Specialist Climate Change Impact Assessment Report

Climate Change Impact Assessment for the proposed Duynefontein Nuclear Power Station as part of the Eskom Nuclear-1 Project

Prepared by Promethium Carbon for:

srk consulting

October 2023

DOCUMENT CONTROL

Date	Amendment	Version Number
24 May 2023	First draft report submitted to SRK	0
21 June 2023	Draft report amended based on comments received from SRK on 5 June 2023 and from Eskom on 13 June 2023.	1
6 July 2023	Draft report amended based on further comments received from SRK and Eskom on 4 July 2023.	2
10 July 2023	Draft report amended based on further comments received from SRK on 10 July 2023.	3
17 July 2023	Draft report amended based on further comments from Eskom.	4
15 August 2023	Draft report amended by addressing minor typos.	5
2 October 2023	Final report amended based on comments received from interested and affected parties, following the public stakeholder meeting and subsequent commenting period.	6

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Note:

In response to stakeholder comments, the draft Specialist Climate Change Impact Assessment report was updated at the end of the comment period to produce this Final Specialist Climate Change Impact Assessment report for submission to the Minister.

All changes in the final Specialist Climate Change Impact Assessment report and executive summary vis-a-vis the previously released Specialist Climate Change Impact Assessment report are italicised and underlined for easier reference.

Executive Summary

Promethium Carbon was appointed by SRK Consulting (South Africa) (Pty) Ltd (SRK) to conduct a Climate Change Impact Assessment (CCIA) for the proposed Duynefontein Nuclear Power Station in South Africa as part of the Environmental Impact Assessment (EIA) for the Eskom Nuclear-1 Project, which was commissioned by Eskom Holdings SOC Ltd (Eskom) in response to an appeal process against the Environmental Authorisation (EA) granted for the project. The proposed Duynefontein Nuclear Power Station has a maximum generation capacity of 4 000 MW.[1]

The approach to the CCIA is:

1. The scope of the assessment covers the following[2]:
    a. The impact of the project on climate change; and
    b. The resilience of the project to climate change.
2. The emissions from the project is handled as follows[3]:
    a. The direct emissions from the project is considered as the project's contribution to climate change; and
    b. The life cycle emissions of the project (emissions of the nuclear fuel cycle) is addressed as part of the cumulative impacts of the projects in terms of the requirements of NEMA.

The methodology used for this CCIA was informed by:

1. The nature of climate change;
2. The project development timeframes;
3. The long-term climate impacts anticipated for the Project and its surrounding areas; and
4. Available climate data for variables specifically relevant to the Project.

The climate-related impacts and vulnerabilities relevant to the Project and surrounding areas are considered throughout this CCIA.

The assessment of the project's impact on climate change was based on a life cycle assessment (LCA) of the project's greenhouse gas emissions, as calculated according to *SANS 14064:2021 Part 1* and the *Environmental Impact Assessment (EIA) Regulations, 2014, as amended* (the Regulations) and *Methodological Guidelines for Quantification of Greenhouse Gas Emissions*, as amended, and published by the Department of Forestry, Fisheries, and the Environment (DFFE).

1 The capacity may however change as a result of studies and vendor selection that still need to be done.
2 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)
3 South Durban Community Environmental Alliance and Another v Minister of Forestry, Fisheries and The Environment and Others (17554/2021) [2022] ZAGPPHC 741 (6 October 2022) http://www.saflii.org/za/cases/ZAGPPHC/2022/741.html

In the absence of formal guidance on determining vulnerability to climate change, the assessment of the project's resilience to climate change was guided by the DFFE's *Framework for Climate Change Vulnerability Assessments* and the *Equator Principles*. The project's vulnerability was assessed across core operations only.

Aspects relating to climate change were referred to in numerous specialist reports as part of the Final Environmental Impact Report (FEIR) submitted to the DFFE in 2016. Where relevant, we have referenced these reports, and have reviewed all instances applicable to climate change in those reports and noted whether the conclusions made are still relevant or if any updates are required.

This report also addresses possible mitigation and adaptation measures that could be considered by the proposed project developer as recommendations to reduce GHG emissions and improve the project's resilience to climate change.

The impact of the project on climate change was assessed in the context of both the LCA GHG emissions from the project, as well as the potential positive impact the project can have through the avoidance of emissions. The project will emit in the order of 570 000 tCO_2e during the 9-year construction phase of the plant and could potentially emit in the order of 470 000 tCO_2e/year over its lifetime. The direct emission intensity of the project is equivalent to 0.3% of the baseline Eskom grid emission factor. The indirect and cumulative emissions represent another 1.7% of the current Eskom grid emission factor.

The climate analysis for the Duynefontein project area shows low impacts, with an increase in sea surface temperature as being the only variable that could impact on the operation and safety of the power plant. The assessment considers the design criteria of the plant as per the (2009 but now superseded) Eskom Nuclear Sites Site Safety Reports,[4] and finds that the design criteria sufficiently address the potential impacts of climate change on the project.

With regards to water stress and droughts, South Africa experiences mean annual precipitation well below the global average, leading to a high demand for limited freshwater resources. South Africa withdraws nearly 64% of its available renewable freshwater, intensifying competition among users and exacerbating water stress. Climate projections indicate increased rainfall variability in the subregion, further aggravating water stress in most catchment areas. The Duynefontein site is situated within a river basin characterized by extremely high water stress, medium-high seasonal variability, and medium-high drought risk. These conditions are expected to persist until 2040, with potential decreased rainfall and heightened water variability. The number of consecutive dry days has been increasing, suggesting a trend towards more frequent and prolonged drought periods. By 2050, the average number of consecutive dry days per year could reach 46-49 days.

4 Eskom Nuclear Sites Site Safety Reports Coastal Engineering Investigations Duynefontein (Report No. 1010/4/102), October 2009, Prestedge Retief Dresner Wijnberg (Pty) Ltd, Section 5.6

The only climate change impact identified as a potential risk relates to the use of sea water for colling in the reactor cooling and the spent fuel storage system. We recommend that the design for the cooling systems take the historic and projected increases in sea surface temperature into account, and that the systems be designed for a maximum sea water inlet temperature of 24°C.

The interventions recommended are offered as non-binding proposals that Eskom could consider limiting the climate change impacts of, and on the project and site as a whole. If there are any conflicting recommendations, Eskom should defer to design measures recommended in the most recent and extremely comprehensive SSRs.

In accordance with the findings of this CCIA, we advise that the proposed Duynefontein Site should not be refused environmental authorisation based on climate change related issues.

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Acronyms and Abbreviations

°C	Degrees Celsius
AR6	Sixth Assessment Report
C3S	Copernicus Climate Change Service
CCDS	Copernicus Climate Data Store
CCPP	Combined cycle power plant
CCIA	Climate Change Impact Assessment
CCKP	Climate Change Knowledge Portal
CMIP6	Coupled Model Intercomparison Project Phase 6
CO_2	Carbon dioxide
CoCT	City of Cape Town [Metropolitan Municipality]
DFFE	Department of Forestry, Fisheries and the Environment
EA	Environmental Authorisation
EIA	Environmental Impact Assessment
ENSO	El Niño–Southern Oscillation
Eskom	Eskom Holdings Limited SOC Ltd
FEIR	Final Environmental Impact Report
GHG	Greenhouse gas
GMSL	Global mean sea level
GWP	Global Warming Potential
IPCC	Intergovernmental Panel on Climate Change
LCA	Life cycle assessment
LNG	Liquified natural gas
NEMA	National Environmental Management Act (Act Nº 107 of 1998)
NERSA	National Energy Regulator of South Africa
NOAA	National Oceanic and Atmospheric Administration
PWR	Pressurised Water Reactor
SRK	SRK Consulting (South Africa) (Pty) Ltd
SSP	Shared Socio-economic Pathway
SST	Sea surface temperature
ToR	Terms of reference
UNFCCC	United Nations Framework Convention on Climate Change

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Key Terms and Definitions

Adaptive capacity[5]	Adaptive capacity is a set of factors which determine the capacity of a system to generate and implement adaptation measures. These factors relate largely to available resources of human systems and their socio-economic, structural, institutional, and technological characteristics and capacities.
Climate change impacts[5]	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 generally 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[5]	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.
Climate exposure[5]	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 resilience[5]	The capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganising in ways that maintain their essential function, identity and structure while also maintaining the capacity for adaptation, learning and transformation.
Climate variability[5]	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).
Climate Vulnerability[5]	The propensity or predisposition to be adversely affected and encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

[5] IPCC, 2022: Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. *et al.*(eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 37–118, doi:10.1017/9781009325844.002.

Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity.

Direct emissions	GHG emissions that occur from sources that are controlled or owned by an organization. Direct emissions are labelled Scope 1 emissions in the GHG Protocol Corporate Standard and Category 1 emissions in SANS 14064 Part 1 (2021).
Extreme weather[6]	Unexpected, unusual, or unforeseen weather which differs significantly to the usual weather pattern, such as droughts, floods, extreme rainfall, and storms.
Greenhouse Gas (GHG)[5]	Greenhouse gases (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 IPCC Assessment Reports deals with the following GHGs, 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. Indirect emissions are classified as Scope 2 emissions for energy indirect emissions and Scope 3 emissions for other indirect emissions in the GHG Protocol Corporate Standard. SANS 14064 Part 1 (2021) classifiers indirect emissions as Category 2 through Category 6 emissions.
Resilience[7]	The capacity of interconnected social, economic and ecological systems to cope with a hazardous event, trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure.
Sensitivity[5]	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 Pathways (SSPs)[8]	The Shared Socioeconomic Pathways (SSPs) are scenarios developed by the Intergovernmental Panel on Climate Change (IPCC) to assess societal and economic developments and how these could affect greenhouse gas emissions and climate change. They are designed to facilitate the integration of climate change research, including climate impacts, adaptation, and mitigation.

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

7 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.

Social vulnerability drivers[9]	Social vulnerability is defined as a dynamic state of societies comprising exposure, sensitivity and adaptive capacity. It is characterised by high levels of dependence on natural resources for livelihoods and economic development, combined with increasing environmental degradation, which can both increase exposure (e.g., wetland destruction) and reduce adaptive capacity (e.g., declining river flows constraining water provision). Examples of social vulnerability drivers include poverty, low awareness and inability to migrate.
Vulnerability[10]	Vulnerability is defined as the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes.

9 Tucker, J., *et a*l. 2015. Social vulnerability in three high-poverty climate change hot spots: What does the climate change literature tell us? *Reg Environ Change* 15: 783. https://doi.org/10.1007/s10113-014-0741-6.

10 IPCC, 2022: Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press. In Press.

Declaration of Independence

The authors of this report do hereby declare their independence as consultants appointed by SRK Consulting (South Africa) (Pty) Ltd (SRK) to undertake a Climate Change Impact Assessment (CCIA) of the Duynefontein site for the Eskom Nuclear-1 Project. 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 this report are their own.

Robbie Louw

Kenneth Slabbert

Joshua Weiss

Juan du Plessis

Details of the Specialist Team

Promethium Carbon is a South African climate change and carbon advisory company with offices in Johannesburg and Cape Town. 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/ies to climate change. Promethium Carbon has calculated GHG inventories for over 60 entities and is proficient in applying the requirements of ISO/SANS 14064-1 and the GHG Protocol's accounting standards, as well as South Africa's GHG Reporting Guidelines. 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 Duynefontein site for the Eskom Nuclear-1 Project.

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.

Kenneth Slabbert is a senior Climate Change Advisor who holds a Masters in Mechanical Engineering specialising in energy management. He has four years of experience in climate change mitigation and energy management. Kenneth's experience includes carbon footprint calculations and reporting, carbon tax calculations, climate change impact assessments, energy management, CDP responses and carbon credit project documentation.

Joshua Weiss is a senior climate change advisor at Promethium Carbon. He holds an MSc in Conservation Biology and a BSc Hons in Ecology, Environment and Conservation. Cumulatively, he has 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*. He has also previously been involved in avifaunal monitoring and reporting, particularly in the renewable energy space, as well as scoping and EIA reporting.

Juan du Plessis is a climate change advisor at Promethium Carbon, providing technical expertise and support in the development of climate change mitigation and adaptation strategies. He has a strong academic background in mechanical engineering, including a bachelor's degree from North-West University and a Master's degree focusing on Additive Manufacturing. Juan has experience in a variety of climate change-related tasks, including calculating and reporting carbon footprints, assessing the impact of climate change, completing CDP responses, documenting carbon credit projects, and calculating carbon tax.

Report structure and reference in terms of NEMA Regulations (2014) as amended, Appendix 6

NEMA Regulations (2014) (as amended) - Appendix 6	Relevant section in report
Details of the specialist who prepared the report	Page xv-xvi
The expertise of that person to compile a specialist report including a curriculum vitae	Page xv-xvi
A declaration that the person is independent in a form as may be specified by the competent authority	Page xiv
An indication of the scope of, and the purpose for which, the report was prepared	Section 3.1
An indication of the quality and age of base data used for the specialist report	Sections 0 and 0
A description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change	Section 4
The duration date and season of the site investigation and the relevance of the season to the outcome of the assessment	No site investigation was necessary as this was a desktop study that relied on requested information
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 4.3
An identification of any areas to be avoided, including buffers	This is not relevant in terms of the climate change impact assessment.
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 as the project's vulnerability to climate change was determined.
A description of any assumptions made and any uncertainties or gaps in knowledge	Sections 0 and 0

NEMA Regulations (2014) (as amended) - Appendix 6	Relevant section in report
A description of the findings and potential implications of such findings on the impact of the proposed activity or activities	Sections 4 and 5
Any mitigation measures for inclusion in the EMPr	Section 5
Any conditions for inclusion in the environmental authorisation	None
Any monitoring requirements for inclusion in the EMPr or environmental authorisation	Not applicable. Project already authorised.
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 6
A description of any consultation process that was undertaken during preparing the specialist report	Not applicable.
A summary and copies of any comments received during any consultation process and where applicable all responses thereto	Not applicable.
Any other information requested by the competent authority	Not applicable.

1. Introduction

1.1. Project description

Eskom Holdings SOC Ltd (Eskom) appointed ARCUS GIBB (Pty) Ltd (now GIBB) to undertake an Environmental Impact Assessment (EIA) for the proposed construction, operation and decommissioning of [new] nuclear power station[s] and associated infrastructure at one of three alternative sites, *viz.* Thyspunt in the Eastern Cape, and Duynefontein and Bantamsklip in the Western Cape. On 11 October 2017, the Department of Forestry, Fisheries and [the] Environment (DFFE) granted Environmental Authorisation (EA) for a new nuclear plant at the Duynefontein site. The decision by the DFFE to grant EA was appealed and on 8 August 2022, the DFFE's Minister, the Honourable Ms. B.D. Creecy, adjourned the appeal process to afford Eskom an opportunity to, *inter alia,* commission an independent specialist to conduct a Climate Change Impact Assessment (CCIA) study." SRK Consulting (South Africa) (Pty) Ltd (SRK) was appointed to review the relevance of the information and data as to whether it is still current or outdated in the EIA Report specialist reports and to commission a CCIA. SRK, on behalf of Eskom, appointed Promethium Carbon (Promethium) to undertake a CCIA specialist study as for the proposed Eskom Nuclear-1 Project at Duynefontein ("Project"), as prescribed by the Minister.

The proposed Duynefontein Nuclear Power Station is situated adjacent and to the north of the Koeberg Nuclear Power Station on the Cape West Coast, approximately 35 km north of Cape Town and has been proposed as a measure to contribute to meeting South Africa's baseload[11] demand for electricity. The proposed power station falls within the existing Eskom owned property, which includes a nature reserve. This power station will add much needed capacity to the grid.

[11] Power station technology designed specifically to generate electricity continuously for all hours of the day and night.

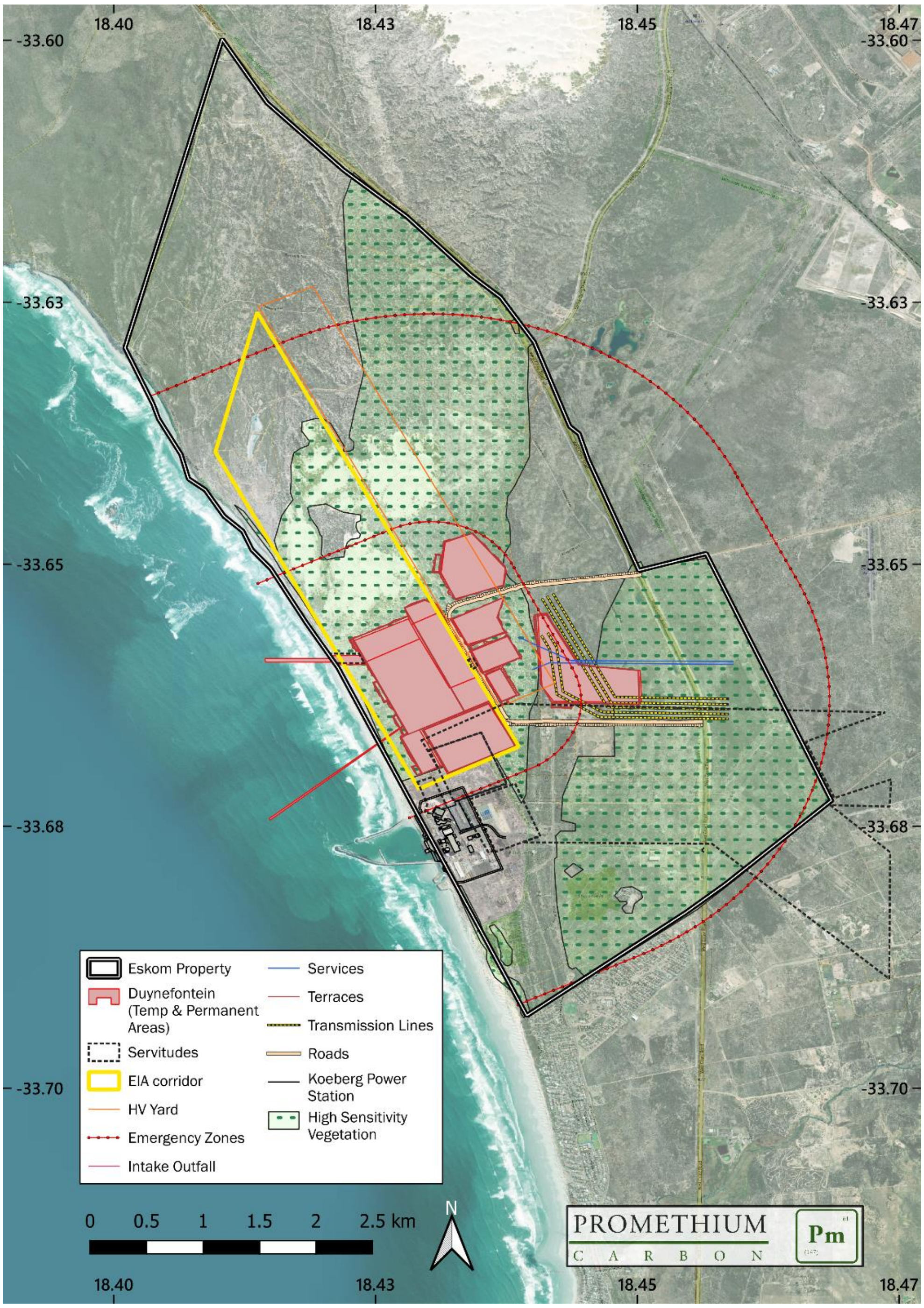

Figure 1: Proposed Duynefontein Nuclear Power Station boundary and layout.[12]

12 Map produced by Promethium Carbon based on data supplied by Eskom.

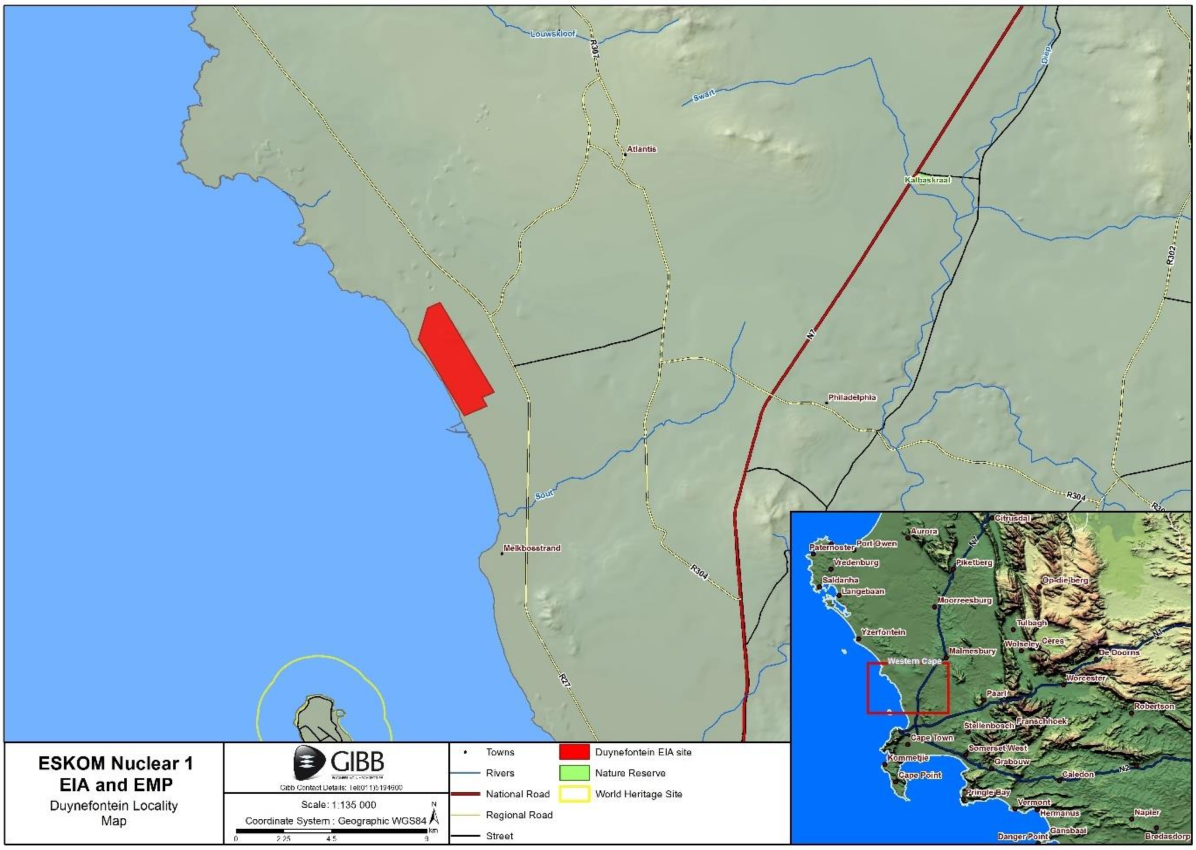

Figure 2: Proposed Duynefontein Eskom Nuclear 1 Power Station locality map. Source: GIBB (2016)[13]

1.2. Project context

Core operations

The core operations are those related to the proposed nuclear power station and related infrastructure within the development area footprint. This includes:

1. Generation of power on site, and
2. Handling and storage of fresh and spent fuel.

Value chain

The value chain of a nuclear power station refers to the series of activities and processes involved in producing and delivering nuclear power to end-users. The upstream value chain typically includes mining and processing of uranium, including enrichment and fuel assembly.

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[13] GIBB. 2016. Final Environmental Impact Assessment Report for the Eskom Nuclear Power Station and Associated Infrastructure (Nuclear-1). Report for Eskom Holdings Limited. DEA Reference Nº: 12/12/20/944.

The downstream value chain includes transmission and distribution. Decommissioning and waste disposal would also be considered as part of the power station value chain when the plant reaches the end of its life.

Throughout the value chain, there are many other activities and processes involved, such as engineering, construction, maintenance, and safety and regulatory compliance, all of which are essential for the safe and reliable operation of a nuclear power plant.

Broader social context

The proposed project is located within the City of Cape Town (Metropolitan Municipality, hereafter CoCT). The sphere of influence of a nuclear power station is largely dependent on the nature of the project (i.e., mining, power generation, retail), however, for the purposes of socioeconomics in the context of climate change, the sphere of influence is around 25 km. This area covers 28 wards across two municipalities: CoCT and Swartland Local Municipality. The total population within the 25 km radius surrounding the proposed site is approximately 828 328 people, with a population density of approximately 217 people/km^2.[14]

The CoCT has very low socio-economic[15] and economic vulnerability[16] scores of 1.2 (i.e., very good); the fourth lowest (on both indices) of all municipalities in South Africa. This is largely due to the higher-than-average access to basic service delivery and diversity of industry contributing to economic growth and social upliftment. The proposed power station is located in CoCT Ward 32 which includes the manufacturing and industrial node of Atlantis, a largely lower income area. It is adjacent to Wards 23 (Melkbosstrand), a medium to high income area, and Ward 29 (Witzands and Atlantis North/Avondale) which is also a fairly low-income ward. Mean annual household income (as per the 2011 Census) in Ward 32 is R30 000, similar to the provincial mean. The employment rate (as per the 2011 Census) is around 45.8%, which is slightly lower than the provincial average but high by national standards.[17] Settlement vulnerability for the two settlements adjacent to the proposed Project location, Atlantis (north-east of the location) and Melkbosstrand (south of the Project location) is shown in Figure 3. The disparities in socio-economic characteristics between the two communities are visible in this graph. Atlantis scores highest (i.e.,

14 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.

15 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.

16 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.

17 Statistics South Africa (2011) South African Population Census 2011. Indicators derived from the full population Census https://wazimap.co.za/profiles/municipality-LIM362-lephalale/.

worst) on socio-economic vulnerability (9.8 out of 10) and economic vulnerability (8.2 out of 10) and has a low service access vulnerability score of 2.8 out of 10. Melkbosstrand's economic vulnerability score is 6.7 out of 10, followed by environmental vulnerability (5.8 out of 10) but has very low socio-economic vulnerability (2.3 out of 10) and service access vulnerability (1 out of 10). These settlements will likely exhibit different levels of vulnerability to climate change based on these factors with higher-income communities likely to exhibit higher resilience.

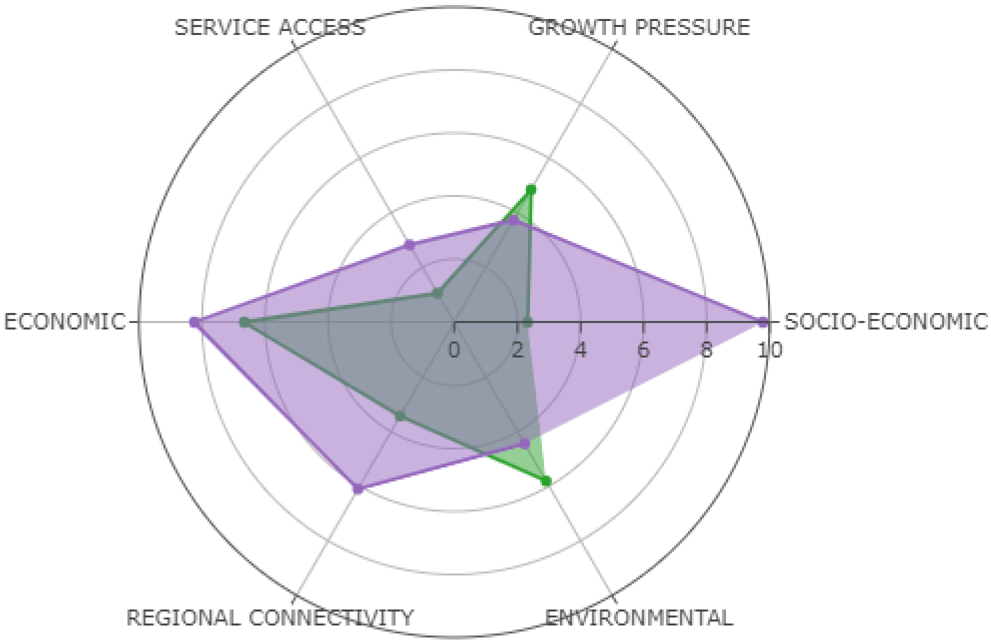

Figure 3: Settlement vulnerability for Atlantis (purple) and Melkbosstrand (green). Source: CSIR (2023)[18]

Broader environmental context

The proposed Project site is located within the Fynbos biome, straddling the West Strandveld and Southwest Fynbos Bioregions. Fourteen ecosystem types are found within a 25 km radius of the proposed development area. These ecosystem types vary in their levels of protection; nine of the fourteen are classified as being either 'poorly protected' or 'not protected.' They also differ in their Red List threat classification: four are regarded as critically endangered, five as endangered and two as vulnerable. (Table 1). The proposed site falls within the Lower Berg Sub-Water Management Area. There are several small natural wetlands in close proximity to the Project boundary.

[18] CSIR. 2023. GreenBook Risk Profile Tool. CSIR: Pretoria. Online available at: riskprofiles.greenbook.co.za.

Table 1: Ecosystem types within a 25 km radius of the proposed Duynefontein Nuclear Power Station and their threat and protection status.[19,20]

	Red List Status				
Protection level	**Least concern**	**Near threatened**	**Vulnerable**	**Endangered**	**Critically Endangered**
Well protected	• Cape Seashore Vegetation • Langebaan Dune Strandveld		• Cape Winelands Shale Fynbos	• Boland Granite Fynbos	
Moderately protected				• Cape Flats Dune Strandveld	
Poorly protected	• Hopefield Sand Fynbos			• Atlantis Sand Fynbos • Swartland Alluvium Fynbos	• Peninsula Shale Renosterveld
Not protected			• Swartland Alluvium Renosterveld	• Swartland Granite Renosterveld	• Cape Flats Sand Fynbos • Swartland Shale Renosterveld • Swartland Silcrete Renosterveld

1.3. Current Climate

Duynefontein falls within the 'Temperate, dry summer, warm summer' zone[21] experiencing a Mediterranean climate: rainfall occurs in winters, which are cool, whilst summers are dry (Figure 4). Mean maximum temperatures range from around 32°C in late summer (February) to 19°C in winter (June to August). Temperatures rarely exceed 35°C except during berg wind conditions. Mean minimum temperatures range from 8°C in July and August to 16°C in February.

The region experiences a mean annual rainfall of 394 ±95 mm/year. Rainfall peaks in June with mean rainfall of 97 mm whilst there is less than 20 mm of rainfall per month between November and March. Extreme rainfall days (> 20 mm) are rare, with an average of 3 days per annum.

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

20 SANBI. 2018. Terrestrial ecosystem threat status and protection level layer [Vector] 2018. Available at: http://bgis.sanbi.org/Projects/Detail/222.

21 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.

Evaporation is high, resulting in the classification of the area being semi-arid. Mean wind speed is approximately 17.4 km/h peaking in summer (December).[22]

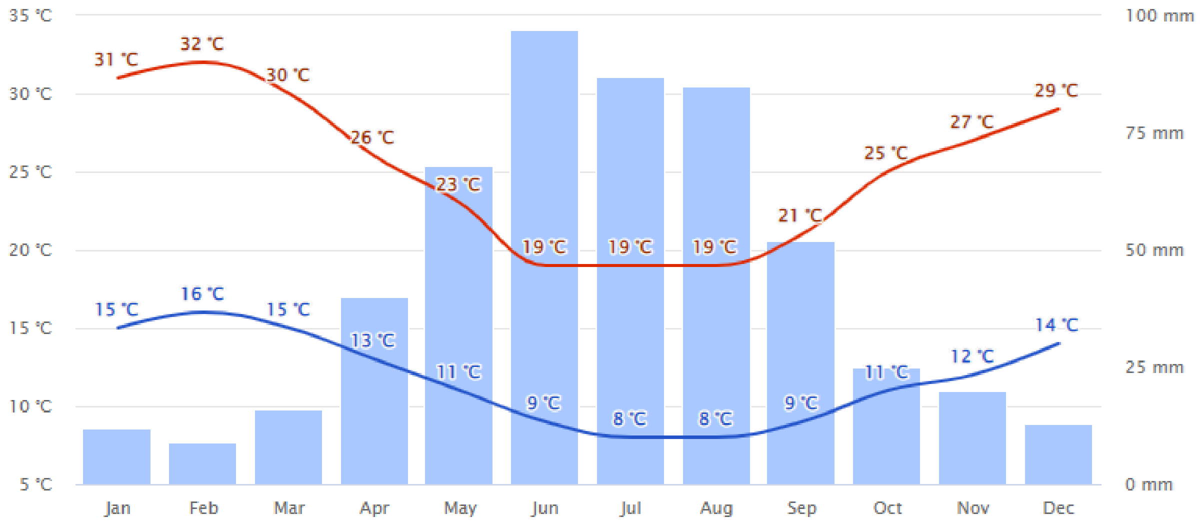

Figure 4: Annual temperature and rainfall graph for Van Riebeeckstrand (33.7°S, 18.44°E; 13 m amsl). Source: MeteoBlue.

2. Background

2.1. Description of Project Activities and Associated Infrastructure

Project's proposed activities

The total spatial footprint for this nuclear power station is ±265 ha. The building that is housing the reactor units and turbines of the power station will occupy roughly one-third of the total footprint, while the remaining disturbed area will comprise various activities such as earthworks, topsoil stockpiles, contractors' yards, and laydown areas. Additionally, the total area of 250-283 hectares encompasses potential future expansion zones for the proposed power station.

Eskom has selected Pressurised Water Reactor (PWR) technology for the Nuclear-1 project, which is widely used internationally. PWRs utilise water as a coolant and moderator. Eskom has significant experience and familiarity with this technology, both in terms of Health and Safety considerations and operational aspects, as it has been successfully used at the Koeberg Nuclear Power Station for the past 35 years. The preference for a standard Generation III design for the nuclear power station stems from its operational simplicity, robust design, high availability, reduced risk of core melt accidents, minimal environmental impact, efficient fuel utilisation, and minimal waste generation.

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

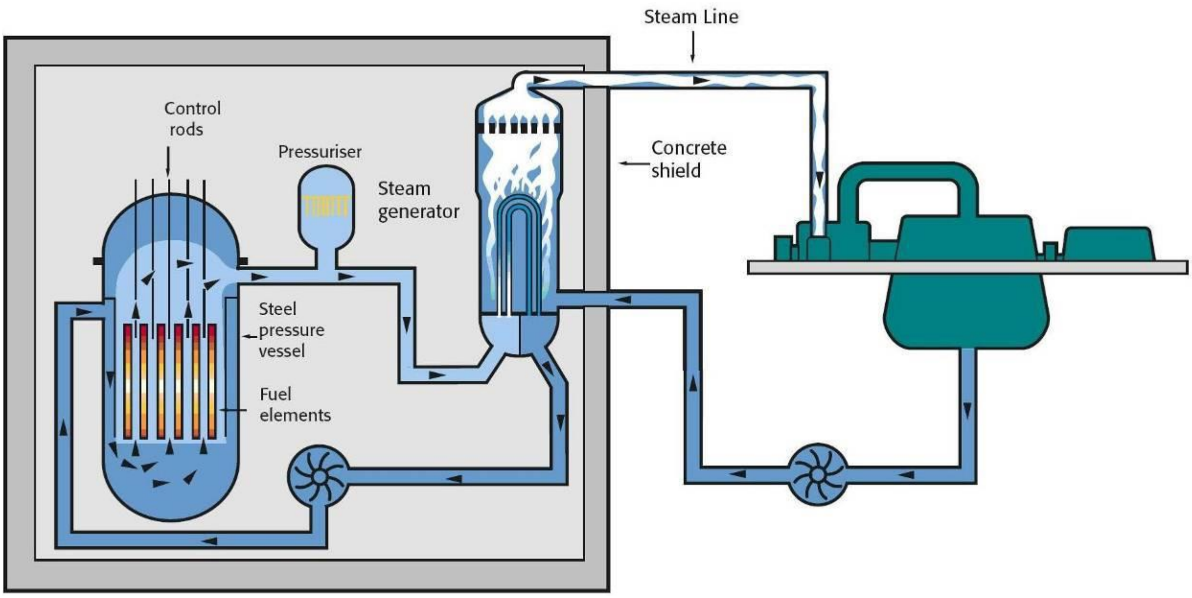

Figure 5: Simplified diagrammatic depiction of a Pressurised Water Reactor.[23]

Infrastructure of proposed Project

According to the FEIR, the proposed power station site will include *inter alia* the **nuclear reactors** themselves and their **auxiliary infrastructure**:

- During construction:
  - A temporary cofferdam in the ocean;
  - A temporary spoil pipeline into the ocean; and
  - A laydown areas and other areas.
- During operation:
  - Turbine halls;
  - Spent fuel and nuclear fuel storage facilities;
  - Waste handling and storage facilities;
  - Wastewater treatment works;
  - Intake and outfall structures into the ocean required to obtain/ release (cooling) water used to cool the process;
  - Desalinisation plant;
  - 132kV and 400kV transmission and distribution lines from the power station to the high voltage yard;
  - Roads;
  - 400kV and 132kV high voltage yard (HV yard);
  - Transmission lines between the power station; and
  - Other auxiliary service infrastructure.

[23] Ragheb, M. 2008. Boiling Water Reactors.

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 establishment 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 Figure 6.

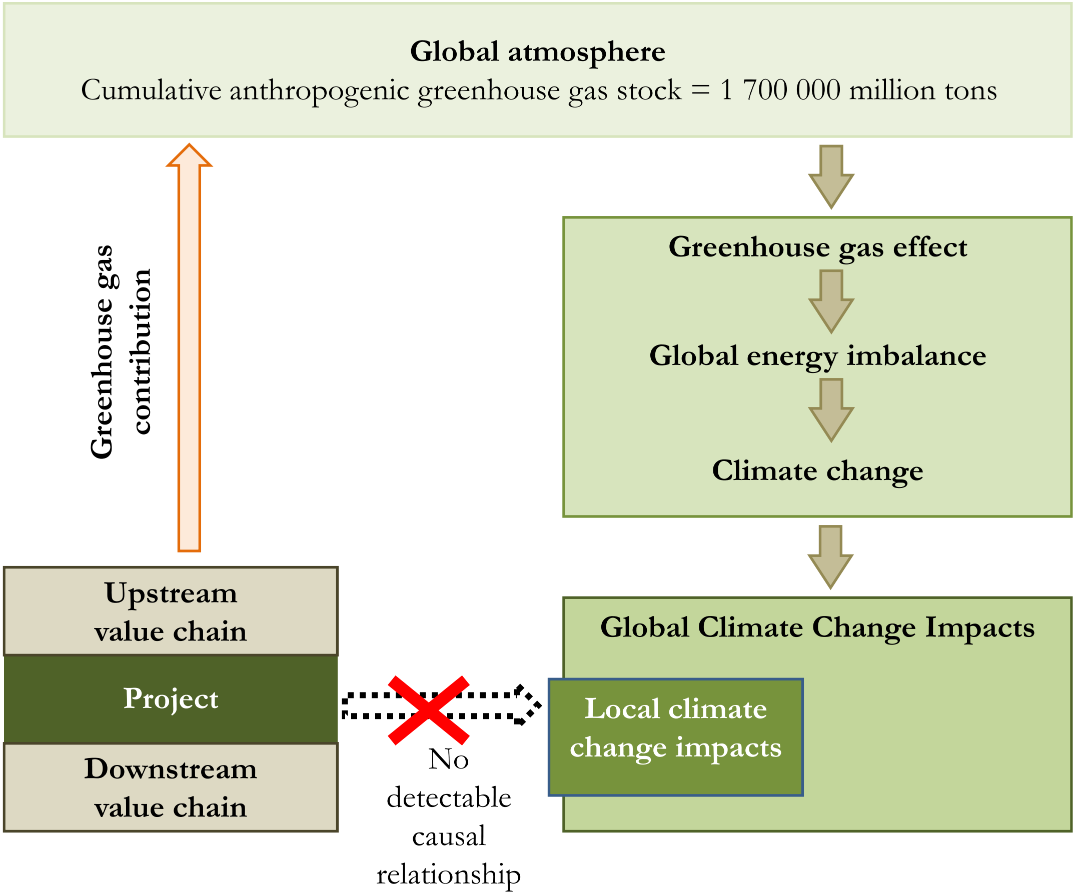

Figure 6: Relationship between a project's GHG emissions and local climate change impacts.

The principle that GHG emissions have 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 did not consider the local cumulative impacts of any potential additional power plants underway or planned within proximity of Duynefontein.

3. Approach and Methodology

The approach to the CCIA is:

3. The scope of the assessment covers the following[24]:
   a. The impact of the project on climate change; and
   b. The resilience of the project to climate change.
4. The emission from the project is handled as follows[25]:
   a. The direct emission from the project is considered as the project's contribution to climate change; and
   b. The life cycle emissions of the project (emissions of the nuclear fuel cycle) is addressed as part of the cumulative impacts of the projects in terms of the requirements of NEMA.

The methodology used for this CCIA was informed by:

5. The nature of climate change;
6. The project development timeframes;
7. The long-term climate impacts anticipated for the Project and its surrounding areas; and
8. Available climate data for variables specifically relevant to the Project.

The climate-related impacts and vulnerabilities relevant to the Project and surrounding areas are considered throughout this CCIA.

3.1. Scope of the Climate Change Impact Assessment

This CCIA includes the following:

1. An assessment of the extent to which **the project will contribute to climate change** over its lifetime. This includes consideration of the life cycle emissions of the project including both the construction and the operational phases. If required, the decommissioning phase will be included although it is understood that there are many uncertainties in the final decommissioning of nuclear plant as it involves the final disposal of the high level radioactive waste;
   - For the construction phase:

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[24] 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)

[25] South Durban Community Environmental Alliance and Another v Minister of Forestry, Fisheries and The Environment and Others (17554/2021) [2022] ZAGPPHC 741 (6 October 2022) http://www.saflii.org/za/cases/ZAGPPHC/2022/741.html

        - Calculate the carbon footprint of the project. This includes the direct and upstream indirect emissions[26] and the potential emissions from biomass and land clearance during construction.
    - For the operational phase:
        - Calculate the carbon footprint of the proposed project during its operational phase (if any), as well as the avoided emissions of the project.
    - **Mitigation measures** to minimise the impacts of the proposed project on climate change.
2. Determination of **the resilience of the project to climate change**, considering how climate change will impact on its operation, through factors such as rising temperatures and extreme weather patterns.
    - A description of the existing climate and projected conditions of the local area;
    - Potential climate change impacts in terms of project risks, the social context, project value chain and broader environmental risks.
    - The processes and associated infrastructure of the proposed project that could be affected by climate change, and the potential magnitude of the impacts;
    - Impacts of climate change on core operations; and
    - **Adaptation measures and measures** to minimise the impacts of climate change on the proposed project during construction and operation.

The analysis of climate change risks can include both physical and transitional risks. The scope of inclusion of these risks are set out in the table 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 they can significantly impact 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

The above methodology is informed and supported by best practice.

SRK will co-ordinate the stakeholder engagement process for the CCIA. Promethium may update the CCIA Report incorporating relevant comments from the stakeholder engagement process.

[26] Where information is not available in this regard, a set of assumptions is used to inform the upstream and downstream greenhouse gas (GHG) emissions.

3.2. Project Contribution to Climate Change

The Project's impact on climate change at Duynefontein was determined by calculating the project GHG inventory (carbon footprint) in the following contexts:

1. The direct emissions during the construction and the operational phase of the project;
2. The indirect emission of the project for:
    a. The construction phase; and
    b. The operational phase.
3. The total emission of the project.

The environmental impact of the project is judged on both its direct emissions and the Cumulative emissions. In line with the Eskom judgement[27], this assessment considers the direct greenhouse gas emissions as being the direct environmental impact of the Duynefontein Nuclear Power Plant Station. NEMA however also requires that cumulative impacts be considered in the assessment. As there is no guidance on this matter, and as there is significant focus on value chain emissions by environmental activists, we include the value chain emissions of the project under cumulative emissions. Cumulative emissions in this context refer to the contribution the project will make to the global stock of greenhouse gasses, as indicated in Figure 6.

GHG Emissions Quantification

Direct Emissions

In a recent judgement, the court determined that a CCIA should only consider the direct emissions from the project. All value chain (life cycle) emissions should be considered under the respective EIAs for that infrastructure. To align with this judgement, the indirect (value chain) emissions for the project are calculated and reported as part of the cumulative emissions, which is the stock of accumulated greenhouse gasses in the global atmosphere. The assessment of the direct impact of the project on climate change only considers the direct operational emissions.

This report makes use of the National GHG Reporting Regulations *No. 40762 of 2017 and its amendments,* and the *Methodological Guidelines for Quantification of Greenhouse Gas Emissions*[28] for the calculation of direct emissions. The direct emissions for the construction phase are calculated from the combustion of diesel used in mobile machinery as well as in generating units. These emissions can be calculated as followed:

$$Cat1_D = (Diesel_D \times EF_{SD})$$

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[27] South Durban Community Environmental Alliance and Another v Minister of Forestry, Fisheries and The Environment and Others (17554/2021) [2022] ZAGPPHC 741 (6 October 2022) http://www.saflii.org/za/cases/ZAGPPHC/2022/741.html. Pages 12 and 13.

[28] DFFE. 2022. *Methodological Guidelines for Quantification of Greenhouse Gas Emissions.* Department of Forestry, Fisheries and the Environment, Pretoria.

Where:

$Cat1_D$ Represents the direct emissions of the Project, measured in tCO_2e/year;

$Diesel_D$ Represents the total combustion of diesel during the construction phase of the Project, measured in litres/year;

EF_{SD} Represents the emission factor of stationary combustion of diesel, measured in tCO_2e/l.

The direct emissions during the operational phase were taken from a life cycle assessment of nuclear power by Koltun *et al.* (2018).

Indirect and Cumulative Emissions

It is noted that the National GHG Reporting Regulations only provides for the calculation of direct emissions. Various environmental authorisation appeals have however referred to the "life cycle impacts" of the activities related to projects seeking environmental authorisation. This means that there is a societal expectation that the GHG emissions of a project are to be considered in terms of all of the emissions associated with the project including the upstream and downstream indirect emissions. To address the expectations for the inclusion of indirect (value chain) emissions, the indirect emissions is calculated and reported but do not form part of the assessment of the direct impact of the project on climate change.

The calculation of the indirect and cumulative emissions for the proposed project, has been guided by the following reference documents:

- *SANS 14064:2021 Part 1: Specification with guidance at the organization level for quantification and reporting of GHG emissions and removals* [29];
- The GHG Protocol's *A Corporate Accounting and Reporting Standard (Revised Edition)*[30];
- The Department of Environmental Affairs' *Technical Guidelines for Monitoring, Reporting and Verification of GHG Emissions by Industry*[31];
- The Department of Forestry, Fisheries and the Environment's *Technical Guidelines for the Validation and Verification of GHG Emissions*[32];

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[29] Standards South Africa, 2021, *SANS 14064-1:2021 GHGs Part 1: Specification with guidance at the organisational level for the quantification and reporting of GHG emissions and removals*, Pretoria.

[30] GHG Protocol. 2015. *A Corporate Accounting and Reporting Standard: Revised Edition.*

[31] Department of Environmental Affairs, 2016, *Technical Guidelines for Monitoring, Reporting and Verification of GHG Emissions by Industry.*

[32] DFFE. 2021. *Technical Guidelines for the Validation and Verification of GHG Emissions.* The Department of Forestry, Fisheries and the Environment, Pretoria.

- The 2006 Intergovernmental Panel on Climate Change (IPCC) *Guidelines for National GHG Inventories*;[33] and
- The Intergovernmental Panel on Climate Change (IPCC) *2019 Refinement to the 2006 IPCC Guidelines for National GHG Inventories, Volume 2, Chapter 4*.[34]

The main guidance document used, in the calculation of the impact of the project on climate change, is the *SANS 14064:2021 Part 1*. This document sets out principles, which are summarised in Table 3 below, that guide the GHG inventory development process. It requires that emissions be categorised into the following groups. In the context of the Eskom Gas-to-Power court case, indirect emissions are referred to as value chain emissions.

The indirect emission categories are:

Category 1 – Direct GHG emissions and removals;
Category 2 – Indirect GHG emissions from imported energy;
Category 3 – Indirect GHG emissions from transportation;
Category 4 – Indirect GHG emissions from products used by an organization;
Category 5 – Indirect GHG emissions associated with the use of products from the organization;
Category 6 – Indirect GHG emissions from other sources.

Table 3: ISO/SANS 14064-1 principles for carbon footprints

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

The calculation of the indirect and cumulative emissions for the proposed Project at Duynefontein, follows the general steps stipulated here:

1. Identifying the sources of indirect GHG emissions related to the project;
2. Assessing the significance of each emission source;
3. Establishing a quantification method for the identified sources; and

[33] IPCC. 2006. *IPCC Guidelines for National GHG Inventories*, [Online] Available at: ipcc-nggip.iges.or.jp/public/2006gl/.
[34] IPCC. 2019. *Refinement to the 2006 IPCC Guidelines for National GHG Inventories.*

4. Calculating the emissions from each of the significant GHG sources.

Note that traditionally, GHG reporting has been done in line with the 2006 version of ISO14064-1, which classified emissions in 3 emission scopes. The relationship between the traditional emission scopes and the latest version of the standard with respect to GHG emission boundaries is shown in Table 4.

Table 4: GHG reporting for both standards SANS 14064-1:2021 and ISO 14064-1:2006.

SANS 14064-1:2021		ISO 14064-1:2006	
Category	**Description**	**Category**	**Description**
1	Direct GHG emissions and removals	Scope 1	Direct emissions
2	Indirect GHG emissions from imported energy	Scope 2	Energy indirect emissions
		Scope 3 Category 3	Fuel- And Energy-Related Activities
3	Indirect GHG emissions from transportation	Scope 3 Category 4	Upstream Transportation and Distribution
		Scope 3 Category 6	Business Travel
		Scope 3 Category 7	Employee Commuting
		Scope 3 Category 9	Downstream Transportation and Distribution
4	Indirect GHG emissions from products used by organization	Scope 3 Category 1	Purchased Goods and Services
		Scope 3 Category 2	Capital Goods
5	Indirect GHG emissions associated with the use of products from the organization	Scope 3 Category 10	Processing of Sold Products
		Scope 3 Category 11	Use of Sold Products
		Scope 3 Category 12	End-Of-Life Treatment of Sold Products
6	Indirect GHG emissions from other sources	Scope 3 Category 5	Waste Generated in Operations
		Scope 3 Category 8	Upstream Leased Assets
		Scope 3 Category 13	Downstream Leased Assets
		Scope 3 Category 14	Franchises
		Scope 3 Category 15	Investments

The indirect emission sources are assessed based on the following significance criteria.

Table 5: Duynefontein Nuclear Power Station - defined and explained criteria.

Criteria	Description	Criteria applied to this project
Magnitude	The indirect emissions or removals that are assumed to be quantitatively substantial.	Include emission sources based on Magnitude when the value of the indirect emissions from a source is **more than 1%** of the total estimated GHG inventory of the project unless it is explicitly excluded by another criterion. Exclude all indirect emissions for specific sources when the value of the emissions from such sources are **less than 1%** of the total estimated GHG inventory of the project, unless explicitly included by another criterion.
Level of influence	The extent to which the organisation has the ability to monitor and reduce emissions and removals (e.g., energy efficiency, eco-design, customer engagement, terms of reference).	Include emissions from emission sources based on Influence when the level of influence of the project over such emission sources is considered to be **high.** Exclude emissions from emission sources based on Influence when the level of influence by the project over the emission sources is considered to be **zero.**
Risk or opportunity	The indirect emissions or removals that contribute to the organisation's exposure to risk (e.g., climate-related risks such as financial, regulatory, supply chain, product and customer, litigation, reputational risks) or its opportunity for business (e.g., new market, new business model).	Include emissions from emission sources based on Risk or Opportunity when risk or opportunity to the project associated with such emission sources is considered **high.**
Sector-specific guidance	The GHG emissions deemed as significant by the business sector, as provided by sector-specific guidance.	Include emissions from emission sources based on Sector-specific guidance when such is **available.**
Outsourcing	The indirect emissions and removals resulting from outsourced activities that are typically core business activities.	Include emissions from emission sources based on Outsourcing when the value of the indirect emissions associated with the outsourcing is **more than 1%** of the total estimated GHG inventory of the company.
Employee engagement	The indirect emissions that could motivate employees to reduce energy use or that federate team spirit around climate change (e.g., energy conservation incentives, carpooling).	Include emissions from emission sources based on Employee Engagement when the impact on emissions of employee engagement is considered **high.** Exclude emissions from emission sources based on Employee Engagement when the impact of employee engagement on emissions is considered **zero.**

Quantifying the LCA of such a nuclear plant was done in a life cycle assessment of nuclear power. This study quoted the life cycle emissions of a nuclear plant, including the front-end (uranium mining and enrichment) without recycling materials such as construction materials, steel, copper, aluminium, and glass to be approximately 9.87 $kgCO_2e/MWh$. These emissions are insignificant due to the low magnitude with regards to the footprint of the project. The decommissioning phase will have minimal energy requirements, and therefore GHG emissions.

The indirect emissions (Category 3 – 6) accounts for the purchased goods and services, fuel and energy related activities, upstream and downstream transportation and distribution, and waste generated. The main calculation that was used for these emissions is:

$$Scope\,3_{IDE} = (A_{ct} \times EF_{Act})$$

Where:

$Scope3_{IDE}$ represents the total indirect emissions during the construction phase of the Project, measured in $tCO_2e/year$;

A_{ct} Represents the activity data occurring at the Project, measured in Unit of Measurement/year. The Unit of Measurement depends on the activity, for example, tonnes of purchased material or distance transported; and

EF_{Act} Represents the emission factor of that activity data, measured according to the activity measurement.

To calculate the carbon stock emissions potentially emitted during construction, the building footprint of Duynefontein Power Station supplied by Eskom was overlaid on the *South African Carbon Sink Atlas* Total Ecosystem Carbon dataset using GIS. The potential loss of carbon stocks (aboveground biomass, belowground biomass and soil organic carbon) based on the entire area becoming converted from its natural existing state, was then multiplied by 3.67 to get the CO_2e emissions.

Data used

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 project developer. The data provided is summarised in the table below.

Table 6: Activity data used in the GHG inventory.

Phase	Quantity	Data source
Construction Phase		
Steel required	117 491 tonnes	Provided by Eskom
Concrete required	686 660 m^3	Provided by Eskom

Phase	Quantity	Data source
Large Bore Pipe	304 352 m	Provided by Eskom
Small Bore Pipe	12 836 m	Provided by Eskom
Cable	3 128 884 m	Provided by Eskom
Conduit	381 256 m	Provided by Eskom
Waste generated	27 000 tonnes	Provided by Eskom
Diesel Consumption*	220 litres/hr	Provided by Eskom
Water Consumption	9 000 litres/day	Provided by Eskom
Employee Commuting	112 295 040 km over 9 years	Calculated from data provided by Eskom and some assumptions made
Heavy goods delivery vehicles	18 973 864 km over 9 years	Calculated from data provided by Eskom and some assumptions made
Heavy construction vehicles	36 019 km over 9 years	Calculated from data provided by Eskom and some assumptions made
Ultra heavy construction vehicles	123 816 km over 9 years	Calculated from data provided by Eskom and some assumptions made
Operational Phase		
Direct emissions	3.2 $kgCO_2e/MWh$	Life cycle GHG emissions of nuclear power[35]
Indirect – upstream and downstream emissions	17.7 $kgCO_2e/MWh$	Life cycle GHG emissions of nuclear power[35]

*The generator was assumed to run year round as a conservative estimate.

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

[35] Hondo, H. 2005. *Life cycle GHG emission analysis of power generation systems: Japanese case*. Energy, 30(11-12), 2042-2056. Doi:10.1016/j.energy.2004.07.020

- Consistent with the intended use of the carbon footprint.

The main sources of the emissions and conversion factors used in this GHG inventory are the South African Methodological Guidelines[36], the IPCC 2006 Guidelines[37] and the DEFRA 2022[38] emission factor sheet. Specifically, the emission factors to calculate category 1 emissions were taken from the South African Methodological Guidelines. The emission factors (and other conversion factors) used in this CCIA are presented in Table 7.

Table 7: Emission and conversion factors used for the GHG inventory.

Emission factor	Value	Unit	Source
Direct Emission Factors			
Diesel Combustion	0.00270	tCO_2e/Litre	DEFRA 2022
LCA Direct emissions	0.0032	tCO_2e/MWh	Life cycle GHG emissions of nuclear power[35]
Energy indirect Emission Factors			
South Africa - Grid	1 .04	tCO_2e/MWh	Eskom FY22 IAR
Other Indirect Emission Factors			
LCA Indirect – upstream and downstream emissions	0.0177	tCO_2e/MWh	Life cycle GHG emissions of nuclear power[35]
Cable	4 .1	tCO_2e/tonne	International Copper Alliance. "Copper Environmental Profile"
Conduit	3 .41308	tCO_2e/tonne	DEFRA 2022
Large Bore Pipe	1 .89	tCO_2/tonne	World Steel Association
Small Bore Pipe	1 .89	tCO_2/tonne	World Steel Association
Steel production	1 .89	tCO_2e/tonne	World Steel Association
Concrete production	0 .784	tCO_2e/tonne	DEFRA 2022
Water	0 .000149	tCO_2e/kl	DEFRA 2022
Waste Generated	1 .29672	tCO_2e/tonne	Internal calculation
Heavy Goods Vehicles	0 .000841	tCO_2e/km	DEFRA 2022
Ultra-heavy Goods Vehicles	0 .000924	tCO_2e/km	DEFRA 2022
Heavy Delivery Vehicles	0 .000209	tCO_2e/km	DEFRA 2022

36 Department of Environmental Affairs, 2022, *Methodological guidelines for quantification of greenhouse gas emissions [G 47257 – GN 2598]* Methodological guidelines for quantification of greenhouse gas emissions [G 47257 – GN 2598] | Department of Environmental Affairs (dffe.gov.za) .
37 IPCC. 2006. Climate Change 2006 – The Physical Science Basis. Summary for Policy Makers. Intergovernmental Panel on Climate Change, Geneva, Switzerland.
38 DEFRA, 2021, UK Government GHG Conversion Factors for Company Reporting.

Emission factor	Value	Unit	Source
Average Petrol Car	0 .00017	tCO_2e/km	DEFRA 2022
Bus Emissions	0 .000097	tCO_2e/km	DEFRA 2022
Mixed (Bus & Average Petrol Car)	0 .000133	tCO_2e/km	Calculated
Conversions and Assumptions			
Methane GWP	23	tCO_2e/tCH_4	Methodological Guidelines
Nitrous Oxide GWP	296	tCO_2e/tN_2O	Methodological Guidelines
Diesel NCV	0 .0381	GJ/litre	Methodological Guidelines
Concrete Conversion – m^3 to tonne	2 .4	Tonne/m^3	SMC Mini-mix Concrete[39]
Copper Density	8 960	Kg/m^3	Constant
Steel Density	8000	Kg/m^3	Thyssenkrupp[40]
Number of Hours in a Year	8 760	Hr/year	Constant
Transmission Cable Diameter	0.0225	m	Sha Li. *et al.*[41]
Large Bore Pipe Outer Diameter	0.9526	m	Ihn Namgung. *et al.*[42]
Large Bore Pipe Inner Diameter	0.7874	m	Ihn Namgung. *et al.*[42]
Small Bore Pipe Weight Conversion	140.81	Kg/m	Euro Steel[43]
Conduit Outer Diameter	0.1143	m	Plastic Pipe Shop[44]
Conduit Outer Diameter	0.1143	m	Plastic Pipe Shop[44]
PVC Density	1 380	Kg/m^3	British Plastics Federation[45]
Nuclear Capacity Factor	0.926	-	Statista[46]

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39 SMC. Mini-Mix Concrete. [Online] Available at: smcminimix.co.uk/resource-centre/faqs/#:~:text=One%20cubic%20metre%20of%20

40 Thyssenkrupp. *Density of Stainless Steel*. [Online] Available at: thyssenkrupp-materials.co.uk/density-of-stainless-steel

41 Sha, Li. et al. 2014. Study on extra-high voltage power line scatterers in time series SAR.

42 Ihn Namgung. et al. 2015. Failure Pressure Investigation of PWR Reactor Coolant Pipe.

43 Euro Steel. *Stainless Steel Piping*. p26 – p27. [Online] Available at: eurosteel.co.za/wp-content/uploads/2018/01/Euro-Steel-ASTM-A312-Pipe-Dimensions.pdf

44 Plastic Pipe Shop. *PVC Pipe Measurements OD, ID, Wall*. [Online] Available at: plasticpipeshop.co.uk/PVC-Pipe-Measurements-OD-ID-Wall_ep_53-1.html

45 British Plastic Federation. *Polyvinyl Chloride PVC*. [Online] Available at: bpf.co.uk/plastipedia/polymers/PVC.aspx

46 Statista. *Capacity factor of nuclear power plants in the United Stated from 1975 to 2022*. [Online] Available at: statista.com/statistics/191201/capacity-factor-of-nuclear-power-plants-in-the-us-since-1975/

Emission factor	Value	Unit	Source
Number of Reactor Units	2	Each	Provided by Eskom
Estimated Construction Time	5.5	Years	Provided by Eskom
Construction Phase Timeline	9	Years	Provided by Eskom
Distance from Cape Town to Site	46.9	Km	Google Maps
Round Trip Distance from Duynefontein to site	6.4	Km	Google Maps
Number of Months per year	12	Months/year	Constant
Number of Weeks per year	52	Weeks/year	Constant
Number of Days per year	365	Days/year	Constant
Number of working days per year	260	Days/year	Estimated

Environmental Impacts of GHG Emissions

The EIA reporting requirements[47] listed in Table 8 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 the only criteria currently available to measure the impact of the project on climate change.

Table 8: EIA Criteria.

Nature	A description of what causes the effect, what will be affected and how it will be affected. *In the case of climate change assessments, the nature of the impact is the contribution of the Project to global anthropogenic climate change.*
Intensity (I)	The intensity is the magnitude of the environmental impact under consideration. These impacts can be positive or negative and range from negligible change to severe irreversible change. The environmental impact assessment reporting requirements were developed to describe and assess environmental impacts, however GHG emissions that have a global impact are yet to be described. For this reason, a materiality threshold was defined to quantify the intensity of the impacts.

47 Republic of South Africa.. 2014 as amended. Environmental Impact Assessment Regulations: Section 3(j) Appendix 1 and Appendix 3 (Scope of assessment and content of Basic Assessment Report and Environmental Impact Assessment, respectively). cer.org.za/wp-content/uploads/1999/01/NEMA-EIA-Regulations-2014-as-amended.pdf

Extent (E)	An indication of whether the impact will be local (limited to the immediate area or site of development), regional, national, or international. Part of the site is considered very low, the whole property - low, affecting immediate neighbours - medium, local area - high and regional/national - very high. *In the case of climate change assessments, the extent is always global, and thus, very high is allocated to all projects that contribute to global anthropogenic climate change.*
Duration (D)	An indication of the lifetime of the impact. Impacts are quantified as follows: less than a year – very low, between 1 and 5 years – low, between 5 and 10 years – medium, between 10 and 20 years – high and longer than 20 years – very high. *In the case of this project, the impact will end at the end of the project life. Therefore, a high rating is allocated.*
Probability (P)	An indication of the likelihood of the impact occurring. The scale of probability ranges from unlikely to definite. The IPCC has reported that it is 95 percent certain that man-made emissions are the main cause of current observed climate change[48]. *Thus, a definite probability is allocated to all projects that contribute to global anthropogenic climate change.*
Consequence (C)	The consequence of the impacts is a function of the intensity, extent and duration, and assesses the overall consequence of the impacts.
Significance (S)	The significance of the impacts is calculated as: S=C x P

Determining the Impact of the Project on Climate Change

The regulatory framework in South Africa does not provide guidance on the impact of GHG emissions. Promethium Carbon has thus developed an approach to determining the impact of projects based on GHG emissions. This approach is summarised in the table below:

Table 9: Impact Rating of Project on Climate Change

Impact rating	Approach to quantification
Low	The draft document - *National Guideline for the Consideration of Climate Change Implications in Applications for Environmental Authorisations, Atmospheric emissions Licenses and Waste Management Licenses* gives guidance for when a specialist climate change impact assessment is necessary. The lower limit is when the activity breaches one of the thresholds stipulated in the *National GHG Reporting Regulations*. Thus, the upper limit of the ***low impact category*** was taken as installation with GHG emissions equivalent to the combustion of coal at a capacity of 10 $MW_{thermal}$ at a 100% utilisation.
Medium	The impact of projects in the ***medium impact category*** was taken as the project falling between the upper limit of the low impact category and an order of magnitude below the upper limit of the high impact category.

48 IPCC. 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

Impact rating	Approach to quantification
High	The impact of projects in the ***high impact category*** was taken as project falling between the upper limit of the medium impact category and the lower limit of the very high impact category.
Very high	The lower limit for the ***very high impact category*** was calculated to be the annual emissions of a new coal fired 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. The annual emissions were calculated using an efficiency taken from the 2017 EPRI Report for new coal-fired power stations and the current availability of the Eskom fleet.

Table 10 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 nationally determined contributions (NDC) carbon budget of 7 758 Mt CO_2e set in September 2021.

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 requirement. 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 10: 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%	

Limitations and Assumptions

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 significant boundary set out by the GHG reporting requirements, as per *SANS14064 (2021)*. The assumptions are the following:

- The concrete reinforcement, large bore pipe, and small bore pipe material was steel.
- The cable was copper transmission cables, and that the conduit was PVC conduit used as electrical cable conduits.

- The total waste generated during construction was all sent to landfill and not recycled.
- The commuting to and from the construction site only had one passenger per vehicle.
- The delivery vehicles transported the materials to be delivered from Cape Town to the site and the employee commuting took place from Duynefontein to the site and back.
- It was assumed that a minimum of stage 4 loadshedding may still be implemented for the next 5 years, with this assumption being used to adjust the diesel consumption of the generators.
- The lifecycle emissions associated with the uranium fuel are only upstream indirect emissions, thus no direct emissions are generated from the use of nuclear fuel.

3.3. Project Resilience to Climate Change

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

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 practices, including:

- *National Climate Risk & Vulnerability Assessment Framework*;[49]
- World Bank Group: Integrating Resilience Attributes into Operations – Guidance Note for Practitioners;[50]
- International Finance Corporation performance standards;[51]
- European Bank for Reconstruction and Development principles;[52]
- The Equator Principles;[53] and

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49 Department of Forestry, Fisheries and Environment. 2020. National Climate Risk and Vulnerability Assessment Framework summary document, Pretoria.

50 Ospina, A.V. & Rigaud, K.K. 2021. *Integrating Resilience Attributes into Operations : A Note for Practitioners*. World Bank Group. Available at: documents1.worldbank.org/curated/en/581881626842596496/pdf/Integrating-Resilience-Attributes-into-Operations-A-Note-for-Practitioners.pdf.

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

52 Operating Principles for Impact Management EBRD Disclosure Statement April 2021.

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

- International Council on Mining and Minerals Adapting to climate change[54]

Key Areas of Impact

The resilience and vulnerability assessment conducted for this CCIA only considers the core operations of the Project.

Data used

This vulnerability assessment refers to various data sources in the process of determining the critical vulnerability factors faced by the project. Data 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 was processed in either Google Earth Engine, R (v4.2.0) and/or using GIS software (Esri ArcGIS Pro or QGIS).

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).[55]

Future projections are based on Shared Socio-economic Pathways (SSPs, see Key Terms and Definitions above) and an associated radiative forcing.[56] Here, SSP1-2.6 (SSP1), SSP2-4.5 (SSP2) and SSP 5-8.5 (SSP5) are presented. SSP2 is seen as one of the most likely future scenarios given that it represents a scenario of modest mitigation,[57] SSP1 aligns to a 1.5 ˚C world,[58] and SSP5 represents a pessimistic (and increasingly unlikely) scenario based on minimal mitigation and

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54 International Council on Mining and Minerals. 2019. *Adapting to a changing climate: Building resilience in the mining and metals industry*. ICMM. Available at: https://www.icmm.com/website/publications/pdfs/environmental-stewardship/2019/guidance_changing-climate.pdf.

55 Eyring, V., Bony, S., Meehl, G. A., Senior, C. A., Stevens, B., Stouffer, R. J., and 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: doi.org/10.5194/gmd-9-1937-2016.

56 The SSPs have been introduced into the latest assessment report (AR6) currently being compiled by the IPCC. They describe five narratives each describing different governance scenarios, application of climate policies and levels of climate change mitigation. The SSPs are useful in that they provide for different trends in economic and human development and the links between different regions in light of these. These are then combined with Representative Concentration Pathways (RCPs) which set pathways for GHG concentrations and the potential warming (radiative forcing) that could occur by 2100. The use of numerous SSPs can be seen as using a number of future scenarios.

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

58 A specific goal outlined in the Paris Agreement to limit global warming to well below 2°C above pre-industrial levels, and to pursue efforts to limit the temperature increase to 1.5°C.

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.

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 to the project. It should be noted that the data used here differs significantly from that used in the air quality assessment[59] done for the Project in 2015 in that it is newer and thus more up to date. The results from that study can still be considered valid. *The data and projections were also validated against the provincial government's 2022 report* SmartAgri: Updated Climate Change Trends and Projections for the Western Cape[60] *which made use of two of the same datasets used in this assessment, both the ERA5 and CMIP6 data, the latter being the most up-to-date available dataset with respect to climate projections.*[61]

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[62] 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*."[63] This definition aligns with the method for determining the Project's climate-related vulnerability proposed in Figure 7.

[59] Airshed Planning. 2015. Environmental Impact Assessment for the Proposed Nuclear Power Station ("Nuclear-1") And Associated Infrastructure. Air Quality Impact and Climatology Assessment Study. Prepared by Airshed Planning for Arcus GIBB Pty Ltd.

[60] *CSAG. 2022. SmartAgri: Updated Climate Change Trends and Projections for the Western Cape. Climate Systems Analysis Group for the Western Cape Government. Available at: elsenburg.com/wp-content/uploads/2022/08/SmartAgri-Climate-Change.pdf.*

[61] *However, the scale at which the results in the SmartAgri report are presented, namely at district (SmartAgri zones) level, at low resolution, make more thorough comparisons with the climate change study, which was done at a local, relatively high resolution, challenging.*

[62] 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.

[63] IPCC. n.d., *Data Distribution Centre Glossary: Vulnerability*, IPCC [Website] Available at: ipcc-data.org/guidelines/pages/glossary/glossary_uv.html

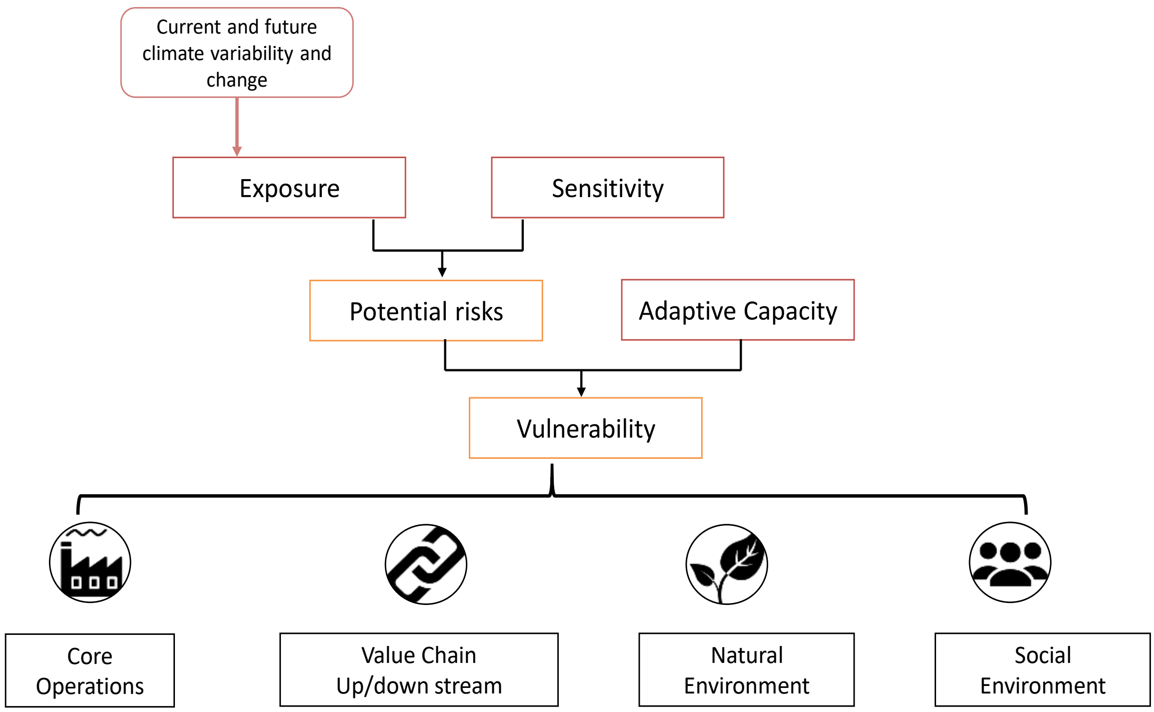

Figure 7: Interrelations of Exposure, Sensitivity and Adaptive Capacity, which makes up the basis of the vulnerability assessment.

Vulnerability to climate change is a challenging metric to derive, due to the complexity and uncertainty inherent to climate change impacts and extreme events associated with climate change. A number of vulnerability assessment frameworks have been developed, many of which are built for this purpose. The IPCC's concept of vulnerability and the factors determining vulnerability themselves have undergone a paradigm shift since the well-known concept of vulnerability developed in 2007. Most climate change vulnerability assessment frameworks are qualitative in nature, including South Africa's National Climate Risk & Vulnerability Assessment Framework. This makes their application challenging in the context of impact assessments.

Here, we have used and adapted the South African National Standard: Risk management – Risk assessment techniques *SANS 31010:2010 / IEC/ISO 31010:2009 Probability-Consequences* (Impacts) matrix. This matrix is relatively simple and introduces a scoring element similar to the impact significance scoring of a project as per South Africa's EIA Regulations included as part of NEMA.

The matrix provides a score for each climate impact based on its likelihood/probability of happening and the consequences/impact on the proposed project/development (Figure 8). These are both determined through expert opinion and informed by the experience and knowledge of previous events of relevance to the project or region. The climate event's extent, magnitude/severity and duration are taken into consideration in determining the consequence/impact. The assessment would normally be made for a time in the future that is suitable for the project's expected lifetime. However, because this deepening is set to be in place in perpetuity, a timeline to limit the temporal extent of the potential impacts is up to the year 2050.

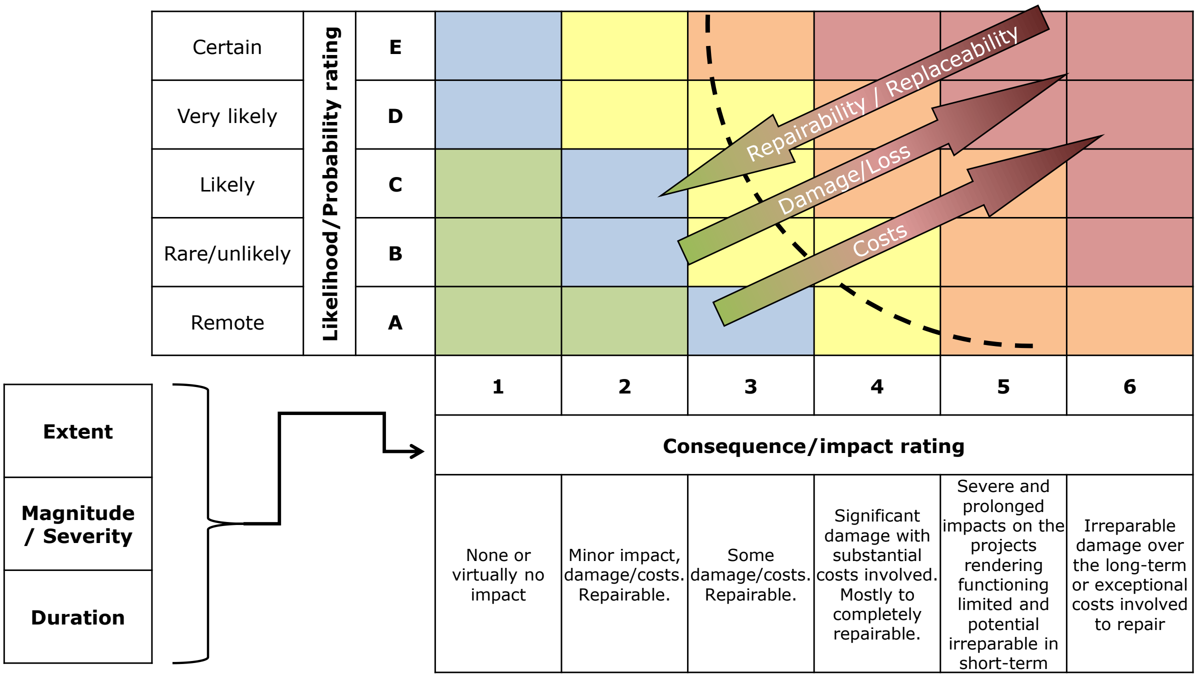

Figure 8: Risk assessment matrix used for determining climate change impacts on a project/development.

Limitations and Assumptions

The project's vulnerability and resilience to climate change is assessed within this CCIA through an analysis of available[64] 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.[65] 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 projections at a local scale.[66] This is particularly relevant for precipitation-related projections in southern Africa. This uncertainty should be noted by the project developers since the impacts of

64 This includes both spatial and temporal availability.

65 *It should be noted that unlike the SmartAgri Report, this assessment does not make use of CORDEX downscaled data and variations in results may be present.*

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

climate change may result in decreased investment value over time and possible increases in costs of maintenance.

The assessment of the vulnerability of the project to climate change is subject to further limitations, namely:

- Only impacts on the core operations and value chain were assessed and;
- Consideration focused on impacts occurring *during the lifetime* of the project.

3.4. Polycentric Integrative Approach

A polycentric approach to the proposed project requires the holistic consideration of all relevant factors, inclusive of potential impacts that the proposed Project could have on the local as well as the broader community. Section 2(4)(b) of NEMA states that Environmental management must be integrated, acknowledging that all elements of the environment are linked and interrelated, and it must consider the effects of decisions on all aspects of the environment and all people in the environment by pursuing the selection of the best practicable environmental option. Sustainable development as per NEMA requires the integration of social, economic, and environmental factors in the planning, implementation, and evaluation of proposed projects, to ensure that development serves the needs of present and future generations.

This specialist assessment considered both the positive and negative impacts of actual and potential impacts on the geographical, physical, biological, social, economic, and cultural aspects of the environment in a polycentric and holistic approach:

- To ensure that all aspects are weighed up against each other;
- To identify the risks and consequences of alternatives and options for mitigation of activities, with a view to minimising negative impacts, maximising benefits, and promoting compliance with the principles of environmental management as set out in section 2 of NEMA.

4. Results

4.1. Project Contribution to Climate Change

This section outlines the Duynefontein Nuclear Power Plant Project's impact on climate change. The GHG inventory is assessed in accordance with the methodology described in Section 3.1. The boundary of this assessment includes the construction of the nuclear power plant which includes direct emissions from the construction and operations of the two nuclear reactor units at Duynefontein, surrounding buildings and infrastructure. The assessment also covers the upstream production and transport of materials such as nuclear fuel. The emissions associated with the upstream activities are accounted for as contributing to the global stock of accumulated greenhouse gasses, as shown in Figure 6.

Project GHG Inventory

Direct emissions

Nuclear power itself doesn't produce greenhouse gas emissions primarily because of the nature of the energy production process. In a nuclear power plant, energy is produced through nuclear fission. This process involves splitting the nucleus of a heavy atom, uranium, which releases a large amount of energy. This energy is then harnessed to heat water, producing steam that turns turbines and generates electricity. This nuclear fission process does not involve burning any fossil fuels (like coal, oil, or gas), which are the primary sources of greenhouse gases such as carbon dioxide and methane. Instead, it relies on the energy that is stored within the atomic nucleus, which is released through the fusion reaction.

This analysis assumes that the proposed project will have direct emissions from operations similar to international operations.

The direct emissions from the project are:

- **Direct emission during the construction phase – 5 000 tCO_2e/year** (3.2 $kgCO_2e$/MWh from Table 6); and
- **Direct emission during the operational phase – 85 660 tCO_2e/year** (0.0032 tCO_2e/MWh (from Table 7)

Indirect and cumulative emissions

The indirect emissions of the project is listed in Table 11.

Table 11: Construction Phase GHG Emissions of the Duynefontein Nuclear Power Station.

Emission category	Emission source	Emissions
Category 3: Indirect GHG emissions from transportation	Heavy goods vehicles	15 950 tCO_2e
	Heavy transportation vehicles	26 tCO_2e
	Ultra heavy delivery vehicles	33 tCO_2e
	Staff commuting	14 990 tCO_2e
Total Category 3 emissions		**30 999 tCO_2e**
Category 4: Indirect GHG emissions from products used by organization	Purchased steel	222 058 tCO_2e
	Purchased concrete	129 202 tCO_2e
	Purchased large bore pipe	98 637 tCO_2e
	Purchased small bore pipe	3 416 tCO_2e
	Purchased Conduit	114 tCO_2e
	Purchased Cable	45 702 tCO_2e
	Purchased Water	1 918 tCO_2e
Total Category 4 emissions		**501 047 tCO_2e**

Emission category	Emission source	Emissions
Category 6: Indirect GHG emissions from other sources	Waste Generated	35 011 tCO_2e
Total Category 6 emissions		35 011 tCO_2e
Total indirect emissions during the construction phase		**567 057 tCO_2e**

The indirect emissions (value chain) associated with the operational phase of the nuclear power plant incorporates all emissions associated with the mining, conversion, enrichment, fuel fabrication, generation, spent fuel storage, and the low-level radioactive waste disposal of the nuclear fuel. The total upstream indirect emissions of the project is 388 148 tCO_2e/year, based on an emission factor of 17.1 kg CO_2e per MWhr.

Impact Assessment

Direct emissions

The operation of the proposed Duynefontein Nuclear Power Station will be 0.0032 tCO_2e/MWh (Table 7), or 85 660 tCO_2e/year.

In comparison to the current Eskom grid emission factor of 1.04 tCO_2e/MWh, the direct emissions of nuclear power is 0.3 % of that of the current grid.

Indirect and cumulative emissions

The proposed Duynefontein Nuclear Power Station would result in approximately 570 000 tCO_2e emissions over the entire construction and commissioning phase of the project. At an emission intensity of 0.0177 tCO_2e/MWh (Table 6), this is equivalent to 1.7% of the emissions on the current Eskom grid.

Assuming that the plant will continuously run for its full life cycle, its associated indirect emissions can result in approximately 470 000 tCO_2e/annum. The emissions over the 60-year lifetime of the project are comparable to less than 2 years of running a new coal fired power station of similar size.

When considering all the emissions related data of the project, it can be reasonably stated that the project has an overall positive impact. While the indirect operational emissions of the nuclear power plant may have a medium intensity impact, it is important to consider the broader context and the comprehensive assessment of all impacts related to the project especially the almost negligible direct emissions impact.

4.2. Project Vulnerability to Climate Change: Climate Change Projections

Due to its proximity to the coastline, the main weather-related risks relevant to the project are **coastal storm activity, rainfall and flooding and sea level**. Air temperature, ocean pH and sea surface temperature (SST) are also relevant but to a lesser degree on the core operations and more on the value chain and surrounding environment. For example, temperature changes and extreme temperature occurrences could affect operations and labour productivity. The proposed site is located in one of the most temperate regions of South Africa and an increase in temperatures to uncomfortable heat levels could impact labour productivity and have a direct bearing on the health and safety of personnel. Heat stress and discomfort felt could lead to unforeseen incidents that could cause damage to equipment/or human injury. This could lead to higher mortality rates, heat-related illnesses, increased injuries, more absenteeism, slow work pace, loss of productive capacity, and poor social well-being.

General Regional Climate Change Considerations

Mean annual temperature at Duynefontein has increased slightly since the 1980s by approximately 0.3°C. The climate change projections for the project area indicate that the annual mean ambient temperatures are likely to increase by up to 0.3˚C by 2030 and 0.4-0.9˚C by 2050 (with significant annual variability) under different climate scenarios. The trend overall is warming under all SSPs at a faster rate than has been experienced in the last few decades (Figure 9).

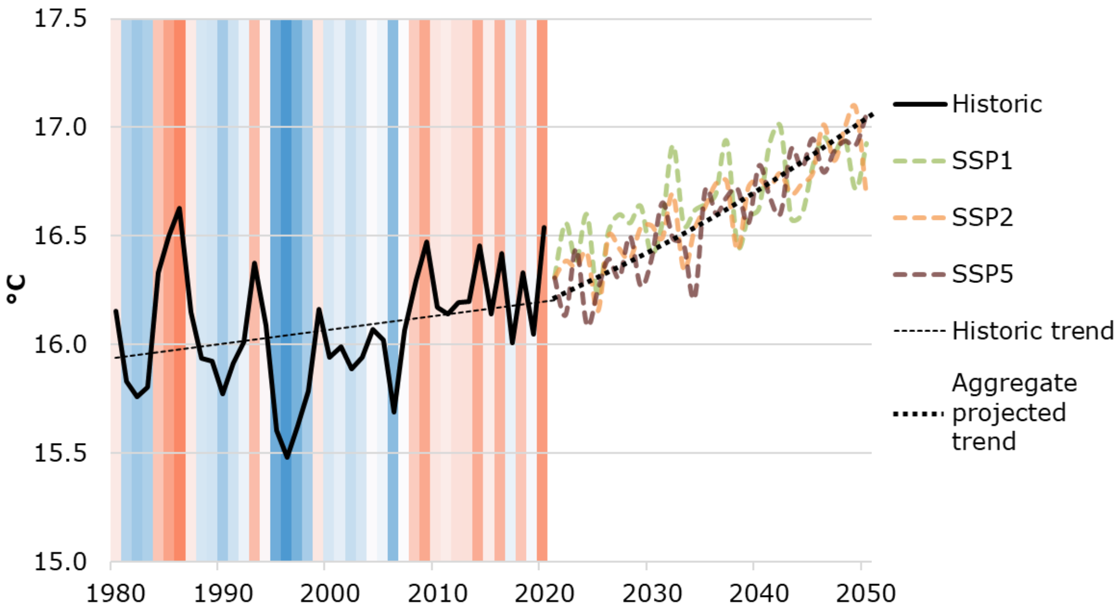

Figure 9: Historical and projected mean annual ambient atmospheric temperature at Duynefontein. Data sources: Copernicus Climate Change Service (C3S)[22] and CMIP6.[55]

Mean annual precipitation has shown a steep downward trend over the last few decades and is likely to continue to decline, but less rapidly over the next three decades with significant year-on-year variability (Figure 10). The region experienced a multi-year drought from 2015-2017 leading to severe water shortages.[60,67] The further declines will heighten the risk of water stress in the region.

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[67] Otto, F.E.L., *et al.* 2018. Anthropogenic influence on the drivers of the Western Cape drought 2015–2017. *Environmental Research Letters* 13: 124010.

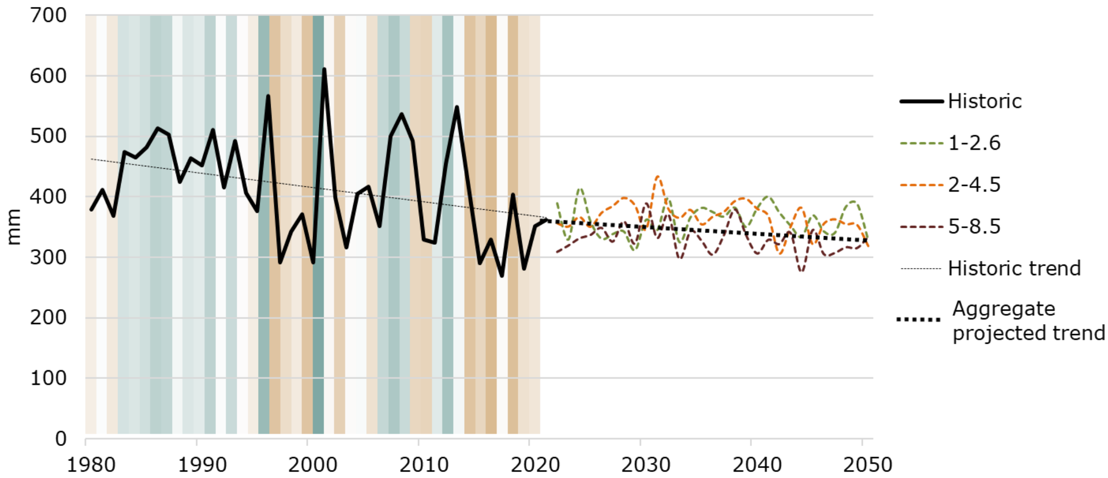

Figure 10: Historical and projected mean annual precipitation at Duynefontein. Data sources: Copernicus Climate Change Service (C3S)[22] and CMIP6.[55]

The current and future changes in climate for Duynefontein, are summarised in the table below.

Table 12: Current and future climate projections for the Duynefontein Nuclear Power Station as part of the Eskom Nuelar-1 Project. Data sources: Copernicus Climate Change Service (C3S)[22,55] and Green Book Risk Profile Tool.[68]

		Projected change by 2040-2059 (median year 2050) relative to baseline		
Climate change impact	Current/Near-historical	SSP1	SSP2	SSP5
Mean annual temperature	16.1 ±0.3°C; slight decreasing trend	Increase of 0-0.5-0.9°C	Increase of 0-0.6-1.0°C	Increase of 0.7-1.0°C
Very Hot Days[69]	<1 day/year (mean)	Not available	No meaningful increase (<1%)	No meaningful increase (<1%)
Mean annual precipitation	394 ±95 mm/year; decreasing trend	Mean decrease of ±35 mm/year	Mean decrease of ±40 mm/year	Mean decrease of ±75 mm/year
Extreme Rainfall Days[70]	0-8 days per year	Not available	50% decline in extreme rainfall days/year	50% decline in extreme rainfall days/year

[68] 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.

[69] A day when the maximum temperature exceeds 35°C.

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

		Projected change by 2040-2059 (median year 2050) relative to baseline		
Climate change impact	**Current/Near-historical**	**SSP1**	**SSP2**	**SSP5**
Drought Risk	Moderate to high	Not available		Extreme risk of increase in drought conditions per decade compared to baseline
Coastal flooding risk	Not exposed	Not available		Not exposed
Fire Risk	Possible	Not available		Moderate risk
Damaging wind risk	Not available			

Storms and storm-related weather impacts

Coastal storms and related impacts such as storm surges are likely to be the foremost impact on the project. There is wide agreement in the climate science community that an increase in global average temperature will be commensurate with an increase in weather extremes.[71] Of particular relevance for the Duynefontein area are storms associated with frontal systems primarily occurring in winter low pressure systems, such as cut-off lows[72] that can bring widespread rain. Duynefontein may be impacted to a small degree by these systems, however, because most of the proposed site is located above the design basis flood level of 11.2 m, the coastal flooding risk is negligible, and regarded as low risk for the proposed outfall and intake tunnels which go beyond the high-water mark and are designed for maritime conditions.[73]

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[71] Arias, P.A. *et al.* 2021. Technical Summary. 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.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 33−144. doi:10.1017/9781009157896.002.

[72] Anti-cyclonic depression that results when air in the mid-atmosphere moving in an easterly direction is disturbed and through the development of a trough. This trough generally intensifies to form a low pressure system that 'cuts off' from the westerly often resulting in heavy rainfall for several days. They are most common in spring and autumn.

[73] DEFF. 2020. National Coastal Climate Change Vulnerability Assessment: Vulnerability Indices – Technical Report. Department of Environment, Forestry & Fisheries, Pretoria.

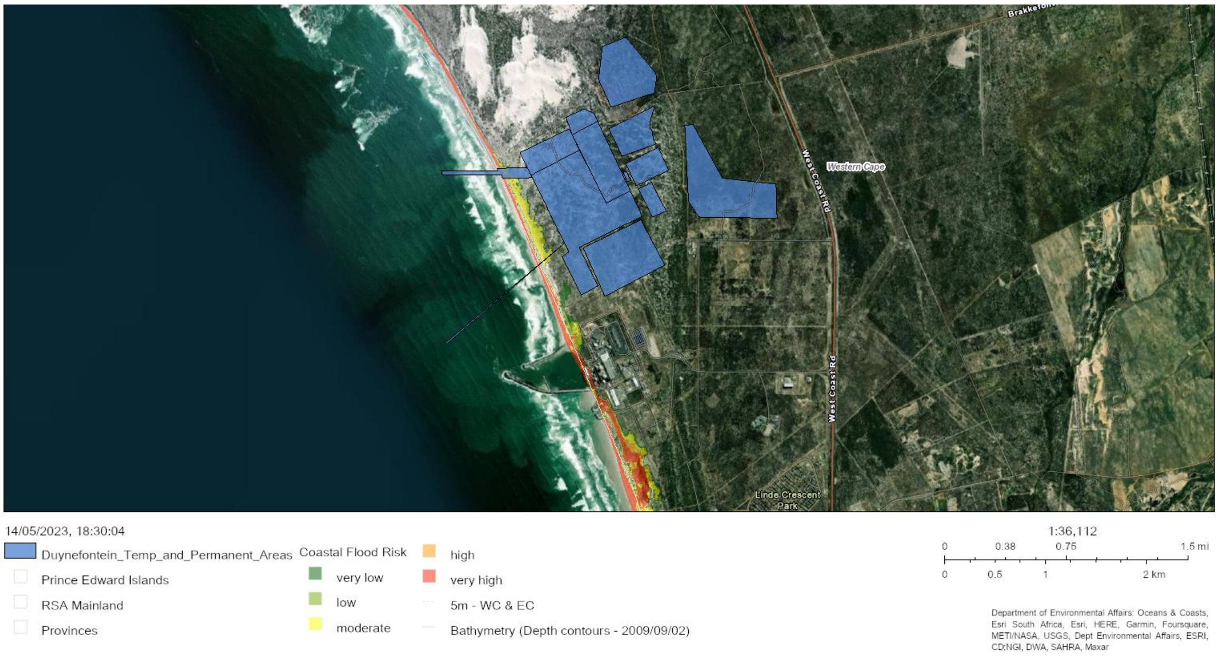

Figure 11: Coastal flooding risk for the proposed Nuclear Power Station. Source: DFFE.[74]

Tropical storms and cyclones

Duynefontein has historically not been impacted by tropical storms or cyclones due to its location. This is not expected to change.

Sea surges and wave action resulting from storm activity

One of the key impacts of coastal and tropical storms are the associated storm surges that result from the high-wind speeds interacting with the ocean surface. In the region, extended onshore winds result in larger swells being experienced. A combination of high sustained onshore winds and the storm area are the two primary variables that influence wave impact.[75]

Waves that impact maritime activities and infrastructure are primarily linked to ocean currents, frontal patterns, cut-off low systems and tropical depressions and cyclones. Wave climate is highly seasonal and varies in intensity and wave period. The west coast of South Africa has a moderate risk overall in terms of wave height and return period on the South African coastline. There is no consensus on the impact that climate change will have on the strength of the Benguela current, which itself has a major impact on waves.[76] Researchers have observed a marginal rise in average wave height in the region, although there is limited evidence indicating a significant increase in severity. This is in contrast to many other parts of the world where the impact of such changes is

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74 DFFE. 2022. mapservice.environment.gov.za/Coastal%20Viewer/ .

75 Mather, A.A., and Stretch, D.D. 2012. A Perspective on Sea Level Rise and Coastal Storm Surge from Southern and Eastern Africa: A Case Study Near Durban, South Africa. *Water* 4: 237-259.

76 Rossouw, M. and Theron, A.K. Investigating the potential climate change impacts on Maritime operations around the southern African coast. CSIR.

more pronounced and confidently documented.[77] Peak wave height during storms appears to have increased, and with an increase in storm activity in the future, there is a possibility of increased storm surges in the future, but substantially more data and research are needed to confirm this.

Near-shore offshore infrastructure and coastal developments are particularly vulnerable to storm surges. This risk increases with a rise in mean sea level. At the proposed Duynefontein site, the proposed outfall and intake tunnels are those areas that are most likely to be affected by a combination of sea level rise (see section 0), tides and storm surges (Figure 12). These components may require increased maintenance to withstand increased storm surges. The main nuclear reactor building should also be constructed, such that it takes all storm surge risks into consideration.[76]

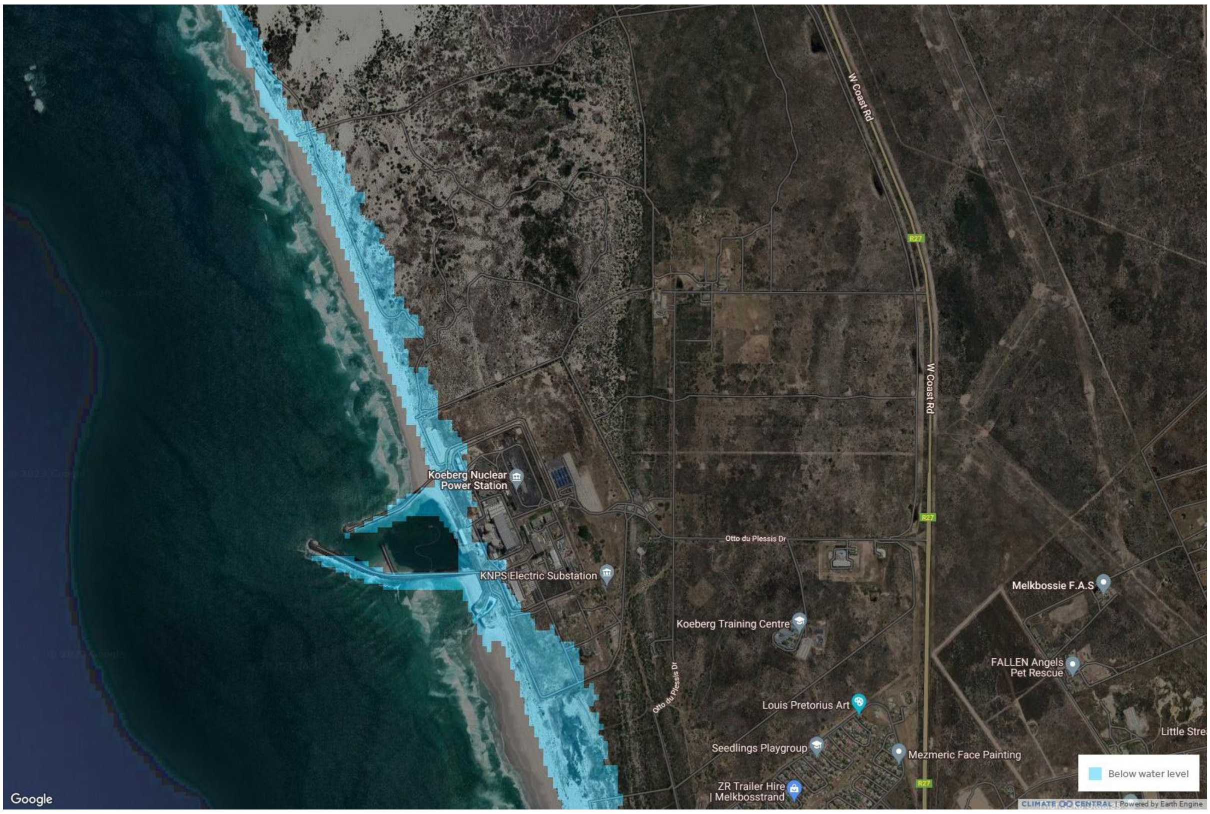

Figure 12: Area impacted (in light blue) at and around the proposed Duynefontein Nuclear Power Station by a 5 m rise (worst-case scenario) in water level through combinations of sea level rise, tides, and storm surge. Source: https://coastal.climatecentral.org/

Ocean Acidification

Ocean acidification occurs due to increased deposition and dissolution of higher concentrations of atmospheric CO_2. The problem is particularly widespread in the open ocean (away from coastlines). There is very high confidence (virtually certain) according to the IPCC's sixth assessment report (AR6) that ocean pH has declined since ca. 1985.[71] At a global level this has

[77] Dasgupta, S., Laplante, B., Murray, S. and Wheeler, D. 2009. Climate Change and the Future Impacts of Storm-Surge Disasters in Developing Countries. Working Paper 182. Center for Global Development.

been from roughly 8.11 to just above 8.05 by 2020 (Figure 13), and around the South African coast at between 0.0018 and 0.0015 per year (around the global mean).[78] Aquatic pH along the west coast of South Africa is slightly more alkaline than water along the south and east coast. Off South Africa's south-western coastline, surface sea water pH has declined from roughly 8.15 to 8.09 (Figure 14).

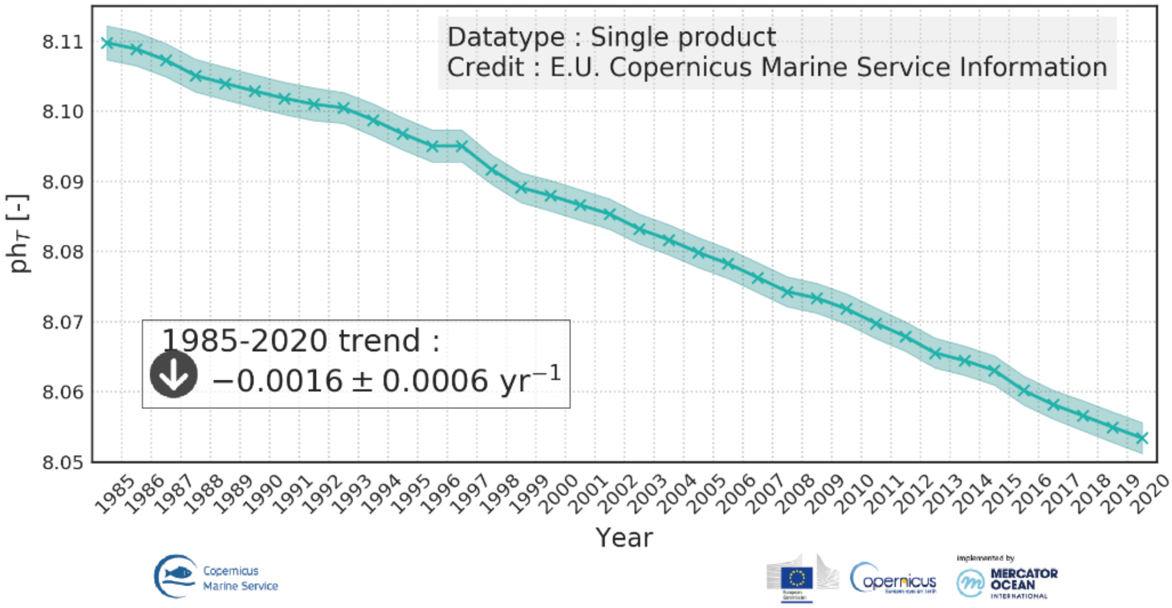

Figure 13: Annual mean surface sea water pH reported on total scale between 1985 and 2020. Source: E.U. Copernicus Marine Service Information.

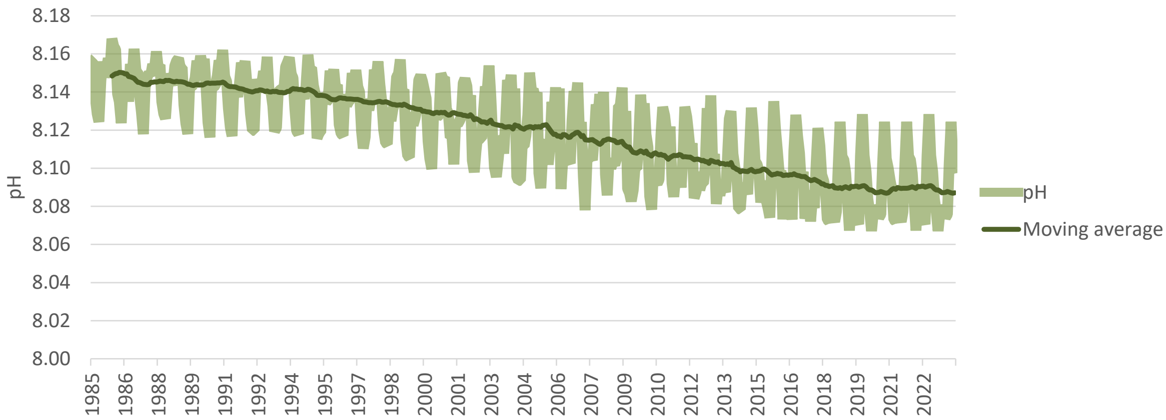

Figure 14: Surface Sea Water pH near Duynefontein between 1985 and 2023. Data source: Global Ocean Biogeochemistry Hindcast.[79]

[78] E.U. Copernicus Marine Service Information.
[79] Copernicus Marine Environment Monitoring-Service.

By 2050, pH is predicted to be ~0.2 lower than a baseline of 1950 along the west coast of southern Africa under SSP5.[80] Change of this magnitude, and based on a trend of historical data, poses a low risk to the project's relevant ocean-based infrastructure.

Wind

The dominant wind direction at Duynefontein is from south and south-southeast and is predominantly classed as a moderate breeze (20-29 km/h) (Figure 15).[81] Wind velocity is expected to increase across all seasons in South Africa, but to a very small degree (maximum 6% increase).[82] On occasions where a 10% increase in wind speed is experienced, a up to a 17% increase in wave height may be experienced.[83] This compounds the impacts during storm surges and can result in significant increases in the transport of sediment into harbours and ports. Other than during storm events, the risk posed to the project from wind speed under climate change is low. Wind direction could shift to a more westerly direction during autumn along the Western Cape coast under future climate change scenarios.[82] This would result in more regular onshore wind occurrence which may result in slightly cooler air temperatures normally associated with onshore winds. Further, there may be an increase in dust and beach material being transported inland from the coastline, however, this is not likely to be material over and above the existing deposition during the remainder of the year.

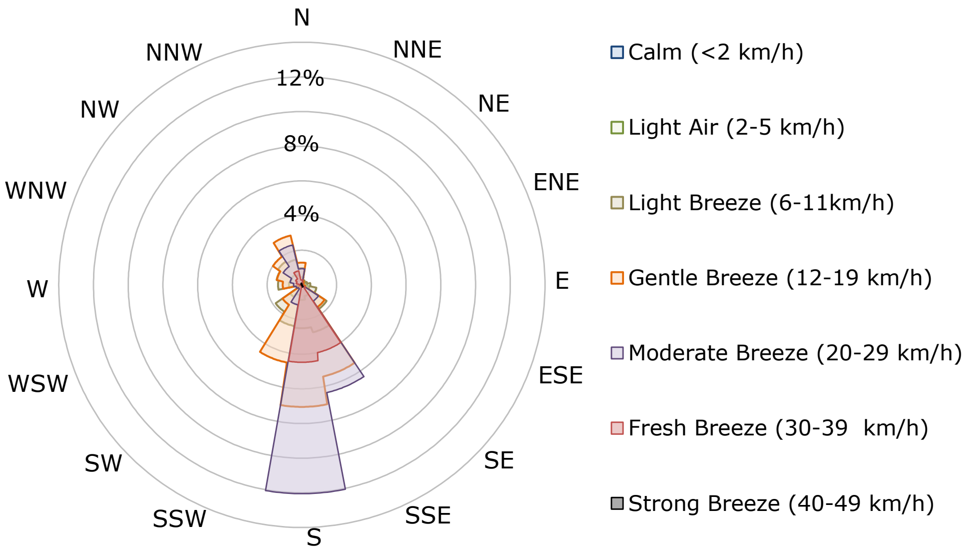

Figure 15: Wind rose for Duynefontein for the period 1980-2020. Data Source: Copernicus Climate Change Service (C3S).[22]

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80 IPCC pH at surface (pH) – Change (pH).
81 These results do not differ significantly from the Air Quality Assessment undertaken.
82 Herbst, L. and Rautenbach, H. 2016. Climate change impacts on mean wind speeds in South Africa. *Clean Air Journal* 25: dx.doi.org/10.17159/2410-972X/2015/v25n2a2.
83 Prestedge Retief Dresner Wijnberg Consulting Port and Coastal Engineers. 2009. Eskom Nuclear Sites Site Safety Reports. Coastal Engineering Investigations. Duynefontein. Report No. 1010/4/102.

Sea level

Local and regional sea level varies in space and time due to a number of factors such as tides, wind, waves and atmospheric conditions.[84] Anthropogenic activity has exacerbated this. Global mean sea level (GMSL) increased by 15 to 25 cm between 1901 and 2018, with a particularly elevated increase since 2006 of 3.7mm yr^{-1} (Figure 16). According to the AR6, it is considered to be virtually certain that GMSL will continue to rise over the 21st century.[71] Mitigation efforts are unlikely to change the trajectory of sea level rise and GMSL is predicted to rise by between 28 and 55 cm under SSP 1-1.9 and 63-101 cm under SSP5-8.5, relative to the average between 1995 and 2014 (Figure 17).[71]

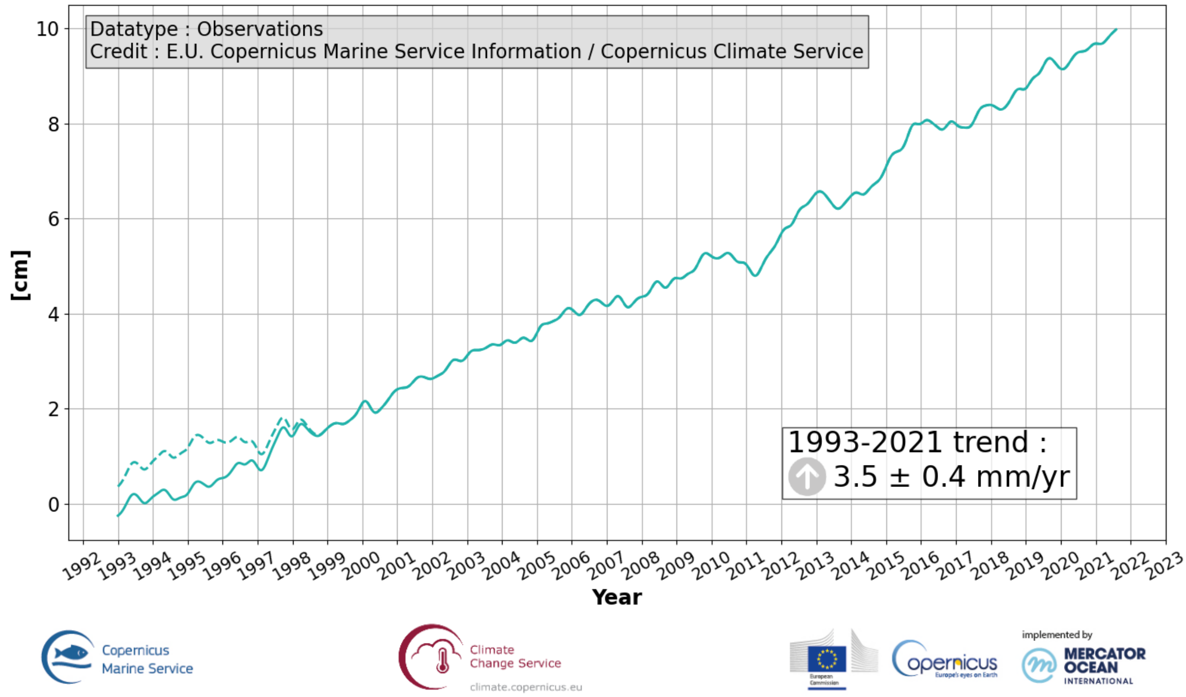

Figure 16: Global mean sea level. Source: E.U. Copernicus Marine Service Information.

[84] In South Africa, sea level generally increases from west to east and measurements are made relative to their level.

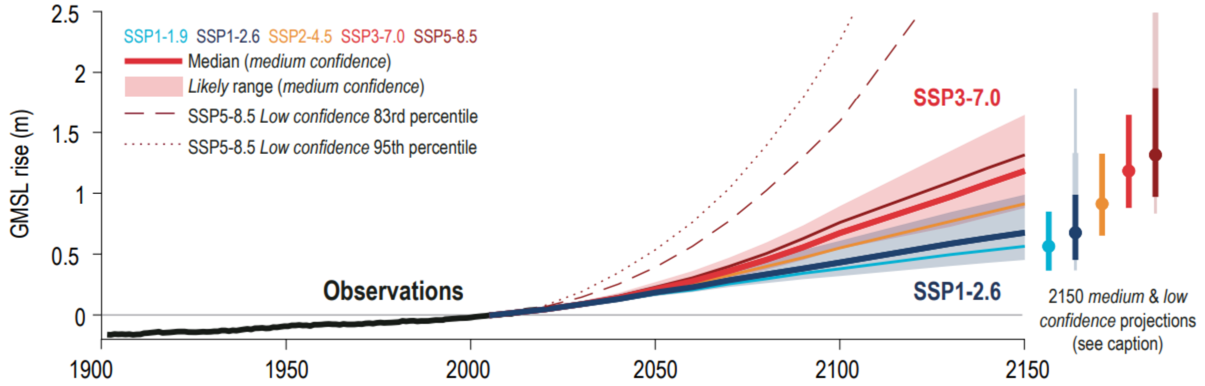

Figure 17: Global mean sea level rise from 1900–2150. Source: Arias, P.A. *et al.* 2021.[71]

Sea level has increased by varying degrees along the South African coastline.[85] Data from the [South African] Hydrographic Office shows that mean sea level at Granger Bay (the nearest recording station with available data) has increased by ±6.0 cm (14.7 mm y^{-1}) between 1967 and 2018 based on a linear trend (Figure 18). According to AR6 projections (medium confidence), sea level around Saldanha Bay is expected to rise by 9-43 cm (from a 1995-2014 mean) by 2050 under different SSPs (Figure 18) with the *earliest* expected 1 m rise (from a 1995-2015 mean) by ca. 2090 under SSP5-8.5. The value of 1.1 m SLR by 2075 indicated in the Botany and Dune Ecology Specialist Study,[86] seems overstated and does not accord with AR6 findings.

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85 Mather, A.A., Garland, G.G. and Stretch, D.D. 2009. Southern African sea levels: corrections, influences and trends. *African Journal of Marine Science* 31: 145-156.

86 Coastec. 2015. Environmental Impact Assessment for the Proposed Nuclear Power Station ("Nuclear-1") And Associated Infrastructure. Botanical and Dune Ecology Impact Assessment. Prepared by Coastec: Coastal and Environmental Consultants for Arcus GIBB Pty Ltd.

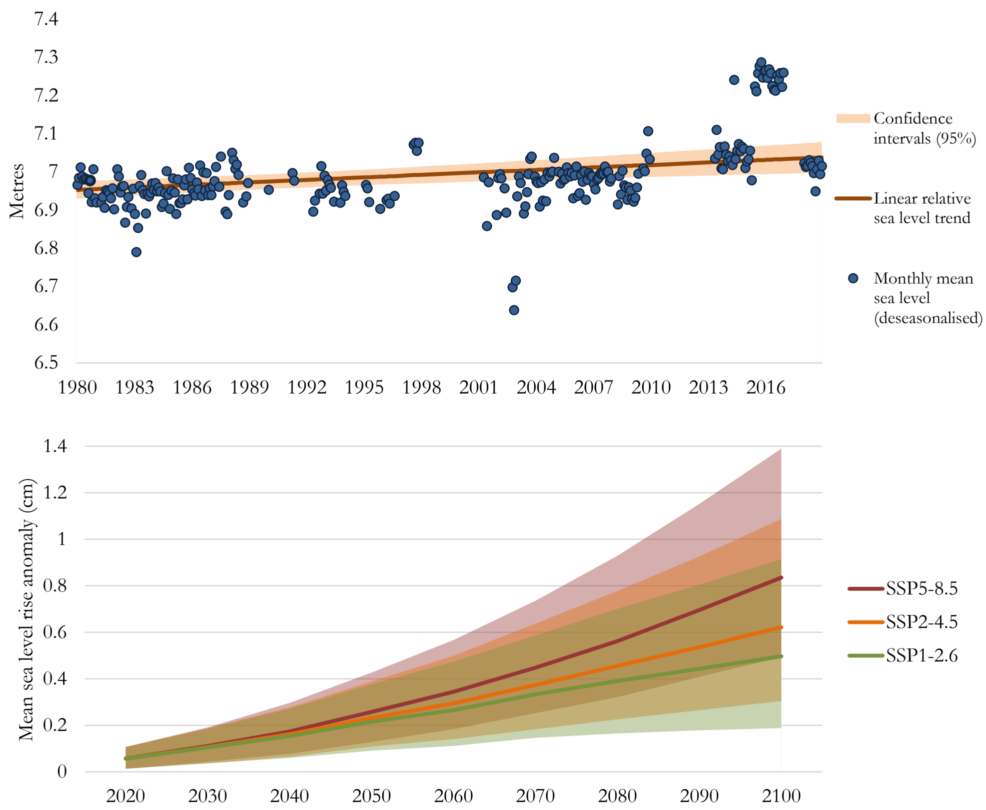

Figure 18: Measured monthly sea level at Granger Bay (Cape Town) from 1978 to 2018. Data source: SAN Hydrographic Office[87] (top) and sea level rise projections under SSPs 1, 2 and 5 & IPCC AR6.[88,89,90] (bottom).

Sea level rise is predicted to be higher along South Africa's west coast than the remainder of the coastline, however, the rise in sea level is not likely to have a material impact on the project during its lifetime. Increases in sea level amplify storm surges during extreme weather events. Increased sea level will result in greater water depth which positively influences wave energy, thus increasing the potential impacts on wave damage during storms and periods of sustained high winds. The impacts from wave activity on near-shore infrastructure of the proposed site is difficult to gauge in this regard and is best determined by a hazard specialist. Furthermore, previous studies as part of the FEIR for the Project found that groundwater levels could increase by ~0.55 m across the site under 0.8 m SLR by 2100.

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87 Hydrographic Office Maritime Headquarters. Extracted from the Permanent Service for Mean Sea Level (psmsl.org).

88 Fox-Kemper, B., H. T. *et al.* 2021, Ocean, Cryosphere and Sea Level Change. 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.)]. Cambridge University Press. In press.

89 Garner, G. G., *et al.*, in prep. Framework for Assessing Changes to Sea-level (FACTS). Geoscientific Model Development.

90 Garner, G. G. *et al.* 2021. IPCC AR6 Sea-Level Rise Projections. Version 20210809. PO.DAAC, CA, USA.

Sea surface temperature

Sea surface temperature is a fundamental component of climate science, given that 71% of earth's surface is covered by oceans and that oceans absorb significant amounts of extra heat arising from GHGs. Sea surface temperature is strongly influenced on a seasonal and annual basis by global circulation patterns and is highly variable along the South African coastline[91] (see Figure 19) and are useful in identifying El Niño and La Niña cycles that are part of the El Niño–Southern Oscillation (ENSO). These cycles strongly influence seasonal weather patterns. For example, La Niña conditions (colder sea surface temperature in the equatorial Pacific area) generally lead to higher rainfall and warmer summer temperatures over eastern South Africa and vice versa.

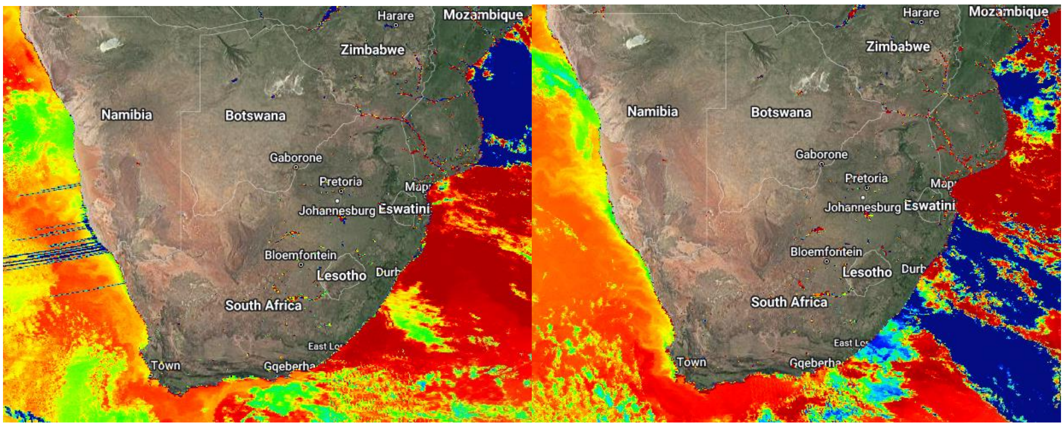

Figure 19: Example of seasonal and annual variation in sea surface temperature around South Africa's coast: mean sea surface temperature for 1985 (left) vs. mean sea surface temperature in 2011 (right). Data source: Baker-Yeboah *et al.* (2016).[92]

In the same way terrestrial air temperature has increased over the last century, so too has sea surface temperature. The AR6 indicates global sea surface temperature increase of between 0.68-1.01˚C across the globe's oceans since the period 1850-1900 to the last decade, most of which has occurred since 1980.[88] Since 1993 the global mean sea surface temperature has increased by ±0.016˚C per annum,[78] with the greater levels of warming being in the Arctic and northern Pacific Oceans.

Mean offshore sea surface temperature near Duynefontein has increased by ±0.79˚C since 1900, with a decadal mean of 17.35˚C at present (Figure 20). There appears to be a continued rise in mean sea surface temperature at Duynefontein under the three SSPs, with an increase from of approximately 0.6°C from ±17.8°C to ±20.4°C under SSP5 with a radiative forcing of 8.5 which could occur under 4°C warming (Figure 20). Although Roualt *et al.* (2009)[93] in Griffiths *et al.*

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91 Schumann, E.J., Cohen, A.L., and Jury, M.R. 2022. Coastal sea surface temperature variability along the south coast of South Africa and the relationship to regional and global climate. *Journal of Marine Research* 53:231-248.

92 Baker-Yeboah, S., *et al.* 2016. *Pathfinder Version 5.3 AVHRR Sea Surface Temperature Climate Data Record*, Fall AGU 2016 Poster (manuscript in progress).

93 Rouault, M. Penven, P. and Pohl, B. 2009 Warming in the Agulhas Current system since the 1980's. *Geophysical Research Letters* 36, L12602 doi: 10.1029/2009GL037987.

(2016)[94] found that inshore SST along the South African west coast had declined in the two decades prior to 2009 as a result of climate change, it is not clear whether this pattern has persisted. It is, however, likely that warming of inshore water will occur, however, there is limited near-shore data from which to draw a projected trend.

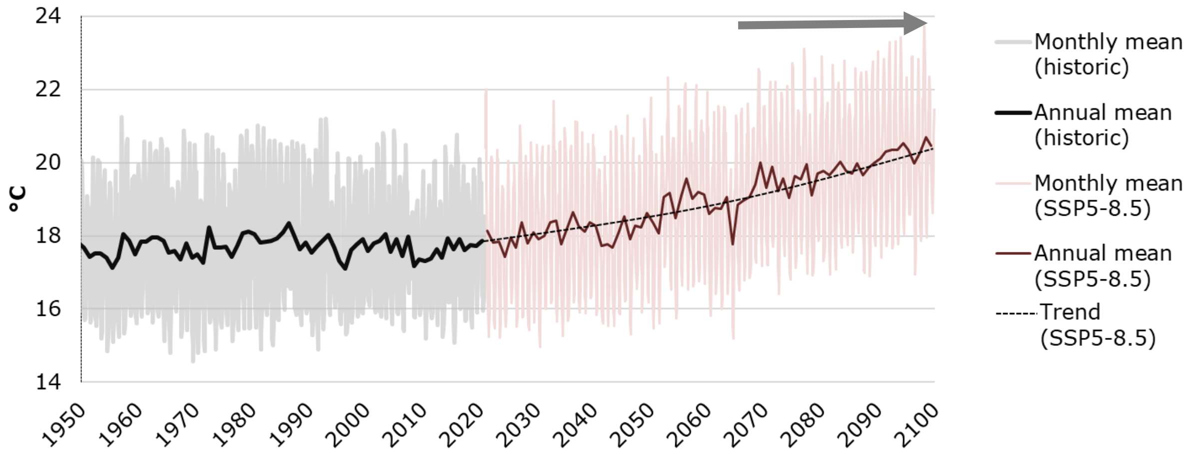

Figure 20: Historical mean sea surface temperature for ocean off Duynefontein since 1950 and projected sea surface temperature up until 2100 under SSP 5. Data sources: HadISST (historical),[95] CMIP6 (future).[55]

Sea surface temperature increases in the Benguela Current, which flows north along the west coast of southern Africa, have resulted in an El Niño effect. The degree to which this impacts the coastal regions is not clear. One impact of this effect is increasing salinity and water pressure in the waters of the Benguela Current. The El Niño effect could have impacts in the form of increased atmospheric-surface turbulence resulting in greater storm activity and a shift in trade winds (a minimal impact on large vessels is expected).[96]

Another key impact of the warming of sea surface temperature is the impact on the temperature of the inflow of sea water into the cooling components of the power station, and the on-site storage of spent fuel. Median sea surface temperature could reach an average of 20°C, with a maximum of 24°C by the end of the century (Figure 20). The maximum value is almost 6°C warmer than the current sea surface temperature.

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94 Griffiths, C.L., Robinson, T.B. and Elwen, S.H. 2016. Environmental Impact Assessment for the Proposed Nuclear Power Station ("Nuclear-1") And Associated Infrastructure. Marine Ecology Impact Assessment. Prepared for Arcus GIBB Pty Ltd.

95 Rayner, N. A., *et al.* 2003. Global analyses of sea surface temperature, sea ice, and night marine air temperature since the late nineteenth century *J. Geophys. Res.*108: 10.1029/2002JD002670

96 Corfield, J. 2022. Benguela Current. *Climate Policy Watcher.* Available at: climate-policy-watcher.org/global-climate-2/benguela-current.html#:~:text=The%20problem%20facing%20the%20Benguela,effect%20has%20already%20been%20detected.

Water stress and drought

South Africa is classified as a water-stressed country.[97] 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 and such a high percentage of water withdrawal increases the competition among users, resulting in greater exposure to water stress. *Furthermore, The Western Cape, including the City of Cape Town has experienced periodic droughts, most notably between 2015 and 2020.*[60] 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 *Aqueduct* tool, the proposed Project falls within a river basin with extremely high water stress, with a medium-high seasonal variability classification and medium-high drought risk (Figure 21). Water stress in the catchment area in which the project area is situated is expected remain extremely high under SSP2-4.5 up to 2040, to medium-high water stress. Seasonal water variability[98] is expected to increase to extremely high, possibly as a result of the projected decreased rainfall. 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.

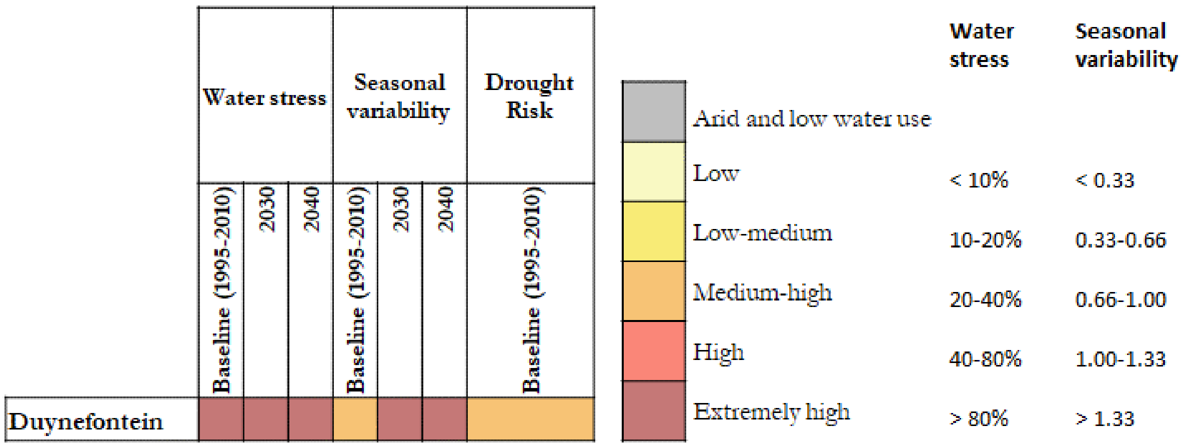

Figure 21: Water stress and seasonal variability classification for Duynefontein currently (baseline) and for 2030 and 2040 under SSP2-4.5. Data source: WRI Aqueduct[99]

Consecutive dry days[100] has shown a declining trend since the middle of the 20th century (Figure 22). The mean number of consecutive dry days per annum since 1980 has been 36±11.1. The number of such days is expected to average around 46 days per annum through to 2050 under SSP1, 47 under SSP2 and 49 under SSP5. Whilst the models are not able to account well for

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

98 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.

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

100 Number of days in the longest period without significant precipitation of at least 1mm.

extreme drought periods in the future, there is a clear trend of an increase from more recent decades, increasing by at least 10 days per year.

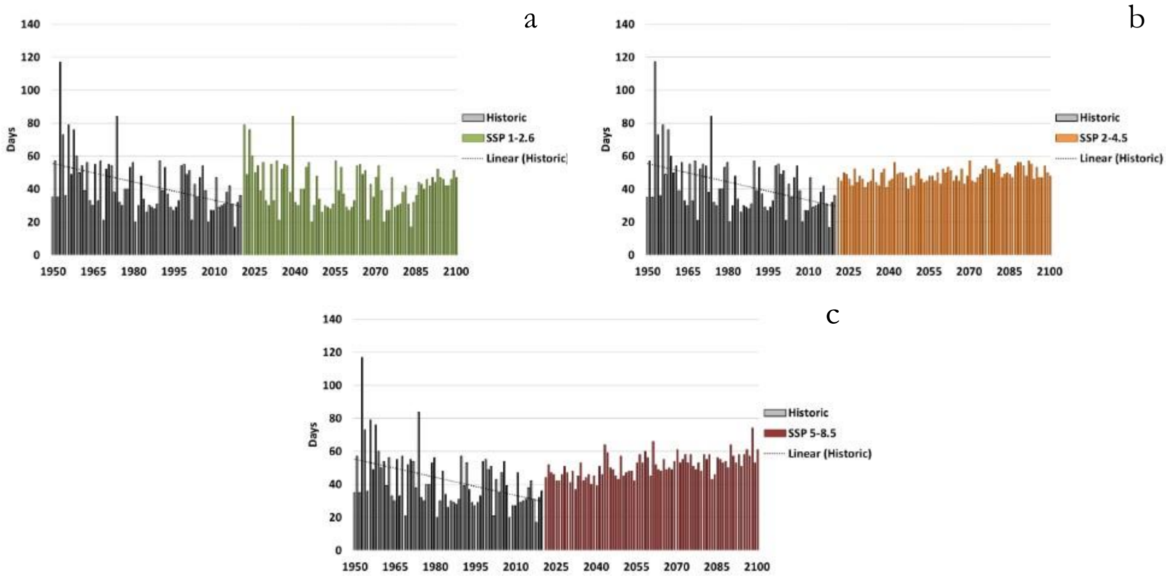

Figure 22: Historical and projected consecutive dry days at the proposed Duynefontein Nuclear Power Station under SSP1 (a), SSP2 (b) and SSP5 (c). Data sources: C3S[22] and CMIP6[55]

4.3. Project Vulnerability Assessment

Vulnerability is defined as the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes.[10] Climate change and climate variability are both damaging and costly to much of the world, and South Africa is no exception. Climate-related impacts such as floods, droughts, heat waves and cyclones pose significant risks to infrastructure, economies, livelihoods, and natural ecosystems. However, the impacts usually differ in both magnitude and rate of change across geographical locations and depend on the capacities of human and biological systems to adapt to changing climates.

Core operations

South Africa is expected to experience a range of climate-related risks and impacts, with some of these impacts having clear implications for energy production, distribution and use. Climate change may affect the efficiency of production processes on site, cost of operations and maintenance. For example, a rise in temperature has the potential to impact the power plant's cooling water temperature, consequently reducing the plant's thermal efficiency and potentially resulting in a decrease in production.[101] Extreme temperatures or intense rainfall events could also alter working conditions, affecting workers' safety and productivity. In addition, coastal operations are directly or indirectly affected by extreme weather events and changing ocean conditions (e.g.,

[101] Linnerud, K., Mideksa, T.K. and Eskeland, G.S. 2011. The impact of climate change on nuclear power supply. *The Energy Journal* 32(1).

sea-surface temperature, ocean pH and rising sea levels), with the timing and magnitude of these effects being largely uncertain. Moreover, the resilience of operational systems (i.e., generation and transmission systems and infrastructure) may be at direct risk from these extreme events, with the potential to cause significant damage.[102]

The average annual atmospheric temperature at the project site is expected to increase, with the mean annual temperature at Duynefontein having increased slightly since 1980 by about 0.3°C. The Green Book tool indicates that by 2050, the average temperature will increase by between 0.5°C to 0.9°C under SSP1 scenario, 0.6°C to 1.0°C under the SSP2 scenario and 0.7°C to 1.0°C under the SSP5 scenario. The number of very hot days is seen to be negligible, as it is predicted that there is a <1% increase in number of very hot days for both SSP2 and SSP5. Typical risks associated with the relationship between increased temperatures and the project's core operations, include the following:

- Higher temperatures places increased stress on cooling systems. These climate changes may exceed the thresholds of essential equipment and systems, causing more frequent failures and operational stoppages over time, and increasing potential fire-hazards.
- Onsite offices and rooms will make increased use of air conditioning due to higher temperatures, thus increasing energy demand and associated costs.
- Increasing ambient temperatures and extreme hot days increase 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, workers may become more exposed to heat stress and increased temperatures and may impact operations.

The mean annual precipitation is expected to gradually decline, with significant variability year-on-year, for the next three decades. The Green Book tool indicates that by 2050, the average precipitation will decrease by ±35 mm/year under SSP1, ±40mm/year under the SSP 2 scenario and ±75mm/year under an SSP5 scenario. The number of extreme rainfall days is expected to have a 50% decline in days/year under SSP2 and SSP5. Due to its proximity to the coastline, the main weather-related risks relevant to the project are coastal storm activity, rainfall and flooding and sea level rise. *Despite the* overall decline in precipitation *and the periods of drought that are likely to recur under climate change, the vulnerability of the project in terms of water resilience is not low and there* is unlikely to *be* a major impact on the core operations as *desalination of seawater can be used for potable water use*

[102] Ciscar, J.C. and Dowling, P. 2014. Integrated assessment of climate impacts and adaptation in the energy sector. *Energy Economics* 46: 531-538.

and seawater is planned for use *to condense steam in the turbine condensers* *and for the majority of operational water requirements*.[103]

Storm surges are one of the main impacts of tropical and coastal storms. Thus, means that, during the landfall of a coastal storm, the sea level is higher than normal. Apart from flooding, storm surges have the potential to affect coastal environments through increased wind speeds and wave impacts. Storm surges increase wind speeds and wave heights, posing major risks to both on-and off-shore activities. Larger storm surges can destabilise the seabed by increasing sediment accretion or erosion, which can lead to embedment or undercutting of underwater pipelines.[104] However, tidal or storm surge barriers at ports often prevent or significantly reduce these processes and therefore, the risks are expected to be low.

In addition, the impacts of rising sea-levels (although mostly indirect) are considered in this analysis as it poses a major risk to coastal communities and industries. Rising sea-levels increase tidal heights, compounding the effects of tropical storms and/or storm surges, increasing the likelihood of coastal flooding. According to IPCC AR6, the projected sea-level rise for the project's location is 9-43 cm by 2050 under various SSPs, with a 1 m rise only being expected in 2090 under SSP5-8.5. Tidal heights and coastal flood risks are therefore expected to increase within the region. Although there is limited infrastructure planned for the coastal zone, large storm surges could increase the vulnerability of project operations by causing detrimental damage to infrastructure and placing workers safety at risk. Construction above the flood design level above 11 m should effectively mitigate any risks posed in this regard. Historic accidents, such as that at Fukushima, was the result of tsunami-induced waves. There is a very low risk of such wave activity around South Africa's coastline. However, increase in storm surges will require an increase in maintenance of the structures to ensure that they can withstand increased storm surges.

The pH of the sea water could have an impact on the corrosion rates of underwater pipelines and infrastructure. Climate-related impacts involving rising sea-surface temperatures and declining pH levels (through ocean acidification) may accelerate the corrosion rates of marine infrastructure, reducing its durability and lifespan.[105] The pH levels of the sea show a slight decline from ±8.15 in 1985 to ±8.09 in 2023, suggesting that pH levels are likely to remain above 8 throughout the project's lifetime (20-30 years). These changes may increase corrosion rates marginally however, its impact may be minimal to underwater pipelines as part of outlet and intake systems.

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103 The FEIR stated that operational water requirements will primarily be met through the use of a desalination plant which will be developed for the component cooling. The use of municipal and groundwater resources were noted as being unfeasible in the long-term. It is further noted that the freshwater supply specialist report (E8) recommended desalination of sea water as the most assured water supply in terms of climate change impacts.

104 Zhang, M., Huang, Y. and Bao, Y. 2016. The mechanism of shallow submarine landslides triggered by storm surge. *Natural Hazards* 81(2): 1373-1383.

105 Garcia, A., Valdez, B., Schorr, M., Zlatev, R., Eliezer, A. and Hadad, J. 2010. Assessment of marine and fluvial corrosion of steel and aluminium. *Journal of Marine Engineering & Technology* 9(3): 3-9.

In the project area, average sea-surface temperature is expected to increase from 17.8˚C to 20.4 ˚C by 2100, with a maximum value of 24 ˚C. This temperature rise needs to be considered in light of the potential use of seawater as cooling medium for both the power station as well as the storage of spent fuel.

We note that climate change has been considered in the Site Safety Report[106] and more recently in (many chapters of) the latest Site Safety Report. The design parameters are listed in the table below:

Table 13: Climate change parameters considered in design phase.

Parameter	Change	This Assessment
Sea level rise to 2100	+ 0.8 m	+ 1 m under RCP 8.5
Sea temperature	+ 3°C	Average expected increase of 2°C with a maximum expected value of 6°C
Wind speed	+ 10%	+10% based on limited data availability
Wave height	+ 17%	+17% based on limited data availability
Storm surge	+ 21% based on a 10% increase in wind speed	Insufficient data available to make an assessment

The recommended increase, as per the(2009 but now superseded) Eskom Nuclear Site Safety Reports, in design parameters to address the potential impacts of climate change is:

Table 14: Design parameters[107]

Parameter		Increase to 2050	Increase to 2100
Sea level rise	Mid-point of projections	+ 0.2 m	+ 0.4 m
	Upper end of projections	+ 0.4 m	+ 0.8 m
	Extreme upper limit	+ 1.0 m	+ 2.0 m
Wind speed		+ 5%	+10%
Storm surge (including shelf-waves, edge waves and meteo-tsunami)		+ 10%	+ 21%
Wave height		+ 8.5%	+ 17%
Seawater temperature		+ 1.5°C	+ 3°C

[106] Eskom Nuclear Sites Site Safety Reports Coastal Engineering Investigations Duynefontein (Report No. 1010/4/102), October 2009, Prestedge Retief Dresner Wijnberg (Pty) Ltd, Table 3.1.

[107] Eskom Nuclear Sites Site Safety Reports Coastal Engineering Investigations Duynefontein (Report No. 1010/4/102), October 2009, Prestedge Retief Dresner Wijnberg (Pty) Ltd, Table 2

We note that the design parameters for the power plant was taken as[108]:

- Maximum cooling water temperature: 30°C
- Minimum cooling water temperature: -0.4°C
- Extreme conditions for safety assessment: 34.5°C

We find that the provision for maximum cooling water temperature and extreme conditions for the safety assessment are adequate in terms of the data requirements as per this climate change impact assessment.

Broader Social Context

A socio-economic specialist study has been undertaken and this CCIA will therefore not provide details with respect to impacts on demographics, inequality, education, employment, household income or service delivery for the local municipality. However, it is noted that the following key points may be considered with respect to climate change and the broader local community:

- More frequent and intense weather events (e.g., coastal flooding, droughts, storm surges etc.) could directly impact human health (i.e., through heat-related illness, or chronic and vector-borne diseases etc.), and contribute to food and water insecurity in the region. Consequently, increased vulnerability and reducing the capacity to adapt to future climate changes.
- Tropical storms and cyclones seem to be moving further south and west over the Indian Ocean and Mozambique Channel. These storms require warm, subtropical waters to form and thus are not expected to occur on the west coast of South Africa due to its cold sea-surface temperatures. Hence, there is no risk to communities residing along South Africa's west coast due to its cold sea temperatures.
- Loss of biodiversity (e.g., fish, crustaceans, mangroves, estuaries etc.) could negatively affect tourism, resulting in the loss of tourism-related jobs, placing further economic strain on local communities.
- Loss of coastal vegetation and ecosystems may increase vulnerability to climate change impacts within the region and along coastlines, as they act as natural barriers to storm surges and floods.
- Households that rely on marine ecosystems for survival (e.g., fisherman) could become more vulnerable, as the impacts of climate change may alter or destroy marine environments (i.e., through increasing temperatures, storm surges, or altering of the ocean's chemistry). Biodiversity may therefore be lost and increase food insecurity within the region.

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[108] Eskom Nuclear Sites Site Safety Reports Coastal Engineering Investigations Duynefontein (Report No. 1010/4/102), October 2009, Prestedge Retief Dresner Wijnberg (Pty) Ltd, Section 5.6

- Change in sea levels is relatively insignificant and may not directly impact coastal communities, however, these changes increase the risks and impacts of storm surges and tropical cyclones (thereby increasing vulnerability to future climatic events).[109]

With respect to the demographic profile, women, children, people with disabilities, the aged, farm workers and rural residents are most vulnerable groups in the communities. In addition, challenges, such as disparities and poverty express themselves along racial and spatial lines. The impacts of climate change will exacerbate the vulnerability of such groups.

A high unemployment rate points to existing socio-economic vulnerabilities. High levels of poverty, low-income distribution and low education levels all contribute to vulnerability. Social vulnerability from climate change will result in further inequalities and reduced capacity to cope with climate shocks. Climate change will superimpose and compound on existing vulnerabilities. For example:

- Access to basic services such as water will become difficult.
- Climate change is likely to impact general comfort and quality of life for communities.
- Changes in rainfall and increases in the number of very hot days will place a burden on subsistence and commercial food production.
- The capacity to cope with climate variability and extreme weather events in itself is highly dependent on the level of economic development within the municipality.

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 is likely to be greater unrest, which at times may be aimed at the commercial operations in the region.

Broader Environmental Context

As part of the EIA, biodiversity and aquatic specialist studies were undertaken and this CCIA will therefore not provide details with respect to impacts on biodiversity within the ecosystems surrounding and within the Project area. It is however noted that the following key points may be considered with respect to climate change and the broader environmental context:

[109] Muis, S., Apecechea, M.I., Dullaart, J., de Lima Rego, J., Madsen, K.S., Su, J., Yan, K. and Verlaan, M. 2020. A high-resolution global dataset of extreme sea levels, tides, and storm surges, including future projections. *Frontiers in Marine Science* 7: 263.

- Climate change will affect terrestrial and marine natural ecosystems, reducing their ability to withstand impacts. This would increase the loss of biodiversity in the region as these environments play a crucial role in supporting both marine and terrestrial life.
- Wetlands have important regulatory functions in that they moderate floods. They allow for attenuation of flood peaks thus reducing the risks to people and infrastructure and improves water quality though filtration and detoxification. In addition, it plays an important role in mitigation and adaptation to climate change, by reducing carbon emissions through carbon sequestration. However, climate change will negatively impact wetlands and their ability to provide essential services.[110] Day (2015)[111] stated that coastal wetlands would likely become more saline which has implications for biodiversity in these wetlands.

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. These systems play a vital role in moderating floods 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 conversion. For the Duynefontein area this risk is low to medium as there is some area being converted within the site Project boundary. Any conversion that does occur, creates more fragmented and smaller areas of natural habitat. This places strain on many species which may need to migrate or shift their distribution in order to remain within their climatic tolerance threshold. The proposed Project falls within the Fynbos biome, which is predicted to shift under climate change; ecosystem species composition and structure in some areas are likely to change significantly. This could result in biodiversity loss and reduce the ability of ecosystems to provide ecosystem services and benefits to people in the region. This is relevant for large parts of the surrounding environment, which are classified as critically endangered owing to the low levels of statutory conservation in these ecosystem types and high levels of historic conversion to crops and built-up land. There is very little that can be done to ameliorate these impacts and adaptation within the biodiversity and ecosystems sector should follow the latest available guidance. This should not fall under the responsibility of Eskom, however, where possible, land surrounding the Power Station should be managed to ensure as little conversion of habitat as possible. Opportunities for area-based conservation (e.g., Koeberg Nature Reserve) should be

[110] Le Grange, L. 2018. Regional Spatial Development Framework for Saldanha Bay Municipality: Pursuing a more Ecologically Integrated Future. Meng, University of Cape Town.

[111] Day, L. 2015. Environmental Impact Assessment for the Proposed Nuclear Power Station ("Nuclear-1") And Associated Infrastructure. Wetland Ecosystems Specialist Study Impact Assessment Phase. Prepared by Freshwater Consulting Group for Arcus GIBB Pty Ltd.

considered and aligned to national and provincial spatial planning mechanisms if opportunities exist.

Project Vulnerability Assessment Matrix

The vulnerability of the project to different physical risks associated with projected climate change was determined using the framework outlined in section 0, using a conservation, near worst-case scenario. The assessment is shown in Figure 23. The assessment is based on a timeline up to 2050. The risks of a) rainfall changes and rainfall intensity; and b) storms, are both difficult to predict being stochastic in nature and both with inherent uncertainty in future projections for these. Rainfall events can also vary significantly in their intensity and impacts. Mitigating these will depend largely on the adaptive capacity of the project and its proponent.

Water stress and potential drought (as indicated by consecutive dry day increases) is one of the most likely impacts. It has been ranked as 3/6 in terms of impact as sufficient water supply is necessary for operations. No weather-related impacts are classified as high or very high in terms of their impact/s on the vulnerability on the proposed project.

The unique impact of increasing sea surface temperatures is also considered to have a moderate impact with a very likely chance of happening. This has implications for the cooling of the power station both in the operational phase and in the storage of spent fuel, as sea water is used for cooling in the power plant. We understand that South Africa does not have a nuclear waste disposal facility that is licensed to accept spent fuel. As such, this assessment is based on the assumption that the spent fuel will be kept on site for a period of 100 years. Increases in sea surface temperature over this period of time could impact on the performance of the cooling system for the spent fuel storage.

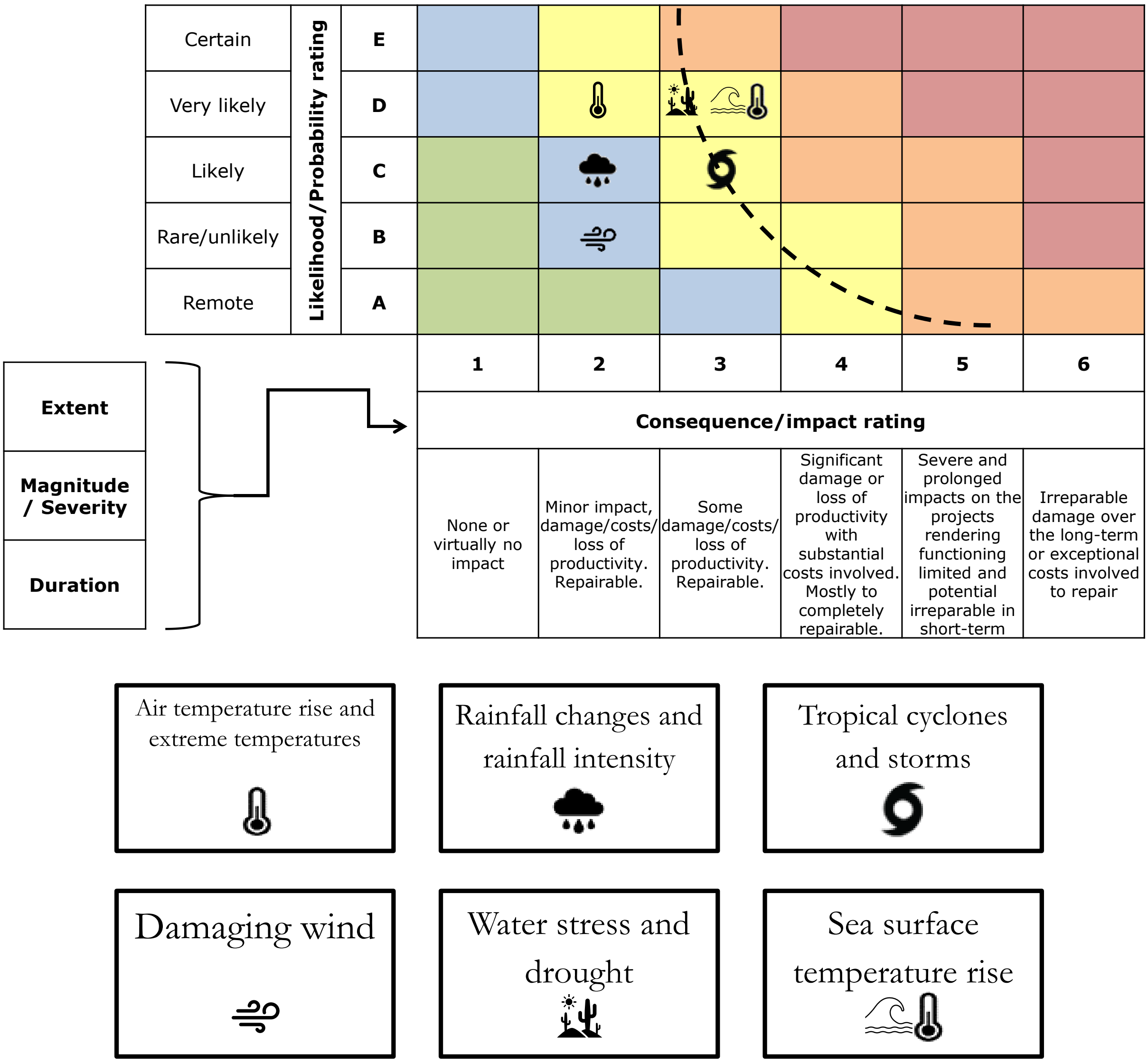

Figure 23: Climate Change vulnerability assessment for proposed Duynefontein Nuclear Power Station.

5. Project Mitigation and Adaptation Recommendations

The interventions recommended in this section are offered as non-binding proposals that Eskom could consider to limit the climate change impacts of, and on the project and site as a whole. If there are any conflicting recommendations, Eskom should defer to design measures recommended in the most recent and extremely comprehensive SSRs.

5.1. Measures to Reduce the Impact of the Project on Climate Change (Mitigation Measures, non-binding)

The assessment of potential mitigation measures concerning climate change for the Project should be considered within the broader context of its various components.

Implementing measures that reduce emissions may not have a significant impact on the project's overall contribution to climate change. Nevertheless, certain measures within each component can be considered based on projected climate changes *and are likely to reduce the project's overall ecological footprint and demand for resources*. These include:

- **Building and Infrastructure Design:** The project should incorporate sustainable building principles, utilising sustainable materials with lower carbon footprints during the design and construction phase.
- **Energy Efficiency:** Implement energy-saving measures to reduce electricity consumption. Examples include installing LED lighting, motion sensors, and energy-efficient Heating, ventilation, and air conditioning systems.
- **GHG Emissions Monitoring:** Implement an annual GHG inventory to monitor all emissions, covering both direct and indirect sources (including infrastructure, fuel-related emissions, and other material sources). The scope of this inventory should go beyond legislative requirements, which typically only monitor direct emissions from stationary sources.

In order to make a significant change to the proposed project's impact on climate change, particularly the emissions related to the project, measures may be implemented across the value chain.

5.2. Measures to Increase the Climate Change Resilience of the Project (Adaptation Measures)

Although some of the climate change risks are considered low, there is significant uncertainty in how climate change impacts may manifest and impact the infrastructure and operations of the proposed new nuclear power station. In order to reduce vulnerability and ensure greater resilience to climate shocks and challenges, several adaptation measures are recommended. These are for both the construction phase and the operational phases of the project, in anticipation of future climate change impacts.

Measures to reduce the impact of heat stress under projected warmer conditions

In light of anticipated increases in temperatures and extreme hot days, it is advised to implement adaptive measures for the buildings and infrastructure within the Project. The following adaptation strategies are recommended:

- **Efficient Cooling Systems:** Cooling systems for both power generation and operational buildings should be designed to effectively handle higher temperatures. This may involve optimising cooling technologies and enhancing heat dissipation capabilities to ensure optimal functioning under elevated temperature conditions.

- **Insulation:** It is recommended to incorporate appropriate insulation measures in operational buildings to mitigate the impact of extreme temperatures on workers. Adequate insulation can help maintain a comfortable working environment by reducing heat transfer between the interior and exterior spaces.
- **Backup Power:** Sufficient backup power capacity is essential to ensure the continuous operation of cooling systems for both power generation and operational buildings during power outages. Reliable backup power sources should be available to maintain the necessary cooling capacity and prevent any potential disruptions due to grid failures.

By implementing these adaptation measures, the Project can enhance its resilience to increased temperatures and extreme hot days, thereby safeguarding the efficient operation of cooling systems and maintaining suitable working conditions for personnel.

Storm activity and storm surge adaptation measures

To adapt to the projected increase in coastal storm activity, rainfall and flooding, it is advisable for the Project to consider the following adaptation measures aimed at protecting infrastructure:

- **Drainage Systems:** Robust and efficient drainage systems are crucial to handle increased precipitation from flooding events. These systems should be designed to effectively channel excess water away from critical areas of the power station, such as equipment and infrastructure, to prevent flooding and water damage.
- **Flood Protection Measures:** Implementing flood protection measures is essential to safeguard the power station against potential inundation during periods of heavy rainfall. This can involve constructing flood barriers, levees, or embankments to prevent water from entering sensitive areas of the facility. Setback lines should be adhered to as these are helpful in reducing the risk posed by climate change.[112] Coastline retreat as a result of higher sea level and from increased storm surges under climate may result in new sandy beaches and dune movement. This can be mitigated by "monitoring dunes and repairing blowouts by placing brushwood or using drift fences on the bare sand surfaces, and then re-vegetating the bare sand with suitable pioneer species," as recommended by Illenberger & Associates (2010).[113]
- **Stormwater Management:** Effective stormwater management techniques, such as retention ponds, can help control and regulate the flow of excess precipitation. These

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112 Coastec. 2015. Environmental Impact Assessment for the Proposed Nuclear Power Station ("Nuclear-1") And Associated Infrastructure. Botanical and Dune Ecology Impact Assessment. Prepared by Coastec: Coastal and Environmental Consultants for Arcus GIBB Pty Ltd.

113 Illenberger & Associates. 2010. Environmental Impact Assessment for the Proposed Nuclear Power Station ("Nuclear-1") And Associated Infrastructure: Dune Geomorphology Environmental Impact Report. Prepared by Illenberger & Associates for Arcus GIBB Pty Ltd.

systems can temporarily store and gradually release rainwater to prevent overwhelming drainage systems and reduce the risk of flooding.

Sea surface temperature

To adapt to the likely warming sea surface temperature near the proposed Project location and its impacts on cooling nuclear waste, the project must seriously consider the following from an engineering and design perspective:

- Design the seawater cooling systems for the operation of the power plant for a maximum seawater temperature of 24°C, as indicated in Figure 20.
- Design the seawater cooling systems for the spent fuel storage for a maximum seawater temperature of 24°C, as indicated in Figure 20.

Site policy related recommendations

Climate-related risks should form part of standard risk assessment procedures and should be updated regularly, with the assistance of a specialist, if necessary. As part of the health and safety procedures of the Project once operational, it is recommended that links to early warning systems are in place (i.e., information from service providers such as the South Africa Weather Service can be accessed), and emergency response plans for extreme weather events are developed, for planning purposes. This is to reduce potential damage and ensure unaffected continuity of operations as far as possible.

6. Opinion of the Project

The assessment of the climate change impact of this project has been done on the impact of the project on climate change, the resilience of the project to climate change, as well as the options for mitigation of the impacts. The measures listed in Section 5 above are recommended, as these are likely to reduce climate change vulnerability and increase resilience in respect of the project.

The impact of the project on climate change was assessed in the context of both GHG emissions from the project, as well as the potential positive impact the project will have for the transition to a low-carbon economy.

The project will emit 570 000 tCO_2e during the construction phase. The indirect emissions associated with the uranium fuel cycle will contribute 470 000 tCO_2e/year in the operational phase. The nuclear power plant can be beneficial in reducing emissions by displacing electricity generation from coal-fired power stations. This displacement can lead to a significant reduction in emissions, which can be viewed as a favourable environmental impact. Moreover, the nuclear power plant can also facilitate the integration of renewable energy sources by ensuring a continuous baseload power supply to the grid. This support for renewables further amplifies the project's positive environmental contribution.

The only climate change impact identified as a potential risk relates to the use of cooling water in the reactor cooling and the spent fuel storage system. We recommend that the design for the cooling systems take the historic and projected increases in sea surface temperature into account, and that the systems be designed for a maximum sea water inlet temperature of 24°C.

In accordance with the findings of this CCIA, we advise that the proposed Duynefontein Nuclear Power Station (as part of the Nuclear-1 Project) should not be refused environmental authorisation based on climate change related issues.