BOSA Transmission Interconnection Project

Final Climate Change Report

SAPP

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Bringing ideas to life

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1 Introduction

1.1 Background

Aurecon has been appointed to undertake an Environmental and Social Impact Assessment (ESIA) study to assess and address environmental and social impacts associated with Botswana-South Africa (BOSA) Transmission Interconnection Project. A Climate Change Study is required to inform the ESIA of the potential impacts posed by the construction and operational activities of the proposed project.

Due to the growing demand for electricity in both South Africa and Botswana, the Southern African Power Pool (SAPP CC) has initiated the BOSA Transmission Interconnection Project on behalf of Eskom of South Africa and Botswana Power Corporation (BPC) of Botswana. The interconnector infrastructure components consist of two 400kV transmission power lines approximately 210 km in length and 60 m apart, connecting the existing Isang 400kV substation in Botswana to the Watershed B area North of Mahikeng (formerly known as Mafikeng) in South Africa Figure 1.

The climate analysis and risk screening conducted as part of this report will serve to provide a greater understanding of the climate change risks faced by the proposed transmission line. The ultimate goal of the report is to facilitate the consideration of climate change vulnerability and likely impacts at the project level during the project planning and design.

1.2 Energy Sector

Energy plays a central role in the economy and is key to achieving various national strategic objectives. On a national level, this sector is overseen by the National Department of Energy. While obtaining their primary mandate from the White Paper on Energy Policy of 1998 and National Energy Act, 2008 (Act No. 34 of 2008), a range of supplementary energy policies have been developed and implemented in the recent past which includes:

- The Renewable Energy White Paper (2003)
- The Integrated Energy Plan (IEP);
- The National Energy Efficiency Strategy (NEES)
- The National Energy Efficiency Action Plan (NEEAP);
- The National Energy Act (Act No. 34 of 2008);
- The Electricity Regulation Act (Act No. 4 of 2006), Second Amendment (2011);
- The Amendment to the Electricity Regulations on new generation capacity (18 August 2015).

Arguably the most significant of these is the IEP, which is currently under development and will guide an integrated approach to energy planning on national level aimed at optimising the energy system.

It is clear that the projected impacts of climate change will be increasingly experienced in the years to come, with significant consequences for the electricity sector (Figure 2). Addressing climate change risks and guaranteeing a consistent supply of electricity will require authorities to address potential design thresholds of electricity infrastructure and, to a lesser degree, current levels of carbon emissions related fossil fuel based power generation.

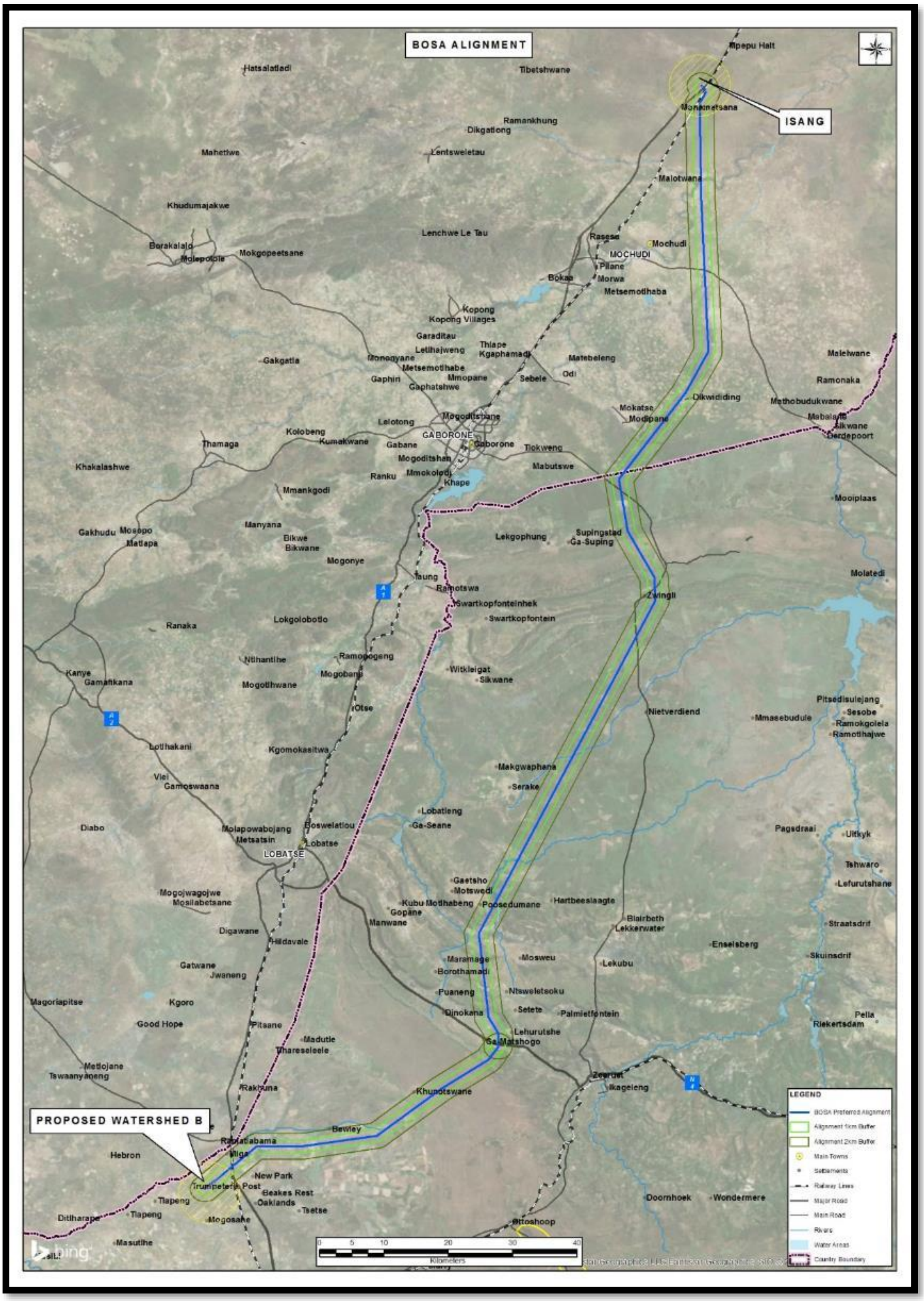

Figure 1. Locality map

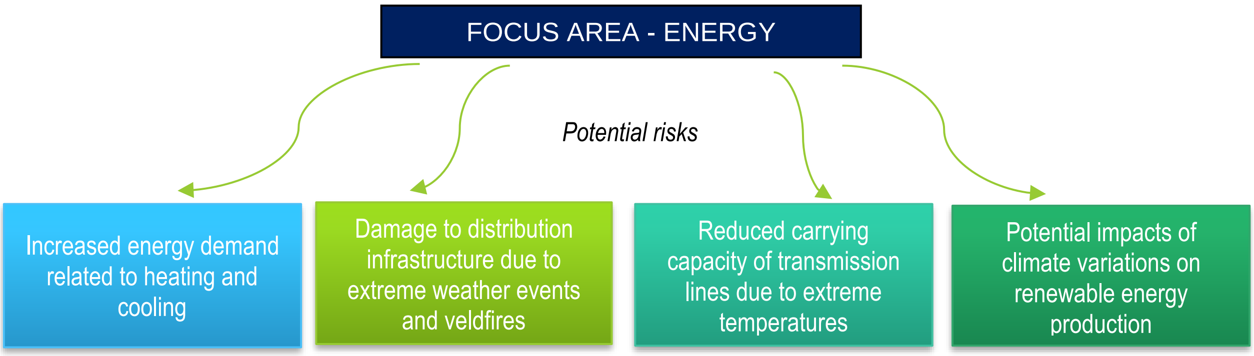

Figure 2. Climate change potential risks within the energy sector

There is a need to differentiate between direct and indirect impacts with regards to potential climate change impacts on the energy sector as a whole.

Direct impacts will affect

- Energy resource availability
- Power production

Indirect impacts include

- Competition for shared resources
- Altered supply and demand trends

Direct impacts are generally more visible but the costs of indirect impacts may exceed direct losses in the long run. Even with current national policies favouring energy efficiency and renewable energy, energy demands are expected to continue increasing. Along with the expected demand for energy, price increases are also anticipated. A variety of climate change variables are expected to increase energy demands as heating and/or cooling requirements change, compounding the existing pressures on electricity supplies and infrastructure.

1.3 Information Gaps

The scope of the study does not allow for the comprehensive analysis of specific upstream, downstream or operational impacts. In light of this it is recommended that the following information gaps be addressed to provide a more comprehensive picture of climate change impacts and their implications at a project level.

- Detailed assessment of reduced carrying capacity efficiency under future climate scenarios;
- Comprehensive fire risk assessment surrounding areas; and
- Life Cycle Analysis to determine carbon footprint of the project.

2 Climate Change Analysis

2.1 General

The climate system is a balance of varying thermal, pressure and moisture characteristics of the atmosphere and ocean. Insolation travels through the atmosphere, largely unobstructed and warms the earth and ocean surface. The heat is re-radiated upwards in the form of long wave terrestrial radiation to the atmosphere. Fossil fuel emission increases through development from pre-industrial levels have resulted in increased levels of greenhouse gasses (GHG) resident in the atmosphere. The fossil fuel emissions trapped in the atmosphere strongly absorb the longer infrared wave lengths of terrestrial radiation, particularly CO_2, N_2O and water vapour. The absorbed heat is re-emitted in all directions, including back down to earth, where it is re-absorbed by the earth surface and re-emitted again, therefore keeping the heat in the system. These gases are found naturally in the atmosphere and make the planet warm enough for humans to survive. However the additional CO_2 and N_2O have increased at a rate beyond what the atmosphere and the carbon system can recycle, such that what has been emitted has increased the heat absorption of the atmosphere.

Temperature differentials and balancing of the thermodynamic gradient in the atmosphere are the driving forces behind global short term weather as well as long term climate. Therefore the change noted already in the baseline temperature will have dramatic effects in all aspects of the meteorological system. The temperature change alters the global pressure systems which in turn impacts air circulation, winds, atmospheric moisture, ocean currents and rainfall distributions. As this is an open system not limited by country boundaries, the non-polluter suffers with (sometimes more than) the polluter. Simply put, this is causing the increase in temperatures globally and the changes to the short term meteorology and the subsequent climate base lines. The changes experienced are not uniform in space and time. There is both spatial and temporal variation in the impacts associated with climate change.

2.2 Background

Climate is defined as the overarching generalised long term set of atmospheric, ocean and land cover conditions that provide the bounding context for the occurrence and likelihood of meteorological events experienced within a localised area. As such, considering the likely climate changes at a local scale will prove ineffectual. The preferred approach entails the assessment of the general large scale climate change projections as the anomaly baseline. From this large scale anomaly the climate assessment should then account for the factors influencing local weather variability such as topography, land use, synoptic influences and ocean currents, and how the large scale change may be manifest on a more specific footprint scale. The data used for the analysis of the climate parameters such as heat waves or changed precipitation profiles is downscaled from the IPCC AR5 models to an approximately 45 km x 45 km grid while additional spatial resolution is garnered from the SimClim data[1] which takes into account the locally influencing climatic factors to a scale of 5 km x 5 km.

Adaptive response must be undertaken in accordance with the projected changing climate parameters. This chapter presents an overview of the meteorological climate changes that are likely to

[1] Warrick, R. (2009). From CLIMPACTS to SimCLIM: development of an integrated assessment model system. In: Integrated Regional Assessment of Global Climate Change. Editors: C. Gregory Knight, Jill Jager. Cambridge University Press. Pgs. 280-311.

occur over the study area over the next four decades. The modelling is done with the aim of informing the decision-making processes.

The scale of the future climate impacts will vary based on the anthropogenic mitigation of factors responsible for currently experienced changes. The mitigation scenarios account for several variances of potential global economic and environmental development and are quantified as the Representative Concentration Pathways (RCP). The four RCP scenarios depicted in Table 1 are estimated concentrations of CO_2, CH_4 and N_2O based on a combination of assessment models (MESSAGE[2], AIM[3], GCAM[4], IMAGE[5]), global carbon cycle, and atmospheric chemistry and climate models. They also integrate assumed land use changes and sector-based emissions of greenhouse gasses from present day levels. These present GHGs include the sectoral assessment of energy supply, industry, transport, and buildings with contributions of 47%, 30%, 11% and 3% respectively.[6]

Table 1 Representative Concentration Pathways

	CO_2 (ppm)	CH_4 and N_2O (ppm)	Resulting radiative forcing ($W.m^{-2}$)	Scenario
RCP 2.6	421	54	2.6	Best case
RCP 4.5	538	92	4.5	Best case - Medium scenario
RCP 6.0	670	130	6.0	Worst case - Medium scenario
RCP 8.5	936	377	8.5	Worst case

These RCPs were used as input for the coupled model ensembles of the IPCC Assessment Report Five [7](AR5).These RCPs show the change from pre-industrial insolation watts per m^2 resulting from the emissions. RCP 2.6 represents the mitigation scenario leading to a very low forcing level – best case – emissions stabilise from 2010 – 2020 and decrease thereafter (best case scenario with global focus on environmentally sustainable practices). RCP 4.5 – likely best case – emissions stabilise from 2040 and decrease thereafter. RCP 6.0 – likely worst case – emission stabilise from 2080 and decrease thereafter. RCP 8.5 represents the very high GHG emission scenario – emissions don't stabilise, worst case scenario with a focus on economic advancement at the expense of environmental sustainability.

[2] Riahi, K. Gruebler, A. and Nakicenovic N. 2007. Scenarios of long-term socio-economic and environmental development under climate stabilization. Technological Forecasting and Social Change 74, 7, 887-935. Available at http://dx.doi.org/10.1016/j.techfore.2006.05.026.
[3] Hijioka, Y., Y. Matsuoka, H. Nishimoto, M. Masui, and M. Kainuma, 2008. Global GHG emissions scenarios under GHG concentration stabilization targets. Journal of Global Environmental Engineering 13, 97-108.
[4] Wise, MA, KV Calvin, AM Thomson, LE Clarke, B Bond-Lamberty, RD Sands, SJ Smith, AC Janetos, JA Edmonds. 2009. Implications of Limiting CO2 Concentrations for Land Use and Energy. Science. 324:1183-1186.
[5] van Vuuren, D., M. den Elzen, P. Lucas, B. Eickhout, B. Strengers, B. van Ruijven, S. Wonink, R. van Houdt, 2007. Stabilizing greenhouse gas concentrations at low levels: an assessment of reduction strategies and costs. Climatic Change. Available at http://dx.doi.org/10.1007/s10584-006-9172-9.
[6] IPCC, 2014: Summary for Policymakers. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
[7] IPCC, 2014: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1132 pp.

These emission scenarios give light to the varying potential climatic futures based on human development goals in the present and near future.

Using climate projection data requires the acknowledgement of various uncertainties. The IPCC projections rely on forty different GCMs with different accuracies forecasting to the varying RCP scenarios. These RCPs are themselves estimates of potential future thermal forcings, as informed by adherence to emission policies and potential future technologies. The downscaling of the IPCC data required robust constraining parameters to present a more accurate local projection. In areas where observational data is limited, these constraining parameters have increased uncertainty. Results obtained and recommendations made based on these data should be used as a guideline to adapt/mitigate to a potential future climate rather than a definitive one. This is particularly prevalent when noting the significant disparity even in the current variability of rainfall regimes. This is influenced by things like topography, wind, vegetation and even ocean currents. Beyond that, a further layer of complexity is added with looking at rainfall intensity, diurnal and seasonal onsets before accounting for short and long term influences such as the diurnal, seasonal, inter annual cycles, the ENSO cycles as well as decadal changes. When projecting precipitation changes into a semi unknown future these uncertainties are further exacerbated.

The projection parameters are therefore presented in terms of a probability of changes highlighting the most likely range of precipitation experienced in the future. The probabilities also allow for the possibility of more extreme anomalous occurrence of events in both directions i.e. probability of more extreme rainfall days as well as less extreme rainfall days. Statistical probability analysis of the climate data is undertaken on the variables of maximum temperature, minimum temperature, precipitation, among others.

The observational data sets used include:

- SimClim IPCC historical downscaled data 5x5 km spatial resolution monthly temporal resolution from the year 1995 to 2015.
- Swedish Meteorological and Hydrological Institute – SMHI Cordex CMIP5 historical experiments at 0.5°x0.5° spatial resolution and daily temporal resolution from the year 1951 to 2005

The projected datasets used include**:**

- SimClim IPCC AR5 downscaled data 5x5 km spatial resolution monthly temporal resolution from the year 2015 to 2100.
- Swedish Meteorological and Hydrological Institute – SMHI Cordex CMIP5 IPCC AR5 projected experiments at 0.5°x0.5° spatial resolution and daily temporal resolution from the year 2006 to 2100 for the 9 IPCC climate models used in AR5.

There is currently a dearth of locally sourced climate change data available. Organisations such South African Weather Services (SAWS) are in the process of building a climate data portal to address this shortfall, yet the model data they will be sourcing is the SMHI cordex data utilised in this study. Research institutions such as the Climate Systems Analysis Group (CSAG) based at the University of Cape Town are the African leaders of the CORDEX simulations and have a Climate Information Portal presenting the climate information along with an interpretive description to better convey understanding. While their downscaling methodologies are unique and account for local scale climate factors, the underlying model data utilised is that of the IPCC suite of models. There does not currently exist a Southern African developed climate model that is able to simulate the coupled global atmosphere ocean relationship to the extent to which existing international GCMs are able.

2.2.1 Natural vs Anthropogenic Climate changes

It must be acknowledged that there are natural cycles that will change the climate over time. However the long term impacts and earth's capacity for system reversibility of natural versus anthropogenic climate changes vary significantly.

Long term natural changes include cosmic influences such as Magnetic field changes (averaging 450 000 years, impacting UV filtering) and the Milankovitch cycles; Eccentricity, Axial tilt and Axial precession. These changes act on the order of 125 000, 41 000 and 26 000 years respectively and will alter the ice age onset and retreat. Terrestrial influences include carbon cycling which changes on the order of seconds to minutes (photosynthesis), in terms of years, decades and centuries (decay and release of organics), and thousands to millions of years (formation of natural gas, oil and coal), which impacts atmospheric CO_2 presence and subsequently the global greenhouse effect. Changes in the Oceanic thermohaline circulation occurs in the order of thousands of years and normally require a triggering event to have any lasting consequence[8] such as alterations to ocean global heat transport.

Short term natural changes include the land surface change such as natural desertification or vegetation migration. This will have a variable time frame of change but can be as quick as a few years in extreme scenarios, these changes impact surface reflectivity and moisture uptake in plants. Solar activity changes in the order of approximately 11 year time scales impacting the amount of incoming solar radiation. Other events include earthquakes, ice melt events, and volcanoes which can very quickly alter the land surface vegetation, albedo and atmospheric composition resulting in rapid but often short lived climate changes.

Natural climate change processes are unavoidable but the most significant climate drivers act over extremely long time frames (several thousand years or more). The changes are also cyclical in nature and therefore the impacts oscillate about the mean climate over time and do not depict irreversible trends long term.

Anthropogenic climate change (introduction of fossil fuels to the atmosphere and land surface changes) is the altering of the climate system at a rate and with a persistence that is not observed in the natural system. This climate change presents long term trends with no oscillation (return to normal state over time). The impacts of anthropogenic climate change is altering ecosystems and sensitive environments beyond the normal thresholds and transforming areas into an irreversible state. This climate analysis and strategy focuses on anthropogenic climate changes.

2.2.2 Climate change in the Southern African context

Climate change in South Africa shows projected rainfall variations (Figure 3) with a distinct gradient of increasing to decreasing precipitation going east to west over the continent. The increase in precipitation over Kwa-Zulu Natal and the north eastern parts of the Eastern Cape is caused partially by the enhanced evaporation from the warm Agulhas current and orographic influence of the Drakensberg mountain range. The areas of Northern Cape and Western Cape and further north will experience less rainfall. There is a marked increase in day time temperatures (Figure 3) with the most major change toward the inland regions of the continent. Temperature increases are still present in areas closer to the coast but are reduced by the mitigating influence of the large bodies of water.

[8] Younger Dryas, influx of fresh water into the gulf stream due to melting glaciers in North America inhibiting subduction of water in the north Atlantic causing a short lived ice age in Europe.

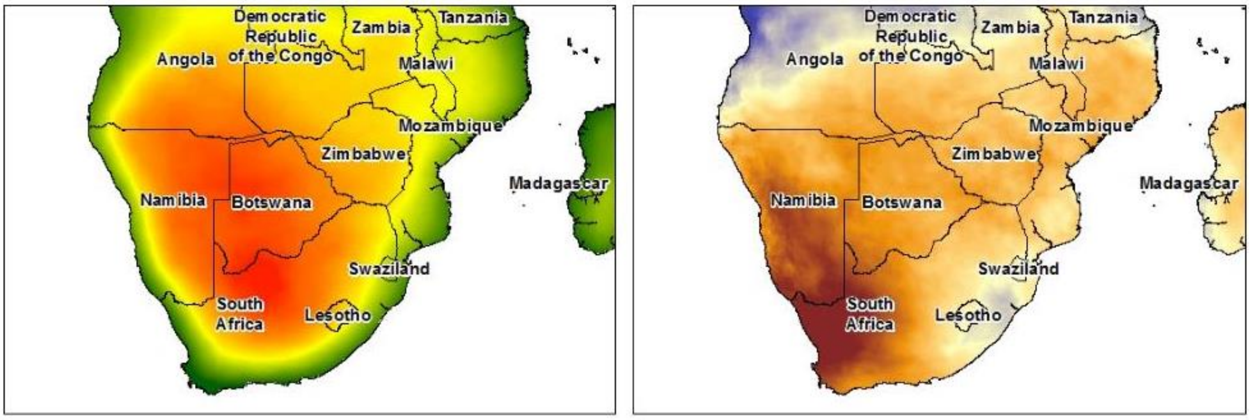

Figure 3: Spatial anomaly pattern. RCP4.5 2050 anomaly from climate baseline. Left: day temperature; darker red (warmer). Right: precipitation; more rain (blue), less rain (brown).

These large scale changes will have dramatic influences on varying meteorological parameters. It is projected that there will be an increase in the number of days exhibiting extreme day time temperatures; as well as the number and duration of heat wave events. Furthermore, a greater number of warm nights will increase general discomfort, reduce overnight frost and morning dew.

The rainfall parameters are more complex but there is general agreement that in areas where either increasing or decreasing rainfall volumes are expected, rainfall will be focused into a shorter timeframe. Some areas are exhibiting a shifting in the rainfall onset and cession timing. The rain season is decreasing in length; in the frontal areas of the western and southern areas of the country, winter rainfall is compressed and the dry summer is extended; to the east and north, the convective rainfall is clustered into fewer summer months and the shoulder seasons of autumn and spring exhibit more summer-like temperatures and reduced rainfall. While it is generally expected that there will be a decrease in the number of rainfall days each year, it's highly likely that there will be an increase in precipitation intensity and the occurrence of more extreme events when it does rain. This is particularly true in the summer convective rainfall areas. There will also be an increase in dry spell duration between rainfall events.

2.3 Climate status quo

The study area is classified generally as an arid desert environment and specifically as a hot semi-arid climate (BSh) according to the generalised Köppen climate classification[9]. This environment is categorised as having low precipitation and long dry spells as well as very high temperatures, see Figure 4.

[9] Peel, M.C., Finlayson, B.L., McMahon, T.A., Updated world map of the Koppen-Geiger climate classification, Hydrol. Earth Syst. Sci., 11, 1633–1644, 2007.

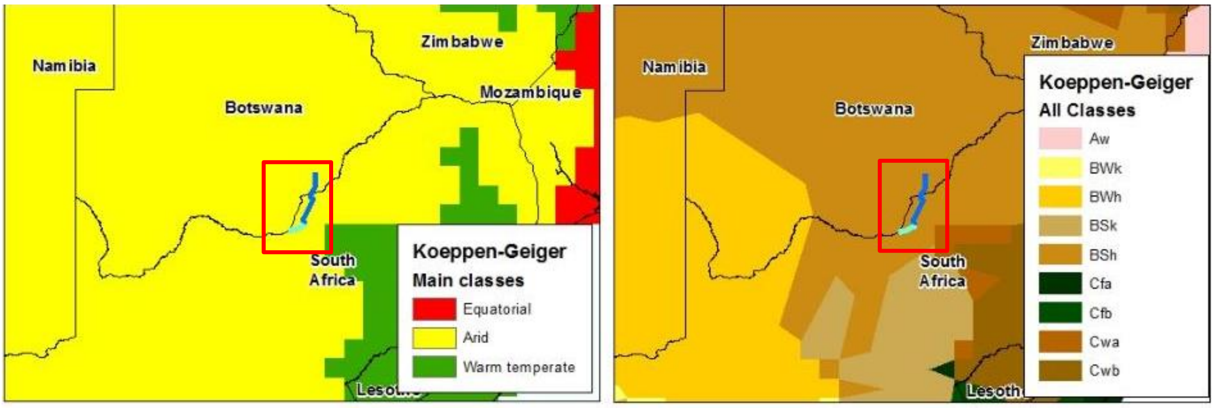

Figure 4: Köppen climate classification – study site

2.3.1 Observed Precipitation

The average annual historical rainfall for the study area is between 460 and 500 mm which is focused more to the south east within the late summer months, corresponding to the peak average temperatures[10] (Figure 5). At 25.0°S, the area is too close to the equator to be significantly affected by the wintertime mid-latitude cyclones that bring precipitation to the African west coast further to the south. It is also are enough away from the ocean to experience the mitigating effects of the large water mass.

The precipitation regime is influenced on a synoptic scale by the movement of the ITCZ (Inter-Tropical Convergence Zone) and localised topographical influences in the south western. The austral (southern hemisphere) summer brings the ITCZ further south and is located just to the north of Namibia/Botswana. The ITCZ is an area of converging convective activity and is associated with enhanced rainfall, often as very intense but short-lived rainfall events.

[10] World Bank Group, Climate change knowledge portal. [Online] Available at: http://sdwebx.worldbank.org/climateportal/index.cfm?page=downscaled_data_download&menu=historical

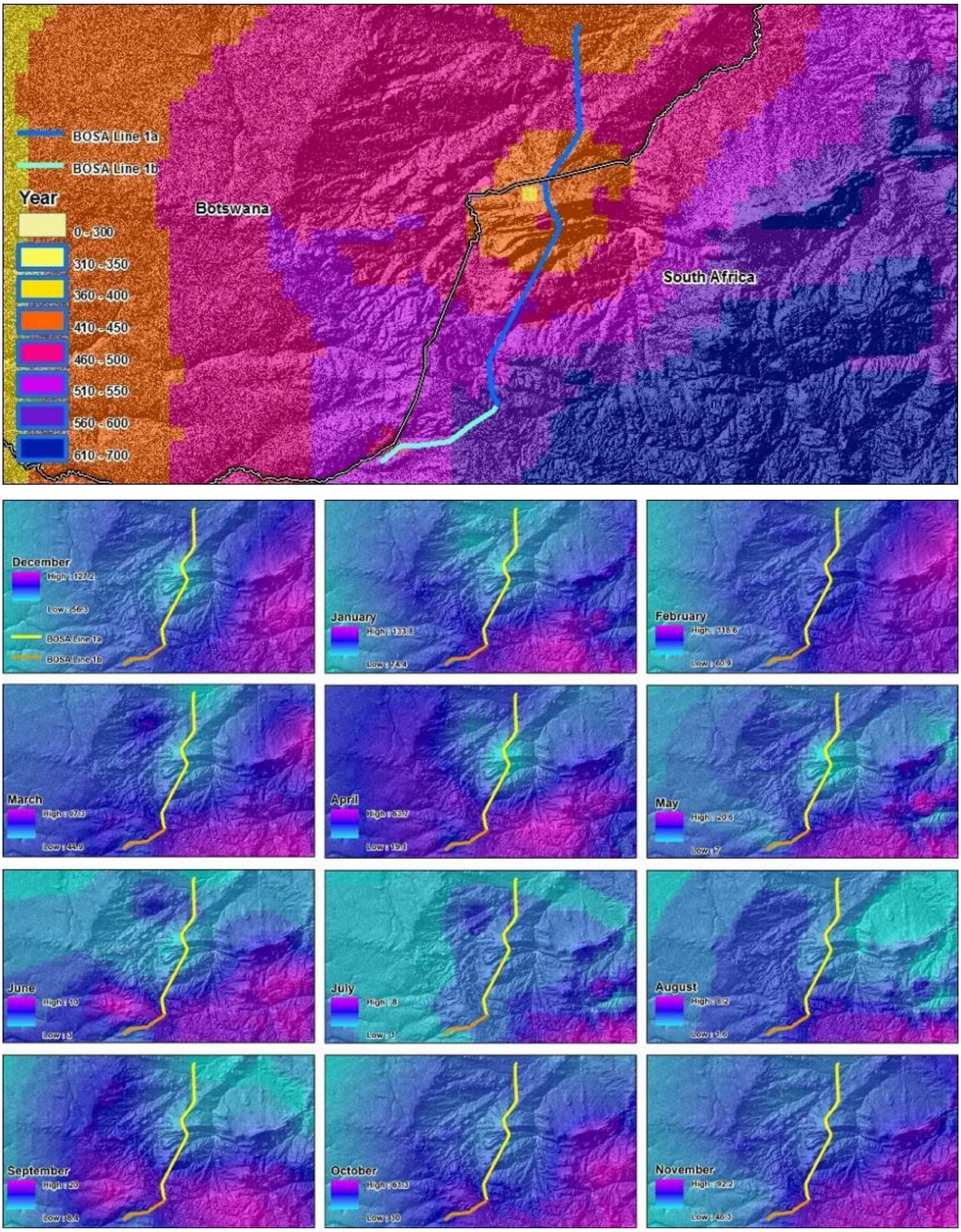

Figure 5: Annual average precipitation (top), monthly precipitation (bottom)

2.3.2 Observed Temperature

Day time temperatures peak in the northern areas of South Africa and in Botswana in summer. There is little heat retentive capacity and there is thus a significant diurnal range (day and night cycles). In areas further inland and away from large water bodies, there is little mitigation influence in the temperature. Areas further to the north are subject to a more orthogonal insolation (sunlight at 90 degrees to the earth surface) and therefore experience greater warming than areas further from the equator to the south (see Figure 6). The warmest temperatures are noted from October through to March with temperatures in the low 30's.

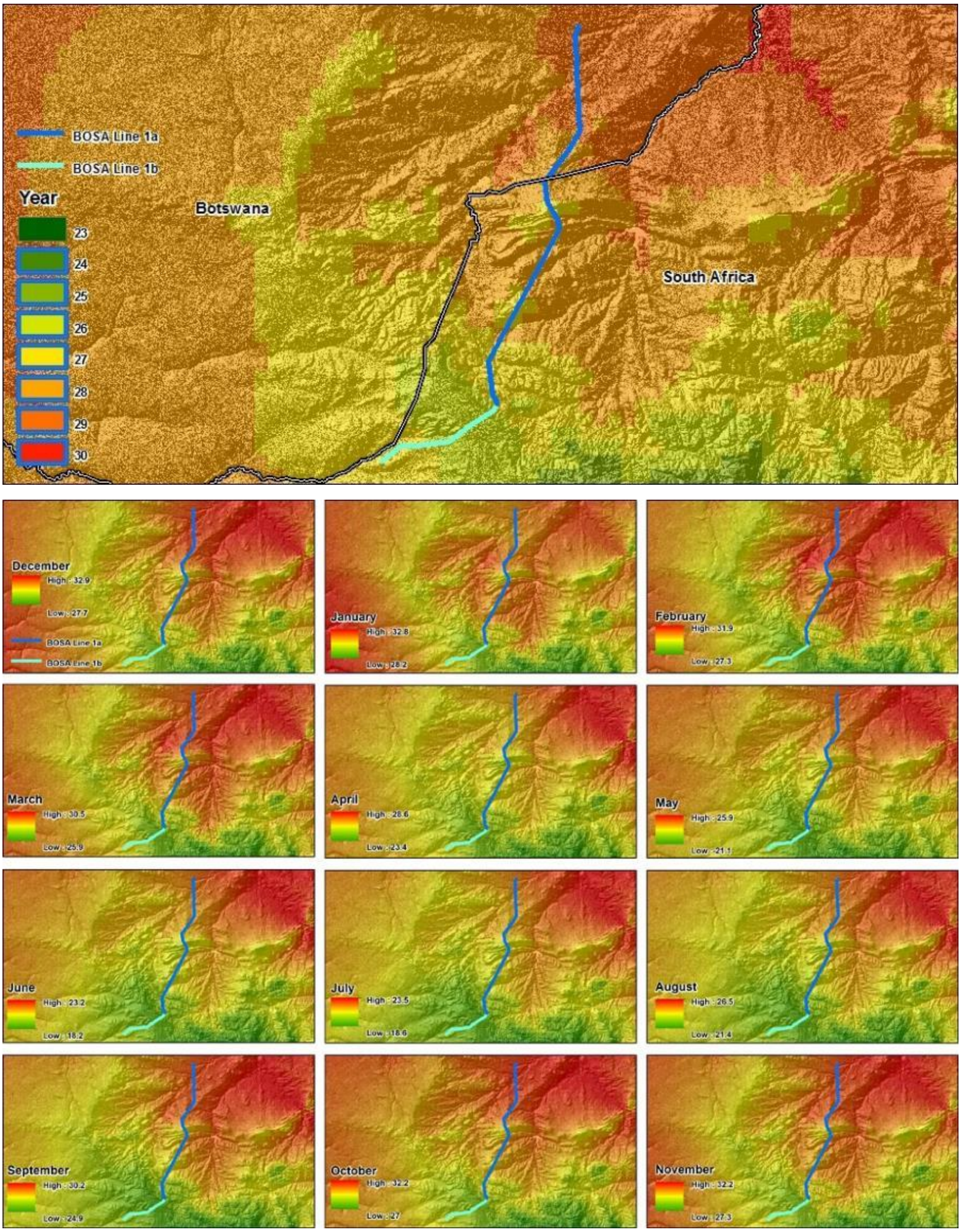

Figure 6: Annual average day time temperature (top), monthly maximum temperatures (bottom)

2.5 Projected changes

The climate can be categorised into two distinct climate zones based on topographical influences present (Figure 7). These are northern and flat, southern and mountainous.

- The northern climatology is influenced by large homogenous landscape. There is little thermal mitigation and these areas will get very warm during the day but by to the lowered heat retention, should be cooler at night.
- The southern climate zone is categorised by the increased in elevation. This will decrease general temperatures and night time temperatures. There is also an increase in precipitation in the more southern areas compared to the northern.

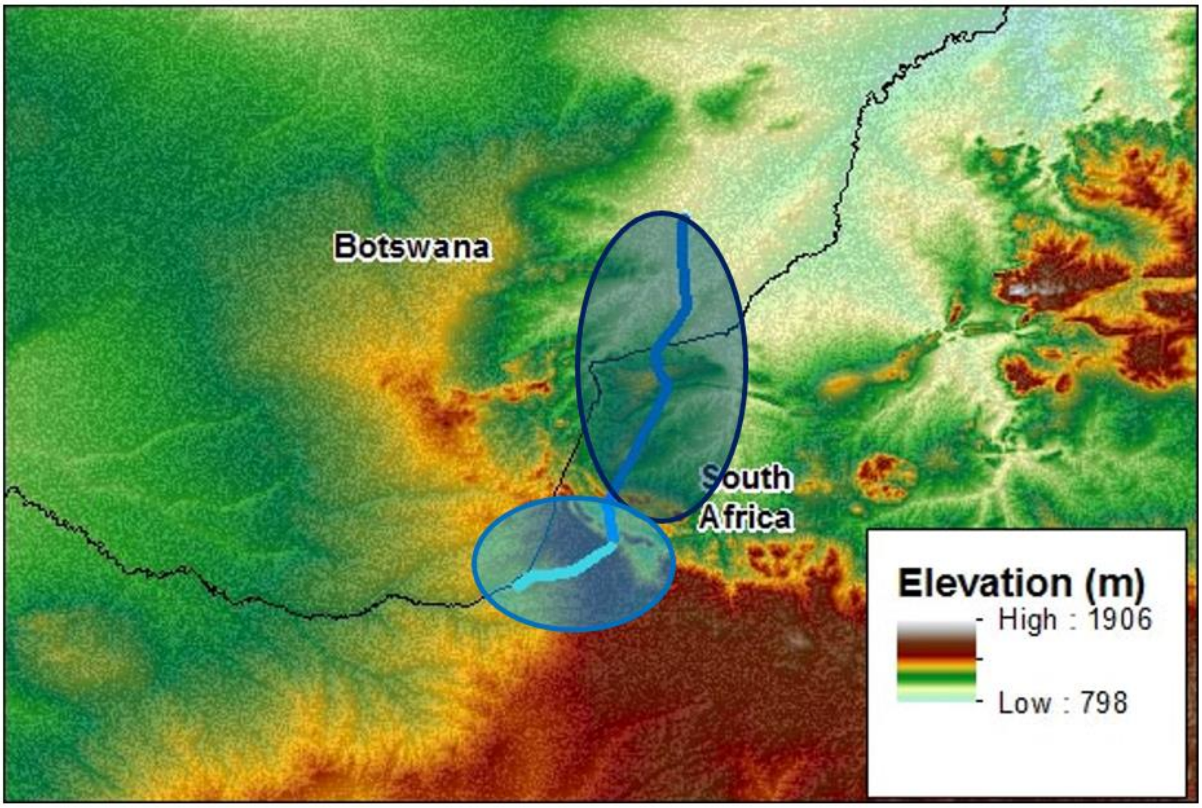

Figure 7: Two distinct climatic zones: northern and flat (dark blue); southern and mountainous (light blue)

2.6 Summarised climate change implications for the study area

The climate change implications for the study area are provided below.

Precipitation

- Decrease in projected annual precipitation espcially in the western sections
- Convective rainfall seasonality shifts towards an increase in rainfall events in summer
- Rainfall events increasing marginally in intensity
- Longer dry-spell duration and potentially more drought events in future

Temperature

- Increase in temperatures, most notably in the western areas
- Increase in warmer days/nights and a decrease in cooler days/nights
- Possibly up to 40% more heatwave events from 2050 onwards
- Large increase in the extreme temperature day occurrence

3 Climate Change: Risk Overview

Climate change has the potential to have profound impacts of the energy sector. A sufficient and consistent energy supply supports economic activities including commerce, transportation, communications, health, water supply and other critical infrastructure. Thus, climate related disruptions in the energy sector can influence economic drivers and livelihoods.

In addition to climate change mitigation efforts to reduce GHGs, the client will have to recognise the importance of adapting and preparing for projected climate change impacts. The report is focussed on Climate Change Risk in the context of the proposed transmission line, but can serve as a precursor to broad-based efforts to improve climate change resilience of transmission infrastructure.

Energy infrastructure has always been vulnerable to natural hazards such as earthquakes, fires, extreme temperatures, floods, etc. Weather related hazards in particular are expected to worsen in light of climate change including, but not limited to, changes in average and extreme temperatures; changes in average, seasonal, and extreme precipitation and hydrology; increasing sea level rise and storm surge; and changes to ecosystems. The primary impacts on the energy sector that may result from climate change are outlined in Figure 8.

Increased water temperatures	• Reduced generation efficienc; • Increased risk of exceeding thermal discharge limits
Increased air temperatures	• Reduced generation efficiency and outputs • ***Increased peak demands, stressing generation capacity and distribution networks*** • ***Reduced transmission efficiency***
Reduced water availability (surface and ground water)	• Adverse impact on hydropower generation • Reduced water availability for cooling systems in thermal and nuclear power plants • Reduction in generation capacity and production
Extreme weather events	• Reduced supply quality of fuel (coal, oil, gas) • Reduced input of energy (e.g., water, wind, sun, biomass) • Damage to generation and transmission infrastructure • Reduced output and impaired security of supply
Variations wind patterns (not limited to climate change)	• Reduced outputs and stability of grids relying heavily on renewable energy • Physical damage to infrastructure

Figure 8. Climate change projections and potential impacts on the energy sector (bold text refers to transmission lines)

Climate influences a wide range factors related to power generation and resource availability including renewable sources such as solar, water and wind. The availability of resources is generally the main factor in the design and location of energy production systems and is relevant to both fossil fuels and renewable energy. Apart from resource availability, climate will also have a significant impact on decision making related to technology, design and operations. Thermoelectric plants, in particular, factor expected air and water temperatures into the design and operation of their cooling systems. In addition, distribution systems are also influenced as transformers and inverters have to be fitted with adequate cooling systems to prevent overheating in hot temperatures. Elevated air temperatures have the potential to decrease the capacity of electricity transmission lines. This is likely to translate into being less able to transmit power during peak hours.

It is clear that weather and changes in climatic patterns have and will continue to shape the design and operation of power generation and distribution systems. As future climate change impacts start to manifest, infrastructure designed according to historical thresholds may not be able to withstand the conditions associated with the projected changes. This may affect structural integrity and operational efficiencies throughout the system. Subsequently, system performance and risk exposure could increase significantly in light of projected climate changes with the identification of vulnerabilities and implementation of resilience enhancing solutions proving imperative for the sustainability of the energy sector.

3.1 Carbon Footprint

Lifecycle assessments (LCA) trace the material, energy and pollutant flows emanating from a system. The assessment considers all stages of the system's lifecycle from the extraction of raw materials processing, manufacture and distribution, construction and maintenance, to the decommissioning or disposal thereof. This allows for estimations of GHG emissions for upstream, downstream and operational processes.

In recent decades a large number of LCAs have been conducted for commercial power generation systems, yielding a diverse range of results. These variances can be partly attributed to technological differences of the systems that were assessed as well as different LCA methodologies and assumptions. Conducting a comprehensive LCA to determine the carbon footprint of a facility will either require guarantees on the technologies to be used or be based on a set of assumptions on configurations, fuel, steam cycle equipment, collectors, heat transfer and storage, foundations and buildings, etc.

The energy sector in South Africa is the primary contributor to GHG emissions and accurate assessment is key for the national GHG inventory. A key factor in complying with the IPCC's principles of good practice in terms of reporting GHGs involves the development of country specific emission factors.

South Africa's energy sector remains dominated by coal, which accounts for an estimated 88% of energy generation with the remainder being nuclear power (5%), hydroelectric (7%), and a small amount from wind and solar[11].

In terms of mitigation potential it is important to note that for the transmission infrastructure, GHGs will largely result from upstream processes such as manufacturing and power generation.

[11] DEA. 2016. The Calculation of Country Specific Emission Factors for the Stationary Combustion of Fuels in the Electricity Generation Sector - South Africa.

3.1.1 Carbon Footprint of Transmission Lines

To date most the accounting of GHG in the energy sector has largely focussed on emissions resulting from power generation. While power generation is responsible for the majority of emissions, the impact of transmission projects are often underestimated. Transmission line losses can range from 7 to 20 percent[12], depending on geographical location and can have a significant impact to warrant more detailed assessment.

For the purpose of assessing the GHG emissions associated with transmission related project, the World Bank[13] outlines three emission categories. These definitions are limited to the physical boundary of the project, i.e. consist of the actual project site:

- Direct non-generation effects - Similar to standard corporate or national inventory. Emissions that occur within the physical boundary of the transmission project, and possibly through the life cycle of that equipment.
- Direct generation effects - Effect on short-term and/or long-term generation emissions that do not require any other actions outside the physical boundary of the transmission project. This would be the case for technical loss reduction projects.
- Indirect generation effects - Effect on short-term and/or long-term generation emissions that requires actions outside the physical boundary of the transmission project. This would be the case for increased reliability, capacity expansion, electrification, and cross-border trade.

Non-generation emission impacts are related to the following potential emission sources: embodied emissions in construction materials; land clearing; energy use in construction, and fugitive emissions.

A cursory assessment of the impacts this transmission line will have on GHG generation contributing to climate changes are as follows in Table 2.

Table 2. GHG generation contributing to climate changes

PHASE	SHORT TERM GHG CONSIDERATION	LONG TERM GHG CONSIDERATION
Feasibility and planning	**Minimal direct effects** Subject to transport types and site visits	**Variable indirect effects** Subject to EIA and mitigation potential commitments.
Construction	**Medium direct effects** Relates to • Efficiency of material construction • Source of constitution materials • Transport requirement • Construction staff local impacts (transport/housing, if necessary)	**Varies between low and medium direct effects** Subject to the impacts and destruction of vegetation along the transmission line and site office locations. Can be mitigated through presence of Environmental Control Officer (ECO on site) to ensure adherence to ESIA and Environmental and Social Management Plan (ESMP) criteria.
Ongoing operations	n/a	**Minimal direct effects** Once established, only ongoing maintenance of the transmission line will have an impact of GHG generation. The

[12] World Bank. 2010. Energy and Mining Sector Board Discussion Paper, Paper No. 21. Washington D.C.
[13] World Bank. 2010. Energy and Mining Sector Board Discussion Paper, Paper No. 21. Washington D.C.

		generation from the production facility is not assessed here.
Decommissioning (if applicable)	**Medium direct** If there is to take place, the decommissioning of the line would likely carry a similar impact to the construction phase. Though this would be reduced through the reuse/recycling of components.	**Varies between minimal positive and negative direct impacts** If decommissioning is undertaken with the intent of environmental rehabilitation this may have long term net positive contribution to climate changes.

The generation emissions impacts can be both positive and negative, with most significant net benefits related power generation plants. A proper understanding of the direct and indirect generation emission impacts will require a net emissions approach to compare the project and baseline scenarios, which was outside of the scope of this study.

3.2 Climate Change Risk: Transmission Lines

While there is generally less research on the impact of climate change on transmission lines than on electricity generation, it is accepted that there are distinct impacts which are summarised in Table 3 and detailed below, and are assessed in terms of the methodology outlined in Appendix 1.

Table 3 Key climate impacts on transmission lines

Variable	Components at Risk	Potential Key Impact
Increased Temperatures	• Transmission lines; • Transformers, inverters and cables.	• Reduced carrying capacity of transmission lines and conductors under high temperatures; • Higher peak loads; • More frequently exceeding maximum operating temperature; • Excess sag
Increased Fire Risk	• Control system, inverters and cables; • Mounting structure (pylons, poles); • Transmission lines.	• Physicals damage; • Power outages.

3.2.1 Temperature

Climate change has the potential to negatively impact electricity supply through increased demand and reduced efficiency of generation and transmission capacity[14]. The climate analysis indicates that

[14] Sathaye J, Dale L, Larsen P, Fitts G, Koy K, Lewis S and Lucena A. 2011. Estimating risk to California Energy Infrastructure from Projected Climate Change, CEC Publication CEC-500-2012- 057

extreme temperatures and dry spells are likely to increase in frequency and intensity in coming decades. As a result, energy infrastructure could face climatic stressors far more regularly, with the potential of compromising design thresholds leading to failure or reduced operational efficiency.

Although not directly impacting on transmission infrastructure, increased temperatures and dry spells have the potential to affect cooling systems and the efficiency of certain generation technologies. This must be noted as it will occur in conjunction with impacts affecting transmission. Although studies have assessed the potential impacts of climate change on power generation, the potential impacts of transmission network and peak electricity loads have received less attention[15].

The primary climate change risk posed to transmission infrastructure relates to the project increase in extreme temperatures. It is accepted that increased ambient air temperatures reduces the carrying capacity of transmission, but current practice is to rate carrying capacity of transmission lines based on historical climate data. The failure to account for the variability and increases linked to climate change could compromise the reliability or future electricity supply.

To date very few studies exist which aim to estimate or determine the impact of increased temperatures on transmission capacity and transmission losses are also influenced by a wide range of non-climatic factor such as conductor technology. Accordingly, it is difficult to assign values to the likely losses which may be incurred due to increased temperatures.

Although impacts and losses may vary it is accepted that all transmission lines will experience reductions in carrying capacity when exposed to projected temperature extremes. Electric power cables suffer decreased transmission capacity as the temperature of the conductor increases. A portion of these capacity losses result from increased electrical resistance at higher conductor temperatures. The current-carrying capacity of a transmission line is primarily limited by the conductor's maximum allowed operating temperature[16]. Maximum operating temperatures are prescribed for different types of conductors to ensure compliance with clearance regulations, and prevent damage to the conductor and other line hardware. Continued operation beyond a conductor's maximum operating temperature can result in excessive sag or damage. To avoid surpassing a transmission line's maximum operating temperature, operators typically curtail the current in an at-risk conductor to satisfy thermal limits. The most significant impact will be on high voltage lines, due to their larger diameter and porter heat dissipation, and during periods of peak load. Depending on demand this may require additional generation capacity to compensate for transmission related losses.

Additional temperature related risk includes damage due to excess sag, permanent damage due to exceeding safe operating thresholds and in extreme cases line sag may contribute to wildfire ignition.
Temperature changes

Projected annual temperatures at the site shows a near linear trend increase from 27.0°C in 2006 to approximately 29°C in 2060 based on the RCP4.5 scenario (see Figure 9). This changing average annual temperature alters the temperature baseline and the derived meteorological parameters will shift relative to this moving average. This shift in baseline temperature shifts the profiles of all the meteorological parameters toward the more extreme range.

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[15] Bartos et al. 2016. Impacts of rising air temperatures on electric transmission ampacity and peak electricity load in the United States. Environ. Res. Lett. 11 (2016) 114008

[16] IEEE Standard for Calculating the Current-Temperature Relationship of Bare Overhead Conductors 2013 IEEE Std 738- 2012 (Revision of IEEE Std 738-2006—Incorporates IEEE Std 738-2012 Cor 1-2013)

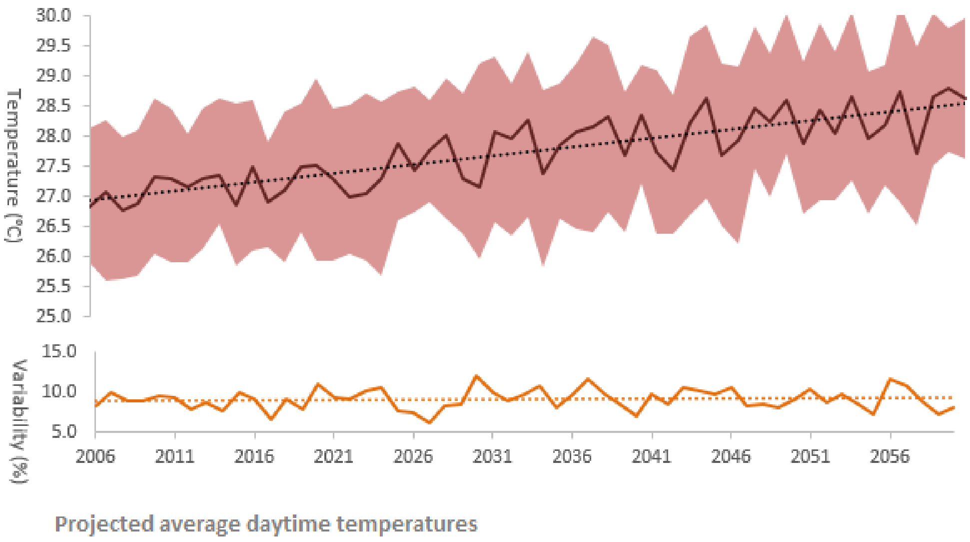


Figure 9: Annual projected day time temperature based on RCP4.5 for the norther area

The temperature profile is changing towards a decreased occurrence of cooler temperatures into the future, relative to the 2000 period (see Figure 9). The spatial change in temperature into the future shows an increase in annual average temperatures of 0.70°C and 0.85°C as near as 2030 from historical data. By 2060 this change is from 1.80°C to 1.95°C with the increase noted to the western side.

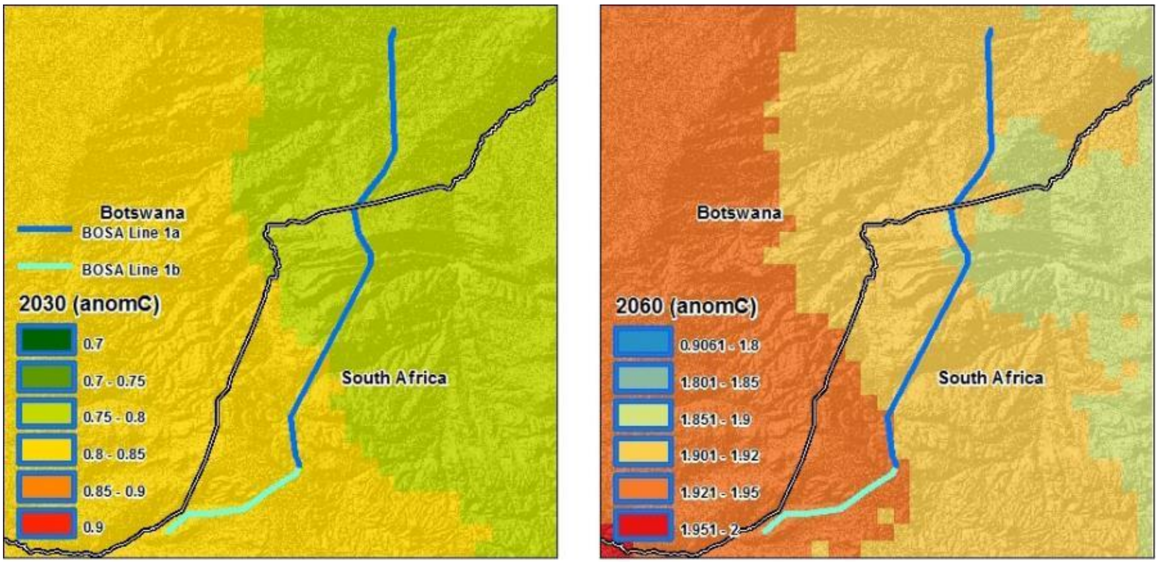


Figure 10: Temperature anomaly from baseline by 2030 (left), by 2060 (right)

There is also an increase in the occurrence of more extreme day time temperatures. The rate of change from 1950 to 2000 is dwarfed by the changes post year 2000. This is suggesting an acceleration away from cooler temperatures toward the more extremely warm temperatures (see Figure 10 - left). The temperature profile has shifted its median temperature from 24°C in 1960 to 28°C in 2060. The shape and range of the temperature profile is retained for the northern areas (See **Error! Reference source not found.** - bottom) and therefore the potential for extreme temperature days has gone from rare to more commonplace, and of extremely cold days from rare to exceptionally rare. This is also noted in the southern areas with a significant anomaly of extremely hot days in the present into the future (See Figure 10 - top).

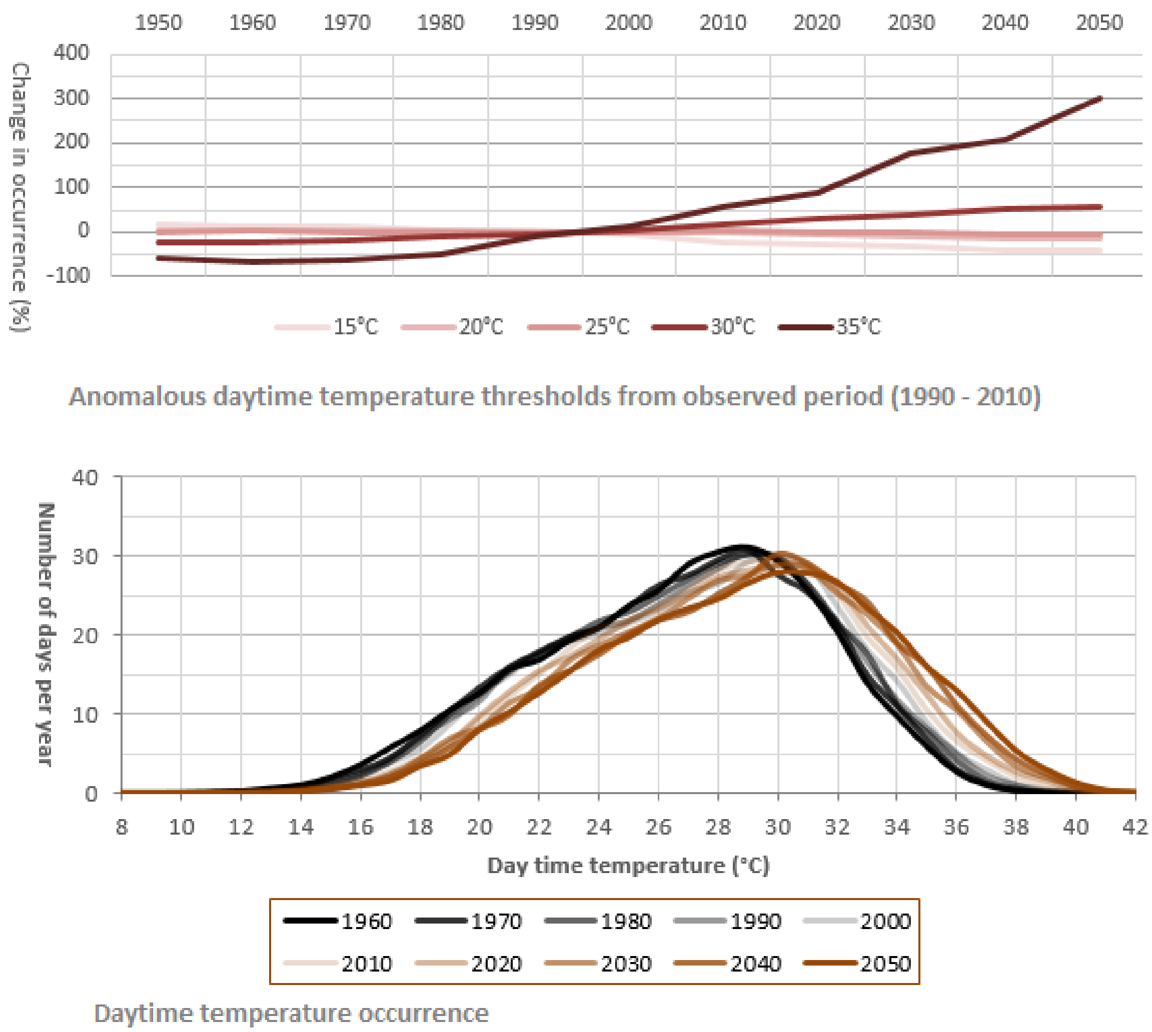


Figure 11: Change in temperature thresholds for the southern area (top) and shifted temperature profile from 1960 to 2050 for the northern area (bottom)

There is a shift in the entire temperature profile toward more extreme temperature days. What was considered to be a cool to average day will become the new lower likely limit of temperature days and current rare extremely hot days will become more common place with the new extremes significantly eclipsing the past extreme days (see Figure 11). Winters will become warmer, with the coldest period being reduced. The shoulder seasons of autumn and spring will expand into the winter timeframe as historically winter months exhibit more autumn or spring temperature characteristics. The peak temperature months will expand to neighbouring periods increasing the hot month character over a longer time. The northern area has a higher temperature profile and the more extreme days will be average 37°C while the southern areas will average closer to 34°C.

The likelihood of heatwaves for both the northern and southern area is enhanced by this shifting temperature profile towards the warmer temperatures (see Figure 12 to Figure 14).

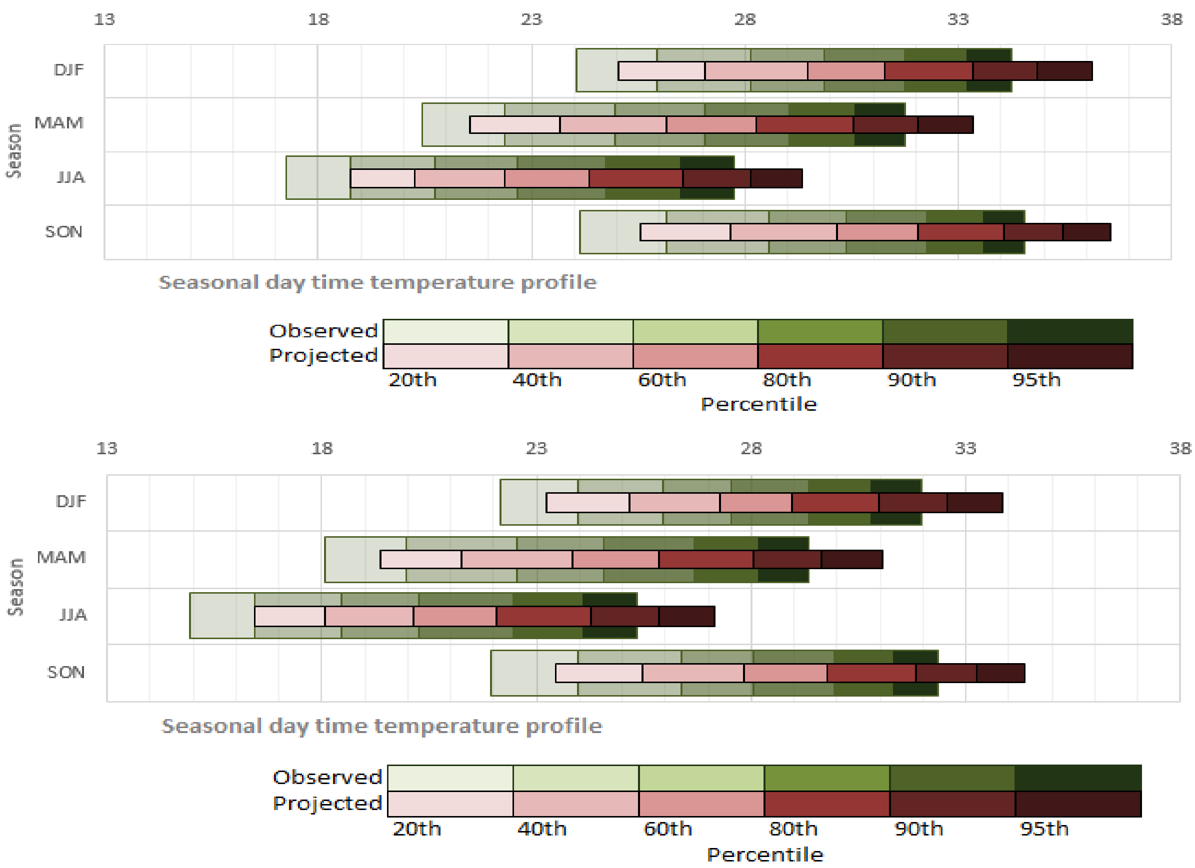


Figure 12: Day time temperature probabilities, observed and projected future. Northern area (top), Southern area (bottom).

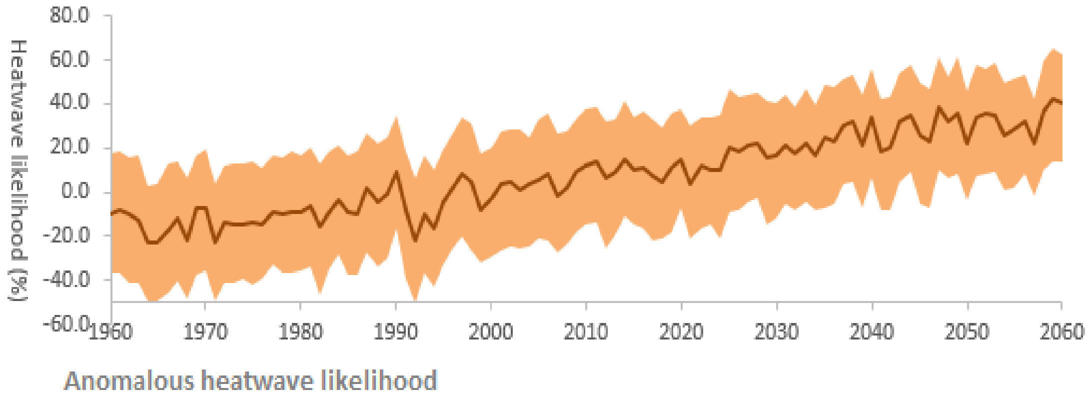


Figure 13: Likelihood of heatwave events from 1960 to 2060. Year 2000 as reference point.

These analyses are looking at the RCP4.5 scenario. The RCP scenario presents greater change into the future with an increase in the month to month average temperatures. There is an associated increase in the extreme ranges of heat waves and across the full temperature profile.

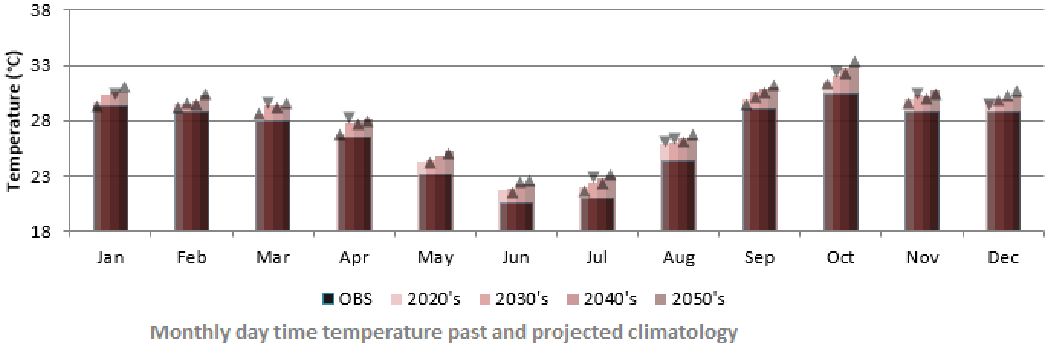


Figure 14: Day time monthly temperature changes. Observed temperature (dark bars), decadal RCP4.5 projected temperatures for 2020,2030,204,2050 (lighter bars), decadal RCP8.5 projected temberatures (arrows).

The significance of reduced energy transmission with heatwave intensity increase and increased daily temperatures is detailed in Table 4.

Table 4. Rating of significance of impacts related to reduced energy transmission

IMPACT DESCRIPTION: Reduced energy transmission from higher temperatures				
Predicted for project phase:	Pre-construction	Construction	Operation	Decommissioning
PRE-MITIGATION				
Dimension	**Rating**	**Motivation**		
Duration	Long-term	Heatwaves will be more regular into the future, with increased intensity	Consequence: Highly detrimental	Significance: High - negative
Extent	Regional	Heatwaves will cover a large extent		
Intensity	Moderate - negative	The nature of the location will mean there will be very little to naturally mitigate the effects of the heatwave		
Probability	Very likely	All climate models agree that heatwaves will increase into the future		
MITIGATION:				
• Mitigation potential is limited on the infrastructure itself, however measures should be taken to decrease heat stress on the people working on the project. • Energy propagation will suffer as a result of increased temperatures and therefore demand management will help to effectively address the efficiency reduction				
POST-MITIGATION				
Dimension	**Rating**	**Motivation**		
Duration	Medium-term	Demand management will effectively reduce the problem to being more a short term issue rather than a low term struggle	Consequence: Moderately detrimental	Significance: Moderate - negative
Extent	Regional	The area coverage will remain the same		

Intensity	Low - negative	If there is planning to address the impacts on staff this impact could be reduced		
Probability	Very likely	All climate models agree that heatwaves will increase into the future		

The climate analysis indicates that a future increase in conditions conducive to wildfire incidence is likely. Fires has potentially significant impacts for transmission infrastructure. Apart from damaging poles and pylons, the greatest risk comes from the smoke and particulate matter associated with wildfires. Smoke and particulate has the ability to ionize the air and creating electrical pathways away from the transmission lines[17]. This can shut down lines causing permanent damage and power outages (Table 5**Error! Reference source not found.**).

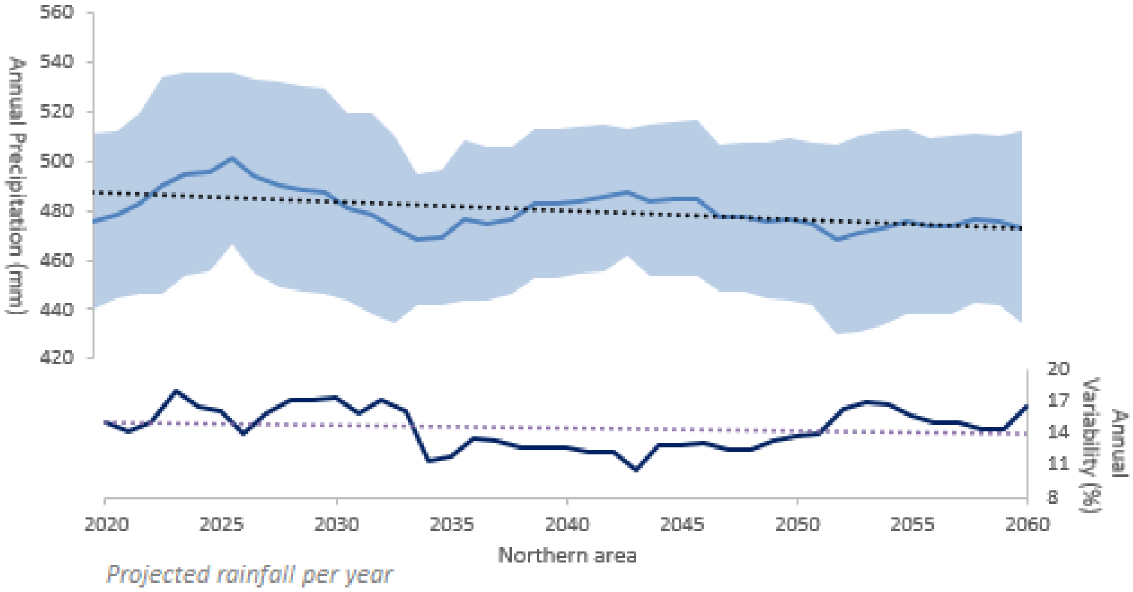
Table 5. Rating of significance of impacts related to veld fire damage

IMPACT DESCRIPTION: Infrastructure damage to line from veld fires				
Predicted for project phase:	Pre-construction	Construction	Operation	Decommissioning
PRE-MITIGATION				
Dimension	**Rating**	**Motivation**		
Duration	Medium-term	This impact is likely constrained to the wild fire season	Consequence: Slightly detrimental	Significance: Low - negative
Extent	Site-specific	The impacts will be specific to the vegetation near the transmission lines.		
Intensity	Low - negative	The density and proximity of the vegetation to the transmission lines will determine the intensity. Though the climate is pointing to more intense wild fire potential		
Probability	Fairly likely	Under the projected climate changes, there are likely going to be higher potential for wild fires to impact the transmission lines		
MITIGATION:				
• If land is cleared below the lines and wildfire is monitored on days when there is high ignition potential, this impact will be reduced				
POST-MITIGATION				
Dimension	**Rating**	**Motivation**		
Duration	Medium-term	This impacts is likely constrained to the wild fire season	Consequence: Negligible	Significance: Very low
Extent	Site-specific	The impacts will be specific to the vegetation near the transmission lines.		
Intensity	Negligible	If monitoring is undertaken, wild fire impacts could be very limited		
Probability	Unlikely	If monitoring is undertaken, wild fire impacts could be very limited		

[17] Ward, D. 2013. The effect of weather on grid systems and the reliability of electricity supply. Climatic Change 121:103–113

3.2.2 Precipitation

Increased precipitation results from the general increase in atmospheric temperature as well as an increase of convective activity at the equator. This rising air is transported north and south and cools at 30° latitude and results in increased subsidence. The resulting high pressure system is enhanced and further hinders the uplift of air and reduces convective potential. Furthermore, the stronger high pressure systems will force the multitude cyclones further toward the poles in winter. Precipitation in both the austral summer and winters will likely be reduced into the future for both areas (see Figure 15). The stronger pressure gradients however create the potential for greater variability in year on year precipitation. The norther areas change from approximately 490 mm/year to 475 mm/year. The decrease in the southern areas is more significant and changes from 570 mm/year to 530 mm/year, both assessing the RCP4.5 scenario.



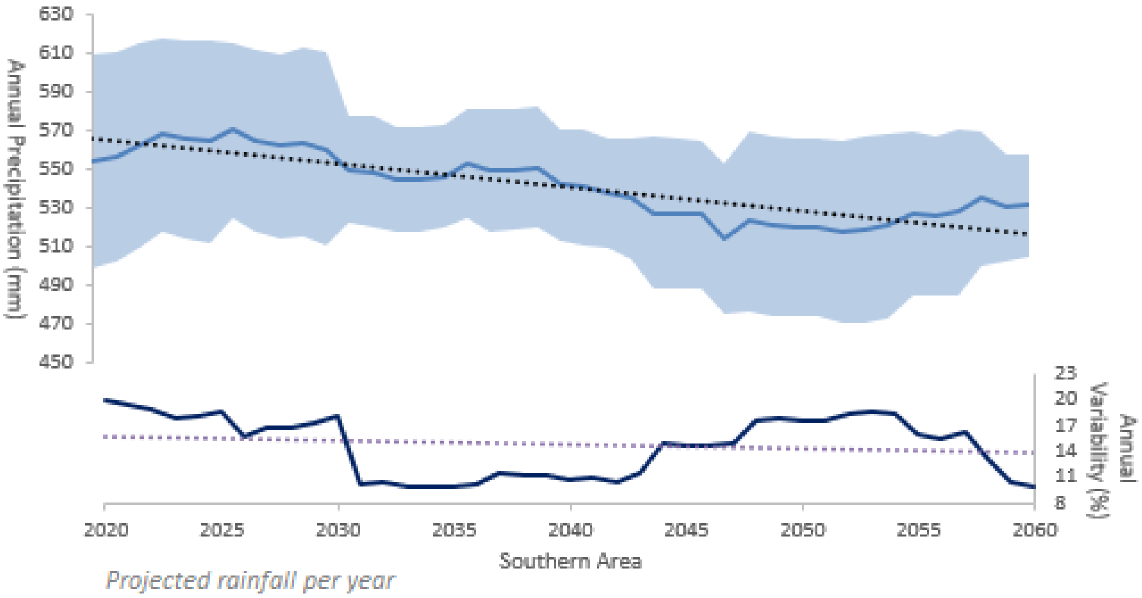


Figure 15: Projected precipitation median, envelope and variability from 2020 to 2060, Norther area (top), Southern area (bottom)

The spatial variation in projected precipitation volumes suggests a general decrease across the whole area with a focused decrease to the eastern side. The areas that are currently experiencing the lowest precipitation volumes will be affected more in the future. At the site there is a decrease of approximately 1% on the annual rainfall volume by 2030 and 3.5% by 2060 (see Figure 16).

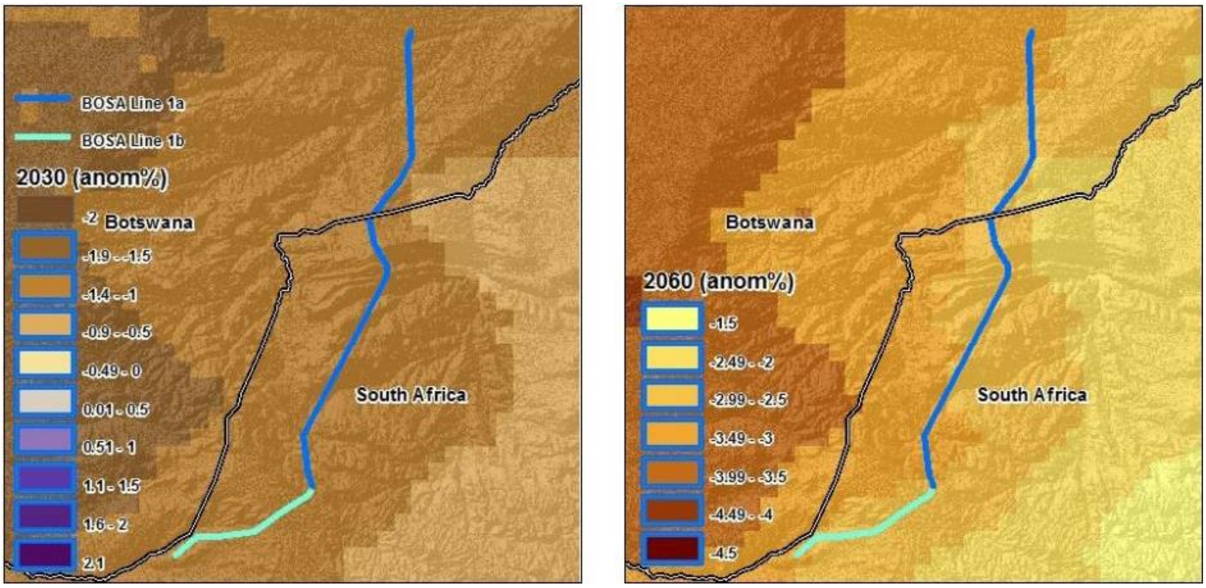


Figure 16: Precipitation anomaly from baseline in 2030 (left), by 2060 (right)

The area the precipitation profile will change between the seasons. The winter profiles sees a decrease in the precipitation range, but this was minimal to begin with and is therefore not significant. The spring profile sees a decrease over the full profile with the likelihood of higher rainfall events decreasing into the future. Both summer and autumn show an increase in the precipitation profiles. There is an increase in the extreme 99th percentile events as well as an increase in magnitude for the remaining less extreme by more frequent events (see Figure 17).

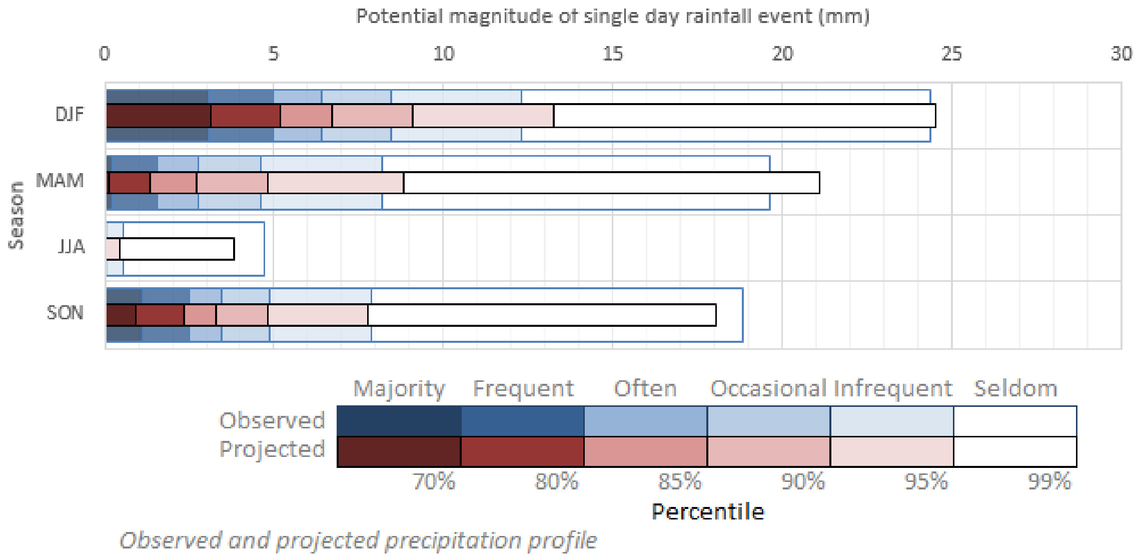
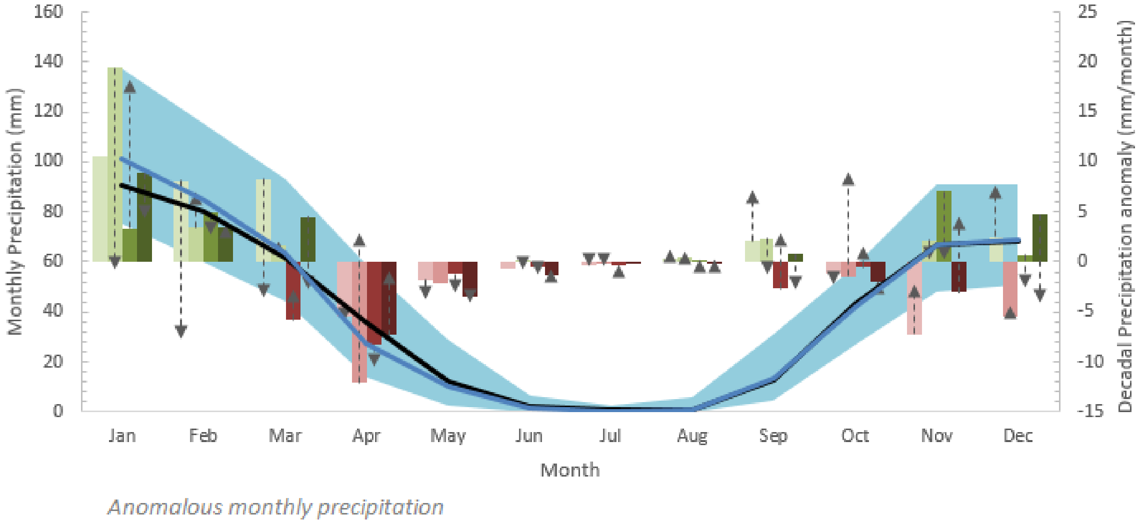


Figure 17: Seasonal simulated precipitation profile for past and projected times

The projected future precipitation follows the same seasonality as currently experienced rainfall (Figure 18). There are deviations from the observed climate between months and between decades; these anomalies are noted at both sites in early to late summer months show an increase in precipitation followed by a large decrease in April and slight variation in precipitation in the winter months. The RPC8.5 data shows greater variability and no significant direction of change in particular months. The increased monthly variance in this scenario makes this future difficult to plan for.



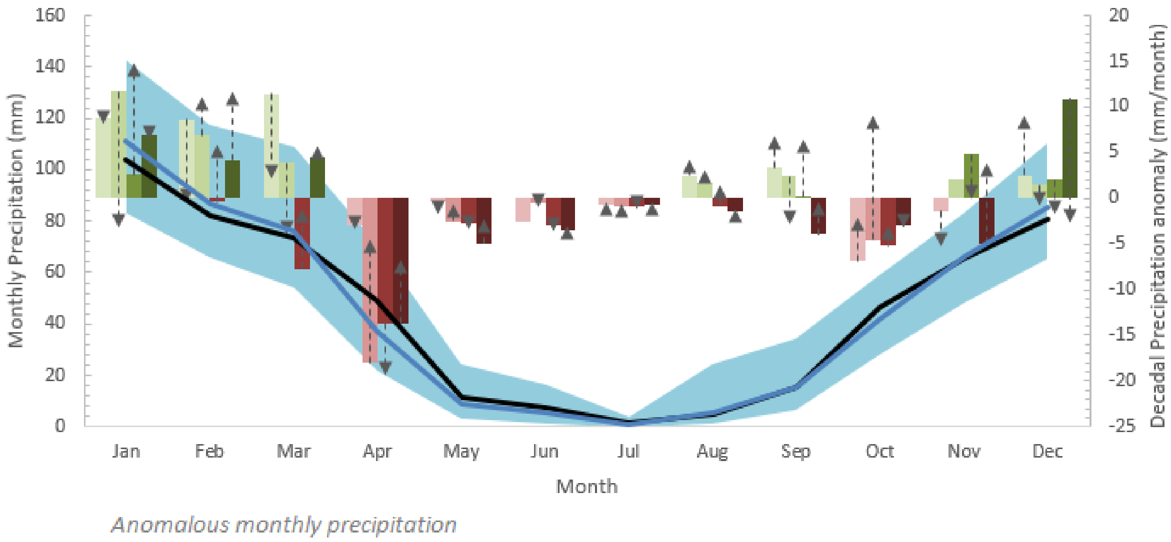


Figure 18: Projected monthly precipitation climate (line graph). Projected monthly decadal anomaly from observed climate based on RCP4.5 (green bars, more rain; red bars, less rain). Projected monthly decadal anomaly from observed climate based on RCP8.5 (grey arrows). Norther areas (top), southern areas (bottom)

The climate models suggest an increase in the precipitation volumes in the late summer months of January, February and March. These increases are in the order of 5 – 10 mm/month with is not largely significant. However due to the likely increased temperatures noted into the future and the fact that precipitation in this region is convectively driven, there is an increased potential for more intense and focused at afternoon thunderstorms. While the total monthly volume of rain may be similar to current conditions, the likely intensity increase may reduce the infiltration potential and therefore enhance overland flow leading to flooding and pooling in the lower lying areas. These storms are however localised and further enhance analysis would be required to fully assess the flood risk.

Increased high rain intensity events can lead to localised and regional flooding which can impact on transmission line infrastructure (Table 6).

Table 6. Rating of significance of impacts related to flooding

<table>
<tr><th colspan="5">IMPACT DESCRIPTION: Flooding from high rainfall intensity events</th></tr>
<tr><td>Predicted for project phase:</td><td>Pre-construction</td><td>Construction</td><td>Operation</td><td>Decommissioning</td></tr>
<tr><td colspan="5">PRE-MITIGATION</td></tr>
<tr><td>Dimension</td><td>Rating</td><td colspan="3">Motivation</td></tr>
<tr><td>Duration</td><td>Short-term</td><td>Rainfall events in the area is limited and short-lived</td><td rowspan="3">Consequence: Negligible</td><td rowspan="4">Significance: Very low</td></tr>
<tr><td>Extent</td><td>Site-specific</td><td>he impacts of the rainfall will impact the local site area and the construction ability</td></tr>
<tr><td>Intensity</td><td>Low - negative</td><td>Rainfall intensity is likely to be low over all, even though there is a slight increase into the future</td></tr>
<tr><td>Probability</td><td>Fairly likely</td><td colspan="2">Rainfall variability is increasing and there are likely to be intense rainfall events</td></tr>
<tr><td colspan="5">MITIGATION:</td></tr>
<tr><td colspan="5">• Doing forecasting of the rainfall events will help to prepare the areas.
• Furthermore building in measures to evacuate excess water away from installations will negate the impacts</td></tr>
<tr><td colspan="5">POST-MITIGATION</td></tr>
<tr><td>Dimension</td><td>Rating</td><td colspan="3">Motivation</td></tr>
<tr><td>Duration</td><td>Short-term</td><td>Rainfall events in the area is limited and short-lived</td><td rowspan="3">Consequence: Negligible</td><td rowspan="4">Significance: Very low</td></tr>
<tr><td>Extent</td><td>Site-specific</td><td>the impacts of the rainfall will impact the local site area and the construction ability</td></tr>
<tr><td>Intensity</td><td>Negligible</td><td>If mitigated the low intensity of the rain events will likely be small</td></tr>
<tr><td>Probability</td><td>Unlikely</td><td colspan="2">Rainfall variability is increasing and there are likely to be intense rainfall events</td></tr>
</table>

4 High Level Response

Investment decisions in the energy sector have long lead times and thus long term implications. Transmission lines are no different with potential lifetimes upward of 50 years, dependent on maintenance schedules. This provides strong motivation for assessing climate change risk in terms of impacts on infrastructure, technical and economic viability of investments and the identification of response options to improve resilience.

Climate change response options can generally be divided into hard and soft engineering and non-engineering options (Table 7). In the majority of cases a "no-regrets" response to climate change will be the best approach to counteracting uncertainties related to climate change, i.e. implementing measures that will create benefits regardless of the nature and degree of climate change where large climate-proofing capital investments cannot be easily justified. However the fact remains that a "no response" approach may be the more appropriate and cost-effective approach in some cases. The calculations of the return of investment of different response options requires in-depth cost benefit analyses beyond the scope of the current study.

However, some of the actions identified below can be applied at a project level and these will be carried across into design and operational activities.

Table 7 Response Options (text in bold is relevant to this project specifically)

Engineering Options	
Measure	Outcome
• **More robust design specifications**	• **Structures able to withstand more extreme conditions: higher wind or water velocity, higher air and/or water temperatures;** • **Improved resilience and reduced redundancy of transmission and distribution system components; e.g. replacing power conductors with stronger steel-core lines, increased transmission line spacing.**
• Relocate or retrofit existing Infrastructure	• Improving existing infrastructure's ability to withstand more extreme conditions; • Relocation and decentralisation may reduce the presence or need for facilities and infrastructure in high-risk areas; • Improved resilience and reduced redundancy of transmission and distribution system components.
• Review and retrofit cooling systems	• Improved resilience of substations and transformers.
• Consider conductors specifications that maximises the dissipation of heat	• **Increased heat dissipation and reduced risk of exceeding maximum operating temperatures;** • **Potential reduction in wear and line sag**.
• Application heat-resistant cells, modules, and components	• Reduced physical vulnerability to high temperatures; • Reduced loss of output related to increased temperatures.

Non-engineering Options	
• More robust operational and maintenance procedures	• Improved resilience of critical components and reduced operational interruptions.
• Coordinated land use planning	• **Avoid development of future power infrastructure in vulnerable areas**.
• Improve forecasting of demand changes and supply and demand	• Balance supply and demand with the impact of climate change on outputs for proactive management of power grid.
• Set up rapid emergency repair teams	• **Rapid repair of damaged infrastructure to limit impact on operations and ensure continuity.**
• Identification and implementation of fire risk reduction measures	• **Reduce fire risk and impacts associated with wildfires (e.g. vegetation management and route selection through low risk areas).**

5 Conclusion

Climate change will have a significant impact on the entire energy sector, internationally and across Southern Africa. While a large body of information exists linking climate change and specific energy technologies, specific project level experiences are less well documented. For this specific site the most severe impacts will likely be related to increased temperatures and increased fire risk.

In recent years attention has been focussed on mitigating the footprint of energy production, while insufficient attention has been paid to adapting the energy sector and critical infrastructure to projected climate change. The long lead times and operating lives of energy sector investments require these investments to fully account for climate change and the implementation of cost-effective strategies to address their risk exposure. Understanding risk and vulnerabilities is a critical first step for all implementing agencies interested in improving their climate resilience and integrate the results into long term resource planning.

With lifetimes upwards of 50 years, there is strong motivation for assessing climate change risk in terms of impacts transmission and distribution systems, technical and economic viability of investments and the identification of response options to improve resilience.

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World Bank. 2010. Energy and Mining Sector Board Discussion Paper, Paper No. 21. Washington D.C.

Younger Dryas, influx of fresh water into the gulf stream due to melting glaciers in North America inhibiting subduction of water in the north Atlantic causing a short lived ice age in Europe.

APPENDIX 1
Methodology for rating of impacts

Rating of Impacts

In order to assess the significance each identified impact, standard methodology in risk analysis was adopted, in which risk is defined as follows (Ansel & Wharton, 1992):

Significance = consequence[18] of an event x probability of the event occurring.

Depending on the numerical result of this calculation, the impact would fall into a significance category of negligible, minor, moderate or major, and the type would be either positive or negative.

For each predicted impact, criteria are applied to establish the significance of the impact based on likelihood and consequence, both without mitigation being applied and with the most effective mitigation measure(s) in place.

The criteria that contribute to the consequence of the impact are intensity (the degree to which pre-development conditions are changed), which also includes the type of impact (being either a positive or negative impact); the duration (length of time that the impact will continue); and the extent (spatial scale) of the impact. The sensitivity of the receiving environment and/or sensitive receptors is incorporated into the consideration of consequence by appropriately adjusting the thresholds or scales of the intensity, duration and extent criteria, based on expert knowledge.

The rating options for each dimension, as well as the criteria for selecting a particular option, are given in the tables below.

Definition of Intensity ratings

	Criteria Rating	
Rating	**Negative impacts (-)**	**Positive impacts (+)**
Very high (-/+ 4)	Very high degree of damage to social systems or resources. These processes or resources may restore to their pre-project condition over very long periods of time (more than a typical human life time).	Great improvement to social processes and services or resources.

[18] The term consequence is used in this methodology instead of magnitude (as included in the definition of "significant impact" in GNR 982). Furthermore, the specialists themselves translate their subjective judgements into numerical ratings to determine the significance score. As this "translation" is undertaken by the specialists themselves, it is asserted that outcomes will be accurately interpreted.

High (-/+ 3)	High degree damage to social system components or resources.	Intense positive benefits for social systems or resources.
Moderate (-/+ 2)	Moderate damage to social system components or resources.	Average, on-going positive benefits for social systems or resources.
Low (-/+ 1)	Minor damage to social system components or resources. Likely to recover over time. Valuable social processes not affected.	Low positive impacts on social systems or resources.
Negligible (0)	Negligible damage to individual components of social systems or resources, such that it is hardly noticeable.	Limited low-level benefits to social systems or resources.

Definition of Duration ratings

Rating	Criteria
2	**Long-term**: The impact will continue for 6-15 years.
1	**Medium-term:** The impact will continue for 2-5 years.
0	**Short-term:** The impact will continue for between 1 month and 2 years.

Definition of Extent ratings

Rating	Criteria
2	**Regional:** The impact will affect the entire region
1	**Local:** The impact will extend across the site and to nearby properties.
0	**Site specific:** The impact will be limited to the site or immediate area.

The procedure for deriving the consequence of an event from its expected duration, extent and severity is based on the numeric values for each rating option given in the last column of the table, with consequence being defined as follows:[19]

Consequence = (Sign of Intensity rating) x (Duration + Extent + |Intensity|)

Depending on the numerical result, the impact's consequence would be defined as either extremely, highly, moderately or slightly detrimental; or neutral; or slightly, moderately, highly or extremely beneficial.

Descriptions of the consequence ratings associated with each derived numerical value are given in the table below.

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19 |*Intensity*| denotes absolute value of Intensity rating. I.e. |-2| = 2.

Descriptions of consequence ratings

Rating	Consequence rating
-8	Extremely detrimental
-7 to -6	Highly detrimental
-5 to -4	Moderately detrimental
-3 to -2	Slightly detrimental
-1 to 1	Negligible
2 to 3	Slightly beneficial
4 to 5	Moderately beneficial
6 to 7	Highly beneficial
8	Extremely beneficial

To determine the significance of an impact, the probability (or likelihood) of that impact occurring is also taken into account. In assigning probability the specialist takes into account the likelihood of occurrence but also takes cognisance of uncertainty and detectability of the impact. The most suitable numerical rating for probability is selected from the table below.

Definition of Probability ratings

Rating	Criteria
4	**Certain/ Definite:** There are sound scientific reasons to expect that the impact will definitely occur.
3	**Very likely:** It is most likely that the impact will occur.
2	**Fairly likely:** This impact has occurred numerous times here or elsewhere in a similar environment and with a similar type of development and could very conceivably occur.
1	**Unlikely:** This impact has not happened yet but could happen.
0	**Very unlikely:** The impact is expected never to happen or has a very low chance of occurring.

Once the significance of an impact occurring without mitigation has been established, the same impacts will be assigned ratings after the proposed mitigation has been implemented.

Although these measures may not totally eliminate subjectivity, they provide an explicit context within which to review the assessment of impacts. The specialists appointed to contribute to this impact assessment have empirical knowledge of their respective fields and are thus able to comment on the confidence they have in their findings based on the availability of data and the certainty of their findings. As with all studies it is not possible to be 100% certain of all facts, and for this reason a standard “degree of certainty” scale (

). The level of detail for specialist studies is determined according to the degree of certainty required for decision-making.

Definition of Confidence ratings

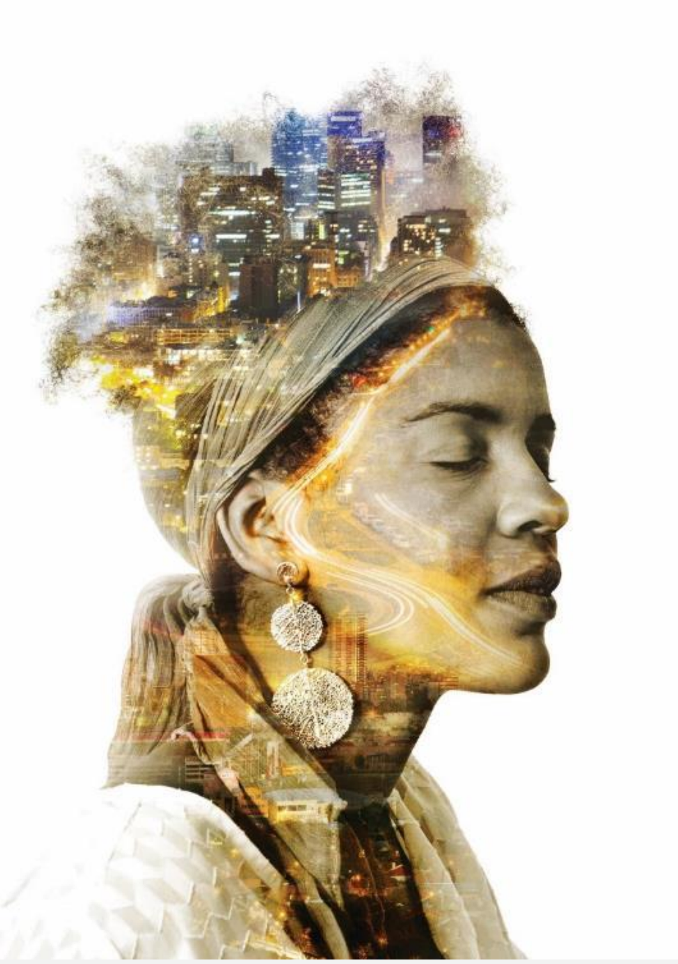
Rating	Criteria
Low	Judgement is based on intuition and there some major assumptions used in assessing the impact may prove to be untrue.
Medium	Determination is based on common sense and general knowledge. The assumptions made, whilst having a degree of uncertainty, are fairly robust.
High	Substantive supportive data or evidence exists to verify the assessment.

Mitigation measures and recommendations

Appropriate mitigation measures must be recommended and amended to avoid or ameliorate negative impacts and to enhance positive ones. The criteria for the selection of mitigation measures included that:

- They should be effective in ameliorating the impact without having severe negative secondary consequences; and
- They should be practically feasible and cost-effective.

After suitable mitigation measures were identified for each identified impact, the rating procedure described above must be repeated to assess the expected consequence, probability and significance of each impact after mitigation. This post-mitigation rating gives an indication of the significance of residual impacts, while the difference between an impact's pre-and post-mitigation ratings represents the degree to which the suggested mitigation measures are expected to be effective in reducing or ameliorating that impact.



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