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BOLGATANGA-BAWKU-PULMAKOM ROAD
CLIMATE CHANGE RISK ASSESSMENT AND GHG EMISSIONS CALCULATION

RAMBØLL

BOLGATANGA-BAWKU-PULMAKOM ROAD CLIMATE CHANGE RISK ASSESSMENT AND GHG EMISSIONS CALCULATION

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

1. INTRODUCTION

1.1 Overview

This document presents the Climate Change Risk Assessment (CCRA) and Greenhouse Gas (GHG) emissions calculation for the Bolgatanga-Bawku-Pulmakom road in the north eastern part of Ghana (the Project). The GHG emissions calculation presents GHG data for the construction and operation phases of the Project. The CCRA identifies and describes potential impacts and risks to the project from climate change-related effects.

The assessment was undertaken in alignment with the applicable Project standards, which have been revised in line with the recent update to the Equator Principles:

- Equator Principles (EP) IV (July 2020);
- Organization for Economic Cooperation and Development Recommendation of the Council on Common Approaches for Officially Supported Export Credits and Environmental and Social Due Diligence (OECD Common Approaches) (April 2016);
- International Finance Corporation (IFC) Performance Standards (PSs) on Environmental and Social Sustainability (January 2012);
- World Bank Group General Environmental Health and Safety Guidelines (General EHS Guidelines) (April 2007);
- Other relevant sector-specific World Bank Group Environmental, Health and Safety Guidelines; and
- Good International Industry Practices.

1.2 Aims and Objectives

The assessment presented in this document aims to:

- Quantify Scope 1, Scope 2 and Scope 3 GHG emissions;
- Identify the potential effects of Climate Change on or from the project;
- Identify how the Project fits into the Government of Ghana commitments under the Paris Agreement;
- Outline the process the Project has or will use to optimise opportunities to reduce GHG emissions;
- Describe how the design phase considers potential effects of climate change on the Project (i.e. floods, increased temperatures, water scarcity); and
- Outline the required mitigation plans either in place or which need to be developed prior to construction.

1.3 Project Background

The Bolgatanga-Bawku-Pulmakom Road Project (the Project) is being developed to upgrade the road conditions in the Northern corridor of Ghana. The rehabilitation of the road is designed to help increase road safety, stimulate economic and social development through trade, further integrate the Upper East and the Northern regions of Ghana, and bring potential benefit to neighbouring countries. The Project is approximately 109km in length, stretching from Bolgatanga town through Bawku to Pulmakom crossing a number of towns. (Figure 1-1)

Ghana Highway Authority (GHA) will be responsible for the operation of the road. GHA contracted Delin as the designated Design Consultant / Engineer and QG Construction UK Limited (QGMI UK) as the Contractor to facilitate project finance and implement construction.

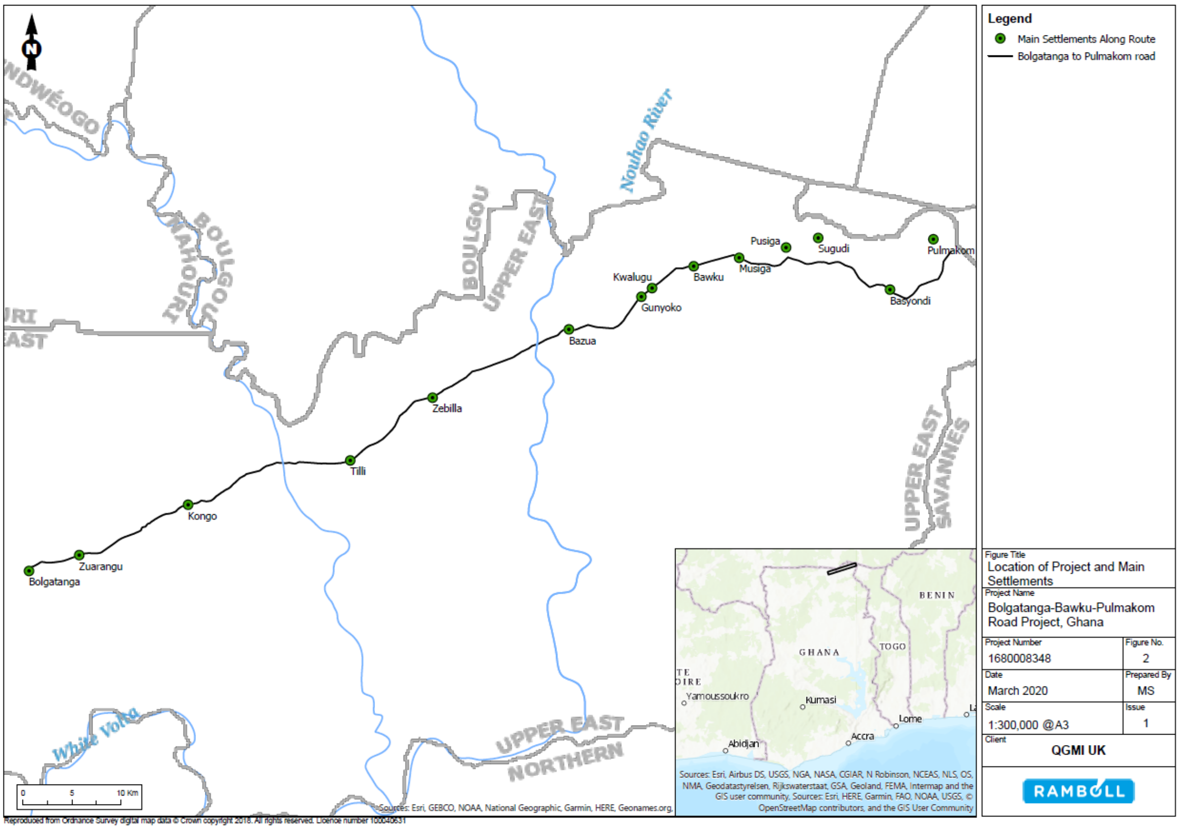

Figure 1-1: Project Location and Main Settlements

The Contractor scope of work includes the following:

- Rehabilitation/construction of those parts of the Bolgatanga-Bawku-Pulmakon;
- Insert surface dressing for the majority of the road length;
- Potential construction of a bypass to be defined at Bawku; and
- Development of three new bridges at the existing bridge locations at Zuarungu, Tilli and Zebilla. The new bridges will likely be located parallel to the existing ones.

1.4 Sources of Baseline Data

Baseline data have been collated from available secondary data sources and are presented in Table 1-1.

Table 1-1 Baseline Data Sources

Baseline Data Source	Organisation and Date	Description/Comment
Climate Data Historical for Ghana. https://climateknowledgeportal.worldbank.org/country/ghana/climate-data-historical [Accessed 08/12/2020]	World Bank Group 2020	A country-wide climate baseline is provided by the World Bank, which presents a set of 43-46- year averages, covering the period 1960-2003, and 1960- 2006 for the parameters of temperature and precipitation. This data also presents mean annual temperature and precipitation over a longer-term period of 1901-2016.

Baseline Data Source	Organisation and Date	Description/Comment
Climate Data Projections for Ghana. https://climateknowledgeportal.worldbank.org/country/ghana/climate-data-projections [Accessed 08/12/2020]	World Bank Group 2020	Future climate change trends in Ghana
The IPCC's Special Report on Climate Change and Land, What's in it for Africa? https://catalogue.unccd.int/1252_IPCC-Land_Africa_WEB_03Oct2019.pdf [Accessed 08/12/2020]	UNCCD 2019	Current climate change trends in Ghana
Climate Change Synthesis Report. https://www.ipcc.ch/site/assets/uploads/2018/02/SYR_AR5_FINAL_full.pdf [Accessed 08/12/2020]	IPCC 2014	Future climate change trends
IPCC Special Report on Climate Change and Land. https://www.ipcc.ch/srccl/ [Accessed 08/12/2020]	IPCC 2020	Future climate change trends
Ghana UNFCCC National Report (2020). https://unfccc.int/sites/default/files/resource/Gh_NC4.pdf [Accessed 08/12/2020]	UNFCCC 2020	Future climate change trends in Ghana
DEFRA Greenhouse gas reporting: conversion factors. https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2020	DEFRA 2020	DEFRA emissions factors (2020, historic emissions factors also available)
IPCC Emissions Factor Database. https://www.ipcc-nggip.iges.or.jp/EFDB/main.php	IPCC 2002-present	Library of emission factors and other parameters
ICE Database. https://circularecology.com/embodied-carbon-footprint-database.html	Circular Economy 2019	Inventory of Carbon and Energy (ICE database) provides embodied carbon data for building materials
Highways England Carbon Emissions Tool. https://www.gov.uk/government/publications/carbon-tool	Highways England	Library of emission factors related to road construction
USEPA Simplified GHG Emissions Calculator Tool https://www.epa.gov/climateleadership/center-corporate-climate-leadership-simplified-ghg-emissions-calculator [Accessed 17 December 2020]	United States Environmental Protection Agency, 2020,	Calculates emissions from road sources including older and larger vehicles.

2. CLIMATE CHANGE LEGISLATION, STANDARDS AND STRATEGIES

2.1.1 International Treaties and Conventions

Ghana has signed and ratified a number of international conventions and treaties that commit the country to reducing GHG emissions. Table 2.1 summarises the key international conventions and protocols that are relevant to the Project.

Table 2-1: Key International Treaties Applicable to the Project

Name	Date Ratified by Ghana	Objective
The United Nations Convention Framework on Climate Change (UNFCC), 1992	6 Sept 1995	The UNFCCC provides the basis for global action to protect the climate system for present and future generations. It aims to achieve stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.
The Kyoto Protocol, 1997	Accession by Ghana 30 May 2003	The Kyoto Protocol operationalises the UNFCC and commits industrialized countries and economies in transition to limit and reduce GHG emissions in accordance with agreed individual targets.
Paris Climate Agreement, 2015	22 Apr 2016	The Paris Agreement builds upon the UNFCCC and sets out efforts for all nations to combat climate change and adapt to its effects. The Paris Agreement aims to respond to the global climate change threat by keeping a global temperature rise below 2^{o}C above pre-industrial levels and to pursue efforts to limit the increase to 1.5^{o}C.

Ghana's commitments under the Paris Climate Agreement (COP21) seek to reduce greenhouse gas emissions by 15% by 2030 compared to the business-as-usual scenario.

2.1.2 Ghanaian Climate Change Legislation and Policies

Key Ghanaian national and sectoral policies prioritising climate change adaptation of relevance to this Project include:

- 2018-2021 Medium-Term Development Framework[1]
- National Climate Change Policy (2015-2020)[2]
- National Climate Change Adaptation Strategy (2010-2020)[3]
- Nationally Determined Contributions (2020-2030)[4]

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[1] Government of Ghana (2017) Medium-Term Development Framework https://s3-us-west-2.amazonaws.com/new-ndpc-static1/CACHES/PUBLICATIONS/2018/08/23/Medium-term+Policy+Framework-Final+June+2018.pdf accessed 10 December 2020

[2] Ministry of Environment, Science, Technology and Innovation (MESTI) (2013) Ghana National Climate Change Policy https://www.un-page.org/files/public/ghanaclimatechangepolicy.pdf accessed 10 December 2020

[3] UNEP/UNDP Climate Change and Development – Adapting and Reducing Vulnerability (CC DARE), National Climate Change Adaptation Strategy (2009) https://www.adaptation-undp.org/sites/default/files/downloads/ghana_national_climate_change_adaptation_strategy_nccas.pdf accessed 10 December 2020

[4] Republic of Ghana (2015) Ghana's intended nationally determined contribution (INDC) and accompanying explanatory note, http://extwprlegs1.fao.org/docs/pdf/gha187060.pdf accessed 10 December 2020

The **Medium-Term Development Framework (MTDF)** outlines strategies aligned with Ghana's commitments under the Paris Agreement. The framework identifies that road transport is the dominant mode of travel in Ghana however only 39% of roads are reported as being in 'good' condition with a significant proportion of the road network unpaved. The limited road capacity, lack of regular maintenance and poor transportation management, particularly in urban areas, are noted to result in heavy traffic congestion.

Priority actions identified within the MTDF which aim to meet Ghana's commitments under the Paris Agreement include:

- Enhancing climate change resilience at all levels and across all sectors – this includes developing climate-responsive and resilient infrastructure;
- Reduce greenhouse gases – including facilitating implementation of the National Low Carbon Growth (LCG) strategy.

With respect to road infrastructure, the MTDF aims to improve efficiency and effectiveness of road transport infrastructure and services. Inefficiencies in the road transport system are a recognised as a major constraint to growth and development, therefore the MTDF seeks capacity improvements by constructing missing links; expanding and maintaining the road network; developing a more rigorous public transport system to help alleviate congestion in urban areas; and tar roads in district capitals and areas of high agricultural production and tourism.

The **Ghana National Climate Change Policy (2013)** is an integrated response to climate change. The Policy recognises that climate change should be considered as part of wider governmental policies and sectoral activities in order to achieve sustainable growth in Ghana through low-carbon economic growth whilst ensuring a climate resilient and climate compatible economy. It has three objectives: (i) effective adaptation, (ii) social development and (iii) mitigation; and is divided into four thematic areas, which include Energy and Infrastructure. The Policy provides direction on issues relating to climate change in Ghana. The policy identifies effective adaptation as a top priority area, in addition to low carbon growth and social development objectives. Of particular relevance to the proposed project, the NCCP includes a Programme Area to build climate-resilient infrastructure. The need for investment in infrastructure to increase climate resilience and support local economic development is recognised. Key policy actions identified include climate-proofing important infrastructure that provide key services so that communities are less exposed and vulnerable during extreme events, and ensuring rural communities have reliable access to markets, key services and lifeline facilities.

The **National Climate Change Adaptation Strategy (NCCAS)** was developed to cover the period 2010-2020. Ghana's adaptation strategy sets out a framework for ensuring that adaptation is incorporated into national development efforts and increasing climate resilience and decreasing vulnerability of the population.

In 2016, Ghana identified 31 priority adaptation and mitigation actions which form the **Nationally Determined Contributions (NDC)** to the UNFCCC. The actions consist of 20 mitigation and 11 climate adaptation actions consistent with the objectives of the MTDF and the National Climate Change Policy. Priority adaptation policy actions identified include climate-resilient strategic infrastructure through city-wide resilient infrastructure planning as well as early warning and disaster prevention. The latest National Development Policy Framework (NDPF) for the period 2017-2024 affirms Ghana's commitment to the NDC under the Paris Agreement.

3. GHG EMISSIONS CALCULATION

3.1 Introduction

GHG emissions will be generated by the Project during construction and operation. During the construction phase GHG emissions sources include plant equipment, power generation and combustion sources, emissions due to land use change, and emissions related to construction materials and transport of such materials. During operation emissions sources include maintenance activities as well as emissions associated with the vehicles using the road.

Project GHG emissions, expressed as tonnes of carbon dioxide equivalent (tCO_2e), have been calculated in line with the GHG Protocol[5]. The GHG Protocol covers the accounting and reporting of seven greenhouse gases defined by the Kyoto Protocol. These are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PCFs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3). GHG emissions are estimated by multiplying activity data (e.g. fuel consumption, grid electricity used) by the corresponding emissions factor. These are then converted into CO_2 equivalents by multiplying emissions by the global warming potential factor of the specific GHG.

For reporting purposes and to avoid double counting of emissions, the GHG Protocol divides GHG emissions into three separate 'scopes':

- Scope 1 Direct GHG emissions — from sources owned or controlled by the Project e.g. from a boiler;
- Scope 2 Electricity indirect GHG emissions—GHG emissions from generation of purchased electricity by the Project; and
- Scope 3 Other indirect emissions— emissions that result from Project activities but occur from sources not owned or controlled by the Project e.g. transport of fuels or materials. Scope 3 emissions are considered an optional reporting category and can often be difficult to quantify.

In line with Equator Principles IV (EPIV), Scope 1 and Scope 2 emissions have been calculated. Scope 3 emissions have been calculated in line with UKEF requirements.

The significance thresholds identified in international guidance vary. Thresholds focus on Scope 1 and Scope 2 emissions. The IFC Performance Standards identify a significance threshold of 25,000 tCO_2e, with annual estimation of GHG emissions required for projects exceeding this threshold, whilst for the Equator Principles emissions of 100,000 tCO_2e trigger additional requirements. Publication of annual reporting is encouraged where emissions are over 25,000 tCO_2e per annum and required for projects exceeding 100,000 tCO_2e annually. The 100,000 tCO_2e threshold also triggers the need for consideration of climate transition risks, as defined under the Task Force for Climate Disclosures (TCFD), as part of the Climate Change Risk Assessment. Further details on the Climate Change Risk Assessment requirements can be found in Section 4.

3.2 GHG Emissions Calculation Methodology

The approach for undertaking the greenhouse gas assessment is set out in Figure 3-1.

3.2.1 GHG Emissions Factors

With the exception of emissions factors for use of electricity produced in Ghana, country specific GHG emissions factors do not exist for Ghana. A range of sources have therefore been consulted to identify appropriate emissions factors in relation to Scope 1 (Project fuel usage and land use

[5] World Business Council for Sustainable Development (WBCSD) and World Resources Institute (WR) (2015) GHG Protocol: A Corporate Accounting and Reporting Standard https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf

change) and Scope 3 (construction materials). Scope 3 emissions associated with future road use have been considered, including the reduction in emissions anticipated to result from reduced congestion. Whilst the number of road users and journeys made are expected to increase over the Project lifetime, this is generally related to development within Ghana rather than as a result of the Project. Specific emissions factors and methodologies used include:

- Construction materials –ICE factors, DEFRA factors
- Construction equipment fuel usage –IPCC factors, DEFRA factors
- Land use change – IFC and IPCC factors
- GHG emissions from road traffic increases expected during the operational phase – calculated using the US EPA Simplified GHG Emissions Calculator[6] (SGEC) for mobile emissions sources, which considers vehicle type, fuel and age of the vehicle fleet.

GHG emissions have been calculated following a precautionary approach. Generic emissions factors have been used in the absence of country and supplier specific factors.

[6] United States Environmental Protection Agency, 2020, Simplified GHG Emissions Calculator Tool https://www.epa.gov/climateleadership/center-corporate-climate-leadership-simplified-ghg-emissions-calculator accessed 17 December 2020

GHG Assessment

Greenhouse Gas (GHG) Assessment

Increased greenhouse gas (GHG) emissions to the atmosphere are a concern with respect to global climate change. The conventional impact assessment process that uses magnitude and sensitivity to determine impact significance is not appropriate for GHG emissions due to the difficulty in linking emissions from an individual Project to impacts on specific receptor. In addition, emissions budgets vary between nations, as agreements such as the Kyoto Protocol grant undeveloped nations more scope to increase emissions than developed nations. It is therefore not possible to set quantitative impact significance criteria based on emissions levels that would apply at an international level. Significance thresholds identified in international guidance also vary. The IFC Performance Standards identify a significance threshold of 25,000tonnes of CO_2 equivalent (tCO_2e), whilst for the Equator Principles emissions of 100,000tCO_2e trigger additional requirements.

Rather than assigning significance in the traditional way (i.e. Negligible, Minor, Moderate, or Major), for GHG assessment only an overall significance based on a threshold of 25,000 tCO_2e, as set out in the IFC's Performance Standard 3, is provided. To provide further context, quantified GHG emissions have also been compared to national GHG emissions based on the Project location.

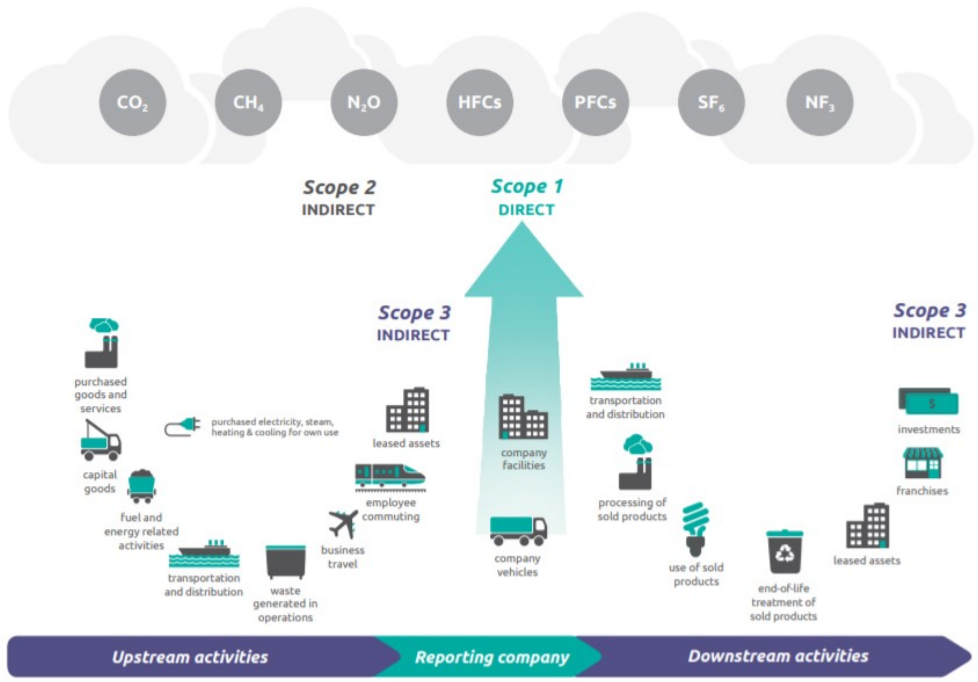
GHG Quantification

GHG emissions should be quantified following an internationally recognised methodology. The GHG Protocol: A Corporate Accounting and Reporting Standard (WBCSD & WRI, 2015) covers the accounting and reporting of seven greenhouse gases covered by the Kyoto Protocol – carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PCFs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3). GHG emissions are estimated by multiplying activity data (e.g. fuel consumption, grid electricity used) by the corresponding emissions factor. These are then converted into CO_2 equivalents by multiplying emissions by the global warming potential factor of the specific GHG.

For reporting purposes and to avoid double counting of emissions, the GHG Protocol divides GHG emissions into three separate 'scopes':

- Scope 1 Direct GHG emissions — from sources owned or controlled by the Project e.g. from a boiler;
- Scope 2 Electricity indirect GHG emissions—GHG emissions from generation of purchased electricity by the Project; and
- Scope 3 Other indirect emissions— emissions that result from Project activities, but occur from sources not owned or controlled by the Project e.g. transport of fuels or materials. Scope 3 emissions are considered an optional reporting category and can often be difficult to quantify.

In accordance with the GHG Protocol and Equator Principles, Scope 1 and Scope 2 emissions for the project are quantified and reported in the ESIA.



Source: WRI & WBCSD (2013)

Assess Significance of the Effect

The significance of GHG emissions is determined based on a threshold of 25,000 tCO_2e, as set out in the IFC's Performance Standard 3.

The significance of the Project quantified GHG emissions is also discussed in the context of the national GHG emissions based on the Project location (Ghana) taking into consideration targets set out under the Paris Climate Agreement (2015) [3]. Ghana's commitments under the Paris Climate Agreement seek to reduce GHG emissions by 15% by 2030 compared to the business-as-usual scenario. The increase in GHG emissions as a result of the Project must therefore be considered in relation to this reduced emissions target and the Nationally Determined Contributions (NDCs)[4] identified by the Republic of Ghana in order to implement the Paris Climate Agreement.

1. World Business Council for Sustainable Development (WBCSD) and World Resources Institute (WR) (2015) GHG Protocol: A Corporate Accounting and Reporting Standard https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf
2. WRI & WBCSD (2013) Technical Guidance for Calculating Scope 3 Emissions https://ghgprotocol.org/sites/default/files/standards/Scope3_Calculation_Guidance_0.pdf
3. UNFCC (2015) Paris Agreement, https://unfccc.int/sites/default/files/english_paris_agreement.pdf
4. Republic of Ghana (2015) Ghana's intended nationally determined contribution (INDC) and accompanying explanatory note https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Ghana%20First/GH_INDC_2392015.pdf

Approach to Impact Assessment

1. Review the proposed Project and quantify GHG emissions

Identify Project activities which may cause an impact

↓

Identify embedded mitigation and ESIA GIIP measures already in place

↓

Obtain GHG emissions data from Project

↓

2. Assess the impacts

Quantify Scope 1 and Scope 2 annual emissions for each phase of the Project

↓

Assess Significance of the Effect

Are the annual GHG emissions greater than 25,000 tCO_2e for any year?

- Yes → Significant
- No → Not Significant

Significant ↓

Are the annual GHG emissions greater than 100,000 tCO_2e for any year?

- Yes → Consider climate transition risks (see separate climate methodology) and evaluate lower GHG intensive alternatives
- No → Proceed to next step

3. Apply additional mitigation (if required) and asses the residual effects

Propose additional mitigation measures to mitigate adverse effects

↓

Can GHG emissions be reduced to below 25,000tCO_2e threshold?

- Yes → Residual effect is Not Significant
- No → Where residual effect remains Significant, annual quantification of Scope 1 and 2 GHG emissions in accordance with internationally recognized methodologies and good practice will be required and public reporting is encouraged. Where annual operational GHG emissions remain above 100,000 tCO_2e, Project must publicly report GHG emissions on an annual basis.

3.3 GHG Emissions Assessment

GHG emissions have been calculated from the following sources:

- Construction materials – calculated using bill of quantity data provided by contractor, and embodied carbon GHG factors;
- Construction equipment – calculated using data on plant type and use amounts provided by contractor, and energy conversion factors; and
- Land use change – calculated using data on areas of land use change and emission factors.

GHG emissions from road traffic increases expected during the operational phase (expressed as tCO2e) have been estimated in accordance with US EPA SGEC tool for mobile emissions sources.

Table 3.1 provides a summary of the GHG emissions impact assessment.

Table 3.1: GHG Impact Summary

Impact	Construction Stage Greenhouse Gas Emissions	Operation Stage Greenhouse Gas Emissions
Scope 1 Emissions: Direct	Fuel use during construction of the proposed development. Emissions associated with land use conversion – clearance of forest vegetation within RoW. **Scoped in**	Fuel use during operational maintenance activities. Comprising predominantly diesel fuel use by equipment. **Scoped in**
Scope 2 Emissions: Electricity	Grid electricity usage in buildings during construction phase. **Scoped out**	Grid electricity usage is planned for lighting during operation phase. **Scoped out**
Scope 3 Emissions: Indirect	Embodied GHG Emissions associated with construction materials and waste disposal. **Scoped in**	Change in GHG emissions associated with vehicles using the road (anticipated increased vehicle numbers and improved journey times of road users) **Scoped in**

3.4 Construction Phase GHG Emissions

The construction GHG emissions are reported in tonnes of carbon dioxide equivalent emissions (CO_2e) for the duration of the 3-year construction period. The GHG emissions have been calculated using client supplied data on anticipated fuel consumption and IPCC GHG emissions conversion factors[7].

The construction of the proposed development is anticipated to lead to land use change. A total of 100 hectares of land is expected to permanently change, excluding settlements which are not included in the GHG assessment as they are not typically a carbon sink. The majority of this area (90%) is comprised of agricultural land, with the remainder degraded forest, savanna and small areas of wetland. For the purpose of the GHG emissions calculations, the existing land uses have all been assumed to comprise annual agricultural land or high growth forest habitats. The high growth forest habitats emissions factor has been applied to degraded forests and wetlands and represent a worst-case scenario. The annual crop production factor has been applied to cropland and savanna grassland, providing a worst-case assessment as grassland typically has a lower carbon emissions conversion factor. This precautionary approach is taken due to a lack of site-

[7] IPCC 5th Assessment Report: https://www.ipcc.ch/assessment-report/ar5/

specific data on carbon intake for the land uses present. The land use change conversion has been calculated in line with the IFC PS3 Guidance Note Annex A[8].

The results of the GHG assessment are summarised in Table 3.2.

Table 3.2: Construction Greenhouse Gas Assessment Summary

Item	GHG Emissions Scope	Total estimated GHG Emissions (tCO_2e) over 3-year construction period	Estimated annual construction phase GHG Emissions (tCO_2e)
On-site emissions	1	10,561.69	3520.56
Land-use change	1	650.27	216.76
Grid electricity usage	2	446.23	148.74
Embodied GHG Emissions associated with construction materials	3	35,119.32	11706.44
GHG emissions from construction waste disposal	3	1,192.49	397.50
TOTAL SCOPE 1 & 2		**11,658.19**	**3886.06**
TOTAL SCOPE 1, 2 and 3		**47,970.00**	**15,990.00**

The total estimated Scope 1 and 2 GHG emissions are 3,886 tonnes CO_2e per annum. As Scope 1 and 2 construction GHG emissions are below 25,000 tonnes CO_2e per annum these are therefore considered *Not Significant*.

This assessment has taken a precautionary approach when calculating GHG emissions. For example, it has been assumed that all aggregate requirement will be supplied by 'new' aggregate, however it is anticipated that a proportion of this would be provided by previously excavated materials. When considering waste, it has been assumed 50% of excavated materials which may meet aggregate requirements would be disposed of to landfill, however it is understood this proportion is likely to be lower resulting in an overestimate of both Scope 3 waste and construction material GHG emissions.

The largest proportion of construction phase scope 3 emissions are associated with aggregate (natural gravel and crushed stone) followed by concrete and cement. As noted previously, emissions associated with aggregate sourcing are expected to be lower due to the potential for reuse of excavated materials during construction.

Enhancement measures could be adopted during construction to further reduce GHG emissions. As a resource efficiency measure, which would reduce Scope 3 GHG emissions, the Project should consider sourcing materials with low embodied carbon where possible; for example, steel with a high recycled content and concrete with a high percentage of cement replacement.

3.5 Operation Phase GHG Emissions

The key operational Project related emissions include:

- Emissions associated with maintenance activities (diesel usage – Scope 1, embodied carbon of materials used in maintenance works – Scope 3)

[8] IFC (2012) Guidance Note 3 Resource Efficiency and Pollution Prevention https://www.ifc.org/wps/wcm/connect/9fc3aaef-14c3-4489-acf1-a1c43d7f86ec/GN_English_2012_Full-Document_updated_June-27-2019.pdf?MOD=AJPERES&CVID=mRQmrEJ

- Grid electricity usage (Scope 2)
- Emissions from road users (Scope 3)

Traffic forecasting was developed as part of the Project feasibility report[9]. Projected traffic along the Bolgatanga-Bawku-Pulmakom Road can be considered as comprising three main traffic categories: normal traffic, diverted traffic and generated traffic. A natural increase in road usage is anticipated in line with Ghana's economic growth, this is considered to be part of the 'normal traffic' category. Diverted traffic comprises journeys which would have been made in the absence of the Project, but which would have utilised other existing routes.

When considering Scope 3 GHG emissions from road users, this assessment has focused on the increase in emissions as a result of additional traffic generated by the Project (i.e. additional journeys made which would not have been made in the absence of the Project). Based on other road projects in Ghana, the typical generated traffic is estimated to be around 25% of the base year. Scope 3 emissions have been calculated based on Project specific traffic predictions considering baseline traffic, generated traffic and diverted traffic.

This assessment has not captured the reduction in GHG emissions that can be expected to arise as a result of the decrease in traffic congestion, which would reduce emissions as a result of the 'stop-start' nature of driving in congested conditions. The assessment is therefore provided as a worst-case scenario.

3.5.1 Road Traffic Increase

Vehicle ownership increased by approximately 2.5 times between 2001 and 2011. An increase in road users is anticipated as Ghana's economy develops. Annual traffic growth assuming a low growth scenario is presented in Table 3.3.

Table 3.3: Annual Traffic Growth Rate (% pa) at Low Growth Scenario

Item	**Annual Traffic Growth Rate (%)**		
	2021-2025	**2026-2030**	**2031-2035**
Motorized 2- Wheelers	7.0	6.2	6.2
Cars	5.8	5.2	5.2
Taxi & Utilities	6.4	5.7	5.7
Buses	4.6	4.2	4.2
Trucks	6.0	5.4	5.4
Source: Delin Consult Ltd (2017)[10]			

Under high growth scenarios, traffic growth rates are approximately 2% higher in each category.

Table 3.4 to Table 3.6 present the forecasted traffic increase along the Bolgatanga-Bawku-Pulmakom Road during Year 1 of the Project operation and Year 20 of the project operation (start and end of Project operational life). The route has been divided into three main sections when considering the increase in journeys made.

[9] Delin Consult Ltd (2017) "Final Report Feasibility Studies And Design Of Bolgatanga-Bawku-Polimakom Road Project – (106Km) (Upgrading Of Northern Corridor)"

[10] Delin Consult Ltd (2017) "Final Report Feasibility Studies And Design Of Bolgatanga-Bawku-Polimakom Road Project – (106Km) (Upgrading Of Northern Corridor)"

Table 3.4: Projected Traffic Volumes Bolgatanga to Nangodi (reproduced from Delin Consult Ltd 2017)

	Bolgatanga-Nangodi (c.24km)							
	AADT-Year 1				AADT-Year 20			
Vehicle Class	**Normal traffic**	**Generated traffic**	**Diverted traffic**	**Total traffic**	**Normal traffic**	**Generated traffic**	**Diverted traffic**	**Total traffic**
Cars	127	32	1	160	491	123	4	618
Taxis	13	3	13	29	57	14	59	130
Pickups/ Vans/4Wds	208	52	1	261	804	201	5	1,010
Small Buses	104	26	1	131	297	74	3	374
Med. Buses/ Mammy Wagons	78	20	1	99	223	56	3	282
Large Buses	52	13	37	102	149	37	105	292
Light Trucks	41	10	1	53	152	38	4	193
Medium Trucks	23	6	37	65	83	21	136	240
Heavy Trucks	27	7	37	71	99	25	136	259
Semi Trailers (Light)	7	2	32	41	27	7	118	151
Semi Trailers (Heavy)	17	4	32	54	64	16	118	198
Truck Trailer	29	7	114	151	108	27	419	554
Extra Large Trucks	11	3	193	206	39	10	709	758
Total MT	738	184	500	1,422	2,593	648	1,817	5,058

Table 3.5: Projected Traffic Volumes Nangodi-Missiga-Bawku (reproduced from Delin Consult Ltd 2017)

	Nangodi-Missiga-Bawku (c.61km)							
	AADT-Year 1				AADT-Year 20			
Vehicle Class	**Normal traffic**	**Generated traffic**	**Diverted traffic**	**Total traffic**	**Normal traffic**	**Generated traffic**	**Diverted traffic**	**Total traffic**
Cars	125	31	1	157	482	120	4	606
Taxis	359	90	13	462	1,619	405	59	2,083
Pickups/ Vans/4Wds	309	77	1	387	1,194	299	5	1,498
Small Buses	126	31	1	158	359	90	3	451
Med. Buses/ Mammy Wagons	1	0	1	2	2	0	3	5
Large Buses	26	6	37	69	73	18	105	197
Light Trucks	49	12	1	62	179	45	4	227
Medium Trucks	11	3	37	51	42	10	136	188
Heavy Trucks	52	13	37	103	193	48	136	377
Semi Trailers (Light)	1	0	32	34	5	1	118	123

	Nangodi-Missiga-Bawku (c.61km)							
	AADT-Year 1				AADT-Year 20			
Vehicle Class	**Normal traffic**	**Generated traffic**	**Diverted traffic**	**Total traffic**	**Normal traffic**	**Generated traffic**	**Diverted traffic**	**Total traffic**
Semi Trailers (Heavy)	3	1	32	36	12	3	118	132
Truck Trailer	27	7	114	148	100	25	419	544
Extra Large Trucks	0	0	193	193	0	0	709	709
Total MT	1,089	272	500	1,862	4,259	1,065	1,817	7,141

Table 3.6: Projected Traffic Volumes Missiga-Pulmakom (reproduced from Delin Consult Ltd 2017)

	Missiga-Pulmakom (c.26km)							
	AADT-Year 1				AADT-Year 20			
Vehicle Class	**Normal traffic**	**Generated traffic**	**Diverted traffic**	**Total traffic**	**Normal traffic**	**Generated traffic**	**Diverted traffic**	**Total traffic**
Cars	29	7	1	37	112	28	4	144
Taxis	220	55	13	288	993	248	59	1,299
Pickups/ Vans/4Wds	98	24	1	123	377	94	5	476
Small Buses	33	8	1	42	95	24	3	121
Med. Buses/ Mammy Wagons	21	5	1	28	61	15	3	79
Large Buses	9	2	37	49	27	7	105	139
Light Trucks	20	5	1	26	69	17	4	90
Medium Trucks	7	2	37	46	24	6	136	166
Heavy Trucks	4	1	37	42	13	3	136	153
Semi Trailers (Light)	8	2	32	42	29	7	118	154
Semi Trailers (Heavy)	1	0	32	33	2	1	118	120
Truck Trailer	4	1	114	120	16	4	419	438
Extra Large Trucks	0	0	193	193	0	0	709	709
Total MT	454	114	500	1,068	1,817	454	903	3,174

The majority of vehicles in Ghana use petrol or diesel, with large buses typically operated on gas oil.[11]. Within West Africa, cars are predominantly diesel, with ratios of 74% diesel to 26% petrol found for personal cars, with a greater proportion of trucks diesel powered. Within West Africa, the age of vehicles has been found to be approximately 40% vehicles aged 0-10 years and 60% aged 10+ years.[12]. When calculating the GHG emission from the vehicle fleet, the ratio of petrol

[11] Environmental Protection Agency (2019), Ghana's Fourth National Greenhouse Gas Inventory Report, https://unfccc.int/sites/default/files/resource/gh_nir4_rev_0.pdf accessed 07 December 2020

[12] Doumbia, M., Toure, N.E., Toure, S., Yoboue, V., Diedhiou, A. and Hauhouot, C. (2018), Emissions from the Road Traffic of West African Cities: Assessment of Vehicle Fleet and Fuel Consumption, *Energies,* 11(2300), https://www.mdpi.com/1996-1073/11/9/2300/pdf accessed 17 December 2020

to diesel vehicles has been applied to cars and taxis, all other vehicles have been assumed to be diesel.

Road Traffic GHG Emissions

Table 3.7 summarises the anticipated emissions from road traffic associated with the normal traffic, generated traffic and diverted traffic. Generated traffic as a result of the Project is anticipated to account for 11% of total GHG emissions from road traffic along the Bolgatanga-Bawku-Pulmakom Road by the end of the Project lifetime.

Table 3.7: Road Traffic GHG Emissions

	GHG emissions (tCO_2e)				Project Contribution (Generated traffic %)
	Normal traffic	**Generated traffic**	**Diverted traffic**	**Total traffic**	
Year 1	43.7	**10.9**	45.7	100.3	11%
Year 20	157.8	**39.4**	165.2	362.4	11%
Average emissions	100.75	**25.15**	105.45	231.35	11%

3.5.2 Operations Phase GHG Emissions Assessment

The operational GHG emissions are reported in tonnes of CO_2e per year. The results of the GHG assessment are summarised in Table 3.7.

Table 3.8: Operational Greenhouse Gas Assessment Summary

Item	**GHG Emissions Scope**	**Estimated GHG Emissions (tCO_2e) per year**
Operational maintenance emissions	1	1000.92
Operational grid electricity emissions	2	1,625.91
Embodied carbon of operational maintenance materials	3	575.11
Scope 3 vehicle emissions [(a)]	3	39.4
TOTAL SCOPE 1 & 2		**2626.83**
TOTAL SCOPE 1, 2 and 3		**3201.94**
Note: (a) Scope 3 emissions associated with additional vehicle emissions generated due the development of the Project in Year 20 as a worst case. Including all emissions generated along the road would give a total of 1904.11tCO_2e per annum.		

3.6 Ghanaian GHG Emissions and Contributions under the Paris Climate Agreement

Ghana's Fourth National Greenhouse Gas Inventory Report[13] sets out the national GHG emission inventory and estimates for the period 1990-2016 and was presented to the UNFCC in February 2019. Ghana’s total GHG emissions were estimated at 42.2 million tCO_2e in 2016. Emissions are classified into four sectors: Agriculture, Forestry and Other Land Use (22.92 million tCO_2e), Energy (15.02 million tCO_2e), Waste (3.17 million tCO_2e) and Industrial Processes and Product

[13] Environmental Protection Agency (2019), Ghana's Fourth National Greenhouse Gas Inventory Report, https://unfccc.int/sites/default/files/resource/gh_nir4_rev_0.pdf accessed 07 December 2020

(1.04 million tCO_2e). Transportation is included as part of the Energy sector, which is second only to Agriculture, Forestry and Other Land Use in terms of emissions.

Within the transportation category, road transport was identified as the most significant emission source due to growing vehicle ownership and the associated traffic congestion in the cities. Transportation emissions increased by 7% in 2016 relative to the levels reported in 2012.

Projected transport emissions are expected to account for 44.1% of the total energy demand by 2030 under the Accelerated Economic Growth (AEG) scenario, equating to 33.2$MtCO_2e$ in 2030 of which 72.1% are expected to be generated by road transport (23.572$MtCO_2e$).

The Ghanaian economy is growing, and emissions are expected to continue to increase as the economy develops. Recent carbon-intensive economic expansion has resulted in increased emissions from road transport, thermal electricity generation, biomass utilisation for cooking, deforestation, and disposal of domestic liquid waste. Implementation of the Nationally Determined Contributions (NDC) under the Paris Agreement is intended to help to reduce emissions.

Road transport is the dominant method for both land-based freight and passenger transport in Ghana, used by over 95% of all passengers and freight traffic. Traffic congestion is on the rise in major urban areas leading to longer travel distances, increasing travel times and cost. As a result, improving the efficiency and effectiveness of road transportation infrastructure is a focus of the Medium-Term Development Framework (MTDF). Priority actions identified within the MTDF which aim to meet Ghana's commitments under the Paris Agreement include enhancing climate change resilience at all levels and across all sectors, this includes developing climate-responsive and resilient infrastructure.

This Project will help to address the NDCs through road improvements which are anticipated to reduce delays and congestion.

Emissions from vehicles travelling along the Bolgatanga-Bawku-Pulmakom Road in the absence of the Project by Year 20 (i.e. normal traffic only) are anticipated to be the equivalent of 0.000005% of the 2030 national road transport emissions. The Project operational emissions are anticipated to result in a further increase of 39.4tCO_2e per annum during operation. The emissions associated all projected road usage per year equates to 0.00002% of the 2030 national road transport emissions. This however does not reflect any decrease in emissions associated the road improvements from this Project, without which an increase in congestion would be expected to arise.

The Project has also been designed to meet future anticipated climatic conditions (see Section 4.4.2), supporting Ghana's commitment to climate resilient infrastructure as part of the NDCs.

4. CLIMATE CHANGE RISK ASSESSMENT

4.1 Introduction

Under EPIV, a Climate Change Risk Assessment is required for all Category A and higher risk Category B Projects considering climate physical risk as defined by the Task Force for Climate Disclosures (TCFD). For all projects with combined Scope 1 and Scope 2 GHG emissions of over 100,000tCO_2e annually, climate transition risks as defined under TCFD must also be considered alongside an alternatives analysis which evaluates lower Greenhouse Gas (GHG) intensive alternatives.

Climate physical risks comprise risks resulting from climate change, which involve event driven (acute e.g. increased severity of extreme weather events such as cyclones, hurricanes, or floods) or longer-term shifts (chronic) in climate patterns (e.g. sustained higher temperatures that may cause sea level rise or chronic heat waves).

Climate transition risks are those which may arise from the process of adjusting to a lower carbon economy. These include policy and legal risks (e.g. policy constraints on emissions, imposition of carbon tax, water or land use restrictions or incentives); shifts in demand and supply due to technology and market changes; and reputation risks (e.g. changing customer or community perceptions of a Project’s impact on transition to a low carbon, climate-resilient economy).

The objective of a Climate Risk Assessment is to determine:

- the current and anticipated climate risks of the Project’s operations; and
- whether the Project has adequate plans, processes, policies and systems in place to manage (mitigate, transfer, accept or control) these risks.

Assessment of physical and transition risks follows a risk assessment approach, considering the likelihood and consequence of a risk on climate sensitive receptors.

4.1.1 Climate Change Risk Assessment Methodology

The approach for undertaking the climate change risk assessment is outlined in Figure 4-1.

Climate Change Risk Assessment Methodology

Climate Change Risk Assessment

Under Equator Principles IV (2020), a Climate Change Risk Assessment is required for all Category A and higher risk Category B Projects considering climate physical risk as defined by the Task Force for Climate Disclosures (TCFD). For all projects with combined Scope 1 and Scope 2 greenhouse gas (GHG) emissions of over 100,000tCO_2e annually, climate transition risks as defined under TCFD must also be considered.

- **Climate physical risks—**risks resulting from climate change, which involve event driven (acute e.g. increased severity of extreme weather events such as cyclones, hurricanes, or floods) or longer-term shifts (chronic) in climate patterns (e.g. sustained higher temperatures that may cause sea level rise or chronic heat waves).
- **Climate transition risks—**risks which can arise from the process of adjusting to a lower carbon economy. These include: policy and legal risks (e.g. policy constraints on emissions, imposition of carbon tax, water or land use restrictions or incentives); shifts in demand and supply due to technology and market changes; reputation risks (e.g. changing customer or community perceptions of a Project's impact on transition to a low carbon, climate-resilient economy).

The objective of a Climate Risk Assessment is to determine:

- the current and anticipated climate risks of the Project's operations; and
- whether the Project has adequate plans, processes, policies and systems in place to manage (mitigate, transfer, accept or control) these risks.

Assessment of physical and transition risks follows a risk assessment approach, considering the likelihood and consequence of a risk on climate sensitive receptors.

Receptor Sensitivity

In the context of climate change, when determining receptor sensitivity consideration of receptor resilience to change (i.e. receptor susceptibility or ability to be affected by a change), vulnerability of the receptor and receptor value including importance. Vulnerability can be seen as a function of the sensitivity and adaptive capacity. Exposure to risks and hazards should also be factored into vulnerability, for example a project structure cannot be vulnerable to increased coastal erosion unless located by the sea. The climate change risk assessment then focuses on receptors considered to be of high sensitivity only.

Sensitivity	Receptor Sensitivity Definition / Examples	Project Sensitivity Definition / Examples
High	• Receptors with a high level of vulnerability, meaning they are directly dependent on climatic factors and reliant on these specific climate conditions in order to function safely.	Project receptors of high sensitivity include: • Rail infrastructure and stations—the scheme cannot function without safe, working infrastructure • Human health receptors because of the importance of their safety and welfare; and • Environmental receptors (e.g. habitats and species) because of their importance to the surrounding area.
Medium	• Receptors with a medium level of vulnerability, meaning they are dependent on some climatic factors but are able to tolerate a range of conditions.	• Project receptors of medium sensitivity have not been considered in this assessment.
Low	• Receptors with a low sensitivity, meaning that climatic factors have little influence on the receptors.	• Project receptors of low sensitivity have not been considered in this assessment.

Likelihood

The likelihood refers to the probability of a climate impact occurring during the lifespan of the proposed project development, rather than just the likelihood of a climatic change occurring.

Likelihood	Definition
Probable	The climate impact may occur multiple times during the lifetime of the proposed development (3 years for construction, 50 years for operation)
Possible	The climate impact may occur a limited number of times during the lifetime of the proposed development (3 years for construction, 50 years for operation)
Unlikely	The climate impact is not anticipated to occur during the lifetime of the proposed development (3 years for construction, 50 years for operation)

Consequence

The consequence of the impact occurring takes into account the geographical extent of the effect or the number of receptors affected (e.g. scale), the complexity of the effect, degree of harm to those affected and the duration, frequency and reversibility of effect.

Consequence	Health and Safety	Public Perception	Schedule / Disruption	Cost
Very High	Multiple fatalities	Extensive and prolonged negative reporting internationally and or public disputes with key stakeholders	Site-wide disruption lasting more than two months	>10 % of the proposed development construction value
High	Single fatality / multiple long-term injuries	Extensive and prolonged negative national reporting and/or public disputes with key stakeholders	Site-wide disruption lasting more than two month but less than 2 months	8-10 % of the proposed development construction value
Medium	Long-term injury or illness, prolonged hospitalisation or inability to work	Significant negative local and/or regional reporting	Site-wide disruption lasting more than two week but less than 1 month	4–8 % of the proposed development construction value
Low	Lost time injury or medical treatment required, short term impact on persons affected	Negative local media reports and/or localised stakeholder concern over sustained period	Partial disruption across elements of the site / proposed development lasting more than 1 day but less than 1 week	1–3 % of the proposed development construction value
Very Low	Minor harm or near miss	Short-term negative local stakeholder reaction, e.g. isolated complaints	Partial disruption across elements of the site / proposed development lasting less than a day	<1 % of the proposed development construction value

Approach to Risk Assessment

0. Scoping

Is the Project considered a Category A or high risk Category B Project?
- Yes → **Consider physical risks**
- No → Physical risk assessment not required

Do annual GHG emissions exceed 100,000tCO_2e?
- Yes → **Consider transition risks**
- No → Transition assessment not required

1. Review the proposed Project and climate change scenarios

Identify current and anticipated future climate risks / Identify current and proposed policy changes, potential technological or market shifts and reputational risks

↓

Identify Project activities on which these may cause an impact

↓

Identify embedded mitigation and ESIA GIIP measures (e.g. plans, processes, policies and systems) already in place

2. Assess the risks

Identify Sensitive Receptors

↓

For High Sensitivity Receptors:

Identify Likelihood / **Determine Consequence**

↓

Significance of Risk

		Likelihood		
		Unlikely	**Possible**	**Probable**
Consequence	**Very High**	Medium	High	High
	High	Medium	High	High
	Medium	Low	Medium	High
	Low	Low	Low	Medium
	Very Low	Low	Low	Medium

3. Apply additional mitigation (if required) and asses the residual risk

Propose additional mitigation measures to mitigate adverse effects (for High significance risks)

↓

Assess the residual risk

4.2 Climate Baseline

4.2.1 Overview

The Project stretches from Bolgatanga town through Bawku to Pulmakom in crossing a number of towns in the Upper East Region of Ghana.

4.2.2 Current Climate Baseline

Ghana's climate is tropical and strongly influenced by the West African monsoon. Climate data available for Ghana shows a mean annual temperature of 27.26˚C (1901-2016) and mean annual precipitation of 1189.93mm (1901-2016)[14].

Historic climate trends can help inform and provide context for future projections. The following trends have been observed across Ghana[14]:

- Mean annual temperature has increased by 1.0˚C, at an average of 0.21˚C per decade, since 1960.
- The rate of temperature increase has been higher in the northern regions of the country, where the proposed development is located, compared to southern areas.
- The average number of 'hot' days per year[15] increased by 4 days over the period 1960 to 2003, whilst the average number of 'cold' days[16] decreased by 12 days over the same period.
- Rainfall over Ghana was particularly high in the 1960s and decreased to particularly low levels in the late 1970s and early 1980s, producing an overall decreasing trend in the period 1960-2006, with an average decrease in precipitation of 2.3 mm per month, per decade.
- Rainfall in Ghana typically decreases from south to north.

Ghana has three hydro-climatic zones. The Volta Basin system, where the proposed development is located, has mean annual rainfall of about 1000 mm in the savanna area and about 1500 mm to 2000 mm in the forest areas. The northern area where the project is located also displays the greatest seasonal variations in temperature in Ghana, with highest temperatures in the hot, dry season (April, May, and June) typically 27-30°C.

The project is located in the northern region where drought is identified as a high hazard[17].

4.2.3 Climate Projections and Future Baseline

Climate projections consider uncertainty due to natural variability and an incomplete understanding of the climate system as well as difficulties in accurately representing climate change in models. The projections do this by giving the probabilities of a range of possible outcomes using an agreed methodology from scientific consensus.

Climate projections can be used to determine the likely future climate conditions in the locality of the proposed development through its operational life. The general climate trends for temperature in Ghana are described below, summarised by the World Bank from the Coupled Model

[14] World Bank, Ghana Climate Data, https://climateknowledgeportal.worldbank.org/country/ghana/climate-data-historical, accessed 14 September 2020

[15] 'Hot' days - are defined as the temperature above which 10% of days or nights are recorded in current climate of that region/season.

[16] 'Cold' days - are defined as the temperature below which 10% of days or nights are recorded in current climate of that region/season.

[17] Ghana's Fourth National Communication to the UNFCC (2020) https://unfccc.int/sites/default/files/resource/Gh_NC4.pdf accessed 09 December 2020

Intercomparison Project, Phase 5 (CMIP5)[18] models included in the IPCC's Fifth Assessment Report (AR5)[19].

Temperature

Generally, trends become more pronounced over time with more extreme trends arising by 2080. Climate projections for Ghana indicate:

- An increase in mean annual temperature of 1.0-3.0°C by the 2060's, and 1.5-5.2°C by the 2090's.
- The rate of warming will be most rapid in the northern inland regions of Ghana.
- Substantial increases in the frequency of hot days and nights are predicted across all projections.
- Increases in the total count of days where the daily maximum temperature rises above 40°C relative to the reference period (1986-2005).

The World Bank indicates warming in all regions of Ghana over the period 2020 – 2099, as shown in Figure 4-2 , with mean annual temperatures rising by 1.69°C (1.15°C to 2.63°C) by 2040-2059 in comparison to 1986-2005. These projections are based on an RCP (Representative Concentration Pathway) 8.5 high emission scenario, using an ensembled model. All scenarios are compared to 1986-2005 dataset. Warming of more than 1.5°C is indicated to increase the risk of aridity for Southern Africa[20].

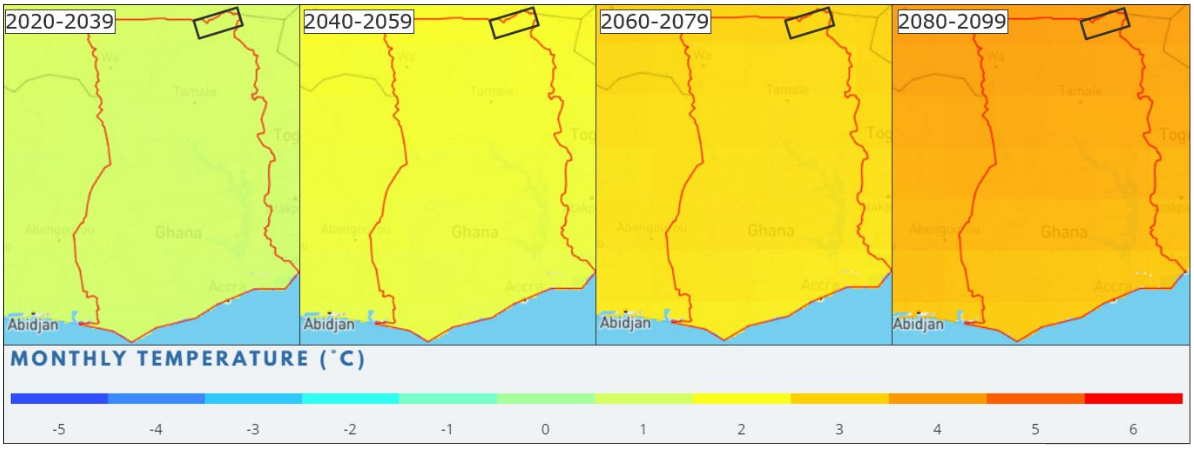


Figure 4-2 Projected Change in Monthly Temperature of Ghana for 2020-2099

Ghana's Fourth National Communication (NC) to the United Nations Framework Convention (UNFCC) on Climate Change identifies that the temperature increases are expected across all agro-ecological zones in Ghana, with the savanna regions, where the Project is located, likely to record average temperatures above 30ºC.

Precipitation

The general climate trends for precipitation in Ghana, shown in Figure 4-3, provide an overview from the World Bank's summary of projections:

- Total annual rainfall is projected to decline by 1.1%, and 20.5% in 2020 and 2080, respectively.

[18] Program for Climate Model Diagnosis & Intercomparison, https://pcmdi.llnl.gov/mips/cmip5/ accessed 23 September 2020

[19] IPCC 2014 https://www.ipcc.ch/site/assets/uploads/2018/02/SYR_AR5_FINAL_full.pdf accessed 23 September 2020

[20] Asante, F. and Amuakwa-Mensah, F. (2015), Climate Change and Variability in Ghana: Stocktaking, Climate 2015, 3(1), 78-99; https://www.mdpi.com/2225-1154/3/1/78/htm accessed 23 September 2020

- The proportion of total annual rainfall that falls in 'heavy' events will increase and there is a trend in the projections toward a decrease in January-June rainfall (dry season) and an increase in July-August rainfall (wet season).
- Projected changes in 1- and 5-day rainfall maxima tend toward increases.

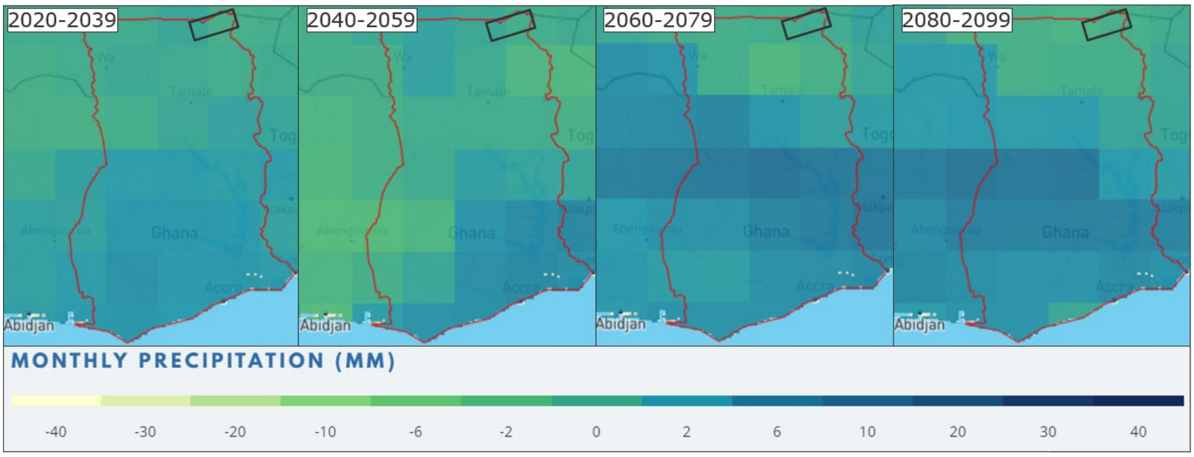


Figure 4-3 Projected Change in Monthly Precipitation of Ghana

Climate trend summary

The Project design life is 20 years, with a 3-year construction period. The project location is indicated by a black box in Figure 4-2 and Figure 4-3.

In the context of the available climate projections for Ghana and the Project design life, the climate-related trends that have the potential to cause an adverse effect on sensitive receptors during the construction and operation phases of the project are:

- Increased frequency of intense rainfall events;
- Increased frequency and intensity of droughts;
- Increase in mean annual temperature; and
- Increased frequency of hot days and heatwaves.

4.3 Receptor Sensitivity

Table 4-1 provides a summary of receptor sensitivity. In relation to climate risk, receptor sensitivity considers the vulnerability of receptors (environmental, community and health) to adapt to climatic changes as well as considering the project infrastructure itself as a receptor to climate change. In relation to Project sensitivity the assessment focuses only on the infrastructure considered of high sensitivity.

Table 4-1: Receptor Sensitivity

Sensitivity	Receptor Sensitivity	Project Sensitivity
High	**Human health receptors –** vulnerable receptors in residential areas, community / road users **Environmental receptors:** • Surface water – considered high sensitivity given potential for drought and water shortages in the region • Biodiversity - forest belt which includes the Red Volta West and Red Volta East National Forest	Project road infrastructure and associated drainage is considered to be of high sensitivity given the integrity of the infrastructure has implications for the safety of road users and potential for impacts to the Project

Sensitivity	Receptor Sensitivity	Project Sensitivity
	Reserve designations which includes habitat that could potentially support globally threatened species known from the region as a whole and elephant migration route.	should infrastructure fail / be insufficient to handle climatic conditions.
Medium	**Human health receptors –** general population and workforce are considered to be of medium sensitivity given capacity to adapt to climatic change. **Environmental receptors:** • Other biodiversity receptors and habitats able to tolerate a range of conditions.	N/A
Low	**Environmental receptors** with wider tolerance/ less affected by climatic conditions (noise, soils). Air quality (dust) is considered to be of low sensitivity as although drier climatic conditions may increase potential for dust, the area experiences naturally dry/dusty conditions particularly during Harmattan period	N/A

4.4 Climate Change Risk Assessment

4.4.1 Construction Stage Climate Change Risk Assessment

Construction activities will occur over a 3-year construction period with construction moving along the route, rather than being continuously present at all location along the entire route. The climate change projections identified focus on change between 2020 and 2099. The shortest timescale projections identified by the World Bank Group Climate Knowledge Portal focus on the period 2020-2039. Within this time period, the climate trends summarised in Section 4.2.3 will still be relevant, with extreme weather events such as heavy rainfall events, heatwaves and drought events potentially having an impact on construction activities. A precautionary approach therefore has been taken, and mitigation measures relevant to the potential changes that may occur have been identified.

For the purposes of this assessment, we have assumed that the design mitigation measures and ESIA mitigation measures will be in place and implemented. The relevant embedded deign measures and relevant additional mitigation measures are documented in Table 4-2. Given the short duration of the construction period, no additional mitigation measures beyond those identified below have been identified.

Table 4-2: Construction Stage Climate Change Risk Assessment

Climate Change Trend	Climate (change) Impact on Receptor	Existing Design and Mitigation Measures
Increased frequency of hot days and heatwaves	**Receptor:** Human health receptors Heatwaves and higher temperatures could result in site personnel welfare impacts including heat stress and unsafe working conditions.	Heat stress is identified as a risk in the OHS Management Plan. Specific measures identified within the plan include: • monitor water and hydration in order to avoid heat stress to the workers; and • Ensure that enough drinking water and that sanitary facilities are provided to the employees and subcontractors.

Climate Change Trend	Climate (change) Impact on Receptor	Existing Design and Mitigation Measures
Increased frequency of intense rainfall events	**Receptor:** Buildings and infrastructure receptors; Human health receptors Extreme rainfall could pose a safety risk and also affect the ability to undertake certain construction activities leading to programme delays and potential damage to construction materials.	The construction stormwater management plan identifies measures to avoid flooding and impacts from stormwater, specifically: • Runoff from areas without potential sources of contamination should be minimized (e.g. by minimizing the area of impermeable surfaces) and the peak discharge rate should be reduced (e.g. by using vegetated swales). The plan also identifies measures to reduce the risk of contamination of stormwater.
Increased frequency and intensity of droughts and increased frequency of hot days and heatwaves	**Receptor:** Human health receptors and environmental receptors Heatwaves and drought conditions could increase dust generated during construction activities which could affect human and environmental receptors	Ghana is a naturally dusty environment, particularly during the Harmattan period. Construction phase management plans include measures related to dust mitigation deemed sufficient to address this issue, including: • Stormwater Management Plan: During the Harmattan period, the air quality is reduced, and therefore the watering of the road is required. The watering of the ways shall be carried out and the Project shall use, when possible stored rainwater from the contractor site. • Air Quality Monitoring Procedure: Biannual monitoring of particulate matter and daily site dust inspection through the Visual Dust monitoring Checklist should be undertaken by a suitable person, trained and nominated by the HSEQSR manager. • Air Quality Monitoring Procedure: Various management actions to reduce dust generation including watering of unpaved roads, vehicle inspections, speed limits and stockpile management measures. • Air Quality Monitoring Procedure: Grievance monitoring
Increased frequency and intensity of droughts and water scarcity	**Receptor:** Infrastructure, environment and human health receptors. Increased likelihood of water scarcity could affect the ability to undertake certain construction activities leading to programme delays. Furthermore, water scarcity could lead to increased competition for water resources, which could create conflict with local water users.	Water abstraction may have impacts due to the use of finite resource. Key mitigation measures developed as part of the Water Management Plan include: • Flow monitoring- Prior to the start of water abstraction, the project will monitor the river flow to ascertain that no impact will be significant in terms of stream flow. This will support the project to ascertain the negligible impact to the water stream and determine the abstraction rate – once it has been determined the abstraction rate, this procedure will be updated. • Water abstraction monitoring - abstraction will be monthly monitored based on the total amount abstracted per month based on the permit. • Additional mitigation measures identified include measures to address and remedy any water leakages identified, and installation of water saving equipment. If any issues are observed or grievances reported water usage and the abstraction will be reviewed.

4.4.2 Operational Stage Climate Change Risk Assessment

Climate change has the potential to impact on road infrastructure in a number of ways:

- High temperatures can cause roads to develop cracks within a short period after their construction[21];
- Increased temperatures combined with increased solar radiation may also reduce the life of asphalt road surfaces[22]; and
- High intensity precipitation may also result in the development of potholes in the road surface or damage to bridge supports.

These may result in impacts on road users and the local communities. Increase temperatures may also impact on the Project workforce. A summary of the climate risk assessment for the operational stage is provided in Table 4-3.

The Project ESIA notes that the proposed road network design will incorporate various considerations aimed at adapting to climate change, in particular extreme events such as droughts and floods in the project area. Measures identified in the ESIA include:

(i) selection of appropriate type of pavement;

(ii) proper design of drainage facilities incorporating the existing natural drainage in the catchment;

(iii) proper level of road embankment; and

(iv) provision of dugouts and boreholes where appropriate.

[21] Twerefou, D.k., Chinowsky, P., Adjei-Mantey, K., and Strzepek, N.L (2015), The Economic Impact of Climate Change on Road Infrastructure in Ghana, Sustainability 2015, 7, 11949-11966; doi:10.3390/su70911949 accessed 14 December 2020

[22] Taylor, M.; Philp, M. Adapting to climate change—Implications for transport infrastructure, transport systems and travel behavior. Road Transp. Res. 2011, 19, 66–79 http://www.trendsa.org.au/sites/default/files/Taylor_Philp_2011.pdf accessed 14 December 2020

Table 4-3: Operational Stage Climate Change Risk Assessment

Climate Change Trend	Climate (change) Impact on Receptor	Existing Design and Mitigation Measures	Impact Magnitude	Additional Mitigation Required
Increased mean temperatures and frequency of heatwaves	**Receptor:** Human health receptors Heatwaves and higher temperatures could result in site personnel welfare impacts including heat stress and unsafe working conditions. Average temperatures are however only predicted to increase by approximately 1-2ºC over the project lifetime which is likely to be manageable through existing OHS practices identified.	Enshrined in the GHA's policy framework are issues regarding the protection of the environment, occupational health and safety. GHA identifies its staff as its key resource[23]. The GHA will require occupational health and safety measures be implemented as part of operational activities. The Environmental and Social Management Framework (ESMF) (2017) states that a comprehensive occupational safety and health (OSH) policy based on the tenets of the Labour Act 651, 2003 will be implemented for the transport sector. Its provisions will be extended to contractors engaged to work in the sector including hazard identification.	**Likelihood level**: Possible **Consequence level:** Low **Impact Magnitude**: Low	GHA should review its operational OHS Plans to confirm measures related to heat stress are sufficient.
Increased mean temperatures and frequency of heatwaves	**Receptor:** Infrastructure (Road Surface), human health receptors Higher temperatures and heatwaves could cause roads to deform (soften and become sticky) or crack resulting in unsafe driving conditions posing a safety.	The Project ESIA notes that the proposed road network design will incorporate selection of appropriate type of pavement. Pavements for the road have been designed in accordance with the steps in Transport Research Laboratory Road Note 31 (ORN 31)[25]. This recommends a double surface treatment, 200mm natural gravel base and 125mm natural gravel subbase.	**Likelihood level**: Possible **Consequence level:** Low **Impact Magnitude**: Low	Current project design considers a road surface which can operate in temperatures up to 55ºC which are deemed to be sufficient considering the 1-2ºC average temperature increase predicted over the lifetime of the Project. Following detailed engineering at the design stage, additives used to increase stiffness and resistance to deformation of

[23] Ghana Highways Authority (2020) Organisational Tenets http://www.highways.gov.gh/organizational-tenets accessed 16 December 2020

[25] Transport Research Laboratory (1993) A Guide to the Structural Design of Bitumen: surfaced roads in tropical and sub-tropical countries Transport Research Laboratory (TRL) Overseas Road note 31, https://webarchive.nationalarchives.gov.uk/20090609164759/http://www.transport-links.org/transport_links/publications/publications_v.asp?id=716&title=ORN31+A+GUIDE+TO+THE+STRUCTURAL+DESIGN+OF+BITUMEN+%2D+SURFACED+ROADS+IN+TROPICAL+AND+SUB%2DTROPICAL+COUNTRIES accessed 14 December 2020

Climate Change Trend	Climate (change) Impact on Receptor	Existing Design and Mitigation Measures	Impact Magnitude	Additional Mitigation Required
	There is a greater chance of cracking and other deformations if the temperature gradients are not accounted for correctly in the design.[24].	For the same number of road users, the GHA Pavement Design Manual recommends the following minimum pavement layer thickness: 50mm asphalt concrete, 200mm aggregate base and 200mm subbase. Project road surface has been designed to operate in conditions up to 55ºC.		asphalt pavements should be considered as necessary.
Increased mean temperatures and frequency of heatwaves	**Receptor:** Infrastructure (Bridges) An increase in temperature could also result in an increase in the expansion and contraction of the bridge materials causing more strain on the expansion joints.	Bridges have been designed in line with: • "Road Design Guide" (Republic of Ghana – Ministry and Highways Ghana Highway Authority); and • Design manual for roads and bridges. Volume 6 Road Geometry Section 1 Links. Part 1 TD 9/93 Amendment No 1 February 2002. Highway Link Design. Although a 1-2ºC increase in temperature may increase strain on expansion joints over the 20-year project lifetime this is unlikely to result in significant stress to impact on bridge operations.	**Likelihood level**: Possible **Consequence level:** Very Low **Impact Magnitude**: Low	No additional mitigation measures identified. As part of the final bridge design it should be confirmed that the design operating temperature is sufficient to allow for an increase of 1-2ºC in the average temperature over the lifetime of the Project.
Increased frequency of intense rainfall events	**Receptor:** Infrastructure, human health receptors Extreme rainfall could result in the overwhelming of drainage assets and culverts. This could result in secondary impacts such as localised flooding which could disrupt road operations and damage road infrastructure.	The ESIA identified proper design of drainage facilities incorporating the existing natural drainage in the catchment will be completed. According to the Project Execution Report (2017)[26], general road structures such as gullies have been designed based on a 5-year return period, road crossings based on a 10 year return period and road side drains to accommodate a 15 year return period. A rainfall intensity of 139mm/hr has been considered for a 0.2hr duration event, which is greater than	**Likelihood level**: Possible **Consequence level:** Low **Impact Magnitude**: Low	No additional mitigation measures have been identified. Design parameters allow for greater rainfall intensity than current requirements. Avoiding sediment blockages in drainage assets is key to operational efficiency. Given historical maintenance frequencies, drainage has been designed to minimise the need for

[24] World Bank (2010) Making Transport Climate Resilient County Report: Ghana http://documents1.worldbank.org/curated/en/174061467990380082/pdf/695990ESW0P102000final00120Aug02010.pdf accessed 14 December 2020

[26] Queiroz Galvao Construction (2017) Bolgatanaga-Bakwu-Pulmakon Road Project Execution Project Report

Climate Change Trend	Climate (change) Impact on Receptor	Existing Design and Mitigation Measures	Impact Magnitude	Additional Mitigation Required
		the 110mm for a 0.2hr event identified for the Navrongo region 5-year return period. Maintenance of drainage assets and culverts to clear any sediment blockages is rarely completed. Drainage channels have therefore been designed to have self-cleansing velocities at minimum flows, whilst avoiding swift and harmful high velocities leading to erosion of unlined drains.		maintenance operations to remove blockages.
Increased frequency of intense rainfall events	**Receptor:** Road infrastructure receptors, human health receptors Extreme rainfall could cause embankment failure and landslides. This could pose a safety risk and damage road infrastructure.	According to the ESIA, proper level of road embankment will be installed. Embankments will be constructed in line with design standards. The approach to the embankments has been considered as part of a review of the geotechnical design as part of the Project Execution Report. As noted in the Project Execution Report (2017)[27], variable height embankments will be required to access the new bridges. On areas of the embankments closest to the bridge abutments and on the culvert surroundings the protection will be carried out with mortared stones. The rest of the embankments need to be protected with seeding and planting. In order to avoid erosion problems in the embankments, the defined drainage for the accesses to Bridge 2 and Bridge 3, a longitudinal shoulder edge up stand will be installed which drains every 50m to a precast concrete spillway.	**Likelihood level**: Possible **Consequence level:** Low **Impact Magnitude**: Low	No additional measures identified. Rainfall intensities considered in the Project Execution Report are higher than current required design levels. Erosion protection and drainage for embankments has been considered in design.

[27] Queiroz Galvao Construction (2017) Bolgatanaga-Bakwu-Pulmakon Road Project Execution Project Report

Climate Change Trend	Climate (change) Impact on Receptor	Existing Design and Mitigation Measures	Impact Magnitude	Additional Mitigation Required
Increased frequency of intense rainfall events	**Receptor:** Infrastructure receptors (Bridges), human health receptors Extreme rainfall could cause flooding, which could damage or destabilise bridges. A World Bank report into climate resilient transport in Ghana[24] noted that an increase in precipitation causing an increase in peak flow and floods and associated scour and bank erosion is one of the main threats to bridges.	All specifications have been made to comply with the Standard Specification for Road and Bridge Works (2007) published by the Ministry of Roads and Highways, Ghana. Detailed design work for the bridges is currently ongoing, with a rerun period of 20 years currently being considered.	**Likelihood level**: Possible **Consequence level:** Medium **Impact Magnitude**: Medium	As part of the final bridge design it should be confirmed that the design flow capacity is sufficient to account for an increase in peak flows as result of climatic change.
Increased frequency of intense rainfall events	**Receptor:** Environmental and human health receptors Extreme rainfall could overwhelm drainage capacity and cause run-off, potentially spreading contamination and polluting nearby environmental receptors.	The ESIA identified proper design of drainage facilities incorporating the existing natural drainage in the catchment will be completed. GHA is responsible for the maintenance of the highway and trunk road network in Ghana. Maintenance of drainage assets and culverts to clear any sediment blockages will be key to maintaining operational capacity.	**Likelihood level**: Possible **Consequence level:** Low **Impact Magnitude**: Low	No additional mitigation measures identified

5. CONCLUSION

The GHG Assessment for Scope 1 and 2 emissions show that the Project emissions are estimated to be well below the 25,000-tonne carbon dioxide equivalent threshold for triggering assessment of alternatives or for formal reporting of the emissions.

The estimation of Scope 3 emissions has focussed on a worst-case scenario and remain well below any threshold for annual reporting.

Under EPIV the project will not trigger any requirement for transitional risks to be considered for the Climate Change Risk Assessment.

Following the climate risk assessment, medium impacts were identified for increased frequency of intense rainfall events and the implications for bridge design.

Additional mitigations have been provided to ensure these are minimised as far as practicable and reduce the residual impact magnitude to Low.

APPENDIX 1
GHG ASSESSMENT

Bolgatanga-Bawku-Pulmakom Road, Ghana: Construction Greenhouse Gas Assessment

	Item	Quantity	Unit	Carbon Factor (tCO_2e per unit)	Carbon (tCO_2e)	Carbon Factor Source	Assumptions and Limitations
	On site emissions						
Construction diesel (Scope 1)	Diesel	3,723,837	Litres	0.00269	10,009.19	DEFRA 2020[1]	Litres of diesel fuel used during the construction process covering all on-site emissions and transport (stationary and mobile combustion sources). Estimate consumption based on Horas Equipamentos Bogatanga.xlsx
	Petrol		litres		0.00		Litres of petrol fuel used during the construction process covering all on-site emissions and transport (stationary and mobile
	LPG	7	tonnes	2.93881	22.01	DEFRA 2020	Tonnes of LPG fuel used during the construction process covering all on-site emissions (stationary combustion sources). Estimate
	Lubricants	103,392	Litres	0.00059	61.00	IPPC 2006[2]	Litres of lubricants used for machinery or other purposes. Estimate consumption based on 2020 QGMI comsuption multiplied
	Grease	2,400	Litres	0.00015	0.36	IPPC 2006	Litres of oil/grease used for machinery or other purposes. Estimate consumption based on 2020 QGMI comsuption multiplied
	Acetylene	450	m3	0.00338	1.52	IPPC 2006	M3 of acetylene used for welding and other purposes. Estimate consumption based on 2020 QGMI comsuption multiplied over 3
	HFC-134a	327	kg	1.43000	467.61	DEFRA 2020	Refrigerants estimate based on consumption based on refrigerant refilling in QGMI offices / buildings
Land Conversion (Scope 1)	Land use change (forest)	10	hectares	22.72727	227.27	IFC PS Gudance Notes[3]	Forest and wetland. Assumed permanent land use change results in loss of high growth carbon sink as a worst case scenario
	Land use change (agri)	90	hectares	4.70000	423.00	IPPC 2019[4]	Cropland and savannah. Assumed annual crop production https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Volume4/19R_V4_Ch08_Settlements.pdf
				Subtotal	**11,211.96**		
	Electricity Usage						
Construciton electricity (Scope 2)	Grid Electricity	842	MWh	0.53000	446.23	Ghana Energy COmmission - Energy Statistics 2020*[5]	MWh grid electricity used in buildings during construction phase - based on grid electricity use identified in QGMI 2020 GHG calculations
				Subtotal	**446.23**		
	Materials (Embodied Carbon)						
Embodied Carbon (Scope 3)	Concrete (general)	5,594	tonnes	0.103	578.22	ICE 2019[6]	General
	Concrete (C20/25)	56,074	tonnes	0.112	6,281.61	ICE 2019	Concrete 20/25mpa
	Concrete (C20/30)	13,803	tonnes	0.119	1,642.83	ICE 2019	Concrete 25/30mpa
	Precast concrete pipe (600mm)	170	m	0.07	12.41	ICE 2019 / Highways England[7]	precast concrete pipe unreinforced
	Precast concrete pipe (900mm)	618	m	0.13	130.16	ICE 2019 / Highways England	precast concrete pipe unreinforced
	Precast concrete pipe (1200mm)	1,510	m	0.21	199.26	ICE 2019 / Highways England	precast concrete pipe unreinforced
	Precast concrete (kerbs and slabs)	8,672	tonnes	0.13	1,144.74	ICE 2019	precast concrete paving (Blocks, Slabs, Channels and Kerbs)
	Aggregates	1,683,039	tonnes	0.01	13,077.21	DEFRA 2020	
	Topsoil	1,843	tonnes	0.024	44.22	DEFRA 2020	Value for imported (if reuse no associated emissions - EF of zero)
	Steel	1,027	tonnes	2.76	2,834.52	ICE 2019	Galvanised steel
	Plastic (thermoplastics)	12	tonnes	5.70	68.40	DEFRA 2020	Sealants and adhesives: Epoxide resin
	Bitumen	3,161	tonnes	0.19	603.75	ICE 2019	Straight-run bitumen
	Bitumen emulsion	64.00	tonnes	0.22	14.21	ICE 2019	Bitumen emulsion
	Asphalt	42,500.00	m2 per 50mm depth	0.01	323.00	ICE 2019	Road surface asphalt
	WEEE	0.15	tonnes	1.76	0.26	DEFRA 2020	WEEE small (for traffic lights)
	Aluminium	71	tonnes	13.19	933.63	ICE 2019	Worldwide aluminium
	Road signs + directional signs	635	number	0.13	83.76	ICE 2019 / Highways England	Worldwide aluminium. Weight of sign taken to be 10kg based on Highways England guidance
	Concrete culvert marker beacons	158	number	0.00	0.28	ICE 2019 / Highways England	Concrete block, assumed weight 15kg
	Concrete kilometer posts	246	number	0.01	1.27	ICE 2019	Concrete block, assumed weight 50kg
Bridge materials	Concrete	4,975	tonnes	0.103	514.20	ICE 2019[6]	General
Bridge materials	Steel	1,901	tonnes	2.76	5,247.72	ICE 2019	Galvanised steel
Bridge materials	Formwork	10,885	m2	0.103	1,125.09	ICE 2019	Concrete - assume 1m thickness to give m3
	Water supply	751,680	m3	0.0003	258.58	DEFRA 2020	Water supply
				Subtotal	**35,119.32**		
	Waste						
	Demolition waste	5,188	tonnes	0.00125	6.48	DEFRA 2020	Aggregates
	Wastewater treatment	752,004	m3	0.00071	532.42	DEFRA 2020	Wastewater treatement (assumes all water and bottled potable water converts to wastewater for disposal)
	Excavation waste	523,337	tonnes	0.00125	653.60	DEFRA 2020	Concrete/Bricks
				Subtotal	**1,192.49**		
				Scope 1 & 2 Total	**11,658.19**	**over the 3 year main construction period**	
				Scope 1 & 2 Total	**3,886.06**	**Per year during construction**	

Scope 1, 2 & 3 Total	47,970.00	over the 3 year main construction period
Scope 1, 2 & 3 Total	15,990.00	Per year during construction

Construction Emissions Summary

Item	GHG Emissions Scope	Total estimated	Estimated annual construction phase
On-site emissions	1	10,561.69	**3520.56**
Land-use change	1	650.27	**216.76**
Grid electricity usage	2	446.23	**148.74**
Embodied GHG Emissions associated with construction materials	3	35,119.32	**11706.44**
GHG emissions from construction waste disposal	3	1,192.49	**397.50**
TOTAL SCOPE 1 & 2		11,658.19	**3886.06**
TOTAL SCOPE 1, 2 and 3		47,970.00	15,990.00

Bolgatanga-Bawkupulmakom Road, Ghana: Operational Greenhouse Assessment

	Item	Quantity	Unit	Carbon Factor (tCO2e per unit)	Carbon (tCO_2e)	Carbon Factor Source	Assumptions and Limitations
	Operation						
Maintenance Activities (Scope 1)	Diesel	372,384	Litres	0.00269	1000.92	DEFRA 2020	Assumed 10% construction
				Subtotal	**1,000.92**		
Operational Power supply (lighting) (Scope 2)	Electricity	3,068	Mwh	0.53000	1625.91	Ghana Energy Commission	Assumed 2100 streetlights 400MW mercury or 250MW High Pressure Sodium, estimated at 0.091-0.146MWh per lamp per hour. Assuming 10hr per day average operation = 1917.125 - 3067.75 MWh. http://darkskysociety.org/lightcost/results.php
				Subtotal	**1,625.91**		
Vehicle emissions (Scope 3)	Vehicle Emissions				39.40		See next tab for detailled assessment.
Maintenance materials (Scope 3)	Asphalt	2,125	m2 per 50mm depth	0.01	16.15	ICE 2019	Assumed 5% of construction materials for surface maintenance
	Bitumen	158	tonnes	0.19	30.19	ICE 2019	Assumed 5% of construction materials for surface maintenance
	Bitumen emulsion	3	tonnes	0.22	0.71	ICE 2019	Assumed 5% of construction materials for surface maintenance
	Concrete	3,774	tonnes	0.12	449.12	ICE 2019	Assumed 5% of construction materials for surface maintenance
	Water	37,584	m3	0.0003	12.93	DEFRA 2020	Assumed 5% of construction materials for surface maintenance
	Wastewater treatment	37,584	m3	0.00071	26.61	DEFRA 2020	Assumed 5% of construction materials for surface maintenance
				Subtotal	**575.11**		
				Scope 1 & 2 Total	**2626.83**	**Per year during operation**	
				Scope 1, 2 & 3 Total	**3201.94**	**Per year during operation**	

References

1 DEFRA 2020 emissions factors https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2020
2 IPCC Emissions Factor Database https://www.ipcc-nggip.iges.or.jp/EFDB/main.php
3 IFC (2012) Performance Standards Guidance Notes https://www.ifc.org/wps/wcm/connect/9fc3aaef-14c3-4489-acf1-a1c43d7f86ec/GN_English_2012_Full-Document_updated_June-27-2019.pdf?MOD=AJPERES&CVID=mRQmrEJ
4 IPCC (2019) 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/
5 Energy Commission (2020), Ghana National Energy Statistics - Energy Statistics 2020 http://www.energycom.gov.gh/files/ENERGY%20STATISTICS-2020.pdf
6 ICE Version 3: https://ghgprotocol.org/Third-Party-Databases/Bath-ICE
7 Highways England Carbon Emissions Tool https://www.gov.uk/government/publications/carbon-tool
IPCC 5th Assessment Report: https://www.ipcc.ch/assessment-report/ar5/

Vehicle Miles Inputs for US EPA Simplified GHG Emissions Calculator
AADT Numbers

	Bolga-Nangodi							
	AADT-Year 1				AADT-Year 20			
Vehicle Class	Normal traffic	Generated traffic	Diverted traffic	Total traffic	Normal traffic	Generated traffic	Diverted traffic	Total traffic
Cars	127	32	1	160	491	123	4	618
Taxis	13	3	13	29	57	14	59	130
Pickups/ Vans/4Wds	208	52	1	261	804	201	5	1010
Small Buses	104	26	1	131	297	74	3	374
Med. Buses/ Mammy Wagons	78	20	1	99	223	56	3	282
Large Buses	52	13	37	102	149	37	105	292
Light Trucks	41	10	1	53	152	38	4	193
Medium Trucks	23	6	37	65	83	21	136	240
Heavy Trucks	27	7	37	71	99	25	136	259
Semi Trailers (Light)	7	2	32	41	27	7	118	151
Semi Trailers (Heavy)	17	4	32	54	64	16	118	198
Truck Trailer	29	7	114	151	108	27	419	554
Extra Large Trucks	11	3	193	206	39	10	709	758
Total MT	738	184	500	1,422	2,593	648	1,817	5,058

	Missiga-Bawku							
	AADT-Year 1				AADT-Year 20			
Vehicle Class	Normal traffic	Generated traffic	Diverted traffic	Total traffic	Normal traffic	Generated traffic	Diverted traffic	Total traffic
Cars	125	31	1	157	482	120	4	606
Taxis	359	90	13	462	1619	405	59	2083
Pickups/ Vans/4Wds	309	77	1	387	1194	299	5	1498
Small Buses	126	31	1	158	359	90	3	451
Med. Buses/ Mammy Wagons	1	0	1	2	2	0	3	5
Large Buses	26	6	37	69	73	18	105	197
Light Trucks	49	12	1	62	179	45	4	227
Medium Trucks	11	3	37	51	42	10	136	188
Heavy Trucks	52	13	37	103	193	48	136	377
Semi Trailers (Light)	1	0	32	34	5	1	118	123
Semi Trailers (Heavy)	3	1	32	36	12	3	118	132
Truck Trailer	27	7	114	148	100	25	419	544
Extra Large Trucks	0	0	193	193	0	0	709	709
Total MT	1,089	272	500	1,862	4,259	1,065	1,817	7,141

	Missiga-Polmakon							
	AADT-Year 1				AADT-Year 20			
Vehicle Class	Normal traffic	Generated traffic	Diverted traffic	Total traffic	Normal traffic	Generated traffic	Diverted traffic	Total traffic
Cars	29	7	1	37	112	28	4	144
Taxis	220	55	13	288	993	248	59	1299
Pickups/ Vans/4Wds	98	24	1	123	377	94	5	476
Small Buses	33	8	1	42	95	24	3	121
Med. Buses/ Mammy Wagons	21	5	1	28	61	15	3	79
Large Buses	9	2	37	49	27	7	105	139
Light Trucks	20	5	1	26	69	17	4	90
Medium Trucks	7	2	37	46	24	6	136	166
Heavy Trucks	4	1	37	42	13	3	136	153
Semi Trailers (Light)	8	2	32	42	29	7	118	154
Semi Trailers (Heavy)	1	0	32	33	2	1	118	120
Truck Trailer	4	1	114	120	16	4	419	438
Extra Large Trucks	0	0	193	193	0	0	709	709
Total MT	454	114	500	1,068	1,817	454	903	3,174

Miles Travelled

Bolga-Nangodi							
AADT-Year 1				AADT-Year 20			
Normal traffic	Generated traffic	Diverted traffic	Total traffic	Normal traffic	Generated traffic	Diverted traffic	Total traffic
1905	480	15	2400	7365	1845	60	9270
195	45	195	435	855	210	885	1950
3120	780	15	3915	12060	3015	75	15150
1560	390	15	1965	4455	1110	45	5610
1170	300	15	1485	3345	840	45	4230
780	195	555	1530	2235	555	1575	4380
615	150	15	795	2280	570	60	2895
345	90	555	975	1245	315	2040	3600
405	105	555	1065	1485	375	2040	3885
105	30	480	615	405	105	1770	2265
255	60	480	810	960	240	1770	2970
435	105	1,710	2,265	1,620	405	6,285	8310
165	45	2895	3090	585	150	10635	11370
11055	2775	7500	21345	38895	9735	27285	75885

Missiga-Bawku							
AADT-Year 1				AADT-Year 20			
Normal traffic	Generated traffic	Diverted traffic	Total traffic	Normal traffic	Generated traffic	Diverted traffic	Total traffic
4625	1147	37	5809	17834	4440	148	22422
13283	3330	481	17,094	59903	14985	2,183	77071
11433	2849	37	14319	44178	11063	185	55426
4662	1147	37	5846	13283	3330	111	16687
37	0	37	74	74	0	111	185
962	222	1369	2553	2701	666	3885	7289
1813	444	37	2294	6623	1665	148	8399
407	111	1369	1887	1554	370	5032	6956
1924	481	1369	3811	7141	1776	5032	13949
37	0	1184	1258	185	37	4366	4551
111	37	1184	1332	444	111	4366	4884
999	259	4,218	5,476	3,700	925	15,503	20128
0	0	7141	7141	0	0	26233	26233
40293	10027	18500	68894	157620	39368	67303	264180

Missiga-Polmakon							
AADT-Year 1				AADT-Year 20			
Normal traffic	Generated traffic	Diverted traffic	Total traffic	Normal traffic	Generated traffic	Diverted traffic	Total traffic
464	112	16	592	1792	448	64	2304
3520	880	208	4,608	15888	3968	944	20784
1568	384	16	1968	6032	1504	80	7616
528	128	16	672	1520	384	48	1936
336	80	16	448	976	240	48	1264
144	32	592	784	432	112	1680	2224
320	80	16	416	1104	272	64	1440
112	32	592	736	384	96	2176	2656
64	16	592	672	208	48	2176	2448
128	32	512	672	464	112	1888	2464
16	0	512	528	32	16	1888	1920
64	16	1,824	1,920	256	64	6,704	7008
0	0	3088	3088	0	0	11344	11344
7264	1792	8000	17104	29088	7264	29104	65408
58612							

Diesel Miles

Bolga-Nangodi							
AADT-Year 1				AADT-Year 20			
Normal traffic	Generated traffic	Diverted traffic	Total traffic	Normal traffic	Generated traffic	Diverted traffic	Total traffic
1409.7	355.2	11.1	1776	5450.1	1365.3	44.4	6859.8
144.3	33.3	144.3	321.9	632.7	155.4	654.9	1443
3120	780	15	3915	12060	3015	75	15150
1560	390	15	1965	4455	1110	45	5610
1170	300	15	1485	3345	840	45	4230
780	195	555	1530	2235	555	1575	4380
615	150	15	795	2280	570	60	2895
345	90	555	975	1245	315	2040	3600
405	105	555	1065	1485	375	2040	3885
105	30	480	615	405	105	1770	2265
255	60	480	810	960	240	1770	2970
435	105	1,710	2,265	1,620	405	6,285	8310
165	45	2895	3090	585	150	10635	11370
10509	184	500	1,422	2,593	648	1,817	5,058

Missiga-Bawku							
AADT-Year 1				AADT-Year 20			
Normal traffic	Generated traffic	Diverted traffic	Total traffic	Normal traffic	Generated traffic	Diverted traffic	Total traffic
3422.5	848.78	27.38	4298.66	13197.16	3285.6	109.52	16592.28
9829.42	2464.2	355.94	12649.56	44328.22	11088.9	1615.42	57032.54
11433	2849	37	14319	44178	11063	185	55426
4662	1147	37	5846	13283	3330	111	16687
37	0	37	74	74	0	111	185
962	222	1369	2553	2701	666	3885	7289
1813	444	37	2294	6623	1665	148	8399
407	111	1369	1887	1554	370	5032	6956
1924	481	1369	3811	7141	1776	5032	13949
37	0	1184	1258	185	37	4366	4551
111	37	1184	1332	444	111	4366	4884
999	259	4,218	5,476	3,700	925	15,503	20128
0	0	7141	7141	0	0	26233	26233
35636.92	8862.98	18365.32	62939.22	137408.38	34317.5	66696.94	238311.82

Missiga-Polmakon							
AADT-Year 1				AADT-Year 20			
Normal traffic	Generated traffic	Diverted traffic	Total traffic	Normal traffic	Generated traffic	Diverted traffic	Total traffic
343.36	82.88	11.84	438.08	1326.08	331.52	47.36	1704.96
2604.8	651.2	153.92	3409.92	11757.12	2936.32	698.56	15380.16
1568	384	16	1968	6032	1504	80	7616
528	128	16	672	1520	384	48	1936
336	80	16	448	976	240	48	1264
144	32	592	784	432	112	1680	2224
320	80	16	416	1104	272	64	1440
112	32	592	736	384	96	2176	2656
64	16	592	672	208	48	2176	2448
128	32	512	672	464	112	1888	2464
16	0	512	528	32	16	1888	1920
64	16	1,824	1,920	256	64	6,704	7008
0	0	3088	3088	0	0	11344	11344
6228.16	1534.08	7941.76	15752	24491.2	6115.84	28841.92	59405.12
58612							

Petrol Miles

Bolga-Nangodi									
AADT-Year 1				AADT-Year 20					
Normal traffic	Generated traffic	Diverted traffic	Total traffic	Normal traffic	Generated traffic	Diverted traffic	Total traffic		
495.3	124.8	3.9	624	1914.9	479.7	15.6	2410.2		
50.7	11.7	50.7	113.1	222.3	54.6	230.1	507		
546	136.5	54.6	737.1	2137.2	534.3	245.7	2917.2	0	0

Missiga-Bawku							
AADT-Year 1				AADT-Year 20			
Normal traffic	Generated traffic	Diverted traffic	Total traffic	Normal traffic	Generated traffic	Diverted traffic	Total traffic
1202.5	298.22	9.62	1510.34	4636.84	1154.4	38.48	5829.72
3453.58	865.8	125.06	4444.44	15574.78	3896.1	567.58	20038.46
4656.08	1164.02	134.68	5954.78	20211.62	5050.5	606.06	25868.18

Missiga-Polmakon							
AADT-Year 1				AADT-Year 20			
Normal traffic	Generated traffic	Diverted traffic	Total traffic	Normal traffic	Generated traffic	Diverted traffic	Total traffic
120.64	29.12	4.16	153.92	465.92	116.48	16.64	599.04
915.2	228.8	54.08	1198.08	4130.88	1031.68	245.44	5403.84
1035.84	257.92	58.24	1352	4596.8	1148.16	262.08	6002.88

Total Diesel Miles Travelled across each route seciton

	Combined Diesel Miles							
	AADT-Year 1				AADT-Year 20			
	Normal traffic	Generated traffic	Diverted traffic	Total traffic	Normal traffic	Generated traffic	Diverted traffic	Total traffic
Car + Taxi	17754.08	4435.56	704.48	22894.12	76691.38	19163.04	3170.16	99012.74
Pickups/ V	16121	4013	68	20202	62270	15582	340	78192
Light duty	9498	2339	136	11988	29265	7331	476	36967
Medium d	2407	613	2584	5605	7578	1861	9452	18891
Heavy duty	4708	1186	27744	33743	17485	4364	102000	123729
Large buse	1886	449	2516	4867	5368	1333	7140	13893
	52374.08	13035.56	33752.48	99299.12	198657.38	49634.04	122578.16	370684.74

Total Petrol Miles Travelled across each route seciton

Combined Petrol Miles							
AADT-Year 1				AADT-Year 20			
Normal traffic	Generated traffic	Diverted traffic	Total traffic	Normal traffic	Generated traffic	Diverted traffic	Total traffic
6237.92	1558.44	247.52	8043.88	26945.62	6732.96	1113.84	34788.26
6237.92	1558.44	247.52	8043.88	26945.62	6732.96	1113.84	34788.26

Vehicles < 10 years old

	Combined Traffic Miles							
	AADT-Year 1				AADT-Year 20			
	Normal traffic	Generated traffic	Diverted traffic	Total traffic	Normal traffic	Generated traffic	Diverted traffic	Total traffic
Car + Taxi	2495.168	623.376	99.008	3217.552	10778.248	2693.184	445.536	13915.304
Car + Taxi	7101.632	1774.224	281.792	9157.648	30676.552	7665.216	1268.064	39605.096
Pickups/ V	6448.4	1605.2	27.2	8080.8	24908	6232.8	136	31276.8
Light duty	3799.2	935.6	54.4	4795.2	11706	2932.4	190.4	14786.8
Medium d	962.8	245.2	1033.6	2242	3031.2	744.4	3780.8	7556.4
Heavy duty	1883.2	474.4	11097.6	13497.2	6994	1745.6	40800	49491.6
Large buse	754.4	179.6	1006.4	1946.8	2147.2	533.2	2856	5557.2
	23444.8	5837.6	13600	42937.2	90241.2	22546.8	49476.8	162189.2

Vehicles 10+ years old

	Combined Traffic Miles							
	AADT-Year 1				AADT-Year 20			
	Normal traffic	Generated traffic	Diverted traffic	Total traffic	Normal traffic	Generated traffic	Diverted traffic	Total traffic
Car + Taxi	3742.752	935.064	148.512	4826.328	16167.372	4039.776	668.304	20872.956
Car + Taxi	10652.448	2661.336	422.688	13736.472	46014.828	11497.824	1902.096	59407.644
Pickups/ V	9672.6	2407.8	40.8	12121.2	37362	9349.2	204	46915.2
Light duty	5698.8	1403.4	81.6	7192.8	17559	4398.6	285.6	22180.2
Medium d	1444.2	367.8	1550.4	3363	4546.8	1116.6	5671.2	11334.6
Heavy duty	2824.8	711.6	16646.4	20245.8	10491	2618.4	61200	74237.4
Large buse	1131.6	269.4	1509.6	2920.2	3220.8	799.8	4284	8335.8
	35167.2	8756.4	20400	64405.8	135361.8	33820.2	74215.2	243283.8
	58612	14594	34000	107343	225603	56367	123692	405473
	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE