Specialist Climate Change Impact Assessment

Proposed Mura Solar PV Development

Prepared by Promethium Carbon for:

redcap
INNOVATING ENERGY

January 2023

Executive Summary

Promethium Carbon have prepared this climate change impact assessment for the Mura Solar PV Development. Red Cap intends to develop four solar projects (Mura Solar 1, 2, 3 and 4). The projects are located close to the approved Nuweveld Wind Farm Development within the Beaufort West (Western Cape) and Ubuntu (Northern Cape) Local Municipalities, east of the R381 provincial road between Loxton and Beaufort West. For this assessment, a Solar Project with a generation capacity of 150 MW has been used and is referred to as the Mura Solar Project. Given that most of the Mura projects will have a higher generation capacity, this is seen as the 'worst' case in terms of a Mura solar project's impact on climate change. Any increase in generation capacity would also, in turn, mean that there is greater avoiding emissions during the operation of the facility.

The core operations include the infrastructure and activities located within the four proposed project areas. Infrastructure includes solar arrays up to a maximum height of 6 m, PV modules, up to two substations, building infrastructure (including offices, a control centre, warehouses/workshops and converter/inverter stations) and a solid-state Battery Energy Storage System (BESS). Supplementary infrastructure includes cables, roads, fencing and stormwater management systems. The Electrical Grid infrastructure (EGI) is included in a separate environmental authorisation application. The total project areas cover approximately 1,451 ha across nine farm portions (incl. the proposed access roads).

The Climate Change Impact Assessment is aligned with International best practice, including the GIZ Framework for Climate Change Vulnerability Assessment, [1] International Finance Corporation (IFC) Performance Standards, [2] the European Bank for Reconstruction and Development (EBRB) principles,[3] the International Council on Mining and Minerals (ICMM): Adapting to climate change,[4] and the Equator Principles.

In this assessment, we discuss both the impacts of the Mura solar PV project *on* climate change (through a greenhouse gas (GHG) inventory calculation and assessment), as well as the impacts *of* climate change on the Projects (through a vulnerability assessment).

A GHG inventory was calculated for the proposed project to quantify the effects of the Project on climate change. The GHG inventory includes the emissions associated with the construction and value chain of the proposed Mura solar PV development.

---

1 GIZ. 2014. The vulnerability sourcebook. Gesellschaft für Internationale Zusammenarbeit, Bonn, Germany.

2 International Finance Corporation, 2012, *Performance Standards*, [Online] Available at: https://www.ifc.org/wps/wcm/connect/Topics_Ext_Content/IFC_External_Corporate_Site/Sustainability-At-IFC/Policies-Standards/Performance-Standards [Accessed on 30/08/2020].

3 European Bank for Reconstruction and Development (EBRB), *EBRD Values*, [Online] Available at: https://www.ebrd.com/our-values.html

4 International Council on Mining and Minerals, 2013, *Adapting to a changing climate: implications for the mining and metals industry*. ICMM.

The GHG inventory presented in this CCIA includes the avoided emissions for a 150MW solar farm, such emissions are expressed per PV panel, per MWh, and per MW. By doing so, such emissions can be adjusted according to the project's proposed generation capacity and per proposed farm. For instance, all four Mura projects GHG inventory can be calculated by using the information presented within the report and based on each project's generation capacity. However, for this assessment the lowest generation capacity has been used. The indirect emissions (Category 3-6) associated with the construction of the farm are analysed within a cumulative emissions context and disclosed in section 7 of the report.

A 150MW solar PV farm will only contribute 18.4 kt of indirect emissions from the construction phase (or 120 tons CO_2e per MW installed capacity) of the project, with most emissions being associated with the upstream production of construction materials and the purchasing of the PV panels. The emissions that would occur from operating and maintenance activities are negligible.

The emissions for a 150MW solar farm would equate to about 0.0005% of South Africa's carbon budget, as defined in this report. Relative to South Africa's updated Nationally Determined Contribution (NDC), this is 0.0004% of the high emission scenario and 0.0005% of the low emission scenario. Based on this assessment, the impact per solar farm in relation to South Africa's carbon budget is *medium* , as each solar farm's Project emissions amount to approximately 0.0005% of the carbon budget (where a value between 0.00039% and 0.019% is considered *medium*).

Avoided emissions are achieved because the project supplies electricity to the South African national grid, which is mainly coal based. In this respect each MWh of electricity supplied by this project results in 1 MWh less being produced by coal fired power stations.

In addition, an assessment of the projected impacts of climate change on the Project's core operations, value chain, and social and natural environments was conducted. This assessment earmarks key vulnerabilities to climate change that could affect the proposed Project.

The proposed Project falls within an arid, desert, cold climate zone. The area experiences warm to hot summers and cool, dry winters. The mean annual temperature is 15.2 ±0.6°C and has increased by approx. 1.0°C since the early 1980s (an increasing trend of approximately 0.025°C per year). Temperatures are predicted to continue to rise under all SSPs. By 2050 median temperatures could increase to between 0.7-1.8°C above current temperatures. Currently there are around 13.3 very hot days per year. This is projected to increase to between 21 and 27 days per annum by 2050.

Mean annual precipitation has shown a decreasing trend in recent decades. This is likely to continue to decline but with a weaker trend to around 150-250 mm per annum by the middle of the century. Heavy rainfall days are rare but are projected to increase to around 2-3 days per year. As such rainfall may be more concentrated in storm events but decline overall. Water stress and seasonal variability of water are likely to remain stable and improve slightly, respectively. Drought frequency and severity is predicted to increase substantially, especially in the latter third of the 21st century. Flood and wildfire risks are not likely to change significantly.

It is our opinion that, from a climate change perspective, each of the Mura Solar PV facilities should receive authorisation based on the following key aspects:

1. The project will adopt solar technology and will therefore significantly reduce the consumption of fossil-fuel generated energy and reduce the environmental impact associated with these fuels. According to the Integrated Resource Plan (2019), Solar PV presents an opportunity to diversify the energy mix to produce distributed generation and provide off-grid electricity in South Africa.
2. The project will contribute to the Nationally Determined Contribution of South Africa, which is aligned to the Paris Agreement, in that it will play a role in the decarbonisation efforts of South Africa.
3. Solar energy presents the basic environmental benefit of the displacement, or the avoidance of emissions associated with conventional electricity generation. Solar energy also has the potential to address the need for energy access in remote areas, create jobs and increase localisation.

Table of Contents

List of Figures

List of Tables

KEY TERMS AND DEFINITIONS

Adaptive capacity	Adaptive capacity is a set of factors which determine the capacity of a system to generate and implement adaptation measures. These factors relate to available resources of human systems and their socio-economic, structural, institutional, and technological characteristics and capacities.
Climate change	The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as: '*a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods*. The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition and climate variability attributable to natural causes. [5]
Climate change exposure	The presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure; or economic, social or cultural assets in places and settings that could be adversely affected.
Climate change impacts	The consequences of realised risks on natural and human systems, where risks result from the interactions of climate-related hazards (including extreme weather and climate events), exposure, and vulnerability. Impacts refer to effects on lives; livelihoods; health and well-being; ecosystems and species; economic, social, and cultural assets; services (including ecosystem services); and infrastructure. Impacts may be referred to as consequences or outcomes and can be adverse or beneficial.
Climate change vulnerability	The degree to which a system is susceptible to and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity.

[5] IPCC. 2021. Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. *et al.* (eds.)]. Cambridge University Press. In Press.

Climate variability	Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all spatial and temporal scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability).
Direct emissions	GHG emissions that occur from sources that are controlled or owned by an organization.
Exposure	Exposure is directly linked to climate parameters, that is, the character, magnitude, and rate of change and variation in the climate. Typical exposure factors include temperature, precipitation, evapotranspiration, and climatic water balance, as well as extreme events such as heavy rain and meteorological drought. Exposure is the contact between one or more biological, psychosocial, chemical, or physical; stressors, including stressors affected by climate change.
Extreme weather	Is unexpected, unusual, or unforeseen weather and differs significantly to the usual weather pattern, such as droughts, floods, extreme rainfall, and storms. [6]
Greenhouse Gas (GHG)	Greenhouse gasses (GHGs) are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of terrestrial radiation emitted by the Earth's surface, the atmosphere itself and by clouds. This property causes the greenhouse effect. The Kyoto Protocol deals with the following greenhouses gases, carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), Sulphur hexafluoride (SF_6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs).
Indirect emissions	GHG emissions that are a consequence of the activities of the reporting entity but occur at sources owned or controlled by another entity.
Nationally Determined Contributions (NDC)	NDC's are climate action plans developed by each country to reduce national emissions and adapt to the impact of climate change.
Resilience	The capacity of interconnected social, economic, and ecological systems to cope with a hazardous event, trend or

6 GIZ. 2014. The vulnerability sourcebook. Gesellschaft für Internationale Zusammenarbeit, Bonn, Germany.

disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure.[7]

Sensitivity

Sensitivity determines the degree to which a system is adversely or beneficially affected by a given climate change exposure and is a function of the natural and socio-economic context of a particular site.

Shared Socioeconomic Pathway 1 (SSP1)

Taking the Green Road (Low challenges to mitigation and adaptation). A gradual but widespread shift to a more sustainable development pathway. This narrative emphasises inclusive development and respects environmental boundaries. The world shifts gradually, but pervasively, toward a more sustainable path, emphasizing more inclusive development that respects perceived environmental boundaries. Management of the global commons slowly improves, educational and health investments accelerate the demographic transition, and the emphasis on economic growth shifts toward a broader emphasis on human well-being. Driven by an increasing commitment to achieving development goals, inequality is reduced both across and within countries. Consumption is oriented toward low material growth and lower resource and energy intensity.[8]

Shared Socioeconomic Pathway 2 (SSP2)

This is the "Middle of the Road" or medium pathway, which extrapolates the past and current global development into the future. In this scenario, there is a certain cooperation between states, but it is barely expanded. Global population growth is moderate, levelling off in the second half of the century. Environmental systems are facing a certain degradation. This scenario is equivalent to RCP 4.5 in the IPCC's Fifth Assessment Report (AR5).

Shared Socioeconomic Pathway 5 (SSP5)

This is the "Fossil-fuelled Development" scenario. In the scenario, global markets are increasingly integrated, leading to innovations and technological progress. The social and economic development is based on an intensified

---

[7] IPCC, 2021: Annex VII: Glossary [Matthews, J.B.R., V. Möller, R. van Diemen, J.S. Fuglestvedt, V. Masson-Delmotte, C. Méndez, S. Semenov, A. Reisinger (eds.)]. In Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 2215–2256, doi:10.1017/9781009157896.022. [Online] Available at: https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_AnnexVII.pdf

[8] Riahi, K. *et al.* 2017. The Shared Socioeconomic Pathways and their energy, land use, and GHG emissions implications: An overview. Global Environmental Change 42: 153-168.

exploitation of fossil fuel resources with a high percentage of coal and an energy-intensive lifestyle worldwide. The world economy is growing and local environmental problems such as air pollution are being tackled successfully. [9]

[9] Böttinger, M and D. Kasang. 2021. The SSP Scenarios. Deutsches Klimarechenzentrum, Hamburg, Germany. [Online] Available at: https://www.dkrz.de/en/communication/climate-simulations/cmip6-en/the-ssp-scenarios.

Declaration of Independence

The authors of this report do hereby declare their independence as consultants appointed by Red Cap Propriety Limited to undertake a Climate Change Impact Assessment as part of the Environmental Authorisation process for the proposed Mura Solar PV Project (four solar facilities). Other than fair remuneration for the work performed the specialists have no personal, financial business or other interests in the project activity. The objectivity of the specialists is not compromised by any circumstances and the views expressed within the report are their own.

Robbie Louw

Shantal Beharie

Indiana Mann

Joshua Weiss

Shannon Murray

DETAILS OF THE SPECIALIST

Promethium Carbon is a South African climate change and carbon advisory company based in Johannesburg. The company has been active in the climate change and carbon management space since 2004.

Promethium Carbon's climate change impact studies include an estimation of the carbon footprint of the activity or group of activities, as well as the vulnerability of the activity/is to climate change. Promethium Carbon has calculated greenhouse gas inventories for over 60 entities and is proficient in applying the requirements of ISO/SANS 14064-1 and the Greenhouse Gas Protocol's accounting standards, as well as South Africa's *Technical Guidelines for Monitoring, Reporting and Verification of Greenhouse Gas Emissions by Industry*. Promethium Carbon has also assisted around 40 clients develop climate change risk assessments, which includes the compilation of climate change specialist reports. Promethium Carbon's assessments include thorough analysis of historical and projected weather data specific to the region in which the client operates. Promethium Carbon's assessment of vulnerability goes beyond core operations to include impacts within the supply chain and broader network of the Hoogland Solar Farm.

Robbie Louw is the founder and director of Promethium Carbon. He has over 18 years of experience in the climate change industry. Robbie holds both a BCom Honours Degree in Economics as well as a BSc degree in Chemical Engineering. Robbie has significant experience with regards to climate change mitigation and adaptation. Robbie's chemical engineering background combined with his extensive experience in climate change has led to him leading several projects related to climate change risk and vulnerability, energy development and developing climate change mitigation and adaptation alternatives. His experience over a period of 35 years covers the chemical, mining, minerals process and energy fields, in which he was, involved in R&D, project, operational and management levels. Robbie is currently a member of The Southern African Institute of Mining and Metallurgy and the Institute of Directors in South Africa (IoDSA). In addition, Robbie is also a member of the Technical Working Group of the Climate Disclosure Standards Board (CDSB). Robbie's experience in climate change includes (but is not limited) to:

- Climate change risk and vulnerability assessments for large mining houses;
- Extensive experience in preparing carbon footprints. The team under his leadership has performed carbon footprint calculations for major international corporations operating complex businesses in multiple jurisdictions and continents;
- Carbon and climate strategy development for major international corporations;
- Climate change impact assessments for various companies and projects;
- Climate change scenario planning and analysis, particularly in terms of the recommendations of the Taskforce on Climate-related Financial Disclosure; and
- In depth understanding of South Africa's climate change regulations and carbon tax requirements.

Shantal Beharie is a climate change advisor at Promethium. She has eight years of experience in the climate change/sustainability field. She holds a master's degree in environmental studies which focused specifically on historical climate change, as well as an honours degree in geography and a bachelor's degree in environmental management. Shantal has experience in sustainability (corporate reporting, climate-change scenario analysis, CDP, ESG, TCFD, Science-based targets/net-zero) climate change risk and vulnerability assessments, carbon credit project documentation, climate impact assessments, strategic projects (environmental management frameworks, strategic environmental assessments and compiling state of environment reports), and policy development.

Indiana Mann is a Climate Change Advisor who holds an honours degree in Atmospheric Science. Her postgraduate studies focused on the impact meteorological conditions have on pollen distribution within Cape Town. With her background in Environmental and Geographical Science and Atmospheric Science, Indiana has knowledge in climate modelling, climate change risk and vulnerability assessments and climate change policies. The projects in which she has been active include Climate Change Risk and Vulnerability Assessment; Climate Change Impact Assessments; The Task Force on Climate-Related Financial Disclosures reports; GHG Reporting Carbon Footprints and Handling of weather data for necessary reports.

Joshua Weiss Joshua holds an MSc in Conservation Biology and a BSc Hons in Ecology, Environment and Conservation. He has cumulatively over six years of experience using GIS to conduct ecological analyses, developing sensitivity maps and cartographic design; producing several other maps for various reports in suitable and meaningful ways. He has a background in natural capital accounting, natural resource mapping and ecosystem service modelling & mapping His work has also included developing scenario maps of degradation, alien invasive plant spread and general spatio-temporal vegetation change. He also has experience in sourcing and analysing up-to-date modelled climate data. He was part of the team that reviewed South Africa's Climate Change Adaptation Plans for South African Biomes and the Biodiversity Sector Climate Change Response Strategy has also previously been involved in avifaunal monitoring and reporting, particularly in the renewable energy space, as well as scoping and EIA reporting.

Shannon Murray is a climate change advisor who commenced her employment with Promethium Carbon in October 2021. She completed her BA Degree in Sign Language, as well as her LLB degree through the University of the Witwatersrand. Furthermore, Shannon obtained course certificates through the Wits Mandela Institute in Energy Law, Environmental and Sustainable Development Law, Land and Water Law and International Environmental Law. Shannon was admitted as an attorney in November 2019 and practised as such for a small commercial litigation firm until September 2021. In the short period of time that Shannon has been employed with Promethium Carbon, she has done extensive research in relation to the climate change field and has formed part of various teams within the company. She has gained experience in:

- The legal aspects of carbon credit purchase agreements;

- Developing a socio-economic development project list, with climate change project funding benefits, for a global mining company;
- Developing a climate change target for a listed pharmaceutical company; and
- Performing an eligibility assessment for a carbon credit project, including the legal aspects of the carbon credit transaction.

REPORT STRUCTURE AND REFERENCE IN TERMS OF NEMA REGULATIONS (2014), APPENDIX 6

NEMA Regulations (2014) (as amended) - Appendix 6	Relevant section in report
Details of the specialist who prepared the report	Page xiv – xii
The expertise of that person to compile a specialist report including a curriculum vitae	Page xiv - xii
A declaration that the person is independent in a form as may be specified by the competent authority	Page xiii
An indication of the scope of, and the purpose for which, the report was prepared	Section 2.2
An indication of the quality and age of base data used for the specialist report	Section 3.1.2 and Section 3.2.2
A description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change	Section 2.6, Section 4 and Section 7
The duration date and season of the site investigation and the relevance of the season to the outcome of the assessment	This is not relevant in terms of the climate change impact assessment
A description of the methodology adopted in preparing the report or carrying out the specialised process inclusive of equipment and modelling used	Section 3
Details of an assessment of the specific identified sensitivity of the site related to the proposed activity or activities and its associated structures and infrastructure inclusive of a site plan identifying site alternative	Section 4 and Section 5
An identification of any areas to be avoided, including buffers	This is not relevant in terms of the climate change impact assessment. However, this report does make mention of the impacts of climate change on sensitive areas surrounding the project.
A map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers;	This is not relevant in terms of the climate change impact study. However, this report does define the boundaries for which the project's impact on climate change, as well

NEMA Regulations (2014) (as amended) - Appendix 6	Relevant section in report
	as the project's vulnerability to climate change was determined.
A description of any assumptions made and any uncertainties or gaps in knowledge;	Section 3.1.5 and Section 3.2.4
A description of the findings and potential implications of such findings on the impact of the proposed activity or activities	Section 5, Section 6 and Section 7
Any mitigation measures for inclusion in the EMPr	Section 8
Any conditions for inclusion in the environmental authorisation	N/A
Any monitoring requirements for inclusion in the EMPr or environmental authorisation	N/A
A reasoned opinion as to whether the proposed activity or portions thereof should be authorised and regarding the acceptability of the proposed activity or activities	Section 9
A description of any consultation process that was undertaken during preparing the specialist report	N/A
A summary and copies of any comments received during any consultation process and where applicable all responses thereto	N/A
Any other information requested by the competent authority.	N/A

1 INTRODUCTION AND CONTEXT

1.1 Project description

Red Cap Energy (Pty) Ltd (hereafter referred to as Red Cap) appointed Promethium Carbon to conduct a Climate Change Impact Assessment (CCIA) for the proposed Mura Solar PV Development (hereafter referred to as the 'Project'). Red Cap intends to develop four solar projects (Mura Solar 1, 2, 3 and 4). The project is located close to the approved Nuweveld Wind Farm Development within the Beaufort West (Western Cape) and Ubuntu (Northern Cape) Local Municipalities, east of the R381 provincial road between Loxton and Beaufort West (

Figure 1). The proposed maximum cumulative generation capacity of the Development is 1 580 MW. For this assessment a Solar Project with a generation capacity of 150 MW has been used and is referred to as the Mura Solar Project. Given that most of the Mura projects will have a higher generation capacity, this is seen as the 'worst' case in terms of a Mura solar project's impact on climate change. Any increase in generation capacity would also, in turn, mean that there is greater avoided emission during the operation of the facility.

This CCIA has been prepared to align with international best practice and the requirements of the Environmental Impact Assessment (EIA) Regulations 2014 (as amended). The CCIA describes the impact of the project on climate change, the resilience of the project to climate change and identifies possible mitigation and adaptation measures that can be taken by the project developer.

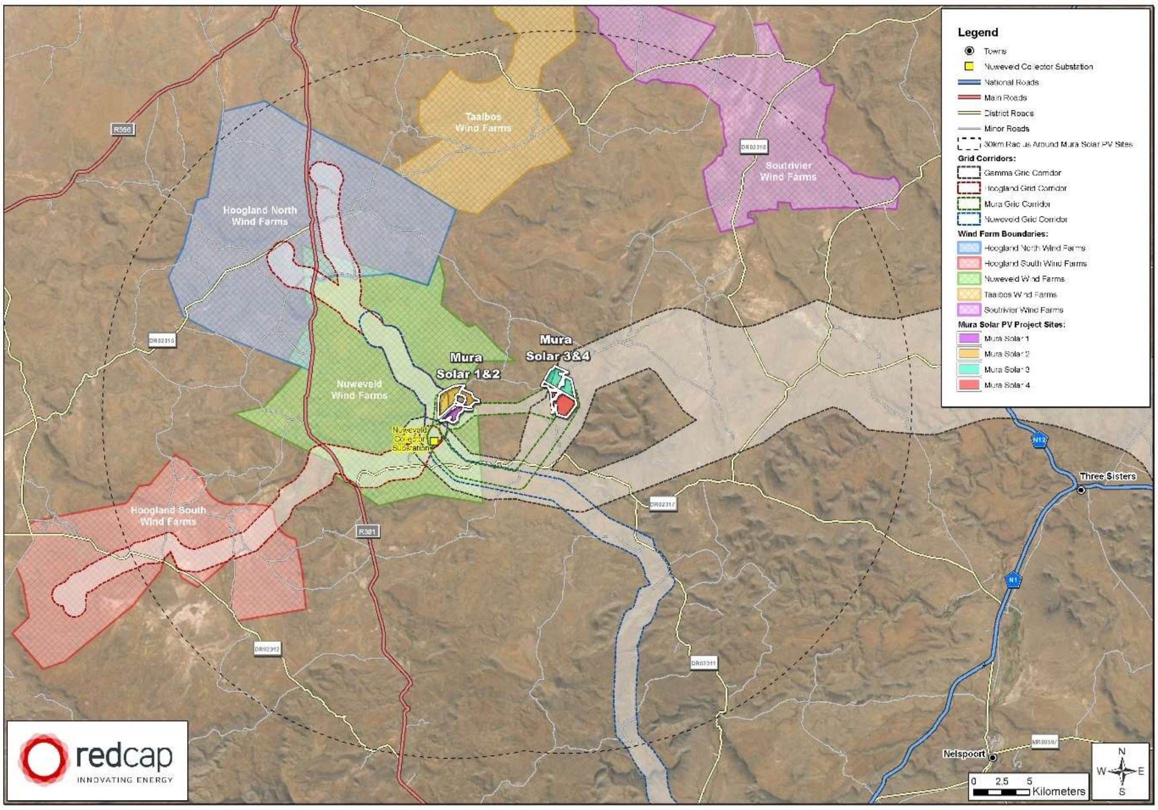

Figure 1: Locality map of the Mura Solar PV Projects. Source: Red Cap.

1.2 Project context

1.2.1 Core operations

The core operations include the infrastructure and activities located within the four proposed project areas. Infrastructure includes solar arrays up to a maximum height of 6 m, PV modules, two substations, building infrastructure (including offices, a control centre, warehouses/workshops and converter/inverter stations) and a solid-state Battery Energy Storage System (BESS). Supplementary infrastructure includes cables, roads, fencing and stormwater management systems. The Electrical Grid Infrastructure (EGI) is included in a separate environmental authorisation application. The total project areas including the access roads cover approximately 1 530 ha across nine farm portions.

1.2.2 Value chain

The value chain of the proposed project activities involves: the upstream manufacturing of components from raw materials, transportation, project development, operations (i.e., energy generation) and distribution of electricity for end use (carried out by the sole national electricity utility, Eskom).

1.2.3 Broader social context

Within the developmental context of South Africa, a Social License to Operate (SLO) is critical to the sustainability of any project. Whilst renewable energy projects are largely considered as net positive contributors to sustainability and climate change (i.e., reducing the impact of climate change on society), there are still impacts that these projects have on nearby communities.[10] However, in the context of climate change, the project is not likely to have any impact on surrounding communities.

The proposed project is located within the Ubuntu and Beaufort West Local Municipalities. The sphere of influence of the proposed project is roughly 50 km (radius). This area covers 6 wards (three in the Ubuntu Local Municipality, two in the Beaufort West Local Municipality and one in the Karoo Hoogland Municipality) and encompasses the settlements of Three Sisters, Nelspoort and Loxton. The total population of the 50 km radius surrounding the proposed project area is 35 465 with a very low population density of approximately 1.24 people/km.[11]

---

[10] Wlokas, H. & O'Keefe, E. 2018. Renewables and social licence: South Africa's new renewable energy projects would do well to consider how they benefit local communities. Synergy Global Consulting.

[11] Using data from: WorldPop (www.worldpop.org - School of Geography and Environmental Science, University of Southampton; Department of Geography and Geosciences, University of Louisville; Departement de Geographie, Universite de Namur) and Center for International Earth Science Information Network (CIESIN), Columbia University (2018). Global High Resolution Population Denominators Project - Funded by The Bill and Melinda Gates Foundation (OPP1134076). https://dx.doi.org/10.5258/SOTON/WP00674.

The Beaufort West Local Municipality has a socio-economic vulnerability score of 2.9, which is low by national standards but places as the fourth highest in the Western Cape.[12] It has a low economic vulnerability score of 3.8, owing to a low population and diverse local economy that reduces the region to external shocks.[13] The relative remoteness of much of the municipality means that it is considered to have a moderate physical risk score.[14] The Ubuntu and Karoo Hoogland Local Municipalities have higher socio-economic, economic and physical vulnerability scores. The economic vulnerability score for Ubuntu is particularly high at 7.2, placing the Ubuntu Municipality within the top five most vulnerable municipalities in South Africa. Growth pressure (and thus pressure on the natural environment, i.e., environmental vulnerability), in all three municipalities, is very low by national and respective provincial standards.[15]

Mean annual household income (as per 2011 Census) for the wards intersecting the proposed project area is around R29 400; roughly the same as the provincial mean. The employment rate (as per the 2011 Census) ranges between 33.2% to 62.5%.[16]

1.2.4 Broader environmental context

The proposed Mura Solar PV Project is located within the Nama-Karoo biome. Seven ecosystem types are found within a 50 km radius of the proposed development area. These ecosystems are largely poorly protected in conservation and protected areas but are all classified as Least Concern under the Red List threat classification (Table 1). There are numerous small natural wetlands within close proximity to the site, as well as two Freshwater Ecosystem Priority Areas (FEPAs) within a 50 km radius of the site. These are critical for water supply in what is an arid environment. They also provide important ecosystem services beneficial to communities and the agricultural sector in the region.

---

12 Score out of ten ranking the vulnerability of households in the municipality with regards to the overall vulnerability in terms of household composition, education, health, access to basic services and safety & security. A higher ranking indicates higher vulnerability.

13 Score out of ten ranking the vulnerability of households in the municipality with regards to the overall their susceptibility of the municipality to external shocks based on economic diversity, size of the economy, labour force, GDP growth rate and the inequality present in the municipality. A higher ranking indicates higher vulnerability.

14 Connectedness of settlements in the municipality. Higher scores indicate lower connectedness and higher structural vulnerability.

15 Le Roux, A., van Niekerk, W., Arnold, K., Pieterse, A., Ludick, C., Forsyth, G., Le Maitre, D., Lötter, D., du Plessis, P. & Mans, G. 2019. Green Book Risk Profile Tool. Pretoria: CSIR. Available at: riskprofiles.greenbook.co.za

16 Statistics South Africa. 2011. South African Population Census 2011. Indicators derived from the full population Census

Table 1: Ecosystem types within a 50 km radius of the proposed Mura Solar Development and their threat and protection status.[17,18]

Ecosystem Type	Remarks	Protection level	Red List Status	Area within 50 km radius (km^2)
Eastern Upper Karoo	Flat and gently sloping plains dominated by dwarf shrubs. Poorly protected, but not threatened.	Poorly protected	Least concern	6 127
Upper Karoo Hardeveld	Steep sloped areas and flat escarpment areas with sparse shrub and grass cover. Poorly protected, but not threatened.	Poorly protected	Least concern	1 730
Western Upper Karoo	Rocky landscape with shrubs, succulents and grasses. Very poorly protected, but not threatened.	Not protected	Least concern	588
Gamka Karoo	Plains with spiny dwarf shrubs and grass in sand areas. Poorly protected and threatened by alien invasive plants.	Poorly protected	Least concern	439
Southern Karoo Riviere	Riverine flats with thorn thickets and shrubs. Threatened by grazing, inundation and alien invasive plants.	Poorly protected	Least concern	246
Karoo Escarpment Grassland	Grass-dominated undulating topography. Protected in some public and private protected areas.	Moderately protected	Least concern	97
Bushmanland Vloere	Flat pans and ephemeral river bottoms lined with scrub comprising shrubs and thorn thickets. Threatened by mining, inundation and alien invasive plants.	Not protected	Least concern	78

17 SANBI. 2006-2018. The Vegetation Map of South Africa, Lesotho and Swaziland, Mucina, L., Rutherford, M.C. & Powrie, L.W. (Editors), Online, http://bgis.sanbi.org/Projects/Detail/186, Version 2018.

18 SANBI. 2022. The 2022 Red List of Terrestrial Ecosystems. Available at: http://bgis.sanbi.org/Projects/Detail/1233/.

2 BACKGROUND TO CLIMATE CHANGE IMPACT ASSESSMENTS

The analysis presented in this report is aligned with the principles of the National Environmental Management Act, 1998 (Act No 107 of 1998) and the National Water Act, 1998 (Act No 36 of 1998).

2.1 Purpose of the Climate Change Impact Assessment

The *Earthlife Africa Johannesburg v Minister of Environmental Affairs and Others (65662/16) [2017] ZAGPPHC 58; [2017] 2 All SA 519 (GP)* judgment (*Thabametsi*),[19] set the legal precedent for South African CCIAs, which has made provision and gives guidance for the inclusion of climate change in specialist assessments. Before the legal precedent was set by the *Thabametsi* case, there was no express provision that stipulated that climate change is a relevant factor to be considered as part of an Environmental Impact Assessment (EIA) in South Africa. It must be noted that the *Thabametsi* case relates to a coal fired power plant, which is fundamentally different than solar projects, as is the case here.

The process of environmental authorisations is in accordance with the requirements of the 2014 EIA regulations promulgated in terms of the National Environmental Management Act (NEMA: Act No 107 of 1998). As part of the specialist requirements under NEMA regulations 12(1) for the EIA, Promethium Carbon will undertake a CCIA for the Mura Solar PV Projects. The analysis presented in this report is aligned with the principles of the *National Environmental Management Act* (NEMA), 1998 (Act No 107 of 1998).

Climate change is generally considered to be covered within existing environmental law frameworks, since climate change impacts the environment and societies living in certain environments. South Africa's overarching environmental law framework is founded in NEMA. The *Environmental Impact Assessment Regulations of 2017* (which were promulgated under NEMA), were predominantly drafted to govern activities which have an impact on the environment within the Republic of South Africa. Therefore, applying NEMA's principles to a global phenomenon, such as climate change, presents a challenge, but in the current circumstances, the nature of the project, being renewable energy, can be seen to mitigate the impact of climate change and not to exacerbate it.

Furthermore, South Africa's Department of Forestry Fisheries and the Environment (DFFE) is in the process of providing further guidelines for Climate Change Impact Assessments, with one of the guidelines for when a specialist climate change impact assessment is necessary, is when the

[19] Earthlife Africa Johannesburg v Minister of Environmental Affairs and Others (65662/16) [2017] ZAGPPHC 58; [2017] 2 All SA 519 (GP) (8 March 2017) (saflii.org)

activity breaches one of the thresholds stipulated in the *National Greenhouse Gas Reporting Regulations*. However, these guidelines are only a draft and have not yet been published.

2.2 Scope of the Climate Change Impact Assessment

Considering the guidance from NEMA, CCIAs cover the following:

- The **impact of the project** on climate change:
  - A greenhouse gas (GHG) inventory for the construction phase of 150MW solar project;
  - An analysis of the GHG inventory regarding the impact of the project on climate change;
  - A description of the existing climate conditions of the local area;
  - An impact assessment of the project, which includes the cumulative impacts of climate change in relation to the project; and
  - Mitigation and adaptation measures to minimise the impacts of the proposed project on climate change.

- The **impacts of climate change** on the project:
  - Impacts on core operations – likely exposure, vulnerability and sensitivity to climate change
  - Cumulative impacts-is aligned to the project requirements and includes Nuweveld and Hoogland
  - Assessment of climate change related impacts on the local natural environment, surrounding communities, local ambient air quality, and human health, and any associated implications for the project;
  - Assessment of potential climate change adaptation measures; and
  - Assessment of the impacts of transitional risks.

- The **resilience of the project** in terms of climate change:
  - An analysis of the climate change impacts for the region in which the project will be located;
  - The processes and associated infrastructure of the proposed project that could be affected by climate change, and the potential magnitude of the impacts; and
  - Mitigation and adaptation measures to minimise the impacts of climate change on the proposed project.

The analysis of climate change risks includes both physical and transitional risks. The scope of inclusion of these risks are set out in the Table 2 below:

Table 2: Coverage of risks in the CCIA

	Risk	Included/excluded
Physical risks	Risks such as extreme weather events, storms, droughts, etc.	Included in the CCIA, as it can significantly impact on the resilience of the project to climate change in the core operations, value chain, natural environment, and social environment.
Transitional risks	Risks such as regulation, carbon pricing, and stranded asset risks.	These risks are excluded from the CCIA as they represent commercial risks to the owner of the project rather than environmental and societal risks that are governed in the context of NEMA.

2.3 Description of project activities and associated infrastructure

The following infrastructure is proposed as part of each of the four solar PV projects:

- Solar field comprising solar arrays
    - Maximum height of 6m and;
    - PV modules that are located on either single axis tracking structures or fixed tilt mounting structures or similar.
- Solar farm substation
    - Maximum height of 12m.
- Two substation yards up to 150m x 75m each, that will include:
    - Substation building and;
    - High voltage gantry.
- Building Infrastructure
    - Maximum height of 8m;
    - Offices;
    - Operational and maintenance (O&M)/ control centre;
    - Warehouse/workshop;
    - Ablution facilities and;
    - Converter/inverter stations.
- Lithium-ion or similar solid state Battery Energy Storage System (BESS):
    - Each solar farm will have up to a 4 ha area for a 240 MWac BESS;
    - BESS substation (same specifications as the solar farm substations) and;
    - Connected to the solar farm sub/switching stations via an underground high voltage cable.
- Other Infrastructure located within the solar area footprint:
    - Internal underground cables of up to 132 kV;
    - Internal gravel roads;
    - Fencing (between 2-3 m high) around the PV Facility;
    - Panel maintenance and cleaning area;

- Storm water management system and;
- Construction work areas.

2.3.1 Infrastructure Outside the solar area footprint

Internal access gravel roads will have a 6m wide driving surface and may require side drains on one or both sides. During construction the roads may be up to 12m wide, but this will be a temporary impact and rehabilitated following the construction phase ;and up to two construction camps within the access road corridor

Electrical Grid Infrastructure (EGI) Corridor Components

This will be covered in separate applications to the Solar PV facilities (and not considered as part of this assessment).

EGI Corridor for the four Mura Solar Facilities:

- Eight Eskom Switching stations:
  - Located adjacent to the solar farm substations within the solar area footprint;
  - Maximum height of 12m and;
  - Footprint of up to 150 m x 75 m.
- Overhead 132 kV lines supported by monopole pylons with a maximum height of 38m;
- Four additional up to 150 m x 75 m switching stations located within the corridor
- ~70km of overhead 132kV lines (~40km will be single overhead 132kV lines and ~30km will be up to two overhead 132kV lines running parallel between the switching stations supported by monopole pylons)
- Access tracks.

2.4 Climate Change Context

This section focuses on providing context to the reader to better understand how the CCIA is conducted.

2.5 Projected climatic changes

GHG emissions from all sources accumulate in the atmosphere and contribute to global climate change. One of the main GHGs is carbon dioxide (CO_2). Like all GHGs, CO_2 contributes to climate change by trapping heat in the atmosphere. The greater the concentration of GHGs, the greater the warming effect.

As a result of the continuous emissions of GHGs, it is highly likely that the mean global surface temperature will, at the very least, exceed 1.5°C above pre-industrial levels by 2100, and more likely to be in the range of 2.1-4.6°C above pre-industrial levels.[20] In addition, heavy precipitation events will become more intense and frequent.[21] The irreversible melting of the ice sheets will be initiated, resulting in harmful sea level rise.[22] These climatic changes increase the possibility of irreversible changes in the way the planet, and in turn, human societies and economies will function.

Based on the most recent climate change projections for the southern African region[23], South Africa is warming at twice the global rate of temperature increase. Temperatures could increase by up to 3°C by ca. 2050 (Figure 2) and between 3-6°C by 2100 above the baseline period (ca. 2005). The north-western interior of South Africa (parts of the Northern Cape, the North-West and western Limpopo) is predicted to have the highest temperature anomaly in the future. Mean maximum and minimum temperatures are also likely to increase countrywide.

Whilst future precipitation is challenging to model, projections show mean annual precipitation is likely to decrease by up to 10% in the western parts of South Africa and increase by up to 10% in the central and eastern interior. Rainfall variability is likely to increase, with generally longer dry spells and shorter wet spells (fewer rain days) with higher intensity.[24,25] Timing of rainfall is also likely to shift; the later onset of rainy seasons has already been observed across much of South Africa. This is likely to increase the frequency, intensity and unpredictability of extreme weather events, such as droughts, storms and floods.[26] Increased water stress is forecast for most catchments in South Africa under future climate change conditions.[27] These changes will have an impact on natural and agricultural ecosystems, society and the economy.

---

20 IPCC. 2021. Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. *et al.* (eds.)]. United Nations, New York.

21 Tabari, H. 2020. Climate change impact on flood and extreme precipitation increases with water availability, *Sci. Rep.* **10**: 13768.

22 Mimura, N. 2013. Sea-level rise caused by climate change and its implications for society. *Proceedings of the Japan Academy, Series B* **89**: 281-301.

23 Engelbrecht, F., Le Roux, A., Arnold, K. & Malherbe, J. 2019. Green Book. Detailed projections of future climate change over South Africa. Pretoria: CSIR. Available at: https://arcg.is/1zKniq.

24 The World Bank Group. 2021. Climate Risk Profile: South Africa. The World Bank Group, Washington D.C.

25 DEA. 2018. South Africa's Third National Communication Under the United Nations Framework Convention on Climate Change. Department of Environmental Affairs, Pretoria.

26 Republic of South Africa. 2021. First Nationally Determined Contribution under the Paris Agreement (Updated September 2021). Republic of South Africa, Pretoria.

27 Hofste, R.W. *et al.* 2019. Aqueduct 3.0: Updated Decision-Relevant Global Water Risk Indicators. World Resources Institute. Available at: https://www.wri.org/applications/aqueduct/water-risk-atlas.

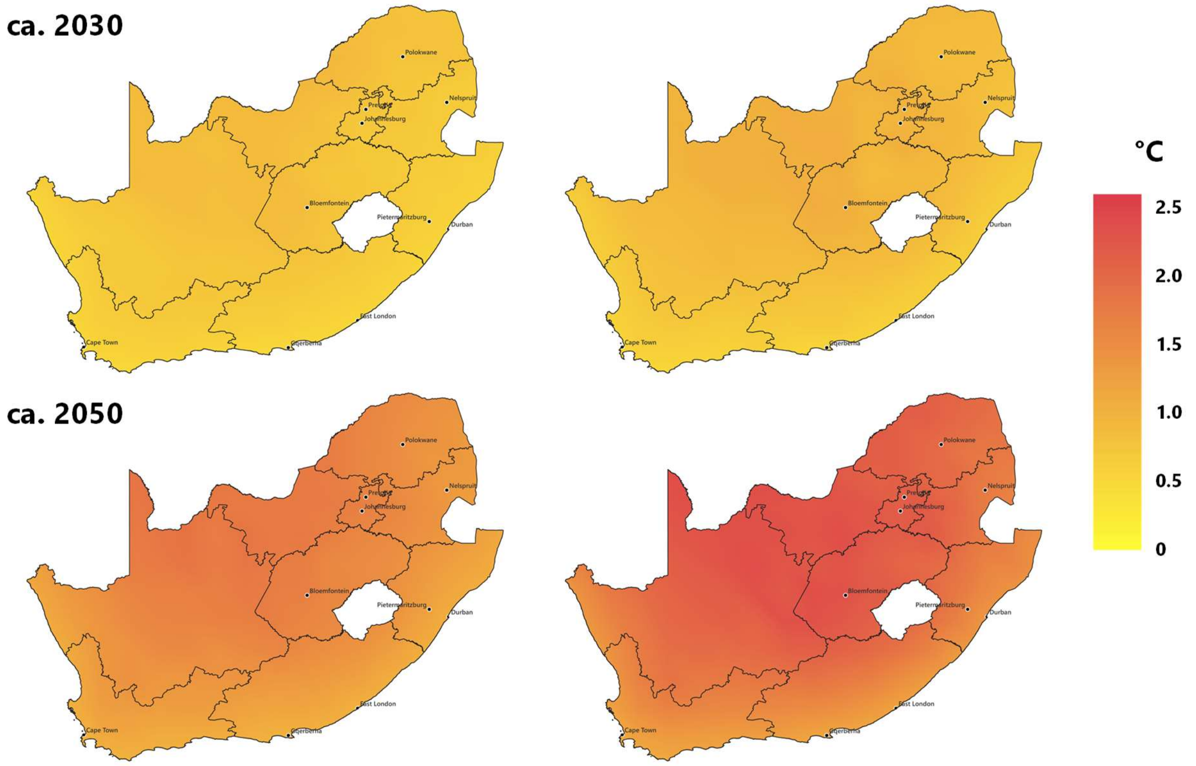

Figure 2: Projected mean annual temperature anomaly for 2020–2039 (ca. 2030) and 2040–2059 (ca. 2050) under SSP 2-4.5 (left) and SSP 5-8.5 (right). Data source: CMIP6.[28]

The chances, however, are still good that the global community can restrict global warming to below 2°C. We need to understand how much more GHGs the global community can afford to emit to collectively prevent changes in the natural system to the extent that they can no longer support socio-economic activities as we know them. This can be done through carbon budgets.

2.6 Receiving environment

Climate change is a global phenomenon. It is caused by an increase in the GHGs in the global atmosphere and cannot be addressed on a local level. This has been established at the Earth Summit in Rio in 1992, and lead to the formation of the United Nations Framework Convention on Climate Change (UNFCCC). It forms the basis of the 1997 Kyoto Protocol and the 2015 Paris Agreement.

The relationship between the GHG emissions of any specific project, and local impacts of GHG emissions is shown in the figure below:

[28] Eyring, V., Bony, S., Meehl, G. A., Senior, C. A., Stevens, B., Stouffer, R. J., & Taylor, K. E. 2016. Overview of the Coupled Model Intercomparison Project Phase 6 (CMIP6) experimental design and organization, *Geosci. Model Dev.*, 9, 1937-1958, DOI: https://doi.org/10.5194/gmd-9-1937-2016.

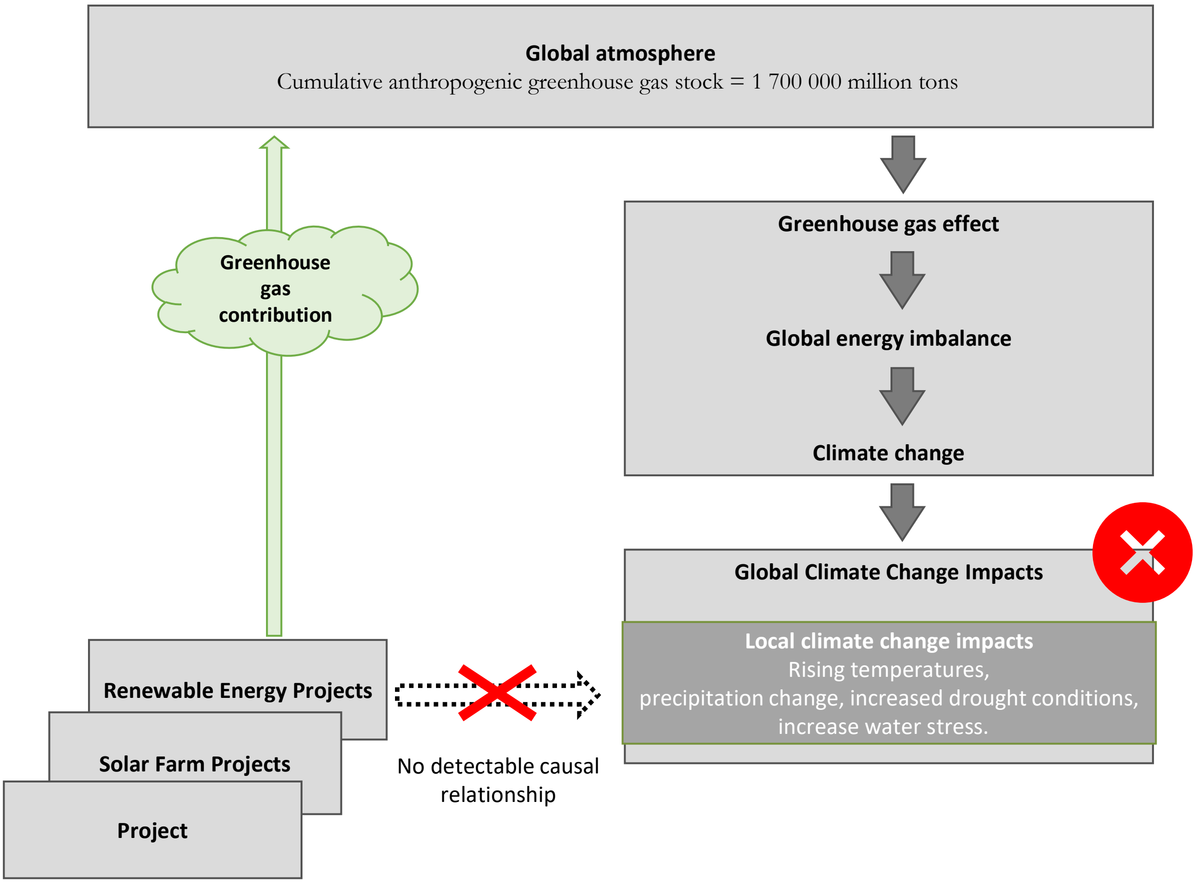

Figure 3: Relationship between a project's GHG emissions and local climate change impacts.

The principle that the emission of GHGs has no local impact and can therefore not be managed on a local level, is fundamental to the formation of the UNFCCC, the Kyoto Protocol, and the Paris Agreement.

It is in this context that the climate change specialist study considers the cumulative impacts of the Mura Solar PV Development in terms of its indirect emissions (category 3-6) during the construction phase of the project. Such impact is discussed in Section 7 of the report.

2.7 Carbon budgets and the Mura Solar PV Project

A carbon budget can be defined as the allocation of a quantity of GHGs that can be emitted over a specified period that would result in limiting global warming to a given level[29,30,31].

29 WWF. 2012. Understanding carbon budgets. WWF-SA, Cape Town, South Africa. Available at: http://awsassets.wwf.org.za/downloads/understanding_carbon_budgets_final_nov_2014.pdf.

30 Sacket, P, Steffen, W. and K. Jesson. 2018. What is a carbon budget? ACT Climate Change Council, Dickson, Australia. Available at: https://www.environment.act.gov.au/__data/assets/pdf_file/0006/1297707/What-is-a-Carbon-Budget.pdf.

31 IPCC. 2021. Climate Change 2021 – The Physical Science Basis. Summary for Policy Makers. Intergovernmental Panel on Climate Change, Geneva, Switzerland.

The guiding principle for the carbon budget will be the emission limits laid out by South Africa's Nationally Determined Contribution[32] (NDC), updated in 2021. Table 3 shows the target emissions for the low and high emissions scenarios, as given in the 2021 NDC.

Table 3: Targeted annual emissions for South Africa, according to the 2021 NDC

	2020	2025	2030	2050	Cumulative Emissions
Low Emission Scenario	398 $MtCO_2e/y$	398 $MtCO_2e/y$	350 $MtCO_2e/y$	0 $MtCO_2e/y$	7 758 $MtCO_2e$
High Emission Scenario	510 $MtCO_2e/y$	510 $MtCO_2e/y$	420 $MtCO_2e/y$	0 $MtCO_2e/y$	9 585 $MtCO_2e$

Thus, the cumulative emissions from 2020 to 2050 across the low and high emissions scenarios are 7 758 $MtCO_2e$ and 9 585 $MtCO_2e$, respectively. These scenarios will be selected as the low and high emission carbon budgets for South Africa. The low emission carbon budget will be used as a conservative estimate of a carbon budget against which to measure the impact of the Project.

In terms of Annex A of the Equator Principles, which provides guidance on climate change risks assessments and the requirements, projects must "…*also consider [the Project's] compatibility with the host country's national climate commitments, as appropriate.*"[33] In this regard, the South African carbon budget is an appropriate local contextualisation of South Africa's climate commitments under the Paris Agreement, even though it does not form part of the country's commitment.

The International Finance Corporation (IFC) Performance Standards highlight the need for "*appropriate and relevant*" risk assessment methodologies, using "*recent environmental baseline data*". The Standards further note the following in terms of Performance Standard 1: Assessment and Management of Environmental and Social Risks and Impacts[34], Paragraph 7:

- "*The type, scale, and location of the project guide the scope and level of effort devoted to the risks and impacts identification process. The scope of the risks and impacts identification process will be consistent with good international industry practice and will determine the appropriate and relevant methods and assessment tools.*"
- "*The risks and impacts identification process will be based on recent environmental and social baseline data at an appropriate level of detail.*"

[32] Republic of South Africa (2021). South Africa – First Nationally Determined Contribution Under the Paris Agreement.

[33] Equator Principles, 2020, The Equator Principles: July 2020, [Online] Available at: https://equator-principles.com/wp-content/uploads/2020/05/The-Equator-Principles-July-2020-v2.pdf

[34] IFC, 2012, IFC Performance Standards on Environmental and Social Sustainability, International Finance Corporation, World Bank Group.

- "*The risks and impacts identification process will consider the emissions of greenhouse gases, the relevant risks associated with a changing climate and the adaptation opportunities…*"

The South African carbon budget meets these requirements in terms of risk assessment, specifically considering the global nature of climate change and the need to assess localised GHG contributions thereto.

The GHG emissions used over the life of the Mura Solar PV Project (as presented in Section 5.3 Project Impact on Climate Change) are calculated as a percentage of South Africa's carbon budget to identify whether the Mura Solar PV Project's impact on climate change is low, medium, high or very high. The methodology to determine the Project's impact on climate change is detailed in section 3.1

3 APPROACH AND METHODOLOGY

The methodology used for this CCIA was informed by:

i. The nature of climate change;
ii. The project development timeframes;
iii. The long-term climate impacts anticipated for Loxton, Beaufort West, and surrounding areas; and
iv. Historical and projected climate data at the Mura Solar PV Project.

The climate-related impacts and vulnerabilities relevant to the proposed Mura Solar PV Project and surrounding areas are considered in this CCIA.

3.1 Project impact on climate change

It is important to quantify the amount of GHG emissions and the possible impact that the GHG emissions could have on the Mura Solar PV Project. The methods of determining the project's GHG emissions are discussed below.

3.1.1 GHG Inventory

The basic premise of calculating a GHG inventory is to determine the relevant activities and the emissions associated with these activities. Thus, the result of these calculations is the GHG inventory. The basic structure is shown in the below equation.

$$Emissions = Activity\ data \times Emission\ Factor$$

The following section provides more details regarding this process.

3.1.1.1 *Standards used*

The quantification of the impacts of the proposed project on climate change, is to be guided by the following reference documents for this CCIA:

- *SANS 14064:2021 Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals* [35]
- The Greenhouse Gas Protocol's *A Corporate Accounting and Reporting Standard (Revised Edition)*[36];
- The Department of Environmental Affairs' *Technical Guidelines for Monitoring, Reporting and Verification of Greenhouse Gas Emissions by Industry*[37]; and

35 Standards South Africa, 2021, SANS 14064-1:2021 Greenhouse Gases Part 1: Specification with guidance at the organisational level for the quantification and reporting of greenhouse gas emissions and removals, Pretoria.
36 Greenhouse Gas Protocol, 2015, A Corporate Accounting and Reporting Standard: Revised Edition.
37 Department of Environmental Affairs, 2016, Technical Guidelines for Monitoring, Reporting and Verification of GHG Emissions by Industry.

- The 2006 Intergovernmental Panel on Climate Change (IPCC) *Guidelines for National Greenhouse Gas Inventories*[38];

The main guiding document used is the *SANS 14064:2021 Part 1*. This document sets out principles, summarised in Table 4, that guide the GHG inventory development process.

Table 4: ISO/SANS 14064-1 principles for carbon footprints.

Relevance	Selecting all the greenhouse gas sources, sinks, reservoirs, data and methodologies that are appropriate.
Completeness	Including all the greenhouse gas emissions and removals relevant to the proposed project.
Consistency	Enable meaningful comparisons to be made with other greenhouse gas related information.
Accuracy	Reducing bias and uncertainties as far as is practical.
Transparency	Disclosing sufficient and appropriate greenhouse gas related information to allow intended users to make decisions with reasonable confidence.

The standard also requires that emissions be categorised into the following groups:

- **Category 1**: Direct GHG emissions and removals (previously Scope 1);
- **Category 2**: Indirect GHG emissions from imported energy (previously Scope 2);
- **Category 3-6**: All other indirect GHG emissions (previously Scope 3).

The calculation of the GHG inventory for the proposed Mura Solar PV Project follows the general steps stipulated below:

- The boundaries of the analysis are set;
- The GHG sources inside the boundary are identified;
- The quantification method is established; and
- The GHG emissions inventory is calculated.

In addition, an international carbon budget is used as a benchmark against which the emissions related to the proposed Mura Solar PV Project are analysed considering the project's impact on climate change (refer to Section 5).

3.1.1.2 *GHG Inventory Development*

For the GHG inventory presented in this CCIA, the significant direct (Category 1) and indirect (Category 2 – 6) emissions for the construction stage of the proposed Mura Solar PV Project, as well as the upstream (related to purchased and/or acquired goods and services) and downstream

[38] IPCC, 2006. *IPCC Guidelines for National Greenhouse Gas Inventories*, [Online] Available at: https://www.ipcc-nggip.iges.or.jp/public/2006gl/ [Accessed on 05/04/2020].

(related to sold goods and services) activities, were considered. The emissions for the operation stage of the project were seen negligible in comparison and therefore excluded.

These emissions are given in CO_2 equivalents (CO_2e). A CO_2 equivalent is when the emissions of other GHGs are equated to an equivalent amount of CO_2 using the 100-year global warming potential (GWP) of that gas. The GWP of any GHG is the amount of heat absorbed per mass unit of a GHG divided by the amount of heat an equivalent amount of CO_2 would absorb over the specified period.

During the operation of the Mura Solar PV Project, solar energy will be converted into electrical energy using PV systems. This does not require the combustion of fossil fuels. Negligible amounts of lubricants will be used for maintenance. The only fossil fuel combustion would be from onsite vehicles used for inspections and maintenance, which is negligible. Thus, the operating emissions for the Mura Solar PV Project are immaterial.

Most emissions associated with the Mura Solar PV Project will originate during the construction phase. Direct (Category 1) emissions include onsite fossil fuel combustion in construction vehicles and construction equipment. The upstream (Category 3 - 6) emissions are from the production/manufacture of the construction materials used. These upstream emissions are much greater than the direct emissions during the construction phase, making the direct emissions negligible.

Therefore, the GHG inventory calculated for the Mura Solar PV Project focuses on the upstream emissions during the construction phase. Cement, sand, and stone are the major materials used during construction and are calculated as follows

$$Upstream_{Const} = \sum_i m_i \times EF_i$$

Where:

- ***$Upstream_{Const}$*** represents the total emissions associated with the production of construction materials, measured in tCO_2e;
- ***i*** represents the different construction materials used;
- ***m_i*** represents the total mass or volume of material *i* used, measured in t or m^3;
- ***EF_i*** represents the upstream emissions associated with the production of one tonne of material *i*, measured in tCO_2e/t or tCO_2e/m^3.

3.1.1.3 *Avoided emissions*

The avoided emissions associated with the development of this Project were calculated as per the Avoided Emissions Framework[39]. This framework follows a step-by-step approach which identifies all life cycle emissions for both the baseline scenarios as well as the life cycle emissions associated with the proposed operational scenario. The difference in emissions between the baseline scenario and the proposed operational scenario can then be claimed as avoided emissions. This framework considers rebound emissions, conservative assumptions, and general sense checks, while always considering the most conservative approach. For this CCIA, rebound emissions[40] are excluded as we do not expect the electricity mix projected in the Integrated Resource Plan[41] to change.

Avoided emissions are achieved because the project supplies electricity to the grid. The product being replaced is the GHG intensive grid electricity. Thus, fewer emissions are released when delivering the same amount of energy to the grid. The calculation of the avoided emissions is as follows:

$$E_{avoided} = \sum_j Energy_{proj,j} \times \left(GEF_{SA,j} - EF_{proj,j}\right)$$

Where:

- $E_{avoided}$ represents the total avoided emissions of the Mura Solar PV Project over the lifetime of the project, measured in tCO_2e;
- j represents all the years for which the project is active;
- $Energy_{proj,j}$ represents the energy generated by the project in year *j*, measured in MWh;
- $GEF_{SA,j}$ is the grid emission factor for South Africa's national grid in year *j*, measured in tCO_2e/MWh;
- $EF_{proj,j}$ represents the emission factor of the Mura Solar PV Project in year *j*, measured in tCO_2e/MWh.

As the operating emissions of the Mura Solar PV Project are zero, the above equation simplifies to the following:

$$E_{avoided} = \sum_j Energy_{proj,j} \times GEF_{SA,j}$$

39 Stephens, A. & Thieme, V., 2019, Towards >60Gigatonnes of Climate Innovations: Module 2. The Avoided Emissions Framework, Missions Innovation.

40 This is the reduction in expected gains from new technologies that increase the efficiency of resource use, because of behavioural or other systemic responses.

41 Department of Energy, 2019, Integrated Resources Plan (IRP2019), Government Gazette, [Online] Available at: http://www.energy.gov.za/IRP/2019/IRP-2019.pdf [Accessed on 10/05/2020].

3.1.2 Data used

Multiple reference documents are used for the development of the GHG inventory of this CCIA, including the ISO14064 standard's significance criteria and the Greenhouse Gas Protocol[42].

The two main data requirements are (i) activity data and (ii) emission factors. The combination of these two data sets results in the development of a GHG inventory. The sources of these data sets vary and are discussed in further detail in the sections below.

3.1.2.1 *Activity Data*

The data used throughout this assessment was obtained from various sources. For the calculation of the GHG inventory for the CCIA, the main information was obtained from the data sheets sent by the client. The key activity data and relevant sources used for this GHG inventory are stipulated in Table 5. Refer to section 3.1.5 for the limitations and assumptions regarding the activity data.

Table 5: Activity data used to calculate GHG inventory

Activity data	Value	Source
Construction		
Capacity of solar facility	150 MW	Data provided by Red Cap
Cement	8 000 t	Data provided by Red Cap
Sand	20 250 t	Calculated from the data provided by Red Cap assuming the density of material is 1.50 tonne/m^3
Stone	41 075 t	Calculated from the data provided by Red Cap assuming the density of material is 2.65 tonne/m^3
Distance the used materials travelled	1 265 km	Data provided by Red Cap
Employees	136 people	Data provided by Red Cap
Operation		
Capacity of PV panel	600 Watt - Peak Installed Capacity (W_p)	Data provided by Red Cap
Capacity of total PV panel	150 000 Kilowatt - Peak (kW_p)	Calculated from data provided by Red Cap
Capacity factor	80%	Data provided by Red Cap

42 See further detail on the ISO 14064 and the Greenhouse Gas Protocol in Section 3.1.1.2 above.

Activity data	Value	Source
Number of panels	250 000	Calculated from data provided by Red Cap for 150MW farm
Water used	18 000 m^3/annum	Calculated from data provided by Red Cap for 150MW farm
Employees	40 people	Data provided by Red Cap
Total water used over Life of Plant	360 million litres	Calculated from data provided by Red Cap
Life of Plant	20 years	Data provided by Red Cap

3.1.2.2 *Emission Factors*

The emission and conversion factors applied in the calculation of the Project's GHG inventory, are aligned with the following principles:

- Derived from a recognised origin;
- Appropriate for the GHG source concerned;
- Current at the time of quantification;
- Take account of quantification uncertainty and are calculated in a manner intended to yield accurate and reproducible results; and
- Consistent with the intended use of the carbon footprint.

The main sources of the emissions and conversion factors used in this GHG inventory (Table 6) are the South African Technical Guidelines[43], the IPCC 2006 Guidelines[44] and the DEFRA 2021[45] emission factor sheet.

Specifically, the emission factors to calculate category 1 emissions were taken from the South African Technical Guidelines. This reference was used as the primary reference for emission factors because they are approved by the DFFE.

The emission factors (and other conversion factors) used in this CCIA are presented below:

43 Department of Environmental Affairs, 2017, Technical Guidelines for Monitoring Reporting and Verification of Greenhouse Gas Emissions by Industry.

44 IPCC. 2006. Climate Change 2006 – The Physical Science Basis. Summary for Policy Makers. Intergovernmental Panel on Climate Change, Geneva, Switzerland.

45 DEFRA, 2021, UK Government GHG Conversion Factors for Company Reporting.

Table 6: Emission factors used to calculate the GHG inventory.

Category 3 Emissions	Value	Reference
Heavy Goods Vehicle	0.000124 tCO2e/tonne.km	DEFRA 2022
Average petrol car	0.0001705 tCO_2e/passenger.km	DEFRA 2022
Taxi	0.0000242 tCO_2e/passenger.km	Toyota Quantum specifications
Bus	0.000102 tCO_2e/passenger.km	DEFRA 2022
Petrol car	60% of employees	Assumed Top, senior, professionally qualified and skilled technical workers use private cars
Taxi	30% of employees	Assumed that the other employees commute by taxi
Bus	10% of employees	Assumed the remainder of employees commute by bus
Distance commuted by car	90 km	Calculated by assuming speed of car is 120km/hour and travel time is 0.75 hours
Distance commuted by taxi	120 km	Calculated by assuming speed of taxi is 120km/hour and travel time is 1 hour
Distance commuted by bus	120 km	Calculated by assuming speed of bus is 80km/hour and travel time is 1.5 hour
Category 4 Emissions	**Value**	**Reference**
Purchased Water	1.4 tCO2e/Ml	Randwater annual report 2017
Cement	0.12 tCO2e/tonne	Promethium carbon calculated: Concrete (EF) - Aggregated (EF) = Cement (EF)
Sand	0.001 tCO2e/tonne	DEFRA 2022, Soils
Stone	0.01 tCO2e/tonne	DEFRA 2022, aggregates
PV Panels	0.04 tCO2e/KW	Ali, A., Koch, T.W., Volk, T.A., Malmsheimer, R.W., Eisenbies, M.H., Kloster, D., Brown, T.R., Naim, N. & Therasme, O., 2022. The Environmental Life Cycle Assessment of Electricity Production in New York State from Distributed Solar Photovoltaic Systems. Energies, 15(19), p.13

3.1.3 Environmental impacts of GHG emissions

The EIA reporting requirements listed in Table 7 below, set out the criteria to describe and assess local environmental impact. However, climate change is a global phenomenon, thus, the criteria are only partially applicable as they are inadequate to fully quantify the impact. Despite this, these criteria are currently the only criteria available to measure the impact of the project on climate change.

Table 7: WSP Impact Assessment Criteria and Scoring System.

CRITERIA	SCORE 1	SCORE 2	SCORE 3	SCORE 4	SCORE 5
Impact Magnitude (M) The degree of alteration of the affected environmental receptor	Very low: No impact on processes	Low: Slight impact on processes	Medium: Processes continue but in a modified way	High: Processes temporarily cease	Very High: Permanent cessation of processes
Impact Extent (E) The geographical extent of the impact on a given environmental receptor	Site: Site only	Local: Inside activity area	Regional: Outside activity area	National: National scope or level	International: Across borders or boundaries
Impact Reversibility (R) The ability of the environmental receptor to rehabilitate or restore after the activity has caused environmental change	Reversible: Recovery without rehabilitation		Recoverable: Recovery with rehabilitation		Irreversible: Not possible despite action
Impact Duration (D) The length of permanence of the impact on the environmental receptor	Immediate: On impact	Short term: 0-5 years	Medium term: 5-15 years	Long term: Project life	Permanent: Indefinite
Probability of Occurrence (P) The likelihood of an impact occurring in the absence of pertinent environmental management measures or mitigation	Improbable	Low Probability	Probable	Highly Probability	Definite
Significance (S) is determined by combining the above criteria in the following formula:	$[\boldsymbol{S} = (\boldsymbol{E} + \boldsymbol{D} + \boldsymbol{R} + \boldsymbol{M}) \times \boldsymbol{P}]$ $\boldsymbol{Significance} = (\boldsymbol{Extent} + \boldsymbol{Duration} + \boldsymbol{Reversibility} + \boldsymbol{Magnitude}) \times \boldsymbol{Probability}$				
IMPACT SIGNIFICANCE RATING					
Total Score	**4 to 15**	**16 to 30**	**31 to 60**	**61 to 80**	**81 to 100**

Environmental Significance Rating (Negative (-))	**Very low**	**Low**	**Moderate**	**High**	**Very High**
Environmental Significance Rating (Positive (+))	**Very low**	**Low**	**Moderate**	**High**	**Very High**

3.1.4 Determining the project impact on climate change

The DFFE has published the draft *National Guideline for the Consideration of Climate Change Implications in Applications for Environmental Authorisations, Atmospheric emissions Licenses and Waste Management Licenses* in January 2021. One of the guidelines for when a specialist climate change impact assessment is necessary is when the activity breaches one of the thresholds stipulated in the *National Greenhouse Gas Reporting Regulations*. Thus, the low impact level was taken as the combustion of coal at a capacity of 10 $MW_{thermal}$ at a 100% utilisation.

$$Upper\ limit\ \text{Low} = 10\ MW_{the} \times \frac{31\ 536\ 000\ s}{year} \times \frac{1\ TJ}{1\ 000\ 000\ MJ} \times EF_{coal}$$

The emission factor for coal is taken as "Other Bituminous Coal" from Table A.1 of the Technical Guidelines[46]. This equates to approximately 30 000 tCO_2e/year. Thus, emissions less than 30 000 tCO_2/y will be considered to have a ***Low*** impact.

3.1.4.1 *Determination of the Very High and High Impact Level for GHG Impact Rating*

The lower limit for the ***Very High*** impact category was calculated to be the annual emissions of a new coal fire power station. The size of the hypothetical power station was equivalent to the average capacity of the Eskom coal-fired fleet, namely 2 900 MW[47]. The annual emissions were calculated using an efficiency taken from the 2017 EPRI Report[48] for new coal-fired power stations and the current availability of the Eskom fleet. The annual emissions calculated, and thus the limit between the ***High*** and ***Very High*** impact categories, was 15 000 000 tCO_2e/year.

The lower limit for the ***High*** impact category was then taken as an order of magnitude less than the lower limit for the ***Very High*** impact category discussed above.

46 Department of Environmental Affairs, 2017, Technical Guidelines for Monitoring Reporting and Verification of Greenhouse Gas Emissions by Industry.
47 Calculated from Eskom's 2021 IAR.
48 Electric Power Research Institute (2017). Power Generation Technology Data for Integrated Resource Plan of South Africa.

3.1.4.2 *Summary of Impact Levels*

Table 8 combines the above calculations into one impact table. This is used to assess the magnitude of the impact of a project on climate change. It also compares the thresholds to the low emission NDC carbon budget of 7 758 Mt CO_2e.

This assessment only considers emissions in the GHG inventory that occur within the boundary of South Africa. This ensures consistency in the impact assessment, as the climate change impact assessment is a South African legal process. There is therefore no jurisdiction over emissions from international sources within this process. This also allows the emissions to be compared to the NDC, which only considers the South African national GHG inventory.

Table 8: Impact category thresholds used to determine the magnitude of the impact of the project on climate change.

GHG impact rating as a % of SA's carbon budget	Amount of GHG emissions		Relative to Low Emission NDC Carbon Budget	
	Lower limit (tCO_2e)	Upper limit (tCO_2e)	Lower limit (tCO_2e)	Upper limit (tCO_2e)
Low	-	30 000	0.000000%	0.00039%
Medium	30 001	1 500 000	0.00039%	0.019%
High	1 500 001	15 000 000	0.019%	0.193%
Very High	15 000 001	+	> 0.193%	

3.1.5 Limitations and assumptions

The Mura Solar PV Project is still in the planning phase. Thus, there are some uncertainties regarding final design and implementation of the project. Therefore, the use of a 150 MW plant to do the assessment was done to create an idea of the impact and emissions. Such assessment can be adjusted according to the actual design and capacity of the plant later on. However, it is the opinion of the specialist that sufficient data was provided to cover all significant GHG emission sources.

The average number of PV panels estimated to be used for the operations of the project were a total of 656 268. However, this equated to a capacity of the facility to be approximately 390MW. As a result of most of the activity data being recorded in terms of a 150MW facility, the number of PV panels were adjusted accordingly. This equated to about 250 000 panels being required for the operation of a 150MW facility and therefore used in the assessment. Noting that should the number of panels reduce, the contribution towards climate change (both the emissions, and the avoided emissions) would also subsequently reduce.

This CCIA makes use of data obtained during a desktop review for the development of this GHG inventory and associated impact assessment. Certain assumptions were made to ensure the development of the most accurate and extensive GHG inventory and the associated impact assessment. These assumptions were made considering the framework required by the EA reporting requirements. It was assumed, based on the specialist's experience, that the following aspects of the Mura Solar PV will not contribute materially towards the GHG footprint of the project during the operational phase:

- Mobile combustion of diesel and/or petrol fuels in onsite trucks or machinery;
- Stationary combustion from backup generators;
- Quantity of construction and municipal waste generated;
- Purchase of capital goods, such as vehicles; and
- Business travel.

3.2 Project vulnerability to climate change

The impacts of climate change are likely to result in increased climate-related vulnerabilities for the Project. Climate change management should, therefore, not be limited to emissions reductions (mitigation) but should also take into consideration measures for increasing the resilience of the Project (adaptation) in the face of climate change. Identifying impacts of climate change on the Project will be considered in this assessment.

3.2.1 International best practice

Due to the current lack of local regulations regarding CCIAs in South Africa, specifically with regards to unpacking and quantifying vulnerability to climate change, international best practice is used in this assessment. In this regard, this report makes use of globally accepted international best practice, including:

- International Council on Mining and Minerals (ICMM): Adapting to climate change;[49]
- GIZ Framework for Climate Change Vulnerability Assessments;[50]
- International Finance Corporation (IFC) Performance Standards;[51]

---

49 International Council on Mining and Minerals, 2013, Adapting to a changing climate: implications for the mining and metals industry. ICMM.

50 GIZ. 2014. The vulnerability sourcebook. Gesellschaft für Internationale Zusammenarbeit, Bonn, Germany.

51 International Finance Corporation, 2012, *Performance Standards*, [Online] Available at: https://www.ifc.org/wps/wcm/connect/Topics_Ext_Content/IFC_External_Corporate_Site/Sustainability-At-IFC/Policies-Standards/Performance-Standards [Accessed on 30/08/2020].

- European Bank for Reconstruction and Development (EBRB) principles;[52] and
- The Equator Principles.[53]

The abovementioned documents were used to develop a rating system (indicated in Table 8 in section 3.1.4.2 of this report) to which the current project is benchmarked. This enables us to adequately assess climate change impacts considering available baselines and relevant information.

3.2.1.1 *Key Areas of Impact*

The resilience and vulnerability assessment conducted for this CCIA considers four key areas[49] (listed in Table 9 below) related to the proposed Project that could be vulnerable to climate change impacts.

Table 9: Key areas of impact

Area of Impact	Relevance
The core operations	These are operations that are performed by the Project and that its management has complete control over.
The value chain (both upstream and downstream)	These are operations that are related to the Project, but that its management does not have control over. These include activities of suppliers, customers, government, and the greater economic market.
The broader social environment (surrounding/impacted communities)	This includes the people that are both directly and indirectly affected by the Project, such as employees, surrounding industry and local communities.
The broader natural environment	This is related to the natural environment directly surrounding the operations of the Project. The surrounding broader natural environment supports the core operations, surrounding industry as well as the livelihoods of the local communities.

For widescale considerations of the impacts of climate change, all four of the abovementioned aspects could be impacted by climate change and the proposed Mura Solar PV Project.

3.2.2 Data used

This vulnerability assessment refers to various data sources in the process of determining the critical vulnerability factors faced by the project. Data up to 2021 has been used, this was extracted in October 2022 which is considered high-quality and has been verified but not downscaled. Data

---

52 European Bank for Reconstruction and Development (EBRB), *EBRD Values*, [Online] Available at: https://www.ebrd.com/our-values.html

53 The Equator Principles Association, 2020, *Equator Principles EP4*, [Online] Available at: https://equator-principles.com/about/ [Accessed on 30/08/2020].

sources are limited to those that are publicly available and where possible using the most up-to-date data from reputable international or local data repositories. These include but are not limited to the World Bank Climate Change Knowledge Portal (CCKP), the Copernicus Climate Data Store (CCDS) and the National Oceanic and Atmospheric Administration (NOAA). The relevant data sources are referenced where applicable. Where processing was relevant, the data were processed in either Google Earth Engine, R (v4.2.0) and/or using GIS software (Esri ArcGIS Pro or QGIS).

These tools and data were used in conjunction with the information sheet received from the client and considering the specialist's background and understanding of climate-related impacts posed on the Project.

3.2.3 Determining project vulnerability and resilience

The overall vulnerability of the Project, and its surrounds to climate change impacts, can be determined by identifying the exposure, vulnerability, and adaptive capacity of the region in which the Project lies. The IPCC Sixth Assessment Report[54] defines vulnerability as: "*the propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.*"[55] This definition aligns with the method of determining the Project's climate-related vulnerability, proposed in the figure below.

Figure 4 indicates the vulnerability of the core operations of the Project's core operations, the value chain, as well as the social and natural environments surrounding the project. The diagram also illustrates how climate change impacts and variability could result in changes in the exposure levels experienced in this region.

---

[54] IPCC, 2021: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press. In Press.

[55] IPCC, n.d., *Data Distribution Centre Glossary: Vulnerability*, IPCC [Website] Available at: https://www.ipcc-data.org/guidelines/pages/glossary/glossary_uv.html [Accessed on 10/08/2020].

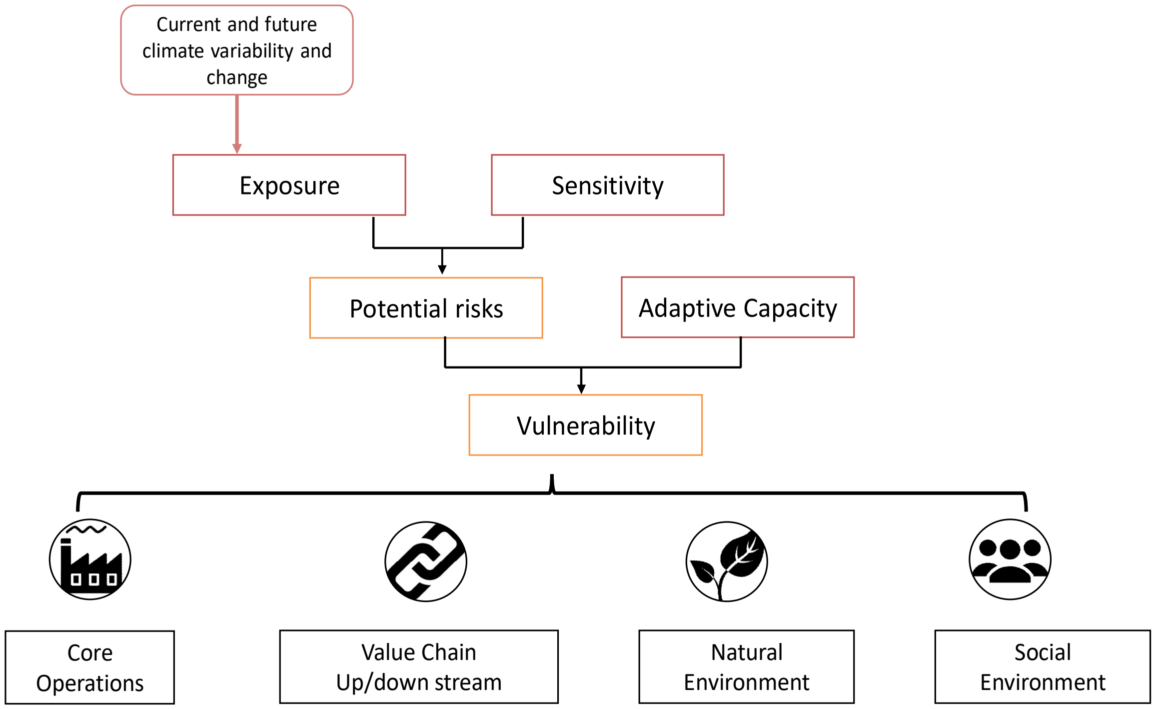

Figure 4: Interrelations of Exposure, Sensitivity and Adaptive Capacity, which makes up the basis of the vulnerability assessment.

The vulnerability assessment is conducted considering the impact of climate change on the region's exposure. Thereafter, the overall vulnerability is determined using project exposure, sensitivity, and the current-day adaptive capacity.

3.2.4 Limitations and assumptions

The project's vulnerability and resilience to climate change is assessed within this CCIA through an analysis of available[56] datasets. It should be noted that climate data was extracted and analysed at the finest scale possible. Modelling climate variables is challenging and thus most datasets for future climate are at a coarser resolution than observed or reanalysed climate data. Whilst every effort was made to use data from the relevant location, some data may represent an aggregation of a larger area. This introduces a level of uncertainty and higher variance than projections at regional or continental scales, however, the overall trend remains similar, and the interpretation is likely to remain the same. Where necessary, non-statistical adjustments have been made based on the historical trend.

Furthermore, while confidence is growing in global climate models, there is a much greater appreciation of uncertainties involved in downscaling global models to illustrate climate

56 This includes both spatial and temporal availability.

projections at a local scale[57]. This is particularly relevant for precipitation-related projections in southern Africa.

This uncertainty should be noted by the project developers since the impacts of climate change may result in decreased investment value over time and possible increases in costs of maintenance.

[57] Bourne, A, P. deAbreu, C. Donatti, S. Scorgie, and S. Holness. 2015. A Climate Change Vulnerability Assessment for the Namakwa District, South Africa: The 2015 revision. Conservation South Africa, Cape Town.

4 STATUS QUO AND PROJECTED CLIMATIC CHANGES

Understanding potential future climate change impacts and risks on the project relies on analysis of both near-historical and future projected/modelled climate data. Appropriate data sources were used for historical and near-future (ca. 1980-2021). Climate projections are primarily drawn out of datasets that form part of the Coupled Model Intercomparison Project Phase 6 (CMIP6).[58] We acknowledge the World Climate Research Programme, which, through its Working Group on Coupled Modelling, coordinated and promoted CMIP6.[59]

Future projections are based on Shared Socio-economic Pathways (SSPs, see Key Terms and Definitions above). Here, SSP1-2.6 (SSP1), SSP2-4.5 (SSP2) and SSP 5-8.5 (SSP5) are presented. The SSP numbers refer to the SSP pathway/scenario followed by a radiative forcing in the year 2100 in W/m^2 (i.e., SSP1-2.6 refers to SSP1 with radiative forcing of 2.6 W/m^2). Although a radiative forcing trend of 8.5 has been the best match to emissions in the last 15 years,[60] SSP2 is seen as one of the most likely future scenarios given that it is premised on modest mitigation and meeting Nationally Determined Contributions (NDCs).[61] SSP1 aligns to a 1.5 ˚C world assuming low challenges to mitigation and adaptation, and SSP5 represents a pessimistic (and increasingly unlikely) scenario based on minimal mitigation and adaptation. These scenarios assist in understanding a range of futures and risks that could occur, and accounts for the inherent uncertainty of modelled future climate.

4.1 Current climate[62]

The proposed Project falls within the arid, desert, cold climate zone.[63] The area experiences warm to hot summers and cool, dry winters. The near-historical (since 1980) Mean annual temperature is 15.2 ±0.6°C. Mean maximum temperatures range from around 27°C in summer (January and February) to 12°C in winter (June and July). Temperatures occasionally exceed 35°C but rarely beyond 40°C in summer. during the recent historical period (since ca. 1980) there have been an average of 8 very hots days (> 35°C) per annum. Two years in the last decade had over 20 very hot days (2015 and 2016; both also intense drought years). Mean minimum temperatures range

58 Eyring, V., Bony, S., Meehl, G. A., Senior, C. A., Stevens, B., Stouffer, R. J., & Taylor, K. E. 2016: Overview of the Coupled Model Intercomparison Project Phase 6 (CMIP6) experimental design and organization, *Geosci. Model Dev.*, 9, 1937-1958, DOI: https://doi.org/10.5194/gmd-9-1937-2016.

59 We thank the climate modelling groups for producing and making available their model output, the Earth System Grid Federation (ESGF) for archiving the data and providing access, and the multiple funding agencies who support CMIP6 and ESGF.

60 Schwalm, C.R., Glendon, S. & Duffy, P.B. 2020. RCP8.5 tracks cumulative CO_2 emissions. *PNAS* **117**: 10.1073/pnas.2007117117.

61 Hausfather, Z. & Peters, G.P. 2020. Emissions – the 'business as usual' story is misleading. *Nature* 577 : 618–620.

62 Copernicus Climate Change Service (C3S). 2017. ERA5: Fifth generation of ECMWF atmospheric reanalyses of the global climate. Copernicus Climate Change Service Climate Data Store (CDS), 13 October 2022, https://cds.climate.copernicus.eu/cdsapp#!/home.

63 Beck, H. E. *et al.* 2018. Present and future Köppen-Geiger climate classification maps at 1-km resolution. *Sci. Data* **5**:180214 doi: 10.1038/sdata.2018.214.

from 0°C in July to 13°C in February. Freezing nights (below 0°) occur regularly between May and October.

Mean annual rainfall is 274 ±80 mm/year. Rainfall peaks in March with a mean of 35 mm and there is less than 15 mm of rainfall per month from July to September. Extreme rainfall days (> 20 mm) are rare with 1.7 days. yr^{-1} since 1980.

Mean wind speed is approximately 6.5 km/h peaking in spring (October and November) and lowest in autumn (March and April). Mean wind speed has been relatively constant over the last four decades. The vast majority of wind is from north-westerly direction (Figure 5).

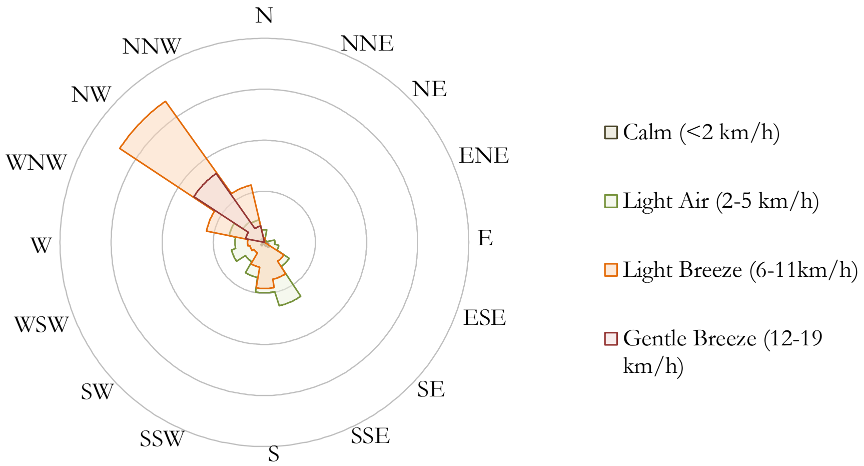

Figure 5: Wind rose based on mean monthly wind speed and direction since 1980 near the Mura Solar PV site. Copernicus Climate Change Service (C3S).[64]

4.2 Climate trends and projected climate change

4.2.1 Temperature

Mean annual temperature around the Project area has increased by approximately 1.0°C since the early 1980s thus showing an increasing trend of approximately 0.025°C per year. Temperatures are predicted to continue to rise under all SSPs. By 2050 median temperatures could increase from the current (last five years) mean (±16.0°C) to ±16.5°C under SSP1 through to ±17.4°C as under SSP5 (Figure 6).

[64] Copernicus Climate Change Service (C3S). 2017. ERA5: Fifth generation of ECMWF atmospheric reanalyses of the global climate. Copernicus Climate Change Service Climate Data Store (CDS), 13 October 2022, https://cds.climate.copernicus.eu/cdsapp#!/home.

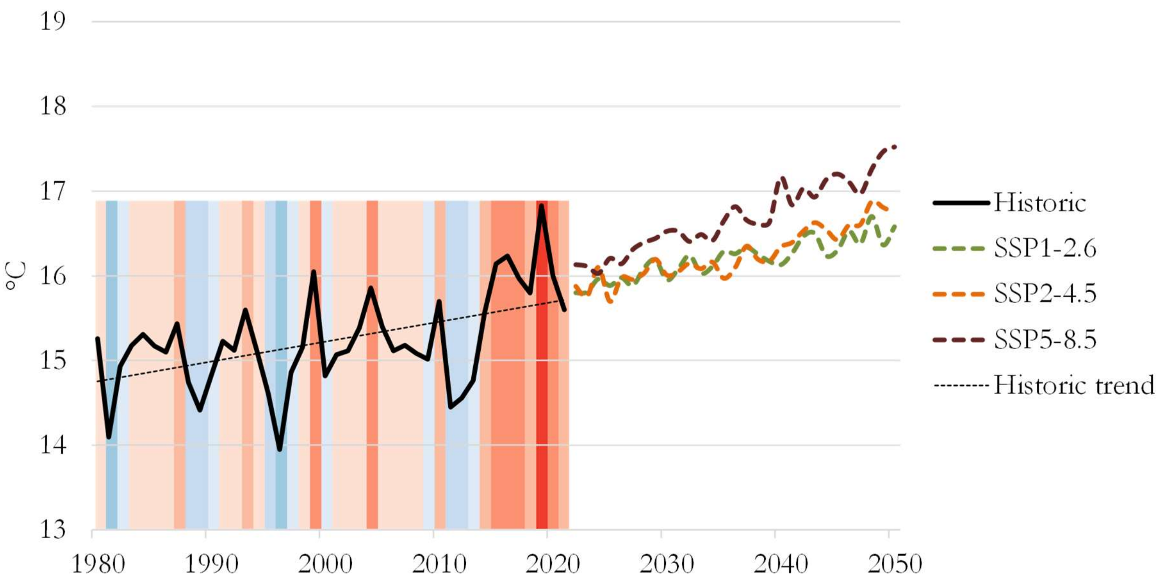

Figure 6: Near-historical and projected mean annual temperature for the Mura Solar PV Project area. Colour bars represent the mean temperature for the year relative to the mean for the time period shown. Data sources: Copernicus Climate Change Service (C3S)[65] and CMIP6.[66]

The near historical trend in very hot days shows a gradual increase with a sharper increase since ca. 2013; 2015 and 2016, both years during which an intense drought persisted, had over 20 very hot days each. The last decade has seen an average of 13.3 very hot days per year. A significant increase in the number of very hot days is projected under all three SSPs (Figure 7). The trend is particularly strong under SSP5. By 2050, the number of very hot days per annum is projected to range from ±21 days under SSP1 to ±27 days under SSP5; thus, more than doubling from the current number. By 2100, the number of very hot days could exceed 90 per annum under SSP5, 50 days per annum under SSP2 and 30 days per annum under SSP1.

[65] Copernicus Climate Change Service (C3S). 2017. ERA5: Fifth generation of ECMWF atmospheric reanalyses of the global climate. Copernicus Climate Change Service Climate Data Store (CDS), 13 October 2022, https://cds.climate.copernicus.eu/cdsapp#!/home.

[66] Eyring, V., Bony, S., Meehl, G. A., Senior, C. A., Stevens, B., Stouffer, R. J., & Taylor, K. E. 2016. Overview of the Coupled Model Intercomparison Project Phase 6 (CMIP6) experimental design and organization, *Geosci. Model Dev.*, 9, 1937-1958, DOI: https://doi.org/10.5194/gmd-9-1937-2016.

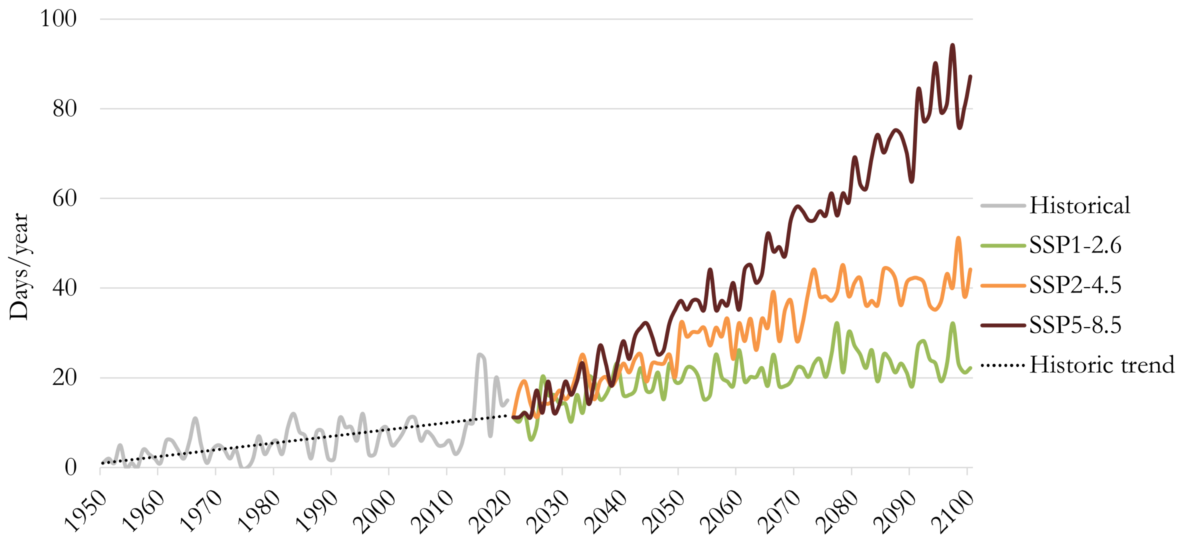

Figure 7: Number of very hot days per annum between 1950 and 2020 and the projected number of very hot days up to 2100 under three SSP trajectories for the Mura Solar PV Project area. Data sources: Copernicus Climate Change Service (C3S)[67] and CMIP6.[68]

4.2.2 Precipitation

Near historical (since 1980) mean annual precipitation around the Project site shows a decreasing trend. There has been a strong recent decline; the last five consecutive years have had less than 250 mm per year with the lowest rainfall experience in 2019 (Figure 8). Projected annual precipitation shows a continued but weaker decreasing trend under the three SSP trajectories. Annual rainfall is likely to be between 150-250 mm by 2050; slightly higher than recent amounts but lower than the historical long-term average (Figure 9).

---

[67] Copernicus Climate Change Service (C3S). 2017. ERA5: Fifth generation of ECMWF atmospheric reanalyses of the global climate. Copernicus Climate Change Service Climate Data Store (CDS), 13 October 2022, https://cds.climate.copernicus.eu/cdsapp#!/home.

[68] Eyring, V., Bony, S., Meehl, G. A., Senior, C. A., Stevens, B., Stouffer, R. J., & Taylor, K. E. 2016. Overview of the Coupled Model Intercomparison Project Phase 6 (CMIP6) experimental design and organization, *Geosci. Model Dev.*, 9, 1937-1958, DOI: https://doi.org/10.5194/gmd-9-1937-2016.

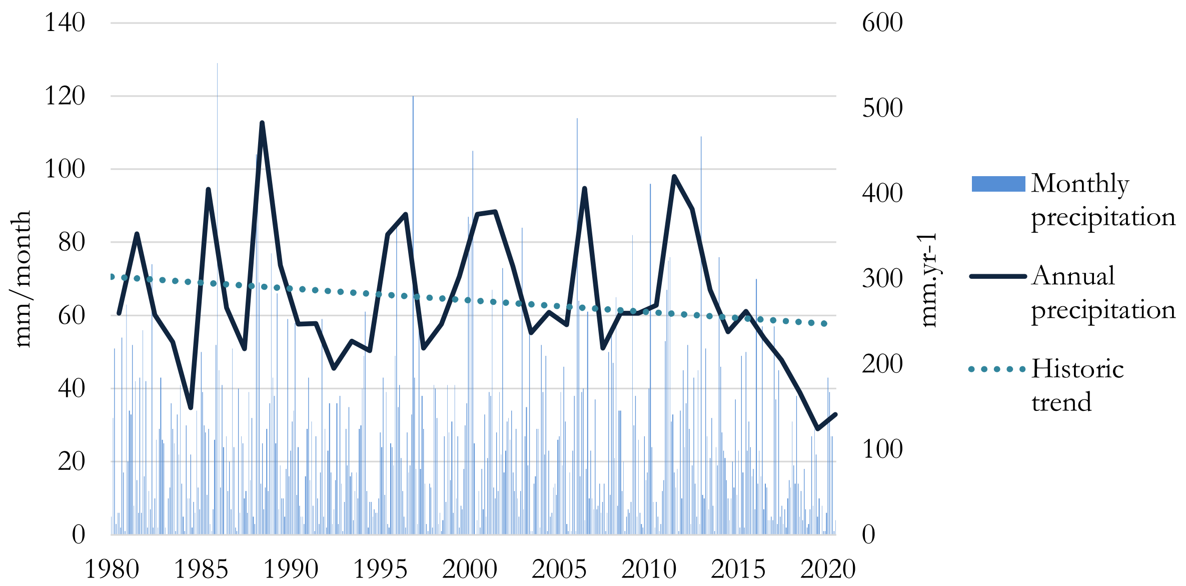

Figure 8: Mean monthly precipitation and mean annual precipitation for the Mura Solar PV Project area. Data source: Copernicus Climate Change Service (C3S).[69]

[69] Copernicus Climate Change Service (C3S). 2017. ERA5: Fifth generation of ECMWF atmospheric reanalyses of the global climate. Copernicus Climate Change Service Climate Data Store (CDS), 13 October 2022, https://cds.climate.copernicus.eu/cdsapp#!/home.

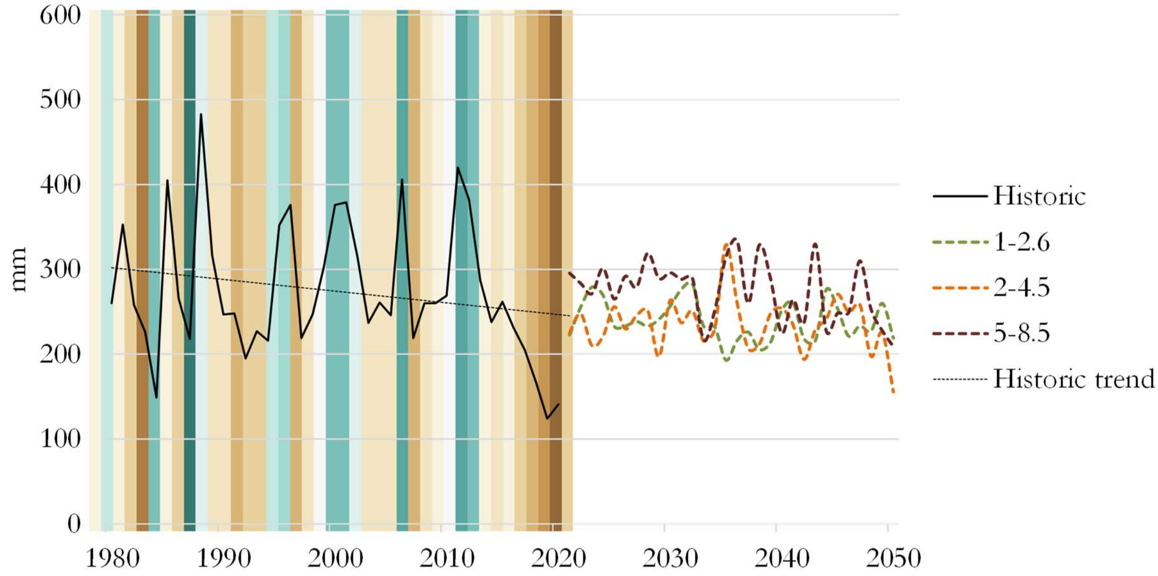

Figure 9: Near historical mean annual precipitation and projected trends in precipitation under three SSP trajectories for the Mura Solar PV Project area. Data source: Copernicus Climate Change Service (C3S)[70] and CMIP6.[71]

Because mean annual precipitation is so variable (Figure 8) and modelling precipitation is more challenging than temperature (due to several factors including topographic influence, isolated occurrence and non-linear interaction), it is useful to assess extreme rainfall events. Since the Project areas site is in an arid area with an average of < 2mm of precipitation a day, the number of days with 20 mm of rain becomes a good indicator of heavy rainfall days.

The Project area has experienced an average of 1.7 heavy rainfall days per annum since 1980, with five heavy rainfall days occurring during 2000. The number of heavy rainfall days up until 2050 is projected to be around 2-3 days per annum under the three SSPs assessed, and thus a slight increase from the current number (Figure 10). It can be concluded that rainfall is likely to decline slightly overall but may be more concentrated during storm events.

70 Copernicus Climate Change Service (C3S). 2017. ERA5: Fifth generation of ECMWF atmospheric reanalyses of the global climate. Copernicus Climate Change Service Climate Data Store (CDS), 13 October 2022, https://cds.climate.copernicus.eu/cdsapp#!/home.

71 Eyring, V., Bony, S., Meehl, G. A., Senior, C. A., Stevens, B., Stouffer, R. J., & Taylor, K. E. 2016. Overview of the Coupled Model Intercomparison Project Phase 6 (CMIP6) experimental design and organization, *Geosci. Model Dev.*, 9, 1937-1958, DOI: https://doi.org/10.5194/gmd-9-1937-2016.

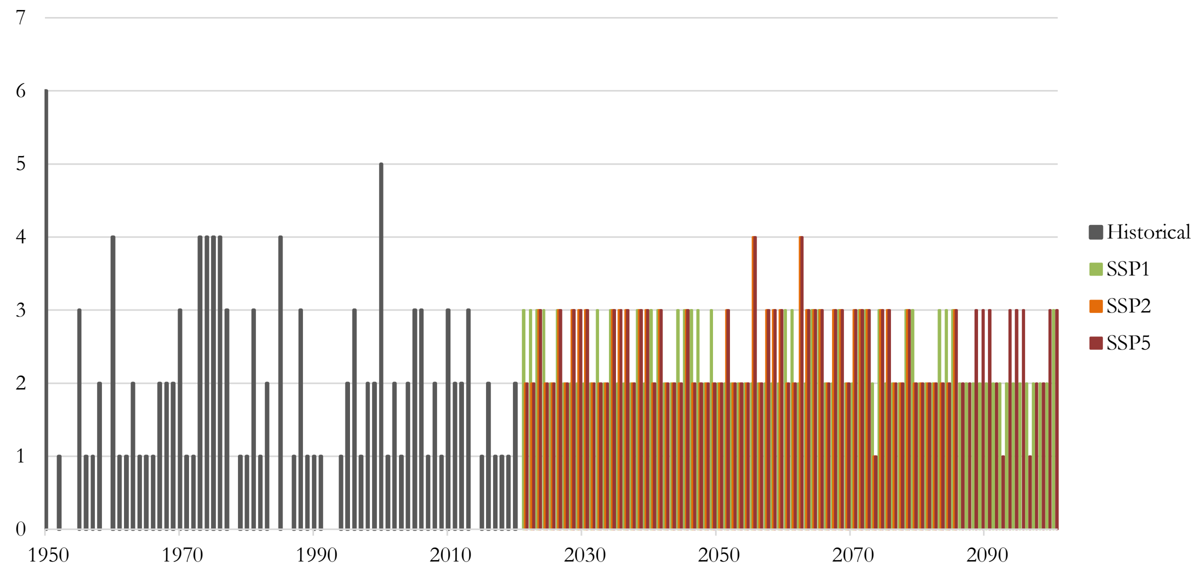

Figure 10: Near-historical and projected number of heavy rainfall days per annum at the Mura Solar PV Project area. Copernicus Climate Change Service (C3S)[72] and CMIP6.[73]

4.2.3 Water stress and drought

South Africa is classified as a water-stressed country.[74] The mean annual precipitation of 450 mm is well below the global mean. As of 2018, South Africa withdrew almost 64% of its available renewable freshwater resources. Such a high percentage increases the competition among users, resulting in greater exposure to water stress. Given that climate projections indicate increase variability in rainfall over the subregion, the high levels of water stress are likely to increase in most catchment areas.

According to the World Resources Institute (WRI) *Aqueduct* tool, the Project area falls within an arid river basin with low water use (Figure 11). Water stress in the catchment area in which Project area is situated is expected to remain under this classification under SSP2-4.5 up to 2040. Seasonal water variability[75] is expected to decline from low-medium to low. These metrics are challenging to model beyond a 20-year period and may well change significantly after 2050. The drought risk is currently classified as medium-high.

---

[72] Copernicus Climate Change Service (C3S). 2017. ERA5: Fifth generation of ECMWF atmospheric reanalyses of the global climate. Copernicus Climate Change Service Climate Data Store (CDS), 13 October 2022, https://cds.climate.copernicus.eu/cdsapp#!/home.

[73] Eyring, V., Bony, S., Meehl, G. A., Senior, C. A., Stevens, B., Stouffer, R. J., & Taylor, K. E. 2016. Overview of the Coupled Model Intercomparison Project Phase 6 (CMIP6) experimental design and organization, *Geosci. Model Dev.*, 9, 1937-1958, DOI: https://doi.org/10.5194/gmd-9-1937-2016.

[74] Water stress is defined as the ratio of total water withdrawals to available renewable surface and groundwater supplies.

[75] Average within-year variability of available water supply, including both renewable surface and groundwater supplies. Higher values indicate wider variations of available supply within a year.

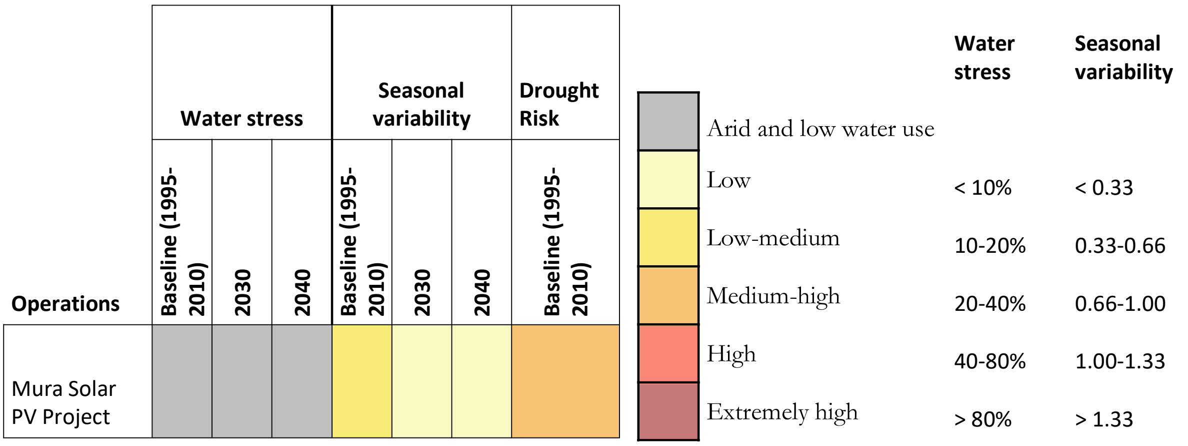

Figure 11: Water stress and seasonal variability classification for the Mura Solar PV Project area currently (baseline) and for 2030 and 2040 under SSP2-4.5. Data source: WRI Aqueduct.[76]

Consecutive dry days[77] has shown a declining trend since the middle of the 20th century (Figure 12). The mean number of consecutive dry days per annum since 1980 is 53. The number of such days is expected to average around 38 days per annum by 2050 (under all SSPs), however the models are not able to account well for extreme drought periods in the future. The trend in consecutive dry days from now until 2050 is slightly increasing (Figure 12).

[76] Hofste, R.W. *et al.* 2019. Aqueduct 3.0: Updated Decision-Relevant Global Water Risk Indicators. World Resources Institute. Available at: https://www.wri.org/applications/aqueduct/water-risk-atlas.

[77] Number of days in the longest period without significant precipitation of at least 1mm.

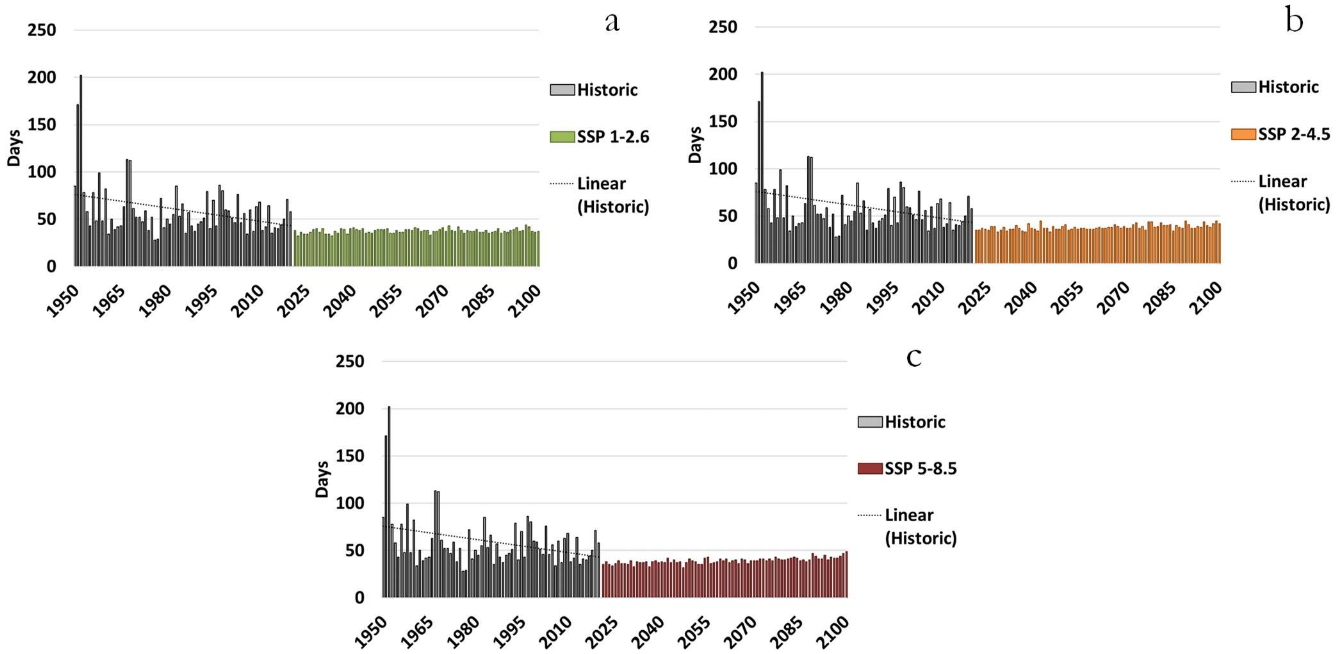

Figure 12: Historical and projected consecutive dry days at the Mura Solar PV Project area under SSP1 (a), SSP2 (b) and SSP5 (c). Data sources: Copernicus Climate Change Service (C3S)[78] and CMIP6.[79]

---

78 Copernicus Climate Change Service (C3S). 2017. ERA5: Fifth generation of ECMWF atmospheric reanalyses of the global climate. Copernicus Climate Change Service Climate Data Store (CDS), 13 October 2022, https://cds.climate.copernicus.eu/cdsapp#!/home.

79 Eyring, V., Bony, S., Meehl, G. A., Senior, C. A., Stevens, B., Stouffer, R. J., & Taylor, K. E. 2016. Overview of the Coupled Model Intercomparison Project Phase 6 (CMIP6) experimental design and organization, *Geosci. Model Dev.*, 9, 1937-1958, DOI: https://doi.org/10.5194/gmd-9-1937-2016.

Drought probability was assessed through the use of the Standardized Precipitation Evaporation Index (SPEI) with a 2-month window over the full period up to 2100. SPEI uses temperature and evaporation to evaluate the impacts on water demand. Following calculation, the SPEI results in values indicating the probability of experiencing severe medium-term drought with values of between -0.5 and -1 indicating mild drought, -1 to -1.5 being mild drought and values between -1 and -2 classified as severe drought.

Figure 13 indicates that the area has experienced several mild and moderate droughts in the last 30 years. Under SSP1, over 10 mild drought periods are projected. Under SSP2, the frequency of mild droughts increases significantly 2050 with at least six moderate droughts forecast. Models for SSP5 show an even higher number of moderate and severe droughts, particularly in the latter half of the century. Up to 20 severe drought years are projected by the end of the 21st century. Overall drought tendencies[80] are likely to increase by around 40-60% by 2050.[81]

80 The number of cases exceeding near-normal per decade.

81 Le Roux, A., van Niekerk, W., Arnold, K., Pieterse, A., Ludick, C., Forsyth, G., Le Maitre, D., Lötter, D., du Plessis, P. & Mans, G. 2019. Green Book Risk Profile Tool. Pretoria: CSIR. Available at: riskprofiles.greenbook.co.za

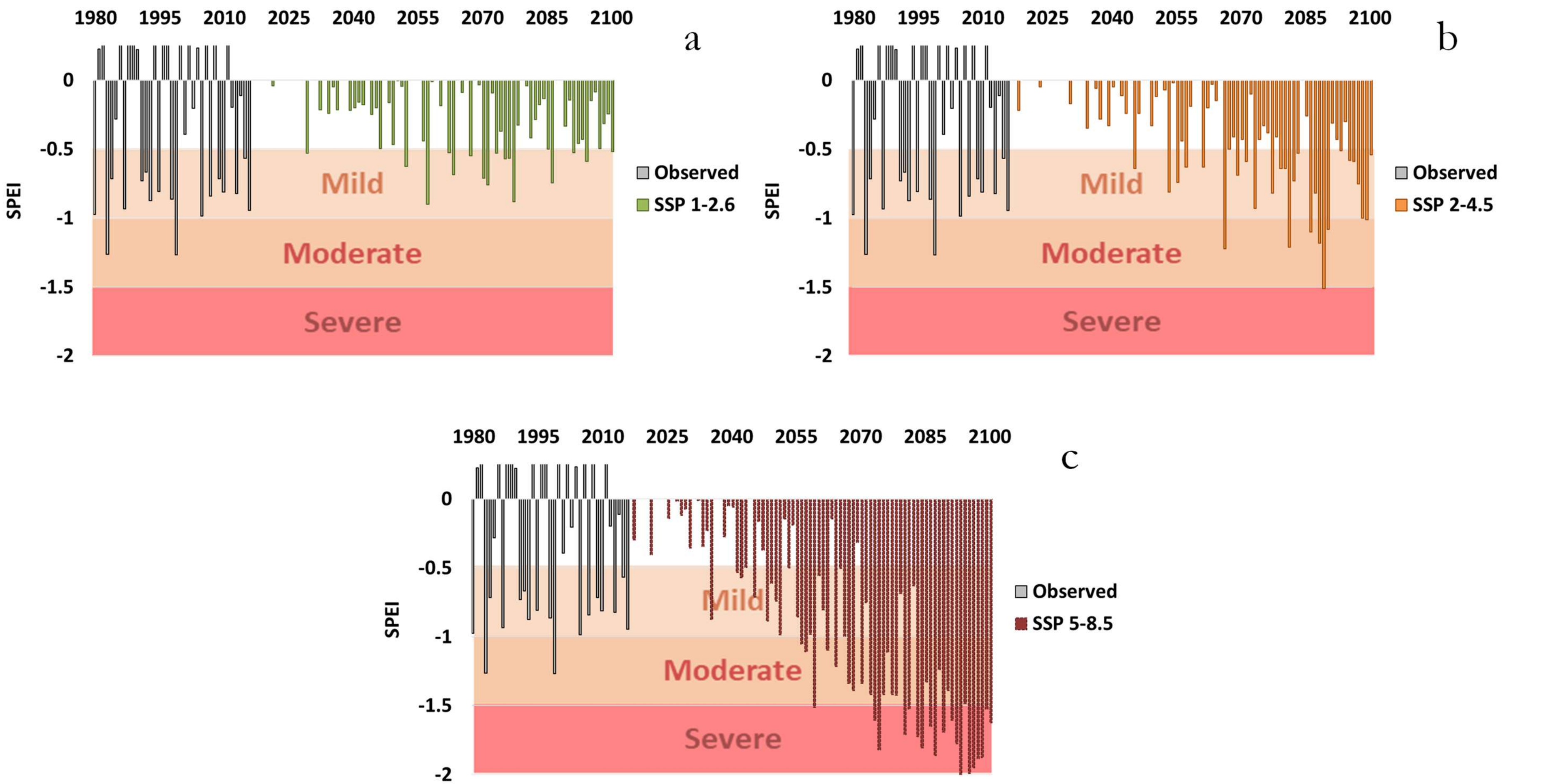

Figure 13: Near-historical and modelled future annual probability of experiencing severe medium-term drought for the Mura Solar PV Project site. The threshold or severe drought is -2. Data sources: Copernicus Climate Change Service (C3S)[82] and CMIP6.[83]

4.3 Summary

The current and future changes in climate for the Mura Solar PV Project, are summarised in the table below.

Table 10: Current and future climate projections for the Mura Solar PV Project area. [84,85,86]

		Projected change by 2040-2059 (median year 2050) relative to baseline		
Climate change impact	Current*	SSP 1	SSP 2	SSP 5
Mean annual temperature	15.7 ±0.6°C; increasing trend	Increase of 0.7-1.0°C	Increase of 0.9-1.2°C	Increase of 1.3-1.8°C
Very Hot (uncomfortable) Days[87]	13 days/year (mean)	Increase of 8 days/year (mean)	Increase of 15 days/year (mean)	Increase of 23 days/year (mean)
Mean annual precipitation	245 ±92 mm/year; decreasing trend	Mean decrease of 12 mm/year	Mean decrease of 37 mm/year	Mean decrease of 24 mm/year
Extreme Rainfall Days[88]	Mean of 1.5 days per annum	Increase of 0.7 days per annum	Increase of 0.7 days per annum	Increase of 0.7 days per annum
Drought Risk	Moderate to high	Not available		Moderate-high risk of increase in drought conditions per decade compared to baseline
Flood risk	Very low			Moderate decrease in risk
Wildfire Risk	Very low			Low increase in risk
Damaging solar risk	Not available			

*Mean for the last decade of available data, not since 1980 (viz near historical).

---

84 Le Roux, A., van Niekerk, W., Arnold, K., Pieterse, A., Ludick, C., Forsyth, G., Le Maitre, D., Lötter, D., du Plessis, P. & Mans, G. 2019. Green Book Risk Profile Tool. Pretoria: CSIR. Available at: riskprofiles.greenbook.co.za

85 Copernicus Climate Change Service (C3S). 2017. ERA5: Fifth generation of ECMWF atmospheric reanalyses of the global climate. Copernicus Climate Change Service Climate Data Store (CDS), 13 October 2022, https://cds.climate.copernicus.eu/cdsapp#!/home.

86 Eyring, V., Bony, S., Meehl, G. A., Senior, C. A., Stevens, B., Stouffer, R. J., & Taylor, K. E. 2016. Overview of the Coupled Model Intercomparison Project Phase 6 (CMIP6) experimental design and organization, *Geosci. Model Dev.*, 9, 1937-1958, DOI: https://doi.org/10.5194/gmd-9-1937-2016.

87 A day when the maximum temperature exceeds 35°C.

88 More than 20 mm of rain falling within 24 hrs over an area of 64 km^2.

5 PROJECT IMPACT ON CLIMATE CHANGE

The proposed Mura Solar PV Project will result in GHG emissions being released into the atmosphere during its lifetime. Its impact is quantified by developing a GHG inventory. The GHG inventory allows for the emissions from the various emission sources to be calculated and quantified. The Project's GHG inventory is discussed below.

5.1 Project GHG inventory

The GHG inventory for the proposed Project was developed in accordance with the ISO14064-1 standard, as stipulated in Section 3.1.1 above. The development of the GHG inventory for the Project is based on certain assumptions (as stipulated in Section 3.1.5 of this CCIA) to overcome some unavoidable data gaps.

The boundaries of the analysis were set, as indicated in Section 1 and throughout Section 3.1. This analysis took into consideration the relevant emissions from core operations, i.e., direct emissions. As a result of the direct emissions not being available currently, the GHG inventory report considers the indirect emissions for only the construction phase of the project. Such information is considered in a cumulative emissions context and disclosed in Section 7 of this report.

5.2 Contribution to the South African transition to a low carbon economy

South Africa's grid is expected to decarbonise in the future. However, it will still rely heavily on GHG intensive technologies, such as coal-fired power stations and gas-to-power technologies. The Mura Solar PV Project will contribute to the inclusion of renewable energy onto the grid, to replace the use of energy from GHG intensive technologies. This will lead to avoided emissions in the amount of 16 tCO_2e per PV panel across the lifetime of each PV panel (0.8 tCO_2e/y/per panel on average for a 20-year lifetime).

Based on the assumption that 250 000 PV panels would be constructed for a 150MW farm, over the lifetime of the project, the avoided emissions are approximately 4.10 million tons CO_2e of emissions for a 150MW solar facility. This equates to approximately 27 324 tonnes CO_2e per MW installed. This could be considered as a *high* positive impact, as the avoided emissions for a 150MW solar farm equate to 0.107% of the carbon budget[89], where a values between 0.019% and 0.193% is considered *High*.

5.3 Overall impact on climate change

The impacts of the Mura Solar PV Project on climate change have been quantified in the sections above.

[89] See Section 3.1.4 for more details on how the carbon budget was calculated.

The project, as a 150MW solar facility, will lead to approximately 4.10 million tons CO_2e of avoided emissions (27.3 ktCO_2e per MW). Table 11 below indicates that as a result, the project's impact will be *High* positive.

Table 11: Climate change impacts of the Mura Solar PV Project (150MW Solar Facility).

<table>
<tr><td colspan="3">Nature: The magnitude of the impact of the Mura Solar PV Project GHG emissions during construction is determined in Section 7. However, during the operation of the Project, the electricity generated by the Project will displace the use of more emission intensive technologies, such as coal-fired power stations. The magnitude of the impact of the Mura Solar PV Project's avoided GHG emissions, during operation, is quantified as 4.10 million tons CO_2e of emissions for 150MW farm as explained in Section 5.1 above.

This results in net avoided emissions of 4.10 million tons CO_2e over the lifetime of the Project (equivalent to 16 tCO_2e per solar PV panel or 27.3 ktCO_2e per MW).

The net impact of the project in relation to South Africa's carbon budget is a high positive over the life of the Project, as the Project's net avoided emissions saves 0.107% of the carbon budget (where between 0.019% and 0.193% is considered High).</td></tr>
<tr><td>Criteria</td><td>Without Mitigation</td><td>With Mitigation*</td></tr>
<tr><td>Magnitude (M)</td><td>High</td><td>N/A</td></tr>
<tr><td>Extent (E)</td><td>International</td><td>N/A</td></tr>
<tr><td>Reversibility (R)</td><td>Recoverable</td><td>N/A</td></tr>
<tr><td>Duration (D)</td><td>Permanent</td><td>N/A</td></tr>
<tr><td>Probability of Occurrence (P)</td><td>Definite</td><td>N/A</td></tr>
<tr><td>Significance</td><td colspan="2">Very High Positive</td></tr>
<tr><td>Can impacts be mitigated? *</td><td colspan="2">The Project serves as mitigation measures to reduce the current level of exhaustion of South Africa's carbon budget, as currently experienced through the existing fossil fuel intensive grid.</td></tr>
<tr><td colspan="3">Mitigation*: Mitigation measures to address the impact of the Project on climate change is not required, as they are classified as renewable energy and therefore have an overall impact of very high positive significance.</td></tr>
<tr><td colspan="3">Residual risks: There are no residual risks associated with the Project, as their overall contribution to climate change is positive.</td></tr>
</table>

6 Climate Change Impacts on the Project/Project vulnerability to climate change

6.1 Core operations

The main weather-related risks that are relevant to project, are the increase in mean temperature and the number of very hot days predicted. These have a bearing on operations and labour productivity. The proposed site is in a region with relatively high temperatures. Uncomfortable heat levels impact labour productivity and have a direct bearing on the health and safety of personnel. This is particularly true of any open-air operations with no access to air-conditioning where engineers, mechanics and cleaners may be impacted by direct exposure to increased temperatures, resulting in heat stress. Heat stress and discomfort could lead to unforeseen incidents that could cause damage to equipment/or human injury. This could lead to heat-related illnesses, increased injuries, more absenteeism, slow work pace, loss of productive capacity, poor social well-being and at worst, mortality.

6.2 Value chain

Analysing the impacts climate change will have on the value chain, the Mura Solar PV Project site will allow for an understanding of how materials, equipment, and resources (upstream), and energy distribution (downstream) processes, will be affected.

6.2.1 Upstream value chain

The impacts on the upstream value chain are summarised in Table 12.

Table 12: Climate change impacts on the upstream value chain of the Mura Solar PV Project

Item	Aspects affected by the impacts of climate change
Water Supply	Water supply may be restricted during periods of drought or dry spells, which are likely to increase in severity and frequency. Measures should be put in place to reduce the vulnerability of the site to water shortages.
Diesel Supply	Extreme weather may affect trade routes and the ability to transport diesel for use on site. Supply chains are considered commercial risks, which should already be taken into consideration.
Transport and storage of all goods	It is anticipated that diesel will also be used onsite for machinery and generators. Similarly, all equipment and other such goods will be transported to the project site. *Increased temperatures* Increasing ambient temperatures and extreme hot days increases exposure to heat and in turn, heat stress. Heat stress at work, as result of (climate-related) increasing temperatures, impacts workers health, safety, productivity, and social well-being. Therefore, the projects transport of goods and services and its workers may be exposed to heat stress and increased temperatures which will inevitably impact operations. In addition, storage areas for the various

Item	Aspects affected by the impacts of climate change
	goods used by the project may experience increased temperatures and possible damage, thus causing delays in product deliveries to the project site. *Extreme weather events.* With increased rainfall variability, the project site may be exposed to erratic rainfall, periods of drought, but also periods of intense rainfall. Increased flooding may also lead to pipeline damages, resulting in potential water supply constraints. This could lead to decreased road access to the project and cause delays in product deliveries to the project site.

6.3 Broader Social Context

Due to the complex nature of climate change, climate vulnerability is not only caused by the level of exposure, but also by the social, economic, environmental, and institutional contexts that interact with the changing climate. In this regard, for the purposes of the climate change impact assessment, the broader social and environmental contexts of the project are noted.

Climate change could negatively impact on the surrounding communities and natural environment. However, negative impacts on the local community will have little impact on the solar farms, as they will operate with a small number of staff due to the solar not being labour intensive.

In general, livelihood sources of the poor are usually narrower and more climate-sensitive than those of the non-poor. Extreme weather events often cause extensive damage and substantial loss of life in a developing country. Poor communities are particularly vulnerable to deviations from average climatic conditions, such as prolonged drought and natural disasters.

Climate change acts as a climate risk multiplier, enhancing existing vulnerabilities and risks. If employment rates continue to decline in communities surrounding operations and dissatisfaction with basic service delivery and infrastructure increases, there may be a risk of social unrest, which at times may be aimed at the commercial operations in the region that have limited employment opportunities due to the nature of the work being undertaken.

6.4 Broader Environmental Context

Promethium understands that biodiversity and aquatic specialist studies have been undertaken for the application. This CCIA will therefore not provide details with respect to impacts on biodiversity within the ecosystems surrounding and within the Project area. However, at a high level, the key environmental risk with regards to climate change is that of water stress and its resulting availability. Freshwater and groundwater resources are expected to come under increasing pressure under warmer and mostly drier conditions. Aquatic ecosystems play a vital role in moderating floods, particularly in arid environments, and removing nutrients, toxins, sediments and pollutants. Ensuring these systems remain in a healthy condition is key to ensuring they continue to provide these regulating ecosystem services.

In terms of surrounding ecosystems, the primary threats relate mostly to the loss of habitat through further land cover conservation. Solar PV facilities have the potential to remove and/or cover large areas of natural vegetation. This creates more fragmented and smaller areas of natural habitat at a hyper-local level. However, from a climate change perspective, the project is unlikely to have a major impact on surrounding ecosystems, nor exacerbate existing pressures, given that the ecosystem types are not classified as threatened, nor do they have a high degree of modification or loss. Significant changes in vegetation in the southern part of the Nama-Karoo (in which the site is located) by 2050, are not likely. However, tree and C4 grass abundance may increase, but are unlikely to impact operations.

7 Assessment of Cumulative Impacts

Cumulative impacts can be defined as "the past, current and reasonably foreseeable future impact of an activity, considered together with the impact of activities associated with that activity, that in itself may not be significant, but may be significant when added to the existing and reasonably foreseeable impacts eventuating from similar or diverse activities" (NEMA EIA Reg GN R982 of 2014). Figure 1 in section 1.1 indicates all the renewable energy developments within 30km of the Mura Solar PV facilities. Therefore, the Project has been assessed cumulatively (i.e., all four Mura Solar PV projects, Nuweveld WEF's, Hoogland WEF's, Soutrivier WEF's, and Taaibos WEF's) including the indirect emissions (Category 3-6) of the Mura Solar PV projects.

In relations to the Hoogland Wind Farm Project, based on the assumption that 60 turbines would be constructed on each wind farm, over the lifetime of the project, the avoided emissions are approximately 11.6 million tonnes CO_2e of emissions per wind farm. This equates to 46.3 million tons CO_2e of emissions for the four wind farms (or 41 000 tonnes CO_2e per MW installed). This could be considered as a *very high* positive impact as the avoided emissions for all four wind farms equate to 1.21% of the carbon budget. Therefore, the cumulative impact of this project on climate change is considered to be *very high* positive as a result of the avoided emissions opportunity. Furthermore, as although not quantified, the Nuweveld Projects cumulative emissions is also considered *very high* as a result of the avoided emissions that will accumulate.

As for the indirect emissions in relations to the Mura Solar PV Projects, the indirect emissions reported below considers only the construction phase of the four Mura Solar PV projects. The operation emissions have been excluded due to being immaterial. It is assumed that each solar facility will have a capacity of 150 MW with approximately 250 000 PV panels. Table 13 summarises the construction indirect emissions of the proposed project, as well as the emissions per MWh and per MW. The emissions were summarised according to emissions for four 150MW farms.

As explained in Table 13, four150MW solar farm will only contribute 73.7 kt of indirect emissions from the construction phase (equivalent to 0.013 tCO2e per MWh or 0.49ktCO_2e per MW installed). Most emissions during the construction phase are associated with the upstream production of construction materials and the purchasing of the PV panels. The emissions that would occur from operating and maintenance activities are negligible.

These emissions would equate to about 0.00195% of South Africa's carbon budget. Relative to South Africa's updated NDC, this is 0.0016% of the high emission scenario and 0.0020% of the low emission scenario. Based on this assessment, the impact of the four 150MW farms in relation to South Africa's carbon budget is *medium*, as the solar Project emissions amount to approximately 0.0019% of the carbon budget (where a value between 0.00039% and 0.019% is considered *medium* as defined in Table 8). However, the cumulative impact of these projects on climate change is considered to be high positive as the Mura Solar PV Projects also further increase the opportunity for avoided emissions.

Table 13: Construction- related emissions for the proposed Mura Solar PV Project (four 150 MW facilities)

Activity	Total Emissions (tCO_2e)	Emissions per MWh produced (tCO_2e/MWh)	Emissions per MW installed capacity (tCO_2e/MW)
	Four Solar Farms		
Construction Category 1	*		
Construction Category 3-6	73 700	0.013	491.3
Total for four 150MW farms	**73 700**	**0.013**	**491.3**

* Data regarding direct emissions during construction and operation (such as onsite fuel combustion in vehicles), as well as indirect emissions during operations, were not available at this stage. Based on the specialist's experience, these were assumed to be immaterial relative to the magnitude of the Category 3 - 6 emissions during construction.

Whilst the Project's indirect emissions for four 150MW solar farm in relation to South Africa's carbon budget is *medium*, the cumulative impact of the Development, with Nuweveld and Hoogland, on climate change is considered to be *very high* positive. This is as a result of the avoided emissions that the Development creates over the lifetime of the project, with the Mura Solar PV Development of all four wind farms resulting in avoided emissions of around 16.39 million tons CO_2e of emissions over the life of the project and the Hoogland Wind Farms resulting in avoided emissions of 46.3 million tons CO_2e.

8 Project Impact Mitigation and Adaptation Measures

8.1 Measures to reduce the impact of the project on climate change

The Mura Solar PV Development has a positive impact on climate change, as its operation will result in avoided emissions of around 16.39 million tons CO_2e of emissions over the life of the project (all four solar farms) and 4.1 million tons CO_2e of emissions per 150 MW farm. his will lead to avoided emissions of 16 tCO_2e per PV panel across the lifetime of each PV panel (0.8 tCO_2e/y/per panel on average for a 20-year lifetime).

This represents around 0.428% of the carbon budget (0.107% per farm), based on the IPCC's 6th assessment report and a 1.5 degrees Celsius ambition

8.2 Adaptation measures to increase the project's resilience to climate change

As described in Section 6 of this report, climate change impacts will influence the Project operations, as well as the surrounding communities and broader natural environment to some extent. However, there are a few adaptive measures that the Project can take to improve the operation's resilience to the identified climate change impacts. Adaptation measures which can be considered in the operation's future include:

1. Water stress in the context of climate change poses a risk to water availability. This is likely to be exacerbated by growing demand for water resources outside of the operations, particularly the agricultural sector in the region. The project should therefore implement water saving and conservation measures, including capturing and reusing as much of the water onsite to reduce dependence on external water sources.

2. There is a high chance of an increase in the number of very hot, uncomfortable days over the next century. These are likely to have the greatest impact on i) water resources and ii) labour productivity. In terms of water resources, the very hot days will increase evapotranspiration and exacerbate water stress. Measures to adapt to this are listed in point 1 above. Regarding the impacts on labour productivity, the operations will need to ensure that the relevant health and safety protocols are observed and potentially updated to reduce the impacts of heat-related health impacts that could occur. Health and safety personnel will need to pay attention to short-term weather forecasts to anticipate hot days and ensure there are either sufficient staff available for higher rotation of shifts during hot times of the day or to ensure there is machinery that can be used as an alternative (and itself be able to operate under more regular high temperatures). Safety training and screening of employees will also be important measures to set up. One or several on-site weather stations, which can alert operations personnel to heat thresholds being reached, would be useful installations.

3. Although heavy rainfall days are not projected to increase significantly, they should nevertheless be considered. Heavy rainfall events can lead to flash flooding in arid environments, which could have an impact on site access both within and outside of the site. Early warning systems including doppler radar storm warning systems (which are often used at facilities with open space such as schools, sports clubs and golf courses) can assist in alerting operations personnel to impending storms in order to evacuate staff from at-risk areas.

9 Climate change specialist Opinion

It is our opinion that, from a climate change perspective, each of the four Mura Solar PV projects should receive authorisation, based on the following key aspects:

1. The project will adopt solar technology and will therefore significantly reduce the consumption of fossil-fuel generated energy and reduce the environmental impact associated with these fuels. According to the Integrated Resource Plan (2019), Solar PV presents an opportunity to diversify the energy mix to produce distributed generation and provide off-grid electricity in South Africa.
2. The project will contribute to the Nationally Determined Contribution of South Africa, which is aligned to the Paris Agreement, in that it will play a role in the decarbonisation efforts for South Africa.
3. Solar energy presents the basic environmental benefit of the displacement, or the avoidance of emissions associated with conventional electricity generation. Solar energy also has the potential to address the need for energy access in remote areas, create jobs and increase localisation.

Each solar farm (if they each have a generation capacity of 150 MW) will only contribute 18.4 kt of indirect emissions from the construction phase (or 0.12 ktCO_2e per MW), with a total contribution of 73.7 5 ktCO_2e (0.49 ktCO_2e per MW) indirect emissions from the construction phase of all four solar farms. This will result in a *medium* impact per solar farm in relations to the South Africa's carbon budget. However, the cumulative impact of the Development, with the proposed wind farms in the area, on climate change is considered to be *very high* positive, as explained in section 5.3 of the report. This is as a result of the avoided emissions that the Development creates over the lifetime of the project.