REPORT

Climate Change Environmental Impact Assessment

NEO I 20MW Solar PV Power Plant

Client: NEO 1 SPV (Pty) Ltd

Reference: MD4071TPRP1904011509_NEO1 CCIA

Status: 01/Final

Date: 29 July 2019

Royal HaskoningDHV

Enhancing Society Together

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Document title:	Climate Change Environmental Impact Assessment
Document short title:	NEO 1 Climate Change IA
Reference:	MD4071TPRP1904011509_NEO1 CCIA
Status:	01/Final
Date:	29 July 2019
Project name:	NEO 1
Project number:	MD4071
Author(s):	Gerard van Weele
Drafted by:	N/A
Checked by:	
Date / initials:	16 July 2019
Approved by:	
Date / initials:	

Classification
Project related

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Declaration of Interest

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Declaration of Independence

I, *Gerard A van Weele*, declare that I am independent of the client and their consultants, and stand to gain no financial benefit from the proposed activity apart from remuneration for the work performed. All views expressed in this report are my own and the use of all material from other sources has been properly and fully acknowledged.

GvWeele

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1 PROJECT BRIEF

Royal HaskoningDHV was requested by One Power to conduct a Climate Change Impact Assessment for a proposed 20MW Photo-Voltaic (PV) power plant project close to the Ramarothole substation, Mafeteng District, Lesotho.

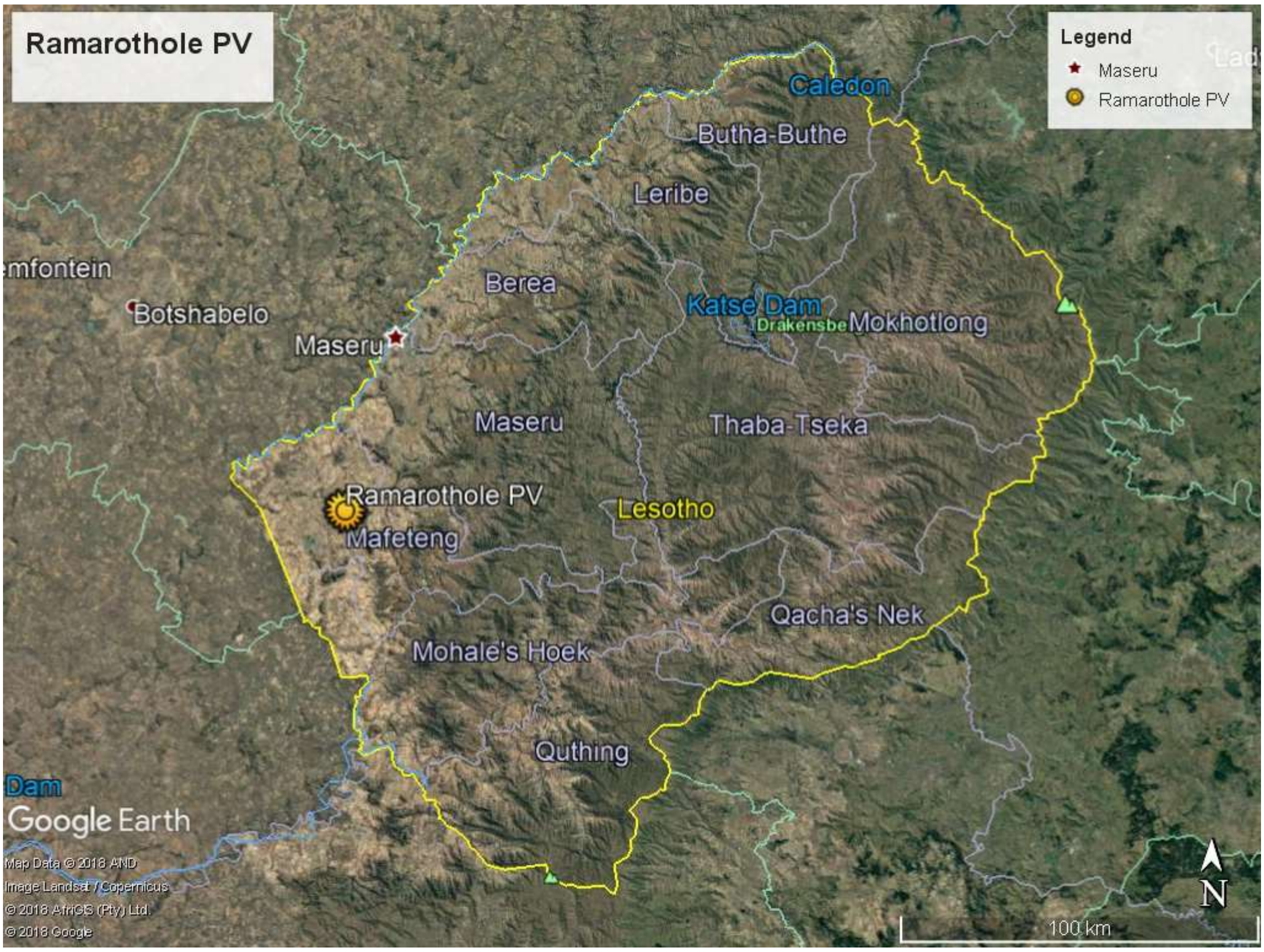

Figure 1: Location of the NEO I PV plant in Lesotho (image courtesy of Google Earth™)

A climate change impact assessment is required as part of the Environmental and Social Impact Assessment (ESIA) process, and is aimed at:

- understanding the potential contribution (both positive and negative) of the proposed power plant to climate change
- recognising the plant's vulnerability to projected climate change
- identifying any impacts of the plant on climate change related risks and vulnerabilities in the immediate surrounds
- quantifying the influence that climatic change will have on the overall environmental impact of the power station.

This includes contextualisation of the situation within current national carbon budgets borne out of global emissions reductions targets.

Some of the drivers of this assessment, which necessarily need to be considered, include:

- Low national greenhouse gas (GHG) emissions due to its predominant dependence on hydropower
- High vulnerability indices due to a large proportion of the population involved in agriculture and water being a key resource
- A Nationally Determined Contribution (NDC) of an unconditional 10% reduction of its GHG emissions by 2030 compared to a Business-As-Usual (BAU) scenario.

2 METHODOLOGY

The climate change impact assessment for the NEO I 20MW PV facility considers three main questions:

1. How will climate change influence the project?
2. How will climate change influence the project's impacts on the environment?
3. How will the project affect Lesotho's ability to mitigate climate change?

This translates into an investigation of the components indicated on the diagram depicted in Figure 2.

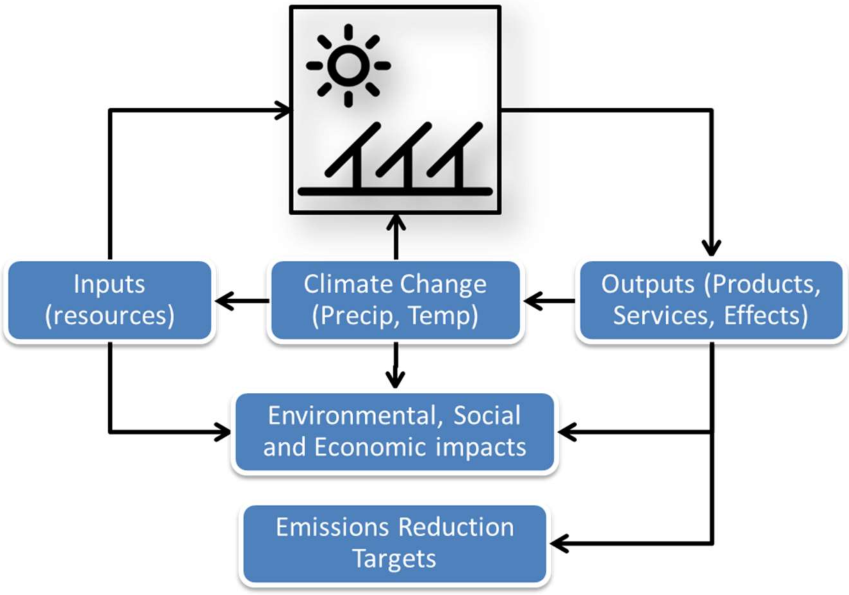

Figure 2: Climate change considerations related to solar PV installations

2.1 The impacts of climate change on the project

As for any infrastructure projects, solar PV installations need to recognise how climate change is likely to play out in terms of patterns of climate variability and extreme weather events, and the risks posed by climate and weather events to the project. Specifically, projections of future climates need to be consulted and interpreted in terms of likely threats to the physical infrastructure and operations of the plant.

Indirect impacts must also be considered. This includes the impacts that climate change responses (e.g. disinvestment in carbon-intensive industries) might have on the conceptualisation of the project.

2.2 The project's impacts on the environment

The immediate and direct impacts of the power station on the local or regional integrity of environmental conditions, will be assessed in the specialist assessments detailing ecological, air quality and water resources impacts. However, one also has to consider how a future climate will affect the availability of operational resources requirements in consideration of potentially variable biophysical and socio-economic conditions.

2.3 Mitigation of climate change

The assessment of the project's impacts on the environment is supplemented by a quantification of the potential greenhouse gas emissions from the plant, within the context of the national GHG emissions reduction commitments. The emissions footprint will be limited to 'territorial' emissions, i.e. those generated within the project boundaries and excluding the emissions related to materials and product sourcing. Recommendations will be made with regards to non-territorial emissions.

2.4 Impact rating

The impacts identified will be rated according to four descriptive criteria, namely Extent (E), Duration (D), Intensity (I) and Probability (P), with the significance determined by the cumulative rating of all four categories. This is achieved through application of a scoring exercise as per Table 3. A cumulative score is then used as an indicator of significance, as per Table 2.

Table 1: Scoring system for the impact rating exercise

Nature	**Category**	
Extent (E)	1	Footprint / site
	2	Local (within a radius of 2 km of site)
	3	Regional
	4	National
Duration (D)	1	Short (less than five years)
	2	Medium term (5-15 years)
	3	Long term (15-30 years)
	4	Permanent
Intensity (I)	1	Low
	2	Moderate
	3	High
	4	Very High
Probability (P)	1	Improbable
	2	Probable
	3	Highly Probable
	4	Definite
IMPACT is Cumulative **Significance = E + D + I + P**		Minimum value of 4, maximum of 16 Status determines if positive / negative

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Table 2: Significance categories

Neg (13 - 16 points) NEGATIVE VERY HIGH	Permanent and important impacts. The design of the site may be affected. Intensive remediation is needed during construction and/or operational phases. Any activity which results in a "very high impact" is likely to be a fatal flaw.
Neg (10 - 12 points) NEGATIVE HIGH	These are impacts which individually or combined pose a significantly high negative risk to the environment. These impacts pose a high risk to the quality of the receiving environment. The design of the site may be affected. Mitigation and possible remediation are needed during the construction and/or operational phases. The effects of the impact may affect the broader environment.
Neg (7 -9 points) NEGATIVE MODERATE	These are impacts which individually or combined pose a moderate negative risk to the quality of health of the receiving environment. These systems would not generally require immediate action, but the deficiencies should be rectified to avoid future problems and associated cost to rectify once in HIGH risk. Aesthetically and/or physically non-compliance can be expected over a medium term. In this case the impact is medium term, moderate in extent, mildly intense in its effect and probable. Mitigation is possible with additional design and construction inputs.
Neg (4 - 6 points) NEGATIVE LOW	These are impacts which individually or combined pose a deleterious or adverse impact and low negative risk to the quality of the receiving environment, and may lead to potential health, safety and environmental concerns. Aesthetically and/or physical non-compliance can be expected for short periods. In this case the impact is short term, local in extent, not intense in its effect and may not be likely to occur. A low impact has no permanent impact of significance. Mitigation measures are feasible and are readily instituted as part of a standing design, construction or operating procedure.
Pos (4 - 6 points) POSITIVE LOW	These are impacts which individually or combined pose a low positive impact to the quality of the receiving environment and health, and may lead to potential health, safety and environmental benefits. In this case the impact is short term, local in extent, not intense in its effect and may not be likely to occur. A low impact has no permanent impact of significance.
Pos (7 - 9 points) POSITIVE MODERATE	These are impacts which individually or combined pose a moderate positive effect to the quality of health of the receiving environment. In this case the impact is medium term, moderate in extent, mildly intense in its effect and probable.
Pos (10 - 12 points) POSITIVE HIGH	These are impacts which individually or combined pose a significantly high positive impact on the environment. These impacts pose a high benefit to the quality of the receiving environment and health, and may lead to potential health, safety and environmental benefits. In this case the impact is longer term, greater in extent, intense in its effect and highly likely to occur. The effects of the impact may affect the broader environment.
Pos (13 - 16 points) POSITIVE VERY HIGH	These are permanent and important beneficial impacts which may arise. Individually or combined, these pose a significantly high positive impact on the environment. These impacts pose a very high benefit to the quality of the receiving environment and health, and may lead to potential health, safety and environmental benefits. In this case the impact is long term, greater in extent, intense in its effect and highly likely or definite to occur. The effects of the impact may affect the broader environment.

2.5 Assumptions, Uncertainties, Exclusions and Gaps in Knowledge

In view of the large uncertainties associated with econo-political decisions and macro-economic policy related to power generation and international finance, this assessment will not consider the effects of the project on aspects such as foreign direct investment or indirect impacts on tourism within a globalised economic system.

3 CONTEXT

3.1 Project Description

The Project will entail construction of a 20MW PV Power Generation Plant that will include operation of the plant and generation of solar power that will be sold to Lesotho Electricity Corporation (LEC), and maintenance of the plant for up to 25 years.

The project will include the following:

- A PV panel array and interconnections
- Construction of a 33kV Powerline from the PV Plant to the Ramathole substation. The exact voltage and tower position will be subjected to a final design and agreement with the Lesotho Electricity Corporation. The powerline will be approximately 1.1km in length and with a servitude corridor of approximately 22m (11m on each side);
- Operation and Maintenance Building;
- Laydown areas;
- Inverter Station (internal substation) to increase (“step-up”) the voltage of the electricity for transmission into the grid;
- The main site entrance road is gravel, 10m in length and 6m wide and will be connecting from the existing access road; and
- Total area to be fenced is approximately 66 hectares.

3.2 Lesotho’s International Climate Change Profile

The Government of Lesotho ratified the UN Framework Convention on Climate Change (UNFCCC) in 1995, thereby embarking on a process of aligning with the international community in respect of the reduction of greenhouse gas emissions and adaptation to the inevitable impacts of climate change. Lesotho submitted a First National Communication (2000) and Second National Communication (2013) to the UNFCC and developed and published a National Adaptation Programme of Action (NAPA) in 2007. In support of the global agreements reached at the Conference of the Parties (COP21) of the UNFCCC in December 2015, the ‘Paris Agreement’, Lesotho also submitted her Intended Nationally Determined Contribution (INDC) in 2015. The country is currently preparing the Third National Communication (TNC), First Biennial Updated Report (BUR1) and National Adaptation Plan (NAP) (LMS, 2017).

The Kingdom of Lesotho has also compiled a National Climate Change Policy (LMS, 2017) as an over-arching and coordinating framework for addressing the challenge of climate change. The policy ascribes to the Guiding Principles of the UNFCCC, Sustainable Development Goals, African Union Agenda 2063, the Paris Agreement, and the National Strategic Development Plan and builds on the core pillars of adaptation and climate risk reduction, mitigation and low-carbon development pathways, governance and institutional arrangements, a climate finance and investment framework, as well as cross-cutting issues.

National Climate Change Policy of the Kingdom of Lesotho, 2017

VISION

The vision of the National Climate Change Policy is to build climate change resilience and low-carbon pathways including a prosperous sustainable economy and environment in Lesotho.

MISSION

Increase climate change resilience and improve the well-being of Basotho through mainstreaming and implementing concrete measures for adaptation and climate risk reduction, mitigation and low-carbon development, aiming at sustainable development, with active participation of all stakeholders in the social, environmental and economic sectors.

OBJECTIVES

The overarching objective of the policy is to ensure that all stakeholders address climate change impacts and their causes through the identification, mainstreaming and implementation of appropriate adaptation and mitigation measures, while promoting sustainable development.

Specifically, the policy fosters development of processes, plans, strategies and approaches that:

1. Promote climate-resilient, social, economic and environmental development that is compatible with, and mainstreamed into, national development planning and national budget-setting processes;
2. Explore low-carbon development opportunities, nationally and internationally, in order to promote the sustainable use of resources and
3. Strengthen a framework that promotes efficient climate change governance, strong international cooperation, capacity building, research and systematic observations, clean technology development, transfer and use, education, training and public awareness and financing in a way that also benefits the most vulnerable through the implementation arrangements to be defined in the strategy.

Lesotho's GHG emissions are relatively small – in 2014, it ranked 146th in the world in terms of total emissions, and 154th in terms of per capita emissions (Boden, Marland, & Andres, 2017). This is due in part to the relatively small size of the country and in part to the reliance on hydropower for its electricity needs (approximately 50% of demand) (SE4All, 2012). Electricity sourced from the South African Power Pool (SAPP) is relatively carbon intensive, and hence has a lot of opportunity for improvement in terms of GHG emissions – a change that will further reduce the national GHG footprint.

The official national GHG inventory for the year 2000 calculated national emissions to total 3 512.89 Gg (3.5 Mt) of CO_2 equivalent (CO_2eq) without compensating for Land Use Change and Forestry (LUCF) (LMS, 2013). The LUCF sector provides a net sink of 1 377.98 Gg CO_2eq emissions which brings the total net emissions to 2 134.91 Gg (2.1 Mt) of CO_2eq (LMS, 2013). Estimates set a more recent (2014) value for the country's emissions, including LUCF, at 4.17 Mt CO_2eq (WRI, 2018), which is less than 0.0001% of global emissions.

According to Lesotho's INDC, the country is committed to achieving its mitigation targets by 2030. Despite contributing very little to global emissions, the Kingdom has committed itself to reduce its GHG emissions unconditionally by 10% by 2030 as compared to a BAU scenario. The conditional target is 35% by 2030 (MEM, 2015). Main contributions will come from the energy, waste and forestry sectors. Within the Energy Sector the desire is expressed to "…*increase energy efficiency significantly and shift the energy supply to more climate friendly technologies*" (MEM, 2015, p. 12). Solar power is identified as potential contributor, with a target of 40MW installed capacity allocated to this technology (MEM, 2015).

3.3 Climate Change

'Climate change' refers to any change in the average long-term climatic trend, and is a natural part of the earth system. Human activities since the Industrial Revolution have, however, succeeded in altering the composition of the atmosphere to such an extent that it will absorb and store increasing amounts of energy in the troposphere within the coming century. This will result in the atmosphere heating up, thereby altering weather and climate patterns. It is expected that the average temperature of the atmosphere will increase by between 1.5 and 4.5 degrees Celsius (°C) in the next 90 years (IPCC, 2013). This will lead to a cascade of effects, including changes to precipitation, seasons, microclimates and habitat suitability. It is also reported that *"…there will be more frequent hot and fewer cold temperature extremes over most land areas on daily and seasonal timescales as global mean temperatures increase. It is very likely that heat waves will occur with a higher frequency and duration"* (IPCC, 2013, p. 18).

The impact of climate change has the potential to adversely affect the economic, natural resources and social sectors of Lesotho, as for the rest of South and Southern Africa. Changes to both weather patterns and longer-term climate will induce changes to how land can be used, and how exposed economic activities and people will be to climate and weather-related threats. Warmer temperatures, for example, will affect crop selection for agriculture, habitat suitability for wildlife, water availability for mining, energy usage by urban populations and the spread of diseases. Climate change furthermore leads to indirect impacts as social and economic sectors attempt to adapt to the changing climate. Global efforts at mitigation will, for example, force a shift towards forms of energy with lower global warming potentials; thereby altering the foundations of coal based economies.

Earth's globally averaged temperature for 2017 made it the third warmest year in NOAA's 138-year climate record, behind 2016 (warmest) and 2015 (second warmest).
However, unlike the past two years, Earth's average temperature in 2017 was not influenced by the warming effect of an El Nino, say scientists from NOAA's National Centers for Environmental Information (NCEI).
The average temperature across the globe in 2017 was 0.84 degrees above the 20th century average of 13.9°C. 2017 marks the 41st consecutive year (since 1977) with global land and ocean temperatures at least nominally above the 20th-century average. The six warmest years on record for the planet have all occurred since 2010.
https://www.noaa.gov/news/noaa-2017-was-3rd-warmest-year-on-record-for-globe

4 CLIMATE CHANGE PROJECTIONS

Of importance to the project are the climatic patterns and weather extremes that might affect the facility directly or indirectly – specifically precipitation, snowfall, extreme temperatures and droughts. In order to evaluate the impact of these factors, the assessment will consider the existing climatic patterns and their evolution over time as global climate change manifests.

4.1 Current climate, existing hazards and extreme events

The Kingdom of Lesotho is located in the sub-tropics but owing to its location on the edge of a broad inland plateau and high altitude has a highly variable climate due to the confluence of climatic influences.

During summer, Lesotho is characterised by high temperatures and precipitation, with the opposite being true in winter due to the predominance of high pressure systems that bring about clear skies and dry air. Frost is common in winter, as are severe frontal storms with snow over the mountains. Spring and autumn are transitional and may exhibit characteristics of either winter or summer.

Precipitation patterns in Lesotho are described in the National Adaptation Plan of Action (LMS, 2007):

- The lowest average annual precipitation occurs in the Senqu River Valley (450 mm) and the highest in the north-eastern mountain zones (1300 mm).
- The amount of precipitation received is highly variable in both time and space resulting in common occurrence of both droughts and floods. High intensity rainfall often produces flash floods that accelerate soil erosion leading to high sediment loads in rivers.
- Snowfall occurs annually over the mountain tops and once every three years in the lowlands.

Between 1833 and 1900, very severe winters were observed in 18% of years, with some indication of a reduction in severity over time (Grab & Nash, 2009). Other significant heavy snowfalls were recorded in 1964, 1988, 1995 (LMS, 2007) and 2016 (NASA, 2018) (see Figure 3). The heavy snow storms cause drastic human problems in the form of cold and restriction of movement and access to the mountain communities. The proposed PV installation is located outside the snow zone however, and therefore likely to only be indirectly affected by snow – in the form of cold temperatures and increased energy demand.

Figure 3: Heavy snowfall over Lesotho - 27 July 2016 (NASA, 2018) – with location of the study site superimposed

According to descriptions provided by the Lesotho Meteorological Services (LMS) (LMS, 2018):

- Temperatures are highly variable, on diurnal, monthly and annual time scales, and are generally lower than those of other inland regions of similar latitude in larger landmasses of both north and southern hemispheres. This is partially due to the tapering of the African sub-continent and overall altitude of the country.
- Normal monthly winter minimum temperatures range from –6.3°C in the lowlands to 5.1°C in the highlands. However, extremes of monthly mean winter minimum temperatures of –10.7°C can be reached, and daily winter minimum temperatures can drop as low as -21°C. Sub-zero daily minimum temperatures can be reached even in summer both in the lowlands and in the highlands.
- Mean minimum temperatures of around 0°C are common in June, the coldest month, with the lowlands recording the monthly mean temperatures ranging from -3°C to -1°C in the lowlands and ranging from -8.5°C to –6°C in the highlands.
- January records the highest mean maximum temperatures throughout the country, ranging from 20°C in high altitudes to 32°C in the lowlands
- Mean annual temperature ranges from 15.2°C in the lowlands to 7°C in the highlands.

Lesotho experienced recurrent droughts in the 19th century with eleven of the droughts reported between 1802 and 1885 (LMS, 2007). Their impacts included famines, food shortages, disease epidemics, locust invasions and dust bowls. Long term records of the 19th and 20th century show occurrence of drought with a quasiperiodicity of nine in ten years up to 1978. The period 1979 to 1996 has experienced the highest incidence of drought in almost 200 years with the longest drought in the country's history lasting from April 1991 to October 1995 (LMS, 2007).

Droughts could have an indirect effect on the project as it significantly affects people's vulnerability, and the project would need to avoid exacerbating the situation by depriving people of livelihoods or access to water resources.

4.2 Climate change projections

Observational data obtained by the LMS for the period since 1980, and analysed for the Lesotho Water Security Assessment (World Bank, 2016), indicate that the variability in precipitation is high – for 67% of the time, rainfall will vary by 20% from the long-term average. This implies that climate change trends will be difficult to ascertain in respect of precipitation, given that data points are likely to remain within these bounds of current-day variability.

On the other hand, the same study found that both minimum and maximum temperatures have increased by 2°C between 1980 and 2003 (World Bank, 2016). This is corroborated by analysis of climate extremes such as number of frost days and growing season length. The higher temperatures will affect soil moisture availability, specifically during periods of below-average rainfall. This has implications for the highly erodible soils of the study area. Severe soil erosion would take place when heavy rainfall follows longer dry spells.

Climate change projections obtained from a range of Global Circulation Models agree in general terms that although average annual precipitation is not likely to change over time, temperatures will progressively increase by between 0.9 and 2.9°C by 2050 relative to the historical average

(World Bank, 2016). Unfortunately, the study did not detail the emissions scenarios used as model inputs.

4.3 Implications for the Ramarothole project

The observed trends confirm the general regional pattern of universally increasing temperature indices, and a possibility of decreased overall availability of moisture due to increasingly erratic rainfall and increased evaporation.

Projections of climate change continue the observed trend – confirmed temperature increases and uncertain changes in precipitation trends. Generally, any changes in precipitation values are overshadowed by present-day patterns of variability and swings between wetter and dryer periods.

The climatic changes will alter the functioning of the natural ecological systems, due to the higher temperatures and lower water availability. The effects will include increased desiccation, species migration, higher wind speeds, increased erosive effects from wind and runoff, etc.

5 IMPACT SCREENING

A scoping assessment was conducted as part of the environmental impact assessment process to identify issues for further investigation. The scoping exercise considered the aspects indicated above, and its findings indicate that a refined assessment is necessary to detail the understanding of some of the impacts of the facility on the social and biophysical environment. In contrast, no further assessment is required in respect of impacts on the facility, or to detail the expected greenhouse gas emissions from the installation.

5.1 Impacts on the facility

The facility's performance may be affected by increased temperatures and increased dust mobilisation that reduce the efficiency of the panels, and intense rainfall that threatens its physical integrity. Neither of these categories of effects are likely fatal flaws, and can be managed as part of the routine planning and management of the project. Appropriate site management such as erosion management through vegetation management and soil stabilisation will manage the risk sufficiently, as long as regular monitoring can ensure early detection of issues.

No further assessment is required in this respect, as long as the necessary mitigation is employed.

5.2 Impacts on the biophysical and social environment

Preliminary links between the power plant and its social and biophysical environment as related to drivers and effects of climate change have been identified. These assessed further in the next section, to determine a likely residual impact after mitigation.

5.3 Greenhouse Gas emissions mitigation

The project will contribute to the unconditional national GHG emissions mitigation target and have the added benefit of lower embodied emissions as compared to fossil fuel-based electricity generation options. The exact quantification of this contribution forms part of this full impact assessment.

6 IMPACT ASSESSMENT

6.1 Biophysical and social impacts

An assessment of the potential links between the construction and operation of the power plant, and its biophysical and social impacts, as contextualised by climate change, is provided below. Important inputs into the assessment are the two main climatic stressors that are expected to play the biggest role in future – water availability and increased temperatures.

6.1.1 Surface and groundwater

Table 3: Assessment of links between climate change and environmental effects on the project

Climate Change concerns	Relation to proposed development	Assessment of impacts	Mitigation options
Local water availability for humans, livestock and ecological requirements will come under pressure	Use of water (construction & operation) Obstructing human movement corridors giving access to water	Water is to be sourced from boreholes where feasible and sustainable – similar to where the surrounding communities get their water from. Alternatively, water will be trucked in from a municipal source. Approximately 150m^3/MW (or 3000 m^3 in total) of water is required for construction, and approximately 20m^3/year is required during operation. There is a natural spring in the area, to the north outside the project boundary (*refer to Figure 12: Simplified Land Use Map in the ESIA*), which is accessed very occasionally when conditions require supplementing of community boreholes. The project will slightly inconvenience one community in terms of access to the spring, but not cut off access completely.	Limit borehole abstraction to sustainable levels
Wetlands will degrade under drier, hotter climate regime	Destruction or sedimentation of wetlands and water sources (refer to *Soils and Agriculture*)	N/A (see related impact category)	N/A

6.1.2 Biodiversity

Climate Change concerns	Relation to proposed development	Assessment of impacts	Mitigation options
Increased pressure to find microclimatic refuge and surface water as grasslands and wetlands deteriorate due to desertification and degradation	Exclusion of wildlife and interruption of movement through extensive fencing Use of water (refer to *Surface and Groundwater*)	No sensitive habitat or ecological features were identified in the biodiversity screening process. The facility is therefore not an impediment to sensitive faunal movement.	Wildlife-friendly fencing, with ground-level openings of at least 150mm and no electrification of the lower section
Desertification will reduce carbon stored in biomass	Desertification and soil erosion (refer to *Soils and Agriculture*)	N/A (see related impact category)	N/A

6.1.3 Soils and agriculture

Climate Change concerns	Relation to proposed development	Assessment of impacts	Mitigation options
Progressive reduction in water availability and desertification that increases erodibility and threat of serious erosion when intense rainfall follows a period of drought	Localised disruption of run-off pattern (panel array, access road, cabling) Reduction in vegetation cover will have a negligible effect on the sequestration effect of natural biomass, and hence a negligible impact on the national GHG accounts.	The project site will be subject to increased intensity runoff due to the concentrating effect of the installed PV panels. This will increase the risk of soil erosion and the resultant sedimentation of local seep wetlands or non-perennial streams. Both these impacts are subject to the adequacy of mitigation measures in the form of soil cover and storm water management during construction and operation. It is important that the species selection for revegetation work remains sensitive to anticipated climatic conditions – i.e. groundcover and tree introduction must be drought and heat resistant.	Revegetation and monitoring of erosion must be included in the construction and operational management plans

Climate Change concerns	Relation to proposed development	Assessment of impacts	Mitigation options
Human vulnerability will increase due to threats to subsistence agriculture	Compensation to previous users of the agricultural lands	No active agriculture is present on the site due to due to the need for labour intensive irrigation. By implication, the site represents a community asset which could be brought into commission should the water availability improve (e.g. through water pumped from boreholes). Such livelihood alternatives are important contributors to making people less vulnerable to climate change. The sterilisation of the land through erection of PV panels therefore impacts on community resilience. By implication, the site lease / compensation plan needs to be adequately compensate the community for the loss of potential livelihood alternatives. Such calculations need to form part of the social assessment.	Since a contingency community asset is being sterilised for the ensuing 20 years or so, on-going livelihoods monitoring must check for decreased community resilience.

6.1.4 Heritage

Climate Change concerns	Relation to proposed development	Assessment of impacts	Mitigation options
Human vulnerability will increase in respect of traditional / historic agricultural practices and access to water	Historic / cultural connections to water resources (refer to *Surface and Groundwater*) Food security (refer to *Soils and Agriculture*)	N/A (see related impact category)	N/A

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6.1.5 Air quality and emissions

Climate Change concerns	Relation to proposed development	Assessment of impacts	Mitigation options
Use of fossil fuels will increase GHG emissions	Increased GHG emissions	The use of fossil fuels on site is inevitable, as construction equipment and vehicles typically run on liquid fuels. These emit various greenhouse gases, depending on the nature of the fuels, the equipment or machinery in use and the efficiency of use. The total GHG emissions footprint is therefore highly sensitive to operational and design parameters. Major construction activities will include basic earthworks (preparing access roads, laying of cabling, stormwater attenuation and preparation of foundations) and limited above-ground installations (powerlines and solar panel arrays). It is anticipated that construction traffic will consist of seven vehicles per hour, of which four will be heavy duty and three will be motor vehicles. The construction period duration is anticipated to be 9-11 months. Project traffic during operation will consist of an average of six vehicles per day of which one will be a heavy duty and five will be motor vehicles. Given this limited scale of the development, and duration of the construction phase, the total on-site (territorial) emissions contribution	Currently, the use of fossil fuels for manufacturing and transport is unavoidable, but it's contribution to global GHG emissions can be mitigated through the use of less carbon intensive alternatives and construction methods that reduce the overall needs for transportation and materials haulage. Construction activities must avoid the use of old or improperly functioning equipment that use fossil fuels in an inefficient manner or that release fugitive emissions. Site administration (e.g. site camp) can also be run off renewable energy sources as far as possible.

Climate Change concerns	Relation to proposed development	Assessment of impacts	Mitigation options
		can be assumed as insignificant relative to other GHG sources such as industrial facilities. Further quantification is therefore not necessary.	
Vehicle movement and construction activities will mobilise dust, which may be exacerbated by increased air temperature and drought conditions	Construction activities will affect human activities where dust is mobilised	Although the predominant wind direction for the site is East-North East, the strongest wind speeds are associated with wind from the West to North. Excessive dust generated on site will therefore be blown towards Sepechele, possibly leading to air quality concerns. Although wind speeds will increase as anticipated climatic changes take effect, the impact is likely to be limited to the construction period, meaning that longer-term climate changes are not a concern.	Appropriate road maintenance, activity staging and revegetation activities must be imposed to reduce the extent of bare surfaces or travel speeds on roads. The use of water for dust suppression must be considered in context of reduced water availability. (*Note that detailed mitigation options are evaluated under the Air Quality Specialist Assessment*)

6.1.6 Human vulnerability

Climate Change concerns	Relation to proposed development	Assessment of impacts	Mitigation options
Human vulnerability will increase in respect of agricultural practices and access to water, with secondary impacts on health and social support systems. This may be exacerbated by climate change-induced migration to less exposed areas such as what surrounds the project site.	Vulnerability will also be related to the availability of water resources (refer to *Surface and Groundwater*), and food security (refer to *Soils and Agriculture*)	As discussed under the *Surface and Groundwater*, and *Soils and Agriculture* sections, the resilience of the affected communities will be impacted on by the sterilisation of agricultural fields and potentially the reduction in water availability if borehole extraction exceeds natural recharge rates. The scale of this impact is, however, relative to	Vulnerable groups, such as those that will lose access to agricultural resources, should ideally be left more resilient by the project, but at least no worse off. In this regard on-going livelihoods monitoring must check for decreased

Climate Change concerns	Relation to proposed development	Assessment of impacts	Mitigation options
		the ability of the community to obtain water for irrigated agriculture in time of need.	community resilience.
Energy security will be affected by increased uncertainty in the hydropower sector	National energy security will be improved by increasing the solar power inputs into the national power grid	The 72MW installed capacity in the hydropower sector will be supplemented by the envisaged 20MW solar PV project. This will reduce the Kingdom's reliance on electricity imports from South Africa and the SAPP and hence improve the country's energy security and carbon footprint. It may therefore not directly affect the reliance on hydropower.	No mitigation required.

6.2 Global Greenhouse Gas emissions mitigation

Provisional calculations indicate that the project will contribute a significant portion of the unconditional national GHG emissions mitigation target, along with the added benefit of having lower embodied emissions as compared to fossil fuel-based electricity generation options.

Given a current national GHG emissions total of 4.17Mt CO_2eq, a 10% reduction in emissions (without adjusting for any future increases under a BAU scenario) will require 417kt CO_2eq to be offset through an improved emissions profile or emissions sequestration.

The project under scrutiny, being a solar PV installation, will itself have a negligible operational territorial emissions profile – i.e. within the project boundaries - and excluding emissions embodied in materials and transport to the site, the directly attributable GHG emissions will be close to zero. Emissions will be limited to maintenance activities that require energy other than what is available on site, such as liquid fuels for vehicles. When considering non-territorial emissions, it has been shown that the embodied emissions of a solar PV installation are relatively low, as compared to conventional coal, gas, bioenergy or hydropower facilities (Pehl, et al., 2017).

By implication, the use of solar radiation for electricity production, as comparted to the local SAPP grid, will result in an emissions reduction of roughly 47kt CO_2eq per year. This assumes a SAPP grid emissions factor of 0.98t CO_2eq/MWh (IGES, 2018) and a project output of 48 000 MWh per year. The project therefore contributes substantially to the national emissions reduction target as calculated above.

In addition, the project satisfies half of the national mitigation objective related to sourcing energy from solar power installations – the INDC specifies a target of 40MW to be sourced from solar by 2020 (MEM, 2015). This also fits in with the policy objective of promoting renewable energy systems across the country, as stated in the National Climate Change Policy (LMS, 2017).

7 IMPACT RATING

The impacts identified in the assessment above are consequently rated in terms of Extent, Duration, Intensity and Probability, as per the scheme depicted in Table 1. All impacts are rated from the perspective of the surrounding communities, a construction period of one year and for an assumed project lifespan of 25 years. Eight impacts are rated for significance (Table 4), and residual impact determined in anticipation of mitigation measures (Table 5).

Table 4: Impact Significance rating (without mitigation)

Impact	Extent	Duration	Intensity	Probability	Significance (Cumulative score)	
Water availability	2	3	2	1	-8	NEGATIVE MODERATE
Movement of animals	2	3	1	1	-7	NEGATIVE MODERATE
Soil erosion and sedimentation of water resources	2	3	1	2	-8	NEGATIVE MODERATE
Loss of agricultural land	1	3	1	4	-9	NEGATIVE MODERATE
GHG emissions	1	1	1	4	-7	NEGATIVE MODERATE
Dust mobilisation	2	1	1	4	-8	NEGATIVE MODERATE
Energy security	4	3	3	4	14	POSITIVE VERY HIGH
GHG mitigation	4	3	4	4	15	POSITIVE VERY HIGH

Table 5: Impact Significance rating (with mitigation)

Impact	Extent	Duration	Intensity	Probability	Significance (Cumulative score)	
Water availability	1	1	1	1	-4	NEGATIVE LOW
Movement of animals	1	1	1	1	-4	NEGATIVE LOW
Soil erosion and sedimentation of water resources	1	1	1	2	-5	NEGATIVE LOW
Loss of agricultural land	1	3	1	4	-9	NEGATIVE MODERATE
GHG emissions	1	1	1	4	-7	NEGATIVE MODERATE
Dust mobilisation	2	1	1	2	-6	NEGATIVE LOW
Energy security	4	3	3	4	14	POSITIVE VERY HIGH
GHG mitigation	4	3	4	4	15	POSITIVE VERY HIGH

The impact significance rating identifies that all but two impacts may be of 'Negative Moderate' significance, preceding mitigation. The remaining impacts, namely the effects on national energy security and GHG mitigation, are considered as 'Positive Very High'.

When reasonable mitigation measures are applied, the two impacts with definite probability, the loss in agricultural land and GHG emissions, remain as 'Negative Moderate'.

The loss of agricultural land, and the community resilience that it represents, must be mitigated through adequate compensation to the affected community members. GHG emissions can only be reduced to an extent, given the reliance on fossil fuels, but the impact is of limited severity, and hence not a serious concern.

8 CONCLUSION

The impact assessment indicates the following salient points:

- The project's contribution to the national GHG emissions mitigation will be significant – i.e. reduce national emissions – and will compensate for the small amount of emissions associated with the construction phase.
- The climatic trends and projections indicate that water availability and temperature stress are likely to affect the region in future, and these effects must be taken into account in the social impact assessment.

Of particular relevance are the following suggestions with regards to potential mitigation of the identified impacts:

- The vulnerability of people will increase in future, partially due to the loss of access to potential agricultural resources. Therefore, on-going livelihoods monitoring should be used as a check on the resilience of people who have lost access to alternative livelihood potential.
- The project can also look into co-use that can increase food security - e.g. an agreement with the locals on a grazing plan for vegetation management under the panels if the activities are compatible. It is recommended that ground cover is (re-) established to prevent erosion and dust.
- Soil erosion risk will increase due to the variability of rainfall combined with higher temperatures. Construction plans and operational runoff management must take this into consideration.

Uncertainties that remain in this assessment are:

- Water requirements for construction and operation will be limited, and no adverse impacts on the groundwater resource is expected. Exact quantification of the relative impact will only be possible with a groundwater resource audit though.
- The site lease / compensation plan needs to adequately compensate the community for the loss of potential livelihood alternatives. Such calculations need to form part of the social assessment.
- The dependencies of GHG emissions quantification preclude a formal assessment at this stage but given the limited construction activities and consequent low significance of on-site emissions, is deemed to not be required.

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