Specialist Climate Change Assessment of the Proposed Richards Bay Combined Cycle Power Plant (CCPP) Power Plant and Associated Infrastructure near Richards Bay, Kwazulu-Natal Province

Produced by Promethium Carbon
for Savannah Environmental (PTY) LTD
on behalf of Eskom

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EXECUTIVE SUMMARY

Eskom has proposed the development of a 3 000MW Combined Cycle Power Plant (CCPP) power plant near Richards Bay. The design of the proposed CCPP power plant enables it to operate in a range of generation modes to provide mid-merit supply to the national electricity grid. This specialist climate change assessment explores the potential greenhouse gas emission and climate change impact of the proposed power plant operating in these various modes. This study calculates the potential direct emissions from the combustion of fuel to generate electricity in the proposed power plant. These emissions from the project are interpreted in terms of their contribution to the national greenhouse gas inventory and global climate change. The emissions intensity of the proposed project is also compared against the alternative technologies and possible mitigation options as well as the baseline emissions of the national electricity grid.

The outcome of the analysis illustrates that the proposed CCPP power plant fired with natural gas is the least emissions intensive of the technology alternatives to provide mid-merit power. It is calculated to have an emissions intensity of 0.37 tonnes CO_2e per MWh. This intensity will position the proposed plant significantly below the emissions intensity for the national grid (historically and in the foreseeable future). Due to its scale, the proposed plant will still produce very large quantities of greenhouse gas emissions annually (4.6 million tonnes CO_2e). These emissions will contribute to anthropogenic climate change and its ensuing environmental impacts. The calculated significance of the power plant's impact on national emissions, and thus climate change, is high for an individual source, as it will account for as much as 1% of the South African greenhouse gas inventory. However, the greenhouse gas emissions from the individual source would not be linked, directly or indirectly, with any specific local environmental impacts as a consequence of climate change.

There are options to mitigate the carbon emissions from the proposed CCPP power plant, which include; switching to alternative biofuels and carbon capture and storage. It is advisable that the design of the project takes into account these options to enable emission reductions during the plant's operation so as to maintain a level of climate responsibility. There will still be residual risks of climate change even when mitigation options are implemented, as a consequence of the cumulative emissions from all other emitting sources. This may result in local environmental impacts for the Richards Bay area which could include increased year round temperatures and drier autumns and winters.

If the proposed CCPP power plant is operated as a load following plant it could play a role in enabling a greater uptake of renewable energy onto the South African grid. This would assist in decarbonising the national grid and reduce emissions within South Africa's national greenhouse gas inventory. This would contribute to the national commitment to mitigate global climate change. While the proposed CCPP power plant as a single source is likely to have a significant impact on the national greenhouse gas inventory it is concluded that it has sufficient potential to reduce its emissions and contribute positively to greater mitigation efforts through enabling the decarbonisation of the national electricity grid if operated as a load following plant.

DECLARATION OF INDEPENDENCE

Robbie Louw, Harmke Immink and Sam Vosper as the authors of this report, do hereby declare their independence as consultants appointed by Savannah Environmental (Pty) Ltd to undertake a climate change assessment for of the proposed Eskom East Coast Combined Cycle Gas Turbine Project, to be developed in Richards Bay. Other than fair remuneration for the work performed, the specialists have no personal, financial business or other interests in the project activity. The objectivity of the specialists is not compromised by any circumstances and the views expressed within the report are their own.

Robbie Louw

Harmke Immink

Sam Vosper

DETAILS OF SPECIALIST

Promethium Carbon

Promethium Carbon is a South African climate change and carbon advisory company group based in Johannesburg. With a vision to making a difference in climate change in Africa and a focus on technical expertise, our team of climate change professionals assists businesses ranging from small enterprises to multinational entities on their journey towards a low carbon economy. We also assist governments and government institutions in planning for the coming global carbon constrained environment. Through our participation on various working groups and standards boards, we have established ourselves as knowledge leaders in the climate space and act as trusted advisors to our clients.

Promethium Carbon has been active in the climate change and carbon management space since 2004. Our client base includes many of the international mining houses and industrial companies that are operating in and from South Africa. One of our clients was awarded the European Energy Risk Deal of the Year award in 2010 for a carbon credit commercial transaction that Promethium advised the client on. Promethium Carbon also received the Star Excellence Award in recognition of its outstanding contribution to Africa's Economic Growth and Development. This award was received in Abu Dhabi during the World Future Energy Summit 2014. Promethium was furthermore awarded with the Best Project Implementer award by the British High Commission in 2015.

An accurate carbon footprint forms the basis from which an organisation can plan its journey into the low carbon economy. The rules, according to which a carbon footprint is calculated, have been developed at a fast pace over a short number of years, and have reached a level of maturity. Promethium has calculated the carbon footprints and greenhouse gas inventories for numerous companies. Through these carbon footprints and strategy documents Promethium Carbon has helped companies to understand their climate change impacts as well as the associated risks.

Robbie Louw

Robbie is the founder and director of Promethium Carbon. He has over 10 years of experience in the climate change industry. His experience over a period of 28 years covers the chemical, mining, minerals process and energy fields, in which he was involved in R&D, project, operational and management levels.

Robbie's experience in climate change includes but is not limited to:

- Carbon foot printing: He has extensive experience in carbon foot printing. The team under his leadership has performed carbon footprint calculations for major international corporations operating complex businesses in multiple jurisdictions and on multiple continents.

- Climate strategy development: He has developed carbon and climate change strategies for major international corporations.
- Climate change impact and risk assessments: He has developed climate change risk assessments for various companies and projects.
- Project development: He has extensive experience in project development in the energy, chemical and mining industries. This covers the scope from project identification, feasibility studies to project implementation. Some examples include carbon sequestration projects focussed on the restoration of impacted grasslands and mining impacted land and greenhouse gas mitigation projects in many industries including farming, mine land restoration and bio-energy production.
- Carbon trading systems: He is the lead author of numerous publications on the design of a potential carbon trading system for South Africa.

Harmke Immink

Harmke is a Director at Promethium Carbon. Her 12 years of climate change expertise is developed from environmental life cycle assessments (LCA), environmental audits and technical performance evaluation. She has a Masters degree in Environmental Measurement Techniques (Sweden), and gained experience across industry sectors through a variety of technical surveys and industry roadmaps.

Harmke's experience in climate change includes but is not limited to:

- South African representative for ISO technical committee 207 on GHG standards, including eco-labelling and carbon footprint of products;
- Technical assessor for SANAS accredited: ISO 14065 GHG validation and verification;
- Part of the World Resource Institute technical development team for the GHG Protocol standard on accounting for goals and targets;
- Climate change related services include GHG baseline evaluations, a survey for practical sustainable development indicators for Clean Development Mechanism (CDM) projects, four new or revised methodologies, twelve successful registration of CDM projects as well as three projects assisted with issuance of carbon credits;
- Standardised Baseline Calculations for Grid Emission Factors in Kenya and South Africa;
- Climate change adaptation projects for mining clients, focused on community vulnerabilities and strategically linking with social responsibility;
- Carbon Disclosure Projects (CDP) is a global initiative to collect and distribute high quality information that motivates investors, corporations and governments to take action in the attempt to mitigate climate change. Promethium Carbon CDP clients consistently are in both the top ten disclosure as well as the performance leadership index since 2007; and
- Project leader for the Private Sector Energy Efficiency audits through the NBI.

Sam Vosper

Sam holds the following degrees: Bachelor of Science (Rhodes University), Bachelor of Science (Hons) (Rhodes University), MPhil Environmental Policy (University of Cambridge). He has completed postgraduate courses in: Energy & Climate Change, Environmental Economics, Climate Change Policy, Policy Assessment & Evaluation, International Environmental Law, Ecological Modelling, Climate Change Adaptability and General Linear Models. Sam's undergraduate studies included: Environmental Science, Mathematics, Mathematical Statistics and Economics. Sam currently works as an environmental consultant specialising in services which include:

- Carbon footprints and Water footprints;
- Researching for South Africa's Third National Communication to the UNFCCC;
- Researching and drafting a measuring, reporting and verification policy for Swaziland to apply to their nationally determined contributions; and
- Energy efficiency and energy management studies.

Sam has previously executed a research project on water supply and catchment sustainability for the town of Mussoorie in the Himalayan foothills. The project involved amalgamating and mapping data on; forest composition, climate change, infrastructural upgrades and land use.

The above listed authors have all worked on previous climate change assessments for power generation projects such as coal fired power plants.

ABBREVIATIONS

CCGT	Combined cycle gas turbine
CCPP	Combined Cycle Power Plant
CCS	Carbon capture and storage
CFB	Circulating fluidised bed
CO_2e	Carbon dioxide equivalent
DEFRA	Department for Environment, Food and Rural Affairs of the United Kingdom
GHG	Greenhouse gas
GJ	Giga Joules – measure of energy 10^9 Joules
HRSG	Heat recovery steam generator
IRP	Integrated Resource Plan
kV	kilo Volt
LNG	Liquified natural gas
MWh	Megawatt hours (unit of measurement for electricity)
OCGT	Open cycle gas turbine
PSH	Pumped-storage hydroelectricity
SANEDI	South African National Energy Development Institute

1. INTRODUCTION

Eskom propose to develop a 3000MW Combined Cycle Power Plant (CCPP) near Richards Bay. The project aims to provide new mid-merit capacity for South Africa. Its location in KwaZulu-Natal will overcome some transmission losses and reduce additional investment in transmission.

The Richards Bay Combined Cycle Power Plant (CCPP) involves the construction of a gas-fired power station which will provide mid-merit power supply to the electricity grid. The weekly mid-merit power supply will be between a range of 20% to 70% of the total electricity supply produced by the Richards Bay CCPP. The power station will be operated on natural gas, with diesel as a back-up fuel. The natural gas is to be supplied by potential gas suppliers via a gas pipeline to the CCPP from the supply take-off point at the Richards Bay Harbour. The Liquefied Natural Gas (LNG) terminal infrastructure at the port and the gas supply pipeline to the boundary fence of the Richards Bay CCPP does not form part of the scope of this assessment as this project focuses only on the footprint activities inside Eskom's boundary fence on site 1D of the Richards Bay Industrial Development Zone (IDZ).

In accordance with the relevant regulations, an Environmental Impact Assessment process must be completed before project development can proceed. In addition to the Environmental Impact Assessment, Promethium Carbon has been appointed to undertake a specialist climate change assessment of the project. This involves assessing the project's prospective contribution to climate change through the emission of greenhouse gases (GHGs) such as carbon dioxide (CO_2).

A power plant's contribution to global climate change is dependent on the greenhouse gas emissions produced by the plant. However, the greenhouse gas emissions from any individual source cannot be attributed, directly or indirectly, with any specific environmental impacts as a consequence of climate change. This assessment focuses on exploring the greenhouse gas emissions and consequent climate change impacts of the respective alternative combustion technologies and mitigation options available to the project developer.

This approach is aligned with the principles of the National Environmental Management Act 1998 (as amended) as it seeks to provide the project developer with the best possible information to evaluate the project's environmental sustainability and impact. For each technology alternative and mitigation option considered the project development would include the construction of access roads, storage facilities, water infrastructure, a power line and a substation.

The broad terms of reference and scope of work for this specialist climate change assessment include the following:

1) Calculating the operational carbon footprint of the project with respect to:
   - Direct emissions from fuel combustion;
2) Analysing the project alternatives with regards to:
   - Pumped storage hydroelectricity;
   - Open cycle gas turbines; and
   - The use of diesel as a back-up fuel.
3) Reviewing emissions mitigation options with regards to:
   - Fuel options such as biogas and biodiesel; and
   - Carbon capture and storage.
4) Conducting an impact assessment of the project, its alternatives and mitigation options by:
   - Considering its contribution to the national emissions inventory and the onset of global anthropogenic climate change;
   - Comparing it against the current Eskom baseline with consideration of impacts on the future baseline; and
   - Exploring the potential climate change impacts faced by the Richards Bay area.
5) Assessing any GHG emission management activities for the plant's operations.

2. RECEIVING ENVIRONMENT

Richards Bay is located on the northern coast of KwaZulu-Natal, 170km north of Durban. To date the Richards Bay port has served as an important export point. Consequently, the harbour area has become densely developed with a dispersed rural settlement beyond the city centre. The local municipality has established an Industrial Development Zone (IDZ) in Richards Bay to support the development of an export oriented, sustainable business environment. This necessitates the strengthening of the electricity supply system.

The electricity generation environment in South Africa is currently dominated by emission intensive coal fired base load technologies. Increased load following technologies such as CCPP enable a greater uptake of variable renewable technologies such as wind and solar. This will help to decarbonise South Africa's currently highly carbon intensive grid. The burning of natural gas in CCGTs may also support the government's energy objective of diversifying South Africa's energy mix and enabling the development of new industry around the new feedstock.

South Africa's Long Term Adaptation Scenarios project that, as a consequence of climate change, the Pongola-Umzimkulu hydrological zone, which covers most of KwaZulu-Natal, is likely to experience extreme warming beyond the natural temperature variability. Reductions in rainfall are also projected for the autumn and winter months particularly. These climatic changes are likely to have significant impacts on the biomes of the Richards Bay region as well as human activities such as agriculture.

However, the greenhouse gas emissions from the Eskom CCPP project cannot be directly attributed to any specific climatic changes and cannot be directly linked to any local environmental impacts as a consequence. Despite this, it is still important to have considered the context of the receiving environment for the power plant.

A project site of approximately 71ha has been identified within Phase 1D of the Richards Bay IDZ as the preferred site for the development of the CCPP power plant.

3. METHODOLOGY

3.1 Estimating Greenhouse Gas Emissions

The carbon footprints presented in this assessment have been guided by the ISO/SANS 14064-1 standard. This standard specifies principles and requirements at the organisation level for the quantification and reporting of historical figures of greenhouse gas emissions and removals. Requirements for the design, development, management, reporting and verification of an organisation's greenhouse gas inventory are also included in the standard. The principles of this standard have been applied in this analysis at a project level to the calculation of the future greenhouse gas emissions of the prospective project.

The basic principles of SANS 14064-1 aim to ensure that the greenhouse gas information presented within a carbon footprint is a true and fair account. These principles include:

RELEVANCE:	by selecting all the greenhouse gas sources, greenhouse gas sinks, greenhouse gas reservoirs, data and methodologies that are appropriate to the needs of the intended user.
COMPLETENESS:	by including all the greenhouse gas emissions and removals relevant to the company.
CONSISTENCY:	to enable meaningful comparisons to be made with other greenhouse gas related information.
ACCURACY:	by reducing bias and uncertainties as far as is practical.
TRANSPARENCY:	by disclosing sufficient and appropriate greenhouse gas related information to allow intended users to make decisions with reasonable confidence.

Following the SANS 14064-1, the carbon footprint of the proposed power plant’s direct combustion emissions was developed through the following process:

- Setting the boundaries of analysis;
- Identifying the greenhouse gas sources inside the boundary;
- Establishing the quantification method that will be applied;

- Selecting or developing greenhouse emission and removal factors; and
- Calculating the greenhouse gas emissions.

The Greenhouse Gas Protocol's Corporate Accounting and Reporting Standard was also used in addition to the SANS 14064-1 standard as a guide in the calculation of the carbon footprint presented in this study. Further details of the boundaries and emissions factors are presented in the subsequent sections of the report.

3.2 Climate Change Impact of Greenhouse Gas Emissions

The EIA reporting requirements, listed below, set out the criteria to describe and assess the environmental impact. It is these criteria that are used to assess the climate change impacts associated with the greenhouse gas emissions from the proposed Eskom CCPP Project in terms of their contribution to the national greenhouse gas inventory.

Nature: a description of what causes the effect, what will be affected and how it will be affected.
Extent: an indication of whether the impact will be local (limited to the immediate area or site of development) or regional, and a value between 1 and 5 will be assigned as appropriate (with 1 being low and 5 being high).
Duration: an indication of the lifetime of the impact quantified on a scale from 1-5. Impacts with durations that are; very short (0–1 years) are assigned a score of 1, short (2-5 years) are assigned a score of 2, medium-term (5–15 years) are assigned a score of 3, long term (> 15 years) are assigned a score of 4 or permanent are assigned a score of 5.
Magnitude: an indication of the consequences of the effect quantified on a scale from 0-10. A score of 0 implies the impact is small, 2 is minor, 4 is low and will cause a slight impact, 6 is moderate, 8 is high with sizable changes, and 10 is very high resulting drastic changes.
Probability: an indication of the likelihood of the impact actually occurring estimated on a scale of 1–5. A score of 1 implies that the impact is very improbable, 2 is improbable, 3 is probable, 4 is highly probable and 5 is definite with the impact occurring regardless of any prevention measures.
Significance: a weighting based on a synthesis of the characteristics described above and can be assessed as low (< 30 points), medium (30-60 points) or high (> 60 points). The significance points are calculated as: $S = (E + D + M) \times P$.

The status of the impact will be described as; positive, negative or neutral. Additional details will also be provided on the degree to which the impact can be reversed and the degree to which the impact may cause irreplaceable loss of resources. The extent to which the impact can be mitigated will also be highlighted.

3.3 Contextualising Impact of Project emissions

The greenhouse gas emissions and climate change impacts of the project case are evaluated on several levels. The emissions and impacts are firstly compared against the technological alternatives to provide mid-merit power. Secondly, the emissions and impacts of the project case are contrasted against a set of possible mitigation options. The emissions from the project case are also considered within the context of South Africa's national inventory and trajectory for the country's greenhouse gas emissions. Lastly the potential local impacts of climate change for the Richards Bay area are also considered.

4. PROJECT DESCRIPTION

The proposed design of the project is a 3000MW combined cycle gas turbine power plant with either a dry air cooled condenser or once through cooling technology. The proposed CCPP project aims to provide new mid-merit (load factor up to 48%) and electricity generation capacity for South Africa.

The main infrastructure associated with the facility includes the following:

- Gas turbines for the generation of electricity through the use of natural gas or diesel (back-up resource).
- Heat recovery steam generators (HRSG) to capture heat from high temperature exhaust gases to produce high temperature and high-pressure dry steam to be utilised in the steam turbines.
- Steam turbines for the generation of additional electricity through the use of dry steam generated by the HRSG.
- Bypass stacks associated with each gas turbine.
- Dirty Water Retention Dams.
- Exhaust stacks for the discharge of combustion gases into the atmosphere.
- A water treatment plant for the treatment of potable water and the production of demineralised water (for steam generation).
- Water pipelines and water tanks to transport and store water of both industrial quality and potable quality (to be supplied by the Local Municipality).
- Dry-cooled system consisting of air-cooled condenser fans situated in fan banks.
- Closed Fin-fan coolers to cool lubrication oil for the gas and steam turbines.
- A gas pipeline and a gas pipeline supply conditioning process facility for the conditioning and measuring of the natural gas prior to being supplied to the gas turbines. It must be noted however that the environmental permitting processes for the gas pipeline construction and operation will be undertaken under a separate EIA Process
- Diesel off-loading facility and storage tanks.
- Ancillary infrastructure including access roads, warehousing, buildings, access control facilities and workshop area, storage facilities, emergency back-up

generators, firefighting systems, laydown areas and 132kV and 400kV switchyards.
- A power line to connect the Richards Bay CCPP to the national grid for the evacuation of the generated electricity. It must be noted however that the due environmental permitting processes for the development of the power line component are being undertaken under a separate EIA Process.

The plant will be able to operate at moderate load factors (48%) as a mid-merit plant which would provide load following capability to the electricity grid. It would even be able to operate at much higher load factors as a baseload plant where it would generate electricity more continuously to meet the base demands. The choice of operation mode for the plant is therefore determined by economics rather than technological design. It is unlikely that the plant when fuelled with natural gas the electricity produced by the plant would be cost competitive with base load coal fired generation. Therefore, it is likely that the plant will perform predominantly as a mid-merit power plant.

The increased load following capability from the mid-merit plant will provide an enabling environment for the uptake of renewable generation technologies such as wind and solar. In doing so the project may be able to assist in decarbonising the South African electricity grid.

The proposed CCPP plant will be fuelled with piped natural gas or liquefied natural gas (LNG). It intends to take advantage of the large natural gas discoveries in the Rovuma Basin in Mozambique. This reserve presents a reasonably priced regional gas resource that could be transported to the Richards Bay area via pipeline or ship as LNG. This may support the government’s objective to diversify South Africa’s energy mix and stimulate new industry around the feedstock. It has been indicated that the plant will be fuelled with diesel, as a backup, when natural gas is unavailable.

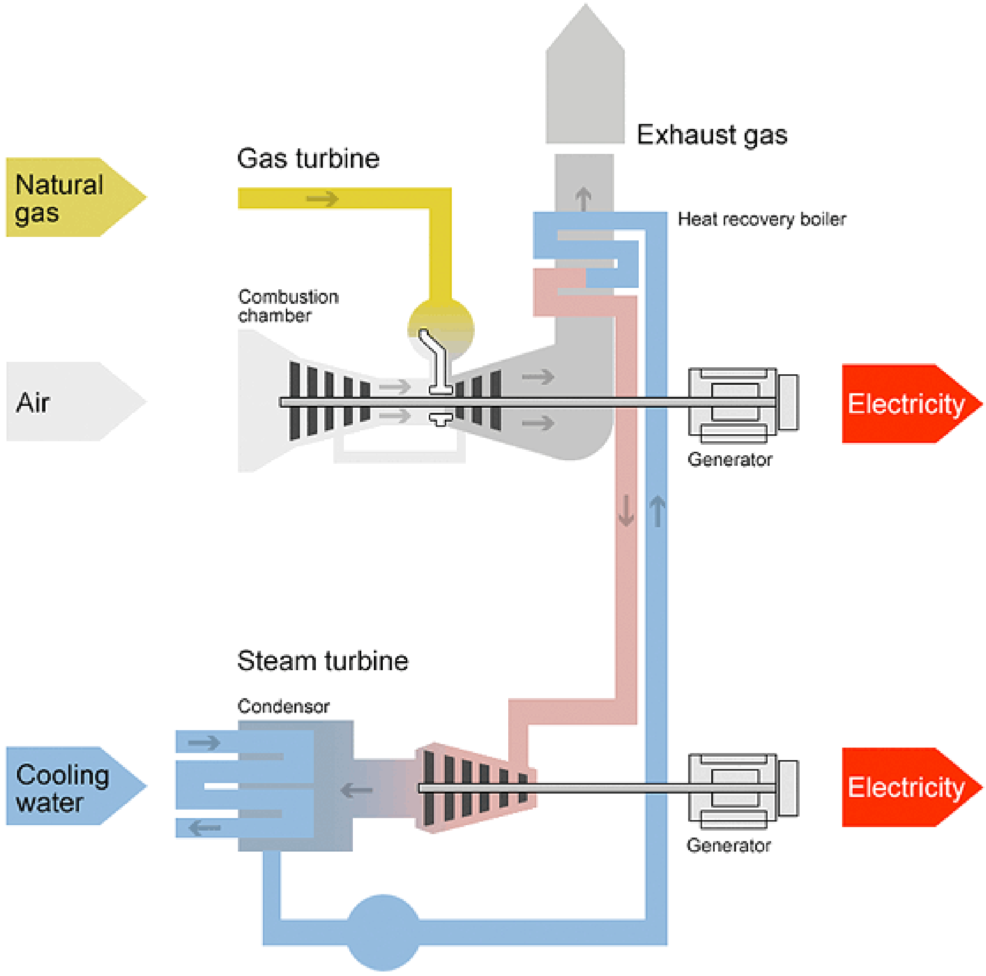

Figure 1: Schematic diagram of a combined cycle gas turbine.

The plant is proposed to be developed in four 750MW strings. Each string will be configured as two gas turbines, of 250MW each, and one steam turbine of 250MW. This configuration is expected to yield a 56% efficiency factor when fired with natural gas. As illustrated in Figure 1, the gas turbine combusts fuel mixed with compressed air to produce a high temperature combustion gas which spins the turbine blades. These spinning blades drive a generator which converts the energy into electricity. The exhaust heat from the gas turbine is channelled into a Heat Recovery Steam Generator (HRSG). The exhaust heat is captured to produce a high pressure and temperature steam. This steam is used in the steam turbine where the energy is again converted to electricity.

The exhaust stack for the combustion gasses from the HRSG is expected to be 40-60m tall. A condenser then converts the exhaust steam from the steam turbine back into water through a cooling process. This may be a dry air cooled technology which consists of a system of fans. Once-through cooling is also an option depending on the technical viability.

After some initial phase of site screening, Site 7, indicated in Figure 2, has been identified as the preferred site for the development of the Eskom CCPP power plant.

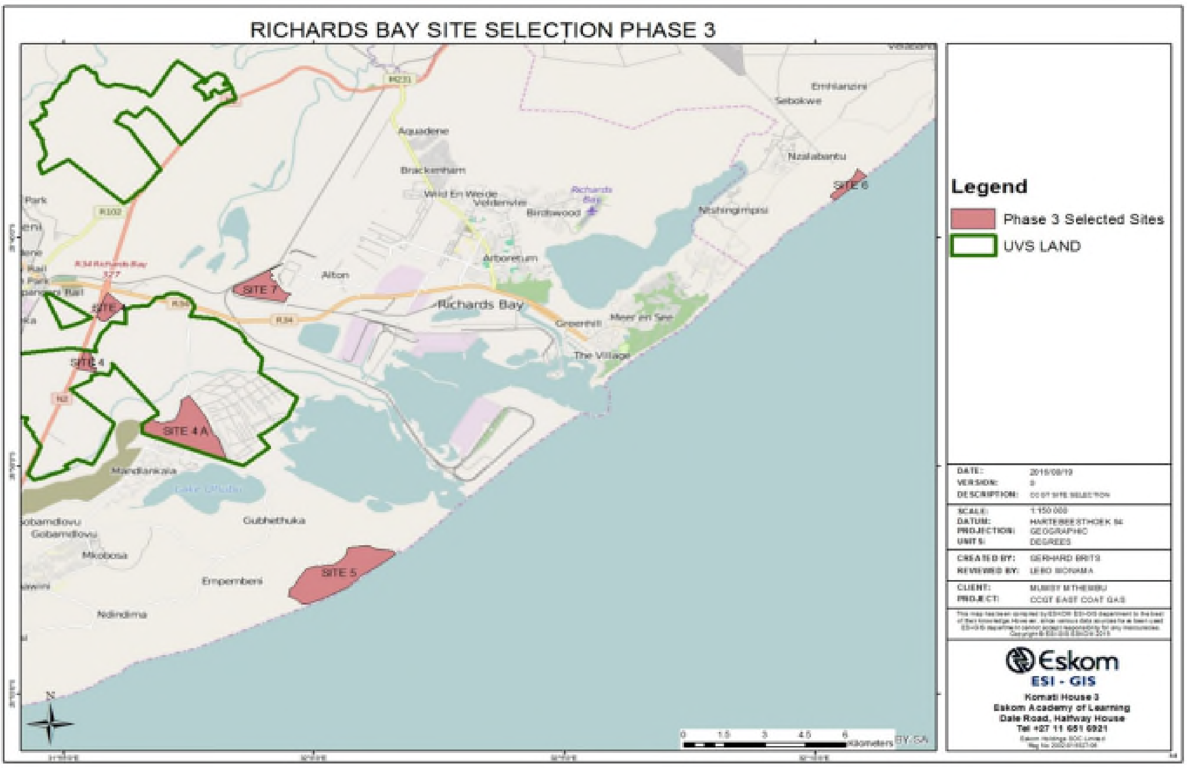

Figure 2: Proposed site for proposed Eskom CCPP Project.

The high quality water required for the system present a number of infrastructural requirements for the plant. These include a water pipeline, water storage tank and water treatment plant and waste water pond. Similarly, a process facility to condition and meter the supplied natural gas will be required. This conditioning will take place prior to the natural gas being supplied to the gas turbine. As diesel will be used as a back-up fuel a diesel offloading and storage facility is also planned.

In addition, the project will include; access roads, administrative buildings, warehouses, chemical storage facilities, emergency back-up generators and a 132kV and 400kV switchyard.

4.1 Setting the Boundaries of Climate Change Impact Analysis

While the ISO/SANS 14064-1 standard sets the boundary of analysis for a company based on an equity share or operational control approach the emissions calculations for the proposed Eskom CCPP Project's construction and operation are applied based on a project boundary. As with most fossil fuel based electricity generation, majority of the total greenhouse gas emissions calculated for the lifecycle of a combined cycle gas turbine can be attributed to the plant's direct combustion emissions (Spath & Mann, 2000). The carbon footprint presented in this study thus focuses on the direct operational emissions from fuel combustion.

4.2 Emission Factors

It is important that the emission factors used in carbon footprint calculations are appropriate for the local context and relevant to the technology being assessed. Local emission factors, such as the grid emission factor, have been sourced from the reports of local entities such as Eskom as it is the main electricity generator of the country. Recognised emission factors have also been sourced in South Africa's Draft Technical Guidelines for Monitoring, Reporting and Verification of Greenhouse Gas Emission by Industry which is based on Intergovernmental Panel on Climate Change's 2006 reporting guidance document.

Emission factors have also been sourced from a number of other appropriate entities, including the UK's Department for Environment, Food and Rural Affairs (DEFRA). Annual resources are published by DEFRA to assist with company level reporting on greenhouse gas emissions. This assessment makes use of the DEFRA resource published in 2016. It is assumed that these emission factors are representative of the activity data supplied for the project.

A detailed list of the emission factors and other factors used in the calculation of the carbon footprints is summarised in Table 1. These emissions factors are presented in tonnes of carbon dioxide equivalent (tonne CO_2e) and considers the global warming potential of all emitted greenhouse gasses including; carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O).

Table 1: Summary of emissions factors and key values in the carbon footprint of the proposed Eskom CCPP Project.

Emissions Factors and Key Values			
Name	**Value**	**Unit**	**Source**
Emission factor of natural gas	2.715	tonne CO_2e / tonne	DEFRA (2016)
Emission factor of diesel	3.19	tonne CO_2e / tonne	DEFRA (2016)
Emission factor of biogas	0.00195	tonne CO_2e / tonne	DEFRA (2016)
Emission factor of biodiesel	0.02227	tonne CO_2e / tonne	DEFRA (2016)
Natural gas net calorific value	47.82	GJ / tonne	DEFRA (2016)
Diesel net calorific value	42.92	GJ / tonne	DEFRA (2016)

Emissions Factors and Key Values			
Name	**Value**	**Unit**	**Source**
Biogas net calorific value	30	GJ / tonne	DEFRA (2016)
Biodiesel net calorific value	37	GJ / tonne	DEFRA (2016)
Net Plant efficiency (Nat Gas CCPP)	0.56	%	Eskom Design Document
Net Plant efficiency (Diesel CCPP)	0.54	%	Eskom Design Document
Net Plant efficiency (OCGT)	0.33	%	Eskom Design Document
Availability factor	0.48	%	Eskom Design Document
Pumped storage efficiency	0.6	%	IRP 2017
Grid emissions factor	0.9624	tonne CO_2e / MWh	Promethium Carbon Calculation
Project gross electricity produced	12698496	MWhs / Year	Eskom Design Document
Project parasitic load	277516.8	MWhs / Year	Eskom Design Document
Project net exported electricity	12420979.2	MWhs / Year	Eskom Design Document
Carbon tax effective rate	48	R / tonne CO_2e	National Treasury (2015)

4.3 Assumptions and Limitations

This report has been developed based upon the assumptions of the proposed modes of operation of the proposed Eskom CCPP power plant, as set out in the project design documents. Even though the CCPP power plant is intended to be operated as mid-merit plant, the proposed technology offer many operating possibilities. This includes operating as a peaking plant to supply shortfalls in supply, a mid-merit plant to provide load following capability or a baseload plant to generate electricity more continuously to meet the base demands. The report has been developed for the case where the plant is used as a mid-merit plant.

The only significant limitation for the report was the limited information that was available to calculate the greenhouse gas emissions associated with the construction of the proposed Eskom CCPP power plant. However, this limitation has been for the most part addressed as with most fossil fuel based electricity generation, majority of the total greenhouse gas emissions calculated for the lifecycle of a combined cycle gas turbine can be attributed to the plant's direct combustion emissions (Spath & Mann, 2000). This study thus focuses on quantifying and assessing the direct operational emissions from fuel combustion for the proposed Eskom CCPP power plant.

5. TECHNOLOGICAL PROJECT ALTERNATIVES

The plant is being designed to operate as a mid-merit dispatch plant. The authors of this report however note that the pant can be operated as in a range of modes such as, peaking, mid-merit and baseload. the performance of the plant will be compared against the alternatives for mid-merit plant.

Information on the alternative technologies considered have be drawn from the Integrated Resource Plan (IRP) released in 2016.

5.1 Open Cycle Gas Turbine

As described above an OCGT functions in a similar way as a CCPP except that the exhaust gas from the gas turbine is not used to power a steam turbine and generate additional electricity. The exhaust heat is simply emitted as waste heat and thus the plant has a lower energy efficiency than a CCPP plant. While these plants can run at low load factors and supply peaking power they can also be run at higher load factors and serve as mid-merit capacity. However, based on the efficiency of these plants and the cost of diesel the electricity produced is not likely to be cost competitive with natural gas options.

5.2 Diesel fuel in Combined Cycle Gas Turbine

Similarly, it has been mentioned that a combined cycle gas turbine can be set up to burn a variety of fuels, including diesel. A CCPP plant fuelled with diesel can provided mid-merit capacity if operated at higher load factors than those required for peaking capacity. In this case, the plant would operate the same as a mid-merit CCPP plant fuelled with natural gas although the fuel costs are likely to be higher.

5.3 Coal

Coal fired power plants such as pulverised fuel or circulating fluidised bed (CFB) plants are able to supply mid-merit capacity by adjusting their power outputs during a day to perform a load following function. While coal is the fuel with the lowest cost these plants typically are the most emissions intensive. These plants are also less efficient when operating at sub-optimal load factors.

6. MITIGATION OPTIONS

The mitigation options presented here are not listed within the scoping design documents for the project. However, they are mitigation options that could be considered for future inclusion within the generation facility. Some mitigation options, such as carbon capture and storage, have also been drawn from the related IRP documents with others being mentioned for completeness sake.

6.1 Alternatives

6.1.1 Biogas or Biodiesel

As mentioned previously a combined cycle gas turbine can be calibrated to burn a variety of fuels. This would include fuels such as biogas where the methane content is similar to that of natural gas. Biogas can be produced from a number of different sources including; landfill gas, agricultural waste, waste water and synthetic gas from wood biomass. Similarly, biodiesel can be used to fuel a CCPP power plant as a substitute for mineral diesel. The emissions factors for these fuels are significantly lower than those of their fossil fuel equivalents, as they only account for the nitrous oxide and methane emitted during combustion as it is assumed that the CO_2 is re-sequestered in the growing of the fuel.

6.1.2 Carbon Capture and Storage

The South African National Energy Development Institute (SANEDI) has established a centre for carbon capture and storage (CCS). The Centre has developed a roadmap for the ultimate commercialisation of carbon capture and storage by 2025. Making provisions for the future addition of carbon capture and storage technologies to new fossil fuel power plants which would be an advisable prospective for project developers.

The proposed CCPP power plant in Richards Bay is located in close proximity to two geological storage sites for captured CO_2. These sites are the Durban-Zululand onshore and offshore saline aquifers. The CCS modelling scenarios conducted to date prioritise the Durban-Zululand basins as some of the most suitable sites for the storage of CO_2. The location of the proposed CCPP power plant will minimise the costs associated with transporting any captured CO_2 between the plant and the storage site. Refer to Figure 3 below for an illustration of the possible geological storage locations in South Africa.

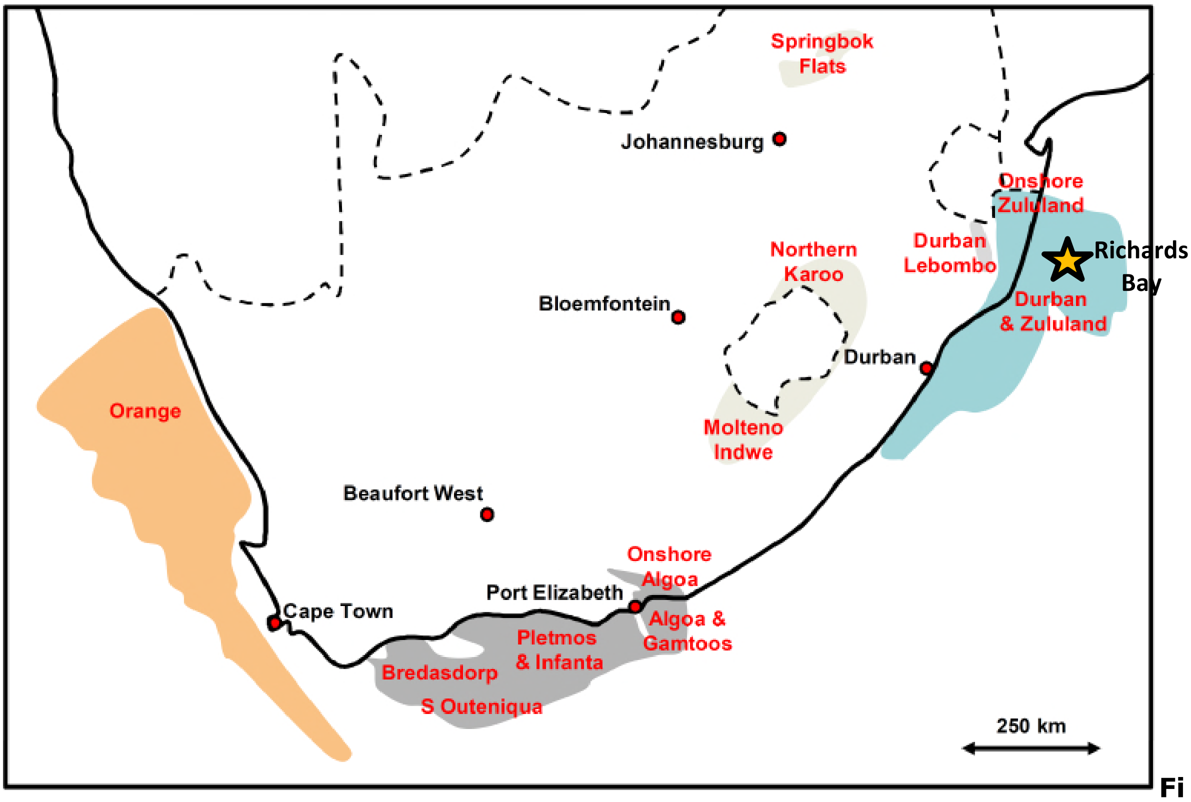

Figure 3: Map of possible geological storage locations in South Africa (Parsons and Brinkerhoff, 2013).

6.2 Technology Option Costs

A summary of the costs of the above discussed technology options for mid-merit electricity generation is presented in Table 2. These figures were produced for the 2016 Integrated Energy Plan. Similarly, the fuel costs are presented in Table 3.

Table 2: Comparison of the capital and operating costs of the assessed combustion technologies, adapted from Electric Power Research Institute (EPRI) (2015).

	Costs		
Technology	Capital cost	Fixed Operation and Maintenance cost	Variable Operation and Maintenance (ZAR/MWh)
OCGT	R 7 472/kW	R 147/kWh per year	R 2.2/MWh
CCPP	R 8 205/kW	R 151/kWh per year	R 20/MWh
CCPP with CCS	R 18 030/kW	R 359/kWh per year	R 31.1/MWh
Pulverised Coal	R 32 420/kW	R 845/kWh per year	R 73.1/MWh
Circulating Fluidised bed	R 33 263/kW	R 463/kWh per year	R 158.2/MWh

Table 3: Comparison of the fuel costs for natural gas and diesel based on Eskom fuel expenditure and gas prices in the US and Japan in 2016.

	Fuel Type		
	Natural Gas	Diesel	Coal
Costs (2016 Rand)	R 40 - R 90/GJ	R 193/GJ	R 25/GJ

7 PROJECT IMPACTS

A power plant's greenhouse gas emissions inherently determine its contribution to the onset of global climate change. As such a carbon footprint of a power plant can help to inform the consequent climate change impact of the project and its comparability to other technologies or baselines.

7.1 Impact of Project Emissions for National Inventory and Climate Change

The Eskom CCPP power plant will have different operational frequencies depending on which mode of operation it performs. In the design case, the plant will be operated as a mid-merit dispatch plant. This would give the pant an average estimated load factor of 48%.

As each MWh of electricity generated by the gas fuelled CCPP plant will produce the same quantity of carbon emissions (emission factor) the longer durations of operation will result in larger quantities of emissions being produced per year. The emission factor for the proposed CCPP power plant and the annual emissions for each operational mode is summarised in Table 4.

Table 4: Summary of the emission factors and annual emissions of the proposed Eskom CCPP power plant for its different operation modes.

Emission factors	
Annual emissions	4 634 758 tons
Emissions factor	0.3731 tons CO_2e/MWh

When fired with natural gas the CCPP power plant has a calculated emissions intensity of **0.37** tonnes CO_2e per MWh. It can be seen in Table 4 that as the plant is run more frequently to perform different function the annual emissions increase proportionally.

It is estimated that the annual carbon emissions from direct fuel combustion for the proposed Eskom CCPP project will be 4.6 million tonnes CO_2e per year. Over the assumed 30 year lifetime of the plant this equates to the emission of tens to hundreds of millions of tonnes of CO_2e into the atmosphere.

In terms of South Africa's most recent greenhouse gas inventory, the annual emissions of the proposed CCPP power plant would account **0.85%** when operated as a mid-merit plant. Should the plant however be operated as a baseload plant, it will contribute **1.69%** to the national emissions each year.

South Africa has committed, through the Paris Agreement in 2015, to a Peak Plateau and Decline (PPD) trajectory for its national emissions up to 2050. Depending on the mode of operation the national emissions from the project would account for **1.1%** of the emissions in 2050, as based on the upper limit of PPD. From this perspective the power plant as an individual source will make a large impact on the national inventory.

Climate change is a global phenomenon which is caused by collective greenhouse gas emissions from all the world's sources. As an isolated source, the greenhouse gas emissions from the proposed power plant alone will not significantly impact global climate change. The global and collective nature of climate change also makes it impossible to link the emissions from the power station to any particular climate change effects. However, in the interest of addressing the issue, each actor can take on an individual responsibility through minimising its negative emissions contributions. Thus, the project's environmental impact can be understood as its contribution to the national greenhouse gas emissions as shown in Table 5.

As the emissions from the proposed CCPP plant will significantly contribute to the national greenhouse gas inventory, the extent of the project's greenhouse emissions are considered to be very large (national). The duration of the impact of the greenhouse gas emissions is considered as effectively permanent as the greenhouse gas emissions produced are assumed to remain in the atmosphere for 100 years. As a single source, the proposed CCPP power plant's relatively large contribution to national emissions classify its impact as low . The combustion of natural gas will definitely produce carbon emissions and it is certain that these emissions will contribute to the onset of global climate change. From these parameters the significance score for the project is calculated to be high (>60). As the emitted greenhouse gases are assumed to remain in the atmosphere for such long durations the impact is effectively irreversible with the effects of climate change often resulting in the irreversible loss of resources.

Table 5: Summary of the climate change impacts of the estimated greenhouse gas emissions from the proposed Eskom CCPP Project.

<table>
<tr><td colspan="2">Nature: The combustion of natural gas at the proposed power plant will produce greenhouse gas emissions which will contribute to the global phenomenon of anthropogenic climate change. Climate change is projected to effect many environmental changes across the globe. However, none of the environmental impacts can be linked directly or indirectly on any particular sources of greenhouse gas emissions. The proposed CCPP power plant will however contribute substantially to South Africa’s national emissions inventory.</td></tr>
<tr><td></td><td>Emissions With Mitigation</td></tr>
<tr><td>Extent</td><td>National (4)</td></tr>
<tr><td>Duration</td><td>Permanent (5)</td></tr>
<tr><td>Magnitude</td><td>Low (4)</td></tr>
<tr><td>Probability</td><td>Definite (5)</td></tr>
<tr><td>Significance</td><td>High (65)</td></tr>
<tr><td>Status</td><td>Negative</td></tr>
<tr><td>Reversibility</td><td>None</td></tr>
<tr><td>Irreplaceable loss of resources?</td><td>Yes</td></tr>
<tr><td>Can impacts be mitigated?</td><td>Yes</td></tr>
<tr><td colspan="2">Mitigation: The project can only mitigate its contribution to the national emissions and climate change by reducing its greenhouse gas emissions. This would involve substituting towards combusting sustainable biofuels or utilising carbon capture and storage technologies. Such options are discussed in Section 5.2 of this report.
In the event that the operation of the CCPP plant provides load following capacity to mitigate grid stability for the introduction of intermittent renewable energy, it will enable increased renewable energy penetration on the South African grid as the load following capacity is able to balance shortfalls in supply from the variable renewable sources. The enabled renewable energy development will more than offset the emissions from this project.</td></tr>
<tr><td colspan="2">Cumulative impacts: In terms of the national inventory, there will be cumulative climate change impacts when considering the emissions from the project with the emissions from other fossil fuel power plants and other sources. Similarly, the onset of climate change is induced by greenhouse gas emissions accumulated in the atmosphere from all sources over time. The onset of climate change is likely to be accelerated and sustained as emissions accumulate in the atmosphere.</td></tr>
<tr><td colspan="2">Residual risks: Even if the proposed project is able to reduce its greenhouse emissions and mitigate its contribution to global climate change the risks associated with the onset of climate change will still be prevalent. This is due the vast number of other sources of greenhouse gas emissions around the world.</td></tr>
</table>

The options to reduce the greenhouse gas emissions from the proposed CCPP power plant are able to mitigate the magnitude of the emissions impact on the national inventory (minor). However, these options are not able to alter the impact that the greenhouse emissions will have on climate change in terms of their extent, duration or probability. The reduced magnitude of the impact for the proposed project with mitigation therefore, yields a reduced significance score in the above impact table. However, this score still places the impact of mitigated project case within the medium significance bracket.

The high renewables energy mix scenario modelled by the Council for Scientific and Innovation Research (CSIR) for 2040 shows that each MW of load following capacity would enable the deployment of 2.9MW of variable renewable energy such as wind and solar. Under the conditions of this assumed scenario, the proposed CCPP plant would enable the deployment of 8 786MW of variable renewable generation capacity. The 3 000MW peaking plant would enable a substitution towards renewable capacity which would reduce grid emissions in the region of; **15** million tonnes CO_2e per year. These indirect reductions for the national grid more than compensate for the direct emissions from the CCPP plant itself.

Even if the emissions from the proposed CCPP power plant are mitigated there will still be risks associated with climate change due to the cumulative nature of climate change impacts resulting from the greenhouse gas emissions from all the world's sources. However, as mentioned previously there is a collective responsibility for individual emitters to reduce their greenhouse gas emissions. To better understand this responsibility, it is worthwhile to compare the project emissions against a national baseline for electricity generation and the alternative project options.

7.2 Impact Compared Against Baseline

The updated version of South Africa's Integrated Resource Plan was released in November 2016, with an update published for public comment in August 2018. The plan outlines the country's electricity future in terms of the projections of generation capacities and carbon emissions. The grid emission factors can be calculated for each year and can serve as an estimation of the national emissions intensity baseline for electricity generation. This baseline is a useful point of comparison for the proposed CCPP power plant. Figure 4 plots the project's emission factor against the forecasted grid emission factors for the national electricity supply, as estimated from the Integrated Resource Plan.

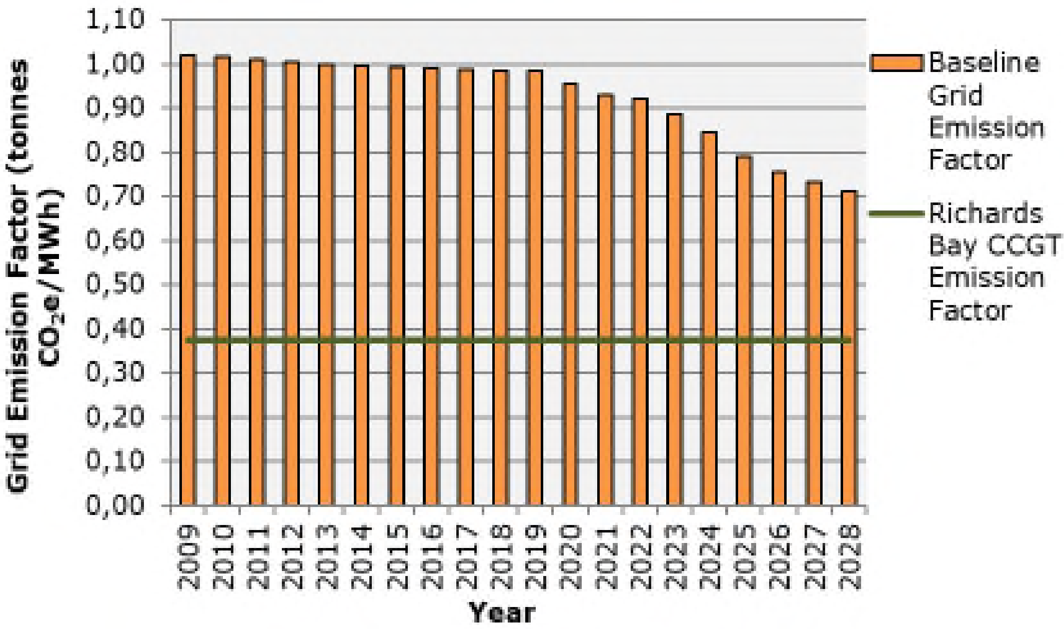

Figure 4: Forecast of the annual grid emission factors and project case in tonnes CO_2e per MWh, based on information in the Integrated Resource Plan for Energy 2010-2030.

The carbon emissions intensity of the proposed CCPP power plant is 0.37 tonnes CO_2e per MWh. This figure is significantly below the historical and projected emissions factors for the national grid. This demonstrates that the electricity generated by the proposed CCPP power plant would be much less emissions intensive than the electricity generation that makes up the majority of the national supply. The reason for this is that the less expensive technologies which combust coal make up the baseload electricity generation and are highly emissions intensive. As such, it is expected that the proposed plant would have a lower emissions factor than the national grid. This will contribute to the lowering of South Africa's grid emission factor.

If operated to supply load following capacity the proposed power plant will also play an important role in potentially lowering South Africa's grid emission factor through enabling a greater uptake of renewable energy onto the grid. The availability of load following capacity from plants such as the proposed CCPP plant enables a national grid to manage greater proportions of variable renewable energy on the grid. The reason for this is that in times of a shortfall in renewable energy, a CCPP plant can quickly supply the excess demand and similarly the plant can be shut down as sufficient renewable energy comes online. However, this option would not be relevant if the proposed CCPP plant is run as a baseload plant.

7.3 Impact Compared Against the Technology Alternative and Mitigation Options

While a CCPP power plant can provide various modes of electricity generation, there are also other options to provide these generation modes. Therefore, it is necessary to consider how the emissions intensity of the project case compares against these alternatives for each mode of generation. As outlined in Section 5.1 these alternative options include an open cycle gas turbines, combined cycle gas turbines fuelled with diesel, hydro power, pumped storage, coal and nuclear. The emissions intensities in tonnes CO_2e per MWh of the project case, CCPP fired with natural gas, and its alternatives are summarised in Figures 5-7. Hydro power is not included in these figures as it is not considered to be a viable new build option in South Africa.

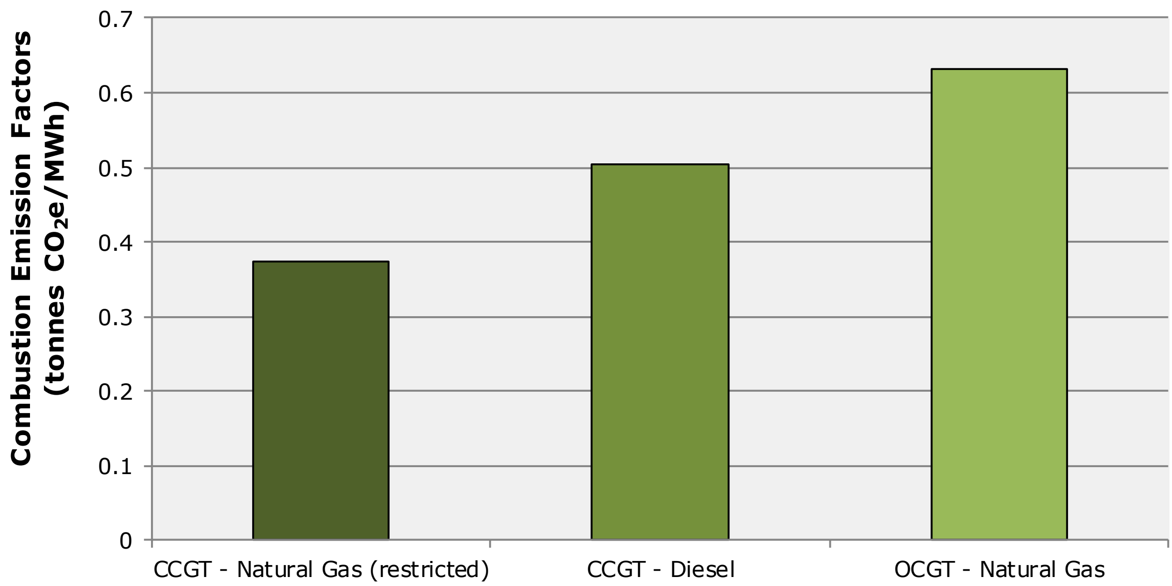

Figure 6: Comparison of emissions intensities of the CCPP natural gas project case and alternative mid-merit options in tonnes CO_2e per MWh.

The project case of a CCPP fuelled with natural gas has the lowest emissions intensity at 0.37 tonnes CO_2e per MWh when operated as mid-merit plant. This emissions factor increases to 0.50 tonnes CO_2e per MWh if the plant uses diesel as a fuel rather than natural gas. This variation is due to the calorific value and carbon content of the different fuels.

In the event that the proposed project is constructed as an OCGT fired on natural gas this would increase the emissions intensity of the plant to 0.63 tonnes CO_2e per MWh. This is a significant 70% increase above the emissions intensity of the project case. This increase is due to the large portion of energy that is lost as waste heat and which is not captured to be used within a steam turbine as in the case of a CCPP.

A combined cycle power plant fired on natural gas is the least emissions intensive of the technological alternatives available for the three modes of generation. Despite this there are still mitigation options to further reduce the emissions intensity of the generated electricity. As discussed in Section 4.2 the options to reduce emissions from the power plant would include firing the plant with biogas or biodiesel. The emissions intensities for a CCPP plant generating various proportions of electricity from biogas and biodiesel is presented in Figure 6.

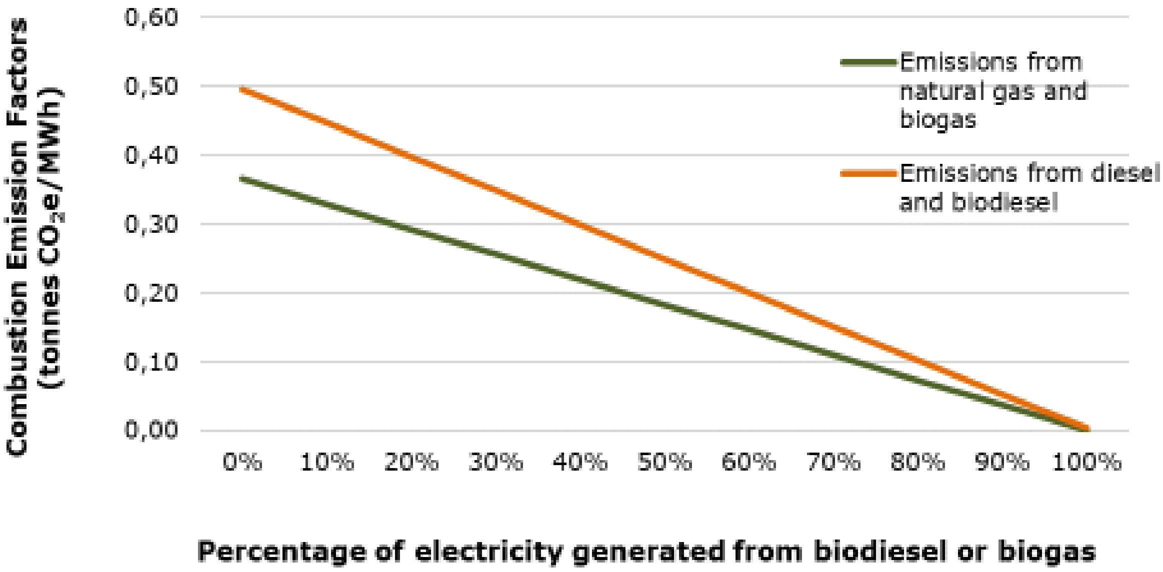

Figure 8: Comparison of the emissions intensities of the biogas and biodiesel mitigation options in tonnes CO_2e per MWh.

As CCPP plants can be calibrated to run on a variety of fuels, it is possible to generate its electricity from varying proportions of alternative fuels. Biofuels, such as biogas and biodiesel, have very low (near zero) emissions factors when produced sustainably as any carbon emitted in combustion is re-absorbed during growth of the fuel. Only the nitrous oxide and methane that is emitted is not re-absorbed.

It can be seen in Figure 8 that switching to biogas to produce 20% of the generated electricity reduces the emissions factor of the plant to below 0.3 tonnes CO_2e per MWh. In a CCPP running on diesel, it would require substituting 40% of the energy requirement with biodiesel to reduce the emissions to a similar level of below 0.3 tonnes CO_2e per MWh. As the proportion of energy generated from biogas or biodiesel increases towards 100% the emissions of the plant will be reduced to near zero.

Another mitigation measure may be to implement carbon capture technology on the plant. This would allow for a large portion of the carbon emissions to be transported and then stored in geological formations such as saline aquifers, therefore avoiding the emissions. Approximately 85% of a CCPP plant's emissions can be captured and then stored. This would result in an emissions factor of approximately 0.06 tonnes CO_2e per MWh.

While the firing of biofuels could take place at any point during the power plant's lifetime the development of carbon capture infrastructure would be most economically sensible to include in the initial construction of the plant. This would allow the plant to be 'CCS ready' for a time when the technology can be implemented. In the event that sustainable biofuels were combusted and the carbon emissions were also captured and stored the plant to could effectively become carbon negative by sequestering carbon emissions.

7.4 Local climate change impacts for Richards bay

As already discussed, the greenhouse gas emissions of the proposed project (mitigated or not) would not directly result in any specific climatic changes or any local environmental impacts as a consequence of climate change. Despite this it is still relevant to consider the potential local impacts of climate change for the Richards Bay area surrounding the proposed power plant.

The coastal area in which Richards Bay is located has a tropical climate. It is typically characterised by warm and wet summers with mild and moist to dry winters. However, over the last year (2015/2016) a very low amount of rain has been recorded for the area. This recent drought has put water resources in the area under considerable pressure. These water resources are essential to the agricultural practices within the area as well as the large portions of protected tropical habitat.

South Africa's Long Term Adaptation Scenarios predict that, as a consequence of climate change, drought conditions as describe above may persist in the future. It is projected that the Pongola-Umzimkulu hydrological zone, which covers most of KwaZulu-Natal, is likely to experience extreme warming beyond the natural temperature variability. It will also see reductions in rainfall, particularly in the autumn and winter month. These climatic changes are likely to continue to impact on the biomes of the Richards Bay region as well as human activities such as agriculture. If water resources are severely affected the proposed CCPP plant may even be impacted upon and may require alternative operational arrangements (sea water for cooling).

8 IMPACT OF CARBON PRICING

It is important to note that the mitigation options of firing the CCPP with biogas and biodiesel or implementing carbon capture and storage would increase the cost of the project. As such, the option may not initially be attractive to the project developer. However, in the presence of a carbon tax it may become financially viable to mitigate carbon emissions. This would be the case if the cost of the tax was higher than the cost of mitigation.

South Africa is currently in the process of finalising its national carbon tax policy. The effective tax rate has been set at R48 per tonne of CO_2e emitted. This effective tax rate is likely to increase through annual revision in the budget speech each year. In addition to these developments it is expected that by 2030 South Africa may be in alignment between the international carbon price and the domestic South African price[1]. A number of projections of this international carbon price are presented in Figure 9.

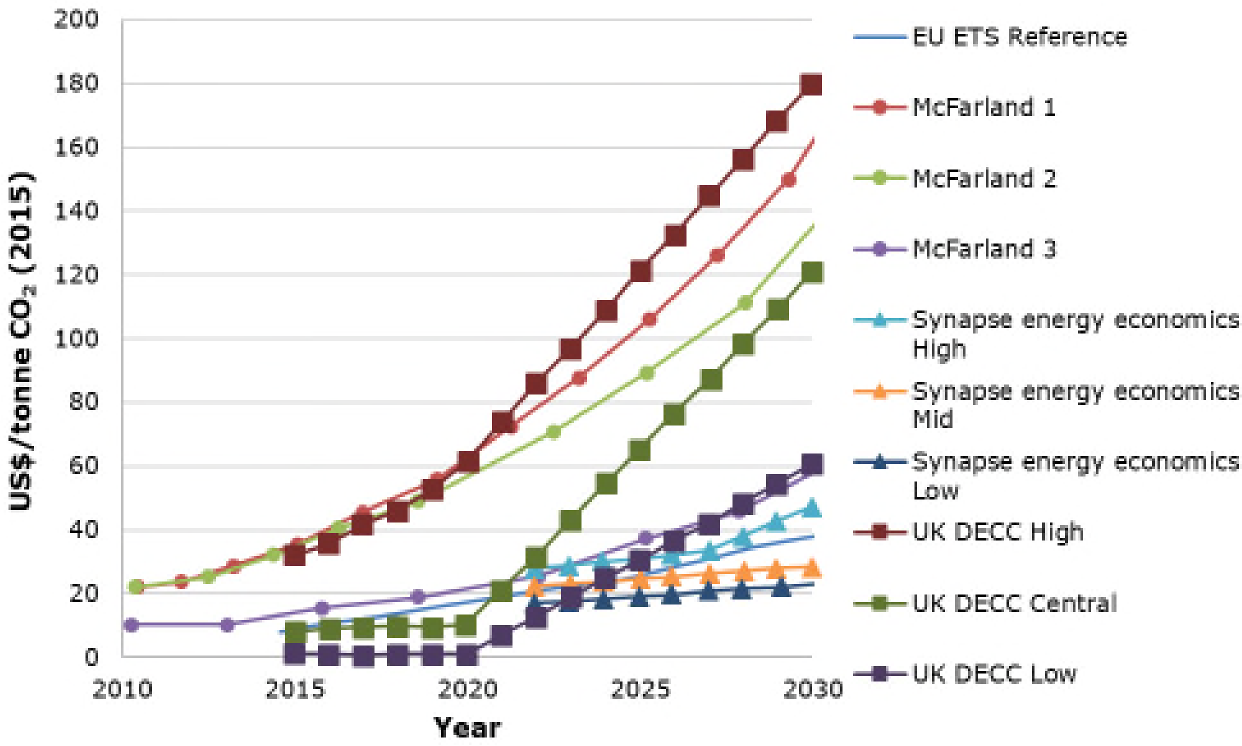

Figure 9: Summary of international carbon price projects from various scenario studies.

While the estimates of the international carbon price vary widely it is useful to consider what impact these prices may have on the operating costs of the plant in the future. As such it is advisable that where possible investments are made to enable the implementation of mitigation options as they are required.

9 OPERATIONAL EMISSIONS MANAGEMENT

Once the design for the proposed CCPP power plant is finalised there will be limited scope to alter the emissions profile of the plant beyond the incorporation of mitigation measures such as; biofuels or carbon capture (if the technology is included). As such, the emissions of the plant will be, for a large part, locked into the technology. Despite this, it is important that the operation is managed in such a way that the power plant does not produce more greenhouse gas emissions than necessary.

The greenhouse gas emissions created per unit of electricity generated typically depends on the performance of the CCPP power plant. As such, it is important from both an

[1] Article 6 of the Paris Agreement makes provision for the creation of an international carbon market.

energy and emissions management perspective that the plant is well maintained and that continuous monitoring is undertaken to track performance. This management system would extend to units that form part of the parasitic load of the plant as any increases in parasitic load will reduce the net electricity supplied for the given quantity of carbon emissions produced.

Another important feature of emissions management for the proposed CCPP power plant would be the transport and storage of natural gas on site. Natural gas is composed of approximately 90% methane. Methane is a greenhouse gas which has a global warming potential that is 25 times higher than that of CO_2. As such, any leaks of natural gas prior to combustion could result in increased carbon emissions without any electricity generation. Therefore, it would be important to monitor the infrastructure that stores and transports natural gas to prevent any possible leakages.

It is advisable for the proposed CCPP power plant to establish a carbon emissions management plan. This plan could follow the principles and the Plan, Do, Check, Act approach of standards such as the; ISO 9001 Quality Management System Requirements, ISO 14001 Environmental Management and ISO 50001 Energy Management Systems. The most effective plans will extend carbon management into the everyday organisation practices and be supported by a good governance structure with high level responsibility. It is advisable to consider the inclusion of emissions measurement systems in terms of ISO 14064.

10 OPINION ON PROJECT

It has been shown that the proposed project case of a CCPP fired with natural gas is the least emissions intensive of the option for the project. With an emissions factor of 0.37 tonnes CO_2e per MWh the proposed power plant will also be significantly below the emissions factor for the national grid.

Despite this, the scale of the proposed plant means that it will still produce significant quantities of greenhouse gas emissions annually (4.6 million tonnes CO_2e). These emissions will contribute to anthropogenic climate change and its ensuing global environmental impacts. The impact of these emissions is considered as high, due to the impact on the national inventory from a single source. The proposed CCPP power plant would account for 0.85% of national emissions each year. The extent of the impact is global and the duration of the impact is considered as permanent. Scientifically the probability of the plant's greenhouse gas emissions impacts on global climate change is virtually certain. Based on this the calculated significance of the power plant's impact on national emissions, and therefore climate change, is high for an individual source.

The proposed project has options to mitigate its carbon emissions. These options include the switching to alternative fuels such as biogas or biodiesel as well as carbon capture and storage. Implementing these technologies will enable the proposed power plant to greatly reduce its greenhouse gas emissions. As such it is advisable that the design of the project takes into account these options to enable the potential retrofit and implementation during the plant's operation phase. Such mitigation actions will help the proposed plant to take on a shared responsibility for climate change mitigation.

The most important feature of the proposed CCPP power plant is its potential role in enabling a greater uptake of renewable energy onto the South African grid. The load following capacity that it could offer would enable the national grid to accommodate greater proportions of variable renewable energy, such as solar power and wind energy. This would assist in decarbonising the national grid and reduce emissions within South Africa's national greenhouse gas inventory. This will be a positive contribution to the national commitment to mitigate global climate change.

This study concludes that while the proposed CCPP power plant as a single source will increase the national greenhouse gas inventory, mitigation options to reduce its emissions are available. The most important aspect of the propose power plant is that it has the potential to enable wider decarbonisation of the national grid through enabling the uptake of variable renewable energy technologies. As such it is suggested here that the proposed CCPP plant be load-following capability of the plant be used to maximise the uptake of intermittent renewable energy in the South African grid.

It is the view of this report that the proposed CCPP power plant is the best technology option, and will not materially result in any direct local climate change impacts, subject to the implementation of appropriate mitigation measures.

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