RESOURCES AND STRATEGY
RESEARCH DIVISION

SCAN REPORT

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ENVIRONMENTAL SCREENING FOR SITING OPEN CYCLE GAS TURBINES IN THE WESTERN CAPE – MOSSEL BAY

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BY	:	Indran Govender
ORGANISATION	:	Technology Services International

SCAN REPORT

ENVIRONMENTAL SCREENING FOR SITING OPEN CYCLE GAS TURBINES IN THE WESTERN CAPE – MOSSEL BAY

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INTRODUCTION

Need for Eskom's Expansion

South Africa's surplus electricity supply is expected to be exhausted by 2007. In order to meet growing electricity demands, South Africa will need to develop additional power generating capacity while at the same time ensuring energy efficiency programmes are implemented to reduce and shift demand.

Integrated Strategic Electricity Planning (ISEP) in Eskom

Eskom's Integrated Strategic Electricity Planning (ISEP) process provides strategic projections of supply-side and demand-side options to be implemented to meet long-term load forecasts.

The most attractive supply-side option is the return to service of the mothballed plant referred to as the Simunye Power Stations, which were placed in reserve storage during the period of high excess capacity on the Eskom system. Eskom has investigated a variety of options, including conventional pulverised fuel plants, pumped storage schemes, gas fired plants, nuclear plants (Pebble Bed Modular Reactor - PBMR), greenfield fluidised bed combustion technologies and renewable energy technologies (mainly wind and solar projects).

The Proposed Project

The Open Cycle Gas Turbine (OCGT) Project is premised on the need for new peaking capacity with a short lead-time to commercial operation. This project uses the research that has been carried out within Eskom for the location of a combined cycle plant as the foundation for the siting of the new OCGT plants. It focuses on two locations for the building of new plants, namely the Cape West Coast and Mossel Bay regions. At the Cape West Coast, liquid distillate fuel will be used to power 600 MW from an OCGT plant, while at Mossel Bay, natural gas from liquid natural gas will be used to power 450 MW.

In light of the need for peaking power generation, environmental screening of the potential sites are to be undertaken in order to identify the best option for location of an OCGT plant. This report covers the sites that are under consideration in the Mossel Bay region.

DESCRIPTION OF PROCESS

This report was compiled using information obtained from the following sources:

- Information from the web.
- Observations from the site visits conducted.
- Information from some of the plant manufacturers.
- Personal communications with Eskom personnel.
- Information obtained from library searches.
- Existing Eskom research reports and environmental impact assessments.

The primary reason for conducting this research scan was to detail the potential environmental impacts associated with locating Open Cycle Gas Turbines at potential sites along the Cape West Coast and Mossel Bay region. This information will subsequently be used to identify feasible alternative sites that can form the bases of an Environmental Impact Assessment (EIA). In the long term, this information would be used in the EIA and aid in obtaining environmental authorisations for the commissioning/construction of new Open Cycle Gas Turbines due to availability of information that would be required for the relevant authorities to make a decision.

ADVANTAGES

Gas-Fired Generation technologies have the following advantages:

- High combustion efficiency under all operating conditions.
- Low investment costs.
- Least environmental impact of fossil fuel options.
- Minimised pollutants and emissions.
- Fastest construction time.
- Most efficient fuel conversion.
- Capital development for the region.
- Facilitates industrial growth by introducing gas energy for other projects.
- Low visual impact of the facility.
- The rapid startup of open cycle gas turbines can minimise the need for hot or spinning reserve in larger stations to cover peak or standby capacity, thereby increasing the overall efficiency of the grid.
- Compact size and a reduction in cooling requirements enable this technology to be located closer to population centres which reduces distribution losses (1-3% possible).

DISADVANTAGES

Current disadvantages confronting wide scale implementation of the technologies are the following:

- The high cost of natural gas and its vulnerability due to the dollar price.
- There are numerous uncertainties with regards to gas development and gas availability in South Africa.
- The major percentage of the capital costs will be spent outside South Africa.

LEADERS IN THE FIELD

- ABB Power Generation Ltd.
- Siemens Power Generation.
- GEC Alstom.
- Hitachi Ltd.
- Westinghouse Canada Inc.

COST

Due to the variety of suppliers and natural gas development initiatives occurring in Africa, it is difficult to determine the costs associated with establishing a gas-fired power station in

South Africa at this time. The potential location, supplier and specification of technology to be utilised will have a major influence on the cost of establishing a gas-fired power station.

TIMESCALE

The screening study will be completed in 2004.

POSSIBLE APPLICATION FOR THE INDUSTRY

Development of a Gas-Fired power station would be preferable at coastal regions or at sea level, as there is a loss in efficiency up to 15% at high altitudes. Proximity to existing gas networks must also be considered as the additional cost of piping gas over long distances to the proposed power station will increase costs.

DIRECT / INDIRECT IMPACT ON ESKOM AND APPROPRIATE TIME SCALES

Utilisation of Gas-Fired Generation Technologies can help Eskom to diversify its primary energy mix and also meet the expected increase in demand for electricity in the future. The added development of gas markets could also aid in the long term by levelling out peaks for electricity demand.

CURRENT LOCAL RESOURCE

The current major natural gas fields that could possibly be utilised are the Kudu (Namibia) and Temane/Pande (Mozambique) gas fields, however, there is limited development of natural gas fields within South Africa. Therefore potential Gas-Fired power stations need to be located in close proximity to the infrastructure for transporting natural gas to South Africa and thereby minimise costs associated with obtaining an adequate supply of gas for the functioning of the power station.

RECOMMENDATIONS

- Gas-Fired Generation should form the basis of future generation options for South Africa as this technology offer opportunities for potential future electricity production diversification in line with Eskom's vision and the South African Energy Policy.
- The fast construction times and environmental soundness of Gas Fired Generation are a means of meeting the future demand for electricity.
- The addition of gas will diversify Eskom's energy mix and result in a skills transfer of a new technology to South Africa.

REFERENCE LIST

Crowther Campbell & Associates. (2004). EIA for the upgrading of PetroSA's refinery near Mossel Bay for the conversion to 100% unleaded fuel production – Final Scoping Report. Cape Town.

CSIR Environmentek. (2001). Environmental Impact Assessment for the Eskom Wind Energy Demonstration Facility in the Western Cape - Final Scoping Report. CSIR Report ENV-S-C 2001-024. Stellenbosch.

CSIR Environmentek (2002). Environmental Impact Assessment for the Eskom Wind Energy Demonstration Facility in the Western Cape – Final Environmental Impact Report. CSIR Report ENV-S-C 2001-103. Stellenbosch.

Dennis Moss Partnership. (1999). Winelands Integrated Development Framework: The image of the winelands. Support Document No. 1. Draft 1. Dennis Moss Partnership. Stellenbosch.

Ninham Shand. (1996). Omega Electrical Substation Public Participation Programme and Environmental Impact Assessment. Report No. 2553A/7155. Ninham Shand Consulting Engineers, Cape Town.

KEYWORDS

Open Cycle Gas Turbines (OCGT)

FUTURE REVIEW

A formal Environmental Impact Assessment will be conducted in 2005.

PROJECT DETAILS

Portfolio	:	GAS PROJECTS
Report Number	:	NON/SC/04/24933b
Project Number	:	PRJ04-00591300-2616
Project Leader	:	Indran Govender
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Customer	:	Resources and Strategy

1. INTRODUCTION

1.1 BACKGROUND

Eskom's core business is in the generation, retail, trading and transmission (transport) of electricity. In terms of the Energy Policy of South Africa "energy is the life-blood of development"[1]. Eskom generates approximately 95% of the electricity used in South Africa. Therefore the reliable provision of electricity by Eskom is critical for industrial development and related employment in the region and therefore a contributing factor to the overall challenge of poverty alleviation and sustainable development in South Africa.

It is important that the investment decisions taken by Eskom to be based on the energy related strategic policies and plans of South Africa. It must also integrate and consider the impact of the developments (both positive and negative) on economic development, environmental quality and social equity. These investment decisions taken include those for capital expansion projects related to power stations and powerlines.

Experience from previous Environmental Impact Assessments (EIA) indicate that many of our Eskom projects are seen out of the context in which they are planned in support of South African legislative, policy and planning requirements.

1.1.1 Need for Eskom's Expansion (Power Stations and Powerlines)

South Africa's surplus electricity supply is expected to be exhausted by 2007. In order to meet growing electricity demands, South Africa will need to develop additional power generating capacity while at the same time ensuring energy efficiency programmes are implemented to reduce and shift demand. The Integrated Resources Plan for electricity for South Africa shows that various options are being considered to meet the demands in the period 2004-2022[2].

1.1.2 Context in which Eskom Build Programme is undertaken

With energy planning and control falling within the mandate of the Department of Minerals and Energy (DME), the Minister of Minerals and Energy is responsible for the governance of the energy industry.

Eskom's electricity planning and decision making is undertaken in support of South African government policy, planning and legislative requirements. These include:

National Energy Policy, National Environmental Management Act (NEMA), Energy Efficiency Strategy & Renewable Policy
DME – National Integrated Energy Plan
National Electricity Regulator (NER) – National Integrated Resource Plan (NIRP)
Project Specific EIAs in terms of Environment Conservation Act and Regulations

[1] White paper on the energy policy of the Republic of South Africa, December 1998
[2] National Electricity Regulator National Integrated Resource Plan 2003/4 Reference Case, 27 February 2004.

1.1.3 National Integrated Resource Plan 2003/2004 - National Electricity Regulator (NER)

The second NIRP (NIRP2) was completed in February 2004 by Eskom, in conjunction with the Energy Research Institute from the University of Cape Town and the National Electricity Regulator. The planning horizon for the study was 2003 to 2022.

Whereas the Integrated Energy Plan (IEP) focussed on broader energy planning options for meeting increasing energy demands, the NIRP2 focuses on the planning options for meeting long-term increases in electricity demand (both through demand side management and increasing electricity supplies). National electricity demand growth forecasts take into account 2.8% average annual economic growth; the development and expansion of a number of large energy-intensive industrial projects; electrification needs; a reduction in energy intensity over the 20 year planning horizon; a reduction in electricity consumers who will switch to the direct use of natural gas; the supply of electricity to large mining and industrial projects in Namibia and Mozambique; and typical demand profiles.

Various demand side management and supply-side options are considered in the NIRP2 process, prior to identifying the least cost supply options for South Africa. The outcome of the process confirmed that coal-fired options are still required over the next 20 years and that additional base load plants will be required from 2010. Taking into account both cost and performance data, pulverised fuel coal-fired power, fluidised bed combustion and Combined Cycle gas Turbine (CCGT) technology are supply options that are shown to be broadly comparable. The study estimated that in order to maintain a supply reserve margin of 15% over the planning period (international best practice), the accelerated return to service of mothballed coal-fired power stations, commissioning of new coal-fired options as well as CCGT power plant(s) will be required.

1.1.4 Integrated Strategic Electricity Planning (ISEP) in Eskom

Eskom’s Integrated Strategic Electricity Planning (ISEP) process provides strategic projections of supply-side and demand-side options to be implemented to meet long-term load forecasts. It provides the framework for Eskom to investigate a wide range of new supply-side and demand-side technologies, with a view to optimising investments and returns.

The plan provides economically and environmentally acceptable options for flexible and timely decision-making. The focus has been to provide a robust plan, taking into account Eskom’s and the shareholder’s objectives.

With moderate growth in demand for electricity, additional supply-side options are anticipated for commercial service from 2006. Eskom has entered into a demand-side management programme in order to defer the commissioning of new plant. The most attractive supply-side option is the return to service of the mothballed plant referred to as the Simunye Power Stations, which were placed in reserve storage during the period of excess capacity on the Eskom system. Eskom has taken the decision to return Camden Power Station to service. The project is currently underway with the first unit planned to come on line in 2005. Eskom has investigated a variety of options, including conventional pulverised fuel plants, pumped storage schemes, gas fired plants, nuclear plants (PBMR), greenfield fluidised bed combustion technologies and renewable energy technologies (mainly wind and solar projects).

There are also potential power plant development projects external to South Africa which could form part of power trading within the Southern African Power Pool (SAPP).

In February 2004 Integrated Strategic Electricity Planning presented the demand side and supply side options in order to meet future energy demands to the Executive Committee (EXCO) Indaba. OCGT's was targeted as an option for the provision of peaking capacity in the short term and an investment-ready business case was requested to be complete by September 2004.

1.2 RESEARCH OBJECTIVES

It is anticipated that this screening study would help identify the best sites in terms of least environmental impact for locating OCGT's in the Western Cape. Proactive identification of the alternative locations would help enhance the project's viability and inform the scope of the formal Environmental Impact Assessment.

1.3 KEY QUESTIONS

The following key research questions have been formulated:

- What are the potential impacts associated with Open Cycle Gas Turbines?
- What are the impacts to be expected at the potential sites including fatal flaws?
- Which are the most preferable sites in terms of least environmental impact?

1.4 IDENTIFICATION OF SITES FOR CONSIDERATION

The past two years have seen an above average growth in the demand for electrical energy. This has put pressure on the existing installed capacity to be able to meet the energy demands into the future. In the short term, two key areas could be used to avoid unnecessary power shortages and brownouts:

- Demand Side Management
- The building of new Open Cycle Gas Turbines

The OCGT option is premised on the need for new peaking capacity with a short lead-time to commercial operation. This project uses the current knowledge and work that has been carried out within Eskom for the location of a new OCGT plant in view of the need for short project turn around times.

The technical site identification process was undertaken in July 2004 by the OCGT project team. The technical selection process involved identification of the regions with:

- The highest load variances,
- Fuel availability and costs,
- Impacts on transmission fault levels,
- Difficulty and cost of transmission integration,
- Benefits to transmission load variances
- Land availability.

The regions experiencing the largest transmission load variances were Gauteng, Western Cape and Kwa-Zulu Natal (KZN) respectively. However, the KZN and Gauteng regions could not be considered at this moment due to the lack of an adequate supply of fuel for the plant and the higher impacts on transmission fault levels for Gauteng. The Western Cape was identified as the most suitable for locating an OCGT for peaking purposes due to the fact that adequate supplies of fuel could be sourced from various suppliers and the transmission integration problems would be minimal.

Two regions were identified for the building of new plants, namely the Cape West Coast and Mossel Bay regions. Liquid distillate fuel could be used to power a 600 MW (4X150MW) OCGT plant at the Cape West Coast, and a 450 MW (3X150MW) plant at Mossel Bay. Depending on fuel availability and the demand for peaking generation, these units could be upgraded to 250 MW units thus enabling a peaking generation capacity of up to 1000 MW at the Cape West Coast and 750 MW in the Mossel Bay region, however for the purposes of this study, the feasible capacities considered were 600 MW at the Cape West Coast and 450 MW at Mossel Bay. Specific sites in these regions were identified on the basis of land availability, access to fuel and transmission integration costs. These identified sites were further subjected to environmental screening and a fatal flaw analysis to identify the best options for the physical location of OCGT power plants. This reports involves screening and a fatal flaw analysis of the Mossel Bay siting options.

2. PROJECT DESCRIPTION

Open Cycle Gas Turbine (OCGT) plants, with a 39% thermal efficiency are being considered for the two identified areas, namely the Cape West Coast and Mossel Bay regions. The first OCGT is expected to be 600 MW in output while the second is expected to be 450 MW in output and could be located at either the Proteus substation site, within the boundaries of the PetroSA refinery or adjacent to the PetroSA refinery. In terms of fuel supplies, it is envisaged that liquid fuel would be obtained from the PetroSA refinery at Mossel Bay. A pipeline from the PetroSA facilities to the power plant would supply the required fuel. It is expected that both plants will run up to a 5% load factor for a 30-year lifetime. Two years would be required prior to construction to conduct an Environmental Impact Assessment (EIA).

2.1 GAS GENERATION TECHNOLOGIES

A gas turbine as shown in Figure 1 below has a compressor to draw in fresh air from the atmosphere and compress it before passing it to the combustion chamber; where fuel is added to the compressed air and the total mixture is combusted resulting in hot gas entering the turbine at a temperature greater than 1300^{0}C. This hot gas imparts the majority of its energy via a turbine, to both the compressor and a generator to produce electricity (Langston & Opdyke, Jr., 1997).

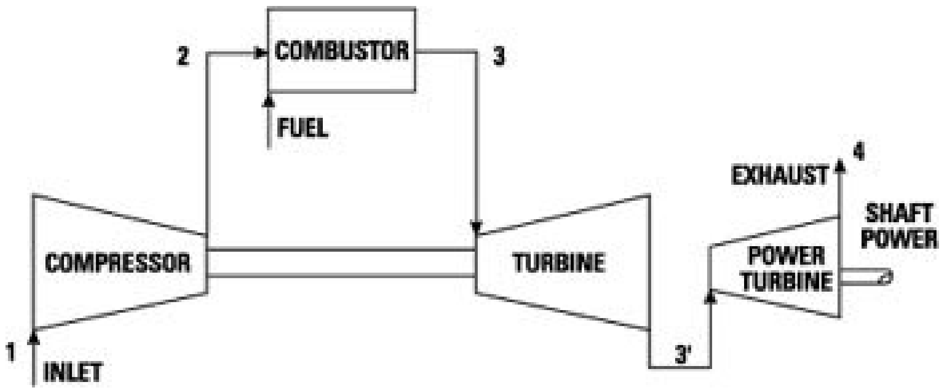

Figure 1: Schematic representation of a power generation gas turbine (Langston & Opdyke, Jr., 1997).

A typical gas turbine can range in power output from 0.05 MW to as high as 240 MW. Although gas turbines are increasingly being used for base load electrical power generation, they are most frequently used to drive compressors for natural gas pipelines, to power ships and to provide peaking and intermittent power for electric utility applications.

Some of the principal advantages of the gas turbine are that:

- It can produce large amounts of electrical power for a unit of relatively small size and weight.
- Its mechanical life is long, due to the fact that the motion of all its major components involves pure continuous rotation and not reciprocating motion as in a piston engine. In light of this the corresponding maintenance cost of a gas-fired turbine is relatively low.
- Although a gas turbine is not able to start on it's own power and requires some external means (a small external motor or other source, such as another gas turbine), it can be brought up to peak output in minutes. This is substantive when compared to a coal-fired unit for which the start up time is currently measured in hours.

- It can utilise a wide variety of fuels, although natural gas is the preferable choice, diesel oil or specially treated residual oils can also be used. Combustible gases derived from blast furnaces, refineries and the gasification of solid fuels such as coal, wood chips and bagasse could also be utilised by a gas turbine.
- The general working fluid is atmospheric air and as a basic power supply unit, the cooling medium for the gas turbines can be air or water.

In the past, one of the major disadvantages of the gas turbine was its lower efficiency when compared to other internal combustion engines and power plants. However, during the last fifty years, continuous development work has pushed the thermal efficiency from 18% for the 1939 Neuchatel gas turbine to present levels of about 40% for the open cycle operation and about 55% for combined cycle operation (Langston & Opdyke, Jr., 1997). Current development work is predicting even more fuel-efficient gas turbines, with open cycle efficiencies as high as 45-47% and combined cycle plants in the 60% range (Langston & Opdyke, Jr., 1997). These projected values are significantly higher than other power generation technologies, such as steam power plants with efficiencies around 35%.

The Brayton cycle (1876) is a representation of the properties of a fixed amount of air as it passes through a gas turbine in operation. It describes what happens to air as it passes through a system and specifies the relationship between volume (V) of the air in the system and the pressure (P) it is under. Air is initially compressed increasing its pressure, as the volume of space it occupies is reduced. This compressed air is then heated at constant pressure. Heat is added by injecting fuel into the combustor and igniting it on a continuous basis. The hot compressed air is then allowed to expand reducing the pressure and temperature and increasing its volume. This expansion takes place in the turbine, where the expansion of the hot gases against the turbine blades turns a shaft. This shaft extends into a generator, which produces electricity. The Brayton cycle is completed by a process in which the volume of air is decreased (temperature decrease) as heat is absorbed into the atmosphere. A gas turbine that is configured and operated to closely follow the Brayton cycle is called the open cycle gas turbine (Langston & Opdyke, Jr., 1997).

A greater understanding of the simple cycle gas turbine and its operation can be gained by considering its three major components: the compressor, the turbine and the combustor. Their features and characteristics are outlined below:

a) The compressor components are connected to the turbine by a shaft in order to allow the turbine to turn the compressor. Gas turbine compressors are either centrifugal or axial, or can be a combination of both. The more efficient, higher capacity axial flow compressors are used in most gas turbines. An axial compressor is made up of a relatively large number of stages, each stage, consisting of a row of rotating blades (airfoils) and a row of stationary blades (stators), arranged so that the air is compressed as it passes through each stage.

b) Turbines are generally easier to design and operate than compressors, since the hot air flow is expanding rather than being compressed. Axial flow turbines will require fewer stages than an axial compressor. There are some smaller gas turbines that utilize centrifugal turbines, but the majority utilizes axial turbines. Turbine design and manufacture is hampered by the need to extend turbine component durability in the hot air flow. This problem is especially critical in the first turbine stage where temperatures are the highest. Special materials and elaborate cooling schemes must be used to allow turbine airfoils that can melt at approximately 1000^{0}C to survive in airflows with temperatures as high as 1700°C.

c) A combustor consists of at least three basic parts; a casing, a flame tube and a fuel injection system. The casing must withstand the *cycle pressures* and may be a part of the structure of the gas turbine. It encloses a relatively thin-walled flame tube within which combustion takes place and a fuel injection system. A successful combustor design must satisfy many requirements and has been a major challenge from the earliest gas turbines. The relative importance of each requirement varies with the application of the gas turbine, with some requirements being of a conflicting nature. This necessitates design compromises. The major design requirements reflect concerns over engine costs, efficiency and the environment and can be classified as follows:

- High combustion efficiency under all operating conditions.
- Low levels of unburned hydrocarbons and carbon monoxide, low oxides of nitrogen at high power and no visible smoke.
- A low pressure drop, three to four percent is common.
- Combustion must be stable under all operating conditions.
- Consistently reliable ignition must be attained at very low temperatures.
- Smooth combustion, with no pulsations or rough burning.
- A low temperature variation for good turbine life requirements.
- Long useful life (thousands of hours), particularly for industrial use.
- Multi-fuel use, characteristically natural gas and diesel fuels are used for industrial applications but they can operate on a range of other fuels.
- Designed for minimum cost, repair and maintenance.

In land applications, additional equipment can be added to the simple cycle gas turbine, leading to increases in efficiency and/or the output of a unit. Three such modifications are Regeneration, Intercooling and Reheating.

- *Regeneration* involves the installation of a heat exchanger through which the turbine exhaust gases pass. The compressed air is then preheated in the exhaust gas heat exchanger, before it enters the combustor. A well designed regenerator that has a highly effective heat exchanger and small pressure drop increases the efficiency over the simple cycle value. However the relatively high cost of such a regenerator must also be taken into account. Regenerated gas turbines increase efficiency by 5-6% and are even more effective in part load applications.
- *Intercooling* also involves the use of a heat exchanger that cools compressor gas during the compression process. If the compressor consists of a high and a low-pressure unit, the intercooler could be mounted between them to cool the flow and decrease the work required for compression in the high pressure compressor. The cooling fluid could be atmospheric air or water.
- *Reheating* occurs in the turbine and is a way to increase turbine work without changing compressor work or melting the materials from which the turbine is constructed. If a gas turbine has a high pressure and a low-pressure unit at the back end of the machine, a reheater (usually another combustor) can be used to "reheat" the flow between the two turbines. This can increase efficiency by 1-3% (Langston & Opdyke, Jr., 1997).

The main advantage coupled to gas technology is the fact that it is considered a “clean” fuel in comparison to either coal or oil. It produces virtually no particulate matter (PM_{10}) and sulphur dioxide (SO_2), less oxides of nitrogen (NO_X) and considerably less carbon dioxide (CO_2). The OCGT functions in a similar manner to a CCGT but the exhaust heat is discharged at a higher level because it is not used to reheat steam to drive the steam turbine of a CCGT. The residual heat is discharged to the environment through flue gas discharge at a height of 40-60 metres. Environmental impacts are expected to be small when compared to other fossil fuel generating technologies and a pumped storage scheme, however, they are larger than those of a CCGT plant. These impacts are related to land usage, gaseous and particulate emissions, noise levels, visual and aesthetic impacts.

2.2 IMPACTS ASSOCIATED WITH OCGT'S

2.2.1 Emissions to Air

- Oxides of Sulphur

The negligible quantity of sulphur present in natural gas means that the concentrations of SO_2 in the flue gas emitted will be minimal. When using distillate fuel oil, the concentration of SO_2 in the flue gas will be limited due to the comparatively low sulphur content of distillate fuel oil (max. 0.3% by weight).

A sulphur content of 5%, does not pose an impact to the environment as the resultant SO_x emissions are well below the allowable regulatory limits.

- Oxides of Nitrogen

The production of nitrogen oxides is a part of fossil fuel burning however this can be limited by the Dry Low NO_x (DLN) combustion system used with certain gas turbines. This system includes the use of a wet control system when burning distillate fuel oil, which has lower levels of nitrogen.

The DLN combustion system is designed to minimise the generation of oxides of nitrogen during the combustion process, but it cannot eliminate them completely. The waste gases are emitted from approximately 40-60m high stacks at sufficient velocity and temperature for a substantial plume rise. This causes dispersion of the NO_x formed during combustion so that the impact on background level concentrations is insignificant. Combustion NO_x emissions as a result of the oxidation of nitrogen compounds in the fuel is not significant due to the low levels of nitrogen compounds in natural gas and distillate fuel oil.

Another NO_x source is from the fixation of atmospheric nitrogen in the flame. This is known as thermal NO_x. Dry low NO_x burners are designed to minimise thermal NO_x generated by fixation of atmospheric nitrogen in the flame. The rate of generation of thermal NO_x is generally accepted as being an exponential function of flame temperature and the time that the hot gas mix is at flame temperature. Flame temperature is highest when there is just enough fuel to react with all of the available oxygen. This is called the stoichimetric mixture. It follows that adjustment of the fuel/oxygen mix away from the stoichimetric mix will reduce the flame temperature. This adjustment can be achieved by either increasing or decreasing the fuel (fuel rich or fuel lean) for available oxygen. It is better to control the NO_x emissions through the fuel lean method since this means that fuel is not wasted and unburned hydrocarbons are not released into the atmosphere.

NO_x formation due to atmospheric nitrogen is however dependant on the maximum flame temperature. The combustion system of the gas turbine must be designed to ensure efficient and reliable turbine operation, while minimising the creation of oxides of nitrogen (NO_x) at source.

- Oxides of Carbon

Gas contains a much lower proportion of carbon than oil or coal, so the use of gas as a primary fuel causes less CO_2 to be produced per unit of electricity. For a fixed amount of energy generated by either gas or coal, gas-fired generation produces approximately 60% of the CO_2 that would normally be produced by coal-fired generation.

Together with the lower carbon content of gas and the greater conversion efficiencies, the OCGT plants result in CO_2 emissions which are about 40% of those emitted from an equivalent coal fired station. Some carbon is converted to carbon monoxide (CO) on combustion. The fuel to air ratio is a principle factor in the production of CO and it is in the interest of both combustion efficiency and overall economy that CO production is minimised.

- Unburned Hydrocarbons

Multi-burner combustion chambers, which characterise most gas turbines, ensure almost complete combustion of all fuels. Approximately 99.99% combustion efficiency results in a minimum of unburnt hydrocarbons (UHC) and negligible CO emissions.

Under mid-merit operating conditions, using natural gas (dry) with a 15% oxygen content, the concentration of UHC in the exhaust gas amounts to only 4ppmv. This corresponds to just 18mg/kWh. Approximately half of this is methane, which is assessed to contribute the equivalent of 30 times more to the greenhouse effect than carbon dioxide. In light of this, the emissions can be considered the same as 740mg CO_2 per kWh. This is insignificant when compared to the actual amount of CO_2 that is released. Burning distillate oil or other fuels increases the UHC emission but this is dependent on the properties of the fuel utilised.

The non-methane components of the total UHC, also known as Volatile Organic Carbons (VOC's) are particularly important because of their ability to form ozone in the atmosphere in conjunction with NO_x and sunlight. They contribute roughly half of the total UHC.

- Particulate Matter

The emission of particulate matter from the combustion process will be negligible. This is because there are negligible quantities of solid matter in the fuel and the air drawn into the gas turbine compressors will be cleaned by passing through filters. These filters must be replaced periodically. The frequency of replacement is typically between 6 months and 2 years. When burning distillate fuel oil, a small emission of particulate matter occurs as the oil will contain very small quantities of ash (approx. 0.01% by weight).

- Heat

The majority of the losses resulting from an open cycle gas turbine are from discharge in the form of hot exhaust gas to the atmosphere. This means that some of the useful energy in the fuel supplied to the turbine is rejected directly into the atmosphere. However, converting the open cycle to a combined cycle gas turbine to obtain a higher than 55% efficiency, results in the plant generating more power for the same amount of fuel thereby leading to a corresponding reduction in heat rejected to the environment. Heat emissions could have an impact on the macroclimate of an area, however, this can only be quantified through atmospheric dispersion modelling.

2.2.2 Emissions to Water

The operation of the gas turbine, where air will be passed through a compressor, heated, expanded through a turbine and then exhausted, may result in the deposition of airborne impurities on the compressor blading. Soiling of the compressor results in reduction of the thermal efficiency of the gas. Cleaning of the compressor is therefore important, if maximum efficiency is to be attained.

Compressors may be cleaned either off line when cold, or on-line during operation. Periodic off line cleaning, combined with cyclic on-line cleaning has been identified as the most effective method of achieving consistently high levels of performance over long periods of operation. On line washing is done with reserve feed water, while for off-line washing, a detergent solution is used.

The gas turbine blading may be cleaned while the plant is on-line or off-line using a hydrocarbon based solvent, which will be mixed with water to form an emulsion. In the course of on-line cleaning, the solvent and any dissolved oils and greases scoured from the blading will be completely burned in the combustion chamber of the gas turbine. The effluent produced by the off line cleaning will be drained from the compressor housing using a controlled process, passed through an oil separator and pumped to an adequate disposal point. The best anti-fouling agent that can be utilised in the cooling water system is a sodium hypochlorite solution, containing approximately 15% available chlorine. The hypochlorite solution will be injected directly into the cooling water by a controlled pumping system. The minimum effective injection of hypochlorite necessary will be used. The residual oxidant in the purge water must be monitored.

2.2.3 Land Requirements

A 1600 MW Combined Cycle Gas Turbine can be sited on 7 ha compared with 200 ha for an equivalent coal-fired facility. Gas-fired power stations do not require the substantial structures required for transport, handling and storage of the coal. In additional, the huge areas required for the disposal of ash and waste is also not required. This area can be further reduced due to the fact OCGT's do require Heat Recovery Steam Generators (HRSG) associated with the combined cycle part of the part.

2.2.4 Water Use

An OCGT does not require water for condenser cooling. The only use of potable water is that required for cleaning, fire fighting and for domestic use thus the water use by an OCGT can be considered as negligible.

2.2.5 Waste Generation

Gas-fired electricity generation technologies generates less waste compared to conventional coal fired stations that produce large volumes of ash. Waste generation is minimal, as there are neither coal discards nor ash disposal requirements. The only general solid waste is as for an office or workshop for ± 100 people.

Environmental damages that occur as a result of waste disposal from the plant are expected to be negligible providing that the wastes are minimised and recycled with only the residual disposed of at a licensed waste disposal facility.

2.2.6 Noise Impacts

An OCGT can generate high noise levels that are associated with air intakes for gas turbines, the combined operation of the gas turbines, generators, transformers, pumps pneumatic controls, diesel generator sets and generator ventilation systems. The gas turbine air intake facility will cause the highest level of residual noise (78dB at 1m from the gas turbine building) as it is located outside (ABB, 1995). Acoustic enclosures will reduce the internal build up of noise and minimise its transmission outside. The induced vibration caused by the rotating machines is a localised event that can be easily mitigated through proper foundation designs and pipe racks that support the facility.

The maximum acceptable levels in terms of the World Bank noise guidelines for an industrial or commercial area are an equivalent sound level (Leq) of 70 dB(A) over an hourly period. This should be measured at receptors located outside the property boundary. The maximum allowable increase in the existing ambient noise levels is Leq 3 dB(A) where existing ambient levels exceed Leq 45 dB(A).

2.2.7 Aesthetics

Conventional coal-fired power plants are usually characterised by high stacks and large boiler furnaces however open cycle plants are relatively inconspicuous due to the absence of boiler furnaces and lower stack heights present.

The low stack height (40-60m above ground) is due to no particulate emission and the low gas emissions typical of gas fired power stations. The area required for siting a gas-fired power station is roughly 30% of that required for a reference coal fired unit. If the requirements for a coal stock yard had to also be taken into consideration, the comparative area would be further reduced to 20%.

The overall visual intrusion is minimal owing to the lower profile design of a gas-fired power station and to a large extent as the clean facility that results from the absence of coal dust, ash and fine particulate. The compact nature of the plant and the reduced need for auxiliary equipment such as precipitators, coal staithes, and ash dumps mean a much-reduced land demand in comparison to conventional coal-fired facilities thereby leaving more land available for other development purposes. The supply of natural gas / liquid fuel to the plant can be achieved via underground piping and this has substantially less impact when compared to a coal-fired facility, which would have to obtain its coal supplies by a conveyer, trucks or rail transport. The visual impact of the power station structures depends also on their relationship to the landscape.

3. THE MOSSEL BAY ALTERNATIVES

Various sites were considered in the site selection process to locate OCGT's in the Mossel Bay Cape region. The factors considered were technical issues (such as land availability, fuel supply, transmission integration requirements) and environmental constraints (such as compatibility with current land use, ecologically sensitive areas, and sense of place). It must be noted that specific information for the Mossel Bay area could not be easily sourced thus the analysis is based primarily on the findings of the site visit.

3.1 SITE ALTERNATIVES

A number of potential sites were identified for further consideration in the Mossel Bay region, viz. within the PetroSA Refinery boundaries, the Proteus substation and adjacent to the PetroSA refinery. The industrial area of Mosdustria was also considered, however, this option was discarded due to space limitations and various economic factors. The location of these sites is indicated in Figure 2 below.

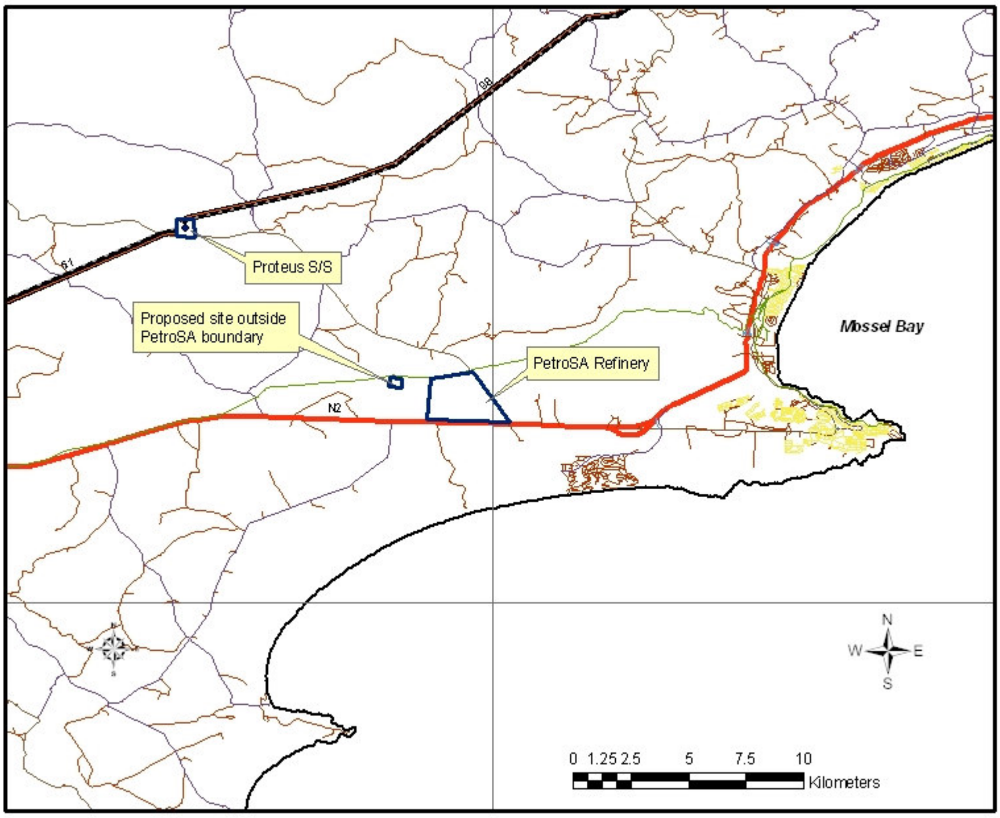

Figure 2: Locality map showing the alternative Mossel Bay sites under consideration

3.2 BIOPHYSICAL ENVIRONMENT

This chapter provides a brief description of the surrounding environment in and around the Mossel Bay area.

- Climate

Mossel Bay receives between 400–600mm of rainfall per annum, peaking in spring and autumn. Light hail may occur once or twice a year, and mist occurs on an average between 20 – 25 occasions annually (PetroSA, undated).

South-easterly winds are predominant especially in summer. The wind in winter blows mainly from a north-westerly direction. The windiest season is mid-winter to spring, which has an average wind speed of 20km/h. The average wind speed in summer is 15km/h (PetroSA, undated).

The mean daily maximum temperature is 21°C and the mean minimum temperature is 14°C. The average annual temperature is 17.6°C (PetroSA, undated).

- Topography

The topography of the area is characterised by undulating hills with deep valleys and prominent high terraces. These terraces command magnificent views in all directions, viz. the Indian Ocean towards the south and the Outeniqua Mountain range towards the north. The PetroSA Refinery is situated on a plateau or plain at an altitude of between 160–180 metres above mean sea level (mamsl) to the west of the port.

- Geology

Mossel Bay is characterised by sandstone and shale beds of the Table Mountain and Bokkeveld Groups. North of the town of Mossel Bay are rocks of the Enon Formation and other similar younger deposits which are of Cretaceous and Tertiary age. These rocks are deposited in an east to west elongated trough and are considered to extend offshore, outcropping locally (eg Seal Island) (PetroSA, undated).

- Groundwater

The Kouga Formation is the principal aquifer in the refinery area. Its recharge area lies to the north of the refinery. Immediately north of the refinery the groundwater lies within the bedrock (PetroSA, undated).

- Flora

The area falls broadly into the category of a mosaic of Thicket and Renosterveld.

The vegetation of the Thicket Biome grows as a closed shrubland to low forest dominated by evergreen, sclerophyllous or succulent trees, shrubs and vines. The Thicket Biome shares floristic components with almost all other Phytochoria and as a result few endemic species are recorded in this vegetation type.

The Renosterveld falls within the Fynbos Biome, which is localised in distribution and is threatened by urbanisation, agriculture and alien invasion. Typically, Renosterveld consists of a matrix of pioneer low branched shrubs one to two metres in height. A herb layer usually occurs beneath in which grasses predominate and deciduous geophytes and annuals are seasonally prominent. However, in South Africa overgrazing has resulted in shrubs becoming more dominant (Hill and Associates 2001). Some lower valleys are infested with rooikrans, wattle and other alien plants

- Fauna

Terrestrial faunal diversity in the are restricted due to farming activities, however, there is evidence of various small mammals (eg rodents, porcupine, grysbok and other small antelope) (Hilland Associates 2001). PetroSA's Nature Reserve is located adjacent to the refinery. Several fauna species can be found in the nature reserve eg springbok, Burchell's zebra, grysbok, Cape hares, stripped mouse, vlei rat and a wide diversity of birds (PetroSA, undated).

Marine fauna found in the waters near Mossel Bay include, amongst others, sharks, whales and seals. Mossel Bay is reputable for the presence of Great white sharks and whales and as a result this has resulted in Mossel Bay becoming a popular tourist destination for boat trips and cage diving. Whales come into the bay each season from June through to November to mate and calve. Approximately 3000 to 4000 seals make use of Seal Island (Hilland Associates 2001).

3.3 SOCIO-ECONOMIC ENVIRONMENT

Mossel Bay has always been a fishing port of substance with limited commercial cargo activity, however, the launch of the Mossgas project has brought about an increase in its activities by assisting in servicing the oil industry. These two industries are currently the major role-players in the development of the port area. Road and rail networks have been developed to connect Mossel Bay to the consumer markets and industrial zones of South and Southern Africa. The relatively small size of the port necessitates that the Port of Port Elizabeth supports it in various specialised fields, ie industrial relations, training, financial management, equipment and infrastructure procurement.

PetroSA Refinery, near Mossel Bay, is an important local and national contributor to the economy and employs an estimate of 1000 people, with about 7000 depending on it for their livelihood (SRK, 2002).

Mossel Bay and the surrounding areas, being located on the Garden Route, is a popular tourist attraction (Crowther Campbell & Associates, 2004b).

3.4 SITE SCREENING

This section attempts to provide a more detailed description of the site and identify the potential impacts that might occur as a result of the development of an OCGT at the alternative locations identified in Mossel Bay. It must be noted that specific information for the Mossel Bay could not be easily sourced thus the analysis is based primarily on the findings of the site visit.

3.4.1 The PetroSA site

The proposed site within the PetroSA Refinery boundaries is located to the NW of the refinery between the contractors village and the waste disposal area (see Figures 3 & 5). The waste disposal area, located to the west of the refinery, is authorised to accept hazardous and general wastes. The refinery is visually prominent, with mainly impacts to the surrounding farms and traffic passing the refinery on the N2.

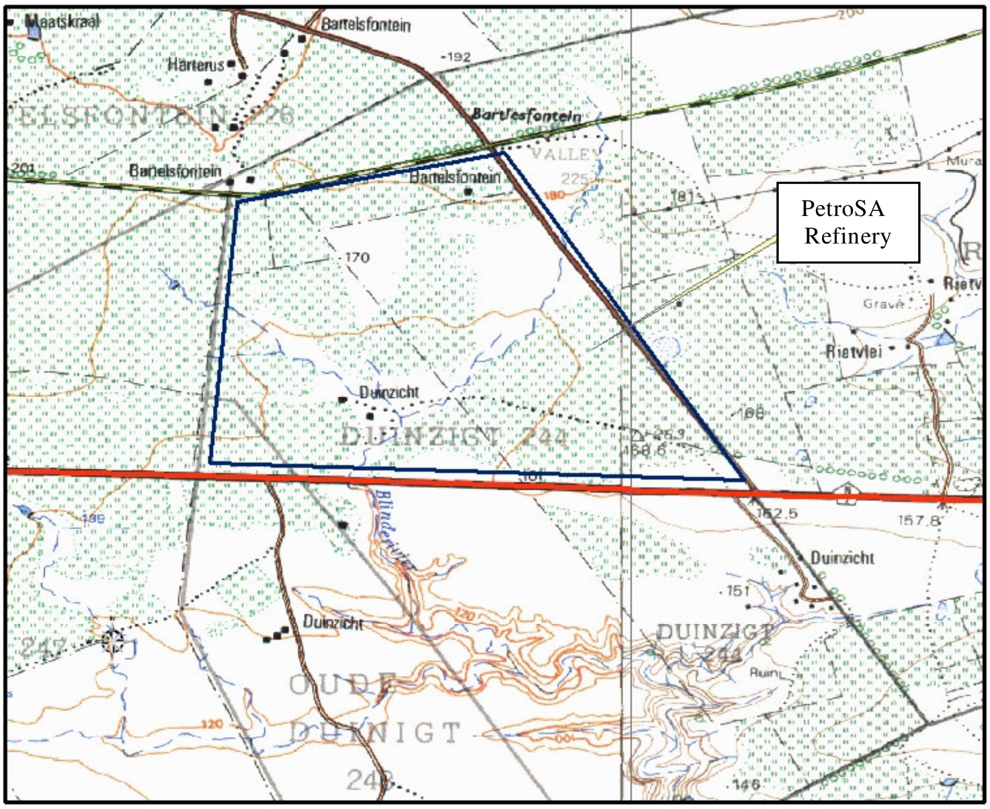

Figure 3: Location of the PetroSA site.

The flora and fauna originally present in the area was largely replaced by farming prior to the PetroSA Refinery being built. The site is largely modified and substantial portions of the area are occupied by the refinery activities. There are no known sites of archaeological importance in the study area. However, during past development projects Stone Age tools were found approximately 200m north of the office building at the waste disposal site (Crowther Campbell & Associates, 2004b).

Substantial noise levels are present at the site due to the refinery's various activities. The air quality is not considered to be problematic due to the substantial levels of emissions that are currently generated by the refinery and the landfill. However, the cumulative impacts are difficult to quantify and must be investigated by a specialist.

Detailed environmental information could not be obtained on the PetroSA Refinery site. PetroSA has carried out an air quality study and noise study, however, the results thereof were not available for inclusion in this assessment. The assessment is therefore largely based on the site visits undertaken.

The PetroSA site is visually prominent to traffic passing on the N2 and the surrounding farmers. The location of an OCGT within the boundaries of the PetroSA site, next to the landfill site, is not expected to have any significant visual impacts on the area. This is due to the fact that the OCGT plant would blend in with the rest of the refinery equipment. The ambient noise and air quality levels are currently quite high as a result of the various processes occurring on the site and the OCGT is not expected to substantially contribute to these levels. These impacts can be considered as minimal and negative. The site has been altered to a large extent and very few, if any, remnants of the original vegetation exists on the site. The development of an OCGT on the site would therefore not impact on the biodiversity of the site in any way.

Figure 4: View of PetroSA Refinery from the Proteus substation site.

PetroSA currently has established infrastructural facilities for its activities. This could be utilised for the construction and operation of the power station, obviating against the need to create new infrastructure. This further reduces the impacts that can be expected as a result of infrastructural development. The establishment of a power station in the area would complement to the industrial activities that are currently occurring.

The construction of a transmission linking to the Proteus substation is expected to impact on the surrounding farmers however an optimal route will have to be determined and impacts thereof reduced to socially and environmentally acceptable levels. A summary of the impacts to be expected is provided in Table 1.

Table 1: Summary of impacts to be expected for an OCGT at the PetroSA Refinery.

IMPACT	EXTENT	SIGNIFICANCE	TYPE
Biodiversity	Local	Neutral	Neutral
Noise & Aesthetics	Regional	Low	Negative
Emissions	Regional	Low	Negative
Sense of place	Regional	Low	Negative
Socio Economic	Regional	Low	Positive
Infrastructural Availability	Regional	Low	Negative
Archaeology & Culture	Local	Low	Negative

3.4.2 Adjacent to the PetroSA site

The proposed site adjacent to the PetroSA Refinery is located to the NW of the refinery in close proximity to the contractors village and the waste disposal area (See Figure 5 below). The less prominent visually in comparison to the refinery due to it being partially screened by the land fill site, however it will impact on the surrounding farms and traffic passing the refinery on the N2.

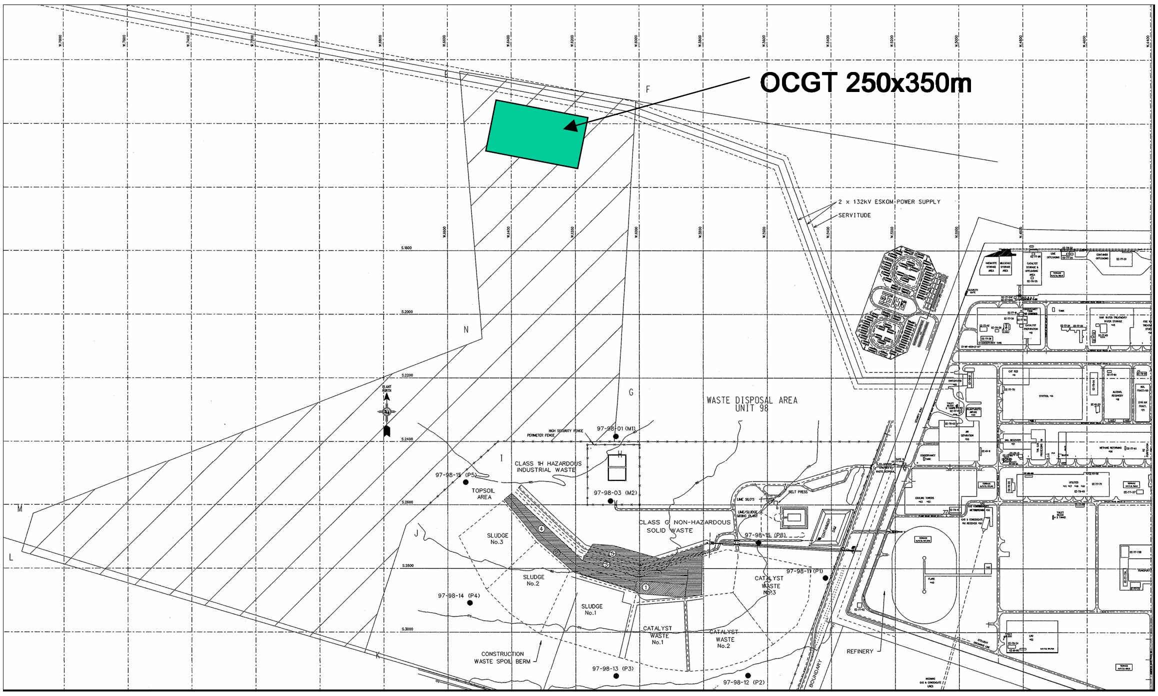

Figure 5: Location of the site adjacent to the PetroSA Refinery.

The impacts associated with this site are similar in nature to the impacts associated with the PetroSA site however it is currently utilised for farming purposes and the establishment of a power station will adversely impact on this activity. The site can be considered marginally more sensitive than the site within PetroSA's boundaries due to its' less degraded state, however, the site has been altered to a large extent and very few, if any, remnants of the original vegetation exists on the site. A summary of the impacts to be expected is provided in Table 2.

Table 2: Summary of impacts to be expected for an OCGT adjacent to the PetroSA Refinery.

IMPACT	EXTENT	SIGNIFICANCE	TYPE
Biodiversity	Local	Low	Negative
Noise & Aesthetics	Regional	Low	Negative
Emissions	Regional	Low	Negative
Sense of place	Regional	Low	Negative
Socio Economic	Regional	Low	Positive
Infrastructural Availability	Regional	Low	Negative
Archaeology & Culture	Local	Low	Negative

3.4.3 Proteus Substation

The Proteus substation is located about 12 km to the NW of the PetroSA Refinery (See Figures 6 and 7). It is visually prominent due to the fact that it is situated on a koppie. The flora present on the site comprises Strandveld Dune Thicket, Renosterveld and Sand Plain Fynbos. The vegetation of the site was originally impacted upon during the construction of the substation however, the vegetation has re-established itself, and a few exotic species are present. Figure 7 below indicates the vegetation that surrounds the substation.

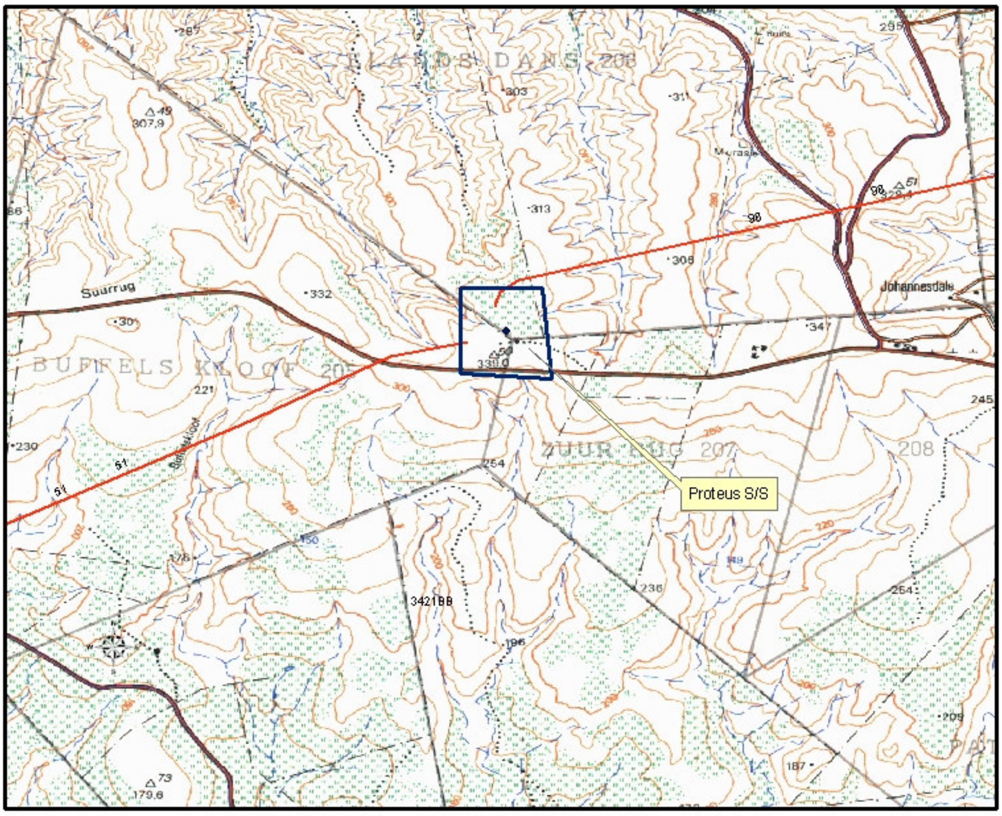

Figure 6: Location of the Proteus substation site.

The substation is separated from the PetroSA Refinery by a number of farms and a large proportion of the indigenous vegetation has been transformed by agricultural practices. The substation site is however surrounded by relatively undisturbed natural vegetation and these exhibit fairly high levels of species diversity and endemism.

The site possesses numerous habitats necessary for faunal communities. A wide variety of mammals and reptiles could be present. A large number of birds are present in the area.

Figure 7: View of Proteus substation and the surrounding vegetation.

The development of an OCGT power station at the Proteus substation is expected to substantially affect the sense of place in that the area is largely undeveloped. Although the substation and transmission lines are present on the site, the area is still generally rural in nature. The site is surrounded by relatively undisturbed natural vegetation comprising Strandveld Dune Thicket, Renosterveld and Sand Plain Fynbos. Impacts on biodiversity could substantial in that the vegetation on the site could be of conservation value and it provides numerous habitats for various faunas. This could be considered to be of a high magnitude and negative in nature.

In addition to the impacts to be expected by the farms, the nature of the area would be altered in that the noise levels would increase as a result of increased traffic flow and the power station. Additional transmission lines and possible fuel pipelines would change the nature of the area to a more industrial setting. The farmers will be impacted by the fuel pipeline however an optimal route will have to be identified and impacts mitigated to socially and environmentally acceptable levels. A summary of the impacts to be expected is provided in Table 3.

Table 3: Summary of impacts to be expected for an OCGT at the Proteus S/S.

IMPACT	EXTENT	SIGNIFICANCE	TYPE
Biodiversity	Local	High	Negative
Noise & Aesthetics	Regional	High	Negative
Emissions	Regional	Low	Negative
Sense of place	Regional	High	Negative
Socio-Economic	Regional	Medium	Neutral
Infrastructural Availability	Regional	Medium	Negative
Archaeology & Culture	Local	Low	Neutral

4. SUMMARY AND CONCLUSIONS

The impacts associated with Open Cycle Gas Turbines are inherently low. The levels of emissions generated are generally lower than a coal-fired plant due to the higher efficiencies of gas turbines and the low levels of sulphur and nitrogen in the fuel. Wastes generated are also minimal due to the lack of the huge quantities of ash that are produced by a conventional coal-fired power station. The CO_2 emissions are approximately half of that produced by a reference coal fired plant. Aesthetic impacts are also reduced due to the compact and lower profile nature of the gas-fired plant. The absence of ash dumps, coal stockyards and coal transport structures further reduces the aesthetic impacts associated with a gas-fired power station. In addition, this reduces the demand for land to locate a power station.

A Life Cycle Assessment conducted by Wibberley *et al.,* in 1999 summarised the impacts of generating 1MWh of electricity from an Open Cycle Natural Gas Turbine as follows:

Resource energy	10.76 GJ
Greenhouse Gases	608 kg CO_2-e
NO_x	1.94 kg
SO_x	4.68 g
Particulate Matter	0.43 g
Fresh water	0.002 m^3
Solid waste to landfill	1.4 kg

It must be noted that the impacts outlined above are those associated with the use of natural gas as a fuel. These impacts would increase with the use of liquid distillate fuel.

4.1 COMPARATIVE ASSESSMENT OF THE SITES

In this section, the potential sites comparatively assessed to determine the most preferable sites in terms of least environmental impact. The following scoring system is utilised to rank the alternatives.

0 = No impact or positive
1= Low
2= Medium
3= High

The sites with the lowest aggregate scores are the best environmental options.

4.1.1 The Mossel Bay Alternatives

The PetroSA site has largely been modified through industrial development and it is highly unlikely that any species of concern are present on the site any more. The refinery site is highly industrialised with numerous structures and activities occurring around the area. Substantial noise levels and atmospheric emissions are currently being generated by PetroSA's activities. The primary visual impacts are limited to the surrounding farms and traffic passing the site on the N2. The site adjacent to the refinery has similar impacts but is currently utilised for farming activities and the development of an OCGT plant will adversely impact on this. The impacts will be marginally higher due to its less degraded state. In contrast, the Proteus substation is located at a substantially higher point from the PetroSA Refinery and is visible from a large area. The site was disturbed during the construction activities for the substation however the flora has re-established itself to large extent with a few exotics present. The area surrounding the substation is largely undisturbed and can be considered as a valuable habitat for species of significance. A large variety of birds are also present at the site. A summary of evaluation of the sites is outlined in Table 7.

Table 4: Comparative Assessment of the Mossel Bay Sites

Impacts	**PetroSA Refinery**	**Adjacent to the PetroSA Refinery**	**Proteus S/S**
Biodiversity	0	1	3
Noise and Aesthetics	1	1	3
Emissions	1	1	1
Sense of place	1	1	3
Socio-Economic	0	0	0
Infrastructural Availability	1	1	2
Archaeology and Cultural	1	1	0
Total	**5**	**6**	**12**

4.2 AUTHORISATION AND SITING A GAS-FIRED POWER STATION

In conclusion, it can be seen that the both the sites around the PetroSA refinery are the most feasible sites for building a new OCGT plant at Mossel Bay. However, the establishment of facilities for commercial electricity generation is listed as item 1(a) of Regulation No. 1182 of the Environment Conservation Act, 1989 (Act No. 73 of 1989), and therefore requires approval from the relevant environmental authority. A detailed Environmental Impact Assessment (EIA) for the location of OCGT's at the identified sites must be submitted and approved by the relevant authority prior to any construction activities.

A generation study in Bangladesh evaluated twelve possible sites based on an extensive matrix of environmental and economic factors (Gore, 1995). The factors included, but were not limited to:

- Availability of land
- Land-use patterns
- Infrastructural capabilities and constraints
- Access to water resources
- Transmission requirements
- Severity of environmental impacts
- Geological constraints
- Hydrological constraints
- Access to fuel sources and associated impacts
- Accessibility to waste disposal sites.

In addition to the above, an Environmental Impact Assessment must address the following:

- Impacts to the natural environment – This should address amongst others, the issues on impacts to surface and ground water supplies, fauna and flora, impacts on the ambient air quality.
- Impacts to the current transport infrastructure – It must be established if the development is going to alter the current transport pattern and if the current infrastructure is going to

be placed under stress. If so, adequate upgrades to the transport network must be proposed.

- Areas of high cultural and heritage significance must be identified and avoided if possible.

5. REFERENCES

ABB. (1993). Combined Cycle Plants - the energy production system of our time; ABB Review 8/93:5-12.

Cape Metropolitan Council (2000). Atlantis Growth Corridor Management Plan, Volume 2: Issues, Vision and Proposals. Planning, Environment and Housing

Crowther Campbell & Associates. (2004a). Final Scoping Report for a New Regional Landfill Site to service the City of Cape Town. Cape Town.

Crowther Campbell & Associates. (2004b). EIA for the upgrading of PetroSA's refinery near Mossel Bay for the conversion to 100% unleaded fuel production – Final Scoping Report. Cape Town.

CSIR Environmentek. (2001). Environmental Impact Assessment for the Eskom Wind Energy Demonstration Facility in the Western Cape - Final Scoping Report. CSIR Report ENV-S-C 2001-024. Stellenbosch.

CSIR Environmentek (2002). Environmental Impact Assessment for the Eskom Wind Energy Demonstration Facility in the Western Cape – Final Environmental Impact Report. . CSIR Report ENV-S-C 2001-103. Stellenbosch.

Dennis Moss Partnership. (1999). Winelands Integrated Development Framework: The image of the winelands. Support Document No. 1. Draft 1. Dennis Moss Partnership. Stellenbosch.

Gore, BJ. (1995). Interim Report on Environmental Issues affecting the Installation and Operation of Combined Cycle Gas-Fired Power Plants. Eskom: JHB.

Hilland Associates. (2001). Specialist ecological study on the vegetation and fauna. In: Proposed Mossspar H (LAD) and Mosspar M (LAK) storage tanks and sub-sea pipeline, Voorbaai, Mossel Bay. SRK Consulting Engineers and Scientists, Cape Town.

Langston, L.S. & Opdyke, G.J. (1997) Introduction to gas turbines for Non-Engineers. *Global Gas Turbine News:* New York.

Low, A B and Rebelo, A G (eds). (1998). Vegetation of South Africa, Lesotho and Swaziland. Dept. Environmental Affairs and Tourism. Pretoria, South Africa. .

MCA. (2001). Klipheuwel Spatial Development Framework. Draft Report. MCA Urban and Environmental Planners, Cape Town.

Ninham Shand. (1996). Omega Electrical Substation Public Participation Programme and Environmental Impact Assessment. Report No. 2553A/7155. Ninham Shand Consulting Engineers, Cape Town.

PetroSA. (undated). PetroSA Nature Reserve Management Plan. PetroSA, Mossel Bay.

Provincial Administration of the Western Cape. (1985). Land Use Planning Ordinance (Ordinance 15:1985). Directorate: Planning Services, Cape Town.

SRK Consulting Engineers and Scientists. (2002). Proposed upgrade of the continuous firewater supply to the Voorbaai tank farm, Mossel Bay. SRK Consulting Engineers and Scientists, Cape Town.

Wibberley, L., Nunn, J., Cottrell, A., Searles, M.,Urfer, A. & Scaife P. (December 1999). LCA of Steel and Electricity Production. Available from http://ciss.com.au/ref/static/reports/public/acarp/acarp1.html (Accessed 3 August 2004).

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