Report by Econometrix (Pty) Ltd

KAROO SHALE GAS REPORT

SPECIAL REPORT ON ECONOMIC CONSIDERATIONS SURROUNDING POTENTIAL SHALE GAS RESOURCES IN THE SOUTHERN KAROO OF SOUTH AFRICA

JANUARY 2012

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Glossary

Glossary of Acronyms Used in this Report		
Acronym	**Term**	**Context**
$/m	Millions of Dollars	Monetary unit
ADO	Automotive Diesel Oil	Refined fuel type
ANC	African National Congress	Political Party
ASGISA	Accelerated and Shared Growth Initiative for South Africa	Government Development Programme
AVGAS	Aviation Gasoline	Refined fuel type
BBC	British Broadcasting Corporation	Media
BBL	Barrel	Petroleum product quantities
BOP	Balance of Payments	Economic Term
BTU	British Thermal Units	Measure of heat energy
CCSA	Competition Commison of South Africa	Regulator
CTL	Coal to liquid fuel conversion	Secondary energy conversion
CNG	Compressed Natural Gas	Gas end-user format
DRC	Democrat Republic of the Congo	Country
FDI	Foreign Direct Investment	Economic Term
GDP	Gross Domestic Product	Economic Term
GEAR	Growth, Employment and Redistribution Programme	Government Development Programme
GFCF	Gross Fixed Capital Formation	Economic Term
GGP	Gross Geographic Product	Economic Term, GDP at Sub-national Level
GOS	Gross operating surplus	Economic Term, GDP less Remuneration
GSA	Gas South Africa	Regulator
GTL	Gas to liquid fuel conversion	Downstream Gas Application
GVM	Gross Vehicle mass	System of clasifying commercial vehicles
GW	Giga Watts	Power measurement, Billions of watts
IK	Illuminating Kerosene	Refined fuel type
LNG	Liquified natural gas	Gas format for long distance transport
LPG	Liquifiied petroleum gas	Refined fuel type
MCF	Thousands of cubic feet	Volumetric measurement
MMCF	Millions of cubic feet	Volumetric measurement
MW	Mega Watts	Power measurement, Millions of watts
NATREF	National Refinery	Inland crude oil Refinery at Sasolburg
NERSA	National Energy Regulator of South Africa	Regulator
PASA	Petroleum Authority of South Africa	Regulator
PETROSA	Petroleum South Africa	Government owned petroleum company
Rm	Millions of Rands	Monetary unit
RSA	Republic of South Africa	Country
SA	South Africa	Country
SAPIA	South African Petroleum Industry Association	Industry umbrella body
SARB	South African Reserve Bank	Central Bank
SASOL	South African CTL processor	Corporation
SOEKOR	South African oil exploration corporation	Government Exploration agency, now part of PetroSA
STP	Standard Temparature and Pressure	Physical standard
TBD	Thousands of barrels per day	Petroleum product quantities
TCA	Technical co-operation Agreement	Agreement between prospective prospectors and SA Government
TCF	Trillions of cubic feet	Volumetric measurement
UK	United Kingdom	Country
US	United States of America	Country
VAT	Value added tax	Form of indirect taxation

Executive Summary

The strategic objective of this report is to present information and analysis that will provide a clear insight into the economic opportunities that may exist if a large gas find can properly be identified in the Southern Karoo.

1. Introduction

This chapter provides broad background information to establish a context for the remaining information in the report.

- The Karoo region is frequently identified by the geographic extent of a region of natural vegetation. Geologically it is much larger, extending northwards to the Democratic Republic of the Congo.
- Natural gas is made up predominantly of methane, the least complex hydro carbon molecule. It differs from manufactured gas (aka town gas) which is distilled from coal, and also differs from liquefied petroleum gas which is made up predominantly of butane and propane.
- The Department of Energy has issued Technical Co-operations permits to a number of prospecting corporations, some of whom have applied to convert these into exploration permits to move their investigations from desktop research to field research.

2. Primary Energy Resources in South Africa

The objective of this section of the report is to provide a summary understanding of energy usage in South Africa.

- The South African economy is highly dependent upon electricity production for its industrial, commercial and domestic energy needs. Electricity production, in the hands of parastatal utility company Eskom, is dominated by coal as the primary energy resource.
- Installed generation capacity ahead of commissioning two new coal fired power stations at Medupi and Kusile between 2012 and 2014, indicates that coal has a 81% share of generation capacity, nuclear a 4.56% share, pumped storage 3.55% a share, hydro 1.5% share and gas turbines a 0.86% share. The power generation capacity outside of Eskom is recorded as 6.0% for municipalities and 2.0% for private companies.
- DOE intentions are to shift the balance of primary energy inputs to include 48% from coal, 14% from nuclear, 16% from renewable energy sources and 9% from open cycle gas turbines by 2030.
- Open cycle gas turbines are currently run by Eskom using diesel fuel, awaiting gas pipeline connections to Western Cape offshore fields.
- Low average rainfall (400mm per annum) and high evaporation contribute to a lack of perennial rivers necessary for hydroelectric power generation, with water availability in a dry country acting as a constraint to other power generation options.
- Natural gas presents as a convincing candidate to fuel peak load electricity applications with distinct possibilities for water efficient, lower carbon emission base-load power generation as well.

- As in the rest of the world, including the most developed economies, water and primary energy resources combine to determine the location of energy harnessing activities, like power generation, synfuel manufacturing, etc.
- Large shale gas deposits could augment primary energy supplies to both the electrical and automotive power environments which dominate the South African energy economy. Ideal for peak load electricity generation and several broad categories of downstream applications, such a large gas play could revolutionise the energy sector, and contribute to displacing energy imports and/or supplying additional energy exports.

3. Future Growth, Energy Demand and New Resources

The objective of this section of the report is to examine three possible growth scenarios as a background to provide a backdrop depicting economic activity levels and energy demand against which the economic impact of large gas deposits may be benchmarked. Gas exploration as at December 2011 is summarised, and the transformational potential of the suspected large Karoo shale gas reserve is introduced.

- Three scenarios of future growth were developed for comparison in this report and to act as scenario background against which the economic importance of shale gas may be estimated later in this report.
- The underlying growth rates for the economy was set at 3% p.a. for the low growth case, 4.5% p.a. for the mid growth case, and 7% p.a. for the high growth case. The low growth case lies above the median probability of potential outcomes, while the mid growth case has previously been estimated to represent the real boundary of potential growth for the South African economy, given medium and long-term constraints in the profile of its assets and resources.
- The high growth case is presented for interrogation simply because it is a politically favoured target growth rate, although planning details of how to achieve the rate are either scant or non-existent.
- The higher the overall level of growth in the three scenarios, the greater the growth emphasis is on the fungible productive sectors of the economy, notably mining and manufacturing, and the less the emphasis on growth being propelled by the tertiary or service sector of the economy.
- The 7% sustained growth scenario creates a profile of skill and capital requirements, that are unlikely to be supplied by surpluses available from domestic resources, implying skilled immigration and FDI inflow, both of very significant proportions. The transition towards this scenario is anticipated to take years and not even medium-term plans by the SA government appear to be based on such growth rates
- The energy requirements of the mid and high growth scenarios presented here leave little doubt that the partial or complete attainment of either of these scenarios will be heavily dependent upon and closely integrated with the expansion of the energy base available to the South African economy over decades to come.

- Work by the International Energy Agency on the subject of Energy Poverty during 2011 leaves little room for belief that substantial energy resources can morally be ignored without proper investigation and consideration.
- An article by Brian Kantor can be seen to conclude that the desktop assessment of the Karoo shale gas reserve places it as a transformational opportunity for the South African economy and those who depend upon it for a livelihood.
- Proper assessment of the reserve is necessary, with physical exploration superseding desktop studies before economic assessment and cost benefit analysis both inside and outside of the pure economic sphere and across other disciplines can be properly undertaken.
- These points inform the assessment of the researchers that growth and development in the South African economy is highly likely to be energy resource hungry, even if supply and demand side efficiencies are achieved.

4. Economic Opportunities and Safeguards in the Gas Supply Chain

This section seeks to provide a link between micro economic concepts, such as industry and sector relationships with the potential gas industry, thinking relating to price formation and gas industry economic regulation.

- Viewing the production process of extracting and converting primary energy resources to end user products is assisted by production column analysis. The analysis forms a first step in identifying sectoral and product value, adding opportunities downstream of the extraction activities which bring the gas to the surface.
- There appear to be six main application clusters for natural gas within the South African context. They include exports of the gas, use of the gas as an industrial, commercial and domestic energy source, the generation of electricity, use as an automotive fuel, conversion to liquid fuels and as an energy feedstock for fertiliser production.
- Judging by existing experience in the limited natural gas market in South Africa, there is likely to be a significant level of price regulation within any expanding gas market in South Africa from regulators like PASA, NERSA and GSA. Commercial considerations, international benchmarking and investment considerations all form part of the price regulation framework.
- The greater the proportion of gas that is exported, the less is the downstream value added potential that exists.
- Suppliers of consumable items to the gas exploration and production phases should enjoy demand increases as a result of the gas related economic activities. It appears likely that the exploration phase will be supplied with imported capital equipment rather than locally produced equipment because of the specialised nature of the work to be undertaken. Local content within capital requirements should naturally evolve with any expansion of the project beyond the exploration stage – downstream capital requirements would probably begin to receive investment funding once resources are measured and geographically located, and gas production plans set out.

- Economic opportunities exist downstream of the gas producers in the form of moving the gas to wherever it is needed for end use. Methods include pipeline networks, LNG and CNG processing and distribution.

5. Macro-Economic Impact Scenarios

This section of the report introduces and describes the logic and output of the macroeconomic model created specifically for this research project.

- As noted previously, a significantly large and geographically diverse literature covering the production of shale gas around the world exists. Where these studies do address macro-economic concepts like contributions to gross value added, employment and fiscal revenue, those estimates are often based on aggregations of highly detailed micro economic data, which information is clearly available in those respective public domains.
- The combination of the information supporting such studies is ex-post rather than of a forecast nature. This compares with the prospect that the mature phase of Karoo shale gas production may well be a minimum of 15 years away, which makes for insurmountable hurdles in translating or transposing approaches in the foreign literature to the South African context.
- Another major difference lies in the fact that many of the developed and some of the developing world's gas resources are located in economies with well-established downstream gas driven value adding industries which are almost entirely absent from the South African economic landscape.
- With no macro-economic model structure readily transferable to the South African environment, the researchers configured a model designed to convert conceptualised large gas finds to macro-economic impact scenarios. The model is essentially Keynesian in structure, treating upstream gas production values as an injection into the existing flow of income of the domestic economy.
- A multiplier effect is calculated and the value of gross production is distributed across gross value added, intermediate consumption, compensation of employees, employment levels and fiscal revenue generation.
- Values for variables defining the resource sizes were informed by material discussed earlier, with values and multipliers and ratios derived predominantly from national accounts data from the SARB, data from Statistics SA's input end-use tables were also used, as was data relating to employment and remuneration. Two test scenarios relating to gas resources of 20tcf and 50tcf respectively are presented. Within each of these scenarios, a major driving assumption is the proportion of gas that may be exported, and therefore not be available for downstream value adding.
- Even if all the gas recovered is exported, downstream production in the economy does not reduce to zero. This is because the economy would still produce intermediate consumption goods used by the upstream activities and there would be rounds of induced demand generating domestic production.
- Benchmarking the model scenarios against the projected macro-economic growth scenarios discussed in section three of the report reveal the macro economic impacts of such large potential gas resources to be substantial, relative to both the last known full year of macro-economic data

(2010), and relative to projected macro-economic values by the midpoint of mature production assumed in these scenarios (2035).

- The modelled scenarios offer some quantitative support for the contention that large gas finds could be "transformational," for the South African economy. Similar expressions of it being a "potential game changing" development are also supported.

Test scenario summary of macro-economic model output

	0% Gas Exports		50% Gas Exports		100% Gas Exports	
Scenario Label	A	B	A	B	A	B
Upstream Production						
Resource Assumption TCF	20	50	20	50	20	50
Production Years	25	25	25	25	25	25
Average Mature production MMCF/Yr	969697	2424242	969697	2424242	969697	2424242
Project turnover $m	160000	400000	160000	400000	160000	400000
Project turnover Rm	1168480	2921200	1168480	2921200	1168480	2921200
Project intermediate consumption Rm	408968	778988	408968	778988	408968	778988
Project Value added Rm	759512	2142212	759512	2142212	759512	2142212
Project Employment - Man years	1377495	3885241	1377495	3885241	1377495	3885241
Maximum Employment	67278	189758	67278	189758	67278	189758
Project Employment Remuneration Rm	177795	501473	177795	501473	177795	501473
Downstream Production						
Project turnover Rm	2863293	6599068	1901347	4194202	939401	1789337
Project intermediate consumption Rm	1616759	3726164	1073596	2368257	530433	1010349
Project Value added Rm	1246535	2872904	827751	1825946	408968	778988
Project Employment - Man years	5951114	13715606	3951790	8717296	1952465	3718985
Maximum Employment	288539	664999	191602	422657	94665	180314
Project Employment Remuneration Rm	623267	1436452	413876	912973	204484	389494
Combined Upstream and Downstream						
Project Turnover Rm	4031773	9520268	3069827	7115402	2107881	4710537
Project Intermediate Consumption Rm	2025727	4505152	1482564	3147244	939401	1789337
Project Value Added Rm	2006046	5015116	1587263	3968158	1168480	2921200
Project GFCF Rm	444990	1133625	365869	935822	286748	738019
Project government Revenue Rm	886808	2223494	705894	1771208	524979	1318922
Project Employment - Man Years	7328608	17600846	5329284	12602536	3329960	7604226
Maximum Employment	355817	854757	258880	612415	161943	370073
Project Employee Remuneration Rm	801062	1937924	591671	1414445	382279	890966
Project Household Consumption Generated	991314	2398182	732192	1750376	473070.177	1102570.9

Key Conclusions

Desktop estimates predict that the shale gas of the Southern Karoo area could be a reserve of 450 trillion cubic feet, which would make it the fifth largest shale gas field in the world.

Test scenario Summary of macro-economic model output

Scenario Label	A	B
Upstream Production		
Resource Assumption TCF	20	50
Production Years	25	25
Project Value added Rm	759512	2142212
Project Employment - Man years	1377495	3885241
Maximum Employment	67278	189758
Downstream Production		
Project Value added Rm	1246535	2872904
Project Employment - Man years	5951114	13715606
Maximum Employment	288539	664999
Combined Upstream and Downstream		
Project Value Added Rm	2006046	5015116
Project Employment - Man Years	7328608	17600846
Maximum Employment	355817	854757

Upstream value added in scenario A represents 31% of total mining sector value added in the year 2010. Scenario D represents value added equivalent to 334% of the entire mining sectors contribution to GDP during 2010. Combined upstream and downstream value added in scenario A is equivalent to 8.3% of the GDP of South Africa during 2010, while scenario D, produces estimates of GDP contribution equivalent to 83% of the entire GDP of South Africa during 2010. All modelled calculations are at constant 2010 prices.

Total upstream and downstream employment in scenario A (0.44% of desktop reserve estimates) peaks at 48 070 jobs, while the highest resource scenario tested (4.4% of desktop reserve estimates) indicates peak total employment at 355 817 jobs.

Recent experiences with electricity supply and pricing developments have brought home to most South Africans the inseparable relationship between usable energy and economic performance. The economy simply cannot grow at any reasonable sustained rate without using additional energy resources.

A common assertion in South Africa is that the country possesses abundant cheap coal. Abundant, yes, but the Rand price of coal has kept pace with the Rand price of crude oil very closely over the past three decades. Nobody asserts that oil is cheap.

Un-exported natural gas has five major downstream uses. Apart from being a safe industrial, commercial and domestic fuel, it may be used to generate electricity with low water consumption, it may be converted into liquid fuels as is done at Secunda, it may be used as a transport fuel with minimal adjustments to existing engines and it may be used to provide the energy necessary in manufacturing fertiliser products. All these options provide substantial value adding, employment and remuneration opportunities.

The first step in harnessing such a potentially transformational economic resource has to be either proving or disproving its size and location. Only after that do prospects become bankable projects.

Four test scenarios, with consumed gas resource sizes ranging between 0.44% and 4.44% of the suspected 450 trillion cubic foot gas reserve were examined.

1. Introduction

1.1 Objectives of the report

The emergence into the public information domain of a number of applications for permission and rights to undertake exploratory work in terms of deposits of natural gas trapped in shale beneath the surface of the Great Karoo, globally and generically referred to as "shale gas," has led to heated public debate in South Africa, which has so far tended to focus on environmental issues. This report, while not ignoring the existence of that side of the debate, is intended to set out information and analysis that will provide a clear insight into the economic opportunities that may exist if a large gas find can properly be identified. With little currently being known about the size of the resource, it is difficult to make proper assessments of risk-reward ratios with only one component of that ratio having received prominent public attention, namely the risks perceived for the environment. This report seeks to outline quantum of the potential rewards of such a gas find as an input to decision making on the subject. With large rewards, environmental protection becomes financially empowered.

While the environmental risk focus that has already been applied to discussions of shale gas prospecting and production and the economic focus of this report provide insights into aspects of the project from two different but related vantage points, recognition must be made of their respective relationships with at least four other major business environment perspectives. These are the social, political, regulatory and technological environments that operate alongside the economic and ecological points of view in building a macro-planning framework within which to assess the strengths, weaknesses, opportunities and threats of such a project.

The main body of this report contains descriptive analysis and argument on **economic aspects** of the Karoo gas project as it is already known, and various avenues of logical expectations that might ensue from viable reserves of gas being discovered and later extracted for use in the South African economy. An econometric model is presented which provides a quantitative insight into important macro-economic indicators such as contribution to gross domestic product, employment and fiscal revenue potentials associated with gas resource size scenarios. Both the discussion portion of the report and the modelled scenarios consider the upstream and downstream economic activities associated with such a gas find. The appendices contain mainly tabulated and graphic data presentations supporting points made in the discursive material of the report, as well as research material considered too long to be conveniently included in the main body of the report.

1.2 What is the Karoo?

As a background to the discussion of the economics of the Karoo gas project, the information below is presented to describe the geographic environment within which the bulk of the proposed natural gas exploration will take place. Most South Africans will be aware of the division of the Karoo in areas commonly referred to as the Great Karoo and the Little Karoo. The latter also often being referred to as the wet Karoo. The Little Karoo is not directly related to the extensive area proposed for shale gas exploration, which is confined mainly to the Southern reaches of the Great Karoo.

The Great Karoo is a semi-desert natural region of South Africa. The High Karoo forms a distinct geological division of the country. The Karoo basin has existed for 250 million years and has not always been a dry area. Wetlands and forests during earlier periods of geological history have provided the basis of rich coal deposits, and there remains rich archaeological evidence of them having been populated by dinosaurs.

During more modern times, herds of large game wandered the grasslands, with the first human habitation having been made by the Koi San people, the last of the Stone Age tribes. The grassland was too poor to support cattle, which probably prevented its habitation by the Bantu peoples of the region. Western European settlers arrived in the Cape during 1652, but largely ignored the dry Karoo areas until the beginning of the 19th Century. When they did move into the area, they farmed sheep, which could more easily survive in the sparse grassland. Over the past 200 years, the vegetation has generally deteriorated because of changing farming methods and climatic changes.

The extension of the railway line from Worcester in the South East through to and beyond Kimberley in the North West, after the discovery of diamonds and gold in the SA interior, created a transport spine for the Karoo. Sheep farming remains the dominant economic pursuit, with other forms of farming where irrigation is possible. Most recently, game farming has developed as has ecotourism. North of the rail link from the Cape to Kimberley, mining provides the bulk of economic activity.

Exhibit 1: Location of the Karoo within Southern Africa

The area of the Karoo depicted in Exhibit 1 is clearly contained predominantly within the borders of the Republic of South Africa. This tends to follow the confines of a geographic natural region as defined by climate and vegetation. In geological terms, the Karoo basin is much larger than the area depicted in Exhibit 1, extending northwards (with some interruptions) as far as the Democratic Republic of the Congo (DRC). The area pertinent to the natural gas exploration project is most frequently referred to as the southern Karoo basin in detailed geological analytical reports.

1.3 What is Natural Gas?

Natural gas[1] is a gas consisting primarily of methane, typically with 0%-20% higher hydrocarbons (primarily ethane). It is found associated with other hydrocarbon fuel, in coal beds. Most natural gas is created by two mechanisms: biogenic and thermogenic. Biogenic gas is created by methanogenic organisms in marshes, bogs, landfills, and shallow sediments. Deeper in the earth, at greater temperature and pressure, thermogenic gas[2] is created from buried organic material.

During the first decade of the 21st century, Sasol, the South African synthetic and petro-chemical manufacturing giant, invested in an 800km gas pipeline connecting gas fields in Northern Mozambique with its liquefaction plants in Secunda. Along the route, several industries have tapped into that supply pipeline, and after the pipeline reached Secunda, the Johannesburg Metropol became the first city to link into the supply chain, replacing its town gas supply with natural gas.

Another possible point of confusion may lie between natural gas, which is predominantly made up of methane, and liquefied petroleum gas (LPG) which is a refined product, made up predominantly of butane and propane gasses, derived from crude oil.

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[1] Gas found in disused mines in the Virginia region of the northern Free State province is suspected of being biogenic in origin. See section 2.4 of this report for comments made by Petroleum Authority of South Africa (Pasa) CEO Mthozami Xiphu.

2 One of the few pieces of information regarding the suspected shale gas reserve that is the focus of this report that the shale is located at depths of 4 to 5km below the surface of the earth.

While a handful of cities have historically provided manufactured gas to residences via pipelines, South Africans are far more familiar with a third type of gas product namely liquefied petroleum gas. This is predominantly made up of butane and propane, and is produced while refining crude oil and synthesising petroleum fuels from coal and natural gas.

Southern Africa possesses off-shore proven gas reserves of commercially viable proportions, stretching southwards from Angola, (which also produces around 1.9 million barrels of crude oil per day) along the Namibian shoreline and onwards to the shoreline of the Northern Cape province of South Africa. Northern Mozambique also possesses viable gas fields, which have already been connected to South Africa's industrial complex, notably the liquid fuel production facilities of Sasol (producing around 193,000 barrels per day of mainly petrol and diesel, as well as other fuels and petrochemical feedstocks) and the city of Johannesburg. During the last months of 2011, new exploitable gas fields were reported in offshore locations along the north east coast of Mozambique. During the 1980's, Mossgas was established at Mossel Bay to manufacture approximately 35,000 barrels per day of diesel from natural gas condensate obtained from small gas fields off the coast of the Southern Cape. Mossgas now forms part of PetroSA.

Natural gas as a primary energy source for electricity generation is, as yet, a fledgling energy chain development in the South African context. Offshore gas from the Northern Cape coast will be brought to an open cycle turbine and generation set situated at Koeberg (the home of the country's only nuclear powered electricity plant) by pipeline. This is a peak load supplementary power generation initiative which is already installed, using diesel fuel as its primary energy source, at a rate of 60 kilolitres per hour. The pipeline will be extended from Koeberg some 500km eastwards to Mossel Bay to feed a second, similarly sized open cycle generator which will supplement electricity supply to the Southern Cape.

1.4 What is Shale Gas?

Shale gas is natural gas extracted from underground shale deposits. Shale gas has become an increasingly important source of natural gas in the United States over the past decade, and interest has spread to potential gas shales in Canada, Europe, Asia, and Australia.

Some analysts expect that shale gas will greatly expand worldwide energy supply. A study by the Baker Institute of Public Policy at Rice University concluded that increased shale gas production in the US and Canada could help prevent Russia and Persian Gulf countries from dictating higher prices for the gas it exports to European countries. The Obama administration believes that increased shale gas development will help reduce greenhouse gas emissions.

Shale gas is one of a number of “unconventional” sources of natural gas; other shale sources of natural gas include coal bed methane, tight sandstones, and methane hydrates. Tight gas is natural gas held in rock pores up to 20 000 times narrower than a human hair. Often the gas will not flow freely into a well or it flows at a much slower rate than n normal gas reservoirs.

Shale gas has been produced for many years from shales with natural fractures; the shale gas boom in recent years has been due to modern technology in hydraulic fracturing (fracking) to create extensive artificial fractures around well bores.

Horizontal drilling is often used with shale gas wells, with lateral lengths up to 10,000 feet (3,000 m) within the shale, to create maximum borehole surface area in contact with the shale.

1.5 Proposals for Exploration[3]

Three foreign-owned companies have been granted permission by the Government (through Petroleum Agency SA) to explore for gas.

The first stage of such exploration takes place under an arrangement known as a Technical Cooperation Permit with government and consists of nothing more than desktop research. Applications to convert these Technical Cooperation Permits (TCP's) to physical exploration permits have been halted by a moratorium imposed by the department of energy, which has subsequently been extended to March 2012. They are Royal Dutch Shell, Falcon Oil & Gas from America, and Sunset Energy (also called Bundu), from Australia.

- Shell wants to extract gas from about 90,000 square kilometres (km^2). That is an area the size of KwaZulu-Natal. It stretches from Bedford in the east to Sutherland in the west.
- Falcon Oil & Gas have got a permit to explore 30,000 km^2 for gas, an area one and a half times the size of the Kruger National Park. It includes the mohair capital of Jansenville, as well as Aberdeen, Rietbron, Merweville and Leeu Gamka.
- Sunset Energy has a slightly larger area – 35,000 km^2 – including Pearston and areas around Graaff-Reinet.

Together they make up an area as big as the entire Eastern Cape.

In addition, a consortium made up of Sasol[4], American Chesapeake Energy and Statoil ASA has applied to explore an area similar in size to Shell's – about 88,000 km^2. It includes a large portion of KwaZulu-Natal and most of the Free State.

The US Energy Information Administration (EIA) confirms the list of TCP holders, adding Anglo Coal to the list. The summary is reproduced in Box 1 below.

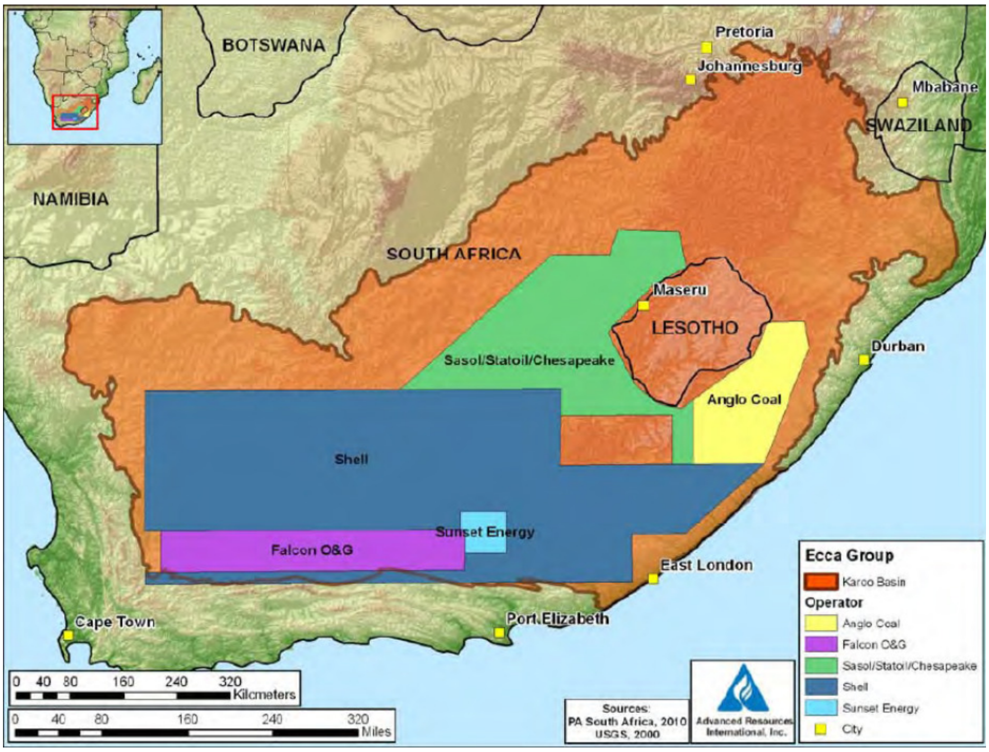
[3] *Information regarding the companies involved in the early phase of exploration was drawn from the article entitled "Fracking 101" (see bibliography). This article described the position as it existed towards the end of 2010. An updated list of shale gas contenders, as well as other gas explorers and producers in the wider South African context is contained in Section 2.4.*

[4] *On the 1st of December 2011, the local media reported that Sasol had announced that it would not seek to extend the deadline for conversion of its existing arrangement with the Department of Energy (DOE) to transform it to exploration rights, due to the moratorium on such rights for shale gas exploration. The reports indicated that the company may return to negotiations with government once greater certainty regarding exploration rights had become available.*

Box 1: List of TCP holders

Falcon Oil and Gas Ltd. Was an early entrant into the shale gas play of South Africa, obtaining an 11,600 mi^2 (30,000 km^2) Technical Cooperation Permit (TCP) along the southern edge of the Karoo basin. Shell obtained a larger 71,400 mi^2 (185,000 km^2) TCP surrounding the Falcon area, while Sunset Energy holds a 1,780 mi^2 (4,600 km^2) TCP to the west of Falcon. The Sasol/Chesapeake/Statoil JV TCP area of 34,000 mi^2 (88,000 km^2) and the Anglo Coal TCP application area of 19,300 mi^2 (50,000 km^2) is to the north and east of Shell's TCP. *See exhibit below.*

Exhibit 2: TCP areas[5]



Shale gas exploration intentions indicated during the first half of 2011 stretch across five of the nine South African provinces, mainly the Western Cape, the Eastern Cape, the Northern Cape, the Free State and Kwa-Zulu Natal.

In the event of commercially viable reserves of shale gas being discovered, the prospecting activity would transform itself into development of gas extraction from the identified reserves. This part of the overall gas supply and use chain is conventionally referred to as upstream production. In its most narrow sense, downstream production would include distribution and application activities directly related to the natural gas produced by upstream activities. It is important to note, for the purposes of macroeconomic modelling outputs referenced in this report, downstream activities are taken to include these generally accepted concepts of downstream activity, but also include suppliers to the upstream producers, as well as suppliers to household and government consumption, and government and business fixed capital formation, dependent upon the value of upstream gas production.

[5] *Exhibit sourced from EIA report: "World shale gas resources: an initial Assessment of 14 Regions outside the US, EIA April 2011.*

2. Primary Energy Resources in South Africa

The objective of this section of the report is to provide a summary understanding of energy usage in South Africa, and to establish the existing relationship between energy resources and end user fuels like electricity and automotive fuels. The importance of water in the fuel production chain is also highlighted, as is South Africa's international trade balance relating to energy.

Table 1: Energy Production, Consumption and Density Statistics of Top 30 Producers (Mt Crude Oil equivalents)

Country	Energy Production Mt Oil Equivalent	Prod Rank	Energy Consumption Mt. Oil Equiv	Cons Rank	GDP 2007 $ Bn	Energy/GDP Mt Oil/$bn	Population - Millions	Energy Cons. Per Capita	Area - SQ. Km	Energy/Area T Oil/Sq. Km
China	1641	1	1717	2	2645.00	0.65	1 323.60	1.30	9 560 900	179.6
United States	1631	2	2340	1	13164.00	0.18	301	7.77	9 372 610	249.7
Russia	1185	3	647	3	987.00	0.66	142.5	4.54	17 075 400	37.9
Saudi Arabia	577	4	140	14	349.00	0.40	25.2	5.56	2 200 000	63.6
India	419	5	537	4	912.00	0.59	1 119.50	0.48	3 287 263	163.4
Canada	401	6	272	7	1272.00	0.21	32.6	8.34	9 970 610	27.3
Iran	304	7	163	12	218.00	0.75	70.3	2.32	1 648 000	98.9
Brazil	288	8	210	9	1068.00	0.20	188.9	1.11	8 511 965	24.7
Ausralia	271	9	122	16	781.00	0.16	20.4	5.98	7 682 300	15.9
Indonesia	263	10	180	10	365.00	0.49	225.5	0.80	1 904 443	94.5
Mexico	259	11	177	11	839.00	0.21	108.3	1.63	1 972 545	89.7
Norway	234	12			335.00		4.6	0.00	323 878	
Nigeria	232	13	104	17	115.00	0.90	134.4	0.77	923 768	112.6
Venezuela	205	14	61	20	182.00	0.34	27.2	2.24	912 050	66.9
United kingdom	204	15	234	8	2377.00	0.10	59.8	3.91	242 534	964.8
Algeria	175	16			115.00		33.4		2 381 741	
United Arab Emirates	168	17			130.00		4.7		83 600	
South Africa	159	18	128	15	255.00	0.50	47.6	2.69	1 225 815	104.4
Kuwait	146	19								
France	137	20	276	6	2248.00	0.12	60.7	4.55	543 965	507.4
Germany	135	21	345	5	2897.00	0.12	82.7	4.17	357 868	964.0
Kazakhstan	122	22								
Japan	100	23			4368.00		128.2		377 727	
Iraq	96	24								
Libya	95	25								
Malasia	94	26	61	21	151.00	0.40	25.8	2.36	332 665	183.4
Argentina	81	27	64	19	214.00	0.30	39.1	1.64	2 766 889	23.1
Ukrane	81	28	143	13	106.00	1.35	46	3.11	603 700	236.9
Poland	79	29	93	18	339.00	0.27	38.5	2.42	31268	2974.3
Egypt	76	30	61	22	107.00	0.57	75.4	0.81	1 000 250	61.0

Source: Econometrix

By the year 2009, the size of the South African economy was ranked number 32 in terms of the size of its GDP converted to US Dollars. Its production and consumption of energy, however, rank much higher in the sample of 30 countries summarised in Table 1 above, indicating a relatively high use of energy relative to overall economic production, and on both a per capita and geographic surface area basis.

2.1 End User Energy - Electricity

One of the initial objectives of establishing Eskom, namely the provision of cheap electricity, provided the basis for economic development in the country until the 1980's when installation of too much new generating capacity created an oversupply of electricity, with the resulting low prices creating significant diseconomies, including:

- Wasteful applications of electricity in industrial, transport and household settings.
- Distribution of surplus capacity to poor consumers, at zero or very low prices.
- Scant regard for maintenance requirements in a regimen of cost saving.
- Lack of foresight at top political management level, which clearly lost the thread of the relationship between GDP growth and power consumption.

- Reduction of reserve margin for power generation to well below the 15% desired level (8 – 10% by early 2008).
- Capacity build programme therefore delayed, emerging in 2008 but should have been in place by 2003.

The comparatively low level of GDP produced for each unit of energy consumed within the South African economy has three main causes.

Firstly, and probably most importantly, has been the fact that electricity has historically been very cheap within South Africa – until 2007, the generation price of electricity was estimated as being the cheapest in the world, and some 30% cheaper than the next economy, namely Australia. After 2007, the electricity pricing position changed significantly, with annual average electricity price increases in excess of 25% having taken place each year, with another already regulated for 2012, and Eskom being on record as having indicated that it will apply for a further three increases in this order of magnitude to bring their price to an equitable cost based pricing level.

Secondly[6], the physical size of the South African land mass is equivalent to the whole of Europe, west of the Russian border. In US equivalent terms, it is roughly the size of the state of Texas, but the GDP of South Africa is considerably smaller than that of Belgium. This results in energy losses in the distribution of electricity, and intermediate consumption of energy products in the distribution of other energy carrying products such as petroleum and coal.

Thirdly, the diseconomies resulting from cheap electricity referred to above have led to intense energy use in productive sectors (e.g. mining and downstream mineral beneficiation) relative to the value added by those sectors and industries.

The table below provides a summary of dominant primary energy sources as they occur in the generation of electricity around the world. Within each primary energy resource class, the numeric values alongside each country listed within the class shows the proportion of electricity generated from the primary energy source.

[1] *Country profile table at the end of the Pocket World in Figures 2012 (and earlier editions), published by the Economist Newspapers.*

Table 2: Sources of Electricity

Oil			Coal		
1	Senegal	100	1	Poland	94.5
2	Yemen	100	2	South Africa	93.1
3	Iraq	98.8	3	Estonia	90.9
4	Jamaica	97.2	4	Austria	78.3
5	Benin	96.8	5	China	77.5
Hydropower			**Gas**		
1	Paraguay	100	1	Turkmenistan	100
2	Nepal	99.8	2	Trinidad & Tobago	99.5
3	Congo	99.7	3	Algeria	97.6
4	Congo-Brazzaville	99.7	4	Belarus	94.2
5	Mozambique	99.7	5	United Arab Emirates	92.1
Nuclear Power					
1	Lithuania	81.8			
2	France	78.7			
3	Belgium	58.5			
4	Slovakia	55.7			
5	Bulgaria	48			

Source: The Economist, World pocket book in Figures, 2010

The dominance of coal in the South African electricity generating environment is very clear. Only Poland has a greater dependence on coal than South Africa does. It is noted that this data refers to a period close to 2005, and the rapid development of the Chinese power generation sector since then may have moved its dependence on coal upwards from the 77.5% mark, closer to the South African level of 93.1%.

The dominance of coal as the primary energy input to electricity generation in South Africa is currently under close inspection because of the pollution challenges that the fuel brings with it. There have been many warnings of the pollution threats in the production chain, including the release of sulphur in the mining process, through to carbon dioxide, particulate emissions and mercury vapour in the flue emissions of the power stations. Other heavy metals are conceivably also emitted in this process. Carbon capture and other environmental safeguards are expected to be retro-fitted to existing power stations and (as will be seen later in this section) coal-fired power stations are not part of the electricity supply expansion plan of government after the Kusile coal fired power station, currently under construction, comes on stream during 2014 and 2015.

Any substantial discoveries of natural gas within the South African environment could contribute meaningfully to the reduction of the heavy reliance on coal in the energy input mix for electricity generation. Other users of coal could also enjoy benefit from the widely accepted status of natural gas being a cleaner energy source than coal, particularly with rising consciousness regarding carbon emissions.

A study by Statistics South Africa (South Africa – energy statistics, energy accounts and institutional Arrangements, www.statssa.gov.za) in 2009, outlining the installed electrical power capacity of South Africa, estimates the total capacity at 39440Mw. Of this, Eskom controls 36240Mw (excluding Medupi and Kusile resources currently under construction), while Municipalities control 2400Mw of capacity and private companies 800Mw of capacity. Installed generation capacity ahead of commissioning two new coal fired power stations at Medupi and Kusile between 2012 and 2014, indicates that coal has a 81% share of generation capacity, nuclear a 4.56% share, pumped storage 3.55% a share, hydro 1.5% share and gas turbines a 0.86% share. The power generation capacity outside of Eskom is recorded as 6.0% for municipalities and 2.0% for private companies. Care must be taken when comparing various data sources regarding the shares of energy inputs into electricity generation. The figures may relate to generation capacity, as in this paragraph, or to actual energy produced. The latter will vary from time to time, because of maintenance and unplanned shut downs, etc.

Hydroelectricity is limited in terms of prospects within South Africa, predominantly because of a lack of large perennial rivers. The existing hydroelectric plants are restricted to a handful of large dams in the interior of the country. The nuclear power plant, built in the early 1980's, is located near Cape Town, which is far away from the coalfields clustered around the north and north eastern part of the country. The pumped storage generation facilities are predominantly found on the Eastern escarpment of the country, which separates Kwa-Zulu Natal from the inland provinces of the Free State, Gauteng and Mpumalanga.

During the last decade, some minor experimental investment has been made in wind farm electricity generation, notably in the Western Cape. At present, this represents less than 1% of total electricity generation, standing at 300Mw capacity.

Between 1974, when the Dock Road power station in Cape Town was closed, and 2007, there was no petroleum power electricity generation supplied to the National Grid.

During the course of 2007, a single open cycle gas turbine was brought into use located near the nuclear power station, in the Western Cape, to provide peak load capacity. This is intended to be fuelled by natural gas which will be piped from offshore platforms further north along the West Coast. Until the pipeline to Koeberg has been completed, the open cycle turbine is being powered by diesel. Most would consider this an expensive interim solution. Eventually, the natural gas pipeline is intended to service similar open cycle turbines further eastward in the Southern Cape, namely at Mossel Bay.

Exhibit 3: Electricity Generation Locations, Electricity Distribution

C = Coal (yellow), N=Nuclear (purple); G= Gas (black); H=Hydro (red); P = Pump Storage (white)

Source: PBMR. This illustration is sourced from Pebble Bed Modular Reactor Organisation, circa 2009

The map in Exhibit 3 gives a rough illustration of the locations of the power generation plants discussed in Section 2 above. Some important location drivers can be associated with the information in this map, and are summarised as follows:

- The major coal fields in South Africa are located in the inland provinces of Mpumalanga, Limpopo and North West provinces.
- Those same provinces tend to be relatively scarcely endowed with water supplies, although rich in coal.
- The coastal areas, slightly richer in water resources, are far away from the coal fields.
- More plentiful coastal water resources will have to be matched with primary energy resources other than inland coal.
- This points to nuclear as a potential primary energy source for coastal electricity generation.
- Wind farm generation appears most suitable for the southern and south-western Cape coastal belt.
- Biomass conversion to energy is more likely to be developed for liquid fuels than for power generation, if at all.
- Pumped storage schemes on the escarpment have to rely on surplus generating capacity during off-peak load periods every day.

Such natural challenges are likely to shape the development of the future mix of primary energy resources used to generate electricity and/or heat energy displacement mechanisms that will reduce the demand for electrical or other energy forms that presently all contribute significantly to greenhouse gas emissions. In summary, the implications of the points made above include:

- Nuclear powered generators will probably be located at the coast, rather than inland.
- Inland power generation expansion is likely to remain centred around known large coal reserves.
- This option constrained by access to suitable quantities of water.
- Coal to be used for power generation is likely to be of low quality, leaving high quality coal available for export.
- Alternate primary energy sources like wind, bio-mass and tidal resources appear expensive and are likely to remain small contributors despite existing tax benefits.
- Known natural gas will grow as a primary energy resource as and where discoveries are made and production put into place.

Opening the second Regional Conference on Energy and Nuclear Power in Africa[7], that took place in Cape Town at the end of May 2011, South Africa's energy Minister Dipuo Peters pointed out in her address that the cabinet had in April of last year approved South Africa's Integrated Resource Plan, which would address the electricity generation mix for the next 20 years:

[7] *Report in Cape Argus of 31st May 2011.*

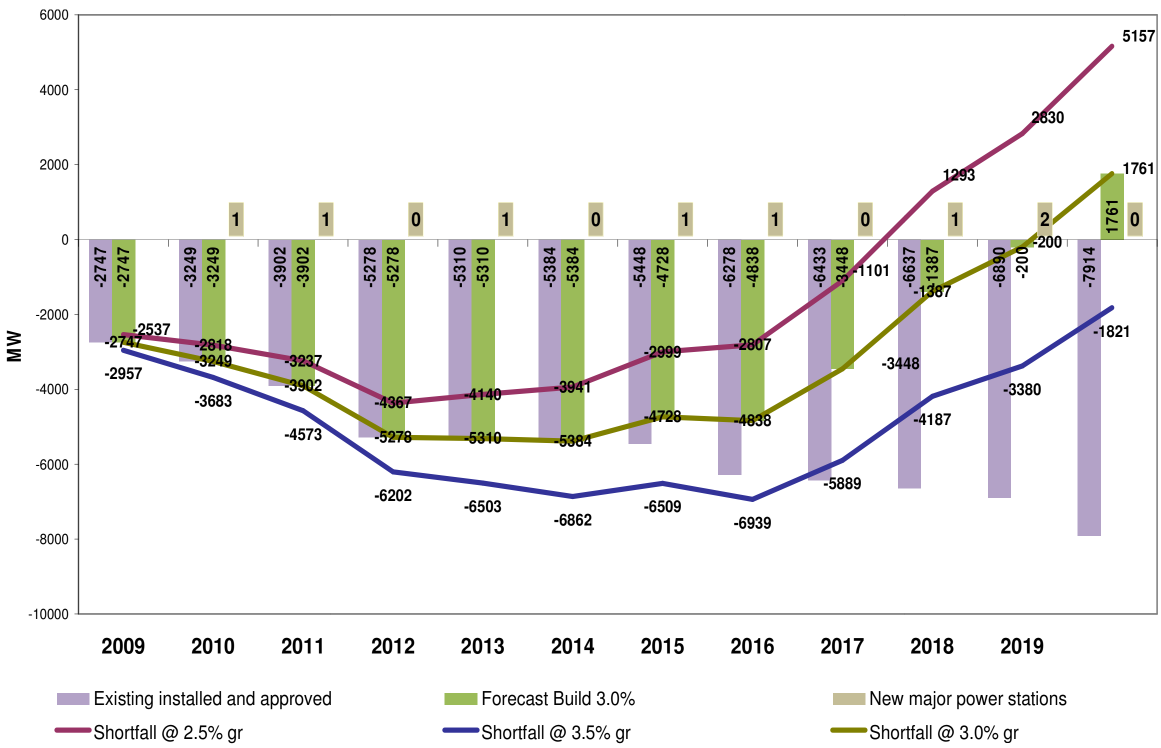
"This is a balanced plan that seeks to responsibly use energy sources available to us, including gas, biomass, nuclear, coal and imports." In terms of this plan,[8] *"new generation capacity of 42% renewable energy, 23% nuclear and 15 % coal was expected by 2030."*

Focussing as it does on the energy resource component of the electricity supply side; the mix of the resources appears achievable. Debates have ensued about timing within the IRP, and which resources may be substituted for others if certain major developments are delayed (e.g. the nuclear power plant perhaps not being on stream by 2019).

South Africa's neighbour, Botswana, has begun development of coal fired power stations close to the South African border, situated on rich coal fields which are estimated to equal the South African reserve of 200 years supply at expanding consumption rates. The economy of Botswana has very little requirement for the massive additional capacity that these developments could make available, and the obvious intention must be to export power to South Africa, and probably nearby Zimbabwe as well.

Chart 1 below reflects a synthesis of available information relating to energy supply and demand over the decade between 2009 and 2019, which would roughly correspond with the period of exploration for shale gas in the Karoo Gas. It is drawn from a number of private studies undertaken in the recent past by Econometrix for players on both the demand and supply side of the electrical energy in South Africa.

Chart 1: Electricity Shortfall



Source: Econometrix Pty Ltd

[8] *Note that this is new capacity, presumably to be installed between 2011 and 2030. The planned overall capacity by 2030 of the IRP for electricity, as per the October 2010 release by the DOE is set out in the article making up appendix D of this report, and includes 48% from coal, 14% from nuclear, 16% from renewable energy sources and 9% from open cycle gas turbines.*

The estimate for 2019 does not include proposals for the nuclear facility referenced by Minister Dipuo Peters at the end of May 2011, but the work being undertaken by Eskom at Medupi and Kusile through to 2014 casts some doubt on the combined engineering and financial capacity of the national electricity supplier to build a nuclear plant that would be in operation by 2019. The obvious implication of Chart 1 is that, by the time Karoo Gas could become available after the exploration phase, South Africa is likely to be short of generating capacity particularly during peak load periods.

Eskom has been driving demand management initiatives for several years in an effort to curb demand on its system. The largest part of the initiative has been the subsidisation of solar water heaters for domestic applications. These subsidies were discontinued during 2011 and no subsidy support was offered for photo voltaic conversion of solar energy to electricity.

Natural gas fired generation capacity is very suited to backing up larger coal and nuclear powered facilities, providing peak load generation capacity. Gas powered open cycle turbines have advantages in the fact that they do not require lengthy start-up periods, and do not require water resources. Combined cycle turbine generating sets do require water for the second portion of the cycle, but compensate for this by being highly efficient, converting around 50% of the gas energy to electrical energy, with additional energy available for heat load applications by bleeding off steam from various stages of the steam turbine cycle. (See: Northwest Power Planning Council, New Resource Characterization for the Fifth Power Plan, Natural Gas Combined-cycle Gas Turbine Power Plants: August 8, 2002: http://www.westgov.org/wieb/electric/Transmission%20Protocol/SSG-WI/pnw_5pp_02.pdf)

2.2 End User Energy – Transport Fuels

Automotive transport in South Africa is predominantly dependent on two petroleum fuel types, petrol and diesel. These fuels are sourced from the refining of mineral oil, or derived synthetically from coal or natural gas or natural gas condensate. There are a handful of hybrid vehicles on South African roads, most of which have been supplied by Toyota, and which convert petrol to electrical energy via a small internal combustion engine. At the time of writing there were no known hydrogen powered internal combustion engine or fuel cell vehicles on the country's roads. Interests in various electrically powered light vehicles has waxed and waned, mainly as a result of liquid fuel prices rising and falling over the past three decades, but a South African designed and built electrically powered car, called the Joule, is expected to be launched in the near future.

Table 3: Natis Vehicle Populations & Forecast

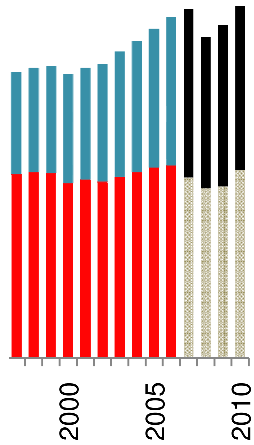
Source	eNaTIS	eNaTIS	%Y-O-Y	ECX	%Y-O-Y	ECX	%Y-O-Y	ECX	%Y-O-Y	ECX	%Y-O-Y	ECX	%Y-O-Y
Year	2009	2010		2011		2012		2013		2014		2015	
Motor Cars & Station Wagons	5411093	5596491	3.43%	5804611	3.72%	6026316	3.82%	6261551	3.90%	6528179	4.26%	6830519	4.63%
Minibuses	282941	285992	1.08%	289885	1.36%	294045	1.44%	298537	1.53%	303550	1.68%	309280	1.89%
Buses, Bus Trains & Midibuses	45217	47342	4.70%	48805	3.09%	50800	4.09%	52662	3.67%	54790	4.04%	57051	4.13%
TOTAL PASSENGER	5739251	5929825	3.32%	6143301	3.60%	6371161	3.71%	6612750	3.79%	6886518	4.14%	7196850	4.51%
Freight GVM< 3500 kg.	1946292	2000915	2.81%	2063974	3.15%	2131366	3.27%	2204144	3.41%	2288956	3.85%	2390033	4.42%
Freight GVM>3500 kg.	321604	325019	1.06%	329243	1.30%	334280	1.53%	339736	1.63%	346118	1.88%	353702	2.19%
TOTAL FREIGHT	2267896	2325934	2.56%	2393217	2.89%	2465646	3.03%	2543879.9	3.17%	2635074	3.58%	2743735	4.12%
OTHER VEHICLES	213632	216465	1.33%	224041	3.50%	231883	3.50%	239999	3.50%	248399	3.50%	257093	3.50%
TOTAL SELF-PROPELLED VEHICLES	8220779	8472224	3.06%	8760558	3.40%	9068689	3.52%	9396629	3.62%	9769990	3.97%	10249246	4.38%
Caravans	105462	105251	-0.20%	106304	1.00%	107367	1.00%	108440	1.00%	109525	1.00%	110620	1.00%
Trailers GVM<3500 kg.	719034	740443	2.98%	762656	3.00%	785536	3.00%	809102	3.00%	833375	3.00%	858376	3.00%
Trailers GVM>3500kg.	146402	150496	2.80%	154744	2.82%	160454	3.69%	166471	3.75%	173059	3.96%	176851	2.19%
Motorcycles	362400	327297	-9.69%	340389	4.00%	354004	4.00%	368165	4.00%	382891	4.00%	398207	4.00%
Others & Unknown	33704	33689	-0.04%	33015	-2.00%	32355	-2.00%	31708	-2.00%	31074	-2.00%	30452	-2.00%
TOTAL VEHICLES	9587781	9829400	2.52%	10157666	3.34%	10508405	3.45%	10880514	3.54%	11299914	3.85%	11772182	4.18%

At the end of 2010, the country had a total of 9.8 million on–and-off road vehicles. The on-road vehicles divide into light vehicles with a gross vehicle mass of less than 3.5 metric tonnes numbering 8.2 million, which require either petrol or diesel fuel. Of these powered light vehicles, the majority use petrol, while the heavier (GVM >3.5t) buses and freight carriers number 0.6 million, and are mainly diesel powered. The main reason for the dominance of petrol in lighter, smaller engine vehicles has been the historic high sulphur content (around 500 parts per million) of locally produced diesel fuel. Sasol's synthetically produced diesel is rated at 0ppm sulphur, and forms a valuable blend stock.

After the threat of international oil sanctions against South Africa disappeared during 1994, the South African Petroleum Industry Association (SAPIA) published long-term historic data for petrol and diesel sales between 1950 and 1994, which were updated by a combined Statistics SA and SAPIA. During 2007, the competition commission of South Africa (CCSA) ruled that the pooling of petroleum sales data contributed to anti-competitive practices, and all subsequent data exists as modelled estimates.

Chart 2 below contains sequential data from SAPIA, Statistics SA and estimates from 2007 onwards by Econometrix, reflecting the long-term development of petrol and diesel sales in South Africa, covering the period 1950 to 2010.

Chart 2: Petrol and Diesel Demand in South Africa - Billions of Litres



Petrol and diesel are overwhelmingly dominant in the mix of liquid fuels consumed in South Africa. Other petroleum fuel types are used in small quantities, but have historically been relatively suppressed by the availability of inexpensive electricity.

The exhibit below shows the physical location of the refineries together with the nameplate capacities, while the pie charts illustrate the relative shares of the crude oil refineries in South Africa.

Exhibit 4: Physical location of SA refineries

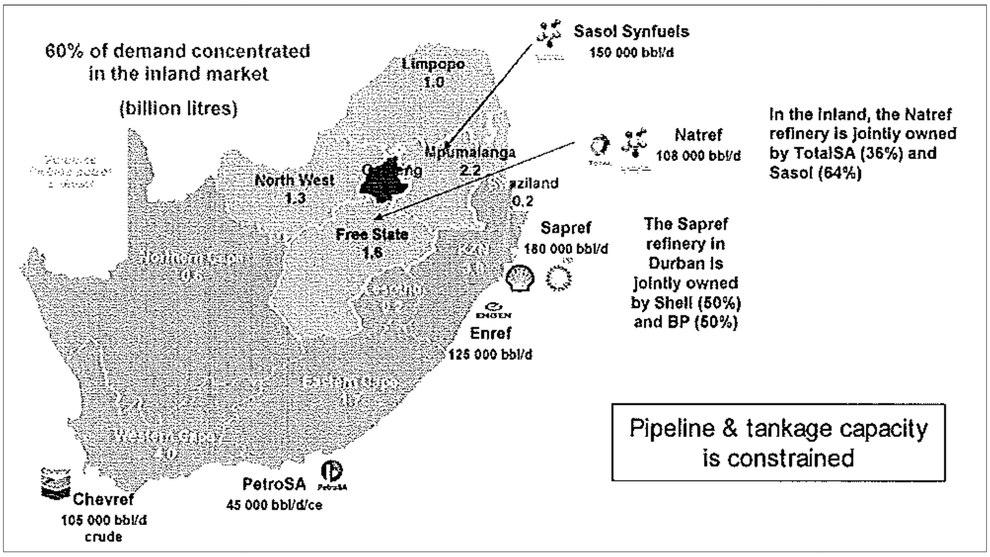
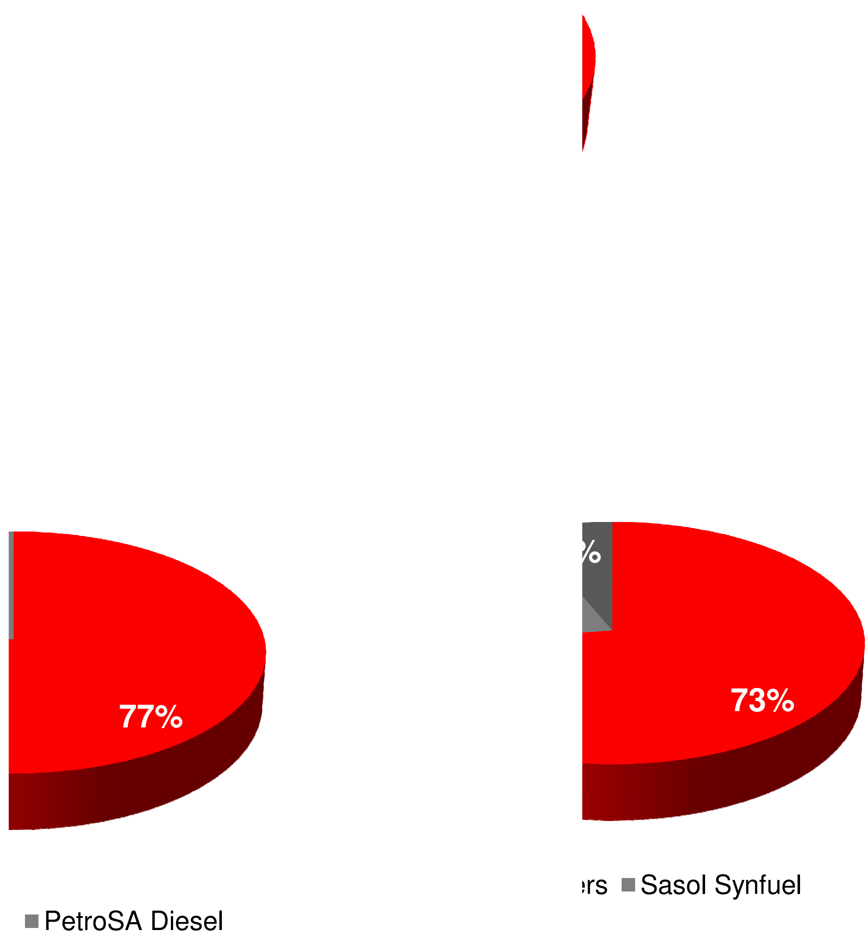


Chart 3: Relative shares of the crude oil refineries



The output of the crude oil refineries is augmented by synthetic fuel production at SASOL 1 in Sasolburg (naphtha for further refining at NATREF), Sasol 2 and 3 at Secunda (wide range of fuel components and petro chemicals) and the PetroSA (gas condensate to diesel fuel) facility at Mossel Bay. Still dealing with nameplate capacities, the above chart depicts the augmentation of crude oil refining for the South African petroleum product mix from these synthetic fuel facilities.

Natural gas has enjoyed growth popularity as an automotive fuel around the world. The most straight forward application is the use of compressed natural gas as a fuel for conventional Otto cycle petrol engines, with relatively simple conversions to power units originally designed for petrol use being available. Switchable multiple fuel vehicles are already in existence, where the driver can instantly select between fuel types (e.g. petrol, natural gas, gasohol and LPG) at the flick of a switch. The use of natural gas as an automotive fuel would require the development of a wide ranging distribution network for the fuel, unless it is to be used in vehicles anchored around a particular point (e.g. municipal buses). A second use for natural gas as a feedstock for automotive fuels already exists in South Africa, namely its conversion to conventional auto fuels like petrol and diesel as is done in the context of Sasol and PetroSA synthetic fuel production. The ability for natural gas to either displace or expand the existing mix of fuels providing automotive power will depend upon relative pricing and market acceptance of CNG powered vehicles.

2.3 End User Energy – Low Volume Petroleum Products

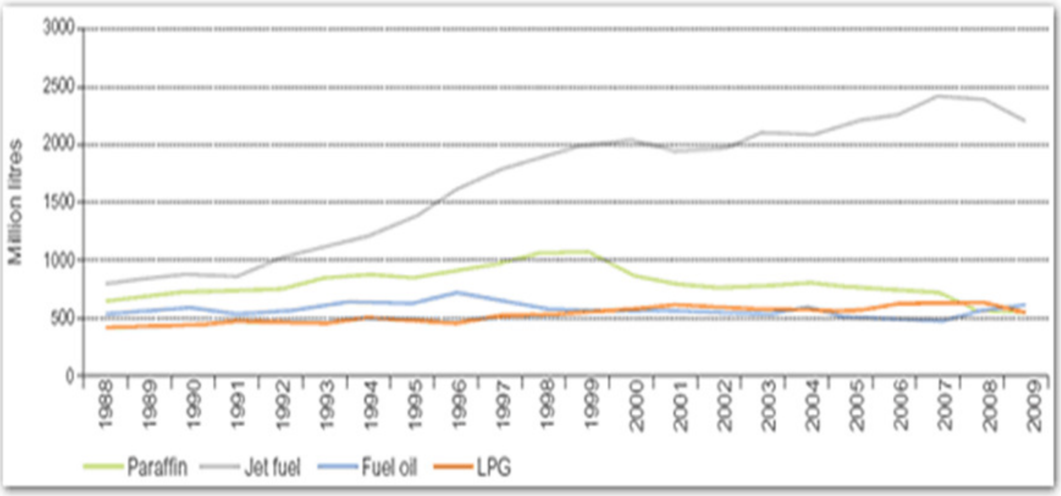
The existence of plentiful and historically relatively cheap electricity in South Africa has curbed the use of many fuels outside of the petrol and diesel categories, which are much more commonly used in both developed and developing economies around the world.

To illustrate this, the chart below presents a graphic representation of sales data for lower volume fuels in the South African liquid fuel mix. The graphic was obtained from the SAPIA website (www.sapia.co.za).

The application of these petroleum fuels is almost exclusively to produce heat for industrial, commercial and domestic applications. Illuminating paraffin and LPG are also commonly used to produce light in areas of the country where electricity may not be available.

In terms of heat generation, natural gas is clearly a potential substitute or augmentation fuel.

Chart 4: Sales data for lower volume fuels in the South African liquid fuel mix



Existing installed capacity of industrial equipment making use of these lower volume petroleum based fuels in South Africa because of the emergence of natural gas supplies, is not likely to take place unless substantial economic savings which outweigh the costs of converting (or more likely, replacing) installed capacity become available. However, natural gas would offer a competing product as an input to heat generation applications of these fuels, and could prove to be more environmentally friendly.

2.4 Current Status of Natural Gas

In comparison to many other developed and developing economies around the world, natural gas usage in South Africa is currently in a very early stage of development. The principal use is of onshore natural gas originating in Northern Mozambique, with the gas transported to Secunda via an 800km pipeline. An extension to that pipeline link stretches from Secunda to the Johannesburg Metropolitan area, where previously supplied town gas has been displaced by natural gas. PetroSA uses gas condensate to synthesise diesel fuel at Mossel Bay. An open cycle gas turbine located near the Koeberg nuclear power plant and intended for peak load generation augmentation, awaits a pipeline link to gas reserves off the Northern Cape coast and is currently run on diesel fuel.

Significant gas-related developments[9] are expected in South Africa in the coming years, as numerous new surveys have been conducted offshore in previously underexplored areas, according to exploration developer Petroleum Agency South Africa (PASA).

Further, PASA CEO Mthozami Xiphu says interest in the unconventional onshore gas potential of South Africa may allow for a diversification of the country's energy production in the not-too-distant future. He highlighted the following opportunities:

- Currently, in terms of onshore gas, there are 58 concessions and 65 applications for exploration rights in South Africa.
- Xiphu[10] says the most interesting onshore development is oil and gas company Molopo Energy's application for production rights in Virginia, in the Free State. Molopo has negotiated a gas sales agreement with renewable-energy company Novo Energy for an initial sale of about 600,000 standard cubic feet a day of gas in the Northern Free State.
- Should the rights be granted, they will be South Africa's first onshore gas production rights.
- It is thought that the gas is biogenic gas.
- In the Karoo region, exploration activities in the central and southern parts of the main Karoo basin are focused on evaluating the basin's shale gas potential, a few companies possessing technical cooperation permits.
- Coal-bed methane exploration is concentrated on the coal-bearing sequences of the northern main Karoo basin and northern sub-basins, and exploration in the Waterberg coalfields, in the Ellisras basin, and at the most advanced stage, with mining group Anglo Operations having already drilled more than 70 wells and conducted production tests.
- PASA estimates there to be about one-trillion cubic feet (tcf) of gas in the Ellisras basin and about five tcf in the Springbok Flats basin.

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[9] *Details relating to expected natural gas developments in this section are extracted from a report by Joanne Taylor published on 2 December 2011 entitled "Gas exploration in South Africa to yield fruitful results". The information in the article originates from an interview with Pasa CEO Mthozami Xiphu.*

[10] *All resource sizes mentioned in this section were attributed to CEO Mthozami Xiphu within the Mining and Engineering news article. The resulting estimate of 48.5tcf provides the basis for the larger resource assumption in the test scenarios generated in Section 5 of this report.*

Box 2

Converting Natural gas volumes to barrels of Oil equivalent values	
Cubic Feet of Natural Gas	**Barrels of oil equivalent**
1	0.0001767
$1x10^{12}$	176.7 million
20	3534 million
48.5	8570 million
500	88350 million
Conversion Source: U.S Department of Energy: Energy Information Administration	

Box 2 provides a convenient conversion matrix showing the equivalent barrels of oil to given volumes of natural gas. Gas volumes of 20, 48.5 and 500tcf are frequently referred to in this report.

- The International Energy Agency has estimated a technically recoverable resource of 485 tcf, but
- PASA believes it to be 10% of that.
- Currently, there are 14 offshore operators spread over 16 concessions and seven applications for offshore gas exploration rights.
- In the northern sector of the Orange basin, on the West Coast, oil company PetroSA has just completed the initial stage of its exploration rights in Block 1.
- Four companies have exploration rights on the West Coast, namely oil and gas companies Thombo Petroleum and Sungu Sungu Exploration, gas exploration company Forest Exploration International and diversified miner BHP Billiton.
- Forest Exploration and its joint venture partners have completed the acquisition of a third round of 3D seismic testing over its Ibhubesi gas-field with the processing of a 710 km2 area in the south-western section of its block underway.
- BHP Billiton has rights in shallow- and deep-water areas while Sungu Sungu Exploration has rights in the mid-basin.
- Rights applications for the deep water Orange basin and the southern Orange basin, from oil and gas companies Shell Exploration International and PetroSA, respectively, are yet to be approved.

The content of the box below is an extract from the IEA report called “World Shale Gas Resources: an Initial Assessment of 14 Regions outside the United States”. It provides the source of the Karoo Shale Gas resource estimate indicated by PASA CEO Mthozami Xiphu.

Box 3: Extract from IEA report[11]

Based on limited preliminary data extracted from a variety of geological studies, ARI believes that the Karoo Basin holds significant volumes of shale gas resources. We estimate that the lower Ecca Group shales in this basin contain 1,834 Tcf of risked gas in-place, with risked recoverable gas resources of 485 Tcf.

Southern Africa produced 115 Bcf of natural gas in 2008. With annual consumption that year of 228 Bcf, South Africa is a net importer, primarily from neighbouring Mozambique and Namibia. The natural gas is used primarily for electricity production and as feedstock for the Mossel Bay gas-to-liquids (GTL) plant. New natural gas production is expected from the Jabulani field in 2012 and the Ibhubesi field in 2013. Natural gas from Mozambique is imported via a 535-mile pipeline, with current peak capacity of 524 MMcfd. Assuming access to new natural gas reserves, a variety of plans have been set forth to expand the natural gas pipeline system of South Africa, Figure X-10. The technically recoverable shale gas resource for South Africa is estimated at 485 Tcf.

The US EIA report on shale gas resources outside of the USA estimates South Africa's production at 115 Bcf and consumption at 228 Bcf during 2008. The difference between production and consumption is made up by imports from Mozambique and Namibia, according to the EIA report.

This section indicates that the South African Government and foreign and domestic business organisations are taking the potential of natural gas as a future primary energy resource very seriously. Prior to 2010, gas off the North West Cape was not given much more recognition as an important resource as was the gas condensate off the Southern Cape Coast. The exploration outline above indicates elevated upstream exploration activity which is likely to increase downstream investment interest. This is amplified by recent offshore discoveries in Mozambique, estimated at recoverable levels between 20 and 30 tcf. Downstream development will always follow upstream development, and South Africa currently has an almost clean sheet of downstream users compared to highly developed gas economies elsewhere in the world.

2.5 Energy Trade Balance

South Africa is both an importer and exporter of energy in both primary and end-user forms. Imports of energy take the form of:

- Crude oil.
- Refined petroleum products to cover imbalances in the supply and demand for the local production mix.
- Natural gas from Northern Mozambique and Namibia.
- Electricity, predominantly from the Carbora Basa HEP facility in Mozambique.

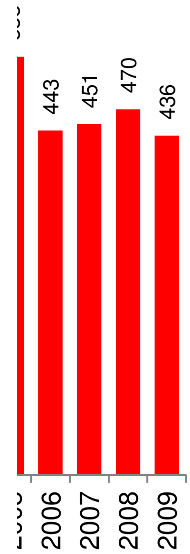
Potential expansion of the energy import position could include natural gas from offshore Mozambican reserves, natural gas and/or electricity produced from natural gas in Namibia, and electricity produced by generation plants currently under development in Southern Botswana. Energy exports currently include:

- Refined and synthetic petroleum products, mainly to Southern African countries.
- Electricity, predominantly to Mozambique, but to other first tier neighbouring economies like Namibia, Botswana and Zimbabwe.

[11] *ARI is the acronym for Advanced Resources International, Inc., the organisation which conducted the research for the EIA – US Energy Information Administration.*

In value terms[12], the predominant energy import takes the form of crude oil imports, with major suppliers being Saudi Arabia and Iran.

Chart 5: Crude oil imports



Any substantial discovery of natural gas in South Africa could potentially alter the energy trade deficit created by the high value of crude oil imports into the country. Such natural gas has the potential to provide export revenue in its own right, as well as from downstream products derived from the natural gas resource. These products obviously could include electricity. Simultaneously, the production of natural gas could provide both energy and derived products to displace both electricity imports and crude oil and petroleum product imports. As will be seen in Section 4.2 of this report, development of the suspected Southern Karoo gas reserve (around 485tcf according to the American Energy Administration) would provide the energy equivalent of around 400 years of crude oil imports. If the more conservative Pasa estimate is considered, the imported oil equivalent reduces to 40 years.

2.6 Natural Gas Prospects in a Coal Dominated Economy

After decades of US Dollar-denominated commodity price stability, crude oil prices began escalating sharply during the early years of the 1970's. Much of the literature on natural gas states that its price is highly correlated with crude oil price, and this correlation may create some nervousness in the minds of energy consumers contemplating the possibilities surrounding large scale gas into a coal based economy like that of South Africa. However, coal prices themselves have correlated closely with crude oil prices in Rand terms since at least the beginning of the 1980s. Most of the country's coal is currently mined in the Highveld, Witbank and Ermelo coalfields located in Mpumalanga province. Geology has determined that the Witbank coalfield is by far the most important source of South Africa's mined coal at present. However, the future of South Africa's coal industry depends on the development of the Waterberg deposits, which extend into Botswana.

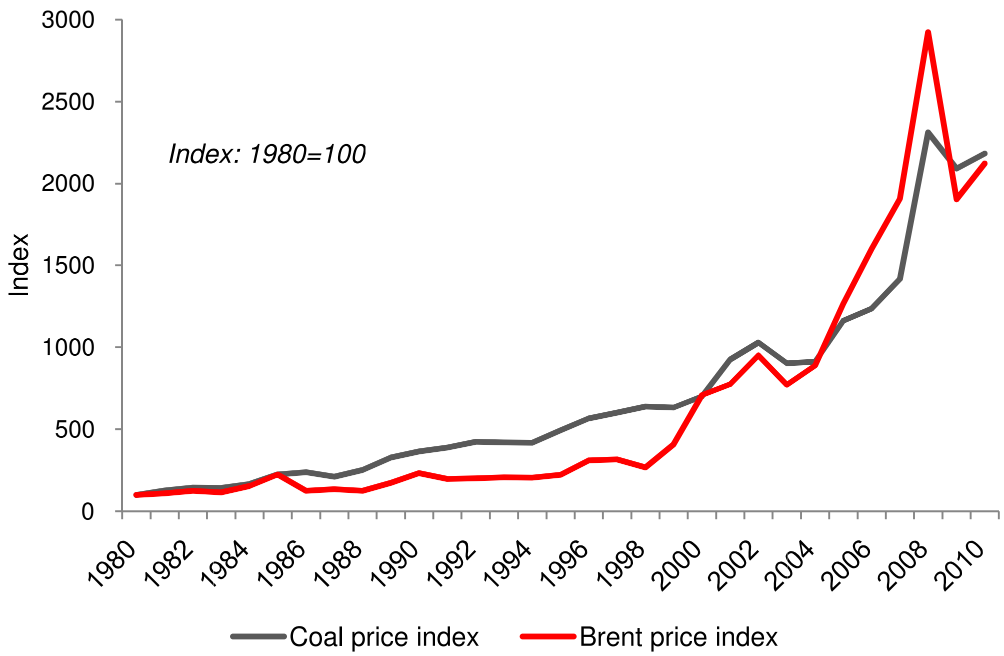
[12] *The data for the period 1984 to 2009 was drawn from the US Energy Information Administration(EIA) (www.usenergyinformationadmin.com).*

Statistics SA publishes monthly data reflecting indexed values of mining production of various mineral commodities, as well as monthly rand values of that mining production. This data is summarised in annual format in the chart below. By dividing the Rand value data by the index of physical production, a unit price index for coal may be calculated; this price index is expressed in Rand terms.

Monthly Brent crude oil price data is kept in a database by Econometrix, as is the monthly average Rand per US Dollar exchange rate. Multiplying these together creates a Rand Crude Oil price time series. This series as well as the coal price series are set to a common base of 1980=100, and the two resulting time series are plotted together in the chart below.

Although the two price indices do diverge from each other for short periods, the overall level of correlation is remarkably high (r=0.966). As both are competing global primary energy resources, this is not unexpected. Obviously, once capacity has been created that relies on one particular primary energy source, it cannot easily be switched to another, and competition between sources relies on expanding the energy conversion network, rather than swopping from one resource to another using existing capacity. The high degree of correlation of long-term coal and crude oil price movements in Rand terms is not widely appreciated by the general public in SA, where the common belief appears to be that Rand coal prices move less rapidly than Rand oil prices over time.

Chart 6: Indices of Rand Coal Production Prices and Rand Brent Crude Oil



This implies that capital investments reliant on particular fuel have to stay with those fuels, no matter how fuel prices change over time. Because domestic coal prices are usually quoted in ZAR, the correlation between those and crude oil prices is not widely appreciated by local analysts and commentators, who continually refer to South African coal as being “cheap” while crude oil is being described as “expensive”. A further implication of this discussion is that potential gas availability is more likely to be absorbed by energy dependant expansion projects than it may be absorbed by displacing previously installed fuel technologies.

Chart 7: Coal Absorption by Product[13]

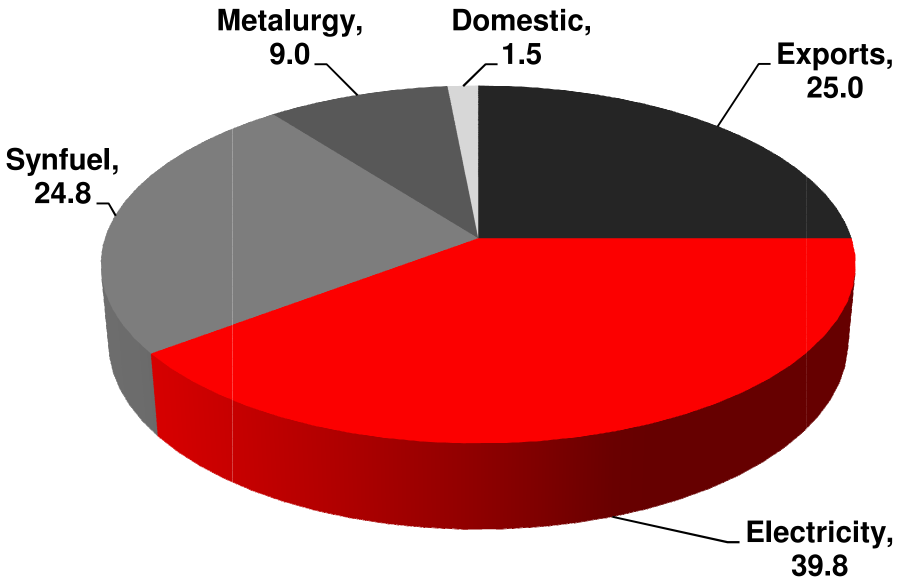


Chart 7 provides a summary of customer segments in the South African coal market. Coal divides into two distinct quality groups, with the high quality (high thermal content and low ash content) coal being exported. The lower grade coal, with opposite calorific and ash contents, is supplied to the domestic market. In any future natural gas expansion within the primary energy mix of South Africa, the export of high grade coal would be largely unaffected. The other user sectors designated in Chart 7 could all be anticipated to be able to use either coal or natural gas as a primary energy source, depending of course on their installed capital equipment.

- Electricity is an obvious option, with energy efficiencies higher than those available from the currently installed generation stock.
- Synfuels already use Mozambican natural gas as a feedstock, this having displaced a certain portion of coal at SASOL 2 and 3 plants.
- Metallurgical applications are probably the least penetrated at present, given the historic reliance on coal and electricity, but potential must surely exist for gas as a primary energy source.
- Domestic users already exist at the end of the Mozambique-Secunda-Johannesburg pipeline.

Unless there were strong pricing differentials in favour of natural gas, its ability to displace coal in the domestic economy may be expected to be limited by the costs of substituting the existing capital equipment of user sectors. The more likely path would be for natural gas to absorb a share of future expansion of primary energy requiring sectors' fuel requirements. There are also applications where natural gas can directly substitute coal based technologies. An example of this would be motor vehicles and trains running on compressed natural gas, which could displace some of the demand for coal-based synthetic fuels.

13 Calculated from data presented in the Anton Eberhard (University of Cape Town) paper entitled "The Future Of South African Coal: Market, Investment, and Policy Challenges", January 2011. http://iis-db.stanford.edu/pubs/23082/WP_100_Eberhard_Future_of_South_African_Coal.pdf

2.7 Water Constraints

South Africa's water resources have been recognised as a potential constraint to economic growth and the socio-economic benefits that such growth may be able to offer. David Hobart-Houghton theorised that an imaginary line drawn between Rustenburg (in the North Western Province) and Middelburg (in the Mpumalanga Province) represents a dividing line, north of which expansion of industrial activity will be limited by water constraints. More than 40 years after setting out this theory, he has been proven largely correct by history.

The single most basic reason for the scarcity of water relative to the potential demand for it for various economic and social applications is that South Africa is a low rainfall country – on average, 400mm of rain falls over the 1.22 million square kilometres of the country. Arid areas may receive virtually zero precipitation over the course of several years, while the wettest areas may receive many times the average within the space of single years.

The first implication for electrical power generation is that opportunities for hydroelectric power are extremely limited by the lack of perennial water flows. A second implication is that, under the somewhat elderly power station complex in the country, each kilogram of coal that is burnt uses 1.33kg of water to generate electricity[14]. Newer coal burning technologies which include carbon dioxide extraction can produce substantial water savings, but are not a practical proposition for retro fitting. These become a possibility for planned new coal fired generation facilities, but not for the old - as discussed more fully in Appendix E. The table below provides a summarised overview of the age profile of the existing power station complex in South Africa, and the historic lack of fixed capital formation since the 1980's provides some insight into levels of technology employed in the existing power generation base.

Table 4: Age Distribution of Eskom

Age group	GW capacity	% share
Over 40 years	3.5	10.0
35-45 years	9	25.7
25-35 years	21	60.0
Under 25 years	1.5	4.3
Total	35	100

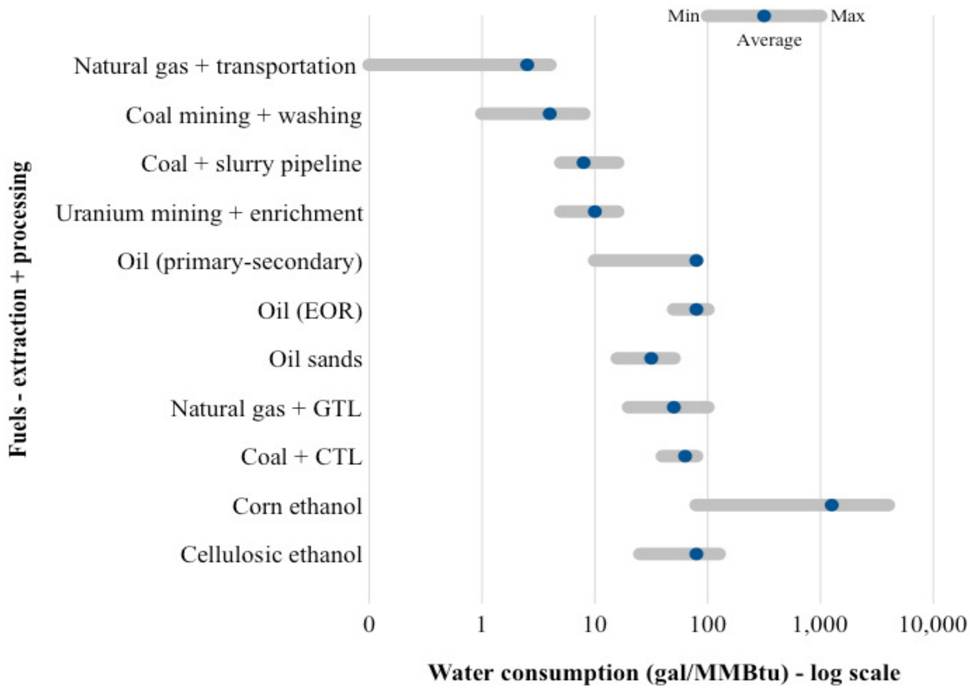
The advanced age profile of Eskom's coal fired power stations is a significant contributor to the average efficiency of this form of power generation in the country. The energy efficiency of the coal fired network is at a low 21%. The 9.6Gw additional capacity currently being constructed at the Medupi and Kusile plants are significantly higher, estimated at 40%.

Researching and refining the comparison of water usage for individual primary energy products and their conversion to end-user friendly products is a task of considerable complexity, and has been left to the Energy Technology Innovation Policy Research Group, working under the auspices of the Harvard Kennedy School – Belfer Centre for Science and International Affairs. In creating our review of the relationship between water and energy production, we have referenced the findings of their report as are set out below.

[14] *Data from slide in undated presentation (circa late March 2010) by Dr. Anthony Turton, available on www.environmentconservation.org.za*

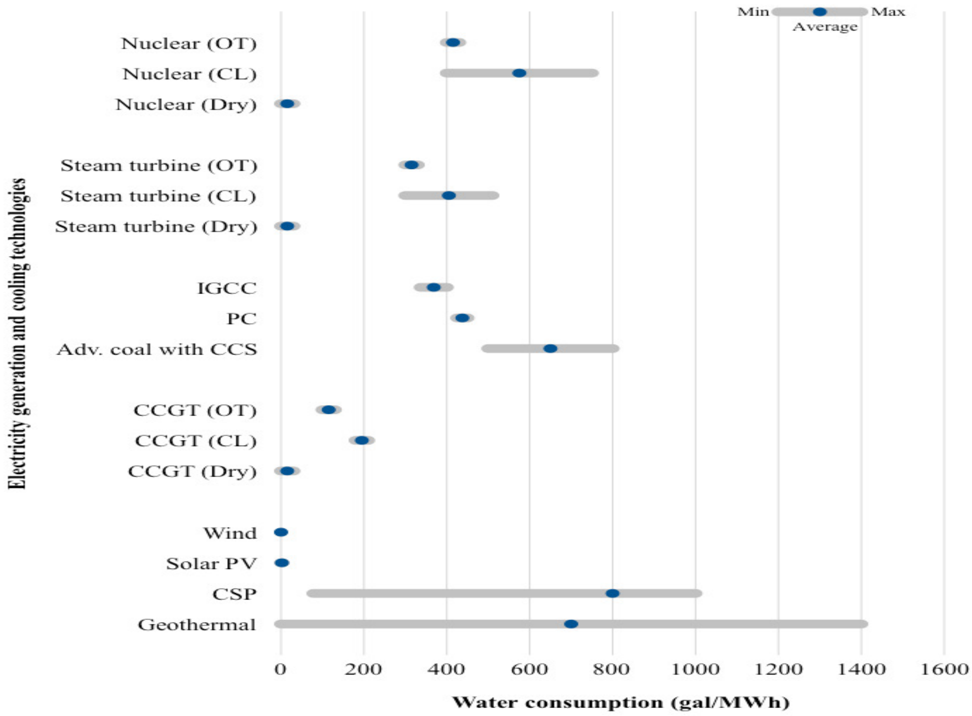
Chart 8 below presents the summary findings of the report. For each fuel type, the horizontal bar represents the span of the lowest to highest water requirements, with the dot inside the bar representing the position of the mean water usage. Chart 9 presents similar information for electricity generation. Appendix G to this report contains all the charts to be found in the research report, allowing greater levels of detailed comparison of the water intensity of various energy resources. In each of the charts, the numbers in the graphic headings refer to the means of identification in the original report

Chart 8: Water consumption of extraction and processing of fuels



Source: Harvard Kennedy School, Belfer Centre for Science and International Affairs

Chart 9: Water consumption in electricity generation using different cooling technologies



Source: Harvard Kennedy School, Belfer Centre for Science and International Affairs

Whatever the source of the primary energy input of the mechanism used to transform that primary energy to user-friendly secondary energy, water forms an important input into the process. The inter-reliance of water and energy is succinctly summarised in the box below by the authors of the paper, from which the above charts were extracted.

Box 4: Inter-reliance of water and energy

Water and energy are closely linked. The water industry is energy-intensive, consuming electricity for desalination, pumping, and treatment of wastewater. The energy industry is also water-intensive, which is the focus of this report. Water is used for resource extraction (oil, gas, coal, biomass etc.), energy conversion (refining and processing), transportation and power generation. Energy accounts for 27% of all water consumed in the United States outside the agricultural sector (Electric Power Research Institute 2008). Water, like energy, is a commodity but with very different characteristics. Water is almost always local where energy tends to be more of a global sector, linked to fungible commodities.

Constraints on water availability often influence the choice of technology, sites, and types of energy facilities. For instance, water has always been a potential constraint for thermal electricity generation, given the large volumes of water typically required for cooling. Water availability is thus of paramount importance when deciding on a suitable location of a power plant.

Sparse as they may be, South Africa's water resources are not without pollution problems. Mining activity, since the discovery of gold on the Witwatersrand in 1883, has left a legacy of acid mine drainage, which has recently achieved headline news status. As underground water overfills previously mined spaces and decants onto the surface, its acid content threatens surface water catchment and storage areas. Coal mining in the present day Mpumalanga province has led to sulphur deposits in the Crocodile River basin of that province. Apart from lowering the PH levels of the surface water, there has been a eutrophic effect in which the acid has driven up the propensity for algae to form in the water.

There has been much debate regarding the threats to water resources that the development of shale gas extraction may or may not hold. One telling point is that at depths of 4000 to 5000m below the surface where the shale deposits are expected to be found, any water in the vicinity or between the surface and those depths is likely to have been rendered unusable through natural contamination with arsenic and uranium. Even more importantly, a holistic examination of water usage in electricity generation by the group of researchers at the Harvard Kennedy School, see above, and according to various studies by (inter alia) Cornell University and the Massachusetts Institute of Technology in the United States of America, the water intensity of shale gas ranks among the lowest of all fuel sources. In other words, the extraction and processing of shale gas consume less fresh water per unit of energy supplied than the extraction and processing of coal, oil or uranium.

A thought regarding the management of risk around the Karoo shale gas exploration and possible development occurs to the researchers. The value of upstream production of a substantial resource of, say, 50tcf amounts to $400 billion a price of $8/mcf. This turnover would provide significant funding for risk management and environmental safety precautions which might be more limited in smaller scale gas development.

2.8 Conclusions from this section

- The South African economy is highly dependent upon electricity production for its industrial, commercial and domestic energy needs. Electricity production, in the hands of parastatal utility company Eskom, is dominated by coal as the primary energy resource.
- Installed generation capacity ahead of commissioning two new coal fired power stations at Medupi and Kusile between 2012 and 2014, indicates that coal has a 81% share of generation capacity, nuclear a 4.56% share, pumped storage 3.55% a share, hydro 1.5% share and gas turbines a 0.86% share. The power generation capacity outside of Eskom is recorded as 6.0% for municipalities and 2.0% for private companies.
- DOE intentions are to shift the balance of primary energy inputs to include 48% from coal, 14% from nuclear, 16% from renewable energy sources and 9% from open cycle gas turbines by 2030.
- Open cycle gas turbines are currently run by Eskom using diesel fuel, awaiting gas pipeline connections to Western Cape offshore fields.
- Low average rainfall (400mm per annum) and high evaporation contribute to a lack of perennial rivers necessary for hydroelectric power generation, with water availability in a dry country acting as a constraint to other power generation options.
- Natural gas presents as a convincing candidate to fuel peak load electricity applications with distinct possibilities for water efficient, lower carbon emission base-load power generation as well.
- As in the rest of the world, including the most developed economies, water and primary energy resources combine to determine the location of energy harnessing activities, like power generation, synfuel manufacturing, etc.
- Large shale gas deposits could augment primary energy supplies to both the electrical and automotive power environments which dominate the South African energy economy. Ideal for peak load electricity

generation and several broad categories of downstream applications, such a large gas play could revolutionise the energy sector, and contribute to displacing energy imports and/or supplying additional energy exports.

3 Moving the Energy Status quo forward

3.1 Background

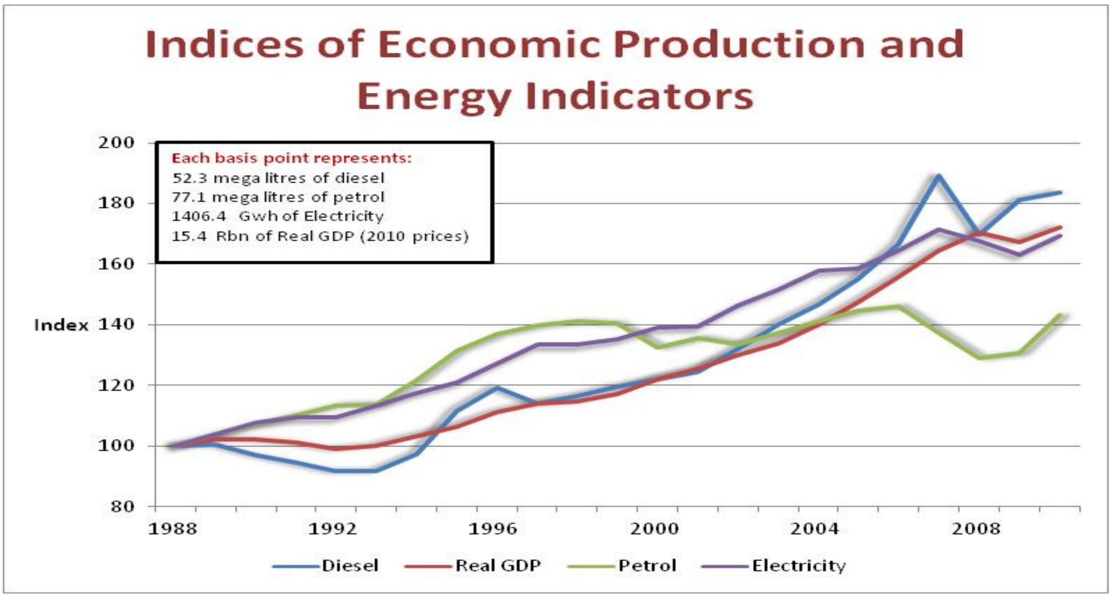
It is an understatement to note that the South African economy is very far from being mature, both in terms of its production mix and the size of its output. The objective of this section of the report is to examine three possible growth scenarios as a background for further discussion of potential applications of natural gas that may be produced from shale gas resources in the Karoo, illustrating impacts of different sectoral growth rates and combinations of growth on examples of energy demand within the economy. The growth scenarios are generated independently from the modelling of economic contributions that could arise from large natural gas resources being exploited from 2020 onwards, which are examined in detail in Section 5 of this report, but they do form an abbreviated backdrop to levels of economic activity and energy demand that would otherwise be void.

The secondary objective of this section is to present an independent a view on the economic risks of ignoring large energy resources, such a view being independent of the Econometrix research team which worked on this report

It is difficult to imagine any national economy being able to grow in terms of its output without increasing the amount of energy that it uses to produce the output. In particular cases where combinations of the type of economic activity contributing to the growth of the economy lend themselves to greater or lesser energy efficient growth, the demand for energy for the productive sectors of the economy may differ from the aggregate growth of the economy for various lengths of time. Whether the bias of the driving forces behind economic growth lean towards either the productive or consumption sides of the economy, the growth will result in increased demand for energy.

Historically, the South African economy does not differ from this general energy economic model. The graphic representation below illustrates the rate of output of the South African economy, measured in terms of the GDP index value, together with indexed values of petrol, diesel and electricity demand in the economy.

Chart 10: Indices of Economic Production and Energy Indicators15



The graphic depiction of data confirming the general economic relationships referred to in the first paragraph of this section for South Africa over the period 1988 to 2010 also show that the correlations between the GDP indicator and the energy usage indicators are far from being absolutely perfect, and variances in both direction and proportional movement occur from time to time. There could be many reasons for these lapses in tight correlation, including pricing shocks, capacity constraints or surpluses and differentials between rates for growth of the supply and demand sides of the local economy from time to time, but the underlying message is certainly confirmed by the graphic representation in the above chart - economic growth and energy usage in South Africa, like many, if not most, other economies around the world, tend to be linked.

3.2 Economic growth scenarios

Three illustrative scenarios depicting different growth paths for the South African economy between the years 2010 and 2050 were generated to form a backdrop against which more detailed modelling of natural gas scenarios could be benchmarked. The backdrop scenarios were very simply constructed, with indicators for each of the single digit ISIC codes being progressed forward in time at assumed rates of expansion. The rationale for the rates van be summarised as follows:

Low growth scenario. Sectoral growth distribution is similarly structured to that which has typified the growth profile since the mid-1970's, with the primary and secondary sectors growing more slowly than the tertiary sector of the economy. Growth is dominated by the sectors making up the tertiary or service sector of the economy, within which four ISIC sectors have been grouped together to indicate private sector service providers. The overall GDP growth for the economy as a whole in this scenario was targeted as 3% p.a. Such a low growth rate is anticipated to hold the potential for socio-economic and

15 Source: Econometrix Pty Ltd. Original sources are SARB for GDP data, SAPIA, Statistics SA and Econometrix for petrol data and Statistics SA for electricity data.

political unrest because of its lack of capacity to make meaningful inroads on the considerable labour surplus (i.e. unemployment) of the economy.

Mid-Growth Scenario. Constructed similarly to the low growth case, but with considerable emphasis on more rapid growth for the fungible sectors of the economy, and less growth for the services sectors. This scenario is aimed at depicting an overall GDP growth scenario of 4.5%pa which the consulting team at Econometrix considers to be close to the maximum sustainable GDP growth rate for any long term scenario beginning in the year 2011. Not only would such a growth rate prove to be considerably more acceptable in economic terms, the structural change to the sectoral growth mix would imply socio-economic benefits for the currently unemployed, mainly lower skilled portions of the workforce.

High growth Scenario. Ever since the 2009 general election, the ruling ANC alliance has often referred to an aspired GDP growth rate of 7% pa, sustained for at least two decades. Although no executable plans reflecting how to achieve such a rate of growth have ever been tabled in public, and most government plans seem to operate under lower growth assumptions for the 20 years following 2010, the 7% p.a. growth scenario is presented here as an outlying growth possibility. The sectoral growth mix would have to favour the tangible goods production sectors, but with even more emphasis on the secondary sector than in the mid-growth scenario, because of its inherent ability to add value at a more rapid rate than the primary sector.

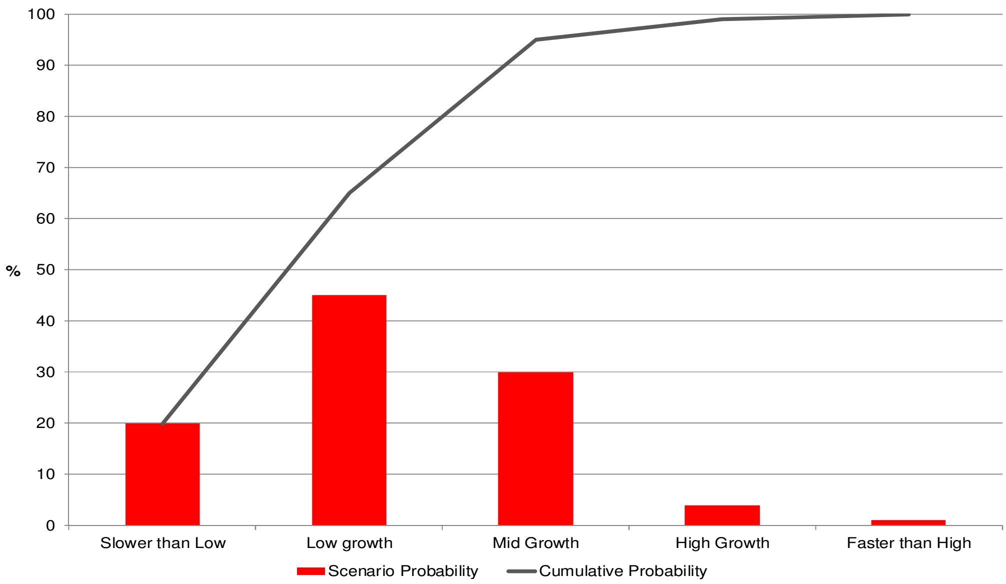
Table 5: Synopsis of the Three Base Case Growth Scenarios

			Low Growth		Mid Growth		High Growth	
	Units	2010 Absolute	2050 Absolute	Growth %pa	2050 Absolute	Growth %pa	2050 Absolute	Growth %pa
Gross Domestic Product								
Agriculture	Constant Rm	59543	159877	2.5	176240	2.8	232110	3.5
Industry	Constant Rm	740743	6067751	5.4	10121579	6.8	29415249	9.6
Services	Constant Rm	1605097	9416113	4.5	15782508	5.9	40485617	8.4
Total	Constant Rm	2405383	15643741	4.8	26080327	6.1	70132976	8.8
Investment								
Total GFCF	Constant Rm	520287	1198298	2.1	4102457	5.3	18023034	9.3
Total Capital Stock	Constant Rm	4869694	16258437	3.1	32748303	4.9	92692773	7.6
National Accounts								
Household Consumption	Constant Rm	1575420	5259770	3.1	9124780	4.5	24755725	7.1
Government Consumption	Constant Rm	572188	2056428	3.2	2746911	4.0	3989579	5.0
Gross Fixed Cap Formation	Constant Rm	520287	1198298	2.1	4102457	5.3	18023034	9.3
Gross Domestic Expenditure	Constant Rm	2669542	8514496	2.9	15974148	4.6	46768338	7.4
Imports	Constant Rm	732994	2337229	2.9	4384904	4.6	12837909	7.4
Exports	Constant Rm	727721	1626790	2.0	5886681	5.4	17467162	8.3
Gross Domestic Product	Constant Rm	2664269	7804057	2.7	17475925	4.8	51397591	7.7
Employment								
Private Sector	Index	200.12	905.03	3.8	1108.37	4.4	1322.97	4.8
Public Sector	Index	118.7	346.37	2.7	454.65	3.4	647.49	4.3
Total	Index	172.32	714.18	3.6	885.04	4.2	166.87	-0.1
Number Employed	000s	11388	47197	3.6	58489	4.2	87430	5.2
Working Age Population	000s	31946	57951	1.5	81674	2.4	111981	3.2
Energy								
Petrol	Gigo Litres	11.0	9.1	-0.5	16.3	1.0	45.8	3.6
Diesel	Gigo Litres	9.6	21.7	2.1	33.0	3.1	81.8	5.5
Oil Equivalent	Tbd	508.3	758.4	1.0	1214.7	2.2	3141.1	4.7
Electricity	Gwh	238272.0	372030.1	1.1	1021905.1	3.7	2945385.9	6.5

Table 6 above provides a concentrated comparative synopsis of the outcomes of the three growth scenarios discussed previously. The chart below presents the relative probabilities of the three scenarios occurring over the 40-year time period as contemplated by the creators of the three scenarios. Note that there is no guarantee that the three scenarios are mutually exclusive to other possible results, with the major risk being assessed as a 20% probability of the low growth scenario not being achieved, with the probability of an outcome in excess of the performance depicted in the high growth scenario being restricted to a single percentage probability.

The energy variables reflecting electricity demand, petrol and diesel demand were modelled behaviourally against historical national accounts data representing GDP performances for the economy as a whole and the key tangible production sectors like mining and manufacturing. The crude oil equivalent of the liquid fuel demand aggregates (calculated as the liquid fuel total divided by 0.7) is conceived as the amount of crude oil that would be necessary to produce the indicated levels of petrol and diesel as if there was no synthetic fuel production within the liquid fuel mix. In the cases of both electricity and the two liquid fuels, a long-term efficiency factor is applied from 2011 onwards, effectively discounting the energy demand at an accumulating rate of 1% pa. Thus, energy demand levels are not strictly proportional to total GDP growth.

Chart 11: Base Case Probabilities



3.3 Energy poverty

Rolling electricity black-outs across South Africa during the early weeks of 2008, due to capacity margin and maintenance related difficulties in the national supply grid would have made urban dwelling South Africans, particularly middle and upper income earners and business operators and owners, more aware than usual of the difficulties of operating without electricity, the end-user electricity format which dominates the energy mix in the country. During 2011, the International Energy Agency (IEA) mobilised a discussion around "energy poverty", which culminated in a conference held in Oslo, Norway during October 2011, entitled "Energy for All". The official report of the conference[16] contributes information points and an action

[16] *Energy for all, Financing the poor, Special Excerpt of the World Energy Outlook 2011, International Energy Agency – October 2011.*

plan adopted at the conference, which are pertinent to this report. Two points of information set the motivation for the action plan.

- Modern energy services are crucial to human wellbeing and to a country's economic development and yet globally over 1.3 billion are without access to electricity and 2.7 billion people are without clean cooking facilities.
- More than 95% of these people either in Sub Saharan Africa or developing Asia; 84% are in rural areas.
- Without new policies having been adopted and investment, predominantly in on-grid connections mainly in urban areas, of $14 billion per annum between 2010 and 2030, one billion people will still remain unconnected. Population growth means that this will still leave 2.7 billion people without clean cooking facilities by 2030.
- To provide universal modern energy access by the year 2030, average annual investment needs to average $48 billion per year, more than 5 times the level of 2009.
- The majority of this investment is required in Sub-Saharan Africa.

While the main focus of this report by Econometrix is on the macro-economic growth potential of a large gas resource within the economic jurisdiction of South Africa, the IEA conference report serves as a reminder that there is a backlog of modern energy access, spread across South Africa's own geographic region, and certainly not absent from poorer urban and rural areas within the country itself. The growth opportunities emphasised in sections four and five of this report should be contemplated alongside an awareness of the backlog in the provision of modern energy resources to those currently without access to those resources. Natural gas availability could contribute to both the energy backlogs referred to in the IEA report, mainly through its potential contribution to electricity generation and its potential use as a domestic heat fuel. The latter application is already deployed in the case of parts of Johannesburg on the municipal gas supply grid.

The IEA conference report went on to recommend a five point action plan:

1. Adopt a clear and consistent statement that modern energy access is a political priority and that policies and funding will be reoriented accordingly. National governments need to adopt a specific energy access target and allocate funds to its achievement and develop strategies for its delivery.
2. Mobilise investment in universal access above the $14 billion per year assumed in our central scenario of $34 billion per year. All sources and forms of investment have their part to play reflecting the varying risks and returns of particular solutions. All need to grow, the sum is large, but it is equivalent to about 3% of global investment in energy infrastructure over the period to 2030.
3. Private sector investment needs to grow the most but significant barriers must first be overcome. National governments need to adopt strong governance and regulatory frameworks and invest in internal capacity building; the public sector including multilateral and bilateral institutions needs to use its tools to leverage greater private sector investment where the commercial case is marginal

and encourage the development of replicable business models. When used public subsidies must be well targeted to reach the poorest.

4. Concentrate an important part of multilateral and bilateral funding on those difficult areas of access which do not initially offer an adequate commercial return. Provision of end user finance is required to overcome the barrier of the initial capital cost of gaining access to modern energy services. Operating through local banks and micro financing arrangements can support the creation of local networks and the necessary capacity in energy sector activity.

5. Make provision for the collection of regular robust and comprehensive data to quantify the outstanding challenge and monitor progress towards the elimination of the constraints.

The economic priority of mobilising investment in modern energy provision which the IEA recommends as being given high priority status must surely rest on a foundation assumption that sustainable primary energy resources are available to feed the end user demand for the energy contemplated for distribution and consumption as per the IEA recommendations. To refuse to scientifically contemplate a major potential primary energy source (which the Karoo shale is suspected of holding) would run completely counter to the recommendations of the IEA conference.

In section 3.4 below, Brian Kantor is seen to pick up on threads of the discussion of the suspected Karoo Shale gas reserve discussed so far, and that will be developed in the remaining sections of this report.

3.4 Estimating reserves as a first step forward

Professor Brian Kantor, one time head of the School of Economics at the University of Cape Town and later Head of Economics at the Graduate School of Business there, and who now is a strategic advisor to South African International Banking Corporation, Investec, examined the economic potential of a sizeable natural gas find as described below:

The theme of the article, as suggested by its title, looks at possibilities offered by the presumed extractable quantities of natural gas in the Karoo region in terms of their potential economic impact. Appendix H reproduces the article in full, and the economic arguments presented are summarised below.

- Kantor estimates domestic crude oil consumption at a level of 555 tbd.
- The estimates of South Africa's technically recoverable shale gas are rated at 500 trillion cubic foot (tcf), but are unproven.
- This would rank as the world's fifth largest resource.
- This is equivalent to 400 hundred years of crude oil requirements for the SA economy at current rates - 365*55000 = 202.575m per annum; (83,000mb/202.575mbpa) = 402 years.
- Benefits of this kind could prove to be transformational for the SA economy.
- It could generate sizeable incomes for the government and for other parties to the economy, including the poor.
- Potential environmental damage can be calculated and traded off by payments to those who may be negatively affected.

- Development of alternate energy resources, e.g. through open cast mining, would also result in environmental damage and need to be brought into the overall economic equation.
- Changes to mineral ownership in favour of the state are interpreted as having escalated the protests against gas exploration by farmers and land owners in the region.
- The negative external effects of extraction of any minerals in the ground do not remove the necessity to actually calculate the relevant tradeoffs as best as science will allow.
- Vested interests are often opposed to opportunities for expanding economic output.

A possible précis of Brian Kantor's points can be seen to reflect the following:

- The suspected, but in no way proven reserves of shale gas are of a huge magnitude in comparison to crude oil (including Synfuel) usage in South Africa
- The suspected resource is estimated to be so large as to be "transformational" for the South African energy sector
- Suspicions of the existence of a mineral resource are worth little until exploration has contributed to confirming or dispelling them

3.5 **Conclusions from this section**

- Three scenarios of future growth were developed for comparison in this report and to act as scenario background against which the economic importance of natural shale gas may be estimated later in this report.
- The underlying growth rates for the economy was set at 3% p.a. for the low growth case, 4.5% p.a. for the mid growth case, and 7% p.a. for the high growth case. The low growth case lies above the median probability of potential outcomes, while the mid growth case has previously been estimated to represent the real boundary of potential growth for the South African economy, given medium and long-term constraints in the profile of its assets and resources.
- The high growth case is presented for interrogation simply because it is a politically favoured target growth rate, although planning details of how to achieve the rate are either scant or non-existent.
- The higher the overall level of growth in the three scenarios, the greater the growth emphasis is on the fungible productive sectors of the economy, notably mining and manufacturing, and the less the emphasis on growth being propelled by the tertiary or service sector of the economy.
- The 7% sustained growth scenario creates a profile of skill and capital requirements, that are unlikely to be supplied by surpluses available from domestic resources, implying skilled immigration and FDI inflow, both of very significant proportions. The transition towards this scenario is anticipated to take years and not even medium term plans by the SA government appear to be based on such growth rates
- The energy requirements of the mid and high growth scenarios presented here leave little doubt that the partial or complete attainment of either of these scenarios will be heavily dependent upon and

closely integrated with the expansion of the energy base available to the South African economy over decades to come.

- Work by the International Energy Agency on the subject of Energy Poverty during 2011 leaves little room for belief that substantial energy resources can morally be ignored without proper investigation and consideration.
- An article by Brian Kantor can be seen to conclude that the desktop assessment of the Karoo shale gas reserve places it as a transformational opportunity for the South African economy and those who depend upon it for a livelihood.
- Proper assessment of the reserve is necessary, with physical exploration superseding desktop studies before economic assessment and cost benefit analysis both inside and outside of the pure economic sphere and across other disciplines can be properly undertaken.
- These points inform the assessment of the researchers that growth and development in the South African economy is highly likely to be energy resource hungry, even if supply and demand side efficiencies are achieved.

4 Economic Opportunities and Safeguards in the Gas Supply Chain

4.1 Introduction

The main economic quantification focus of this report which is contained in Section 5 and its appendices is macro-economic in nature. As such it deals with highly aggregated quantum estimates of economic indicators closely related to national income indicators like gross domestic product, employment and fiscal revenue. Section four of the report seeks to provide a link between more micro economic concepts, such as industry and sector relationships with the potential gas industry, thinking relating to price formation and gas industry economic regulation.

Two outstanding and highly detailed research studies are available via the internet, which describe the economic relationships and the impacts at both a micro and macro-economic level of natural gas extraction activities in two locations on either side of the North Atlantic. The first of these studies[17] is entitled "The Marcellus Shale Report", published by Earthworks Action. Highly detailed discussions of gross output (i.e. turnover), value added, remuneration, employment levels, supply chains, first tier beneficiaries from employee spending, per capita remuneration rates and many other topics are presented. While much insight is provided into the economic structure and impact of this large shale gas resource in the North Eastern USA, attempts to emulate the study are hampered by several differences between the South African, North American and British gas industry environments. These are summarised in bullet form below.

The second wide ranging report[18] covering similar content matter is a report by Regeneris Consulting, entitled "Economic Impact of Shale Exploration and Production in Lancashire and the UK". Once again, the information presented is of great interest, but becomes difficult to transport to the South African situation in any kind of formal quantitative assessment setting.

For both these stores of knowledge and analysis, comparison with the South African Karoo gas play is made difficult by:

- The reports deal with known historic experiences, as opposed to events that have not yet taken place in the South African context.
- Both the US and UK gas industries came into production with fully fledged downstream distribution and end-user configurations, compared to the very confined penetration of natural gas in the South African energy mix.
- Access to significantly more detailed economic data in the public domain than is available in South Africa, notably regarding employment and earnings levels.

[17] http://www.earthworksaction.org/files/publications/OGAPMarcellusShaleReport-6-12-08.pdf?pubs/OGAPMarcellusShaleReport-6-12-08.pdf

[18] http://www.google.co.uk/search?sourceid=navclient&aq=1&oq=&ie=UTF-8&rlz=1T4ACAW_en___ZA415&q=lancashire+natural+gas%2bstudy%2bregeneris+consulting&gs_upl=0l0l0l6328llllllllll0&aqi=s97

- Experienced and highly upstream suppliers in highly competitive industries relative to those already existing in South Africa.
- Product familiarity and confidence on the part of end users in developed gas markets versus lack of familiarity in the South African context.
- Little being known prior to exploration about the physical distribution of the Karoo shale gas, making estimates of extraction facilities and manpower required almost impossible.
- Downstream uses being a virtual blank page in the South African context. Six main channels, all of which would have to grow from virtually nothing.

A third impressive study by Wood and McKenzie, entitled “Unconventional Gas Service Analysis / South Africa/Karoo Basin shale”, which together with similar reports for other locations, provides significant analytical insight into the investment economics of the Karoo Gas play, but translation into macro and micro economic impact analysis beyond the investment return focus of the report(s) is hampered by the assumptions that would have to be made regarding the number and location of drilling platforms.

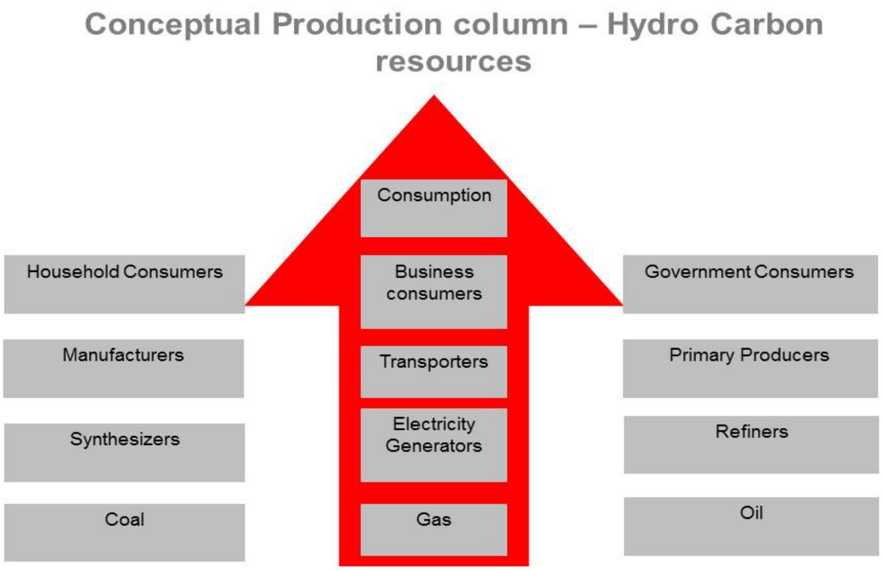
A simple example of translation of the South African difficulties is provided by the following comparison. The sum of the exploration surface areas listed in Box 1 in Section 1.5 is 358 000 square kilometres, which converts to approximately 139 000 square miles. The total surface area of the United Kingdom is 243 610 square kilometres, or 94 060 square miles. The exploration area in South Africa is 47% bigger than the surface area of the UK. By comparison, the Marcellus formation in the North East USA has a surface area equivalent to 54 000 square miles, or 138 240 square kilometres. The South African exploration area is 159% bigger than the surface area of the Marcellus formation.

4.2 A Four-Stage Energy Production Column

Economic theory uses the concept of the production column to explain the linkages between the stages of adding value during the production process. A common example of production columns used in many economic primers is that of farmers growing wheat, millers extracting flour from the wheat, bakers making bread from the flour and, as the final production stage, retailers selling the bread to end consumers. At each stage of production, the value added from the previous stage is calculated by subtracting the input cost of the previous stage’s sales value from the new stage’s sales value. In reality, there will usually be more than one input into any production stage, which is left out of the simple theoretical model, but the costs of which would reduce the value added by any stage of production in the real world.

The exhibit below conceptualises a four stage production column for the value adding chain in the energy sector of the economy.

Exhibit 5: Conceptual Production Column – Hydro Carbon Energy Resources[19]



In the exhibit above, the individual stages of the value adding process between the mining capture of energy carriers at the base of the production column, to the delivery of end user products to each of the household, business and government sectors, have been separated from each other to indicate that not all of the elements of a given level of production feed all of the elements in the next production stage. It is easy to understand why primary text books on the subject use wheat rather than energy resources as their example.

The above exhibit therefore serves as a graphic reminder that the mining or extraction capture of the energy carrying resources is at the beginning of a production chain and is not an end in itself. Thus, to imagine that the value of, say, natural gas extracted from the ground is the sum total of its contribution to an economy is clearly naive. Even if an energy resource is mined or captured and then exported from an economy without any further value added, there are still benefits to the producing economy.

It is very often the second, third or even later rounds of value addition to basic primary products in an economy that provide the biggest proportions of overall value added. Of course, the producers at the base of any production column make use of outputs from higher up the column (e.g. machinery and equipment, transport), which clearly implies that not the entire output value of the primary stage of production is value added by the first producer in the chain.

The exploration for and extraction of gas that may be found should not be considered as an economic end in itself, but rather as a primary production stage which itself will require economic inputs, and which will enable further value adding at later production stages.

4.3 Markets

The largest potential market for any Karoo shale gas produced would clearly be the export market, which is well established, sophisticated and accessible with the least amount of development and investment costs. The disadvantage of exporting gas is clearly in terms of the loss of potential value that may

[19] *Source: Econometrix*

otherwise have been added through downstream processing if the gas had moved through one of the following downstream gas users.

Electricity generation is a major potential customer area for natural gas, particularly for peak load power generation. The existence of the national electricity grid provides relative ease of entry for the electricity generated, implying that the gas may not have to be transported vast distances before being converted to electrical energy and entering the national distribution network.

Gas as a transport fuel would require the development of distribution networks covering significant parts of the county, which may become as complex as liquid fuel wholesale and retail distribution networks.

Gas to liquid fuel conversion would require substantial investment in at least one GTL plant, implying pipeline investments if the geographic distribution of platforms is not sufficiently concentrated. The liquid fuels produced would then have to be moved through the existing fuel depot network.

Gas for use as fuel in industrial, commercial and domestic applications would require pipelines to urban areas and population nodes. From those points, distribution pipelines would be required to carry the gas to end users. Some of the end user applications could be supplied in the form of CNG.

Gas used for the production of fertiliser would either have to be transported to existing production plants, or new plants would have to be established either near the source of the gas or along pipeline networks that may possibly be established to service other end users.

The brief analysis above strongly indicates that there would be important intermediate players in the developing gas industry that could emerge from a large Karoo shale gas find. End-users would be separated from upstream gas producers by a distribution chain at least, and by value adding processors in many of the potential applications.

4.4 Natural Gas Pricing

Ahead of even the exploration phase of any Karoo Gas Project, it is difficult to attempt to pin down either short or long-term cost parameters with any precision. Not even the size of the gas resource or set of resources is known, which is clearly critical to assessing amortisation costs for the exploration, production and transport costs to the first set of users beyond the extraction industry. Knowing these costs alone would only represent one side of the price structuring process – price is always a function not just of the costs of supply, but also levels of demand and related price and income elasticities of that demand. In by far the majority of downstream applications, natural gas presents as something of a novelty to the South African economy, and the rate at which it may gain acceptance as a primary energy source becomes an important factor in contemplating determining prices.

Table 6: International Commercial Terms 2010 –definitions for abbreviations frequently used in natural gas pricing descriptions & analysis

Delivered at Terminal	DAT
Delivered at Place	DAP
Delivered at Frontier	DAF
Delivered Ex Ship	DES
Delivered Ex Quay	DEQ
Delivered Duty Unpaid	DUU

Clearly, natural gas would have to compete against the prices of other primary energy resources, notably coal and crude oil in the South African market place. If the bulk of natural gas that may be produced from onshore South African fields is to find its way into electricity generation, conversion costs will also enter the permutations of variables used in the computation of its commercial viability.

4.5 Commercial Aspects

Where gas pipelines would have to be of unmanageable lengths to allow for international or intra-regional transport of gas, the gas is usually liquefied, and transported in specially designed vehicles and/or vessels. It appears that the construction of such vessels is relatively inexpensive. For many years, the contracts for LNG supply were both long-term in nature and very inflexible, but more recent experience has indicated both shorter term contracts and greater flexibility within such contracts. The trade of LNG is completed by signing a sale and purchase agreement (SPA) between a supplier and receiving terminal, and by signing a gas sale agreement (GSA) between a receiving terminal and end-users. Some of the terminology used for LNG prices is reflected in Table 6 above.

Table 7: Imputed Sasol and Mosgas Input Gas Prices since Mid 2010

	Brent Crude $/Bbl	Gas Price $/Tbd	Gas Price Rand/$ Rate R/Tbd
2010.06	75.700	6.000	7.663
2010.07	76.760	6.084	7.260
2010.08	76.260	6.044	7.370
2010.09	76.260	6.231	6.960
2010.1	83.580	6.625	7.011
2010.11	86.480	6.854	7.095
2010.12	93.490	7.410	6.620
2011.01	98.250	7.787	7.177
2011.02	112.170	8.891	6.963
2011.03	115.160	9.128	6.770
2011.04	123.500	9.789	6.720
2011.05	113.250	8.976	6.980
2011.06	118.000	9.353	7.100

In a study by Wood and Mackenzie, dated June 2010, modelled micro economic prospects for the Karoo Gas project, based on many complex assumptions, reveal a situation of close to break-even for the gas production at a constant mid 2010 gas price of $7.00, which rises quickly to percentage values in the low teens at a constant gas price of $8.00. At the time of the study the price of natural gas in the USA was just above $5.00.

If we assume that the linkage between the prices of Brent Crude oil and natural gas are linked by reality, and not just by contractual agreement, it would appear that a gas price of $7.00 (as at late 2010) would coincide with a Brent Crude oil price of around $93/bbl.

NERSA and PASA (the latter being the Petroleum Authority of South Africa) between them hold the rights to regulate prices at different stages of the natural gas production and delivery chain. These regulators need to balance the interests of gas energy producers (well operators), transporters, traders and users in a gas supply and usage market that has suddenly expanded in terms of its potential, alongside the increase in exploration interest since the end of 2010.

It seems to be quite reasonable to expect regulation of gas prices in one form or another to extend into the future and NERSA has already entered into discussions with industry players in this regard. In a discussion document distributed during October 2010, NERSA has set out its objectives in defining future regulation. The following is an extract from this section of the discussion paper:

Box 5: Synopsis of Section 3 and 4 of the National Energy Regulator Act, 2004

NERSA is established pursuant to section 3 of the National Energy Regulator Act, 2004 which in terms of section 4 requires it to "undertake the functions of the Gas Regulator as set out in section 4 of the Gas Act".

Section 4 of the Gas Act, 2001 (the Act) establishes that NERSA:

"… must, as appropriate, in accordance with this Act: …

*(g **Regulate** prices in terms of section 21(1) (p) in the prescribed manner;*

*(h) monitor and **approve**, and if necessary **regulate**, transmission and storage tariffs and take appropriate action when necessary to ensure that they are applied in a non-discriminatory manner as contemplated in section 22 …" [Gas Act 4(g) & (h)]*

Section 21 of the Act provides that NERSA:

*"… may impose **licence** conditions within the following framework of requirements and limitations: …*

*(p) **maximum prices** for distributors, reticulators and all classes of consumers must be **approved** by the Gas Regulator where there is inadequate competition as contemplated in Chapters 2 and 3 of the Competition Act, 1998 (Act No. 89 of 1998); …" [Gas Act 21(1)(p)].*

From these legislative provisions it may be observed that NERSA's mandate in respect of gas pricing is, inter alia, to approve maximum prices for different classes of consumers.

Regulation of Gas Prices

Section 4(g) of the Act outlines NERSA's functions to include the regulation of piped-gas prices which must be in the prescribed manner and in terms of section 21(1) (p) of the Act.

In line with this obligation, NERSA when imposing licence conditions to its licensees must approve maximum prices for piped-gas for:

i. distributors;

ii. reticulators; and

iii. all classes of consumers1

However the Act explicitly excludes reticulators (in their capacity as suppliers) from the requirement to hold a licence:

"… a person engaged in an activity referred to in Schedule 1 is not required to apply for or to hold a licence …" [Gas Act 15(2)] and, Schedule 1 includes: "Gas reticulation and any trading activity incidental thereto". As NERSA's mandate to approve maximum prices is established through its ability to impose licence conditions, customers that are served by reticulators will not be subject to maximum prices. It should also be noted that NERSA's responsibility to approve maximum prices requires inadequate competition (as contemplated by chapters 2 and 3 of the Competition Act, 1998).

Methodology to approve maximum prices for piped Gas – Discussion paper.

It is important to note that the maximum price of piped-gas is a composite of different charges and tariffs accruing up to the point of sale. To this end, NERSA is mandated in terms of section 4(h) of the Gas Act to "monitor and approve, and if necessary regulate, transmission and storage tariffs and ... ensure that they are applied in a non-discriminatory manner."

The role of NERSA is further enunciated in the Gas Act: Piped Gas Regulations, 2007, where pursuant to regulation 4:

The Gas Regulator must, when approving the maximum prices …:

(a) be objective i.e. based on a systematic methodology applicable in a consistent and comparable basis;

(b) be fair;

(c) be non-discriminatory;

(d) be transparent;

(e) be predictable; and

(f) include efficiency incentives. [Piped Gas Regulations, 4(3)]

Some classes of consumer are served by reticulators which are not required to be licensed by NERSA. Furthermore, maximum prices referred to in sub-regulation (3) must enable the licensee to:

(a) recover all efficient and prudently incurred investment and operational costs; and

(b) make a profit commensurate with its risk. [Piped Gas Regulations, 4(4)].

Whilst the above principles must be dominant in the task undertaken by NERSA, the actual operational activity is provided for in regulation 4(7) where licensees are to provide NERSA with such information that will enable NERSA to determine the maximum price applicable to that licensee.

Licensees are therefore required to submit maximum prices to NERSA for approval and this inevitably will require that NERSA either accept or reject these prices.

With very little gas currently supplied and consumed in the RSA economy, future market penetration of indigenous gas, such as material shale gas reserves with sufficient security of supply, would likely come down to alternative energy substitution pricing with an allotted provision for referencing to acknowledged international indices. This is consistent with the status quo of GSA pricing arrangements and existing NERSA approved gas licenses.

NERSA's ultimate objective is to facilitate investment in the gas industry in support of developing a competitive gas market and gas service industry. They wish to establish a systematic methodology that would effectively limit customer discrimination and development in the existing gas market (limited supply and monopolistic behavior by Sasol), yet incentivise new supply in the form of gas exploration and production and import.

The price of a perfect substitute is the accepted maximum economic price any consumer will pay for a particular product/service. Under this option, a basket of fuel alternatives could be used as a proxy of the market price for natural gas.

In a constrained market the economic cost of gas supply will trend toward the cost of the alternative fuel. The level of the alternative fuel cost can be managed by using a basket of alternative fuels and:

- Recognising that no single fuel is a perfect substitute for gas; and
- Prices to be determined at a level that reflects the balance between encouraging new entry and sharing economic surplus between consumers and producers.

The following alternative fuels may be appropriate for determining a maximum price for gas energy:

- Gas displacing a percentage of the current coal, nuclear, renewable, diesel capacity in the electricity generation mix
- Natural gas (methane) and its derivative products, LNG, CNG and GTL displacing currently used petrol, diesel, fuel oil, LPG etc.

4.6 Supply Opportunities to the Natural Gas Industry

Upstream inputs to productive processes are nowadays commonly outsourced, allowing the operations of particular stages of a productive process to concentrate on their own strengths, while buying the specialised productive know-how of outside suppliers, rather than trying to encapsulate the entire production chain within a given organisation. In terms of natural gas exploration and production, the inputs required to add value in the productive process are just as likely to be bought in from outside suppliers as in any other industry. The production column, or supply chain of the natural gas industry will resemble almost any other physical production industry. The table below provides a summarised wide angle snapshot of some of the items which would probably be brought into exploration and production operations in the natural gas industry, providing turnover and demand for the outputs of the economic sectors indicated in the table.

.ctivities

	Inputs to Natural Gas Industry
Agriculture	Food, non-food items
Mining - Coal	Primary Energy Resource
Mining - Gold	
Other mining	Primary metals, non-metals resources
Food, beverages, tobacco	Processed goods
Textiles, leather	Processed goods
Footwear	Processed goods
Petroleum, chemicals	Processed goods
Glass, non-metallic	Processed goods
Metal, machinery, equipment	Processed goods
Electrical	Processed goods
Radio,TV,optical instruments	Processed goods
Motor vehicles, transport	Processed goods
Furniture, other	Processed goods
Electricity	Energy Input
Water	Raw and processed input
Construction	Built environment inputs
Trade	Service inputs
Hotels, restaurants	Service inputs
Transport	Service inputs
Communication	Service inputs
Financial, insurance	Service inputs
Real estate	Service inputs
Other business	Service inputs
General government	Service inputs
Health	Service inputs
Other services, Non-profit	Service inputs

Source: Econometrix using Statistics SA input and matrix as a guideline.

Three modes of transport are prevalent, namely gas pipelines, large bulk transport of liquefied natural gas (LNG) and usually smaller volumes transported in the form of compressed natural gas (CNG). Each has its economic and engineering advantages under different circumstances.

Gas Pipelines are found in three main formats:

- Collector systems of small diameter pipes linking well-heads to each other and collection points.
- Trunk pipelines of considerably larger diameter, transporting pumped gas across long distances to points of bulk consumption or conversion.
- Distribution pipelines, usually of smaller diameter than trunk lines, taking gas to domestic and/or industrial end-users.

Natural gas is non-corrosive, enabling various types of sufficiently structurally strong metal to be used to make the pipes. Pipe diameters vary from around 15mm for collection and distribution networks, upwards to 1.5m trunk pipeline applications.

As with hydro-carbon fuels, the gas is moved along the pipelines by means of a series of pump stations.

Liquefied natural gas is created by chilling natural gas to a temperature of -163 degrees Celsius, at which point it has been reduced to one 600th of its standard temperature and pressure (STP) volume. LNG is denoted as holding around 60% of the energy of an equivalent volume of diesel fuel sustained at such low temperatures by means of cryogenic technologies. Large equivalents of gas volume can be more easily transported as LNG in tanks by road, rail and across vast ocean expanses on board ships. This overcomes underwater pipeline difficulties, which can be solved by ingenious engineering applications, but which become exponentially more difficult. LNG is the preferred solution for the intercontinental trade of natural gas.

Compressed natural gas is created by compressing natural gas to a pressure of approximately 200-248 Bar, which reduces the gas to approximately 1% of its volume at STP. CNG's volumetric energy density is estimated to be 42% of that of liquefied natural gas (because it is not liquefied), and 25% of that of diesel. CNG is widely used in final consumption applications of natural gas, such as in the powering of motor vehicles and even trains. In countries where natural gas is far more widely used than in South Africa, refilling stations for CNG cylinders are common, with two particular standards of filling nozzles that connect to the on board cylinders of vehicles in use. CNG[20] also has stationary applications.

Thus, it can be seen that LNG generally fulfils tasks that might otherwise be performed by gas trunk pipelines (i.e. long distance transport technology) while CNG relates more closely to the distribution pipeline end of the delivery channel, providing end-use applications with natural gas supplies. Information received by the researchers of this report suggests a delivery radius from the location of compression to end use of around 160km as being a benchmark useable distance for CNG.

[20] *The researchers of this report came across undocumented information indicating that extraction permits had been issued for natural gas seeping through deserted and flooded mines in the Northern Free State province (near Virginia), with the intention of supplying this gas for use in CNG powered public transport vehicles owned by local authorities in the region.*

4.7 Conclusions from this section

- Viewing the production process of extracting and converting primary energy resources to end user products is assisted by production column analysis. The analysis forms a first step in identifying sectoral and product value adding opportunities downstream of the extraction activities which bring the gas to the surface.
- There appear to be six main application clusters for natural gas within the South African context. They include exports of the gas, use of the gas as an industrial, commercial and domestic energy source, the generation of electricity, use as an automotive fuel, conversion to liquid fuels and as an energy feedstock for fertiliser production.
- Judging by existing experience in the limited natural gas market in South Africa, there is likely to be a significant level of price regulation within any expanding gas market in South Africa by regulators like PASA, NERSA and GSA. Commercial considerations, international benchmarking and investment considerations all form part of the price regulation framework.
- The greater the proportion of gas that is exported, the less is the downstream value added potential that exists.
- Suppliers of consumable items to the gas exploration and production phases should enjoy demand increases as a result of the gas related economic activities. It appears likely that the exploration phase will be supplied with imported capital equipment rather than locally produced equipment because of the specialised nature of the work to be undertaken. Local content within capital requirements should naturally evolve with any expansion of the project beyond the exploration stage – downstream capital requirements would probably begin to receive investment funding once resources were measured and geographically located, and gas production plans set out.
- Economic opportunities exist downstream of the gas producers in the form of moving the gas to wherever it is needed for end use. Methods include pipeline networks, LNG and CNG processing and distribution.

5. Macro-Economic Impact Scenarios

5.1 Introduction

This section of the report introduces and describes the logic and output of the macroeconomic model created specifically for this research project. The introductory remarks at the beginning of Section 4 of the report apply as equally to the quantitative macroeconomic works as they did to the qualitative micro economic outline of natural gas opportunities contained in Section 4. Adding to the three reports mentioned in the introductory remarks of Section 4 would be other studies listed in the bibliography of this report. Recognition of the substantial problems in translating or transposing much of the output of published studies which were briefly noted at the beginning of Section 4 re-emerge in this, the econometric modelling focal point of this research. In addition to the list of bullet points regarding these difficulties mentioned in Section 4, the following points should be considered:

- The reports accessed focus more on summaries of methodology and outputs, rather than detailed discussions of how various components of models were derived.
- In most instances, the estimates of impacts of shale gas development have been written about gas plays that have been in production for many years, and for which a great deal of data is available.
- This contrasts sharply with the South African situation which is totally void of any public domain information on the Karoo gas operations, simply because there have been none.
- Thus, bottom up modelling of elements of the required model are simply not available in the South African context.
- As an example of the last point, the Marcellus shale report uses a model structure of the number of production platforms, surface area of the shale gas play and other specific data to estimate employment numbers and remuneration. The data for this simply does not exist in the South African context, except perhaps in highly secured private corporate studies rather than the public domain.

Translation and transposition of the foreign studies to the Karoo gas play was rendered largely impractical by differences in the availability of data and information. Certainly, it is always dangerous to transpose multiplier and coefficient values from one economy to another, rendering such research on foreign gas is of considerable interest but little practical use in the South African environment to be modelled.

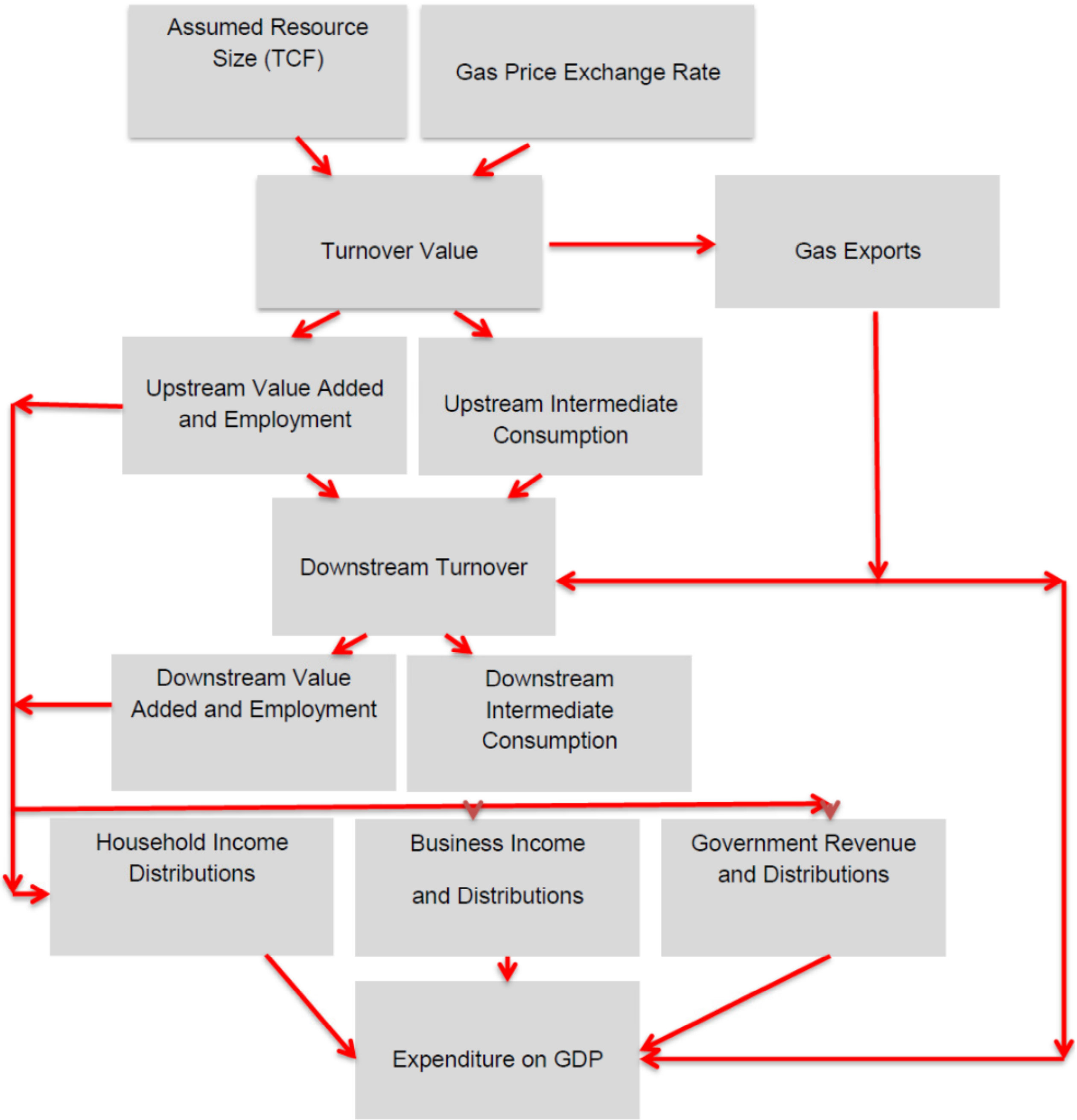
5.2 Description of the model and test scenarios

The model created for these purposes is principally Keynesian in design. The logical flow begins with assumptions of the gas resource size, which produces estimates of upstream production values. These production values are then split into scenarios defined by export and residual local flows. The local flows are subjected to a multiplier to calculate their estimated impact on the economy as a whole via multiple rotations through the circular flow of income. An estimate of the resulting total turnover within the economy is produced, which is then reduced by upstream turnover to provide an estimate of downstream turnover. Both upstream and downstream turnovers are apportioned across two major categories namely intermediate consumption and gross value added, the latter equivalent to contributions to GDP.

The next step estimates of the income, taxation and other distribution values across each of the household, business and government sectors. Upstream and downstream employment numbers are estimated using the value added and a labour mix average earnings indicator for upstream employment, while downstream employment is calculated by means of downstream value added as a portion of the mid growth rate scenario generated in Section 3 of this report being apportioned according to the downstream GDP of the gas scenario model.

The logical flow of these groups of variables is set out in the schematic chart below. A far more technical analysis of the model in terms of individual variable relationships is presented in the Appendices of this report.

Exhibit 6: Logical flow of Macroeconomic Model



Two test scenarios were generated using the model. The major point of differentiation is the assumption relating to the gas resource size. For scenario A, the extractable resource is assumed to be 20tcf, motivated principally by the desire to depict the macroeconomic impact of the development of a large resource, but one that is well within the existing estimates of extractable gas from the Southern Karoo play. The benchmark for extractable gas of 48.5tcf, discussed in Section 2.4 of this report, forms the basis of the assumption of a resource size of 50tcf, which is used to inform scenario B. Prior to physical exploration beginning, a difference of 1.5tcf in what is believed to be a very large resource is not material, and 50tcf was selected as a round number estimate. Prior to processing the reserve size according to the description of the model logic above, the resource size is allocated into periods of annual production. The model is set up to consider either 20 or 25 year production life spans, and the 25 year period was used for both of scenario's A and B. The production life relating to the resource is split into a five year ramp up period, followed by a 15 year mature production phase in the 25 year life span option, which is followed by a five year run out period. In the 20 year life span option, the mature phase extends for 10 years, leaving the ramp up and run out phases at five years each.

For both scenarios, a well head gas price of $8/mcf was used, informed by the Wood and Mackenzie study on the Karoo shale gas play. At that price, rates of return are estimated as being between about 12% and 15%, which most investors would hope to exceed, given the relatively high risks involved in shale gas plays when compared to development of conventional gas resources. Conversion to Rand values is achieved by the assumption of a Rand/US Dollar exchange rate equal to the actual value achieved during 2010, namely R7.303/$. The model is set to work in constant 2010 prices.

A major factor determining downstream impacts on the economy is the proportion of the natural gas production that is exported, becoming unavailable for downstream value adding activities within the local economy. Sensitivities for scenarios A and B were run using export assumptions ranging from 0% to 100% of upstream production and turnover. These are presented in the Appendices of this report.

The model is set up to estimate economic values for either a 20 or 25 year production span beginning in the year 2020. That start date is almost immaterial because the model uses constant price data set to a base year of 2010. Where the real time dates do become material is in the portion of the model that estimates employment numbers, specifically downstream employment. The model logic uses the estimate of total employment projected for 2025 in the mid-growth (4.5% p.a. for GDP) scenario presented in Section 3 of this report, and apportions downstream employment levels according to the modelled downstream GDP values, to generate downstream employment levels. In all other aspects, the start year of the production years is immaterial; it becomes material when comparisons against projected levels of economic activity are made, as in the final part of this section.

5.3 Upstream and downstream activities

In terms of the model logic, upstream and downstream economic activities are defined as:

- Upstream activity is confined to activity directly related to the extraction of gas and excludes consumption and capital goods and services supplied to the extraction activities by outside suppliers.
- Downstream activities begin conceptually at the outlet flange of the upstream production facilities. They include the production of goods and services supplied to the upstream operations. Because of the use of Keynesian multiplier theory, the downstream production estimates also include

production that supplies rounds of induced consumption spending emanating from incomes generated by gas production activities[21].

An intuitive reaction to a scenario in which all of the upstream gas production is exported might be that there could not be any downstream production. However, the mathematics of the model and the definition of 'downstream' set up above combine to produce downstream value added and downstream consumption values in excess of zero even when 100% of upstream gas production is exported because:

- Upstream employment is ultimately a function of upstream value added, which is not distinguished between revenues from exported or domestic gas sales.
- Downstream value added and employment shrinks as gas export proportions move upwards from 0 to 100%.
- These downstream measures do not reduce to zero, because there is always some downstream value added by upstream intermediate consumption, with that value added creating employment and the employment creating final consumption by households and government because of implicit remuneration and taxes.
- Upstream intermediate consumption implies production from sources defined as downstream for the purposes of the model, and also creates incomes, taxes and operating surpluses that in turn finance demand for products from the downstream (i.e. non-upstream) quarters of the economy.

Thus, even if all the gas produced is exported, there will be elements of demand generated in the upstream sector which will induce production, employment and remuneration in the downstream sector; even if they are not directly related to conventional ideas of products produced using upstream gas production.

In summary, the definition of downstream activity including supplies of intermediate consumption items to upstream productive efforts necessarily implies that any upstream production (or turnover) that occurs will generate some downstream production to feed the consumed inputs into the upstream productive effort. Income generated by this upstream and downstream value added induces distributions into final consumption by households, business sector gross operating surpluses and government sector tax revenue, even if all the gas produced is exported.

5.4 Model flows and linkages

The schematic chart of the logical flow pattern of the model was presented in Section 5.2 above. Reference to this flow chart enhances an understanding of the more technical description of variable linkages set out in the Appendices of this report.

The major driving variables of the two test scenarios, and the basic origins of the quantum levels assumed, have been discussed in Section 5.2. Other flexible assumptions used in the model structure, together with a discussion of the quantum levels assumed for each are contained in Section 5.4 below.

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[21] *The induced demand for goods and services in the complete circular flow of income implicit in the model's structure will render the results different to those found in the literature scan, as the foreign studies usually stop at first tier suppliers. The ability to produce such first tier supplier value added estimates clearly depends on the foreign researchers' ability to isolate spending patterns and data from existing direct and indirect value adding chains, using ex post analytical information. This is not an option in the pure future analysis required by the South African research.*

5.5 Assumptions required as inputs to the model

Outside of the major exogenous assumptions which collectively define the size and Rand value of the gas resource for any resulting economic scenario, together with the ability to flex the modelled scenario to reflect the proportion of natural gas assumed to be exported, the remaining explicit assumptions required by the model, generally take the form of ratios informed by historic reserve bank data, illustrations of which have been included in the Appendices. The bulk of the required data to provide quantum estimates for these assumption variables will be found in tables that have been published in the statistical section of the SA Reserve Bank quarterly bulletins. The table below provides a summary overview of the assumptions required by the model and their linkages. The headings in the variable list indicate the section of the model in which the variables can be found.

Table 9: Exogenous assumptions defining modelled scenarios

Assumption	Drives	Source	Comment
Resource valuation			
Resource volume	Turnover Value	Main exogenous variable	Key point of departure for scenario
Well head price USD	Turnover Value	Wood Mackenzie Study	$8/mcf yields project returns in low teen %
Rand/Dollar Excahnge rate	Turnover Value	SARB data	Actual outcome for 2010
Upstream value added			
Share of intermediate Consumption	Rand value of intermediate Consumption	Informed by STATS SA data	Other mining has values between 35% and 41%
Exports			
Gas Export Share%	Gas export values	Main exogenous variable	Defines scenario permutation
Export share of downstream turnover %	Downstream export value	Main exogenous variable	Defines scenario permutation
Downstream			
Intermediate consumption Co-efficient	Intermediate consumption value	SARB Data	Long term average for SA Economy
GDP Multiplier	Total GDP	Regression Calculation of SARB Data	Stable over long term
Household Sector			
Tax share of remuneration	Household tax values	Informed by SARB data	Long term average for household sector
Average propensity to consume PDI %	Household consumption value	Informed by SARB data	Rendered high by other income, credit
Remuneration to GDP ratio %	Downstream renumeration	SARB data	Stable long term average
Tax to Remuneration Ratio%	Downstream household tax	SARB data	Stable long term average
Business Sector			
Direct tax:GOS ratio %	Direct tax value	SARB data	Stable long term average
GFCF:GOS Ratio %	GFCF value	Secondary exogenous variable	Historically unstable, included to flex GFCF estimates
Government Sector			
Tax:GDP Ratio %	Total tax revenue value	SARB data	Stable mean, short term historic fluxtuations
Other Tax:GDP Ratio %	Other tax revenue value	SARB data	Stable mean, short term historic fluxtuations
Employment			
*Upstream remuneration premium index	Remuneration per employee	See description	Rises from value of 1 to 2 over time
Labour Mix			
Mining Share	Drives upstream wage rate estimate	Secondary exogenous variable	Flex point for labour mix
Construction Share	Drives upstream wage rate estimate	Secondary exogenous variable	Flex point for labour mix
Manufacturing Share	Drives upstream wage rate estimate	Secondary exogenous variable	Flex point for labour mix

* Premium informed by Marcellus and Lancashire study reports, indicating premium paid for shale gas workers relative to rest of economy

The values for ratios and multipliers are discussed in greater depth in the Appendices of this report with a detailed description of the derivation of the value of the GDP multiplier being provided.

The source of the value of the upstream intermediate consumption proportion of upstream turnover is also referenced. In summary, it is drawn from Statistics SA input, and uses matrix coefficients, which indicate values of between 35% and 41% of turnover for various types of mining being absorbed by intermediate consumption. The Regeneris study of the oil and gas sector within the UK estimates a gross production (equivalent to turnover) value for the industry during 2008 of £36.2 billion, and estimates gross value added of £25 billion. Intermediate consumption is, by definition, equal to the difference between these two values, amounting to £11.2 billion or 31% of turnover. While the consumption patterns of the British oil and gas industry and the potential Karoo shale gas industry may not be directly comparable, the example does indicate that the intermediate consumption co-efficient value assumed for upstream gas production, although reasonably representative of general mining in the South African context, might be producing a conservative residual calculation of value added by the upstream industry and a slightly boosted value added estimate by the downstream sector particularly as export proportions rise towards the 100% mark.

The replications of the SARB data tables - in the Appendix - display data from 2002 to 2010. Values for each of the SARB variables were examined for calculation of assumption values. Where ratios had changed noticeably over the 16-year period contained in the electronic data base series, values most typical of the post-change period were used for the test cases. The model structure allows these variable values to be flexed, in order to check impacts of assumed future alterations to the historically prevailing values, and projections of the historic values that were used in the test scenarios.

5.6 Model sensitivities

Apart from the mathematical sensitivity of the model to the assumed values of its scenario defining and distribution coefficient assumptions, some caution needs to be exercised in the acceptance of the output of the model without critical regard for the fact that it is a model, and not a report of measurable (historic) reality.

The first caution must be indicated as the real time context of the model. Production ramp up is implicitly assumed to begin in the year 2020 and production is then assumed to extend for 25 years, with final run-out occurring in 2045. Clearly, many of the assumed ratio values upon which the model depends, including the important multiplier connecting upstream and downstream economic aggregates, could shift in value between the most recent data points (for the year 2010) and the start and end points of the forecast scenarios.

The necessary quantum assumptions for the resource volume and the prevailing US dollar price of gas at the upstream exit point, the latter at constant 2010 prices, are clearly right at the root of the calculation of the remaining economic data. Given the current state of knowledge of the resource size used in scenario generation, the modelled scenarios can at best be described as being illustrative, rather than predictive.

The estimates for gross fixed capital formation relating to the project and downstream activities generated or induced by the project must be viewed as extremely tenuous. The values are generated by applying an assumed distribution factor to the modelled gross operating surplus of the business sector, and the resulting GFCF expenditure estimates of this sector are then extended to calculations of GFCF expenditure by the general government sector. The business sector GFCF:GOS ratio has been very unstable over the 16 year period (for which data is obtainable), with fixed investment cycles being sensitive to confidence and interest rate cycles within the local economy, given that these major drivers were exposed to foreign economic developments. Also, the investment related to a large gas find would be predominantly loaded towards the front end of the forecast period, as gas extraction facilities, infrastructure and downstream value adding facilities are built up to create an almost entirely new sector within the local economy. The activities and nature of downstream economic activities are largely undefined, and are likely to be spread over the six main downstream activities considered in Section 4.2 of this report. The assumed GFCF:GOS ratio values are entirely notional at this stage – fortunately, the

GFCF Rand quantum value does not feed back into the model, and any misjudgement of the ratio assumption will only impact on the distribution of values of components of expenditure on GDP within the model.

Any assumption made for the proportion of natural gas produced that will be exported is also very notional in nature at the time of preparing test scenarios. In the fullness of time, the quantity of gas that becomes available, the duration of the gas production life cycle, the cost of capital and confidence in potential downstream returns on investment, are some of the major variables which will determine the appetite for domestic value adding activities, and these decisions will impact on the balance between domestic gas demand and the desire to export gas. Awareness of the gas export proportion used in any scenario is therefore important, with the proportion being a scenario defining assumption, rather than being endogenous to the model.

The balance of payments impact generated by the model depends not only on the export of natural gas, but also on the exports of downstream products (made possible by the development of a large scale natural gas resource). On the imports side of the balance of the current account, specialised equipment and consumable items are likely to vary in relation to upstream and downstream outputs over various time periods, and will depend heavily on micro economic considerations, notably relative prices between imported and locally produced items as and where the latter option exists. The capital account is likely to be boosted by FDI inflows during the exploration and ramp up phases of production – the pre-production or exploration phase does not form part of the focus of this report, and the financing of upstream and downstream economic activities during the production phases is subject to an implicit assumption that domestic and foreign capital markets are of sufficient depth and sophistication to provide the finance.

The modelled outcomes for remuneration and employment variables rest on a number of assumptions regarding the mix of upstream employment in terms of its similarity to a possibly moving basket of employment in each of the mining, manufacturing and construction sectors of the South African economy. Each of these sectors have different mean remuneration rates to the others in the basket, and incorrect assumptions for appropriate mix proportions may influence upstream employment numbers upwards or downwards from future actual results. The assumed premium for upstream gas workers, based on information in the Marcellus and UK studies, may also prove to be more or less important in the South African context and therefore adversely impact on employment estimates. Downstream employment estimates are more directly modelled on general South African economic ratios, but rely on projected employment numbers for the economy as a whole drawn from the mid-growth scenario for the South African economy presented in section 3 of the report. As noted, this so called mid-growth scenario is at the upper limit of long term growth expectations, not only as exist in other studies recently undertaken by Econometrix, but also as exist in the Integrated Resource Plan of the Department of Energy, and recently published work by The National Planning Commission within the President's office. Deviations from this long term growth projection would proportionally influence the quantity of downstream employment associated with the gas resource in the same direction as the variance between the growth that the overall economic growth rate assumed and whatever develops in reality.

The Keynesian structure of the model resides on an assumption that the supply side (resources like labour, capital and so on) are not already fully deployed. If they are, the theory is that the discovery of a large gas resource might, in the long term, result in a reallocation of available resources and adjustments to the relative prices of both resources and outputs within the economy, with no long term increase in total economic output. This would be valid in an economy where either labour or capital is already fully employed. However, this may not be the case in the South African economy in the time frame assumed for the productive phase of the natural gas resource. Unskilled and semiskilled labour is certainly in surplus, with youth (which will be more widely educated than its older counterparts because of the 17 years of democratised education) unemployment estimated at around 74% at the end of 2011. South Africa also has porous borders in terms of both labour and capital, which adds a dimension of growth flexibility more prominent in reality than in Keynesian theory. The availability of capital will depend on a combination of risk appetite, confidence and material yields anticipated by potential investors. South Africa is well integrated into global capital markets, with a strong domestic financial sector able to convey and trade the capital requirements for upstream and downstream developments. As a result, the researchers raise the theoretical zero-sum Keynesian argument, but simultaneously suggest that it might not apply to the South African economy over the period to 2044, because of the empirical realities of aspects of global economic integration, versus the nation state economies contemplated at the time at which JM Keynes developed his economic theories.

5.7 Test Scenarios

5.7.1 Assumptions

As noted in Section 5.2 above, two test scenarios were modelled for the purposes of this report.

- Scenario A has an assumed resource size of 20tcf
- Scenario B has an assumed resource size of 50tcf

In each scenario, a five year ramp-up to mature production levels is assumed to be required, notionally beginning in the year 2020. All four scenarios then see a run-out production period of 5 years. **Scenario outputs**

Table 10: Test Scenario Summary of Macro Economic Model Output

Scenario Label	A	B
Upstream Production		
Resource Assumption TCF	20	50
Production Years	25	25
Average Mature production MMCF/Yr	969697	2424242
Project turnover $m	160000	400000
Project turnover Rm	1168480	2921200
Project intermediate consumption Rm	408968	778988
Project Value added Rm	759512	2142212
Project Employment - Man years	1377495	3885241
Maximum Employment	67278	189758
Project Employment Remuneration Rm	177795	501473
Downstream Production		
Project turnover Rm	2863293	6599068
Project intermediate consumption Rm	1616759	3726164
Project Value added Rm	1246535	2872904
Project Employment - Man years	5951114	13715606
Maximum Employment	288539	664999
Project Employment Remuneration Rm	623267	1436452
Combined Upstream and Downstream		
Project Turnover Rm	4031773	9520268
Project Intermediate Consumption Rm	2025727	4505152
Project Value Added Rm	2006046	5015116
Project GFCF Rm	444990	1133625
Project government Revenue Rm	886808	2223494
Project Employment - Man Years	7328608	17600846
Maximum Employment	355817	854757
Project Employee Remuneration Rm	801062	1937924
Project Household Consumption Generated	991314	2398182

From an estimated gas turnover of R1.168 trillion in **scenario A**, total turnover for both upstream and downstream participants is modelled at R4.031 trillion, measured at constant 2010 prices. Of this turnover value of production, the total value added in the economy is estimated at R2.006 trillion. Maximum employment created is calculated as 355 817 jobs, that level being achieved during the mature production phase of the projects production life. Maximum remuneration of employees generated by the project reaches R801 billion per year. The project contributes R887 billion in government revenue, which is equivalent to 22% of turnover, or 44% of value added by the project.

Data drawn from table 10 above (and later from table 11), can be compared to two benchmark periods. The first of these periods is the last year for which national accounts data is known for South Africa, i.e. the year 2010. The second period used for benchmarking predicted macro economic impacts dependent upon the natural gas upstream scenario assumptions as for the year 2025, which represents a convenient point in the mature phase of the production life of the two scenarios. Comparisons for the year 2035 are made against anticipated values in the mid growth scenario (i.e. GDP growing at 4.5%pa) described in section 3.1 of this report and further illustrated in appendix A.

From an estimated gas turnover of R2.921 trillion in **scenario B**, total turnover for both upstream and downstream participants is modelled at R9.520 trillion, measured at constant 2010 prices. Of this turnover value of production, the total value added in the economy is estimated at R5.015 trillion. Maximum employment created is calculated as 854 757 jobs, that level being achieved during the mature production phase of the projects production life. Maximum remuneration of employees generated by the project reaches R1.937 trillion per year. The project contributes R2.223 trillion in government revenue, which is equivalent to 23% of turnover, or 44% of value added by the project.

A resource of 20tcf would produce combined upstream and downstream value added contributions equivalent to 83% of GDP in the year 2000 during its lifetime, or 28% of GDP in 2035, assuming 4.5% p.a. GDP growth. The measure of GDP used here is that at constant 2000 basic prices, i.e. the inflation free indicator of the sum of rewards to the factors of production (land, labour, capital, entrepreneurship) rewarded out of economic production. Average annual GDP contribution would be equivalent to 3.3% of GDP in 2010, 1.1% of the projected 2035 total GDP value.

A 50tcf resource produces a lifetime value added contribution equivalent to 239% of 2010's SA GDP or 69% of the value of the projected GDP in 2035. On average annual GDP contribution from this larger assumed resource is equivalent to 9.6% of 2010's actual GDP for the country, or 2.8% of the projected GDP level in 2035[22].

The maximum total employment achieved in any year of the project in scenario A is equivalent to 2.7% of total employment during 2010, or 0.98% of total employment projected for 2035. Scenario B's maximum employment level of 854 757 is equivalent to 6.5% of 2010's total employment level, or 2.4% of projected employment in 2035.

These benchmark comparisons create a context for the major macroeconomic indicators shown in the summary table for the two text scenarios. The potential economic impact of such large gas resource finds are clearly very significant in relation to the historic and projected future sizes of the South African economy. The lower contributions to GDP and employment aggregates in 2035 than the theoretical comparisons that are benchmarked for 2010 are as a result of the fact that the economic aggregate variables are growing in line with the mid-growth case scenario presented in section 3.1 of this report, while the average annual contributions of the gas production scenario are held flat. Clearly, this must result in lower percentage shares for the contributions of gas to the overall economy the further out one goes in time.

Few individual projects in the history of the South African economy would have had equivalent or greater sustained impacts on the economy. Probably the most recent would have been the opening of the Free State gold fields in the early 1950's, when the economy was much smaller than it was in 2010 and will be in 2035, followed by the massive electricity infrastructure build during the early years of the 1980's. The macroeconomic aggregates produced by the model are only one aspect of the possible benefits to the

[22] *The 2035 benchmark was selected as it is virtually at the mid-point of the mature production phase of the 25 year production life assumed for the project. Individual years in the mature phase will produce slightly higher values than those indicated as average contributions, because the total life cycle has lower absolute values during the ramp-up and run out phases of production.*

economy. Less measureable beneficial effects would include the impact that large gas resources might make on the energy poverty which South Africa shares with other African nations, the possibilities of creating employment across the corporate size spectrum, ranging from international energy companies to small and micro enterprises in South Africa, and the spread of benefits, both in terms of upstream and downstream product availability, and the economic development of an area of the country with few other growth prospects of this magnitude. The local region would actually be able to export energy products in various forms to the rest of the country and create value adding opportunities for exports to the rest of the world as well.

Table 11: Test scenario summary of macro-economic model output

	0% Gas Exports		50% Gas Exports		100% Gas Exports	
Scenario Label	A	B	A	B	A	B
Upstream Production						
Resource Assumption TCF	20	50	20	50	20	50
Production Years	25	25	25	25	25	25
Average Mature production MMCF/Yr	969697	2424242	969697	2424242	969697	2424242
Project turnover $m	160000	400000	160000	400000	160000	400000
Project turnover Rm	1168480	2921200	1168480	2921200	1168480	2921200
Project intermediate consumption Rm	408968	778988	408968	778988	408968	778988
Project Value added Rm	759512	2142212	759512	2142212	759512	2142212
Project Employment - Man years	1377495	3885241	1377495	3885241	1377495	3885241
Maximum Employment	67278	189758	67278	189758	67278	189758
Project Employment Remuneration Rm	177795	501473	177795	501473	177795	501473
Downstream Production						
Project turnover Rm	2863293	6599068	1901347	4194202	939401	1789337
Project intermediate consumption Rm	1616759	3726164	1073596	2368257	530433	1010349
Project Value added Rm	1246535	2872904	827751	1825946	408968	778988
Project Employment - Man years	5951114	13715606	3951790	8717296	1952465	3718985
Maximum Employment	288539	664999	191602	422657	94665	180314
Project Employment Remuneration Rm	623267	1436452	413876	912973	204484	389494
Combined Upstream and Downstream						
Project Turnover Rm	4031773	9520268	3069827	7115402	2107881	4710537
Project Intermediate Consumption Rm	2025727	4505152	1482564	3147244	939401	1789337
Project Value Added Rm	2006046	5015116	1587263	3968158	1168480	2921200
Project GFCF Rm	444990	1133625	365869	935822	286748	738019
Project government Revenue Rm	886808	2223494	705894	1771208	524979	1318922
Project Employment - Man Years	7328608	17600846	5329284	12602536	3329960	7604226
Maximum Employment	355817	854757	258880	612415	161943	370073
Project Employee Remuneration Rm	801062	1937924	591671	1414445	382279	890966
Project Household Consumption Generated	991314	2398182	732192	1750376	473070.177	1102570.9

The table above presents the output of the model sensitised for each of 50% of the annual gas production being exported and 100% of the gas production being exported. Significant differences in output can be seen vs. the zero upstream export scenario presented in the above table. As the export proportion of upstream production increases to 50% and then 100%, the following declines in the potential of the downstream (relative to the zero export scenario) are noted as:

- Total GDP contribution declines by -20.8% and -41.8%, respectively.
- Downstream GDP never reduces to zero, because there will always be downstream (as defined for this study) production of inputs to upstream activities.
- Total gross production (or turnover) declines by -23.9% and -47.7%, respectively (slightly more for scenario B).
- Total employment declines by -27.3% and -54.6%, respectively (slightly more for scenario B).
- Total government revenue declines by -20.4% and -40.8%, respectively.

Of their own accord, exports of gas are not necessarily a negative strategy. Depending on the appetite for investment in downstream value adding activities that make direct use of the natural gas in these scenarios, and the timing and cost of investments required to bring them to fruition, levels of exports may well be the only available option to upstream producer. While downstream gas dependant value adding activities clearly enhance the productions columns total contribution to GDP, employment and Government revenue, the micro economic circumstances of the downstream production may mitigate in favour of electing to export gas product, rather than enhancing its value within the local economy. Organised business and government economic, industry and planning authorities would collectively need to closely monitor trends in these downstream developments (or possible lack of developments) and work on mitigating or eliminating economic bottlenecks or hurdles which may be encouraging exports, and/or discouraging local downstream value adding activities.

Even if 100% of the gas is exported, reducing downstream value added to the level of upstream intermediate consumption, the implicit improvement in the country's international energy trade balance would represent an improvement over the situation if no gas production was to take place at all. It would represent the lower value added choice between reducing crude oil imports by displacing crude oil based automotive fuels with local gas based fuels, versus exporting the gas as a trade balance offset against oil imports.

More detailed scenario outputs are to be found in the Appendices of this report.

5.8 Impacts on the Energy Trade Balance

- Much will depend on which of the major application routes for natural gas that may be produced from the envisaged southern Karoo gas field are selected
- Each of these downstream usage roots imply different imported machinery requirements
- They also imply variable mixes of potentially exportable commodities, exportable electrical energy, reductions of imported materials, beginning with natural gas and going on to end user consumables, such as:
  - Primary energy for electricity generation

  - Feedstock for GTL conversion displacing crude oil
- Energy feedstock for fertilizer production
- Energy resources for transport equipment, displacing crude oil generated liquid fuels
- Industrial heating fuel, displacing crude oil generated liquid fuels
- Creation of various petro chemical feedstocks, displacing crude oil generated liquid fuels

- There are possibilities, each linked to the potential size of the resource, to export the natural gas in LNG form
- On the imports side, many of these downstream applications will require technology imports of their own (consider the technology imports necessary for the long term development of Sasol, balanced against long term crude oil import displacement)
- The gathering, trunk and distribution pipeline networks necessary for commercially viable production distribution may or may not present as an import load.
- Fresh investment opportunities are bound to arise from medium to large scale commercially viable levels of natural gas production, attracting foreign direct investment into such downstream opportunities

In the modelled scenarios, exports from upstream production can be exogenously assumed as a proportion of annual gas production. In the scenario summaries presented in table 15 above, zero exports of upstream gas were assumed, allowing the maximum benefit of local gas production to flow through to downstream producers. The higher the export of upstream gas production, the lower will be the value added downstream, and consequently the lower will be downstream employment, GFCF and exports. In the modelled scenarios, estimates of GDE and GDP, together with export value estimates are all available and the resulting import values are calculated on the basis of the identity linking these four variables.

5.9 Conclusions from this section

- As noted previously in this report, a significantly large and geographically diverse literature covering the production of shale gas around the world exists. Where the studies do address macro-economic concepts like contributions to gross value added, employment and fiscal revenue, those estimates are often based on aggregations of highly detailed micro economic data, which information is clearly available in those respective public domains.
- The combination of the information supporting such studies ex-post rather than of a forecast nature, compared with the prospect that the mature phase of Karoo shale gas production may well be a minimum of 15 years away in the future, makes for insurmountable hurdles in translating or transposing approaching in the foreign literature to the South African context.
- Another major difference lies in the fact that many of the developed and some of the developing world's gas resources are located in economies with well-established downstream gas driven value adding industries which are almost entirely absent from the south African economic landscape
- With no macro-economic model structure readily transferable to the South African environment, the researchers configured a model designed to convert conceptualised large gas finds to macro-

economic impact scenarios. The model is essentially Keynesian in structure, treating upstream gas production values as an injection into the existing flow of income of the domestic economy.

- A multiplier effect is calculated and distributions of the value of gross production are distributed across gross value added intermediate consumption like intermediate consumption, compensation of employees, employment levels and fiscal revenue generation are calculated.
- Values for variables defining the resource sizes were informed by material discussed earlier, with values and multipliers and ratios derived predominantly from National Accounts drawn from the SARB, data drawn from Statistics SA's input and use tables was also used, as was data relating to employment and remuneration. Two test scenarios relating to gas resources of 20tcf and 50tcf respectively are presented. Within each of these scenarios, a major driving assumption is the proportion of gas that may be exported, and therefore not be available for downstream value adding.
- Even if all the gas recovered is exported, downstream production in the economy does not reduce to zero. This is because the economy would still produce intermediate consumption goods used by the upstream activities' and there would be rounds of induced demand generating domestic production.
- Benchmarking the model scenarios against the projected macro-economic growth scenarios discussed in section three of the report reveal the macro economic impacts of such large potential gas resources to be substantial, relative to both the last known full year of macro-economic data (2010), and relative to projected macro-economic values by the midpoint of mature production assumed in these scenarios (2035)
- The modelled scenarios offer some quantitative evidence supporting the contention that large gas finds could be "transformational," for the South African economy. Similar expressions of it being a "[potential game changing" development are also supported.

Test scenario Summary of macro-economic model output

Scenario Label	A	B
Upstream Production		
Resource Assumption TCF	20	50
Production Years	25	25
Project Value added Rm	759512	2142212
Project Employment - Man years	1377495	3885241
Maximum Employment	67278	189758
Downstream Production		
Project Value added Rm	1246535	2872904
Project Employment - Man years	5951114	13715606
Maximum Employment	288539	664999
Combined Upstream and Downstream		
Project Value Added Rm	2006046	5015116
Project Employment - Man Years	7328608	17600846
Maximum Employment	355817	854757

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