



Climate Change Assessment Report for Cluster 2 of the Gas Gathering Project in Virginia, South Africa

Project done on behalf of **EIMS (Pty) Ltd**

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Competency Profiles

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After earning her master's degree in science from the University of Johannesburg (formerly RAU) in Geography and Environmental Management. Hanlie Liebenberg-Enslin began her professional career in air quality management in 2000 when she joined Environmental Management Services (EMS). The same department at the University of Johannesburg awarded her a PhD in June 2014 with a focus on aeolian dust transport. She is one of the founding members of Airshed Planning Professionals and served as a director of the organization until May 2013, when she assumed the role of managing director.

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Report author: Gillian Petzer, (Pr. Eng.), BEng Chemical (University of Pretoria)

Gillian has been with Airshed since 2003. She holds a bachelor's degree in chemical engineering from the University of Pretoria. Her experience in air quality started in 2000 with the "Indoor Air Quality" division of Building Research Establishment (BRE) in the UK. Over the last two decades she has been actively involved in the development of atmospheric dispersion modelling and its applications, air pollution compliance assessments, health risk assessments, mitigation measures, development of air quality management plans, as well as meteorological and air quality monitoring programmes. She registered as a professional engineer in 2017. Whilst most of her working experience has been in South Africa, a number of investigations were made in countries throughout Africa as well as recent countries such as Afghanistan and Armenia.

Report reviewer: Dr Theresa (Terri) Bird, Pr. Sci. Nat., PhD (University of the Witwatersrand)

Dr Terri Bird holds a PhD from the School of Animal, Plant and Environmental Sciences, University of the Witwatersrand, Johannesburg. The focus of her doctoral research was on the impact of sulfur and nitrogen deposition on the soil and waters of the Mpumalanga Highveld. Since March 2012 she has been employed at Airshed Planning Professionals (Pty) Ltd. In this time, she has been involved in air quality impact assessments for various mining operations (including coal, mineral sand, diamond and platinum mines) as well as coal-fired power station ash disposal facilities. She has been a team member on the development of Air Quality Management Plans, both provincial and for specific industries. Recent projects include assessing the impact of Postponement and/or Exemption of Emission Standards for various Listed Activities.

Executive Summary

Tetra4 wishes to expand the natural gas operations within the approved production right area and around the Cluster 1 project. This planned expansion to the existing approved production activities will involve up to 300 new production wells, gas transmission pipelines and associated infrastructure, three (3) compressor stations and an additional new combined Liquid Natural Gas (LNG) and Liquid Helium (LHe) plant ("LNG/LHe Plant") and associated infrastructure.

A Climate Change Assessment (CCA) was conducted to determine the potential long term climate change impacts as a result of the Tetra4 Cluster 2 operations. Greenhouse gas (GHG) emissions for the project were calculated based on the Department of Forestry, Fisheries and Environment (DFFE) 2022 Methodological guidelines for quantification of GHG emissions which are based on the Intergovernmental Panel on Climate Change (IPCC) emission factors. This study considered Scope 1, Scope 2 and Scope 3 emissions, where Scope 1 are the emissions directly attributable to the project and Scope 2 emissions are the emissions associated with bought-in electricity. Scope 3 emissions consider the "embedded" carbon in bought-in materials and transport as well as the use of exported materials. Only Scope 1 emissions need to be quantified to be in line with the DFFE guidelines; the addition of Scope 2 would place the assessment in line with the guidelines provided by the International Finance Corporation (IFC).

The conclusions and recommendations of the assessment are summarised below:

- The region around Welkom and Virginia where Tetra4 Cluster 2 project is proposed to be developed is likely to experience increased temperatures and extreme weather-related events in the future. Climate change impacts will disproportionately affect underdeveloped communities that lack the physical and financial resources to cope with the physical effects of climate change, such as droughts, floods and increases in diseases.
- Scope- 1, 2 and 3 emissions were estimated based on emission factors and expected production rates or raw material use. The main construction activities attributed to GHG emissions are well drilling, well testing and well servicing followed by off-road mobile equipment. During operations, the electricity bought from ESKOM (Scope 2) is the main source, followed by gas production fugitives and road transportation (Scope 1). The main source of Scope 3 GHG emissions would be the end use of the LNG, but as LNG will be replacing other fuels already in use, it will result in a reduction of 14.6% in indirect GHG emissions.
- Construction- and operational-related GHG emissions from the proposed Tetra4 Cluster 2 project cannot be attributed directly to any climate change effects, and, when considered in isolation, will have a Low to Medium impact on the National GHG inventory total. The main GHG impact is associated with downstream use of LNG, i.e. Scope 3. GHG emissions per unit of combusted gas, however, are less than per unit coal.
- Since climate change is a global challenge, there is a collective responsibility to address climate change and Tetra4 has an individual responsibility to minimise its own negative contribution to the issue. It is recommended that renewable energy (such as photovoltaic solar panels) be considered to replace/ reduce the reliance on ESKOM electricity which is likely to reduce the significance from the Tetra4 Cluster 2 project from Medium to Low, since ESKOM's contribution to the operational phase is the main source of GHG emissions. Also, the use of LNG instead of diesel will reduce the GHG footprint further. Maintenance of vehicles and machinery, the implementation of a leak-detection program, and the minimisation of flaring and venting would reduce the potential for GHG emissions.
- Once operational, it is recommended records be kept of actual fuel usage for transport of materials and products, energy requirements, production rates, flare and venting rates and raw material consumption for GHG reporting purposes and refinement of the emissions inventory.

Based on Tetra4 Cluster 2 Scope 1, 2 and 3 GHG emissions, it is the specialist opinion that the project may be authorised due to its low to medium impact significance.

Table of Contents

1	Introduction.....	1
1.1	Study Objective	1
1.2	Scope of Work	4
1.3	Study Approach and Methodology	4
1.3.1	Project and Information Review	4
1.3.2	Carbon Footprint Calculation	4
1.3.3	Scope of Carbon Footprint.....	5
1.3.4	Impact Assessment Methodology	5
1.4	Project Description	5
1.4.1	Construction.....	5
1.4.2	Operations	6
1.5	Assumptions and Limitations	6
2	Regulatory Requirements.....	7
2.1	Introduction.....	7
2.1.1	The Greenhouse Effect.....	7
2.1.2	IFC Literature on GHG.....	7
2.1.3	International Agreements.....	7
2.2	South Africa's Status in terms of Climate Change and Quantification of Greenhouse Gases	8
2.2.1	Nationally Determined Contribution	8
2.2.2	National Climate Change Response Policy	9
2.2.3	Greenhouse Gas Emissions Reporting	10
2.2.4	National GHG Emissions Inventory	11
2.2.5	GHG Emission Inventory for the Sector.....	11
2.2.6	Draft National Guideline for Consideration of Climate Change in Development Applications, June 2021	11
3	Physical Risks of Climate Change on the Region.....	13
3.1	Vulnerability	13
3.2	Climate	13
3.2.1	Baseline Climate.....	13
3.2.2	Projected Future Climate	19
3.2.2.1	RCP4.5 Trajectory.....	19
3.2.2.2	RCP8.5 Trajectory.....	24
3.2.2.3	IPCC's Sixth Assessment Report: Temperature and Rainfall Projections	29
3.3	Hazards	29

3.4	Impact of Climate Change	34
3.4.1	Water Supply	34
3.4.1.1	Current Resources	34
3.4.1.2	Impact on Resources	34
3.4.2	Surface Water	35
3.4.2.1	Current Situation	35
3.4.2.2	Projected Impact	37
3.4.3	Ground Water	37
3.4.3.1	Current Situation	37
3.4.3.2	Projected Impact	38
3.4.4	Economy	39
3.4.5	Agriculture, Forestry and Fisheries	40
3.4.6	Other Resources	41
4	Impact Assessment: The Project's Carbon Footprint	53
4.1	Scope 1 GHG Emission Sources	53
4.1.1	Clearing and Rehabilitation – Carbon Sequestration and Carbon Sink	53
4.1.2	Construction fuel combustion	53
4.1.3	Construction well drilling, testing, and servicing	54
4.1.4	Operations	54
4.1.5	Decommissioning	54
4.2	Scope 2 GHG Emissions	55
4.3	Scope 3 GHG Emissions	56
4.4	The Project's GHG Emissions Impact	56
4.4.1	Impact on the National Inventory	56
4.4.2	Alignment with National Policy	57
4.4.3	Physical Risks of Climate Change on the Project's Construction and Operations	57
4.4.3.1	Temperature	57
4.4.3.2	Rainfall, Water Stress, and Extreme Events	58
4.4.4	Impact Assessment: Potential Effect of Climate Change on the Community	58
4.4.4.1	Temperature	58
4.4.4.2	Rainfall, Water Stress, and Extreme Events	58
4.5	Project adaptation and mitigation measures	59
5	Impact Significance Rating	60
5.1	Construction	60
5.2	Operation	60

5.3	Alternative Significance Rating	61
6	Conclusion.....	62
7	References	63
8	Appendix A – Emission Factors	65
9	Appendix B – Impact Significance Rating Methodology	69

List of Tables

Table 1: South Africa's NDC mitigation targets.....	9
Table 2: Forecasted economic gains or losses for the RCP4.5 and RCP8.5 scenarios.....	40
Table 3: Economic contribution of main commodities for Matjhabeng Local Municipality	41
Table 4: Projected economic contribution of main commodities for Matjhabeng Local Municipality	41
Table 5: The impacts of climate change on other resources	42
Table 6: Tetra4 Cluster 2 land clearance during construction	53
Table 7: Tetra4 Cluster 2 construction fuel combustion.....	54
Table 8: Tetra4 Cluster 2 operational phase fuel combustion per year	54
Table 9: Tetra4 Cluster 2 gas processing during an operational year	54
Table 10: Tetra4 Cluster 2 transmission (pipeline fugitives and venting) and storage during an operational year.....	54
Table 11: Tetra4 Cluster 2 ESKOM electricity supply during construction and operations.....	55
Table 12: Tetra4 Cluster 2 Scope 1 and 2 GHG emission summary	55
Table 13: Tetra4 Cluster 2 GHG Scope 3 emission summary	56
Table 14: Tetra4 Cluster 2 GHG scope 3 use of sold products to replace other fuels currently in use	56
Table 15: Significance rating for potential Climate Change impacts due to the construction activities	60
Table 16: Significance rating for potential climate change impacts due to the Project operations	61
Table 17: GHG and Climate in EIA – Elements to consider	61
Table 18: Criteria for determining impact consequence	69
Table 19: Probability scoring.....	70
Table 20: Determination of environmental risk	70
Table 21: Significance classes.....	70
Table 22: Criteria for determining prioritisation	71
Table 23: Determination of prioritisation factor	71
Table 24: Final environmental significance rating	72

List of Figures

Figure 1: Project history and mineral tenure	2
Figure 2: Cluster 2 study area and proposed infrastructure footprint buffer zones	3
Figure 3: Baseline (1961 to 1990) annual average temperature for the project area (CSIR, 2019)	14
Figure 4: Baseline (1961 to 1990) number of very hot days (>35°C) annually for the project area (CSIR, 2019).....	15
Figure 5: Baseline (1961 to 1990) annual average rainfall for the project area (CSIR, 2019)	16
Figure 6: Baseline (1961 to 1990) annual average number of extreme rainfall days (>20 mm in <24 hours) for the project area (CSIR, 2019)	17
Figure 7: Annual average temperature (top panel) and temperature anomaly (lower panel) between 1979 and 2023 (meteoblue AG, 2024).....	18
Figure 8: Annual average rainfall (top panel) and rainfall anomaly (lower panel) between 1979 and 2023 (meteoblue AG, 2024)	19
Figure 9: Projected change in annual average temperature for the near future (2021 – 2050) for the RCP4.5 trajectory	20
Figure 10: Projected change in very hot days for the near future (2021 – 2050) for the RCP4.5 trajectory	21
Figure 11: Projected change in annual average rainfall for the near future (2021 – 2050) for the RCP4.5 trajectory	22

Figure 12: Projected change in annual average number of extreme rainfall days (>20 mm in <24 hours) for RCP4.5 trajectory	23
Figure 13: Projected change in annual average temperature for the near future (2021 – 2050) for the RCP8.5 trajectory	25
Figure 14: Projected change in very hot days for the near future (2021 – 2050) for the RCP8.5 trajectory	26
Figure 15: Projected change in annual average rainfall for the near future (2021 – 2050) for the RCP8.5 trajectory	27
Figure 16: Projected change in annual average number of extreme rainfall days (>20 mm in <24 hours) for RCP8.5 trajectory	28
Figure 17: Risk of increased wildfires for Matjhabeng Local Municipality in 2050 based on RCP8.5 trajectory (dark blue marker indicates approximate location of the project).....	30
Figure 18: Risk of increased drought tendencies for Matjhabeng Local Municipality in 2050 based on RCP8.5 trajectory (dark blue marker indicates approximate location of the project).....	30
Figure 19: Risk of increased heat extremes for Matjhabeng Local Municipality in 2050 based on RCP8.5 trajectory (dark blue marker indicates approximate location of the project)	31
Figure 20: Risk of increased flooding for Matjhabeng Local Municipality in 2050 based on RCP8.5 trajectory (dark blue marker indicates approximate location of the project).....	31
Figure 21: Current water stress for the project area (Hofste, et al., 2019) (blue dot indicates project location)	32
Figure 22: Projected (2050) water stress for the project area (Hofste, et al., 2019) (blue dot indicates project location)	33
Figure 23: Current water availability for the Matjhabeng Local Municipality	34
Figure 24: Estimated current and future (2050) water supply vulnerability based on medium population growth for the Matjhabeng Local Municipality.....	35
Figure 25: Quaternary catchment areas for the Matjhabeng Local Municipality	36
Figure 26: Current annual and monthly surface water runoff, precipitation and evaporation for the Matjhabeng Local Municipality which falls under the Vaal Primary Catchment	36
Figure 27: Projected monthly change to future (2050) evaporation, precipitation, and estimated runoff values	37
Figure 28: Groundwater potential and dependency for the Matjhabeng Local Municipality (dark blue marker indicates approximate location of the project).....	38
Figure 29: Groundwater potential and depletion for 2050 for the Matjhabeng Local Municipality (dark blue marker indicates approximate location of the project).....	39
Figure 30: The contribution that the different economic sectors make to the total GVA of the Matjhabeng Local Municipality	40

Abbreviations

Airshed	Airshed Planning Professionals (Pty) Ltd
AR5	IPCC Fifth Assessment Report
CCRA	Climate Change Reference Atlas
CCS	Carbon Capture and Sequestration (or Carbon Capture and Storage)
COP	Conference of the Parties
DEA	Department of Environmental Affairs (now DEFF)
DEFRA	United Kingdom's Department of Environment, Food and Rural Affairs
DFFE	Department of Forestry, Fisheries and Environment (previously DEA)
EIA	Environmental Impact Assessment
EIMS	Environmental Impact Management Services (Pty) Ltd
ETF	Enhanced transparency framework
FOLU	Forestry and Other Land Use
GCMs	Global Climate Change Models
GHGIP	National Greenhouse Gas Improvement Programme
GWP	Global Warming Potential
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
IPP	Independent Power Producer
IPPU	Industrial Processes and Other Product Use
IRP	Integrated Resource Plan
LT-LEDS	Long-term low greenhouse gas emission development strategies
NAEIS	National Atmospheric Emissions Inventory System
NCCRP	National Climate Change Response Plan
NDC	Nationally Determined Contribution
NDCR	National Dust Control Regulations
NEMAQA	National Environmental Management Air Quality Act
PPP	Pollution Prevention Plan
RCPs	Representative Concentration Pathways
SAELIP	South African Atmospheric Emission Licencing and Inventory Portal
SAAQIS	South African
SAGERS	South African Greenhouse Gas Emission Reporting System
SAWS	South African Weather Services
UNFCCC	United Nations Framework Convention on Climate Change

Symbols and Units

°C	Degree Celsius
C ₆ H ₆	Benzene
CH ₄	Methane
CO	Carbon monoxide
CO ₂	Carbon dioxide
CO ₂ -eq	Carbon dioxide equivalent
Gt	Gigatonne
ha	Hectare
HFC	Hydrofluorocarbons
kg	Kilograms
1 kilogram	1 000 grams
km	Kilometre
m	Metres
mm	Millimetres
mamsl	Metres above mean sea level
m/s	Metres per second
mm	Millimetres
Mt	Million tonnes
NO	Nitrogen oxide
N ₂ O	Nitrous oxide
NO ₂	Nitrogen dioxide
NO _x	Oxides of nitrogen
O ₃	Ozone
Pb	Lead
PFC	Perfluorocarbons
PM _{2.5}	Inhalable particulate matter (aerodynamic diameter less than 2.5 µm)
PM ₁₀	Thoracic particulate matter (aerodynamic diameter less than 10 µm)
SF ₆	Sulfur hexafluoride
SO ₂	Sulfur dioxide (1)
tpa	Tonnes per annum
1 ton	1 000 000 grams

Notes:

The spelling of "sulfur" has been standardised to the American spelling throughout the report. The International Union of Pure and Applied Chemistry, the international professional organisation of chemists that operates under the umbrella of UNESCO, published, in 1990, a list of standard names for all chemical elements. It was decided that element 16 should be spelled "sulfur". This compromise was to ensure that in future searchable data bases would not be complicated by spelling variants. (IUPAC. Compendium of Chemical Terminology, 2nd ed. (the "Gold Book"). Compiled by A. D. McNaught and A. Wilkinson. Blackwell Scientific Publications, Oxford (1997). XML on-line corrected version: <http://goldbook.iupac.org> (2006) created by M. Nic, J. Jirat, B. Kosata; updates compiled by A. Jenkins. ISBN 0-9678550-9-8.[doi: 10.1351/goldbook](https://doi.org/10.1351/goldbook))"

1 INTRODUCTION

Tetra4 holds the first and only onshore petroleum production right in South Africa, making Tetra4 the front runner in domestic natural gas distribution. A Production Right (Ref: 12/4/1/07/2/2) was granted in 2012, spanning approximately 187 000 hectares (ha) for the development of natural gas (Helium and Methane) production operations around the town of Virginia in the Free State Province. Within this approval, the 2010 Environmental Management Programme (EMPr) was approved which is applicable to a large portion of the Production Right area (Figure 1). Activities within the Production Right areas include:

- Continued exploration activities;
- Drilling and establishment of further production wells throughout the entire production area (260 production wells);
- Installation of intra-field pipelines throughout the entire production area (~500 km);
- Installation of boosters and main compressors; and
- Central gas processing plant (not approved in the original Environmental Impact Assessment (EIA) and approved EMPr).

An integrated environmental authorisation (EA) for the first phase gas field production referred to as Cluster 1, in terms of the National Environmental Management Act (NEMA), was issued on 21 September 2017 by the Department of Mineral Resources and Energy (DMRE) to Tetra4 ("Cluster 1 EA", reference: 12/04/07) and amended on 26 August 2019 and 1 September 2020. In this EA approval, various new wells and pipelines, booster and compressor stations, a Helium and Liquid Natural Gas (LNG) Facility and associated infrastructure was approved which comprises the first gas field for development within the approved Production Right area. The Cluster 1 EA also authorises certain waste management activities as per the List of Waste Management Activities (Government Notice 921, as amended) published under the National Environmental Management: Waste Act 59 of 2008 (NEMWA).

Tetra4 now plans to expand the natural gas operations (referred to as Cluster 2) to be located within the approved production right area and around the Cluster 1 project (Figure 2). This planned expansion to the existing approved production activities will include:

- Drilling and establishment of further production wells (up to 300 new production wells);
- Installation of gas transmission pipelines and associated infrastructure;
- Installation of three (3) compressor stations;
- An additional new combined LNG and Liquid Helium (LHe) plant ("LNG/LHe Plant") and associated infrastructure, and
- Establishment of powerlines as part of the Cluster 2 expansion of the Project in order to meet the future production requirements.

Airshed Planning Professionals (Pty) Ltd (Airshed) was appointed by Environmental Impact Management Services (EIMS) (Pty) Ltd to conduct a Climate Change Assessment (CCA) for the project. The main objective is to quantify the greenhouse gasses (GHG) associated with the project and the potential long term climate change impacts as a result.

1.1 Study Objective

The main objective of the CCA is to quantify the greenhouse gasses (GHG) associated with the project and to determine the significance of potential climate change impacts as a result.

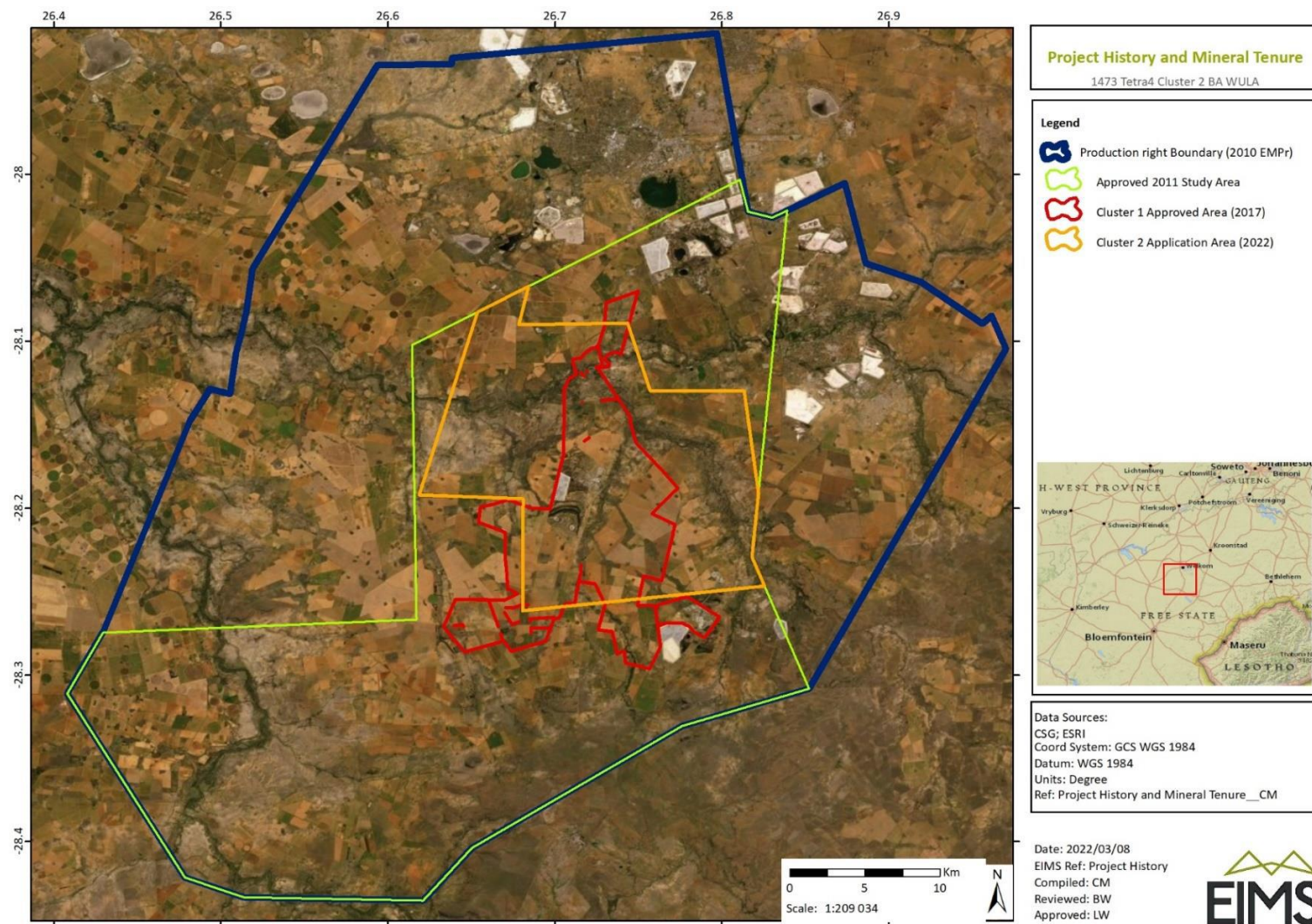


Figure 1: Project history and mineral tenure

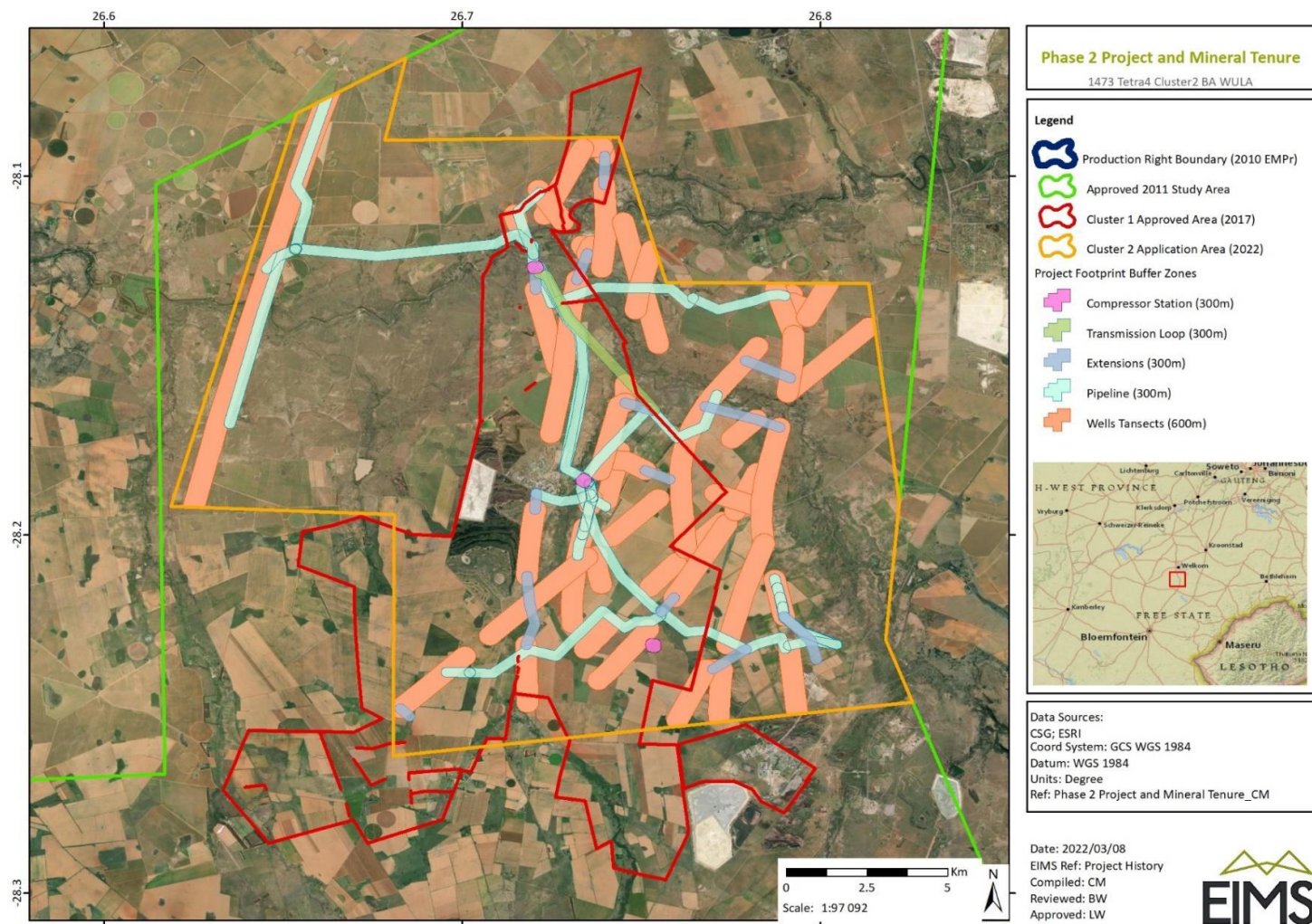


Figure 2: Cluster 2 study area and proposed infrastructure footprint buffer zones

1.2 Scope of Work

The tasks proposed as part of the scope of work for the CCA for the Construction and Operational Phases of the project, are:

- Identification of the Transitional and Physical Risks associated with the project (as per the Task Force on Climate-related Financial Disclosures).
- GHG emissions during the construction and operation of the project covering Scope 1, Scope 2 and Scope 3 emissions.
- Comparison of GHG emissions to the global and national emission inventories, and to international benchmarks for the project.
- The robustness of the project in terms of forecasted climate change impacts to the area over the lifetime of the project.
- The vulnerability of communities in the immediate vicinity of the project to climate change.
- Proposed management and mitigation strategies.
- Compile a report that complies with the requirements of Appendix 6 of the EIA Regulations, 2014 (Government Notice (GN) R 982 of 2014, as amended); and/or
- The Department of Forestry, Fisheries and Environment (DFFE) "Protocols for the assessment and minimum report content requirements of environmental impacts" (GN 320 of 2020 and GN 1150 of 2020); and/or
- Any other applicable sector-specific guidelines and protocols.

1.3 Study Approach and Methodology

GHG emissions for the project were calculated and compared to the global and national emission inventory and compared to international benchmarks for the project.

1.3.1 Project and Information Review

A review of the project from an air quality perspective in order to identify sources of GHG emission was conducted. In the review the following documents were referenced:

- Project information supplied by EIMS, including the AQIA conducted in 2017 (Akinshipe, 2017); and
- Section 21 of the National Environmental Management: Air Quality Act (NEMAQA).

1.3.2 Carbon Footprint Calculation

The Carbon Footprint is an indication of the GHGs estimated to be emitted directly and/or indirectly by an organisation, facility, or product. It can be estimated from

$$\text{Carbon emissions} = \text{Activity information} * \text{emission factor} * \text{GWP}$$

where

- *Activity information* relates to the activity that causes the emissions.
- *emission factor* refers to the amount of GHG emitted per unit of activity.
- *GWP* or global warming potential is the potential of an emitted gas to cause global warming relative to carbon dioxide (CO₂). This converts the emissions of all GHGs to the equivalent amount of CO₂ or CO₂-e.

For combustion processes, the emission factor is often calculated from a carbon mass balance, where the combustion of each unit mass of carbon in the fuel leads to an equivalent emission of 3.67 mass units of CO₂ (from 44/12, the ratio of molecular weight of CO₂ to that of carbon).

GWPs from the recently published DFFE guideline on quantification of GHG emissions (based on the IPCC Third Assessment Report, 2001) were applied in this study. These GWPs are compliant with UNFCCC Reporting Requirements. The 100-year GWPs were used: 23 for methane (CH₄) and 296 for nitrous oxide (N₂O).

In the quantification of Scope 1 emissions, the recently published DFFE guideline on quantification of GHG emissions (DFFE, 2022) was used. Scope 3 emissions were estimated using the United Kingdom's Department of Environment, Food and Rural Affairs (UK DEFRA) 2022 emission factors (<https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2022>). A summary of the emission factors applied is provided in Appendix A.

1.3.3 *Scope of Carbon Footprint*

The three broad scopes for estimating GHG are:

- Scope 1: All direct GHG emissions.
- Scope 2: Indirect GHG emissions from consumption of purchased electricity, heat, or steam.
- Scope 3: Other indirect emissions, such as the extraction and production of purchased materials and fuels, transport-related activities in vehicles not owned or controlled by the reporting entity, electricity-related activities not covered in Scope 2, outsourced activities, waste disposal, etc.

In this study, Scope 1 emissions are the emissions directly attributable to the project and Scope 2 emissions are the emissions associated with bought-in electricity. Scope 3 emissions consider the “embedded” carbon in bought-in materials and transport as well as the use of exported materials. Only Scope 1 emissions need to be quantified to be in line with the DFFE guidelines; the addition of Scope 2 would place the assessment in line with the guidelines provided by the International Finance Corporation (IFC, 2012).

1.3.4 *Impact Assessment Methodology*

As the emission of greenhouse gases has a global impact, it is not feasible to follow the normal impact assessment methodology viz. comparing the state of the physical environment after implementation of the project to the condition of the physical environment prior to its implementation. Instead, this study assessed the following:

- (i) The GHG emissions during the construction, operation and decommissioning of the project compared to the global and South African emission inventory and to international benchmarks for the project.
- (ii) The impact of climate change over the lifetime of the project taking the robustness of the project into account.
- (iii) The vulnerability of communities in the immediate vicinity of the project to climate change.

1.4 **Project Description**

1.4.1 *Construction*

The construction phase comprises activities, such as drilling and construction of new wells, construction of access roads, installation of pipelines, construction of the helium and LNG plant, as well as site clearing or upgrade activities on existing wells. Each of these operations has its own duration and GHG emission potential with typical activities land clearing, topsoil removal, material loading and hauling, stockpiling, grading, bulldozing, compaction, well drilling etc. It is anticipated therefore that the extent of GHG emissions would vary substantially from day to day depending on the level of activity and the specific operations.

1.4.2 Operations

The operational phase of the Project will include mainly the combined LNG/LHe plant with continuous and emergency flares, three electrically powered compressor stations and booster stations that would require natural gas generators. Nitrogen (N₂) will be trucked to the plant, and the LNG and LHe products will be exported by truck from the plant via road. In addition, maintenance vehicles and equipment will operate as needed.

1.5 Assumptions and Limitations

The following important limitation applies to the study and should be noted:

- Project information required to calculate GHG emissions for proposed operations was provided by Tetra4 via EIMS. Where necessary, assumptions were made based on common industry practice and experience.
- The compressor stations were assumed to be electrically powered, whereas the booster stations were assumed to use natural gas generators.
- The methodological guidelines for quantification of GHG emissions (DFFE, 2022), published in October 2022, have been used to estimate the Scope 1 GHG emissions. The 100-year GWPs were used.
- GHG emissions from the well drilling¹, well testing², and well servicing³ were based on measurements provided by the client and not calculated using emission factors. These activities were included under construction operations.
- Scope 3 emissions were estimated using the UK DEFRA (2022) emission factors (<https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2022>).
- The following Scope 3 categories are excluded since these are not regarded applicable to the project:
 - Category 2: Capital Goods
 - Category 8: Upstream Leased Assets
 - Category 10: Processing of Sold Products
 - Category 12: End-of-Life Treatment of Sold Products
 - Category 13: Downstream Leased Assets
 - Category 14: Franchises
 - Category 15: Investments.
- The following assumptions apply to the Scope 3 assessment:
 - Raw materials needed for the wells and plants were assumed to be 100 980 tonne concrete, 26 060 tonne metal and 9 000 tonne HDPE.
 - It was assumed that the raw materials would be transported by truck to site (450 km).
 - Industrial waste to be sent to a landfill was assumed to be 31 428 tpa.
 - Business travel was assumed to be 6 people travelling to USA and Europe per year.
 - It was assumed that contractors and permanent staff (total 1 254 people) would have the following split for employee commuting to work (2.8% diesel car, 4.6% petrol car, 19.6% taxi and 73% bus). It was assumed that the return trip per day was 60 km.
 - It was assumed that 60% of the LNG (~ 90 000 tpa) would be shipped by sea tanker to China.
 - It was assumed that the Helium (1 825 tpa) would be transported by truck to Durban (600 km), and then by ship (cargo ship average bulk carrier) to either Europe, Asia or North America (average 14 461 km).
 - It was assumed that the LNG (~ 160 000 tpa) would be combusted (end use of product).

¹ Data obtained from kestrel flow meter while drilling and extrapolated for duration of exploration drilling in gas bearing units.

² Data obtained from flow testing and flaring of existing exploration wells.

³ Data obtained from fugitive monitoring of both existing production and exploration wells.

2 REGULATORY REQUIREMENTS

2.1 Introduction

2.1.1 *The Greenhouse Effect*

Greenhouse gases (GHG) are “those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of thermal infrared radiation emitted by the earth’s surface, the atmosphere itself, and by clouds. This property causes the GHG effect. Water vapour (H₂O), CO₂, nitrous oxide (N₂O), methane (CH₄) and O₃ are the primary greenhouse gases in the earth’s atmosphere. Moreover, there are a number of entirely human-made GHG gases in the atmosphere, such as the halocarbons and other chlorine and bromine containing substances, dealt with under the Montreal Protocol. Beside CO₂, N₂O and CH₄, the Kyoto Protocol deals with the greenhouse gases sulphur hexafluoride (SF₆), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) (IPCC, 2007). Human activities since the beginning of the Industrial Revolution (taken as the year 1750) have produced a 40% increase in the atmospheric concentration of carbon dioxide, from 280 ppm in 1750 to 406 ppm in early 2017 (NOAA, 2017). This increase has occurred despite the uptake of a large portion of the emissions by various natural “sinks” involved in the carbon cycle (NOAA, 2017). Anthropogenic CO₂ emissions (i.e., emissions produced by human activities) come from combustion of fossil fuels, principally coal, oil, and natural gas, along with deforestation, soil erosion and animal agriculture (IPCC, 2007).

2.1.2 *IFC Literature on GHG*

The International Finance Corporation (IFC) lists methods that countries and projects can reduce GHG impacts. These include carbon financing; improvement of energy efficiency; GHG sinks and reservoir protection and improvements; that environmentally friendly agriculture and forestry be encouraged; the increased use of renewable energy methods; implementation of carbon capture and sequestration methods; and, improved waste management (recovery and use of methane emissions) as well as reducing GHG emissions from vehicle use and industrial, construction and energy production processes (IFC, 2007). Carbon financing may have much potential in developing countries as well as sustainable agriculture and forestry practices (IFC, 2012), and when supported by governments may be a way of reducing the country’s GHG impacts, where projects receive carbon credits and financing for reducing GHG emissions and installing more environmentally friendly alternatives. Because different industries contribute various amounts of GHG emissions, the IFC performance standards suggests that for industrial processes the CO₂-equivalent (CO₂-e) emissions per year do not exceed 100 000 tonnes, this including direct (Scope 1) and indirect (Scope 2) sources (IFC, 2012).

2.1.3 *International Agreements*

In 1992, countries joined an international treaty, the United Nations Framework Convention on Climate Change (UNFCCC) as a framework for international cooperation to combat climate change by limiting average global temperature increases and the resulting climate change, and coping with impacts that were, by then, inevitable.

By 1995, countries launched negotiations to strengthen the global response to climate change, and, two years later, adopted the Kyoto Protocol. The Kyoto Protocol legally binds developed country parties to emission reduction targets. The Protocol’s first commitment period started in 2008 and ended in 2012. As agreed in Doha in 2012, the second commitment period began on 1 January 2013 and would end in 2020 (UNFCCC, 2017) but due to lack of ratification has not come into force.

The Paris Agreement was adopted by 196 Parties at Conference of the Parties (COP) 21 in Paris, on 12 December 2015 and commenced 4 November 2016. The Paris Agreement (2016) builds upon the Convention and – for the first time – brings all

nations into a common cause to undertake ambitious efforts to combat climate change and adapt to its effects, with enhanced support to assist developing countries to do so. As such, it charts a new course in the global climate effort.

The Paris Agreement's central aim is to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5°C. Additionally, the agreement aims to strengthen the ability of countries to deal with the impacts of climate change. To reach these ambitious goals, appropriate financial flows, a new technology framework and an enhanced capacity building framework will be put in place, thus supporting action by developing countries and the most vulnerable countries, in line with their own national objectives.

The Paris Agreement is founded on the idea of countries improving on their climate change strategies in 5-year cycles. The Paris Agreement requires all Parties to put forward their best efforts through “nationally determined contributions” (NDCs) and to strengthen these efforts in the years ahead. This includes requirements that all Parties report regularly on their emissions and on their implementation efforts.

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In 2018, Parties took stock of the collective efforts in relation to progress towards the goals set in the Paris Agreement to inform the preparation of NDCs. There will also be a global stocktake every five years to assess the collective progress towards achieving the purpose of the Agreement and to inform further individual actions by Parties.

As of October 2022, 194 Parties of the 197 Parties to the UNFCCC Convention, including South Africa, had ratified the Paris Agreement. South Africa submitted its NDC to the UNFCCC on 25 September 2016 and an updated NDC in September 2021.

2.2 South Africa's Status in terms of Climate Change and Quantification of Greenhouse Gases

2.2.1 Nationally Determined Contribution

The first South African NDC submission was completed in 2016. This was undertaken to comply with decision 1/CP.19 and 1/CP.20 of the Conference of the Parties to the UNFCCC. An update of the first NDC was published submitted to the UNFCCC on 27 September 2021⁴ in preparation for the 26th Conference of the Parties (held in Glasgow, Scotland in November 2021). This document describes South Africa's NDC on adaptation, mitigation and finance and investment necessities to undertake the resolutions with updated revisions to the adaptation goals and mitigation targets.

As part of the updated adaption portion the following goals have been assembled:

1. Goal 1: Enhance climate change adaptation governance and legal framework.
2. Goal 2: Develop an understanding of the impacts on South Africa of 1.5 and 2°C global warming and the underlying global emission pathways through geo-spatial mapping of the physical climate hazards, and adaptation needs in the context of strengthening the key sectors of the economy. This will provide the scientific basis for strengthening the national and provincial governments' readiness to respond to climate risk.
3. Goal 3: Implementation of National Climate Change Adaptation Strategy (NCCAS) adaptation interventions for the period 2021 to 2030, where priority sectors have been identified as biodiversity and ecosystems; water; health;

4

<https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/South%20Africa%20First/South%20Africa%20updated%20first%20NDC%20September%202021.pdf>

energy; settlements (coastal, urban, rural); disaster risk reduction, transport infrastructure, mining, fisheries, forestry and agriculture.

4. Goal 4: Mobilise funding for adaptation implementation through multilateral funding mechanisms.
5. Goal 5: Quantification and acknowledgement of the national adaptation and resilience efforts.

As part of the mitigation portion the following have been, or can be, implemented at National level:

- The approval of 79 (5 243 MW) renewable energy Independent Power Producer projects as part of a Renewable Energy Independent Power Producer Procurement Programme. An additional 6 300 MW is being deliberated.
- A “Green Climate Fund” has been created to back green economy initiatives. This fund will be increased in the future to sustain and improve successful initiatives.
- It is intended that by 2050 electricity will be decarbonised.
- CCS.
- To support the use of electric and hybrid electric vehicles.
- Reduction of emissions can be achieved through the use of energy efficient lighting; variable speed drives and efficient motors; energy efficient appliances; solar water heaters; electric and hybrid electric vehicles; solar photovoltaic (PV); wind power; CCS; and advanced bioenergy.
- Updated targets based on revised 100-year global warming potential (GWP) factors (published in the Annex to decision 18/CMA.1 of the IPCC 5th assessment report) and based on exclusion of land sector emissions arising from natural disturbance. The updated NDC mitigation targets, consistent with South Africa’s fair share, are presented in Table 1.

Table 1: South Africa’s NDC mitigation targets

Year	Target	Corresponding period
2025	South Africa’s annual GHG emissions will be in a range between 398 - 510 Mt CO ₂ -e.	2021-2025
2030	South Africa’s annual GHG emissions will be in a range between 398 - 440 Mt CO ₂ -e.	2026-2030

2.2.2 National Climate Change Response Policy

South Africa ratified the UNFCCC in August 1997 and acceded to the Kyoto protocol in 2002, with effect from 2005. However, since South Africa is an Annex 1 country it implies no binding commitment to cap or reduce GHG emissions. South Africa later also ratified the Paris Agreement (as signed on 22 April 2016) which although not bound to commit to a cap or reduce GHG emissions, pledged to reduce emissions by 34% below Business-As-Usual (BAU) emissions by 2020 and 42% below BAU by 2025. The proposed 2030 target range represents a 28% reduction in GHG emissions commitment from the original 2015 NDC targets. However, these original goals were ambitious and South Africa subsequently shifted from BAU-based targets for 2020 and 2025 in terms of the Cancun Agreement under the UNFCCC, to absolute GHG emissions targets under the Paris Agreement. This update demonstrates reducing the upper range of South Africa’s targets by a more realistic 17% for 2025 and 28% for 2030, respectively.

The National Climate Change Response White Paper, passed by Cabinet in October 2011, stated that in responding to climate change, South Africa has two objectives: to manage the inevitable climate change impacts and to contribute to the global effort in stabilising GHG emissions at a level that avoids dangerous anthropogenic interference with the climate system. The White Paper proposes mitigation actions, especially a departure from coal-intensive electricity generation, be implemented in the short- and medium-term to match the GHG trajectory range. Peak GHG emissions are expected between 2020 and 2025 before a decade long plateau period and subsequent reductions in GHG emissions.

The White Paper also highlighted the co-benefit of reducing GHG emissions by improving air quality and reducing respiratory diseases by reducing ambient particulate matter, ozone, and sulfur dioxide concentrations to levels in compliance with the National Ambient Air Quality Standards (NAAQS) by 2020. To achieve these objectives, the Department of Forestry, Fisheries and Environment (DFFE) established a national GHG emissions inventory that reports through the South African Atmospheric Quality Information System (SAAQIS).

The Climate Change Act was gazetted on 23 July 2024. The Act objects to make a fair contribution to the global effort to stabilise greenhouse gas concentrations in the atmosphere at a level that avoids dangerous anthropogenic interference with the climate system; to ensure a just transition towards a low carbon economy and society. The aim of the Act is to enable the development of an effective climate change response and a long-term, just transition to a low-carbon and climate-resilient economy and society for South Africa in the context of sustainable development; and to provide for matters connected therewith.

The arrangements of the Act include:

- Establish the provincial and municipal forums on climate change which will be responsible for co-ordinating climate change response actions in each province.
- Establish the Presidential Climate Change Coordinating Commission (4PC). Although, the 4PC was already established prior to the Act, its establishment only carries legal force now that the Act is in place.
- Establish a National Adaptation Strategy to guide South Africa's adaptation to the impacts of climate change and develop adaptation scenarios which anticipate the likely impacts over the short, medium, and long term.
- Determine a national GHG emissions trajectory, which must be reviewed every five years, and which indicates an emissions reduction objective.
- Put in place a 5-yearly sectoral emission targets for identified sectors and sub-sectors that must be aligned with the national GHG emissions trajectory and include quantitative and qualitative GHG emission reduction goals.

Bring into force the carbon budget allocation mechanism. A person to whom a carbon budget has been allocated in terms of subsection (1) must prepare and submit to the Minister, for approval, a greenhouse gas mitigation plan.

2.2.3 Greenhouse Gas Emissions Reporting

Regulations pertaining to GHG reporting using the National Atmospheric Emission Inventory System (NAEIS) were published on 3 April 2017 (Government Notice (GN) 257 in Government Gazette (GG) 40762 and amendment – GNR 994 in Government Gazette 43712). The South African mandatory reporting guidelines focus on the reporting of Scope 1 emissions only. The three broad scopes for estimating GHG are:

- Scope 1: All direct GHG emissions.
- Scope 2: Indirect GHG emissions from consumption of purchased electricity, heat or steam.
- Scope 3: Other indirect emissions, such as the extraction and production of purchased materials and fuels, transport-related activities in vehicles not owned or controlled by the reporting entity, electricity-related activities not covered in Scope 2, outsourced activities, waste disposal, etc.

The South African Greenhouse Gas Emission Reporting System (SAGERS) web-based monitoring and reporting system will be used to collect GHG information in a standard format for comparison and analyses. The system forms part of the national atmospheric emission inventory component of South African Atmospheric Emission Licensing and Inventory Portal (SAAELIP). Tetra4 operations will have to report their GHG emissions to SAGERS since there is no threshold for annual GHG emissions reporting for the Natural Gas producers as per the amended GHG reporting guidelines (GG43712, 7 September 2020).

The DFFE is working together with local sectors to develop country specific emissions factors in certain areas; however, in the interim the IPCC default emission figures may be used to populate the SAAQIS GHG emission factor database. These country specific emission factors will replace some of the default IPCC emission factors. Methodological guidelines for quantification of GHG emissions (DFFE, 2022), published in October 2022, have been issued to estimate emissions.

Also, the Carbon Tax Act (No 15 of 2019) (Republic of South Africa, 2019) includes details on the imposition of a tax on the CO₂-e of GHG emissions. Certain production processes indicated in Annexure A of the Declaration of Greenhouse Gases as Priority Pollutants (Republic of South Africa, 2017) with GHG more than 0.1 mega tonnes (Mt) or million metric tonnes, measured as CO₂-e, are required to submit a pollution prevention plan to the Minister for approval.

2.2.4 National GHG Emissions Inventory

South Africa is a GHG contributor and is undertaking steps to mitigate and adapt to the changing climate. DFFE is categorised as the lead climate change institution and is required to coordinate and manage climate related information such as development of mitigation, monitoring, adaption and evaluation strategies (DFFE, 2022a). This includes the establishment and updating of the National GHG Inventory. The National Greenhouse Gas Improvement Programme (GHGIP) has been initiated; it includes sector specific targets to improve methodology and emission factors used for the different sectors as well as the availability of data.

The 2020 National GHG Inventory was prepared using the 2006 IPCC Guidelines (IPCC, 2006). According to the draft 9th National GHG Inventory Report (DFFE, 2024), the total GHG emissions in 2022 were estimated at approximately 478.89 Mt CO₂e (excluding Land Use, Land Use Change and Forestry (LULUCF)). This was a 2.2% decrease from the 2000 total GHG emissions (excluding LULUCF). LULUCF is estimated to be a net carbon sink which reduces the 2022 GHG emissions to 435.83 Mt CO₂e. The assessment (excluding LULUCF) showed the main sector contributing to GHG emissions in 2022 to be the energy sector, contributing 78% to the total GHG emissions.

2.2.5 GHG Emission Inventory for the Sector

The proposed Cluster 2 operations would be categorised in the energy category for both the global GHG inventory and for the national GHG inventory. According to the World Resources Institute – CAIT Climate Data Explorer⁵ the 2021 global GHG emissions from the energy category were approximately 37.4 Gt CO₂-e; 75.5% of the total GHG emissions (including Land-Use Change and Forestry (LUCF)). The South African energy sector contributed 373 533 Mt CO₂-e, ~0.01% of the global energy sector emissions in 2021.

2.2.6 Draft National Guideline for Consideration of Climate Change in Development Applications, June 2021

The DFFE has, on 25 June 2021, published a Notice under the NEMA requesting public comment on the *Draft National Guideline for the consideration of climate change implications in applications for environmental authorisation, atmospheric emission licences and waste management licences*.

The Draft National Guideline has been developed to support the inclusion of climate change considerations into the EIA process, and to create a consistent approach for such incorporation, which will help proponents to assess:

- how a proposed development will likely exacerbate climate change;
- the impact of a development on features (natural and built) that are crucial for climate change adaptation and resilience; and

⁵ <http://cait.wri.org/>

- the sustainability of a development in the context of climate change projection.

The Guideline puts forward “a consistent approach in providing interested and affected parties (e.g. proponents, EAPs and specialists) with the minimum requirements to consider when undertaking a climate change assessment, which forms part of an application for environmental authorisation (EA), an atmospheric emissions licence (AEL) and/or waste management licence (WML)”.

One of the impact requirements for a climate change assessment is an estimation of the GHG emissions, direct and indirect (including upstream GHG emissions) that will be released into the atmosphere annually throughout the impact related to the activity.

The comment period for amendments to the draft guideline has now closed but the final guideline has not yet been published. As far as possible the guideline has been followed in the preparation of this climate change impact assessment in support of environmental authorisation

3 PHYSICAL RISKS OF CLIMATE CHANGE ON THE REGION

The discussions of physical risks of climate change discussed in this section are likely to be relevant to the project as well as to the communities surrounding the project even if the project is not authorised.

3.1 Vulnerability

The Green Book (CSIR, 2019); was developed to be an online platform providing quantitative scientific evidence on the likely impacts that climate change and urbanisation will have on South Africa's cities and towns. A profile for each local municipality, including individual settlements and neighbourhoods, was built in terms the rates of socio-economic, economic, physical and environmental risks associated with urbanisation, population growth and climate change (Le Roux, et al., 2019). The risk profile was accessed for the Matjhabeng Local Municipality⁶. The Matjhabeng Local Municipality socio-economic vulnerability score⁷ (out of 10) is 5.3 for 1996, reducing to 4.2 for 2011. The lower score in 2011 compared to 1996 indicates improvement of socio-economic factors. A high vulnerability score (closer to 10) indicates a scenario where an undesirable state is present e.g. low access to services, high socio-economic vulnerabilities, poor regional connectivity, environmental pressure or high economic pressures. The Matjhabeng Local Municipality for socio-economic vulnerability ranks 4th out of 19 in the province and 81st out of 213 in the country. The Matjhabeng Local Municipality economic vulnerability score⁸ (out of 10) is 7.7 for 1996, increasing to 9.9 for 2011. The economic vulnerability ranks 19th out of 19 in the province and 211th out of 213 in the country. The physical vulnerabilities⁹ ranks 4th out of 19 in the province and 50th out of 213 in the country. The environmental vulnerability¹⁰ ranks 13th out of 19 in the province and 102nd out of 213 in the country.

3.2 Climate

3.2.1 Baseline Climate

Climate change metrics focus on temperature; the number of very hot days (where the maximum temperatures exceed 35°C); rainfall and extreme rainfall events (more than 20 mm of rain occurring within 24 hours). The baseline (1961 to 1990) annual averages for these metrics were accessed for the area near the project site from the South Africa 'Green Book'¹¹ (CSIR, 2019). The metrics include three percentiles¹² (10th, 50th, and 90th) as an indication of the variability within the measured data set. Baseline annual average temperature was in the range 16.1°C (10th percentile) and 16.3°C (90th percentile) (Figure 3) with the number of very hot days varying between 2 (10th percentile) and 4.5 (90th percentile) days per year (Figure 4). The annual average rainfall range between the 10th and 90th percentiles is 1 079 mm and 1 168 mm (Figure 5). Extreme rainfall days varied between 12.4 (10th percentile) and 13.8 (90th percentile) days per year (Figure 6).

⁶ <https://riskprofiles.greenbook.co.za/>

⁷ Defined as the vulnerability of households based on household composition; education and health; access to basic services; safety and security.

⁸ Defined as the susceptibility of the municipality to external shocks based on economic diversity; size of economy; labour force; gross domestic product (GDP) growth rate; and inequality.

⁹ Defined by the physical fabric of connectedness of the settlements within the municipalities and structural robustness.

¹⁰ This indicator represents the balance between preserving the natural environmental and the pressures of population growth, urbanisation, and economic development. The indicator is based on air quality, environmental governance and competition between ecology and the urban environment.

¹¹ <https://greenbook.co.za/>

¹² A percentile is a statistical measure to indicate the value below which a given percentage of observations in a group of observations falls. For example, the 90th percentile is the value below which 90% of the observations fall. The 10th percentile is the value below which 10% of the observations fall.

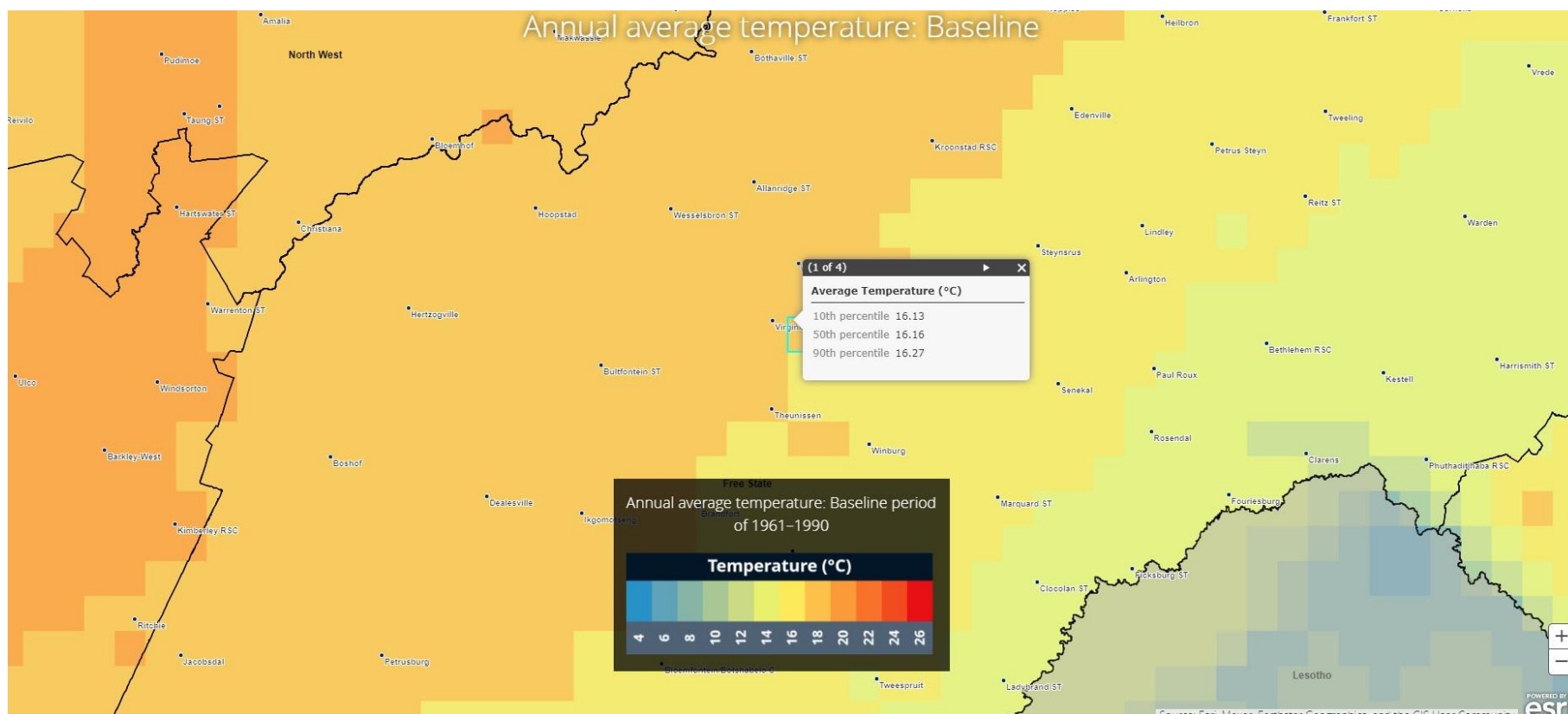


Figure 3: Baseline (1961 to 1990) annual average temperature for the project area (CSIR, 2019)

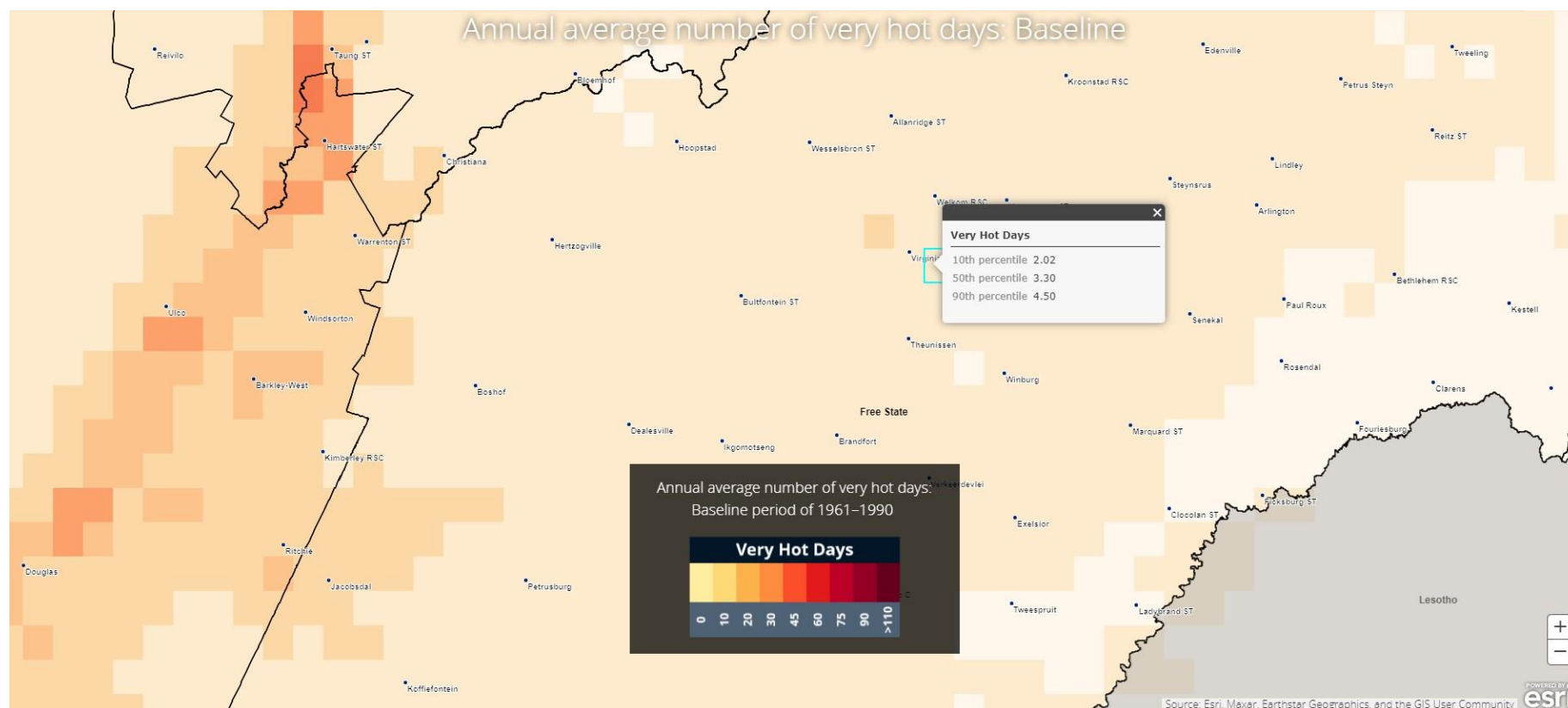


Figure 4: Baseline (1961 to 1990) number of very hot days (>35°C) annually for the project area (CSIR, 2019)

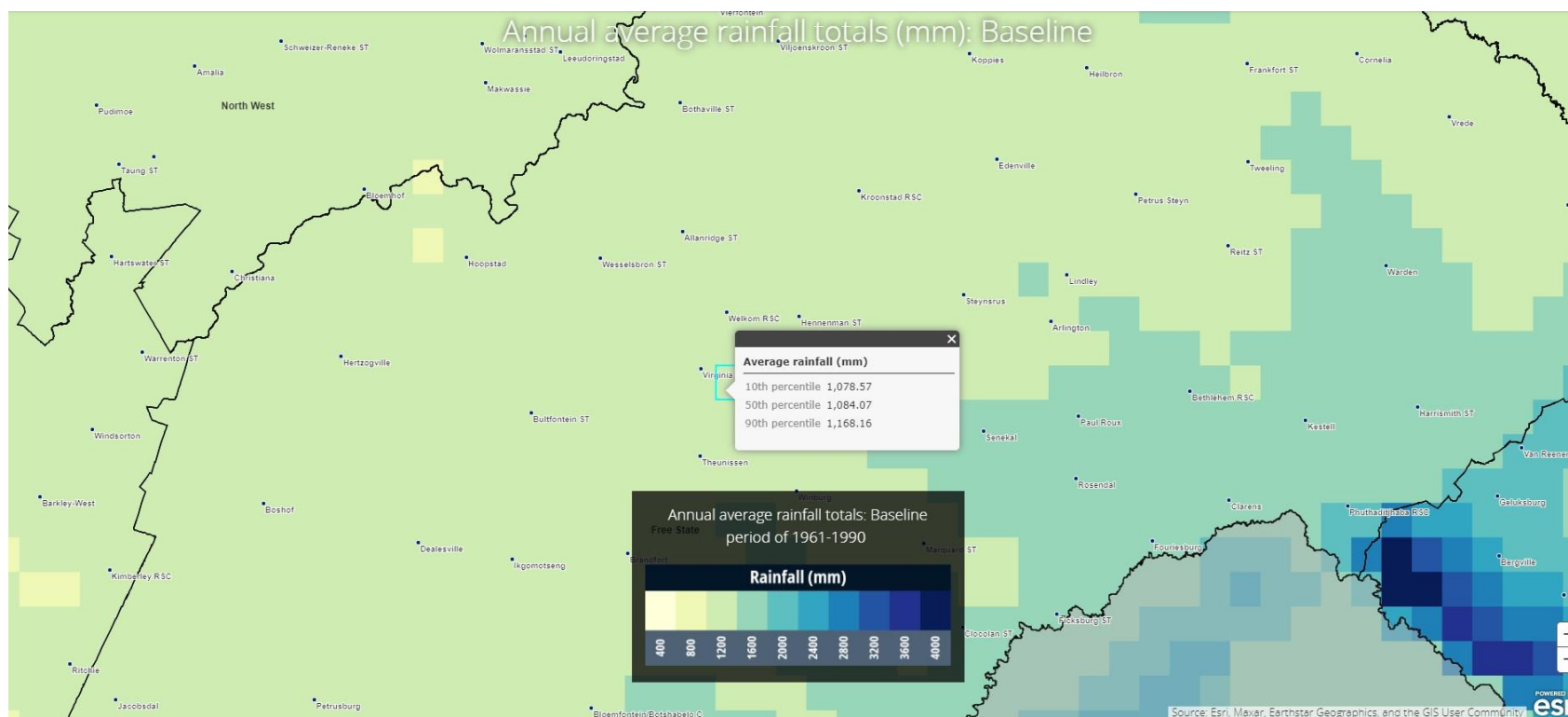


Figure 5: Baseline (1961 to 1990) annual average rainfall for the project area (CSIR, 2019)

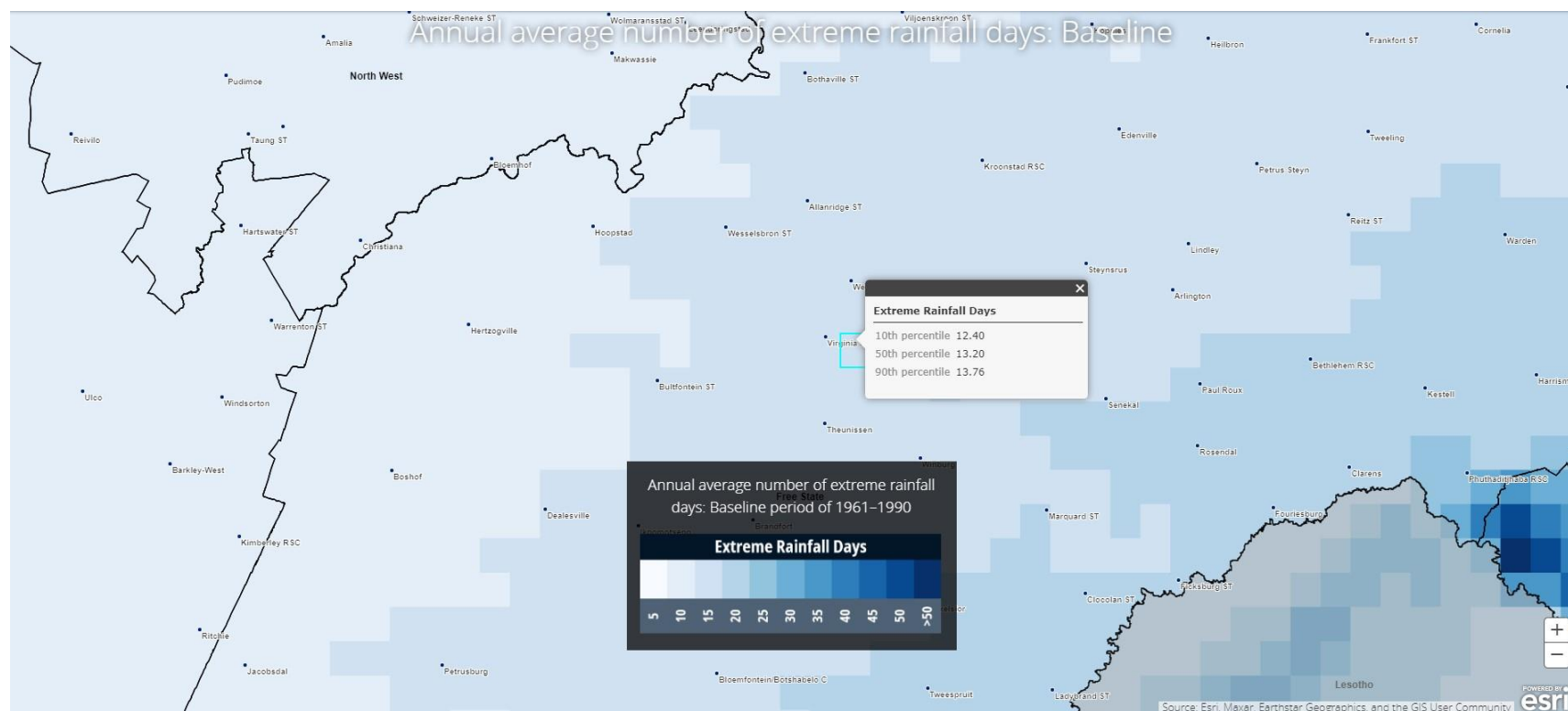


Figure 6: Baseline (1961 to 1990) annual average number of extreme rainfall days (>20 mm in <24 hours) for the project area (CSIR, 2019)

Recent change in climatic conditions near the project site were accessed from MeteoBlue¹³ a weather forecasting platform developed at the University of Basel, Switzerland and based on models of National Oceanic and Atmospheric Administration (NOAA) or National Centres for Environmental Prediction (NCEP). The data sets also include historical climate data tracking changes in climate by referencing ERA5, the fifth generation ECMWF (European Centre for Medium-Range Weather Forecasts) atmospheric reanalysis of the global climate, for the period between 1979 to 2021, with a spatial resolution of 30 km. Based on a point selected over the project site, an increasing trend in the annual average temperatures have been observed from 16.9°C in 1979 to 17.5°C in 2023 (Figure 7 – top panel). The lower part the graph shows the so-called warming stripes. Each coloured stripe represents the average temperature for a year - blue for colder and red for warmer years. The change in rainfall over the same period (1979 – 2023) displays a slight decreasing trend from 646 mm in 1979 to 555 mm in 2023 (Figure 8), where the difference from long-term average for each year in the data set is visualised by the stripes in the lower panel of Figure 8 (brown stripes indicate lower than average rainfall and green stripes above average rainfall).

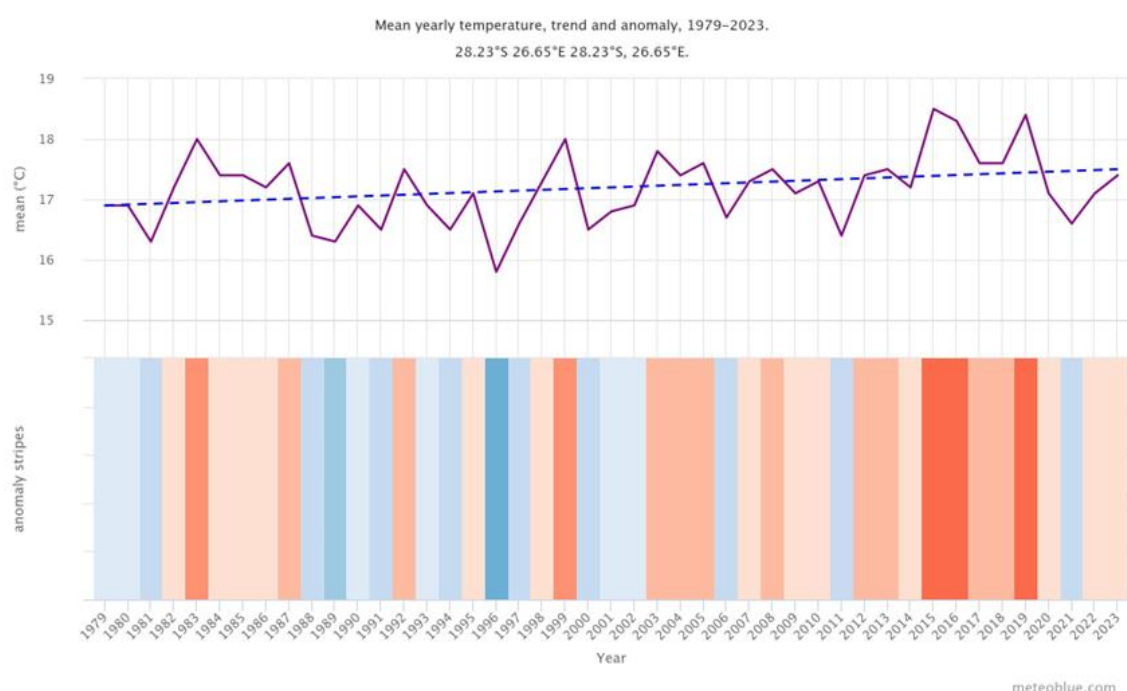


Figure 7: Annual average temperature (top panel) and temperature anomaly (lower panel) between 1979 and 2023 (meteoblue AG, 2024)

¹³ <https://www.meteoblue.com>

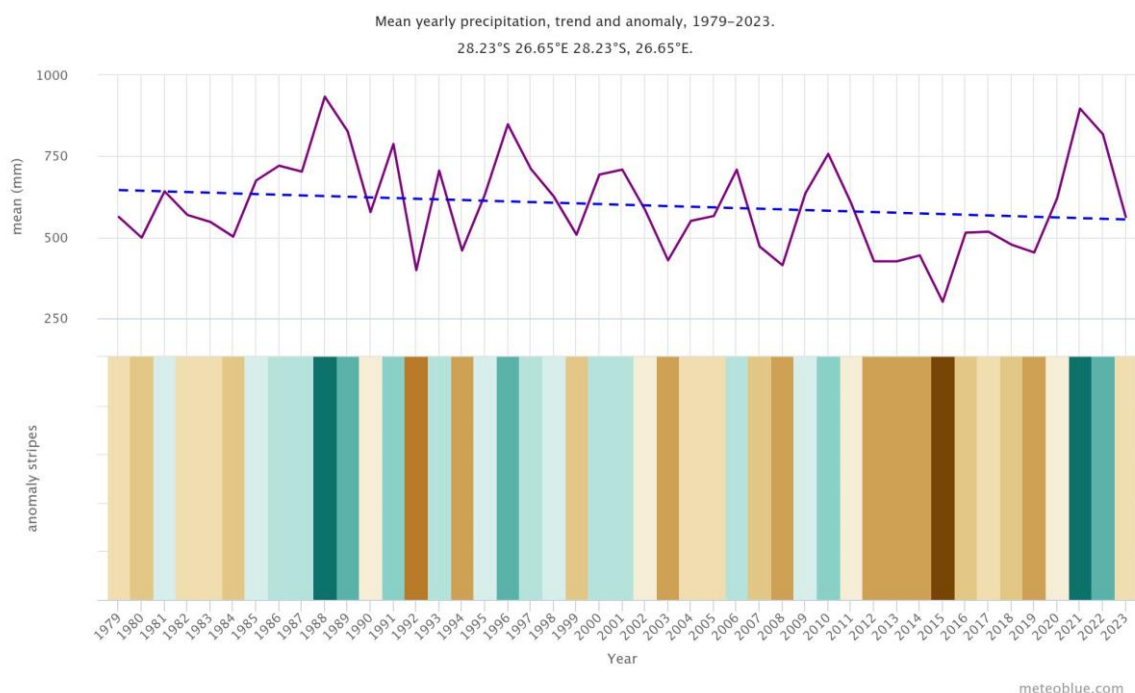


Figure 8: Annual average rainfall (top panel) and rainfall anomaly (lower panel) between 1979 and 2023 (meteoblue AG, 2024)

3.2.2 Projected Future Climate

In 2017 the South African Weather Services (SAWS) published an updated Climate Change Reference Atlas (CCRA) based on Global Climate Change Models (GCMs) projections (SAWS, 2017). It must be noted that as with all atmospheric models there is the possibility of inaccuracies in the results because of the model's physics and accuracy of input data. The Rossby Centre regional model (RCA4) was used in the predictions for the CCRA which included the input of nine GCMs results. The RCA4 model was used to improve the spatial resolution to $0.44^{\circ} \times 0.44^{\circ}$ - the finest resolution GCMs in the ensemble were run at resolutions of $1.4^{\circ} \times 1.4^{\circ}$ and $1.8^{\circ} \times 1.2^{\circ}$. Findings from downscaled climatic simulations using six GCMs, at an 8 km x 8 km resolution over South Africa, for the time slab 2021 to 2050 were included in the Green Book (Engelbrecht, 2019).

In both the CCRA and the Green Book, two trajectories are included based on the four Representative Concentration Pathways (RCPs) discussed in the IPCC's fifth assessment report (AR5) (IPCC, 2013). RCPs are defined by their influence on atmospheric radiative forcing in the year 2100. RCP4.5 represents an addition to the radiation budget of 4.5 W/m^2 as a result of an increase in GHGs. The two RCPs selected were RCP4.5 representing the medium-to-low pathway and RCP8.5 representing the high pathway. RCP4.5 is based on a CO_2 concentration of 560 ppm and RCP8.5 on 950 ppm by 2100. RCP4.5 is based on if current interventions to reduce GHG emissions being sustained (after 2100 the concentration is expected to stabilise or even decrease). RCP8.5 is based on if no interventions to reduce GHG emissions being implemented (after 2100 the concentration is expected to continue to increase).

3.2.2.1 RCP4.5 Trajectory

The Green Book projected temperature changes in the near future (2021 to 2050) indicate a 50th percentile increase of 2.3°C and a 90th percentile increase of 2.8°C (Figure 9, Engelbrecht, et al., 2019). The number of very hot days are expected to increase by 9.7 days per year (50th percentile) to 15.1 days per year (90th percentile) (Figure 10). Between 2021 and 2050 the annual rainfall near the project site is projected to increase by 180 mm per year (50th percentile) (Figure 11, Engelbrecht, et al., 2019), with extreme rainfall days potentially increasing by 1.7 days (50th percentile) in the near future (Figure 12, Engelbrecht, et al., 2019).

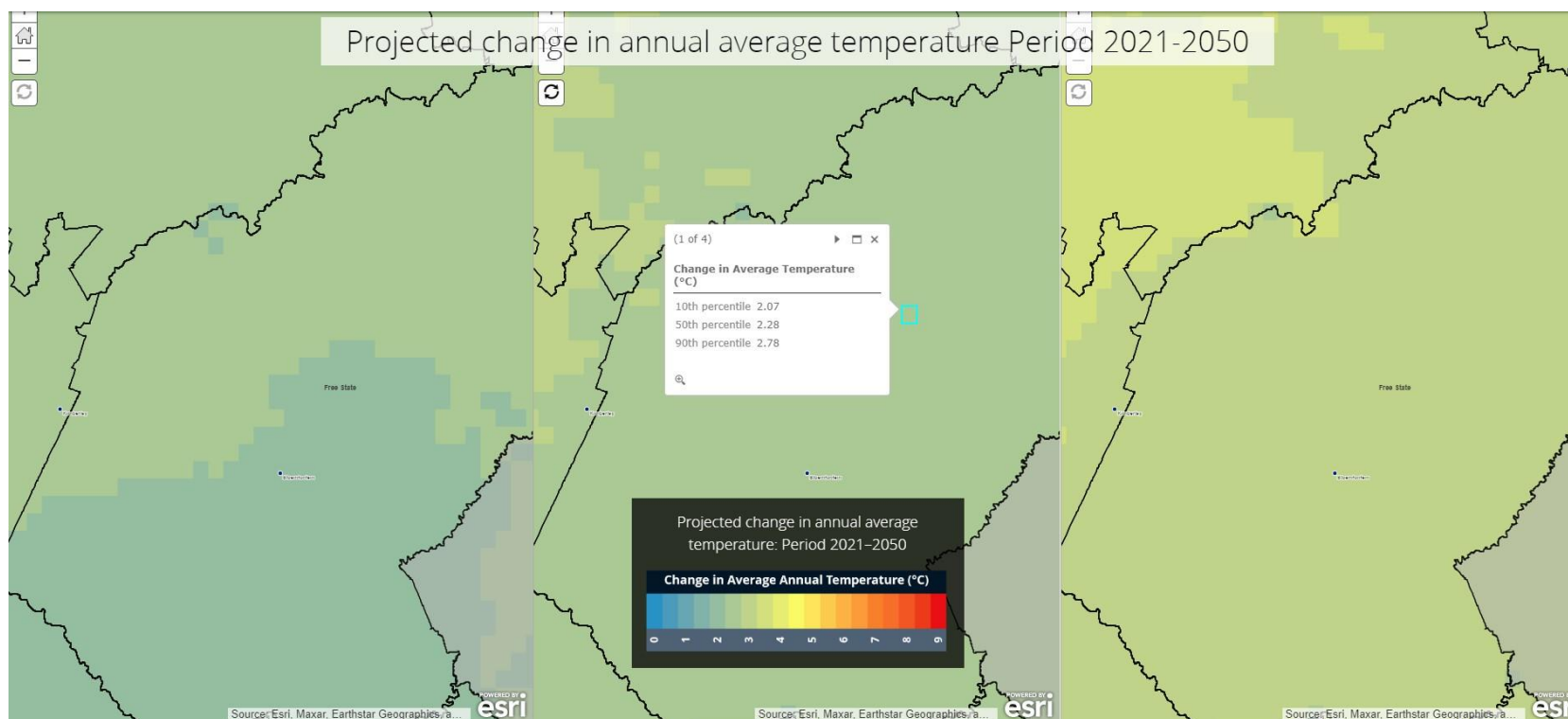


Figure 9: Projected change in annual average temperature for the near future (2021 – 2050) for the RCP4.5 trajectory

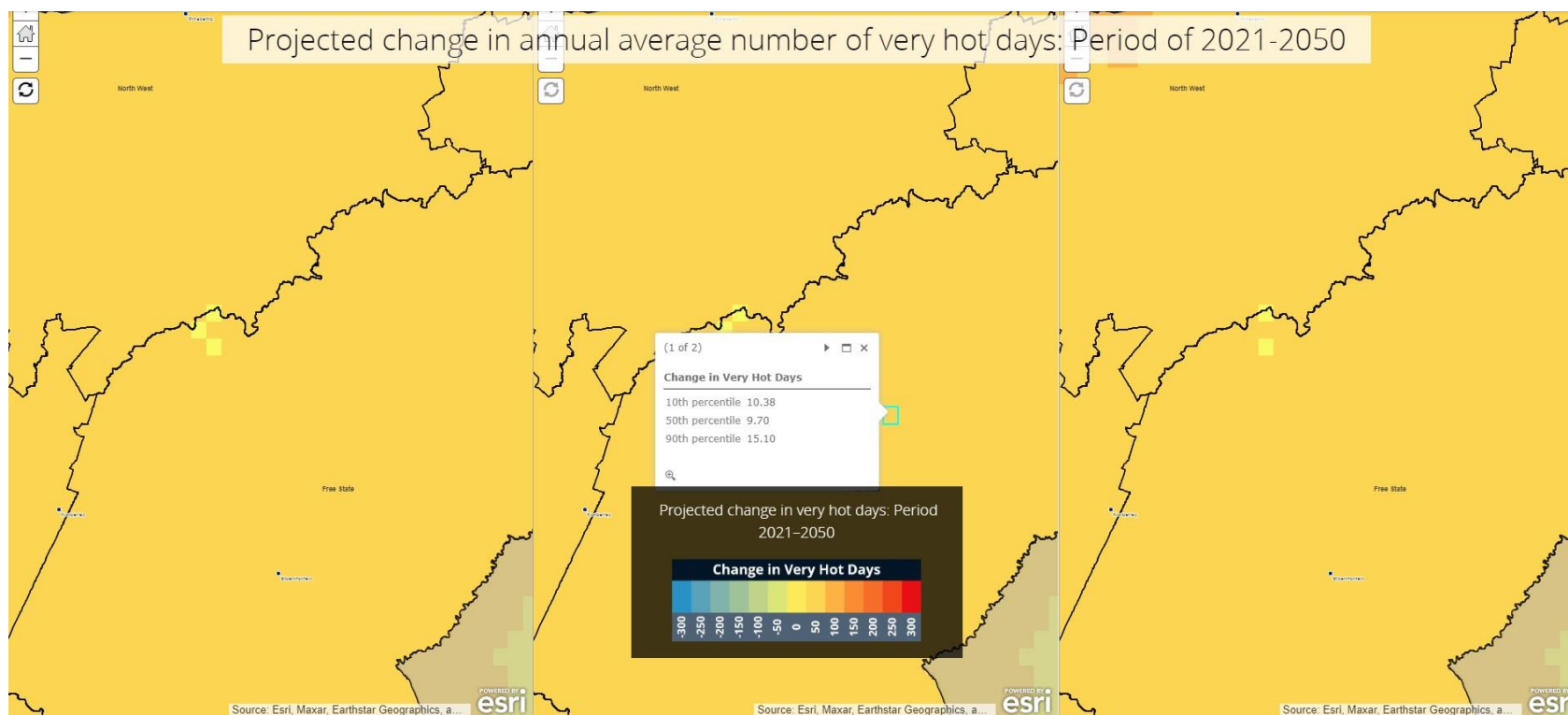


Figure 10: Projected change in very hot days for the near future (2021 – 2050) for the RCP4.5 trajectory

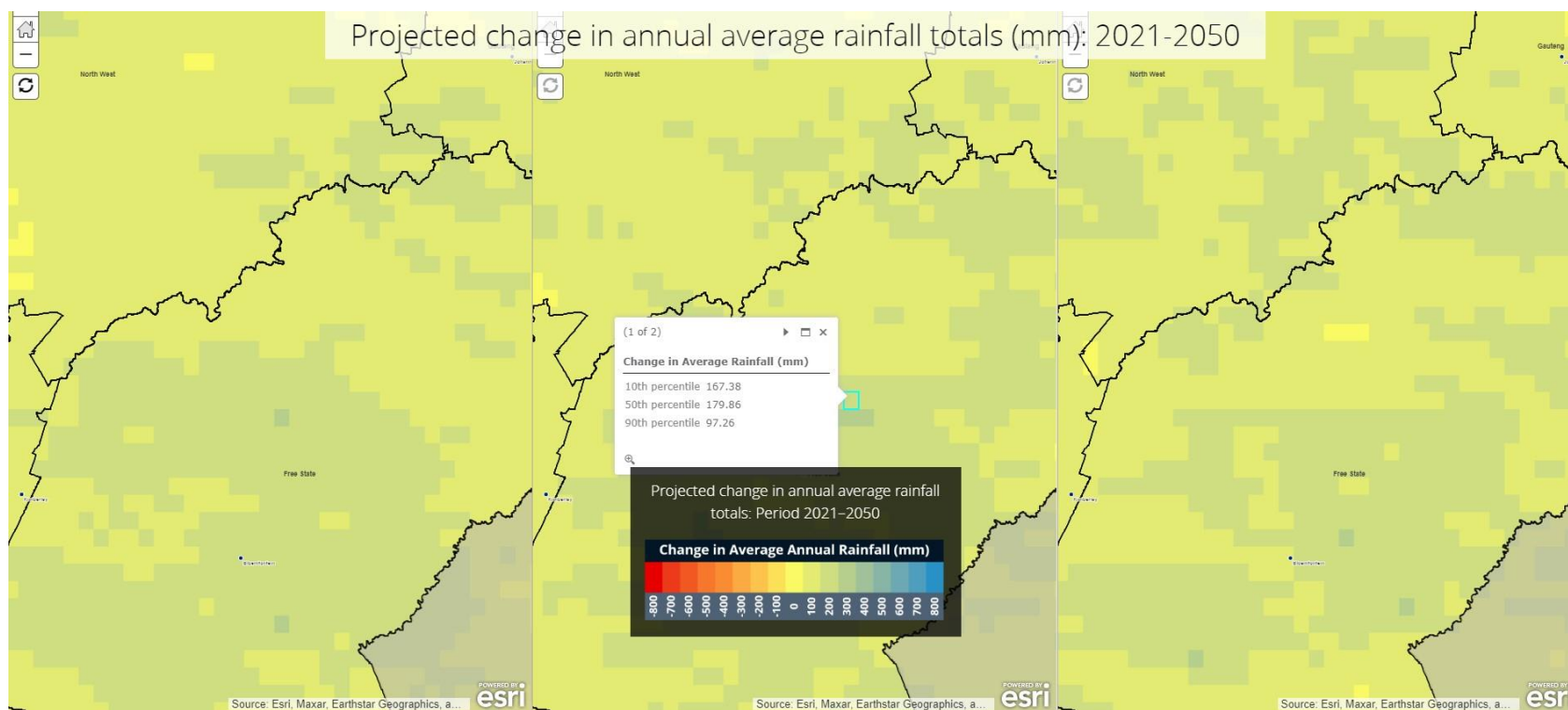


Figure 11: Projected change in annual average rainfall for the near future (2021 – 2050) for the RCP4.5 trajectory

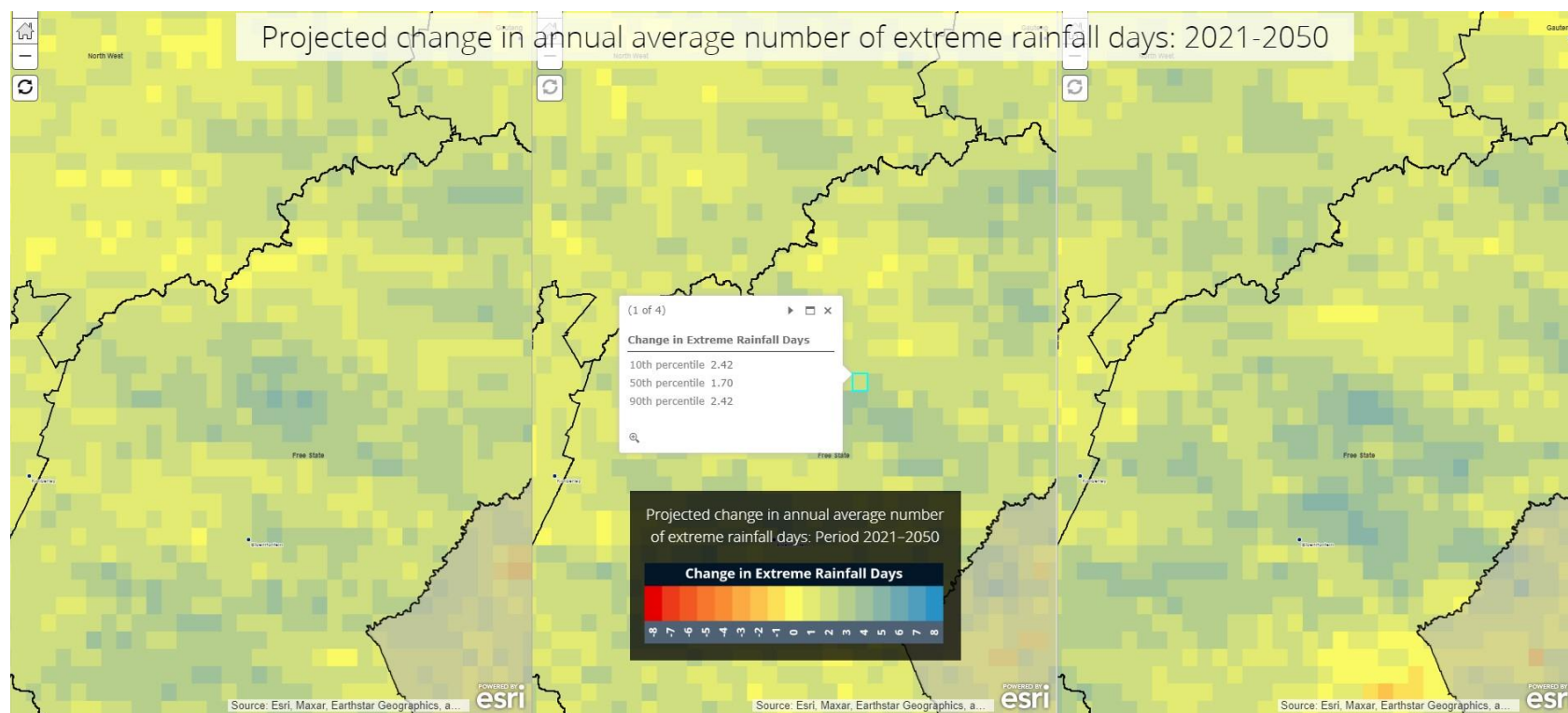


Figure 12: Projected change in annual average number of extreme rainfall days (>20 mm in <24 hours) for RCP4.5 trajectory

3.2.2.2 RCP8.5 Trajectory

The Green Book projected temperature changes in the near future (2021 to 2050) indicate a 50th percentile increase of 2.6°C and a 90th percentile increase of 3.2°C (Figure 13, Engelbrecht, *et al.*, 2019). The number of very hot days are expected to increase to 17.1 days per year (50th percentile) (Figure 14). Between 2021 and 2050 the annual rainfall near the project site was projected to increase by 200 mm per year between 2021 and 2050 (50th percentile) (Figure 15, Engelbrecht, *et al.*, 2019), with extreme rainfall to increase by 1.5 days (Figure 16, Engelbrecht, *et al.*, 2019).

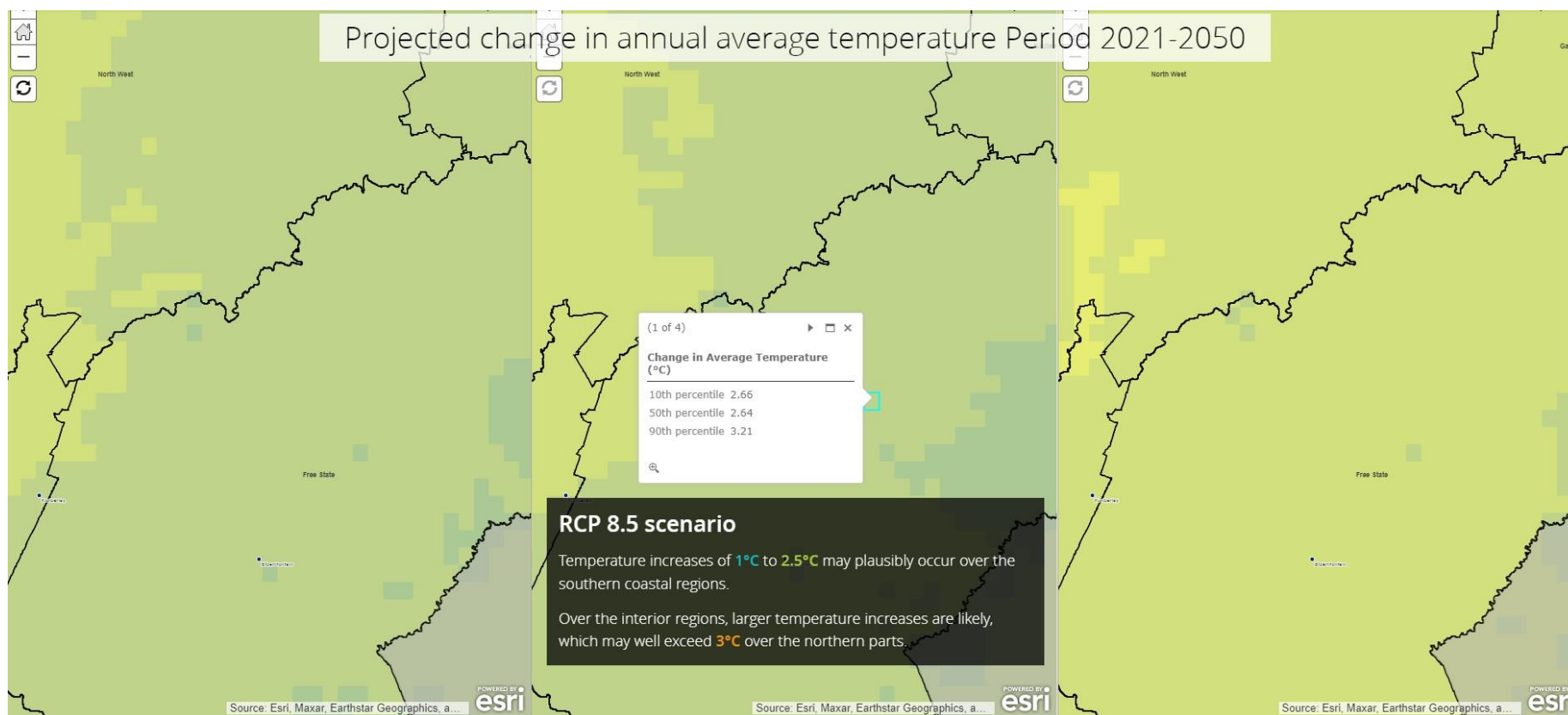


Figure 13: Projected change in annual average temperature for the near future (2021 – 2050) for the RCP8.5 trajectory

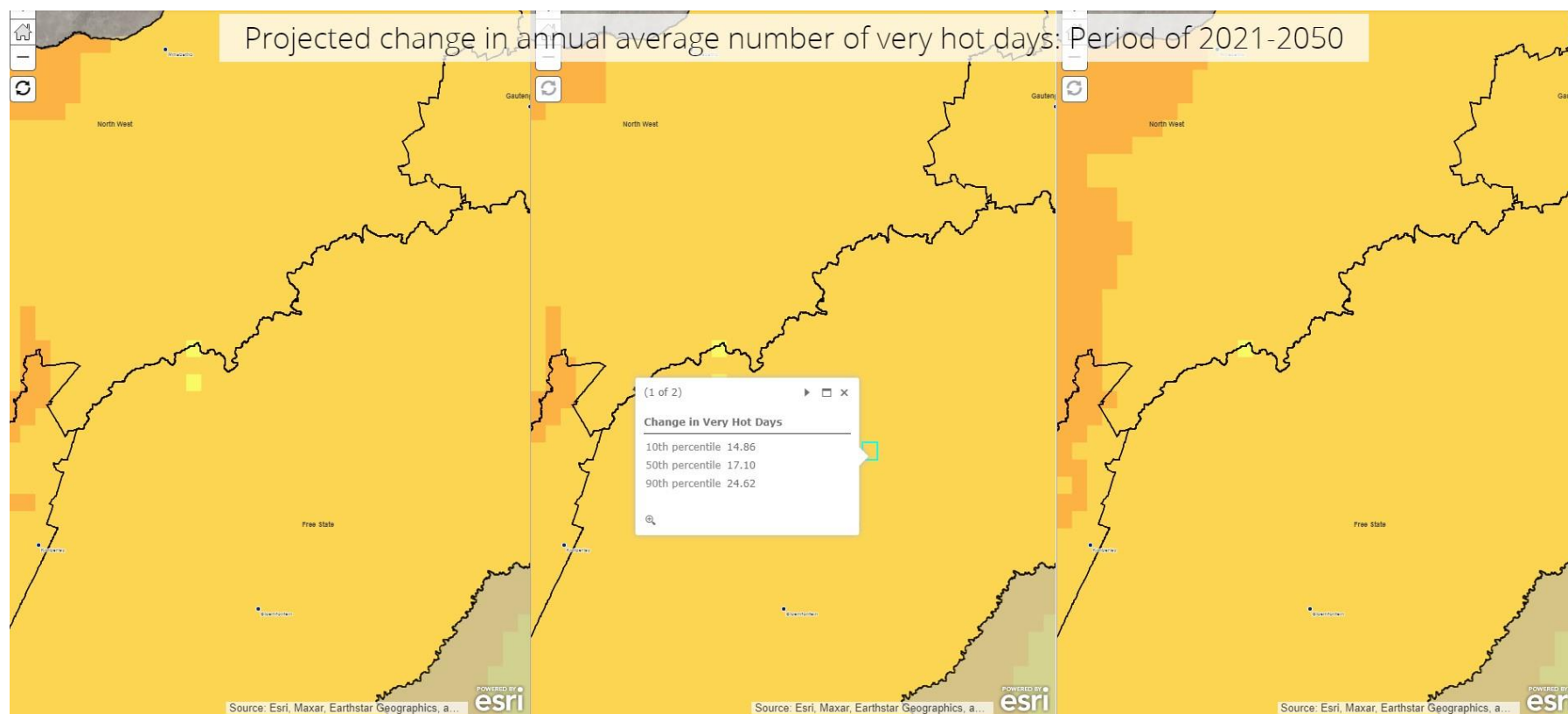


Figure 14: Projected change in very hot days for the near future (2021 – 2050) for the RCP8.5 trajectory

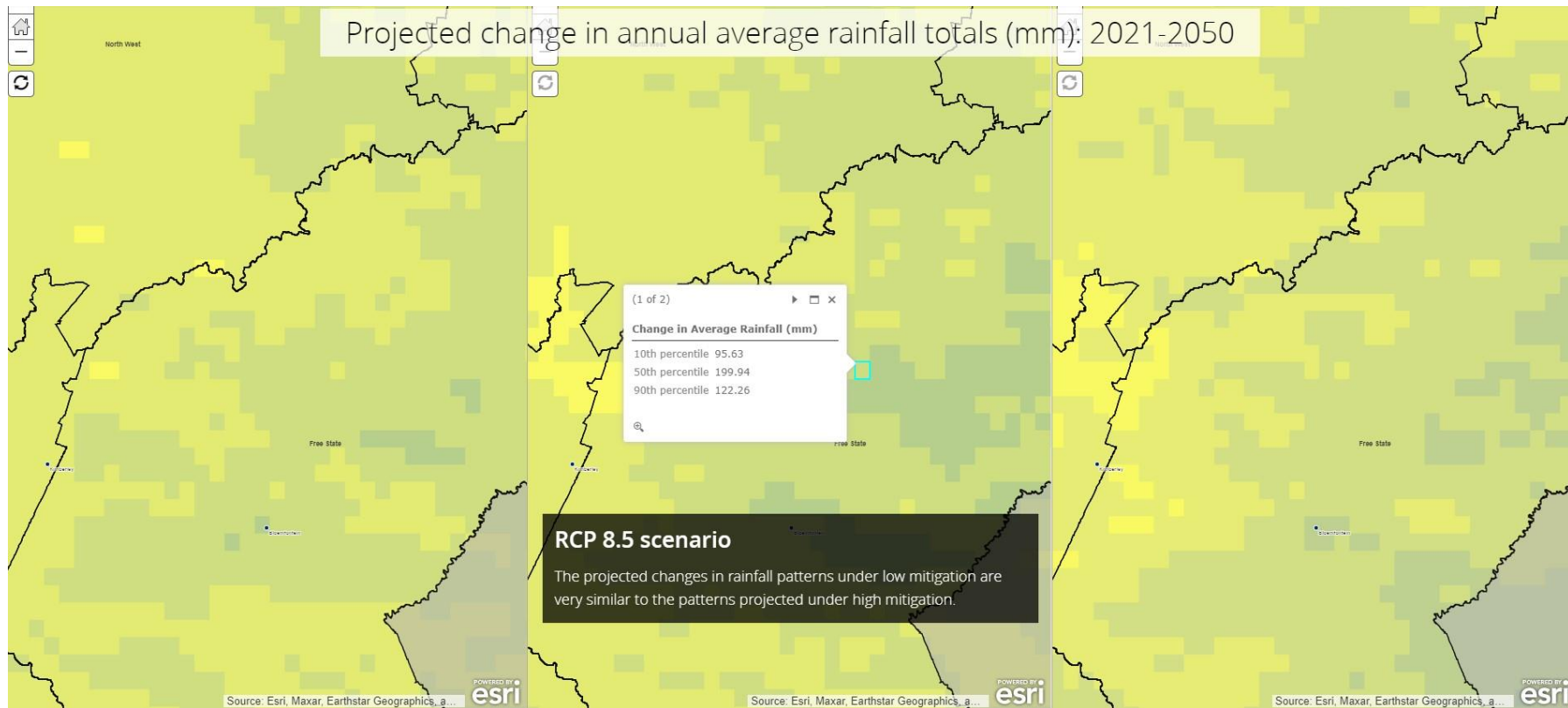


Figure 15: Projected change in annual average rainfall for the near future (2021 – 2050) for the RCP8.5 trajectory

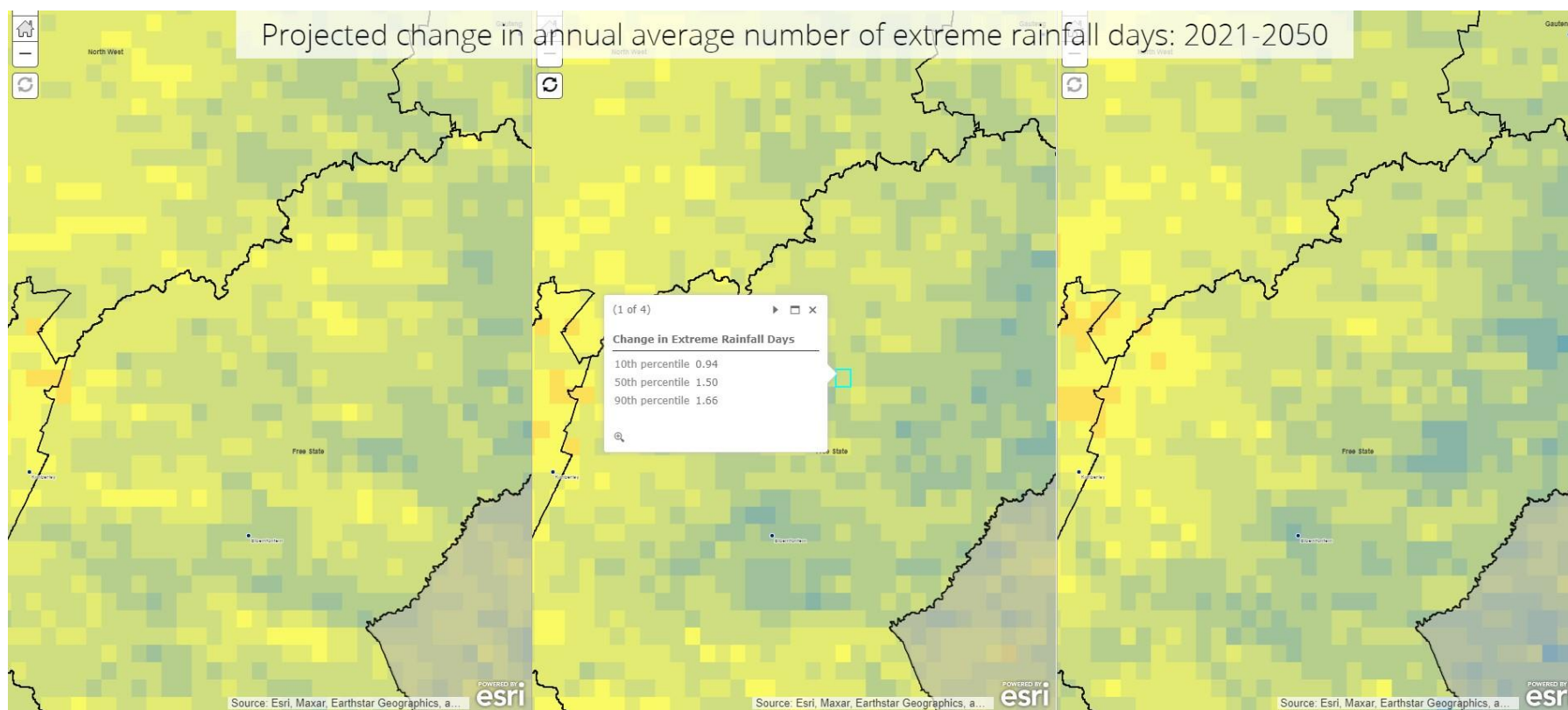


Figure 16: Projected change in annual average number of extreme rainfall days (>20 mm in <24 hours) for RCP8.5 trajectory

3.2.2.3 IPCC's Sixth Assessment Report: Temperature and Rainfall Projections

The most recent IPCC data are from the Coupled Model Intercomparison Project (CMIP) which were derived from the sixth phase of the CMIPs (CMIP6) and supports the IPCC's Sixth Assessment Report (AR6) which was released on 9 August 2021 (Working Group I), 28 February 2022 (Working Group II and 4 April 2022 (Working Group III). Projection data is presented at a 1.0° x 1.0° (100 km x 100 km) resolution. The scenarios are the result of complex calculations that depend on how quickly humans curb greenhouse gas emissions, whilst also capturing socioeconomic changes in areas such as population, urban density, education, land use and wealth. For example, a rise in population is assumed to lead to higher demand for fossil fuels and water. Education can affect the rate of technology developments. Emissions increase when land is converted from forest to agricultural land. Each scenario is labelled to identify both the emissions level and the so-called Shared Socioeconomic Pathway, or SSP, used in those calculations. This first scenario is the only one that meets the Paris Agreement's goal of keeping global warming to around 1.5°C above preindustrial temperatures, with warming hitting 1.5°C but then dipping back down and stabilizing around 1.4°C by the end of the century. Projected changes are defined relative to a historical 20-year period (1995 to 2014).

The AR6 projections for the study area for the scenario RCP4.5 indicate an increase in annual average temperatures of 2.4°C for the period 2041 to 2060 and 3.4°C for the period 2081 to 2100. The projections for the RCP8.5 indicate an increase in annual average temperatures of 2.9°C for the period 2041 to 2060, to 6.2°C for the period 2081 to 2100 (IPPC, 2022). The AR6 temperature projections for the period 2041 to 2060 are slightly higher than the AR5 projections (increase in annual average temperatures of 2.3°C for RCP4.5 and 2.6°C for RCP8.5) for the period 2021 to 2050. It should be noted, however, that these projections are based on different projected time frames.

The AR6 projections for rainfall in the study area for RCP4.5 indicate a decrease in annual rainfall of 5.9% for the period 2041 to 2060. The projections for RCP8.5 indicate decrease of rainfall of 8% for the period 2041 to 2060 (IPPC, 2022). The AR5 projections indicate an increase in annual rainfall of 16.6% for the RCP4.5 scenario.

3.3 Hazards

The Green Book risk profile includes an assessment of projected risk to the Matjhabeng Local Municipality in 2050, mostly based on the low mitigation RCP8.5 climate simulations, and highlights the following:

- For 2050 there is 26 increased fire danger days over the project area (Figure 17);
- There is an increase in drought tendencies (i.e. the number of cases exceeding near-normal per decade) for the period 2035–2064 relative to the 1986–2005 baseline period, under the low mitigation scenario (RCP 8.5). The Standardized Precipitation Index (SPI)¹⁴ is -0.46 (Figure 18). A negative value is indicative of an increase in drought tendencies per 10 years (more frequent than baseline);
- There are no settlements at risk of encountering increasing heat stresses over the project area (Figure 19); and,
- There is no significant increase in extreme daily rainfall for the project area (1.005)¹⁵ (Figure 20).

¹⁴ The Standardized Precipitation Index (SPI) is a widely used index to characterize meteorological drought on a range of timescales. SPI index.

¹⁵ A value of more than 1 indicates an increase in extreme daily rainfalls.

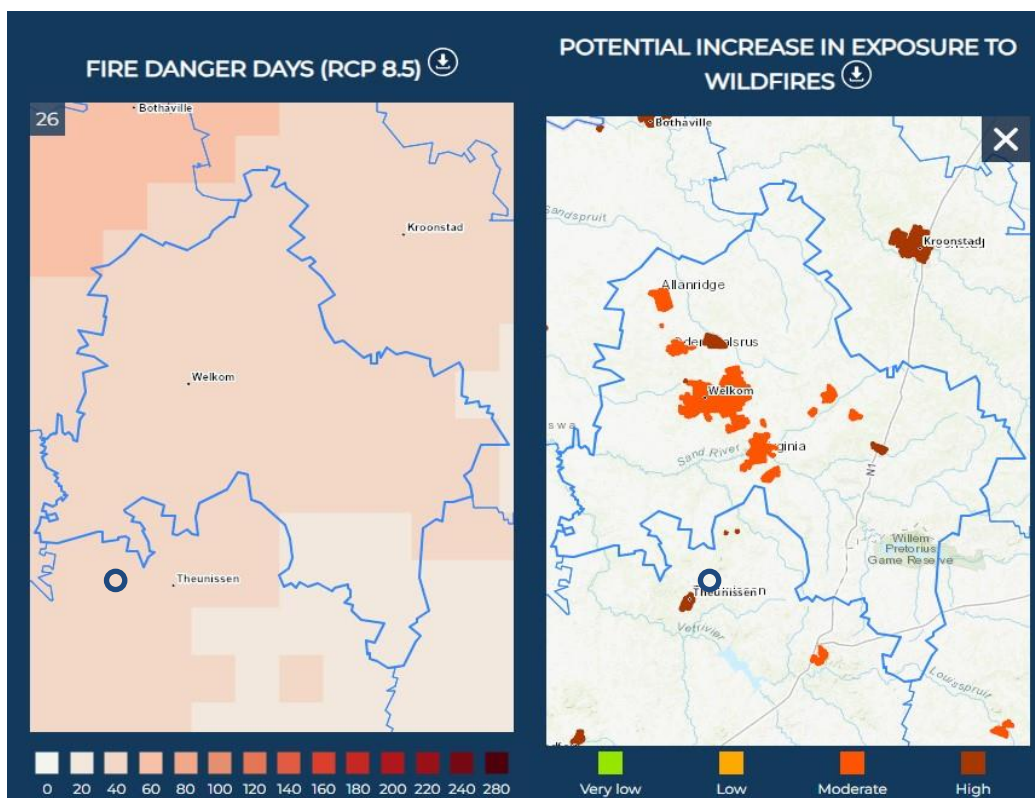


Figure 17: Risk of increased wildfires for Matjhabeng Local Municipality in 2050 based on RCP8.5 trajectory (dark blue marker indicates approximate location of the project)

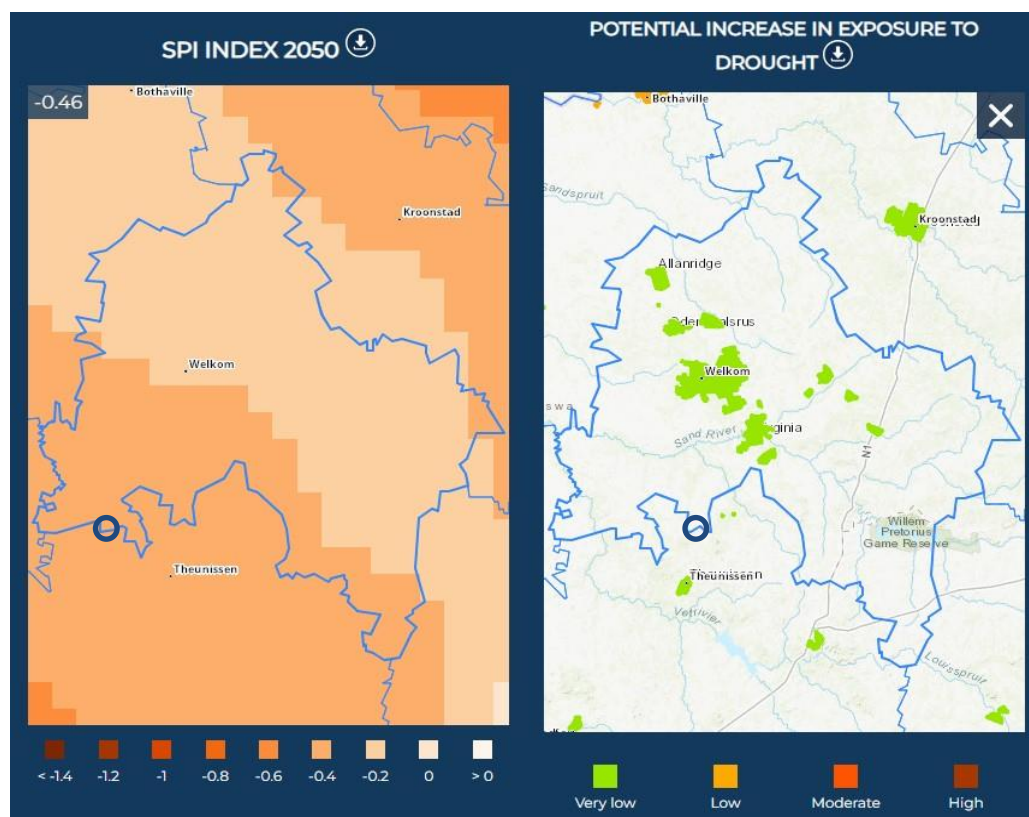


Figure 18: Risk of increased drought tendencies for Matjhabeng Local Municipality in 2050 based on RCP8.5 trajectory (dark blue marker indicates approximate location of the project)

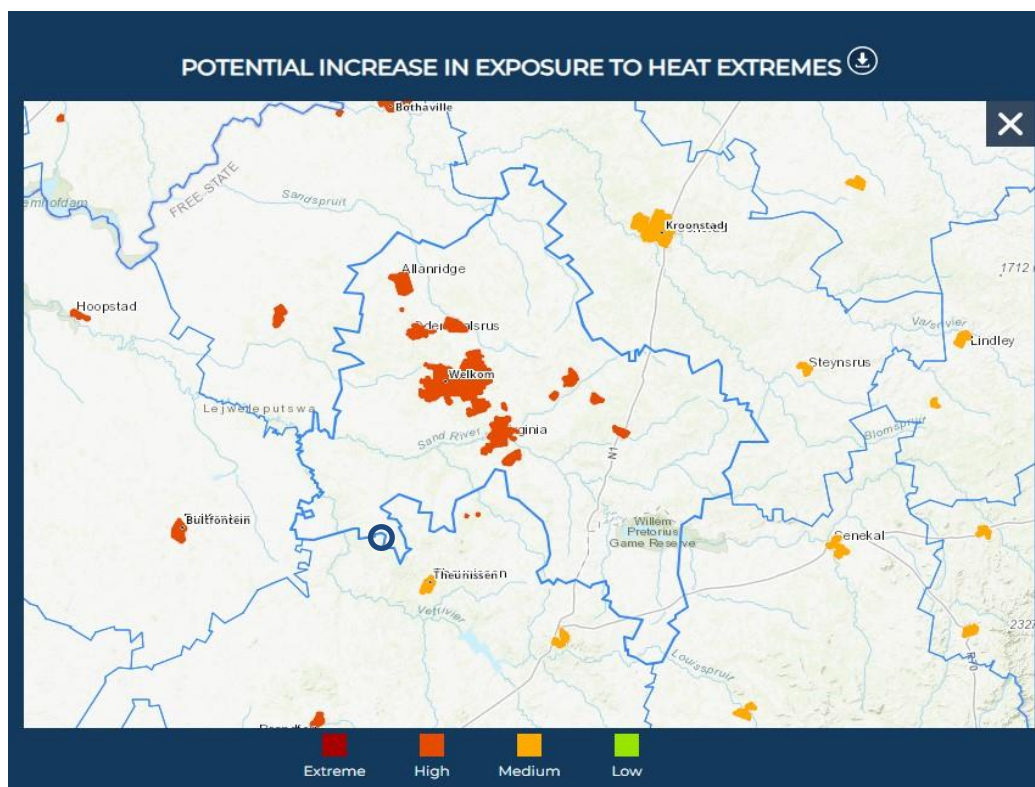


Figure 19: Risk of increased heat extremes for Matjhabeng Local Municipality in 2050 based on RCP8.5 trajectory (dark blue marker indicates approximate location of the project)

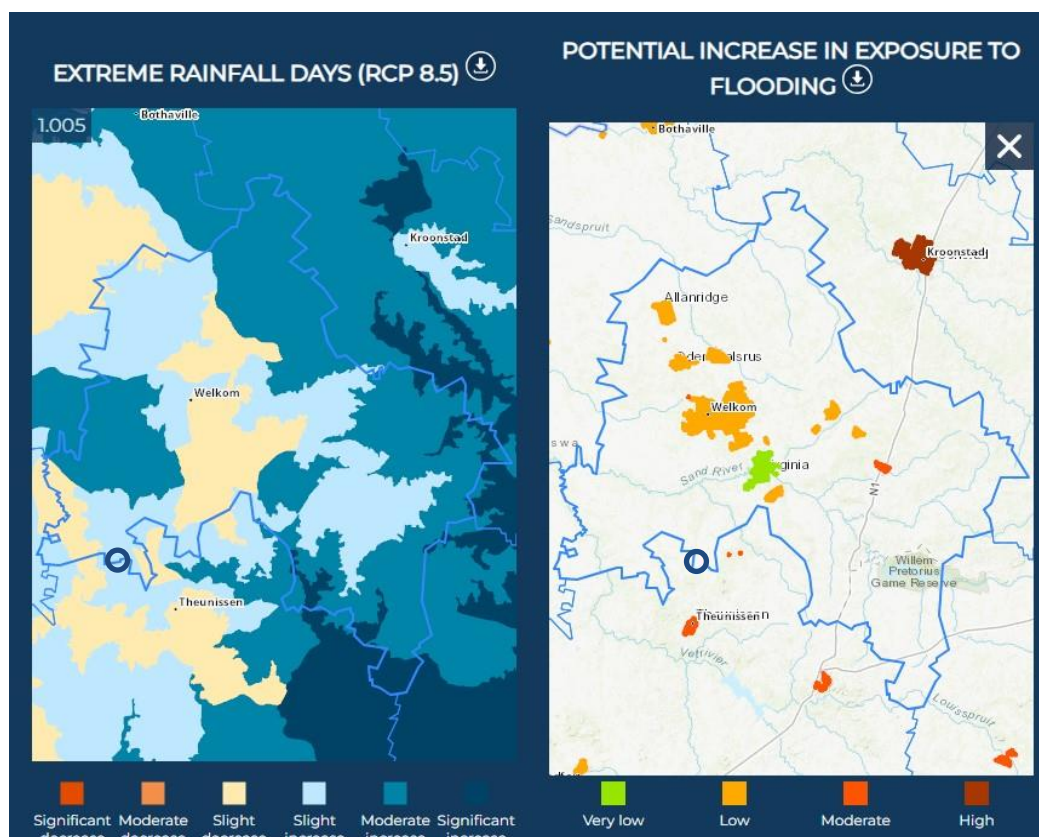


Figure 20: Risk of increased flooding for Matjhabeng Local Municipality in 2050 based on RCP8.5 trajectory (dark blue marker indicates approximate location of the project)

In addition to the hazards identified in the Green Book, Hofste, *et al.*, (2019) currently rate the project area at arid with low water use (Figure 21) with a projection of near normal risk of water stress for the future (2050 based on a conservative low mitigation trajectory) (Figure 22).

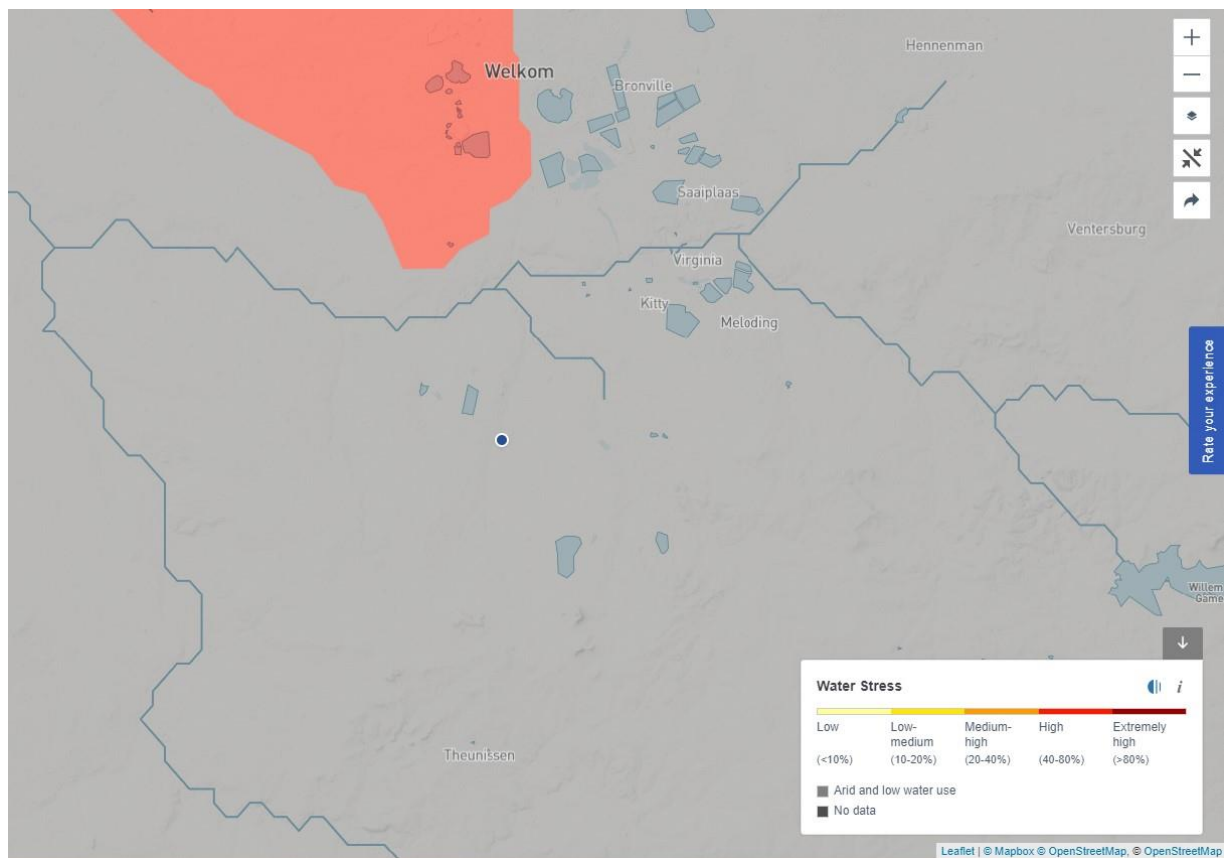


Figure 21: Current water stress for the project area (Hofste, et al., 2019) (blue dot indicates project location)

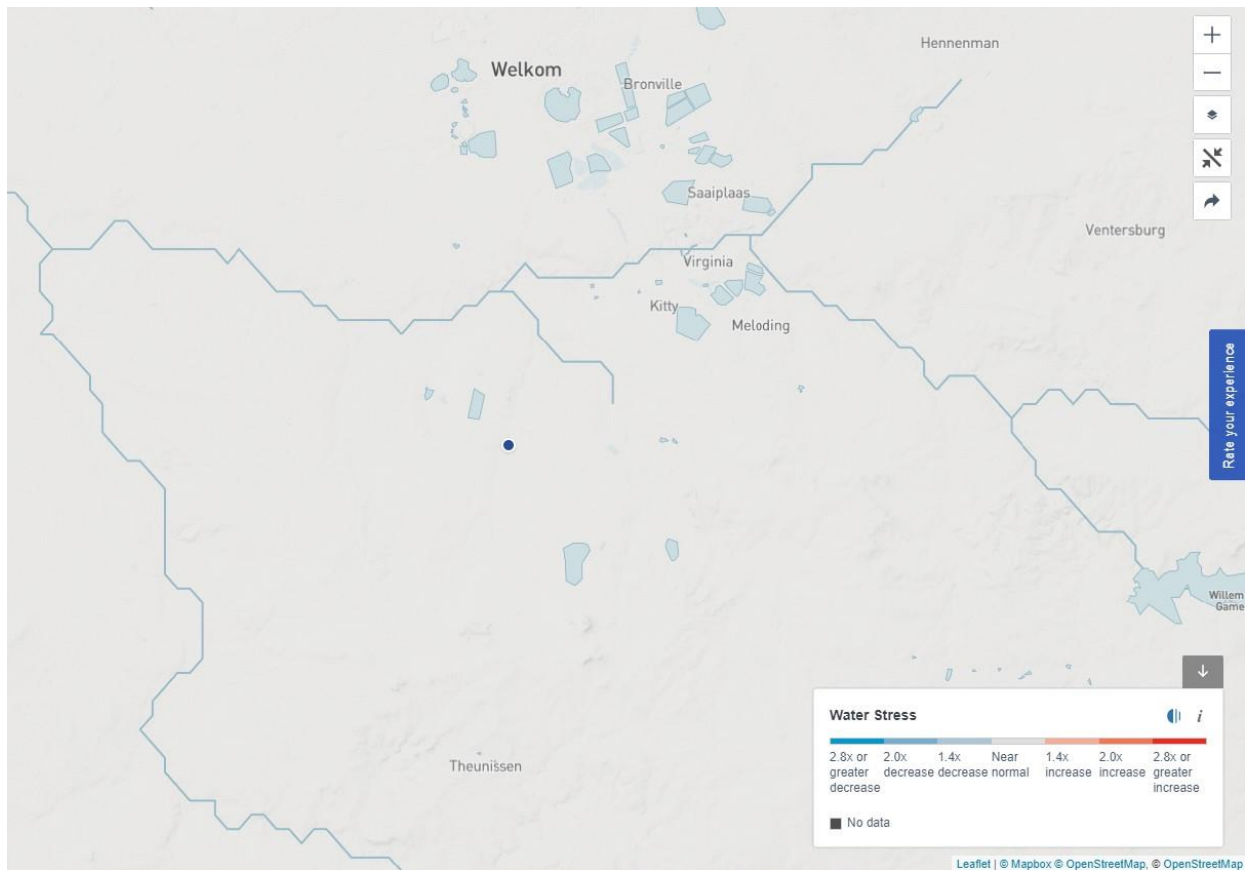


Figure 22: Projected (2050) water stress for the project area (Hofste, et al., 2019) (blue dot indicates project location)

3.4 Impact of Climate Change

To understand the impact that climate change might have on the major resources of the Matjhabeng Local Municipality it is first necessary to provide an overview of the current situation, which has been provided for water, economy, and agriculture.

3.4.1 Water Supply

3.4.1.1 Current Resources

Figure 23 provides the current water supply vulnerability (i.e., demand versus supply) for the Matjhabeng Local Municipality based on the data compiled for the Department of Water and Sanitation (DWS) All Town's Study (Cole, 2017). The current water demand for the municipality is 207 l/p/d (litres per person per day), and exceeds the supply of 144.5 l/p/d, with 100% of all water sourced from surface water.

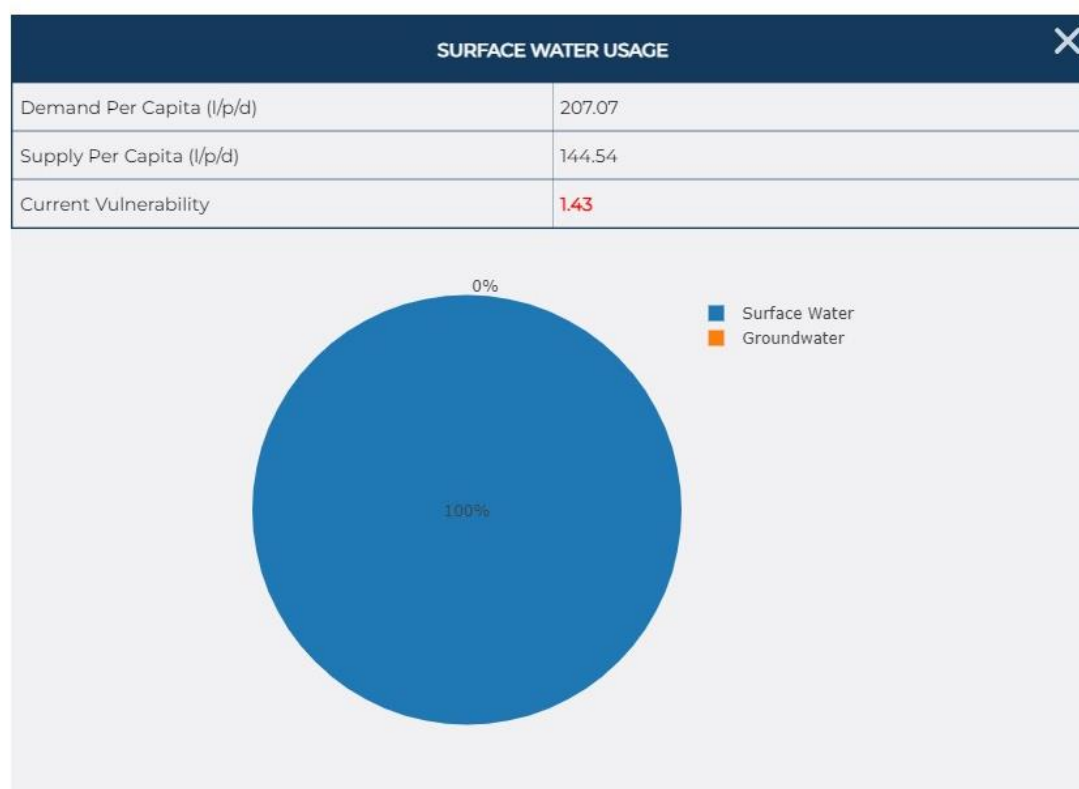
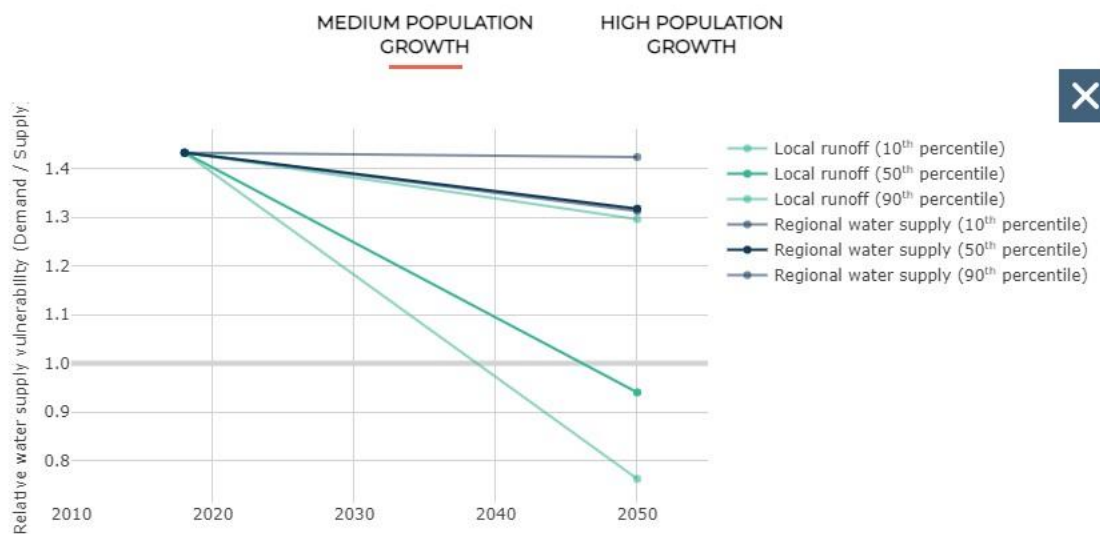


Figure 23: Current water availability for the Matjhabeng Local Municipality

3.4.1.2 Impact on Resources

Figure 24 shows the estimated current and future water supply vulnerability (i.e., the ratio of demand to supply) based on: 1) a local water supply perspective incorporating changes to population growth coupled with exposure to climate risk (based on impacts on local runoff), and 2) a regional water supply perspective (based on impacts of regional water supply assuming supply is part of the integrated regional and national bulk water supply network). The mean annual precipitation for the municipality is predicted to increase by 6.5% for 2050 with a regional urban water supply increase of 11.91%.



VULNERABILITY CONTRIBUTION FACTORS			PERCENTAGE CHANGE
	Mean annual precipitation		6.5%
	Mean annual evaporation		8.02%
	Mean annual runoff		56.82%
	Regional urban water supply		11.91%
	Population growth		-4.72%

Figure 24: Estimated current and future (2050) water supply vulnerability based on medium population growth for the Matjhabeng Local Municipality

3.4.2 Surface Water

3.4.2.1 Current Situation

The Matjhabeng Local Municipality is within the Vaal Primary Catchment (Figure 25).

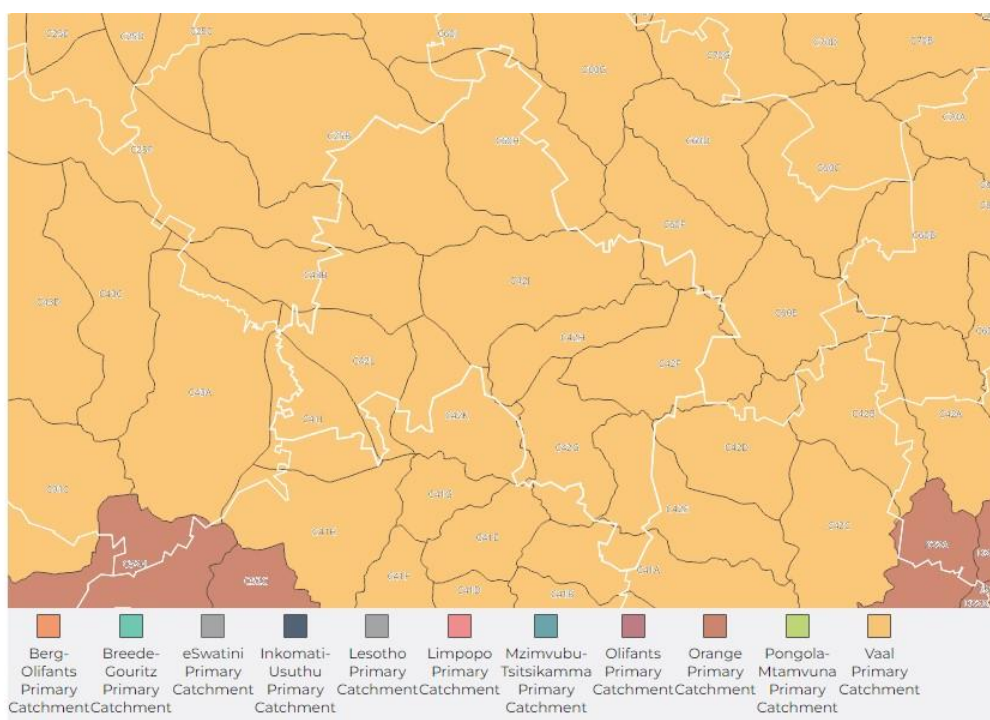


Figure 25: Quaternary catchment areas for the Matjhabeng Local Municipality

Figure 26 depicts the current annual and monthly surface water runoff, precipitation and evaporation for the Vaal Primary Catchment associated with the Matjhabeng Local Municipality. Precipitation and evaporation for the municipality is currently 534 mm/yr and 1 615 mm/yr respectively.

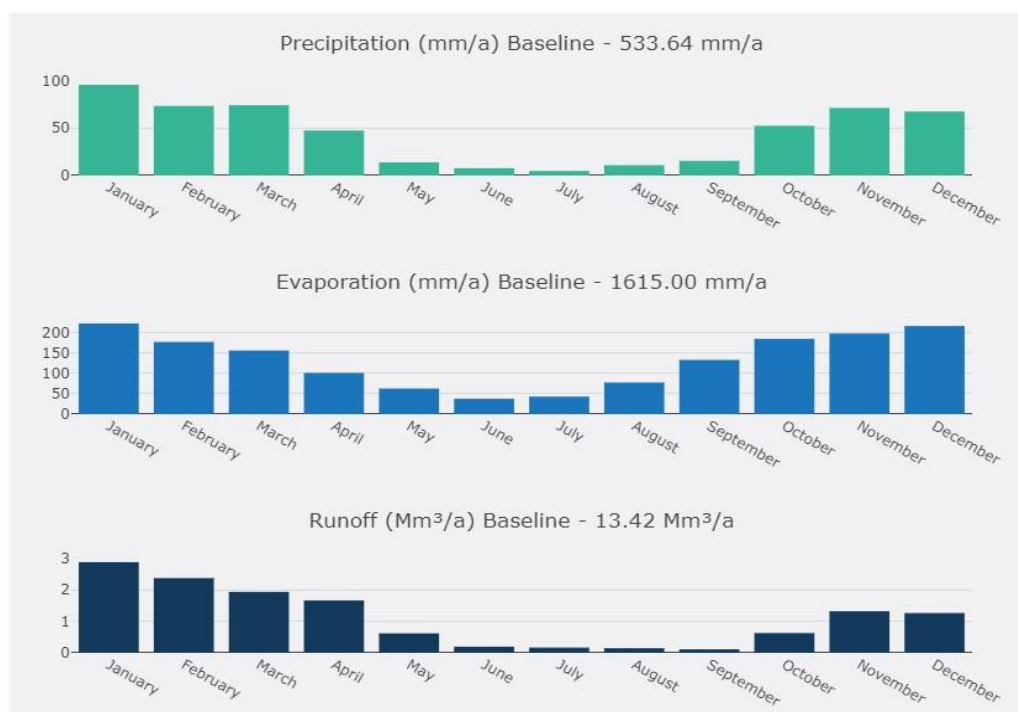


Figure 26: Current annual and monthly surface water runoff, precipitation and evaporation for the Matjhabeng Local Municipality which falls under the Vaal Primary Catchment

3.4.2.2 Projected Impact

Figure 27 provides the projected monthly change for future (2050) evaporation, precipitation, and estimated runoff values.

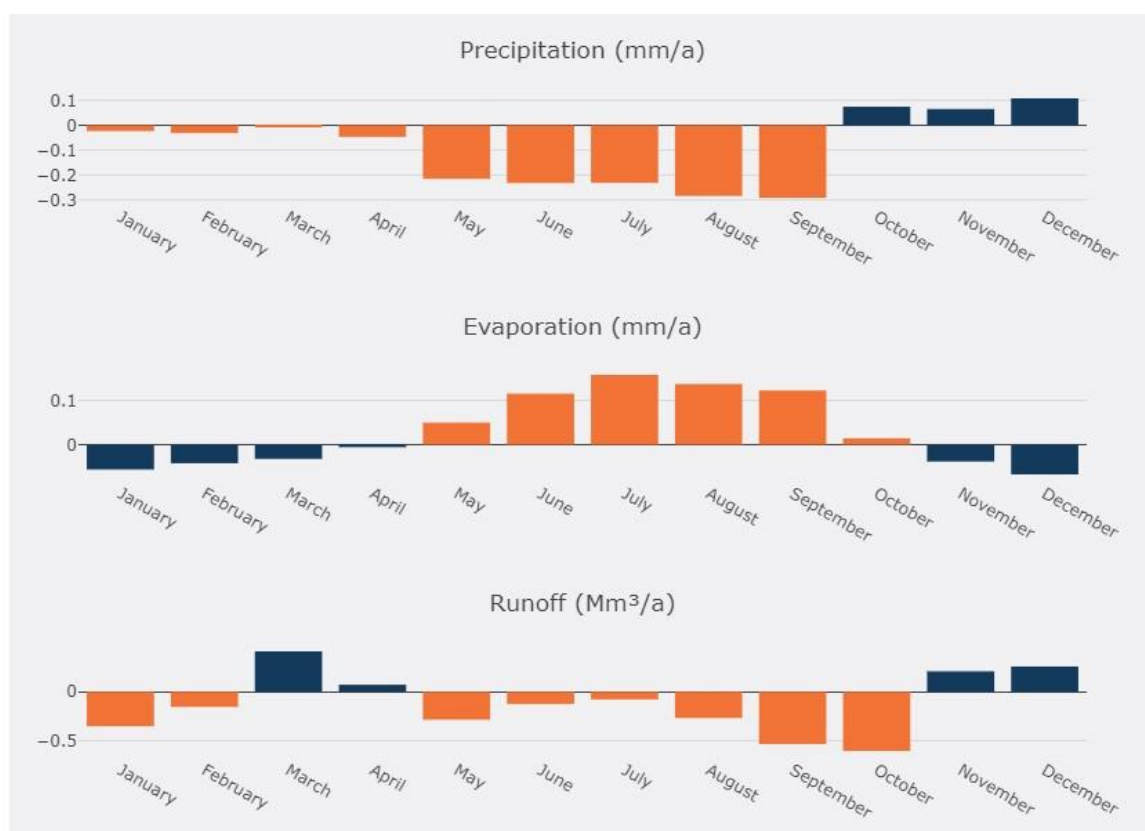


Figure 27: Projected monthly change to future (2050) evaporation, precipitation, and estimated runoff values

3.4.3 Ground Water

3.4.3.1 Current Situation

The groundwater recharge potential map indicates the occurrence and distribution of groundwater resources across the municipality, showing distinctive recharge potential zones. The groundwater dependency map indicates where settlements get their main water supply from, be it groundwater, surface water or a combination of both sources. Settlements that rely on groundwater, either entirely or partially, are deemed groundwater dependent. The project area is surface water dependent.

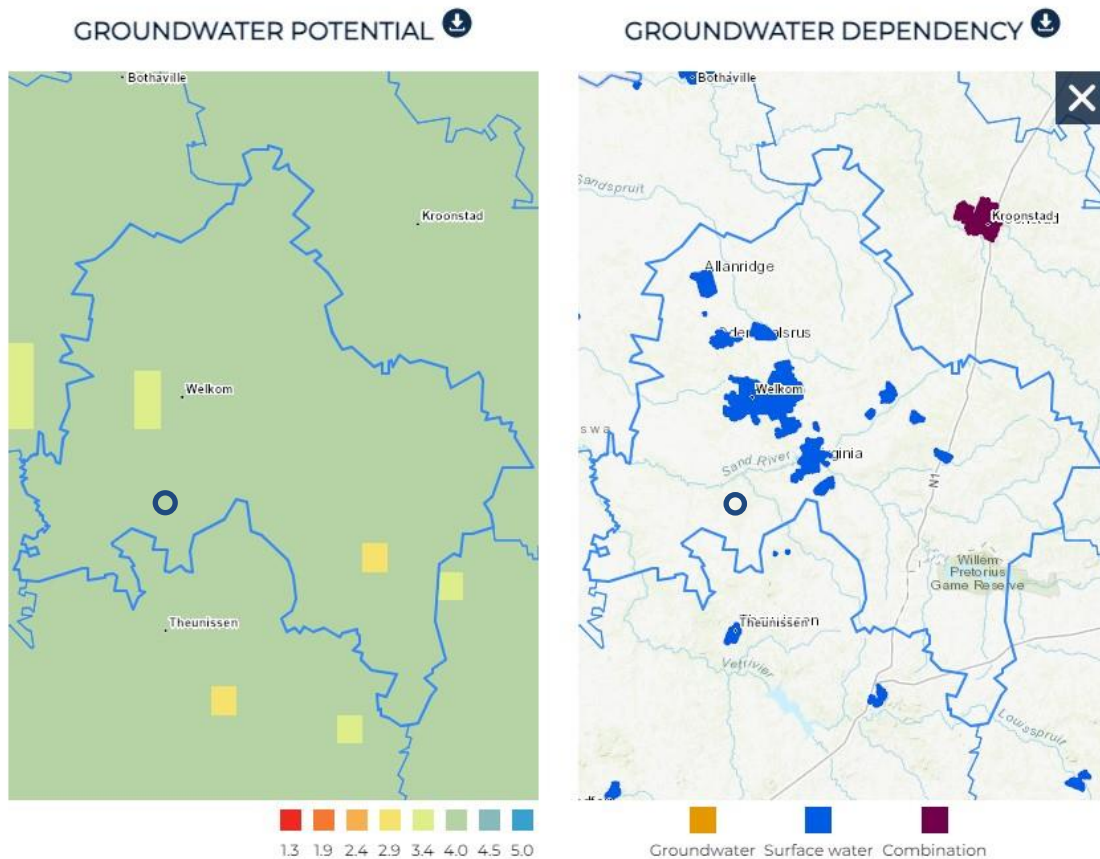


Figure 28: Groundwater potential and dependency for the Matjhabeng Local Municipality (dark blue marker indicates approximate location of the project)

3.4.3.2 Projected Impact

A groundwater depletion risk map was created to determine which of South Africa's groundwater dependent settlements may be most at risk to groundwater depletion based on decreasing groundwater aquifer recharge potential and significant increases in population growth pressure by 2050. The groundwater depletion risk map (Figure 29) is based on the settlement aquifer recharge potential of the 50th percentile RCP8.5 scenario, and the medium population growth scenario. There is a slight change to groundwater potential in the area.

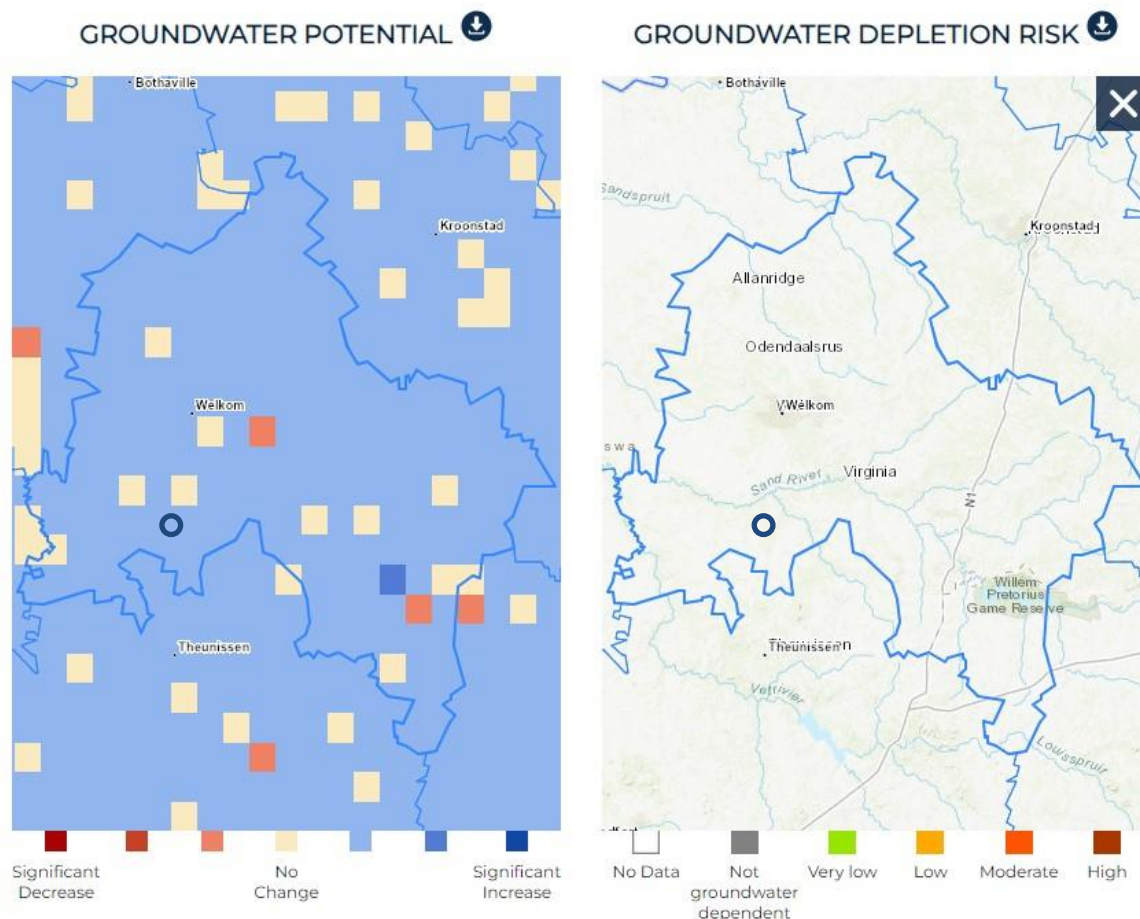


Figure 29: Groundwater potential and depletion for 2050 for the Matjhabeng Local Municipality (dark blue marker indicates approximate location of the project)

3.4.4 Economy

Figure 30 shows the contribution that the different economic sectors make to the total Gross Value Added (GVA)¹⁶ of the Matjhabeng Local Municipality as well as its national GVA rank (total GVA contribution to the national GVA). The Matjhabeng Local Municipality ranks 15th in the national GVA rank.

¹⁶ Gross value added (GVA) is an economic productivity metric that measures the contribution of a corporate subsidiary, company, or municipality to an economy, producer, sector, or region.

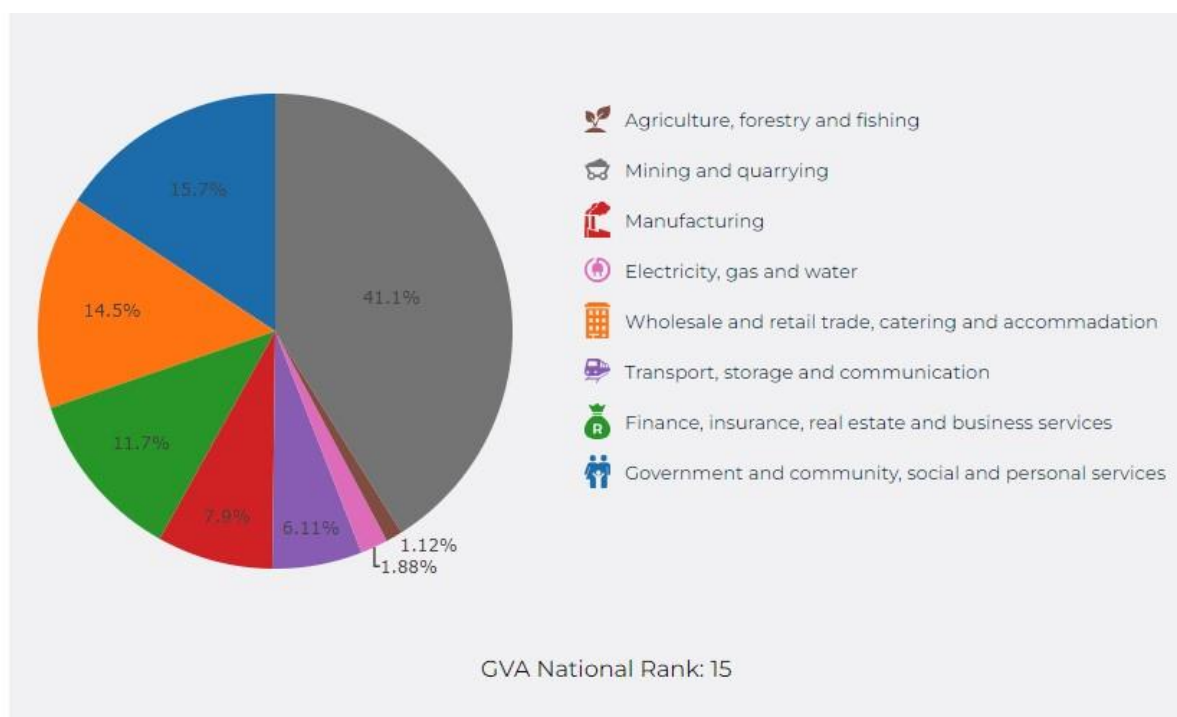


Figure 30: The contribution that the different economic sectors make to the total GVA of the Matjhabeng Local Municipality

Table 2 summarises the forecasted economic gains or losses for the Matjhabeng Local Municipality, under both the RCP4.5 and RCP8.5 scenarios, for each of the contributing economic sectors.

Table 2: Forecasted economic gains or losses for the RCP4.5 and RCP8.5 scenarios




RCP 4.5 Impacts			RCP 8.5 Impacts		
Average	0.92%		Average	-0.05%	
Agriculture Sector	1.23%		Agriculture Sector	-0.64%	
Forestry Sector	1.73%		Forestry Sector	-0.91%	
Fishing Sector	1.24%		Fishing Sector	-0.65%	
Mining Sector	-0.1%		Mining Sector	-0.03%	
Manufacturing Sector	-0.54%		Manufacturing Sector	0.76%	
Electricity & Gas Sector	4.78%		Electricity & Gas Sector	1.29%	
Water Sector	-1.54%		Water Sector	-0.42%	
Service Sector	0.57%		Service Sector	0.17%	

3.4.5 Agriculture, Forestry and Fisheries

The main agricultural commodities for the Matjhabeng Local Municipality are maize, beef cattle and milk and cream (Table 3). Agriculture, Forestry and Fishing (AFF) sector contributes 1.12% to Matjhabeng Local Municipality GVA production and 4.28%




to Matjhabeng Local total employment. The total AFF GVA production of Matjhabeng Local Municipality contributes 0.51% of the national AFF GVA ranking them as the 62nd biggest contributor (Table 3).

Table 3: Economic contribution of main commodities for Matjhabeng Local Municipality

MAIN COMMODITIES		
 <p>MAIZE FOR GRAIN</p>	 <p>BEEF CATTLE</p>	 <p>MILK AND CREAM</p>
AFF contributes 1.12% to Matjhabeng GVA production	AFF contributes 4.28% to Matjhabeng total employment	The total AFF GVA production of Matjhabeng Municipality contributes 0.51% to the national AFF GVA, ranking them as the 62 nd biggest contributor

The main agricultural commodities for 2050 for the Matjhabeng Local municipality are still maize, beef cattle and milk and cream (under an RCP8.5 low-mitigation scenario) (Table 4). There is the potential increase in maize yield for near future with heat stresses potentially negatively impacting on production towards the end of 2050. There is the potential for increased water availability over the Matjhabeng Local Municipality which, with hot and moist conditions, would cause increased spread of disease and parasites. This could lead to reduced growth and reproduction performance due to heat stress. Hot and moist conditions cause increased spread of disease and parasites. Potential increase in heat stress which could negatively affect conception rates, milk yield and milk quality.

Table 4: Projected economic contribution of main commodities for Matjhabeng Local Municipality

MAIN COMMODITIES		
 <p>MAIZE FOR GRAIN</p>	 <p>BEEF CATTLE</p>	 <p>MILK AND CREAM</p>
CLIMATE IMPACT		
<p>Change in climate expected: Hotter and wetter with more extreme rainfall events.</p>		
Potential increase in maize yield for near future. However, towards 2050, heat stress can negatively impact on production.	Increased water availability. Hot and moist conditions cause increased spread of disease and parasites. Reduced growth & reproduction performance due to heat stress.	Hot and moist conditions cause increased spread of disease and parasites. Potential increase in heat stress which could negatively affect conception rates, milk yield and milk quality.

3.4.6 Other Resources

The impacts of climate change on other resources are summarised in Table 5.

Table 5: The impacts of climate change on other resources

Parameter	Results of Climate Change				Reference
	Increase in temperature and heat stress	Drought and decrease in rainfall	Increase in rainfall and inland flooding	Increased wind speed	
Transport and Mobility	<ul style="list-style-type: none"> Increased rate of infrastructure deterioration leading to pavement failure including cracking, rutting, potholes, flushing, and stripping. Increased stress on bridges, particularly expansion joints, through thermal expansion and increased movement. Corrosion of steel reinforcing in concrete structures due to increase in surface salt levels in some locations. Increased infrastructure maintenance cost for road repair and reconstruction work, causing traffic delays and emergency service response delays. Increased frequency and intensity of wildfires leading to more road closures. Increased vehicle accidents, due to low pavement adhesion, leading to higher rates of transport-related fatalities. 	<ul style="list-style-type: none"> Reduced water resources available for construction and maintenance. Reduced production of some agricultural produce leading to changes in freight flows in the network. 	<ul style="list-style-type: none"> Increased rate of infrastructure deterioration, especially in areas with poor infrastructure maintenance history. Temporary and permanent flooding of road, rail, port and airport infrastructure. Structural integrity of roads, bridges and tunnels could be compromised by higher soil moisture levels. Potential destruction of bridges and culverts. Erosion of embankments and road bases leading to undermining of roads or railways. Increased risk of landslides, slope failures, road washouts and closures. Undermining of bridge structures (scouring). Closure of roadways and tunnels leading to traffic delays. Transportation system disruptions, impacts to traffic signalling and low water crossings. Increased weather-related accidents. 	<ul style="list-style-type: none"> Increased drag on vehicles resulting in increased fuel consumption. Increased safety risk for pedestrians and cyclists due to flying objects or being uncontrollably dragged by winds, additionally leading to reduced trip making by pedestrians and cyclists. 	(Mokonyama & Van Wyk, 2018)

Parameter	Results of Climate Change				Reference
	Increase in temperature and heat stress	Drought and decrease in rainfall	Increase in rainfall and inland flooding	Increased wind speed	
Solid Waste	<ul style="list-style-type: none"> • Increased risk of combustion at open waste disposal sites and illegal dumps and increase in explosion risk associated with methane gas. • Increased rate of decay of putrescible waste resulting in increased odour, breeding of flies, and attracting of vermin. • Increased health and safety concern regarding heat stroke to staff collecting waste. • Increased risk of landfill site instability and failure due to changes in consumption patterns with increased waste creation (i.e., glass, plastic and paper cups). 		<ul style="list-style-type: none"> • Increased risk of flooding due to pressure on stormwater and leachate management systems at landfills. • Increased demand for capacity to cope with large volumes of waste generated by flood events. • Increase in soil saturation causing decreased stability of slopes and landfills linings (if clay or soil based) at waste management facilities. • Inundation of waste releasing contaminants to waterways, pathways and low elevation zones. • Potential loss of value and degradation of paper and cardboard for recycling due to increased moisture content. • Increased flooding causing the risk of localised disruption of waste collection rounds. • Flooding in areas with untreated, dumped waste causing the risk of groundwater contamination. • Increased flooding causing the risk of litter entering the storm water systems. 	<ul style="list-style-type: none"> • Possible increase in nuisance due to waste dispersed by high winds leading to increased health effects associated with particulate matter (air pollution). 	(Oelofse, 2018)

Parameter	Results of Climate Change				Reference
	Increase in temperature and heat stress	Drought and decrease in rainfall	Increase in rainfall and inland flooding	Increased wind speed	
Stormwater	<ul style="list-style-type: none"> • Potential risk of undermining the temperature regime of temperature-sensitive stormwater ponds and receiving waters, resulting in a decrease in water quality. • Increased corrosion in stormwater drains due to a combination of higher temperatures, increased strengths, longer retention times, and stranding of solids. 	<ul style="list-style-type: none"> • Increased shrinking soils increasing the potential for cracking, increased infiltration and exfiltration of water mains and sewers, which in turn exacerbates treatment and groundwater or storm water contamination. 	<ul style="list-style-type: none"> • Increased risk of flooding due to pressure on stormwater systems. • Increased risk of litter entering the stormwater systems. • Increased risk of damage and failure of stormwater systems due to overloading during floods and intense rainfall events. • Failure of stormwater treatment devices during high flow events leading to by-pass and / or flushing of contaminated water. • High wet-weather hydraulic loads and bottlenecks in stormwater and networks due to inflow and sewer infiltration, leading to local inundation and overflows of untreated wastewater. • Increased rainfall causes soil erosion thus damaging underground stormwater systems. • Increased surface and stream erosion causing deposition of sediments in receiving environments. • Stream morphology for undeveloped, developing and fully developed urban areas, may change, hence affecting existing outfall structures and potential stormwater pond locations. 	<ul style="list-style-type: none"> • Increased wind speed and intensity causing changes in rainfall over complex topography including increasing upwind of hills and ranges. 	(Dunker & Van Wyk, 2018)

Parameter	Results of Climate Change				Reference
	Increase in temperature and heat stress	Drought and decrease in rainfall	Increase in rainfall and inland flooding	Increased wind speed	
Sanitation	<ul style="list-style-type: none"> Increased heat waves, accompanied by dry weather, can exacerbate already stressed water supply systems leading to competition between sectors for water services, affecting sanitation. 	<ul style="list-style-type: none"> Decrease in water supply for sanitation through decrease in available water to flush sewage systems adequately. Declining annual rainfall threatening the viability of water-borne sanitation systems, and the capacity of surface water to dilute, attenuate and remove pollution. Sewers are structurally vulnerable to drying, hence shrinking soils increase the potential for cracking, increased infiltration, and exfiltration, which in turn exacerbates treatment and groundwater or storm water contamination. Increased corrosion in sewers due to a combination of higher temperatures, increased strengths, longer retention times, and stranding of solids. 	<ul style="list-style-type: none"> Increased wet-weather hydraulic loads and bottleneck in stormwater and sanitary sewer networks due to inflow and sewer infiltration, causing local inundation and overflows of untreated wastewater. Increased rainfall and heavy rainfall events increasing the washing of faecal matter into water sources due to flooding of wastewater treatment works. Increased risk of flooding resulting in both infrastructure damage and contamination of surface and groundwater supplies. Increased groundwater levels due to flooding, putting risk on sewage treatment plants (which are often positioned on low-lying ground as sewerage systems rely on gravity). Increased vulnerability of sewerage pipe systems due to their size and complexity, and their exposure to multiple flood damage threats from source, through treatment, to delivery. Increased vulnerability of pit toilets (widely used in rural areas) due to flooding, causing serious environmental contamination. Increase in groundwater recharge and groundwater levels causing flooding of subsurface infrastructure such as pit toilets or septic tanks. 		(Duncker, 2018)

Parameter	Results of Climate Change				Reference
	Increase in temperature and heat stress	Drought and decrease in rainfall	Increase in rainfall and inland flooding	Increased wind speed	
Information and Communication Technology	<ul style="list-style-type: none"> Increased weathering and deterioration of infrastructure resulting in increased maintenance and repair costs. Heat stress causing structural damage to infrastructure. Increased energy demands during heatwaves resulting in power outages which can impact on delivery of telecommunications services. Increases in temperature and higher frequency, duration, and intensity of heat waves increasing the risk of overheating in data centres, exchanges, and base stations, which can result in increased failure rates of equipment. Increased mean temperature increasing operating temperature of network equipment which may cause malfunctions if it surpasses design limits. 	<ul style="list-style-type: none"> Decreased precipitation leading to land subsidence and heave, reducing the stability of telecommunications infrastructure above and below ground (foundations and tower structures). 	<ul style="list-style-type: none"> Increased risk of flooding of low-lying infrastructure, access holes and underground facilities. Increases in storm frequency or intensity increasing the risk of damage to aboveground transmission infrastructure and impacting on telecommunications service delivery. Increases in storm frequency leading to more lightning strikes, consequently damaging transmitters, and overhead cables, causing power outages. Increased cost of insurance for infrastructure in areas with repeated incidents of flooding, as well as withdrawal of risk coverage in vulnerable areas by private insurers. Road closures due to flooding thus inhibiting service and/or restoration efforts. Rising sea levels and corresponding increases in storm surges, increasing the risk of saline corrosion of coastal telecommunications infrastructure, and leading to erosion or inundation of coastal and underground infrastructure. 	<ul style="list-style-type: none"> Increased risk of storm surges impacting on coastal infrastructure. Increased storm intensity and frequency impacting on electricity and telecommunications infrastructure. 	(Naidoo, 2018)

Parameter	Results of Climate Change				Reference
	Increase in temperature and heat stress	Drought and decrease in rainfall	Increase in rainfall and inland flooding	Increased wind speed	
Health	<ul style="list-style-type: none"> • More exposure to high temperatures causing increased health risks including heat strokes. • Heat waves increase threat of cardiovascular, kidney, and respiratory disorders. • Increase in fire danger days causing increased loss of life and damage to health infrastructure. • Wildfire smoke significantly reducing air quality, both locally and in areas downwind of fires. Smoke exposure increases respiratory and cardiovascular hospitalizations; emergency department visits; medication dispensations for asthma, bronchitis, chest pain, chronic obstructive pulmonary disease, and respiratory infections; and medical visits for lung illnesses. • Increased emissions in biogenic volatile organic compounds from vegetation causing increases in air pollution. • Increase in evaporative emissions from cars contributing to exposure to, and health impacts from, air pollution. • Increase in distribution of vector-borne diseases in warmer areas. • Increased water temperatures leading to an increase in algal blooms which can likely lead to increases in food- and waterborne exposures. • Increased temperatures combined with fewer clouds (e.g., from increased subsidence that is projected for parts of South Africa) causing increased exposure to Information and Communication Technology which will 	<ul style="list-style-type: none"> • Decreased soil moisture potentially creating more wind-blown dust which has negative impacts on air quality. • Increase in water-borne diseases and diarrhoeal diseases due to inadequate water availability. • Decreased precipitation causing changes in salinity of water, resulting in an increase in algal blooms which can likely lead to increases in food- and waterborne exposures. • Increase in stagnant air, decreasing air quality. 	<ul style="list-style-type: none"> • Wetter climate combined with increased temperatures may have negative health impacts as many diarrhoeal diseases vary seasonally, typically peaking during the rainy season. • Extreme rainfall and higher temperatures increasing the prevalence of fungi and mould indoors, with increased associated health concerns. • Increased flooding increasing the risk of drinking and wastewater treatment facilities being flooded, meaning that diarrhoeal diseases can be transmitted as wastewater systems overflow or drinking water treatment systems are breached. • Increase in natural disasters (e.g., floods) creating a conducive environment for the occurrence of mental health problems. 	<ul style="list-style-type: none"> • Increase in wind-blown dust combined with low humidity causing increased cases of meningitis (Davis, 2014). 	(Garland, 2018)

Parameter	Results of Climate Change				Reference
	Increase in temperature and heat stress	Drought and decrease in rainfall	Increase in rainfall and inland flooding	Increased wind speed	
	<p>have negative impacts on health.</p> <ul style="list-style-type: none"> Increased temperatures increasing the reaction between certain pollutants and sunlight and heat, resulting in more severe hazardous smog events. 				

Parameter	Results of Climate Change				Reference
	Increase in temperature and heat stress	Drought and decrease in rainfall	Increase in rainfall and inland flooding	Increased wind speed	
Energy	<ul style="list-style-type: none"> • Increased heat causing expansion of overhead cables, and cable sag. Sagging below a certain level result in a reduction in the amount of electricity transmitted. • Increased heat stress on electricity transmission networks (overhead cables). • Increase in heat island effect increasing energy demand for cooling, leading to grid stress. • Increased threat of wildfires causing widespread damage to infrastructure and causing disruptions to service provision. 		<ul style="list-style-type: none"> • Increase in flooding causing damage to electricity transmission and distribution infrastructure, poles, lines and sub-stations. • Increase in frequency and cost of maintenance of concrete structures due to frequent and intense rainfall, flooding, or sea level rise. • Increased repair events increasing stress put on service crews and resulting in delays to power restoration. 	<ul style="list-style-type: none"> • Winds causing damage to energy supply infrastructure as winds cause overhead lines to sag, reducing electricity transmission. • Extreme winds causing poles and trees to fall, causing further damage to energy supply infrastructure such as overhead lines. 	(Thambiran & van Wyk, 2018)

Ecosystem Services	<ul style="list-style-type: none"> • Increased risks of water shortages increasing demand for irrigation of gardens and agriculture. • Increased evapotranspiration rates with rising temperatures, reducing the water available in reservoirs and water available for reliant ecosystems. • Increase in temperature leading to water loss via evapotranspiration resulting in decreased water quality and loss of wetlands. • Loss or degradation of indigenous species, including threatened species or ecosystems. • Increased threat from invasive species as competition for water increases. • Dieback or death of susceptible plants (e.g., street trees) and animals (e.g., fish). • Reduced availability of water and increased evapotranspiration resulting in reductions in harvested area (cropping area), yield (ton/ha) and quality. • Warmer winters resulting in reduced period of dormancy (rest period) in deciduous fruit crops, decreasing the production and quality of associated food products. • Warmer climate resulting in shifts in the growing season and life cycles of various plants, including crops, resulting in pests and diseases having a greater destructive impact as well as a shift in climatically suitable areas for specific crops. • Increased humidity levels resulting in higher rates of microbial growth in fresh produce, reducing their expiry time. • Increased heat stress on crops changes the micro-nutrients of crops 	<ul style="list-style-type: none"> • Decreased amounts of rainfall reaching ecosystems as settlements use rainwater harvesting techniques for increased household use. • Increased reliance on irrigation and greater demand for water to maintain public open space and gardens. • Reduced planting and pollination leading to greater risk of erosion and soil loss. • Increasing temperatures together with increased intensity of drought will potentially increase the occurrence of algal blooms in reservoirs and dams which are damaging to ecosystem functioning and water services. • Drought and decreased rainfall causing wetland habitat loss. • Locally specific changes in humidity levels will have impacts on local vegetation. • Increased threat to watershed and aquifer recharge areas, affecting vegetation. • Reduced soil moisture availability increasing moisture stress leading to dieback and death of plants and the loss or degradation of indigenous communities, including threatened species or ecosystems. • Increased moisture stress leading to decline in crop yield and quality, and reduced fodder quantity and quality for livestock. • Drying up of aquatic systems, perennial systems will become seasonal and seasonal systems will die off and be replaced by terrestrial plants. • Increased spread of drought-adapted alien invasive plant species. 	<ul style="list-style-type: none"> • Rainfall in shorter and more violent spells making recharging groundwater difficult. • Increase in intensity of rainfall and flooding leading to increased surface runoff, resulting in increased soil erosion, soil loss and degradation. • Increased rainfall and floods resulting in waterlogged soils which increase the likelihood of crop failure. • Increasingly saturated soils leading to more standing water (ponding) which can result in more insect (pest) activity and their potential to carry diseases. • Increased wave energy and run-up (sea level rise and more storms) causing degradation of natural coastal defence structures. 	<ul style="list-style-type: none"> • Evapotranspiration rates increase with wind speed, reducing the water available in reservoirs and water available for reliant ecosystems. • Increased rate of fire spread and spotting (the ignition of fires ahead of the main fire front) of fires. • Potential damage to or uprooting of vegetation including trees, which can also damage infrastructure. • Potential wind damage to crops, reducing yield and quality (e.g., sandblasting and fruit fall). • Increased windblown materials (e.g., dust, litter) increasing the need for maintenance and city cleaning. • Degradation of natural coastal defence structures and increased damage to hard coastal infrastructure. 	(Pieterse & Crankshaw, 2018)
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	<p>products, decreasing the nutrient density and quality of food.</p> <ul style="list-style-type: none"> • Increased water temperature leading to increased growth of aquatic weeds which increases breeding of disease vectors and reduces water oxygen levels. • Milder winters and reduced frost increase the duration of the growing season, increasing the survival rate of insects and diseases. • Increased sea surface temperatures (SST) causing shifts in the spatial distribution of fish species. • Increased SST and ocean acidification decreases marine phytoplankton growth and synthesis of omega-3 polyunsaturated fatty acids (PUFA's), affecting the oceanic food chain and consequent ecosystems. • Increased heat stress and higher humidity levels potentially resulting in the exceedance of the temperature humidity index in livestock, causing reduced immunity, fertility, productivity and even mortality of livestock. 				
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Parameter	Results of Climate Change				Reference
	Increase in temperature and heat stress	Drought and decrease in rainfall	Increase in rainfall and inland flooding	Increased wind speed	
Culture and Heritage	<ul style="list-style-type: none"> • Increased temperature having significant impacts on the comfort levels of built heritage resources, resulting in the building no longer being fit-for-purpose. • Increased demand for additional heating and cooling resulting in the installation of heating, ventilation, and air-conditioning systems with potential negative consequences on the heritage value. • Increased heat stress potentially impacting on the materials and structural integrity of heritage resources. • Migration of several plant species due to changing climate patterns, posing a threat to the conservation of biodiversity hotspots, and potentially altering heritage places. • Increase in veld and forest fires raising the threat of fire to all heritage resources, natural and built, as well as posing health risks to heritage resource dwellers from exposure to smoke and ash pollution. 	<ul style="list-style-type: none"> • Decreased rainfall impacting negatively on ground moisture levels and thus the geological conditions of sensitive heritage resources. Drying out clays, for example, will shrink and potentially undermine founding conditions. 	<ul style="list-style-type: none"> • Increased rainfall in areas with clay soils resulting in swelling which poses a threat to the structural integrity of heritage resources. • Increased floods and changes in precipitation resulting in increasing vulnerability of archaeological evidence buried underground due to changing stratigraphic integrity of the soils. • Increased threat to materials and structural integrity of heritage resources exposed to higher humidity/precipitation levels. 		(van Wyk, 2018)

4 IMPACT ASSESSMENT: THE PROJECT'S CARBON FOOTPRINT

4.1 Scope 1 GHG Emission Sources

4.1.1 Clearing and Rehabilitation – Carbon Sequestration and Carbon Sink

Accounting for the uptake of carbon by plants, soils and water is referred to as *carbon sequestration* and these sources are commonly referred to as *carbon sinks*. Quantifying the rate of carbon sequestration is however not a trivial task requiring detailed information on the geographical location, climate (specifically temperature and humidity) and species dominance (Ravin & Raine, 2007).

Photosynthesis is the main sequestration process in forests and in soils. Carbon is absorbed as fixed carbon into the roots, trunk, branches, and leaves and during the shedding of leaves, but is emitted – although at a reduced percentage – from foliage and when biomass decays. Several factors also determine the amount of carbon absorbed by trees such as species, size, and age. Mature trees, for example, will absorb more carbon than saplings (Ravin & Raine, 2007).

Aspects required to calculate the carbon stock change in the pool (in tons of carbon per year) include the climate, the type of forest or vegetation removed and the type to be re-introduced, and management measures. Soil type also has different absorption and release ratios that need to be included. “Decomposition of soil organic matter in drained inland grassland” was used to the carbon losses from the cleared areas. It should be noted that carbon losses apply to the replacement of vegetation with built infrastructure, except where temporary clearing activities could have long-term impacts on water resources, including rivers, aquifers, streams, and wetlands, or water infrastructure (for example dams and storm water systems) (Government Gazette No. 44761, Notice 559, 25 June 2021), where in this case, vegetation may recover over the pipeline areas.

The areas to be cleared were accounted for as indicated in Table 6.

Table 6: Tetra4 Cluster 2 land clearance during construction

Construction Activity	Description of Area	Area (m ²) (unit area)	No of units	Total area (m ²)
Land Clearance	Road construction	5 000	1	5 000
	Pipeline construction ^(a)	2 500	139	346 530
	Well construction	900	300	270 000
	Booster station construction	3 600	30	108 000
	Compressor station construction	3 600	3	10 800
	Plant construction	93 979	1	93 979
Area (m ²)				834 309
Area (ha)				83.43

Notes: ^(a) This is a conservative approach since vegetation may recover over the pipeline areas.

4.1.2 Construction fuel combustion

There will be an initial carbon sink loss due to the vegetation removal for the new and expansion Cluster 2 areas. GHG will also be emitted through operating diesel-powered mobile and stationary equipment, as listed in Table 7.

Table 7: Tetra4 Cluster 2 construction fuel combustion

Mobile Diesel Equipment	Total kWh	Stationary Equipment	Total kWh
Plant	11 799 841	Natural gas generator	210 287
Pipeline	854 684		
Wells	1 275 986		
Booster Stations	1 275 986		
Compressor Stations	1 275 986		
Drilling	862 682		

4.1.3 Construction well drilling, testing, and servicing

There will be fugitive emissions (excluding venting and flaring) from gas well drilling, drill stem testing and well completions during construction. Emission factors are provided in Appendix A, and emissions are calculated in Gg per 10³m³ total production. Gas processing was given as 203 786.67 10³m³ and assumed to apply to raw gas feed and gas production.

4.1.4 Operations

The main sources of GHG due to the proposed operations are the mobile (trucking) and stationary equipment (generators) (Table 8), emissions from gas processing (fugitives, flaring and raw CO₂ venting) (calculated in Gg per 10⁶m³ raw gas feed – see Table 9) and emissions from transmission and storage (calculated in Gg/year/km and Gg/year/m³ respectively – see Table 10)

Table 8: Tetra4 Cluster 2 operational phase fuel combustion per year

Road transportation (diesel)	Total tonne-km per year	Stationary Equipment	Total kWh
Trucking	187 091 100 ^(a)	Natural gas generator	36 842 352

Notes: ^(a) Total tonne-km per year = assumed 155 909 tpa trucked over 1 200 km

Table 9: Tetra4 Cluster 2 gas processing during an operational year

Gas processed	Volume (10 ³ m ³)
Raw gas processed ^(a)	203 786.67

Notes: ^(a) Latest figures provided

Table 10: Tetra4 Cluster 2 transmission (pipeline fugitives and venting) and storage during an operational year

Gas transmission	Length (km)	Storage per year	Volume (m ³ /year)	Product (tpa)	Density (kg/m ³)
Pipeline length	120	Product	232 558.14	100 000 ^(a)	430

Notes: ^(a) Maximum product storage per annum provided as 100 000 tpa; product density 430 kg/m³

4.1.5 Decommissioning

As operations progress, the previously cleared areas that form part of the project will be rehabilitated resulting in a carbon sink gain. Even assuming rehabilitation uses the same indigenous vegetation, the carbon balance will not be completely restored. There may also be potential soil degradation due to stockpiling. However, there is insufficient data at this point to determine the decommissioning GHG emissions. This is likely to be equivalent or less than the construction phase, with the reestablishment of a carbon sink in the revegetation of the site.

4.2 Scope 2 GHG Emissions

Scope 2 GHG emissions apply to consumption of purchased electricity, heat, or steam. Tetra 4 Cluster 2 will make use of ESKOM electricity supply for some operations as listed in Table 11.

Table 11: Tetra4 Cluster 2 ESKOM electricity supply during construction and operations

Project phase	Activity	MW	No of hours/ year	Total MWh
Construction	Gas gathering			
	Plant	0.16	5 278	844
Operations	Gas gathering	9.72	8 322	80 890
	Plant	23.06	8 322	191 905

A summary of the calculated GHG emissions for the construction and operational phases is provided in Table 12 and the emission factors used provided in Appendix A.

Table 12: Tetra4 Cluster 2 Scope 1 and 2 GHG emission summary

Emission summary					
Construction	Activities	CO ₂ (as tCO ₂ -e)	CH ₄ (as tCO ₂ -e)	N ₂ O (as tCO ₂ -e)	Total CO ₂ -e (tonnes/year)
Scope 1 emissions	Land clearance	509			509
	Off-road mobile equipment	4 627	6	529	5 162
	Generators	42	0.09	0.02	43
	Well drilling	10 716			10 716
	Well testing	14 517			14 517
	Well servicing	1 534			1 534
Total Scope 1 emissions	Land clearance, heavy construction, generators, well drilling, well testing and well servicing	32 479			32 479
Total Scope 2 emissions	Electricity bought from ESKOM	861			861
Total emissions					33 341
Operations	Activities	CO ₂ (as tCO ₂ -e)	CH ₄ (as tCO ₂ -e)	N ₂ O (as tCO ₂ -e)	Total CO ₂ -e (tonnes/year)
Scope 1 emissions	Road transportation	19 858			19 858
	Generators	7 441	15	4	7 460
	Gas production (fugitives)	37	112 490	n/a	112 527
	Gas production (flaring)	326	5	0	331
	Gas processing (fugitives)	71	5 156	n/a	5 227
	Gas processing (flaring)	509	7	2	519
	Gas processing (CO ₂ venting)	8 151			8 151
	Gas storage		12		12
	Gas transmission (pipeline fugitives)	2	6 900		6 902
	Gas transmission (pipeline venting)	1	2 760		2 761
Total Scope 1 emissions	Road transportation, gas processing, transmission and storage, generators	50 411			163 748
Total Scope 2 emissions	Electricity bought from ESKOM	278 251			278 251
Total emissions					441 999

The total CO₂eq emission rate from the Tetra4 Cluster 2 construction phase is 32 479 tpa (Scope 1) and 861 tpa (Scope 2). For a single operational year, the Scope 1 GHG emissions are 163 748 tpa, with Scope 2 accounting for the largest part at 278 251 tpa.

4.3 Scope 3 GHG Emissions

Scope 3 GHG emissions are listed in Table 13.

Table 13: Tetra4 Cluster 2 GHG Scope 3 emission summary

Scope 3 sector	Activities	Total CO ₂ -e (tonnes/year)
Total Scope 3 emissions – Transportation	Category 4 – Upstream transportation and distribution	6 498
	Category 6 – Business travel	26
	Category 7 – Employee commuting	2 297
	Category 9 – Downstream transportation and distribution	17 962
Total Scope 3 emissions – Products used	Category 1 – Purchased goods and services	147 442
Total Scope 3 emissions – Use of products	Category 11 – Use of sold products	398 391
Total Scope 3 emissions – Other sources	Category 5 – Generated in operations	14 677
Total emissions		587 293

The main source of scope 3 emissions would be the end use of the LNG. As LNG will be replacing other fuels already in use, there will be a reduction in indirect GHG emissions as shown in Table 14. By using LNG, indirect GHG emissions would be reduced by 85 960 tpa.

Table 14: Tetra4 Cluster 2 GHG scope 3 use of sold products to replace other fuels currently in use

Scope 3 sector	Activities	Total CO ₂ -e (tonnes/year)
Total Scope 3 emissions – Use of products currently (diesel)	Category 11 – Use of sold products	289 531
Total Scope 3 emissions – Use of products currently (LPG)	Category 11 – Use of sold products	122 476
Total Scope 3 emissions – Use of products currently (HFO)	Category 11 – Use of sold products	72 345
Total Scope 3 emissions – Use of products currently (Total)	Category 11 – Use of sold products	484 352
Total Scope 3 emissions – Use of products in future	Category 11 – Use of sold products	398 391
Total emissions reduction		85 960

4.4 The Project's GHG Emissions Impact

4.4.1 Impact on the National Inventory

The operational phase of Tetra4 Cluster 2 will likely result in an increase in Scope 1 & 2 emissions. The annual operational CO₂-e emissions from the Tetra4 Cluster 2 operations would contribute approximately 0.12% to the South African “energy” sector total (374.07 million metric tonnes CO₂-e, excluding FOLU) and represent a contribution of 0.09% to the National GHG inventory total (478.88 million metric tonnes CO₂-e, excluding FOLU), based on the published 2017 National GHG Inventory (DFFE, 2024)(see Section 2.2.4). The annual CO₂-e emissions from the construction phase would contribute approximately 0.009% to the South African “energy” sector total and represent a contribution of 0.007% to the National GHG inventory total (DFFE, 2021).

4.4.2 Alignment with National Policy

Regulations pertaining to GHG reporting using the NAEIS were published in 2017 (Republic of South Africa, 2017) (as amended by GN R994, 11 September 2020) where mandatory reporting guidelines focus on reporting of Scope 1 emissions only. The DFFE is working together with local sectors to develop country specific emissions factors in certain areas; however, in the interim the IPCC default emission figures may be used to populate the SAAQIS GHG emission factor database. With the operational Scope 1 CO₂-e emissions below 100 000 t/a, Tetra4 does not have to report on SAGERS, calculate its Carbon Tax nor compile a pollution prevention plan (PPP).

Whereas a framework for future power generation in South Africa is set out in the NDC (Section xxx), energy policies for South Africa are provided in the Integrated Resource Plan (IRP) as developed by the Department of Mineral Resources and Energy's (DMRE). These energy policies are based on the demand in electricity and what energy generation types should be procured to meet that demand, along with the generation capacity, timing, and cost. The IRP acts as the government's roadmap for expanding capacity in the electricity sector, setting targets for all technologies, including renewable energy. The 2023 update of the IRP (IRP-2023) includes two key timeframes. The first focuses on the period leading up to 2030, primarily aimed at addressing existing generation capacity constraints and bridging the electricity supply gap. The second horizon spans from 2031 to 2050, concentrating on the country's long-term electricity strategy to inform future policy decisions.

The IRP 2030 projection for electricity demand is 1.3% per annum for the first 10 years, with a 0.3% per annum up to 2050. The production of thermal energy in SA is expected to decrease by 10.5 GW by 2030, with a decrease of 25% in the current energy generation potential due to the shutting down of coal-fired power stations. Although the aim is to eventually replace fossil fuels completely, there is a strong case to use natural gas in the interim to replace coal for baseload capacity.

The concern with natural gas is around the leaking methane emissions, occurring mainly during the extraction, processing, and transportation of natural gas. The estimated Scope 1 and 2 CH₄ emissions from the operational phase at Cluster 2 accounts for 78% of the total CO₂-eq emissions. Even though CH₄ emissions are 28 times more effective than CO₂ at trapping heat in the atmosphere over a 100-year timescale (US EPA, 2024a), studies show gas has a lower life cycle GHG impact than coal with a lifetime of roughly a decade (PACE, 2015). According to the UK Department for Environment Food & Rural Affairs (DEFRA), natural gas releases 46% less CO₂-eq lifecycle emissions compared to coal-fired facilities and 49% less than diesel-fired facilities for the same electricity generation rate. The IPCC reports, based on the median value, indicate natural gas to result in less than 51% direct- and 40% lifecycle CO₂-eq emissions compared to CO₂-eq emissions from coal (Schlömer S., 2014).

The projects' contribution to the national CO₂-eq is only 0.09%, and 0.12% to the national energy sector CO₂-eq.

4.4.3 Physical Risks of Climate Change on the Project's Construction and Operations

4.4.3.1 Temperature

With the increase in temperature, including heat waves, there is the likelihood of an increase in discomfort, possibility of heat related illness (such as heat exhaustion, heat cramps, and heat stroke). Both these have the potential to negatively affect staff process performance and productivity.

From a process point of view, elevated ambient temperatures (up to 45°C) may slightly reduce the fuel requirements needed to meet the generating capacity required. However, water use as a dust control measure during construction, may increase.

4.4.3.2 Rainfall, Water Stress, and Extreme Events

Rainfall decreases in autumn, winter and spring could result in constrained water supply outside of summer months. During drought conditions water supply could decline and intended use of reclaimed water and boreholes/wellpoints should be investigated to secure long-term supplies.

The impact of intense rainfall events on the LNG/LHe Plant cannot be ruled out, where the frequency of intense rainfall events could increase from the long-term baseline. These events could affect production capacity during intense rainfall (unless fully protected from rain and wind), flooding affecting site access, safe operation of equipment, delivery of fuel; collection of compressed gas product, as well as physical damage to infrastructure during high wind speed events associated with intense storms.

4.4.4 Impact Assessment: Potential Effect of Climate Change on the Community

4.4.4.1 Temperature

With the increase in temperature, including heat waves, there is the likelihood of an increase in discomfort and possibility of heat related illness (such as heat exhaustion, heat cramps, and heat stroke). There is also the possibility of increased evaporation which in conjunction with the decrease in rainfall can result in water shortage. This does not only negatively affect the community's water supply but can reduce the crop yields and affect livestock resulting in compromised food security.

4.4.4.2 Rainfall, Water Stress, and Extreme Events

As discussed above the decrease in rainfall can result in the following effects:

- Reduced water supply of reduced water quality; and,
- A negative impact on food security.

The impact of intense rainfall events on the local communities cannot be ruled out, where the frequency of these event could increase from the long-term baseline. These events could affect road access within the area due to flooding, and physical damage to public and private infrastructure through flooding and high wind speeds.

4.5 Project adaptation and mitigation measures

Climate change management includes both mitigation and adaptation. The main aim of mitigation is to stabilise or reduce GHG concentrations as a result of anthropogenic activities. This is achievable by lessening sources (emissions) and/or enhancing sinks through human intervention. Mitigation measures are typically the focus of the energy, transport, and industry sectors (Thambiran & Naidoo, 2017). Adaptation measures focus on the minimising the impact of climate change, especially on vulnerable communities and sectors. Inclusion of the climate change adaptation in business strategic implementation plans is one of the outcomes defined in the Draft National Climate Change Adaptation Strategy (Government Gazette No.42466:644, May 2019).

Additional support infrastructure can reduce the climate change impact on the staff and project, for example the improving thermal and electrical efficiency of buildings to reduce electricity consumption, ensuring adequate water supply for staff and reducing on-site water usage as much as possible. A community development program could be initiated to assist communities near the Tetra4 project site that are vulnerable to climate change impacts, such as thermal and electrically efficient buildings (to minimise electricity needs for heating and cooling), energy efficient stoves (to minimise the use of coal and woody biomass), or small-scale renewable energy innovations suitable for use in homes.

Project specific mitigation measures, may include:

- GHG emissions from vehicles and equipment:
 - Maintain vehicles and machinery in accordance with manufacturers standard specifications; and
 - A leak-detection program to be implemented to reduce product loss.
- GHG emissions from flaring, venting and fugitives:
 - Emissions of GHG should be limited as much as possible to reduce the global impact;
 - Flaring and venting of GHG should be minimised; and
 - Prudent operations and reductions in plant upsets would lead to fewer maintenance, startup, and shutdown events that cause flare and blowdown emissions, with the added benefit of retaining more product.
- GHG from National Grid:
 - The implementation and use of renewable energy such as solar photovoltaic (PV) units to replace/ reduce the reliance on ESKOM electricity would reduce the Tetra4 Cluster 2 GHG emissions significantly since ESKOM's contribution to the operational phase is the main source of GHG emissions; and
 - The use of LNG instead of diesel for generators and other stationary equipment would reduce the Project's GHG footprint further.

5 IMPACT SIGNIFICANCE RATING

The significance of climate change impacts was based on Scope 1, 2 and 3 GHG emissions and assessed according to the methodology provided by EIMS (Appendix A). Since climate change is a global phenomenon, the criterion is not fully applicable to an assessment of the impacts of GHG emissions on climate change. However, the criterion is currently the best tool for the climate change impact analysis.

5.1 Construction

Given the nature of construction activities for the roads/pipeline, wells and booster stations (where the location may vary depending on the gas reserves in the area) the negative climate change impacts are considered to be of **Low** significance without mitigation and **Low** significance with mitigation (Table 15).

Table 15: Significance rating for potential Climate Change impacts due to the construction activities

Impact Name	Climate Change risk due to Scope 1 & 2 construction				
Alternative	NA				
Phase	Construction				
Environmental Risk					
Attribute	Pre-mitigation	Post-mitigation	Attribute	Pre-mitigation	Post-mitigation
Nature of Impact	-1	-1	Magnitude of Impact	2	1
Extent of Impact	-	-	Reversibility of Impact	5	5
Duration of Impact	1	1	Probability	3	3
Environmental Risk (Pre-mitigation)					-8.0
Mitigation Measures					
As construction will be of limited duration. Develop and implement management programs and procedures.					
Environmental Risk (Post-mitigation)					-7.0
Degree of confidence in impact prediction:					Low
Impact Prioritisation					
Cumulative Impacts					2
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					2
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.17
Final Significance					-8.17

Note: ^(a) The extent of climate change impact is always national or wider and therefore can result in an overly conservative significance, and since the overall consequence and significance are not influenced by the extent, but rather by the intensity of emissions, "extent" was not included in the significance rating.

5.2 Operation

Vehicle and trucks, natural gas generators, the processing and flaring of gas, fugitive releases, and indirect upstream and downstream emissions could result in **Medium** significance on climate change and could reduce, although still **Medium** significance with mitigation and adaptation measures in place (Table 16).

Table 16: Significance rating for potential climate change impacts due to the Project operations

Impact Name	Climate Change risk due to the operational phase of the project				
Alternative	NA				
Phase	Operations				
Environmental Risk					
Attribute	Pre-mitigation	Post-mitigation	Attribute	Pre-mitigation	Post-mitigation
Nature of Impact	-1	-1	Magnitude of Impact	3	2
Extent of Impact	-	-	Reversibility of Impact	5	5
Duration of Impact	4	4	Probability	3	3
Environmental Risk (Pre-mitigation)					-12.0
Mitigation Measures					
Emissions of GHG should be limited as much as possible to reduce the global impact.					
Flaring and venting of GHG should be minimised.					
A leak-detection program to be implemented to reduce product loss.					
Replacing ESKOM electricity supply with renewable energy.					
Using LNG instead of diesel in equipment and machinery.					
Environmental Risk (Post-mitigation)					-11.0
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Cumulative Impacts					3
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					2
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.33
Final Significance					-14.67

Note: ^(a) The extent of climate change impact is always national or wider and therefore can result in an overly conservative significance, and since the overall consequence and significance are not influenced by the extent, but rather by the intensity of emissions, "extent" was not included in the significance rating.

5.3 Alternative Significance Rating

Other literature (Murphy & Gillam, 2013) suggests use of thresholds (Table 17) presented as tonnes of CO₂e per year, as basis for specific consideration of the specific elements to be assessed in the EIA, as guidance states that the contribution of an individual project to climate change cannot be measured.

Table 17: GHG and Climate in EIA – Elements to consider

GHG emissions (tonnes CO ₂ e/year)	Qualitative rating	Elements of assessment to consider
GHGs < 25 000	Very Low	Quantify GHG
25 000 < GHGs < 100 000	Low	Look at possible mitigation, quantify GHG, place in context
100 000 < GHGs < 1 000 000	Medium	As above and prepare management plan, describe existing climate conditions, consider how changes in climate may affect project and surroundings
GHGs > 1 000 000	High	As above and consider adaptation analyses

Based on the suggested thresholds from Table 17, the construction phase Scope1 GHG emissions would result in **Low** significance, and Scope 2 **Very Low**, with a combined significance of **Low**. The operational phase would result in **Low** significance for Scope 1 emissions, and **Medium** for Scope 2 emissions, where the combined (Scope 1 and Scope 2) significance would be **Medium**. The contribution of Scope 3 to GHG emissions would result in a **Medium** significance.

6 CONCLUSION

The region around Welkom and Virginia where Tetra4 Cluster 2 project is proposed to be developed is likely to experience increased temperatures and extreme weather-related events in the future. Climate change impacts will disproportionately affect under-developed communities that lack the physical and financial resources to cope with the physical effects of climate change, such as droughts, floods and increases in diseases.

Scope- 1, 2 and 3 emissions were estimated based on emission factors and expected production rates or raw material use. The main construction activities attributing to GHG emissions are well drilling, well testing and well servicing followed by off-road mobile equipment. During operations, the electricity bought from ESKOM (Scope 2) is the main source, followed by gas production fugitives and road transportation (Scope 1). The main source of Scope 3 GHG emissions would be the end use of the LNG, but as LNG will be replacing other fuels already in use, it will result in a reduction of 14.6% in indirect GHG emissions.

Construction- and operational-related GHG emissions from the proposed Tetra4 Cluster 2 project cannot be attributed directly to any particular climate change effects, and, when considered in isolation, will have a Low to Medium impact on the National GHG inventory total. The main GHG impact is associated with downstream use of the LNG, i.e. Scope 3. GHG emissions per unit of gas combusted, however, is less than per unit coal.

Climate change is a global challenge and there is a collective responsibility to address the global challenge of climate change and Tetra4 has an individual responsibility to minimise its own negative contribution to the issue. It is therefore recommended that:

- Renewable energy (such as PV Solar) be considered to replace/ reduce the reliance on ESKOM electricity – this is likely to reduce the significance from the Tetra4 Cluster 2 project from Medium to Low, since ESKOM's contribution to the operational phase is the main source of GHG emissions.
- Also, the use of LNG instead of diesel will reduce the GHG footprint further.
- Maintenance of vehicles and machinery, the implementation of a leak-detection program, and the minimisation of flaring and venting would reduce the potential for GHG emissions.

Once operational, it is recommended records be kept of actual fuel usage for transport of materials and products, energy requirements, production rates, flare and venting rates and raw material consumption for GHG reporting purposes and refinement of the emissions inventory.

Based on Tetra4 Cluster 2 Scope 1, 2 and 3 GHG emissions, it is the specialist opinion that the project may be authorised due to its low to medium impact significance.

7 REFERENCES

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8 APPENDIX A – EMISSION FACTORS

IPCC Category	Description	Emission source	Fuel/material I	Emission factors			Unit	Source	Notes
				CO ₂	CH ₄	N ₂ O			
	Scope 1 - Direct Emissions								
1.A.3.e.ii	Mobile combustion	Off-road mobile equipment	Diesel	74100	4.15	28.6	kg per TJ	2006 IPCC default	
1.A.3.b		Road transportation	Diesel	0.10614			kg CO ₂ e per tonne.km	2022 UK DEFRA	All HGVs. Average laden. Assumed 155 909 tpa trucked 1 200 km.
1.A.4.a	Stationary combustion	Generator	Diesel	74100	3	0.6	kg per TJ	2006 IPCC default	
			Natural gas	56100	1	0.1	kg per TJ	2006 IPCC default	
1.B.2.b.ii	Natural gas flaring and venting	Well drilling	Natural gas	1E-04	0.000033	ND	Gg/10 ³ m ³ total gas production	SA 2022 Methodological guidelines for quantification of GHG emissions	Provided gas processing 203 786 67 m ³ .
		Well testing	Natural gas	9E-03	5.1E-05	6.8E-08	Gg/10 ³ m ³ total gas production		
		Well servicing	Natural gas	1.9E-06	1.1E-04	ND	Gg/10 ³ m ³ total gas production		
1.B.2.b.iii.3	Gas processing	Fugitives	Gas	1.5E-04 to 3.2E-04	4.8E-04 to 1.03E-03	NA	Gg/10 ⁶ m ³ raw gas feed	SA 2022 Methodological guidelines for quantification of GHG emissions	Sweet gas plants. Assumed raw gas feed 203 786 67 m ³ .
1.B.2.b.ii		Flaring	Gas	1.8E-03	1.2E-06	2.5E-08	Gg/10 ⁶ m ³ raw gas feed		Default.
1.B.2.b.i		Raw CO ₂ venting	Gas	0.04	NA	NA	Gg/10 ⁶ m ³ raw gas feed		Assumed raw gas feed 203 786 67 m ³ .
1.B.2.b.iii.4	Gas transmission and storage	Transmission - fugitives	Gas	1.6E-05	2.5E-03	n/a	Gg/year/km	SA 2022 Methodological guidelines for quantification of GHG emissions	Assume 120 km.
1.B.2.b.i		Transmission - venting	Gas	8.5E-06	1E-03		Gg/year/km		
1.B.2.b.iii.4		Storage	Gas			2.32E-09			Gg/year/m ³
3.B.3.b	Decomposition of soil organic matter in drained inland grassland	Land clearance	Grassland	6.1	n/a	n/a	tonnes CO ₂ -C/ha/yr	1996 & 2006 IPCC default	

IPCC Category	Description	Emission source	Fuel/material I	Emission factors			Unit	Source	Notes
				CO ₂	CH ₄	N ₂ O			
	Scope 2 - Indirect Emissions								
	ESKOM energy grid	Electricity generation	Coal	1.02	n/a	n/a	tonnes CO ₂ per MWh	Median value from Eskom Integrated Reports (2016-2021)	
	Scope 3 - Indirect Emissions								
	Transportation	Category 4 - Upstream transportation and distribution	Plant, pipeline and overhead line goods.	0.10614			kg CO ₂ e per tonne.km	2022 UK DEFRA	All HGVs. Average laden. Assumed 125 540 tonne/year trucked from (450 km)
			Well casing goods.	0.10614			kg CO ₂ e per tonne.km	2022 UK DEFRA	All HGVs. Average laden. Assumed 10 500 tonne/year trucked from (450 km)
		Category 6 - Business travel	Air	0.18362			kg CO ₂ e per passenger.km	2022 UK DEFRA	International. Average passenger. Assumed 14 400 km (USA) – 2 trips, 3 people. Assumed 9 500 km (Europe) – 2 trips, 3 people.
		Category 7 - Employee commuting	Car petrol	0.17048			kg CO ₂ e per km	2022 UK DEFRA	Average car. Assumed 58 people 60km/day.
			Car diesel	0.170824			kg CO ₂ e per km	2022 UK DEFRA	Average car. Assumed 35 60km/day.
			Taxi	0.02136			kg CO ₂ e per passenger.km	Toyota Quantum specifications	299g CO ₂ e/km, assumed 14 passengers. Assumed 246 people 60km/day.
			Bus	0.0965			kg CO ₂ e per passenger.km	2022 UK DEFRA	Average local bus. Assumed 915 people 60km/day.

IPCC Category	Description	Emission source	Fuel/material	Emission factors			Unit	Source	Notes
				CO ₂	CH ₄	N ₂ O			
		Category 9 - Downstream transportation and distribution	He	0.10614			kg CO ₂ e per tonne.km	2022 UK DEFRA	All HGVs. Average laden. Assumed He trucked to Durban (600 km).
			He	0.003539			kg CO ₂ e per tonne.km	2022 UK DEFRA	Cargo ship. Average bulk carrier. Assumed He shipped to Asia, Europe and USA (14 461 km average).
			LNG	0.011548			kg CO ₂ e per tonne.km	2022 UK DEFRA	Sea tanker. Assumed 445 tonne/day produced, 350 days/year. Assumed % 60 LNG shipped to China (16 433 km).
	Products used	Category 1 – Purchased goods and services	Concrete	131.751			kg CO ₂ e per tonne	2022 UK DEFRA	Assumed tonne/year concrete: 5 940 (wells) + 95 040 (plant, pipeline and overhead line).
			Metal	4018.003			kg CO ₂ e per tonne	2022 UK DEFRA	Assumed tonne/year metal: 4 560 (wells) + 21 500 (plant, pipeline and overhead line).
			HDPE	3269.839			kg CO ₂ e per tonne	2022 UK DEFRA	Assumed tonne/year HDPE: 9 000 (pipeline).
	Use of products	Category 11 –	LNG	2559.17			kg CO ₂ e per tonne	2022 UK DEFRA	Assumed 445 tonne/day

IPCC Category	Description	Emission source	Fuel/material	Emission factors			Unit	Source	Notes
				CO ₂	CH ₄	N ₂ O			
		Use of sold products							produced, 350 days/year.
	Other sources	Category 5 - Waste generated in operations	Waste	467.0084			kg CO ₂ e per tonne	2022 UK DEFRA	Industrial waste. Landfill. Assumed 31 428 tonne/year waste.
Conversion Factors									
	Global Warming Potential (GWP) (100 year time horizon)			1	23	296	tonne CO ₂ e/tonne	Annexure G (DFFE, 2022)	

9 APPENDIX B – IMPACT SIGNIFICANCE RATING METHODOLOGY

The impact assessment methodology is guided by the requirements of the NEMA EIA Regulations (2010). The broad approach to the significance rating methodology is to determine the environmental risk (ER) by considering the consequence (C) of each impact (comprising Nature, Extent, Duration, Magnitude, and Reversibility) and relate this to the probability/likelihood (P) of the impact occurring. This determines the environmental risk. In addition, other factors, including cumulative impacts, public concern, and potential for irreplaceable loss of resources, are used to determine a prioritisation factor (PF) which is applied to the ER to determine the overall significance (S).

Determination of Environmental Risk:

The significance (S) of an impact is determined by applying a prioritisation factor (PF) to the environmental risk (ER). The environmental risk is dependent on the consequence (C) of the particular impact and the probability (P) of the impact occurring. Consequence is determined through the consideration of the Nature (N), Extent (E), Duration (D), Magnitude (M), and reversibility (R) applicable to the specific impact.

For the purpose of this methodology the consequence of the impact is represented by:

$$C = \frac{(E+D+M+R)}{4} \times N$$

4

Each individual aspect in the determination of the consequence is represented by a rating scale as defined in Table 18.

Table 18: Criteria for determining impact consequence

Aspect	Score	Definition
Nature	- 1	Likely to result in a negative/ detrimental impact
	+1	Likely to result in a positive/ beneficial impact
Extent	1	Activity (i.e. limited to the area applicable to the specific activity)
	2	Site (i.e. within the development property boundary),
	3	Local (i.e. the area within 5 km of the site),
	4	Regional (i.e. extends between 5 and 50 km from the site
	5	Provincial / National (i.e. extends beyond 50 km from the site)
Duration	1	Immediate (<1 year)
	2	Short term (1-5 years),
	3	Medium term (6-15 years),
	4	Long term (the impact will cease after the operational life span of the project),
	5	Permanent (no mitigation measure of natural process will reduce the impact after construction).
Magnitude/ Intensity	1	Minor (where the impact affects the environment in such a way that natural, cultural and social functions and processes are not affected),
	2	Low (where the impact affects the environment in such a way that natural, cultural and social functions and processes are slightly affected),
	3	Moderate (where the affected environment is altered but natural, cultural and social functions and processes continue albeit in a modified way),
	4	High (where natural, cultural or social functions or processes are altered to the extent that it will temporarily cease), or
	5	Very high / don't know (where natural, cultural or social functions or processes are altered to the extent that it will permanently cease).

Aspect	Score	Definition
Reversibility	1	Impact is reversible without any time and cost.
	2	Impact is reversible without incurring significant time and cost.
	3	Impact is reversible only by incurring significant time and cost.
	4	Impact is reversible only by incurring prohibitively high time and cost.
	5	Irreversible Impact

Once the C has been determined the ER is determined in accordance with the standard risk assessment relationship by multiplying the C and the P (Table 20). Probability is rated/scored as per Table 19.

Table 19: Probability scoring

Probability	1	Improbable (the possibility of the impact materialising is very low as a result of design, historic experience, or implementation of adequate corrective actions; <25%),
	2	Low probability (there is a possibility that the impact will occur; >25% and <50%),
	3	Medium probability (the impact may occur; >50% and <75%),
	4	High probability (it is most likely that the impact will occur- > 75% probability), or
	5	Definite (the impact will occur)

The result is a qualitative representation of relative ER associated with the impact. ER is therefore calculated as follows:

$$ER = C \times P$$

Table 20: Determination of environmental risk

Consequence	5	5	10	15	20	25
	4	4	8	12	16	20
	3	3	6	9	12	15
	2	2	4	6	8	10
	1	1	2	3	4	5
		1	2	3	4	5
	Probability					

The outcome of the environmental risk assessment will result in a range of scores, ranging from 1 through to 25. These ER scores are then grouped into respective classes as described in Table 21.

Table 21: Significance classes

Environmental Risk Score	
Value	Description
< 9	Low (i.e. where this impact is unlikely to be a significant environmental risk),
≥9; <17	Medium (i.e. where the impact could have a significant environmental risk),
≥ 17	High (i.e. where the impact will have a significant environmental risk).

The impact ER will be determined for each impact without relevant management and mitigation measures (pre-mitigation), as well as post implementation of relevant management and mitigation measures (post-mitigation). This allows for a prediction in the degree to which the impact can be managed/mitigated.

Impact Prioritisation:

In accordance with the requirements of Regulation 31 (2)(l) of the EIA Regulations (GNR 543), and further to the assessment criteria presented in the Section above it is necessary to assess each potentially significant impact in terms of:

- Cumulative impacts; and
- The degree to which the impact may cause irreplaceable loss of resources.

In addition, it is important that the public opinion and sentiment regarding a prospective development and consequent potential impacts is considered in the decision-making process.

In an effort to ensure that these factors are considered, an impact prioritisation factor (PF) will be applied to each impact ER (post-mitigation). This prioritisation factor does not aim to detract from the risk ratings but rather to focus the attention of the decision-making authority on the higher priority/significance issues and impacts. The PF will be applied to the ER score based on the assumption that relevant suggested management/mitigation impacts are implemented.

Table 22: Criteria for determining prioritisation

Cumulative Impact (CI)	Low (1)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.
	Medium (2)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cumulative change.
	High (3)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is highly probable/definite that the impact will result in spatial and temporal cumulative change.
Irreplaceable loss of resources (LR)	Low (1)	Where the impact is unlikely to result in irreplaceable loss of resources.
	Medium (2)	Where the impact may result in the irreplaceable loss (cannot be replaced or substituted) of resources but the value (services and/or functions) of these resources is limited.
	High (3)	Where the impact may result in the irreplaceable loss of resources of high value (services and/or functions).

The value for the final impact priority is represented as a single consolidated priority, determined as the sum of each individual criteria represented in Table 22. The impact priority is therefore determined as follows:

$$\text{Priority} = \text{PR} + \text{CI} + \text{LR}$$

The result is a priority score which ranges from 3 to 9 and a consequent PF ranging from 1 to 2 (refer to Table 23).

Table 23: Determination of prioritisation factor

Priority	Ranking	Prioritisation Factor
3	Low	1
4	Medium	1.17
5	Medium	1.33
6	Medium	1.5
7	Medium	1.67
8	Medium	1.83
9	High	2

In order to determine the final impact significance the PF is multiplied by the ER of the post mitigation scoring (Table 24). The ultimate aim of the PF is to be able to increase the post mitigation environmental risk rating by a full ranking class, if all the priority attributes are high (i.e. if an impact comes out with a medium environmental risk after the conventional impact rating, but there is significant cumulative impact potential, significant public response, and significant potential for irreplaceable loss of resources, then the net result would be to upscale the impact to a high significance).

Table 24: Final environmental significance rating

Environmental Significance Rating	
Value	Description
< 10	Low (i.e. where this impact would not have a direct influence on the decision to develop in the area),
≥10 <20	Medium (i.e. where the impact could influence the decision to develop in the area),
≥ 20	High (i.e. where the impact must have an influence on the decision process to develop in the area).