			t CO2e			Does not allow for vehicle idling time which may be substantial
Assumed Annual emissions	57.9			t CO2e			Does not allow for long distance haulage of hydro generation plant or other non-bulk items
Excavation Transport							
Excavated material	0						Assumed that the excavated material will be used as aggregate within the concrete (mixed up at the batching plant). If required, additional aggregate will be sourced from the site quarry (to be confirmed). Excavated material will also be used along the transmission line and new roads.
Excavation Transport Emissions		Breakdown of emissions over time not known					
Excavation vehicles	**0**			t CO2e			
				t CO2e			
On-Site Construction Activity							
Fuel Use for construction machinery, and on-site power generation (including for project townships).	1,274,000	1,274,000	1,274,000	litres	100% mineral diesel		Information from SP "Based on information from similar project we estimate at least 3,500 litres per day". Assuming a 364 day working year (7 day working week). Assumed that this estimated consumption rate will continue across the 7 year construction period.
Diesel - 100% mineral diesel	2.69			kg CO2e/litre			UK Government GHG Conversion Factors for Company Reporting 2018 (version 1.01)
Grid electricity use	0			kWh			No connection to the grid during construction
Construction Activity Emissions							
Machinery and on-site power generation	**3,424**	**3,424**	**3,424**	t CO2e			Even if this was five times wrong, effect is not great
Grid electricity	**0**	0	0	t CO2e			
Land Use Change							
Total land area changed by transmission lines	0.44			ha			Transmission lines 487 tower pads, each 9m2 (3mx3m) Total 4,393m2
Total land area changed by roads	178			ha			Roads total 1,780,000m2 (as set out below) Main roads (including new and upgrade): 1,365,000m2 (105,000m x 13m) Staff township roads: 250,000m2 (25,000m x 10m) Service roads: 130,000m2 (26,000m x 5m) Site roads: 35,000m2 (7,000m x 5m)
Total land area changed by project townships	420			ha			North side BGHES (Zambia) - Project township estimated area 210 ha South side BGHES (Zimbabwe) - Project township estimated area unknown, therefore assumed to be 210 as per the north side.
Total land area changed by impoundment area	2200			ha			Impoundment area 22km2
Total land area changed by surface power plants, switch yards and batching areas	0.3						Data not available. Assumed to be 3,000m2
Total land area changed by quarry	0						Excluded as creation of the quarry is not certain and will depend on the quality of aggregate taken from the dam excavation area.
TOTAL land area changed by development	2799			ha		From Rachel Melbourne re Habitats Assessment - a number of land use categories are identified	
Agriculture Land	0			ha			4383
Built environment	0			ha			
Hillslope Forest	0			ha			
Riparian Forest	0			ha			
Secondary habitat	0			ha			
Water environment	0			ha			
Wooded Grassland	2799			ha			
Land Use Change Emissions							
All land use types	**461,835**			t CO2e		One-off maximum change	

OPERATION ACTIVITY DATA							
Name	**Value**			**Unit**	**Fuel Type**	**Source**	**Notes**
	Year X	Year Y	Year Z				
Annual Generation	10,046			GWh		Annual	SP data "On the base of the updated analysis carry out by SP Annual energy production is equal to 10'046 GWh/years"
Project lifetime generation	502,300			GWh		Total	
Operation Phase							
O & M Transport							
O & M transport distance	10			km		Assumed	Operational distance (average one-way journey length) is assumed to include journeys within the BGHES site boundary and not shuttling between BGHES and Livingstone/othertownships, as was the case within the Construction phase distance assumptions. Average Operational phase distances are liklely to be lower and, with no data available, it has been assumed that these will be an average of 10km.
				km			
O & M vehicle - journeys	75			journeys		Assumed	Assumed to be 75 journeys per month, based on operational data form a previous HES ESIA. 75 journeys equates to between 1 and 2 (1.44) journeys per week.
O & M vehicle total distance travelled	1500			km			Average distance (one way) multiplied by estimated number of journeys. Total multiplied by 2 to account for return journeys.
Vans Average (up to 3.5 tonnes)	0.2568			kg CO_2e/km		UK Government GHG Conversion Factors for Company Reporting 2018 (version 1.01)	O&M vehicle assumed to be a van (up to 3.5 tonnes)
O & M Transport Emissions							
O & M vehicle I	**0.39**			t CO_2e			
On-Site Operation Activity							
Fuel Use for machinery	100			litres	100% mineral diesel	Assumed	
Fuel use for on-site power generation	50			litres	100% mineral diesel	Assumed	
Grid electricity use	0					Assumed	It is understood that any electricity consumption will be taken from the BGHES generated output, which is renewable and therefore has zero associated GHG emissions.
Diesel - 100% mineral diesel	2.68779			kg CO_2e/litre		UK Government GHG Conversion Factors for Company Reporting 2018 (version 1.01)	
Operation Activity Emissions							
Machinery	**0.27**			t CO_2e			
Power generation	**0.13**			t CO_2e			
Grid electricity	**0.00**			t CO_2e			
Decay of Reservoir Biomass Material							
CO_2 emissions				tCO_2e			
CH_4 emission				tCO_2e			
Decay of reservoir biomass material	0	0	0		ALTERNATIVE CALCULATION SHEET		

The assessment of biochemically generated GHGs from the reservoir is recommended to follow a stepwise process to evaluate the supply of carbon stock and the reservoir's condition to create and release GHGs:

1. Does the reservoir have the capacity to create large carbon stock (amount of flooded organic matter, inflowing organic matter, and organic matter produced in the reservoir)? If the carbon stock is small, Global Warming Potential (GWP) is likely negligible.
2. Does the reservoir have the capacity to convert the organic matter to GHGs and, if so, to what type? If the physical conditions disfavour decomposition of organic matter, and especially do not favour creation of CH_4 and N_2O, GWP is likely negligible.
3. Does the reservoir have the capacity to release the created GHGs into the atmosphere? If the pathways of CH_4 and N_2O to the atmosphere are few and if the physical conditions favour transformation of these to CO_2 before emission, GWP is likely negligible.

In a reservoir, the flooded and inflowing carbon will thus be exported to the atmosphere, stored in the bed sediments, or transported further down the river system. These three processes occur in parallel in varying degrees, depending on the topographical, geological, and climatological conditions, and the biological configuration of the water body.

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