INTEGRATED ENERGY PLAN

FOR THE

REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF MINERALS AND ENERGY

19 MARCH 2003

INTEGRATED ENERGY PLAN FOR THE REPUBLIC OF SOUTH AFRICA

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GLOSSARY

bpd	Barrels (oil) per day
Capacity load factor	The percentage output of a plant compared with the maximum possible on a continuous basis.
Energy Intensity	Ratio of the energy required to produce a Rand of product- here measured nationally as PJ/Rbillion.
GWhr	Giga Watt hour – a measure of energy. (1GWhr is equivalent to 3.6×10^{12} Joules)
IEA	International Energy Agency
KWh	kilo Watt hour – measure of energy, usually electricity.
Levelised cost	Levelised cost where capital is levelised over the life of a plant taking the annual production (average annual production factor) into account. It is derived by dividing the total cost of building and operating the plant over its life by the net production output over the same time period taking into account inflation.
Net discount rate	The discount rate can be defined as the required rate of return by investors in a company in real terms. The net discount rate is the return after subtracting inflation.
ppm	Parts per million
PJ	Peta Joules (10^{15} Joules)
Program	Computer instruction set.
MGJ	Million Giga Joules – measure of energy
MW	Mega Watts – measure of power
Mwe	Mega Watts electrical – measure of power
Reserves	Reserves are economically exploitable in this case energy sources, eg coal, oil, gas and hydro.
Resources	Resources are in this case energy sources, eg coal, oil, gas and hydro, but not at this stage economically exploitable.
tcf	Trillion cubic feet – standard term to measure natural gas volume.

INTEGRATED ENERGY PLAN FOR THE REPUBLIC OF SOUTH AFRICA

Energy is a necessary but insufficient requirement for development.

INTEGRATED ENERGY PLAN OVERVIEW

- Energy supply will remain reliant on coal for at least the next two decades.
- Diversify energy supply through increased use of natural gas and new and renewable energies.
- Continue investigations into nuclear options as a future new energy source.
- Promote the use of energy efficiency management and technologies.
- Maximise load factors on electricity generation plant to lower levelised lifecycle costs.
- Lessen reliance on imported liquid fuels by exploring and developing oil and gas deposits.
- Increase existing oil refineries capacity when appropriate rather than greenfields development.
- Continue with existing synfuel plants and supplement with natural gas as feedstock.
- New electricity generation will remain coal based with potential for hydro, natural gas and nuclear capacity.
- Ensure environmental considerations in energy supply, transformation and end use.
- Promote universal access to clean and affordable energy, with emphasis on household energy supply being co-ordinated with provincial and local integrated development programmes.
- Introduce policy, legislation and regulation for the promotion of renewable energy and energy efficiency measures and mandatory provision of energy data.
- Undertake integrated energy planning on an ongoing basis.

1. INTRODUCTION

Energy is one of the key elements in production processes. A lack or shortage of energy has a serious effect on the economy and gross domestic growth. By virtue of its size and economic importance, the energy sector periodically requires considerable investments in new and replacement supply capacity. Historically, such decisions were primarily driven by concerns regarding maintaining supply security, without giving full consideration to the economic, environmental and social impacts of all alternatives. As a consequence, the tendency has been towards the construction of large-scale capital-intensive supply facilities and the neglect of alternatives that might have been more cost effective in the long term, and had greater employment benefits and more favourable environmental impacts. Consequently, the policy espoused in the White Paper[1] stated that;

The Department of Minerals and Energy will ensure that an integrated resource planning approach is adopted for large investment decisions by energy suppliers and service providers, in terms of which comprehensive evaluations of the economic, social and environmental implications of all feasible supply and demand side investments will have to be undertaken.

Over the recent years, the contribution of different sectors to the country's Gross Domestic Product has changed significantly. In the past two years the industrial policy has shifted towards a greater focus on knowledge-intensive sectors and human resource development, placing less emphasis on comparative advantage based on natural endowments[2]. Primary

[1] White Paper on the Energy Policy of the Republic of South Africa, December 1998

[2] South Africa – Locomotive for African Growth?, UNECA

production like agriculture and mining now contribute less to the economy than the tertiary or services sector. The tertiary sector now contributes almost two-thirds of our gross domestic product. This implies a lowering of overall energy intensity, as generally the energy required per unit product (measured in Rands) is less for the tertiary sector compared with the primary sector. This shift is similar to what has occurred in most industrialising nations. This does not mean that agriculture and mining are becoming unimportant, but that the energy sector may re-focus efforts on how to further exploit South Africa's endowments. Such re-focusing may be based on integrated energy planning.

According to the White Paper, integrated energy planning is a process that entails the following technical functions:

- interpreting the requirements of national economic, social and environmental policies for the energy sector;
- analysing energy needs in terms of how their fulfilment will contribute towards attaining national economic and social goals;
- analysing the potential of energy supply systems and demand side management to meet current and potential future energy needs. This would include analyses of individual supply sub-sectors and the linkages between sub-sectors;
- analysing energy sector linkages to the macro-economy;
- analysing the potential effects on the energy sector of global and technological developments;
- evaluating the effects of legislative, institutional and industry structure arrangements on energy supply and demand; and
- specifying, sourcing and presenting data on energy supply and demand, energy sector institutions, and linkages with economic and social factors in order to provide a statistical description of the energy sector's historic evolution and current impact on economic and social development.

The integrated energy planning process is a relatively new tool world-wide and is still under evolutionary development. There are many documents internationally that address integrated energy planning, but a dearth of explicit integrated energy plans. The development of the energy plan addressed here is the first for South Africa. As such, it has been a learning process and some aspects addressed above have been absent from the process because of time constraints. Moreover, the process has identified a number of gaps and deficiencies. These gaps and deficiencies are scheduled to be addressed during the follow-up process.

The energy plan addressed here is based on the scenario modelling done for the Department of Minerals and Energy and Eskom by the Energy Research Institute of the University of Cape Town. Details of scenario development, energy supply, demand, economic and environmental modelling may be found in the final report[3] - approximately 400 pages. This document summarises and analyses that report. Details of the methodology are addressed in Section 4.

As addressed above, the purpose of the integrated energy plan or strategy is to balance energy demand with supply resources in concert with safety, health and environmental considerations. An integrated energy plan or strategy is not a precise blueprint for the energy sector, but is a framework within which specific energy development decisions can be made.

The format of this text will be to:

a) briefly describe an overview of the current energy sector;
b) briefly describe available energy resources;
c) describe the modelling methodology of the energy planning process;
d) summarise and discuss the results of the modelling process;

[3] *"Energy Outlook 2002"*, Energy Research Institute, University of cape Town.

e) based on the results develop an integrated energy plan;
f) identify the gaps in the current process; and
g) discuss the furtherance of the integrated energy planning process.

2. ENERGY SECTOR OVERVIEW

The first step of integrated energy planning is to assess the present situation in the context of current consumptions and trends.

2.1 Energy Flows

The flow of energy from its source, through transformation, transport to final use has a number of conversion losses as determined by the laws of physics. The flow of energy from production to final use is illustrated in Figure 1, where the portion of use and conversion losses are indicated approximately to scale.

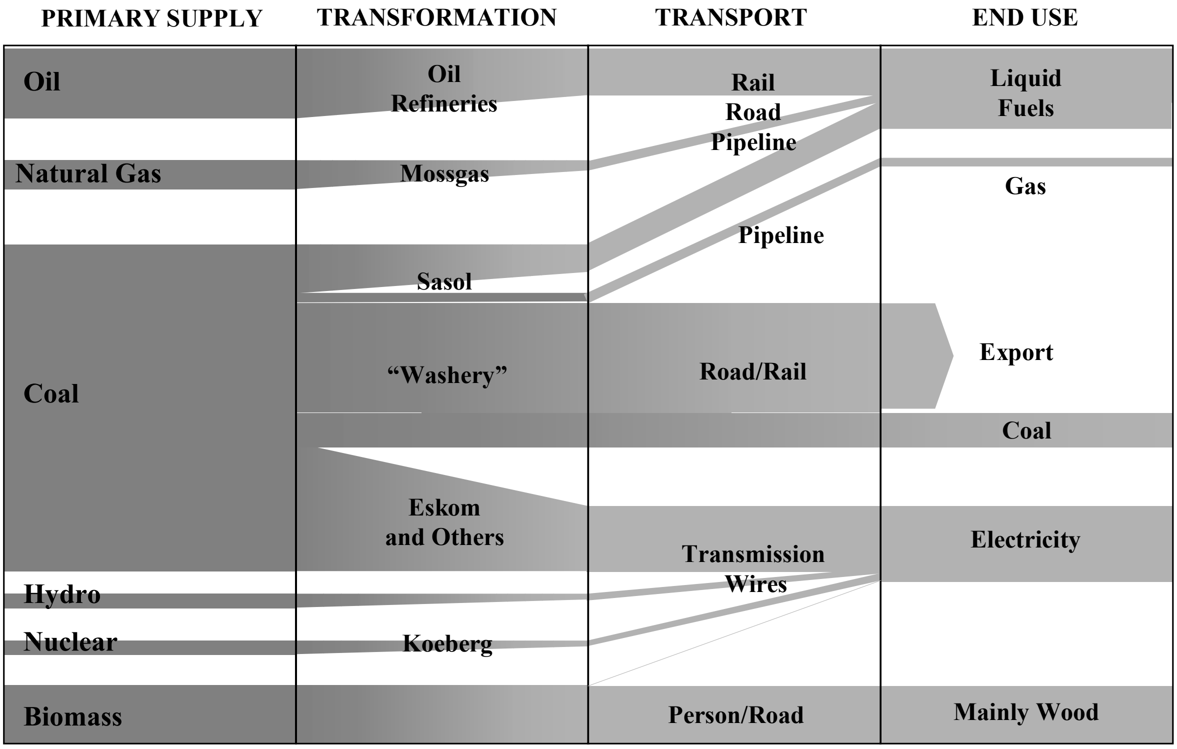

Figure 1: Energy flow from primary energy supply to final use – roughly to scale.

Note the dominance of coal in the primary energy supply. Biomass (renewable energy) features relatively highly, it being mostly fuel wood in rural areas where accurate and reliable data is difficult to obtain.

2.2 Primary Energy Supply

The primary energy supply for the South Africa energy sector is dominated by coal – Figure 2 - it being plentiful and inexpensive by international standards. The total primary energy supply is approximately 4 782 PJ for the year 2000.

Most of South Africa's liquid fuel requirements are imported in the form of crude oil. Approximately 30% of South Africa's liquid fuel requirements are sourced from coal via Sasol. Further, 100% of South Africa's current natural gas production (Mossel Bay) is converted into liquid fuels, supplying 8% of national liquid fuel requirements.

With respect to forthcoming new primary energy supply, it is pertinent to state that natural gas is scheduled to be delivered to South Africa from Mozambique during the year 2004. The initial capacity of the gas transmission pipeline is 120 MGJ per year. To place this into perspective, the 120 MGJ per year is equivalent to approximately 3 800 MW, which assuming a 50% conversion efficiency to electricity, is equivalent to 1 900 MWe or approximately one half an Eskom ("six-pack") electricity generation station. Approximately one third of the natural gas coming from Mozambique is scheduled to be used by Sasol as a replacement for coal as a feedstock, another one third is scheduled to replace the syngas in Sasol's existing gas market, and the remaining one third is to go into Sasol's expansion of the gas market.

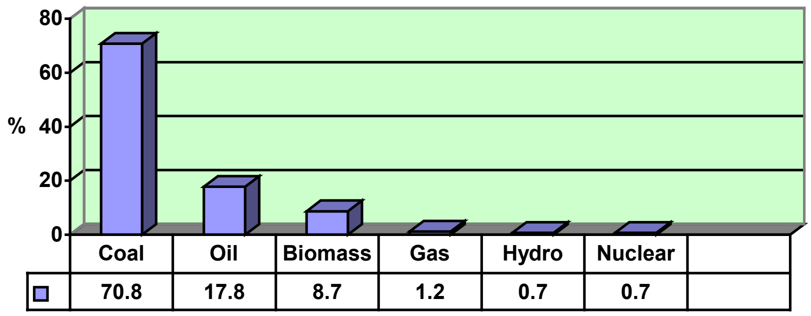

Figure 2: South Africa primary energy supply by energy carrier for the year 2000.

2.3 Energy Demand

The final energy demand during the year 2000 was 2363 PJ. Liquid fuels, coal and electricity are the main forms of the end use of energy, dominating biomass and other forms of energy – Figure 3.

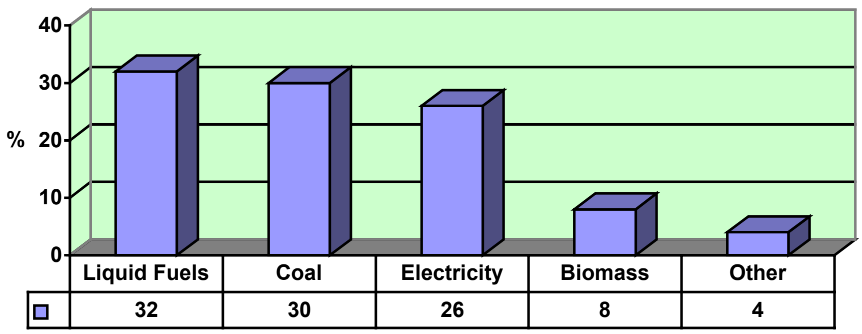

Figure 3: South Africa final energy demand by energy carrier for the year 2000

Biomass and other energy accounted for only ~8% of energy demand, mainly rural use of fire-wood that is currently not being renewed.

The historic energy demand by sector is shown in Figure 4. A comparison of energy consumption between 1992 and 2000 shows that: residential use has remained almost constant, commerce and public service has fallen 25%, agriculture has fallen 18%, transport has risen 27%, mining and quarrying has fallen 15% and industry risen 22%.

The underlying reasons for these changes are not yet apparent, except to say that the historic trends in energy demand for mining and quarrying and industry are consistent with the gold mining output falling (gold mining uses more energy than all other mining) and the increase in tertiary industry activities.

By international standards, South Africa has a high energy intensity, that is a high energy input per unit of gross national product (GDP). This is because of low energy costs and an abundance of mineral deposits have led to an emphasis on primary extraction and processing, which is inherently energy intensive. Table 1 indicates South Africa's energy intensity between 1993 and 2000, where post 1995, GDP rises and final energy consumption falls resulting in a lowering of energy intensity over that period.

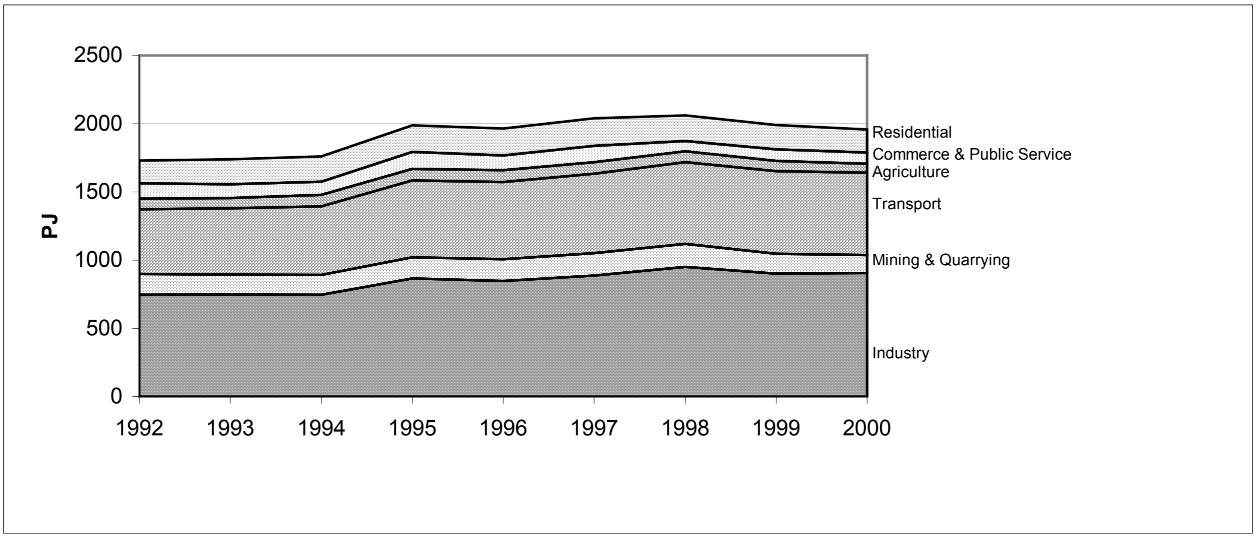

Figure 4: Time series of final energy consumption excluding renewables (because of ill defined data) and non-energy use)

The lowering of energy intensity reflects the swing away from primary industry to tertiary industry. Preliminary studies have shown that there is scope for energy efficiency measures, that is, undertaking the same functions using less energy, with a preliminary savings potential of approximately 20%. As energy comprises approximately 15% of gross domestic product, there is potential for energy efficiency measures to contribute to an approximately 3% GDP growth.

Table 1: National energy intensities between 1993 and 2000.

	1993	1994	1995	1996	1997	1998	1999	2000
GDP- All industries at basic prices R billion(constant 1995 prices)	472	486	500	521	534	538	549	571
Total Final Energy Consumption (Renewable and Waste excluded) PJ	1766	1789	2016	1996	2071	2098	2026	2003
Energy intensity (Total energy consumtion/GDP) PJ/Rbillion	3.74	3.68	4.03	3.83	3.88	3.90	3.69	3.51

2.4 Energy Transformation Capacity by Sector

A large portion of the primary energy is transformed into other forms of energy more appropriate for final use. The two major energy transformation sectors concern the generation of electricity and the production of liquid fuels (including petrol, diesel and paraffin) from coal, crude oil and gas. Sufficient capacity in these sectors, including a provision for planned and unplanned outages, is critical for the balance between supply and demand.

2.4.1 Electricity Generation Capacity

South Africa currently has approximately 37,000 MWe of generating capacity, of which 87% is coal fired – see Table 2. Table 2 excludes imported electricity, for example from the Cahora Bassa hydro scheme.

Note that the pumped storage unit is a net energy loss system, its purpose being to store energy generated during off-peak periods for conversion back to electricity during peak periods. On the other hand, a pumped storage system could make the overall system more efficient by the judicious storage of energy during low cost periods for use during high cost periods.

Table 2: South Africa electricity generation capacity

Energy Source	**Capacity / MWe**
Coal	32,202
Nuclear	1,840
Pumped Storage	1,580
Hydro	667
Gas Turbine	662
Bagasse	105
TOTAL	***37,056***

Eskom produces 92% of South Africa's electricity requirements, the remainder being provided through local authorities, industry and imports via the South African Power Pool. Eskom's generation capacity, assuming a 50 year life per plant, is indicated in Figure 5. The solid line in Figure 4 indicates electricity actual and projected demand.

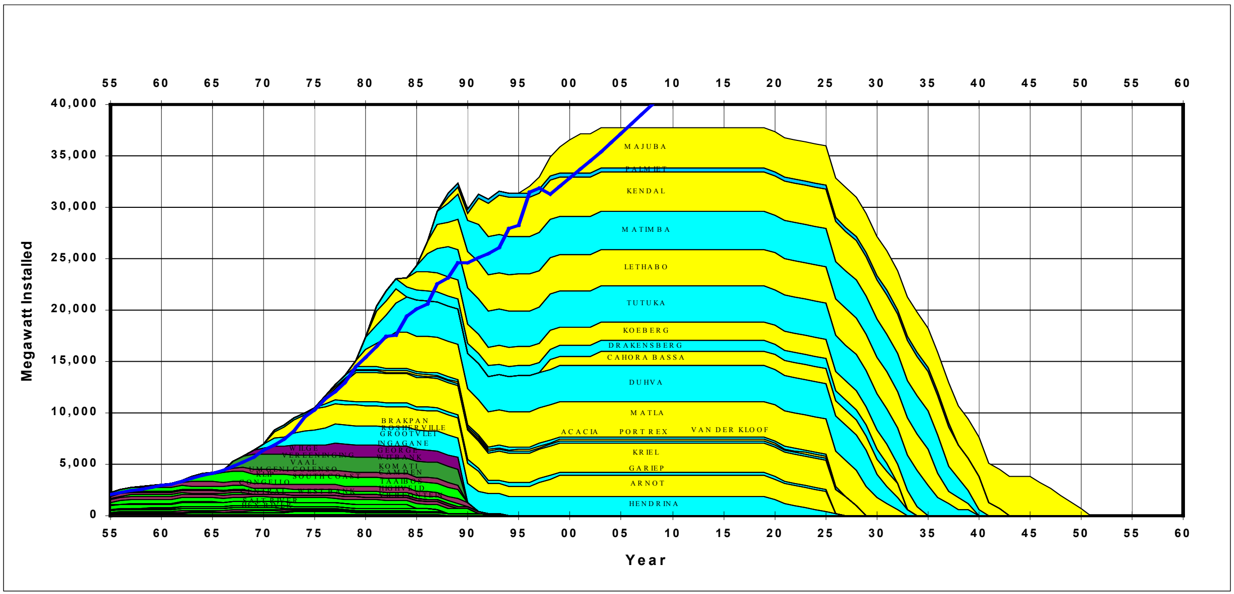

Figure 5: Eskom Electricity generating capacity as a function of time - the solid line indicates actual and projected demand

The capacity is primarily coal-fired and the graph indicates that current plant is scheduled to be operational until at least the year 2020. The projected demand line indicates that further electricity generation plant will be required at approximately year 2007. It is pertinent to note that whilst current concerns relate to new capacity to accommodate growth in demand, after the year 2020 and for the following three decades, generating capacity to replace the existing 37 000 MWe will need to be addressed. Current concerns may seem trivial when compared with the foreseen task after the year 2020.

Current peak electricity demand is approximately 31 500 MWe (July 2002), and national installed capacity is approximately 37 000 MWe. According to the Baseline Simulated scenario (see anon), which assumes a 10% reserve margin, South Africa will be short on capacity by 2005-2007, unless demand side management or new plant is built. Assuming the 10% reserve margin on a gross capacity of 37 000 MWe, the current net capacity is 33 300 MWe, which is only 1 800 MWe (that is the size of Koeberg) above the peak demand. Given the time to commission new plant, the current electricity generation system could soon be viewed as vulnerable.

2.4.2 Oil Refineries Capacity

Oil refineries capacities are indicated in Table 3.

Current refinery output is approximately 493 000 bpd and South African final demand about 427 000 bpd. The surplus production, mainly diesel, is exported.

Table 3: Oil refineries' capacity[4]

Facility	barrels / day (Crude or equivalent)
Calref (Cape Town: Caltex)	100 000
Sapref (Durban: BP/Shell)	180 000
Genref (Durban: Engen)	105 000
Natref (Sasolburg: Sasol/Total)	86 000
Sasol CTL	150 000
Mossgas GTL	45 000
Total	**666 000**

In this sector, there is currently a mismatch between petrol/diesel production and demand. Because of the almost fixed ratio between petrol and diesel production quantities (ranges approximately between 60:40 to 40:60), and in order to meet the demand for petrol, South Africa currently produces a surplus of diesel. During year 2001[5], the consumption of petrol and diesel was 10 340 million litres and 6 448 million litres respectively. During the period 2000/01, diesel sales grew by 3.4% in contrast with petrol sales declining by 0.5%. During year 1998, exports of petrol and diesel were 2178 million litres and 4782 million litres respectively. Imbalances in petrol and diesel production and demand is addressed through exports (mainly diesel) and imports (for example petrol during 2001 as an aftermath of the refinery fire).

3. ENERGY RESOURCES

South Africa's major energy resource is coal, which is plentiful and inexpensive to exploit. Hence the current dominance of coal in the energy supply composition. The other main energy sources are addressed in Table 4.

Table 4: Estimation of South Africa's untapped potential energy reserves/resources

Energy Carrier	Reserve/Resource	Comment
Coal	55 billion tonnes	Coal technology well developed and inexpensive. Coal resources/reserves are currently under re-appraisal.
Oil	Potential reserves (P90) 40 million barrels. Potential (resource) 5 billion barrels.	Oribi/Oryx audited remaining reserves 12 million barrels plus Sable field reserves of 150 million barrels sufficient for four years production. Untested deep-water potential.
Natural Gas	Reserves (P50): 1.3 tcf Potential (resource): 25 tcf	F-A/E-M and satellites audited (P50) 0.5 tcf and 11.8 million barrels condensate plus Ibhubesi field. Upside potential of untested areas.
Uranium	261 000 Tonnes	Uranium beneficiation (conversion and enrichment) and fuel fabrication are done outside the country.
Hydro	~300 MWe potential	South Africa classified as a "water stressed" country and therefore has limited potential for hydro-power.
Renewable	Undefined	Largely untapped solar based resource that is variable depending on weather conditions. Non-commercial biomass energy mainly used in rural areas and is currently not being replenished. Technologies not fully developed and expensive.

South Africa also imports energy (electricity, soon natural gas) from neighbouring countries. An estimation of energy resources in southern African countries is addressed in Table 5.

[4] SAPIA Annual Report 2001
[5] SAPIA Annual Report 2002

The majority of South Africa's crude oil is imported, mostly sourced from the middle-east, primarily Saudi Arabia and Iran who account for approximately 81% of imported crude oil.

Table 5: Estimation of regional energy resources

Country	**Reserves/Resources**	**Comment**
Mozambique	Gas: ~2.0 tcf proven ~5 tcf potential Hydro: ~5 0000 MWe	Pipeline to South Africa currently under construction – schedule completion 2004 - with an initial carrying capacity of 120 MGJ/y. Cahora Bassa 1800 MWe the majority of which is assigned to Eskom. Mepanda Uncua potential ~2 200 Mwe
DRC	Hydro Gas: > 50 bcf proven Oil: > 200 million barrels	Potential for approximately 50 000-100 000 MWe of hydro generated electricity at Inga.
Zimbabwe	No oil and gas reserves Coal	Large coal reserves and potential for coal bed methane.
Namibia	Gas: 1.2 tcf proven Upside potential 7 tcf	Investigations currently underway to import gas to the western Cape.
Angola	Oil: 5.4 billion barrels proven Gas: > 20 tcf	

4. INTEGRATED ENERGY PLANNING METHODOLOGY

Under the methodology of integrated energy and resource planning, calculations were done under likely scenarios. Two basic scenarios were used: a "Baseline" or business as usual scenario, and a "Siyaphambili" (we are going forward) scenario that promoted diversification of supply and environmental improvement.

With respect to environmental aspects, the Treasury and the Department of Environmental Affairs and Tourism are currently investigating the financial internalisation of environmental externalities. Because these internalisation of externalities have not yet been quantified, environmental aspects were primarily addressed here through efficiency measures and renewable energy. When these internalisation of externalities have been quantified, they will be included in the modelling.

The two scenarios were used both in a simulated and an optimised mode. The simulated mode is where options are prescribed. The optimised mode is where the options are selected on a least cost basis.

Detailed descriptions of the two scenarios (for both the simulated and optimised modes) are addressed in Table 6, where the specifics for each are itemised.

In summary, the:

<u>"Baseline Simulated"</u> scenario is "business-as-usual", continuing present trends based on coal;

<u>"Baseline Optimised"</u> optimises that scenario on least cost, taking into account energy efficiency and fuel switching;

<u>"Siyaphambili Simulated"</u> scenario promotes fuel diversification away from coal, prescribing other energy technologies at set times; and

<u>"Siyaphambili Optimised"</u> optimises that scenario based on least cost, using energy efficiency and fuel switching.

Table 6: Scenario descriptions

<table>
<tr><th>Baseline Simulated</th><th>Baseline Optimised</th><th>Siyaphambili Simulated</th><th>Siyiphambili Optimised</th></tr>
<tr><td colspan="4">General</td></tr>
<tr><td>Business as usual - external costs excluded</td><td>Business as usual, but can select technologies to obtain lowest costs - external costs excluded.</td><td>Deliberate policy to diversity supply and improve the environment - external costs excluded.</td><td>Similar to simulated, but can select technologies to obtain lowest costs - external costs excluded.</td></tr>
<tr><td>No regional co-operation</td><td>Regional co-operation if economic</td><td>More regional co-operation</td><td>More regional co-operation if economic</td></tr>
<tr><td>No active energy efficiency</td><td>Energy efficiency if it reduces costs</td><td>Drive to increase energy efficiency and demand side management</td><td>Drive to increase energy efficiency and demand side management</td></tr>
<tr><td>Fuel switching only to follow current trends.</td><td>Burn fuel directly in end use thermal applications, if economic.</td><td>Fuel switching only to follow current trends and limited fuel switching from coal to gas.</td><td>Burn fuel directly in end use thermal applications, if economic, but with no increase in use of coal over the simulated case.</td></tr>
<tr><td colspan="4">Electricity</td></tr>
<tr><td>Coal continues to dominate</td><td rowspan="5">Any technology on cost alone:
• Conventional coal without FGD
• Combine cycle gas turbine
• Imported hydro
• Nuclear
• Solar
• Wind
• Municipal waste</td><td rowspan="5">New technologies before coal
• mothballed stations
• Combine cycle gas turbine
• Imported hydro
• Pebble bed modular reactor
• Fluidised bed coal
• Peaking gas turbine
• Wind and solar
Thereafter a conventional coal-fired station with FGD</td><td rowspan="5">Can chose on cost from any:
• conventional coal with FGD
• Fluidised bed coal combustion
• Combined cycle gas turbine
• Imported hydro
• Nuclear
• Wind and solar
• Municipal waste</td></tr>
<tr><td>Mothballed coal fired power stations brought back into operation</td></tr>
<tr><td>New coal fired stations without flue gas desulphurisation FGD</td></tr>
<tr><td>Some combined cycle gas turbine</td></tr>
<tr><td>New pumped storage and gas turbines for peaking power</td></tr>
<tr><td colspan="4">Liquid Fuels</td></tr>
<tr><td>Keep existing sulphur levels</td><td>Keep existing sulphur levels</td><td>Low sulphur fuels</td><td>Mandatory low sulphur</td></tr>
<tr><td>Mossgas ends 2008</td><td></td><td></td><td></td></tr>
<tr><td>New refineries built to meet demand, if necessary</td><td>Least cost to build new refineries or import refined product.</td><td>New refineries build to meet demand if necessary</td><td>Least cost to build new refineries or import refined product.</td></tr>
<tr><td></td><td>Sasol uses coal or gas to liquid fuels technology</td><td>Sasol used gas to liquid technology</td><td></td></tr>
<tr><td colspan="4">Natural Gas</td></tr>
<tr><td>No increase in use except for electricity generation</td><td>Increase if economic</td><td>Gas provide 5% primary energy</td><td>Gas used if economic</td></tr>
<tr><td colspan="4">Residential Sector</td></tr>
<tr><td>Current trends continue</td><td>More electrification if economic</td><td>More demand. Electrification increases.
More electricity for cooking, heating appliances</td><td>More demand and more electrification if economic</td></tr>
<tr><td colspan="4">Commercial Sector</td></tr>
<tr><td>No increase in energy efficiency</td><td>Some increase in energy efficiency</td><td>Increased energy efficiency</td><td>Increased energy efficiency</td></tr>
<tr><td colspan="4">Transport</td></tr>
<tr><td>No taxi recapitalisation</td><td>Taxi recapitalisation if economic</td><td>Taxi recapitalisation</td><td>Taxi recapitalisation if economic</td></tr>
<tr><td></td><td></td><td>More electric trains</td><td>More electric trains if economic</td></tr>
</table>

The energy and resource plan addressed here is based on the scenario modelling done for the Department of Minerals and Energy and Eskom by the Energy Research Institute of the University of Cape Town. The key parameters and drivers were decided by specialists at the public participation workshops.

It should also be born in mind that the further the projections are made into the future, the less reliable the outputs of the scenarios become. Hence, the energy planning process should be seen as an ongoing process that should be updated periodically.

The general assumptions and constraints of the calculations for the four scenarios are given in Table 7. These parameters were agreed at the initial public workshop and by the Steering Core Group during October 2001. These parameters can be altered but, because of the model structure, to vary some of the parameters would require considerable reworking of the calculations.
Although the validity of the results was unaffected, it is currently a time consuming process to change input parameters (such as rate of exchange, discount rate etc). To advance the process for future work, the calculation programs should be optimised to allow more ready facilities to change driver parameters and baseline data both up-front and over the planning period.

Table 7: General assumptions and constraints pertaining to the calculations made in the scenarios' development.

General Assumptions
❖ Twenty year planning period (2001 to 2020)
❖ Process performance data and costs and commodity prices at 1 January 2001 values
❖ \$1 = R8 (1 Jan 2001)
❖ Net discount Rate: 11%
❖ Inflation rate: 5.5% (SARB target 3-6%)
❖ Population Growth: 2000 = 44 Million, 2010 = 50 Million (1.3% p.a.), 2020 = 57 Million (0.87% p.a.)
❖ GDP Growth: 2.8% average annual growth over period
❖ Gas generally available from SA, Namibia and Mozambique at \$2.5 / GJ escalating at SA PPI.
❖ 20% coal price increase for Sasol from 2008.
❖ At least 15% Sasol coal/liquid process replaced by gas/liquid process by 2015
❖ Coal supplied to industrial and other processes, except electricity generation, at R6/GJ
General Constraints
❖ All energy projects must be South African or joint ventures with South African partners. All energy projects must be technologically feasible, economically viable and with adequate accuracy of costs.

The calculations for the scenario development were undertaken using the MARKAL and LEAP computer models. To do so, it was necessary to:

- configure the model structure and the reference energy system for South African conditions
- research, collect and collate required data, including energy and economic data
- configure the database on which the calculations were done
- determine the primary planning assumptions and scenarios
- populate and refine the reference energy system
- undertake the calculations and analyse the results
- iterate the process on advice from the Steering Core Group and sector experts.

This process normally takes approximately two to three years, including the collection of the appropriate data. The current modelling process (for which much of the data was already available), excluding the training to operate the models, was undertaken over a period of 8 months. The current structure for the use of the models is less than optimum, but did allow the production of results within a short period of time. For future work (see below) the use of the models needs to be optimised.

The processes, including the scenarios and data, were reviewed by local experts at the

Workshops and were found to conform to requirements. The model structure, the reference energy system and the modelling process were reviewed by international experts (the International Energy Agency's Energy Technology Systems Analysis Programme and others) and found to conform to international standards.

The integrated energy and resource planning process takes into account physical, technical, resource and economic considerations. The modelling process cannot by itself account for matters pertaining to sociological effects, political imperatives, global changes etc.

5. INTEGRATED ENERGY PLANNING PROCESS

The integrated energy plan addresses energy demand balanced with energy supply, transformation, economics and environmental considerations in concourse with available resources. By addressing the integrated energy plan under the umbrella of the scenarios, it is possible to take into account the various consequences of each scenario. The output of each scenario is addressed in Section 5.1. The consequences are detailed in the following sections.

5.1 Plan Descriptions

The calculations were done according to the methods outline above for the four scenarios and the outcomes generated the energy plans that are summarised in Table 8. This Table summarises the outputs of the scenarios for electricity generation, liquid fuel production and energy demand trends.

5.2 Energy Demand

For the above scenarios, the calculated overall final energy demand projections are displayed in Figure 6.

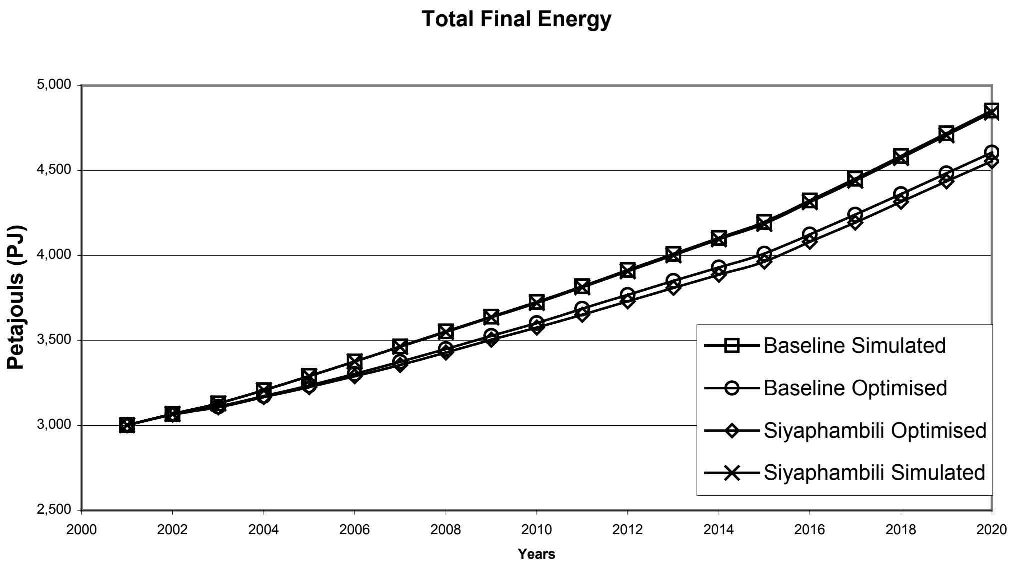

Figure 6: Total final energy demand per year projection (including non-energy use) – note that the Y axis starts at 2 500 PJ to emphasise the differences between each scenario (ERI, 2002).

*Table 8: Energy supply/demand results for the four scenarios (**Electricity and Oil Capacity Expansion plans for each of the 4 scenarios)***

	Baseline Simulated	Baseline Optimised	Siyaphambili Simulated	Siyaphambili Optimised
Electricity Generation	Based on coal as primary fuel source: o builds 3556MWe mothballed PF Stations from 2007 o Four sites for new 6X640MWe dry-cooled coal-fired plants with FGD from 2013 o 1x750MWe CCGT plants in 2014 o Four sites with each 3x333MWe pumped storage plants from 2011 o 5x240MWe simple cycle gas turbines (oil) for peaking built at max rate of one pa. from 2011 o No new hydro imports, nuclear, renewable energy sources are built	o Builds 3556MWe mothballed PF Stations from 2011 o Builds Four 6X640MWe dry-cooled coal-fired stations without FGD from 2015. o Build pumped storage plants from 2011 o No new hydro imports, nuclear, renewable energy sources are built	New technologies built before new coal options as specified: o 3556MWe mothballed PF Stations from 2007 at a max rate of 500MWe/a o 3x750MWe CCGT plants in 2005, 2006, 2007 using Kudu gas o 1X750MWe CCGT using Pande gas in 2014 o Builds part of the four sites with each 3x333MWe pumped storage plants from 2011 o 2684MWe imported Hydro Electricity from 2008 at max rate of 550MWe/a o 125MWe PBMR in 2005 followed by 250MWe/a from 2008 with a max of 1375MWe. o 2333MWe new FBC built at max rate of 466MWe/a from 2015 o 5x240MWe simple gas turbines (oil) for peaking at max rate of 1 pa from 2020 o 5% of electricity generation supplied by renewable options as specified by DME o New 6X640MWe dry-cooled coal-fired plants with FGD are only considered once previous alternatives are built	o Builds 3556MWe mothballed PF Stations at a max rate of 500MWe/a from 2018 o Builds 1X750MWe CCGT using Pande gas from 2014 o Builds pumped storage plants from 2011. o Builds 2333MWe new FBC built at max rate of 466MWe/a from 2020 o Builds 5x240MWe simple gas turbines (oil) for peaking built at max rate of one pa from 2020 o No new hydro imports, nuclear, renewable energy sources are built
Liquid Fuels	o All the oil refineries increase their capacity to 307 million bbl/year o Imports of finished liquid fuel products to meet increased demand.	o All the oil refineries increase their capacity to 307 million bbl/year o Imports of finished liquid fuel products to meet increased demand	o All the oil refineries increase their capacity to 307 million bbl/year o Imports of finished liquid fuel products to meet increased demand.	o All the oil refineries increase their capacity to 307 million bbl/year o Imports of finished liquid fuel products to meet increased demand.
Energy Demand	No active fuel switching or energy efficiency measures	o Moderate uptake of efficient practice, high during times of low capacity, from 2005 onward. o General switching to coal and some biomass away from electricity and oil. Increasing the system efficiency. o In the transport sector there is switching from oil to electricity. Partial taxi-recapitalisation takes place. Generally there is also a move away from petrol to more efficient diesel vehicles.	Moderate fuel switching to gas, and switching from petrol to diesel due to petrol taxi recapitalisation.	o High uptake of energy efficient practice especially during times of low power plant capacity from 2005 onward. Fuel switching away from oil and electricity to natural gas. At the end of the period there is some switching from electricity to oil, when the marginal cost is of electricity is high. At the beginning of the period there was some fuel switching from oil to electricity, especially in the transport sector. o In the transport sector there is partial petrol taxi recapitisation, and a move toward electric trains, especially during the beginning of the period. Generally there is also a move away from petrol to more efficient diesel vehicles.

The total final energy demand includes non-end-use-energy applications (eg the conversion of coal to chemicals) of approximately 690 PJ per year.

Note that the total primary demand varies by approximately only 7% between the scenarios by the year 2020, because the major drivers for energy demand are GDP and population growth and these are the same for all scenarios. Moreover, over the planning horizon, the average primary energy consumption rises by approximately 58% - or approximately 3% per year.

The activities for which energy is required remains the same for all four scenarios, however the total final energy demand differs because of different technologies and efficiencies used in each scenario.

The sector energy demand can be gleaned by expanding the final energy demand for the Baseline Simulated scenario – Figure 7. The major sectors of energy use are industry and transport. The largest increases are for; transport 75%, other 70%, industry 75% and Commerce 65% - over the planning horizon.

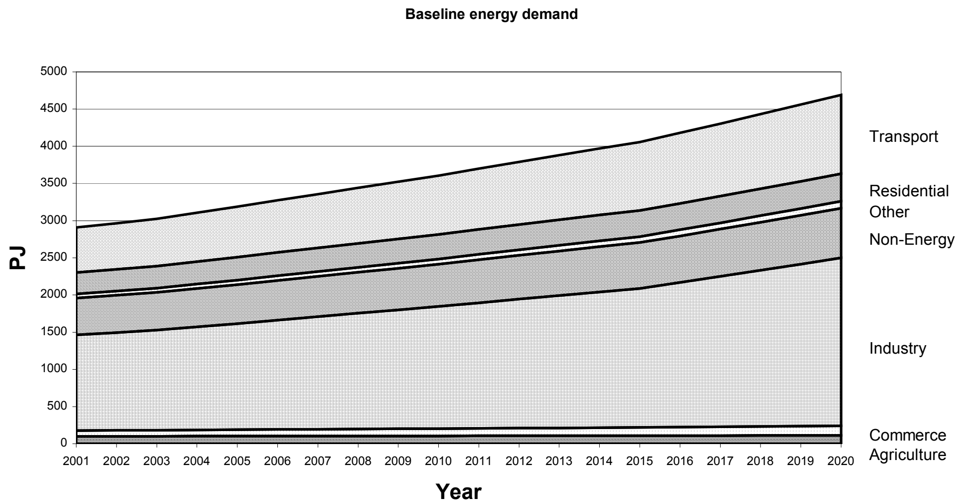

Figure 7: Final energy demand by sector (ERI).

The other three sectors show a moderate increase; residential 29%, non-energy 35%, and agriculture 13% - over the planning horizon

5.3 Primary Energy Supply

To accommodate the above energy demands, overall energy supply projections have been calculated and illustrated in Figure 8.

Note that the total primary energy supply varies by approximately only 12% between the scenarios by the year 2020 to meet the same energy service demand. This variation is because of the selection of final energy options which require less processing (with lower transformation efficiency losses), such as coal or natural gas versus electricity or liquid fuels. The result is a potential decrease in primary energy demand that is greater than the decrease in final energy demand. The average increase in primary energy supply over the planning horizon is approximately 60% - or approximately 3% per year.

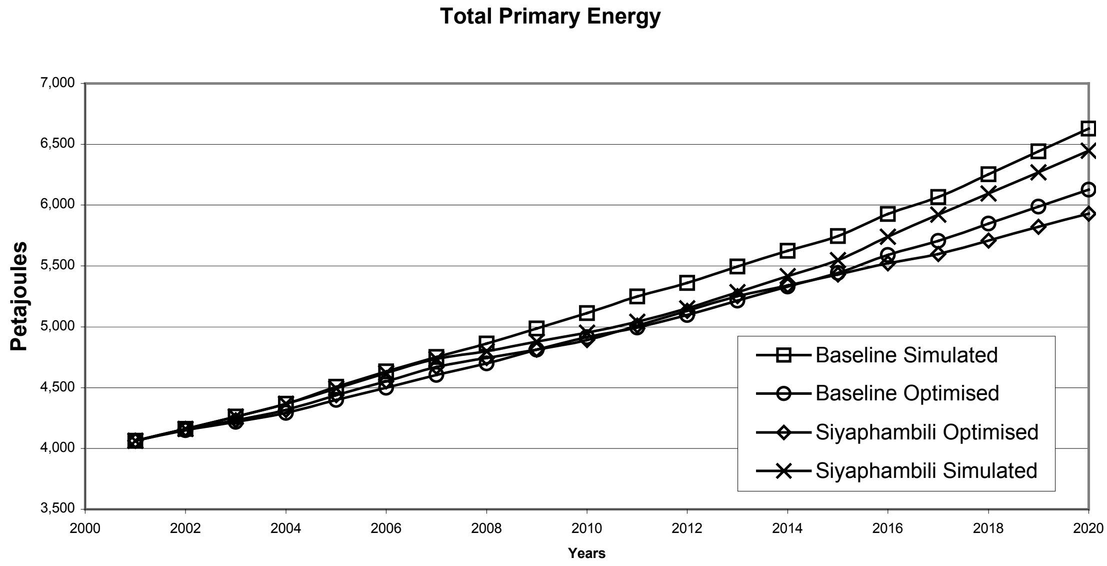

Figure 8: Primary energy supply projections under the scenarios – note that the Y axis starts at 3 500 PJ to emphasise the differences between each scenario (ERI, 2002).

The total energy supply differs because of different efficiencies of the technologies used in each scenario, for example when one uses natural gas as final energy (for thermal requirements) instead of electricity, then there is less need to transform a primary energy into electricity with its commensurate losses in energy.

5.4 Energy Costs

Projected energy costs can be gleaned from calculating the overall costs of energy supply and then addressing the factors that contribute to the variation in costs for each scenario. The total net discounted energy costs relative to the Baseline Simulated scenarios are projected in Figure 9. Positive costs mean costs greater than the Baseline Simulated scenario and negative costs means costs less than the Baseline Simulated scenario. Remember that the Baseline Simulated describes the "business-as-usual" scenario based on coal - it is the reference case for all scenarios.

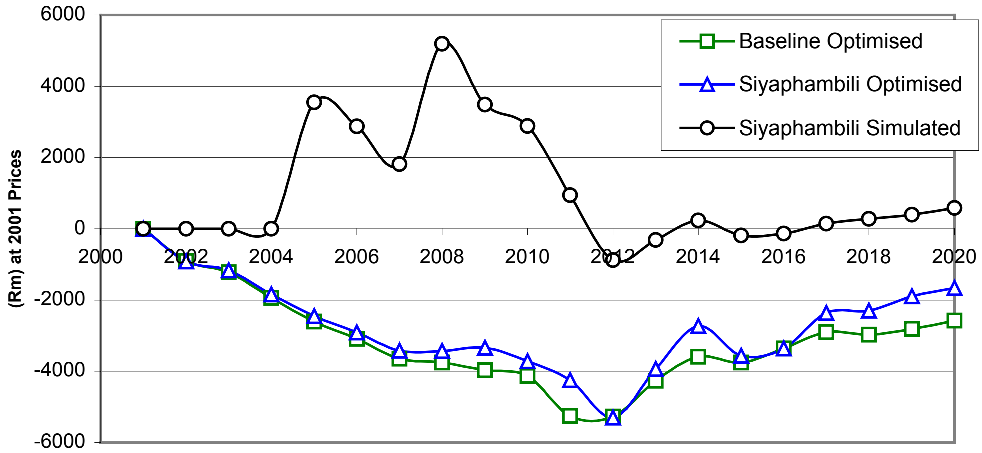

Figure 9: Total energy costs, discounted at 11%, for the three scenarios compared with Baseline Simulated (ERI, 2002).

The Siyaphambili Simulated plan is more expensive than the Baseline Simulated plan because expensive options (gas combined cycle plants, renewable energy, PBMR, imported electricity) are implemented early instead of coal.

The Siyaphambili Optimised plan is less expensive than the Baseline Simulated plan because the implementation of energy efficiency measures and fuel switching (oil to electricity and gas, and some electricity to gas) delays the onset of new plant (electricity generation and liquid fuel refineries). At the end of the projection period, the marginal costs of electricity increase because the plan can only invest in certain new plant (renewable energy, pebble bed modular reactor). The result is that at the end of this period there is a switch away from expensive[6] electricity to imported oil.

The Baseline Optimised plan is less expensive than the Baseline Simulated (and slightly less expensive than the Siyaphambili Optimised plan) because the implementation of energy efficiency measures and fuel switching (electricity and oil to coal) delays the onset of new plant (electricity generation and liquid fuel refineries).

Note that the three scenarios show a trend to become more expensive (when compared with the Baseline Simulated scenario towards of the planning horizon as more expensive energy supply options take effect.

As the modelling process optimises the "optimised" scenarios for least cost, it is to be expected that these two scenarios are the least expensive.

Another factor pertaining to energy costs is the manner in which plant is used. For example, the load factor for electricity generation – Figure 10. It is immediately obvious that as the load factor rises the levelised costs decrease markedly. Therefore, to minimise the levelised unit costs, it is apparent that electricity generation units/stations and refineries should be run at their maximum appropriate load factors consistent with appropriate margins for planned and unplanned outages.

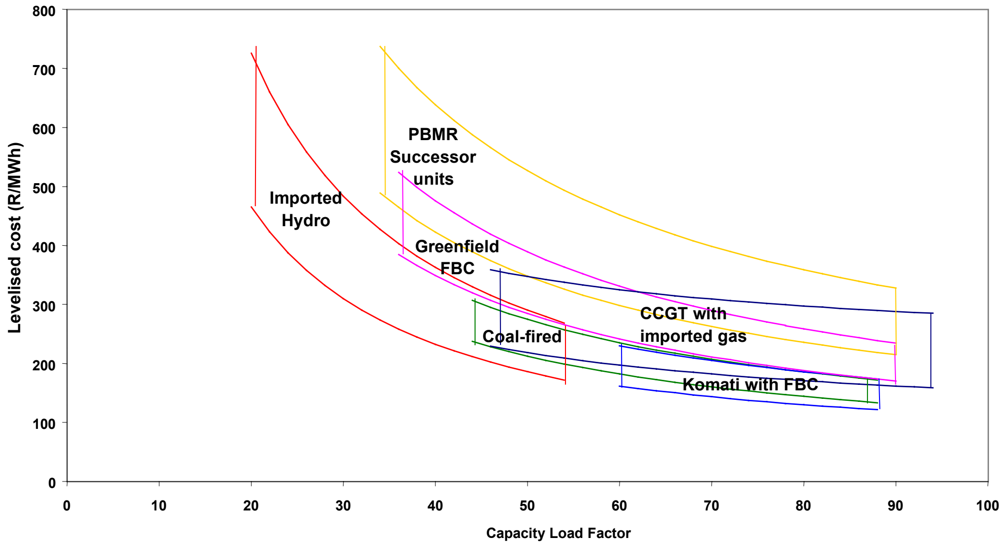

Figure 10: Lifetime levelised costs of new base load electricity generation supply-side options – from "An Integrated Electricity Outlook For South Africa" – Eskom/NER (2002)

Other calculations have confirmed that running plant at highest possible capacity load

[6] Under the Siyaphambili Optimised Scenario, cheap coal is not an option for electricity generation and the imported hydro is expensive and limited.

factors and “resting” spare capacity will lower overall electricity generation costs.

Figure 10 also indicates the levelised cost regimes for various electricity generation technologies, namely:

- ❖ Pebble bed modular reactor (PBMR) successor units
- ❖ Imported hydro
- ❖ Greenfield fluidised bed coal combustion (FBC)
- ❖ Combined cycle gas turbine (CCGT) with imported gas
- ❖ Current coal fired technology
- ❖ De-mothballed Komati electricity generation station with fluidised bed coal combustion (FBC)

Clearly the lowest cost option is the re-activation of mothballed plant.

With regard to liquid fuel production comparisons, the approach will be to use a levelised cost[7] methodology to enable different technologies, plant productions and lifetimes to be compared on an equal footing.

Based on this life-cycle costing approach with nominal return on investment (11% net discount rate), Figure 11 illustrates the calculated Rand per barrel of refined product as a function of plant production load factor for three averaged cases of new gas-to-liquid, new oil refinery and new coal-to liquid.

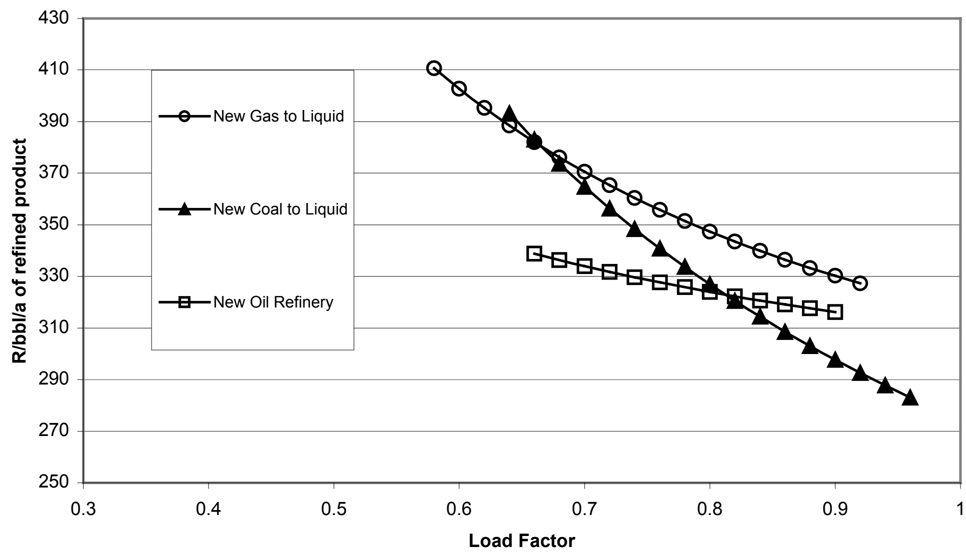

Figure 11: Costs of new liquid fuel production options based on the following assumptions: Brent crude $US 24.09 /barrel (5.8 GJ/barrel), sulphur content 10 ppm by year 2015, Gas at $2.5/GJ and coal at R6/GJ, levelised over a 25 year period lifetime (ERI).

The first point of note is that as may be expected the unit cost falls as the plants are producing nearer their maximum capacity. This is similar to electricity generation as discussed above. This is a clear illustration that it is inefficient and cost ineffective to

[7] Levelised cost where capital is levelised over the life of a plant taking the annual production (average annual production factor) into account. It is derived by dividing the total cost of building and operating the plant over its life by the net production output over the same time period taking into account inflation.

have too much spare capacity on a national basis. Due care should be given to permitting production capacity in line with national needs, with sufficient spare capacity for maintenance and planned expansion to meet demand.

Moreover, the calculations indicate that at high load factors, the unit cost of refined product for a new coal-to liquid plant is less than new oil refinery, which in turn is less than new gas-to-liquid plant. On the other hand, at low load factors, a new refinery plant has lower unit costs than both the coal-to-liquid and gas-to-liquid plants.

The reason for this counter-intuitive outcome is that if the plants are operated at high load factors, then, notwithstanding the higher capital and operational expenses of the synthetic fuel plants, the fuel feedstock costs for coal and gas are lower than that for oil – see below.

	New Oil Refinery R/bbl	New Coal to Liquid R/bbl	New Gas to Liquid R/bbl
Levelised Plant Capex	44.97	178.63	110.00
Total O&M Cost	18.29	61.12	103.90
Total Fuel Cost	251.84	43.83	116.95
Total Cost	315.10	283.58	330.85
Capacity Load Factor	*Full capacity: Refinery 92%, Coal to Liquid 96%, Gas to Liquid 93%*		

On the other hand, at low capacity load factors, the synthetic fuel plants have a higher levelised cost.

Given the increase in oil price, deterioration of the Rand/Dollar exchange rate and feedstock costs, coal-to-liquid would appear to be a more economic option than a new refinery on a levelised costs basis. This relationship could change when comparing costs on another basis.

5.5 Carbon Dioxide Emissions

The environmental component was addressed through carbon dioxide emissions – a critical factor pertaining to global climate change considerations and the implementation of the Kyoto Protocol. The total carbon dioxide emission reductions for the three scenarios relative to the Baseline Simulated are illustrated in Figure 12.

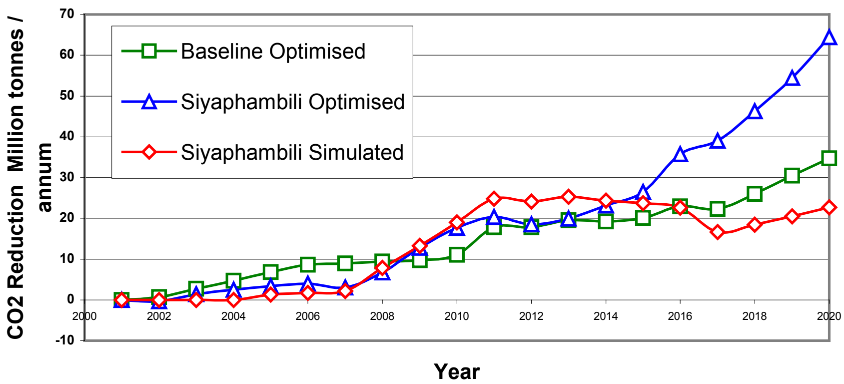

Figure 12: Carbon dioxide emission reductions, for the three scenarios compared with Baseline Simulated (ERI, 2002)

The reduction of carbon dioxide emissions generally increases over time for all three scenarios of Baseline Optimised, Siyaphambili Optimised and Siyaphambili Simulated when compared with the Baseline Simulated scenario. However, from approximately year 2015 onwards, the Siyaphambili Optimised scenario decreases its carbon dioxide emissions (increases savings) significantly more than the other scenarios because the use of coal (both for power generation and as an end use fuel) is retarded.

5.6 Energy Supply Reserves/Resources

The availability of sufficient energy reserves/resources is the other side to the energy planning equation. Without sufficient energy reserves/resources, supply side options to meet demand will be severely strained.

5.6.1 Energy Reserves/Resources

The four scenarios addressed require sufficient energy supply resources to implement. Table 9 addresses the availability of energy supply resources for the four scenarios.

Energy transformation usually requires water (eg coal to electricity – 1.8 litre per kWh). South Africa is classified as a “water stressed” country, therefore the conversion of coal/oil/gas energy may be limited by the provision of process water. This condition may however be resolved by using dry cooling systems even though they have inherently lower physical efficiency and higher cost.

Table 9: Energy Resources

Energy Carrier	Resource Availability
Coal	There are sufficient coal reserves/resources to supply all scenarios for the planning horizon and beyond.
Natural Gas	There is insufficient certified natural gas reserves in South Africa for the planning horizon for a major switch to gas. These gas reserves can be supplemented by natural gas reserves in neighbouring countries. Further exploration is necessary in the region to firm-up resource estimates. (See discussion below regarding the ratio of natural gas and coal reserves.)
Oil	Currently only approximately 5% of crude is supplied from indigenous reserves, the remainder is imported. Although there are some prospects of deep-water oil deposits off the west coast, these are yet to be confirmed. Hence, South Africa remains reliant on imported oil for the foreseeable future.
Hydro	There are limited unused hydro reserves in South Africa (approximately 300 MWe) with other opportunities for pumped storage. Imported hydro electricity still requires development.
Renewables	South Africa has large areas of untapped reserves of solar (especially in the central regions) and wind (mainly on the coast) energy.
Nuclear	There are sufficient uranium reserves in South Africa, but currently the material must be exported to be processed into usable fuel.

From the above, it may be concluded that the energy plan is not unreasonably constricted by the current availability of energy and water resources over the current planning horizon.

5.6.2 Coal/Natural Gas Ratio

The current euphoria (primarily on an environmental basis) regarding a potential shift to natural gas as a significant contributor to energy supply needs to be placed in the context of available local and regional gas reserves. The potential contribution that natural gas can make to the overall primary energy supply portfolio is currently limited as the energy content of natural gas reserves/resources is significantly lower than those of coal, even on an optimistic assessment of gas reserves. Table 10 indicates the energy content of current coal and gas reserves and potential coal and gas resources.

Table 10 indicates that the energy content of the known gas reserves is only 0.5% of known coal reserves. Even if the gas reserves were 20 tcf (and compared with coal reserves of 55 billion tonnes), then the gas reserves would amount to only 1.9% of coal reserves. On the other hand, the equivalent ratio for gas and coal resources is 0.9%.

Table 10: Gas/Coal reserves and resources ratio

	Reserves	Unit	Energy Content		Energy Content PJ
Coal Reserves	55	billion tonnes	22	MJ/kg	1,210,000
Coal Resources	115	billion tonnes	22	MJ/kg	2,530,000
Natural Gas Reserves	5	tcf	41	MJ/m3	5,802
Natural Gas Resources	20	tcf	41	MJ/m3	23,206

Coal: South Africa	**Gas reserves as a function of coal reserves**	**0.5%**
Gas: SA/Nam/Moz	**Gas resources as a function of coal resources**	**0.9%**

Hence, it is manifest that under these circumstances gas is unlikely to form any major component of primary energy supply over any extended period when compared with coal. There is however no reason why natural gas cannot take a momentary high profile in energy supply, especially if imported gas (including liquefied natural gas sources from outside southern Africa) is considered.

5.7 Discussion of Results

The investigations were aimed at sustainable energy options, the development of the economy, poverty alleviation, energy efficiency, environmental protection and renewable technologies.

In all scenarios, the most economic energy strategy for the next twenty years uses coal as the main primary energy source. Moreover, the use of coal and other forms of energy can be enhanced through the implementation of programmes for improved energy efficiency.

Diversifying transformation processes away from coal as primary fuel source will result in a more expensive option for the economy. However, if this strategy is tempered with economic implementation and more efficient use of energy, it will to some extent, offset the additional cost of diversification.

5.7.1 Energy Demand

The two simulated scenarios show a greater energy demand projection than the two optimised scenarios. The lower projected energy demand is because of energy efficiency measures including fuel switching (eg. end use burning fuel for thermal applications rather than first converting into electricity and then later using electricity to generate low grade heat).

Increased energy efficiency reduces energy demand significantly with a substantial decrease in cost to the energy system. In addition, strategies aimed at switching some thermal energy requirements from electricity to coal or gas would result in significant savings to the economy by deferring investment in expensive new electricity supply options, as well as being physically more energy efficient. It is more economic to switch from electricity to coal rather than gas if environmental externalities are not considered.

Implementing energy efficiency measures and fuel switching for end thermal use can result in the following savings:

- Implementing moderate energy efficiency and switching to coal in the Baseline scenario results in a decrease in cumulative energy demand of 2533 PJ by 2020 with a present value cumulative cost saving of approximately R62 billion over the 20 years. Further there is a cumulative reduction of 294 Mega tonnes of carbon dioxide emissions by 2020.
- Implementing moderate energy efficiency and fuel switching to gas in the Siyaphambili scenario results in a decrease in cumulative energy demand of 2981 PJ by 2020 with a present value cumulative cost saving of approximately

R75 billion over the 20 years. In this case there is a marginal increase of 131 Mega tonnes of carbon dioxide emissions by 2020 because more environmentally friendly generation technologies are deferred beyond the planning horizon.

Improvements in existing devices, new technologies and changes in energy usage patterns are likely to cause:

- Increased production of hybrid cars (regenerative braking, hydrogen, fuel cell technology, battery etc.)
- Increased usage of electricity for mass transit systems for public and freight transport

There is significant potential for the Black Economic Empowerment options, job creation and poverty alleviation through:

- Development of energy service companies
- Provision of low cost, cleaner energy to industry to attract investment and sustain energy intensive industries (e.g. gold mines)
- Reduction of household energy costs by supplying an optimal energy and appliance mix

5.7.2 Energy Transformation

Although in some circumstances electricity may be the energy carrier of preference because of its ease of use, it may not always be the most physically efficient energy source.

Implementing energy efficiency including switching devices from electricity to coal or gas (especially where thermal energy as an end use is required) will result in reduced demand for electricity. In the Baseline and Siyaphambili scenarios, moderate implementation of energy efficiency programmes and switching from electricity usage to coal and gas results in a cumulative reduction from current projections in demand for electricity of 141 PJ and 193 PJ respectively by 2020.

All scenarios show that electricity generation based on coal remains the most economic available to South Africa under current national environmental legislation. Alternative electricity generation technologies have been identified to diversify supply and environmental concerns. These are ranked approximately in increasing economic cost to the economy over coal-fired electricity generation plant (fitted with Flue Gas Desulphurisation):

- Importing Hydro electricity from plants located in neighbouring States such as Mozambique (inclusive of Transmission costs and taking account of losses);
- Options using coal with Fluidised Bed Boiler Technologies;
- Gas combined cycle technologies using natural gas, both local production and that imported from neighbouring states;
- New nuclear technologies such as the Pebble Bed Modular Reactor, pending feasibility analyses;
- Renewable technologies using wind and solar.

The current expanding gas industry is displacing inter alia electricity as a thermal end use. Such an arrangement is more physically efficient and cost effective (as manifest by the conversions from other forms of energy to gas). It may be argued that, considering the insignificant natural gas reserves when compared with coal (natural gas energy reserves are currently only at best 2% of those of coal), and that for thermal requirements it is more efficient to burn gas at the end user rather than first convert it into electricity then produce heat, the use of natural gas for electricity generation should be done sparingly. Moreover, switching from electricity to gas will alleviate the demand on electricity and defer the requirement for increased supply capacity.

With respect to liquid fuel production, with the recent increased refinery capacity and the levelising in demand over the past four years, there appears to be no immediate need for further refinery capacity nationwide. On the other hand, refinery capacity in the centre of the country produces less than the demand, and refined products need to be transported inland. In this case, limited pipeline capacity may be a confounding factor.

Major shifts in petrol/diesel consumption, for example the taxi re-capitalisation programme, may affect supply parameters. The taxi industry currently uses approximately 15% of petrol (approximately 10 000 million litres) consumption nationwide. Converting that to diesel would comprise about 25% of current diesel exports (~4 700 million litres per year). Therefore, the taxi recapitalisation programme could be accommodated by exporting less diesel and at the same time free-up 15% of current petrol consumption and delay the need for further refining capacity.

As addressed earlier, based on levelised costs, it may be more economic to produce liquid fuels from new coal-to-liquid plant than from new refineries using imported oil. Moreover, it is more economic to import finished liquid fuel products than to build any new refinery capacity. As new refinery capacity is not urgent at this stage, such options should be further investigated.

Nuclear Pebble Bed Modular Reactor and renewable energy supply options are not economic for grid electricity generation when compared with non-coal supply options such as imported hydro, gas (assuming price increase with South African PPI) combined cycle plants and fluidised bed technologies within the next twenty years. These technologies are not included for electricity generation in the Siyaphambili Optimised scenario.

Implementing plans for renewable energy supply by installing 300 MWe of wind electricity generation by 2010 increases the total present cost of the Siyaphambili plan by R1,038,000. However, there is a reduction of 7.86 million tons of carbon dioxide emissions over the 20 year period.

Bio-diesel production will have marginal effect on the plan, replacing at most 1% to 2% of diesel production by 2020.

5.7.3 Additional Considerations

The major shift from the business-as-usual scenario is the additional use of renewable energies and the promotion energy efficiency measures.

Renewable energy currently forms approximately 8% of South Africa’s primary energy supply, nearly all of that being non-commercial energy in the form of fire wood in the rural areas – that is not being renewed. South Africa is endowed with large resources of renewable energy potential that can be harnessed to contribute significantly to the national energy supply with minimal impacts on the environment. The cardinal conundrum regarding renewable energy is the introduction of initially expensive new energy technologies into a low priced energy environment. Energy efficiency measures are generally cost effective with pay-back periods of one to three years being acceptable depending on the circumstances. Similar to renewable energy, energy efficiency measures need to be kick-started.

The introduction of renewable energy technologies and energy efficiency measures is confounded by the managed liberalisation of the energy market and the multitude of private sector players expected to participate. In order to achieve a cross-sector goal, the government needs to regulate the sector accordingly.

6. INTEGRATED ENERGY PLAN

The integrated energy plan has been developed by channelling economic data through two scenarios based on assumptions and constraints determined by a group of specialists. Remembering that an integrated energy plan or strategy is not a precise blueprint for the energy sector but is a framework within which specific energy policy and development decisions can be made, and in recognising the need to balance the requirement of low cost energy with other imperatives such as social development, environment and security of supply, analysis of the results of the scenarios has lead to the following conclusions.

Coal Dominance: Notwithstanding the different scenarios, coal remains the dominant primary energy source over the planning horizon. In all circumstances where cost is the major driver, coal generally emerges as the least expensive option. The use of such coal energy presupposes the increased use of clean coal technologies. Moreover, coal remains the largest indigenous energy resource currently available.

Diversification: Notwithstanding coal's continued dominance, it is important to diversify energy resources to other energy forms such as natural gas and renewable energies to improve supply security, improve environmental performance and facilitate regional development. This diversification to other energy sources will have associated cost implications that must be traded off against other benefits on a project-by-project basis.

Energy Efficiency: Improved economic and environmental performance are brought about by sustained energy efficiency measures, including end use fuel switching. Energy efficiency measures are effective in both the "business as usual" scenario (that resulted in cost savings of up to R62 billion and carbon dioxide savings of up to 294 million tonnes) and the Siyaphambili scenario (that resulted in a decrease in cumulative energy demand of 2981 PJ with a present value cumulative cost saving of approximately R75 billion over the planning horizon).

Renewable Energies: Although the introduction of renewable energies has higher costs over the planning horizon, it is important to promote renewables for environmental reasons and for diversification of supply and to establish an infra-structure in South Africa that can develop to the extent where renewable energies can contribute significantly to energy supply on an economic basis. For grid connected electricity, it is important to bear in mind that wind and solar generation cannot produce electricity in response to demand. These technologies only produce when the source (wind or solar) is available. This increases the system costs, as extra storage is necessary if such is the only source of energy. Wind energy is at least 300% more expensive than new coal fired plant. So the large scale use of wind energy will be costly for the economy. However, there are renewable energy sources that are economic in the South African energy sector, such as biomass, especially in industry. South Africa's current target for renewable energy is 10 000 GWhr by the year 2012.

Nuclear: The technical and economic feasibility studies into the Pebble Bed Modular Reactor should be completed to determine if it could be a viable future source of electricity generation and the possible beneficial role that it could play in diversification of supply, replacement of fossil fuel as its use diminishes, contributing to the problem of global climate change by lowering carbon dioxide emissions and the possibility of establishing a nuclear export industry

Natural Gas: The diversification of energy supply by the increased use of natural gas has been shown to improve environmental performance, with the potential for regional development and security of supply. The increased use of gas will have associated cost implications that must be traded off against other benefits on a project-by-project basis. The end use of natural gas for thermal applications is physically the most efficient use of the energy contained in the gas. There may however be the need for large anchor customers, such as electricity generating stations, to catalyse the introduction of natural gas into a region. Moreover, when considering the quantity of current coal reserves and current an prospective gas reserves, natural gas in unlikely to become a serious competitor of primary energy supply over any extended period when compared with coal.

<u>Exploration:</u> Notwithstanding the dollar price base of oil, increasing the oil and gas reserve/resource base will increase security of supply and contribute to foreign exchange savings. Therefore the current oil and gas exploration measures should be expanded.

<u>Oil Refineries Expansion:</u> It is more cost effective to expand existing refinery capacity than to build green-fields plant, even taking into account the capital requirements for low sulphur fuels. The importation of refined product should be undertaken during the period when demand exceeds capacity until importation reaches levels where it becomes economically viable to expand the existing plant. Currently strain is put on the system due to a relatively high petrol to diesel ratio. (Petrol to diesel ratios close to one are more economic for refineries to produce.) The calculations show that this balance can be rectified with current trends in the transport sector for more diesel driven vehicles and the petrol to diesel taxi recapitalisation.

<u>Synthetic Liquid Fuels:</u> The outputs of the scenarios indicate that production of synthetic liquid fuels from gas appears uneconomic in comparison with a new oil refinery. On the other hand, it appears that at high load factors, synthetic fuels from coal could be economic when compared with new refinery capacity. These findings contradict findings in other investigations and the fact that globally investment in gas-to-liquids is taking place but not coal-to-liquids. The production of synthetic liquid fuels needs to be investigated further.

<u>Electricity Generation:</u> Coal based electricity generation remains the least cost option during the planning horizon. However, there is potential for hydro, natural gas and nuclear generation capacity that will have associated cost implications that must be traded off against other benefits on a project-by-project basis. The use of natural gas to generate electricity should be considered sparingly because of limited reserves and the higher efficiencies obtainable by burning gas directly at the point of application for thermal applications. Moreover, switching from electricity to gas will alleviate the demand on electricity and defer the requirement for increased supply capacity. However, a gas-fired power electricity generation station could provide a base-load for gas to be introduced into a region.

<u>Universal Access:</u> Although addressed only implicitly in the integrated energy planning process, the programme for universal access to affordable, clean and appropriate energy gives rise to a number of concerns – the most important being the conversion of non-commercial energy to commercial energy especially in the rural areas. Energy demand rises with increased energisation (especially electrification) in households. Such energisation programmes should be linked to the integrated development programmes both at provincial and local level. The synergy between regional/local development and energy supply would enable sustainable growth.

<u>Load Factors:</u> Calculations for both the electricity sector and the oil refining sector have indicated that running plant at highest possible load factors – and “resting” spare

capacity – will lower overall generation costs. Therefore, to minimise the levelised unit costs, it is apparent that electricity generation units/stations and oil refineries should be run at their maximum appropriate load factors consistent with appropriate margins. This factor also mitigates against the construction of too much spare capacity in these sectors and the need for suitable planning to match demand.

Reserves/Resources: There are sufficient energy and water resources currently available so that the integrated energy plan is not constricted over the current planning horizon.

Governance: It will be a major shift to increase significantly the use of renewable energies and to promote energy efficiency measures. Such goals require government intervention that in the first instance will be undertaken through the promulgation of a *White Paper on Renewable Energy and Clean Energy Development*, the introduction of an Energy Bill[8] and electricity regulatory amendments to be administered by the National Electricity Regulator.

7. COMPARISON WITH INTERNATIONAL ENERGY AGENCY PERSPECTIVES

It is pertinent at this stage to assess the above with the International Energy Agency's perspectives.

Notwithstanding the diversification of South Africa's energy supply from coal through the increased use of natural gas and renewable energies, and the increasing implementation of energy efficiency measures, the major source of primary energy remains coal over the next two decades. This of course presupposes the wider use of clean coal technologies.

The above is in concert with the International Energy Agency's forecast – Figure 13.

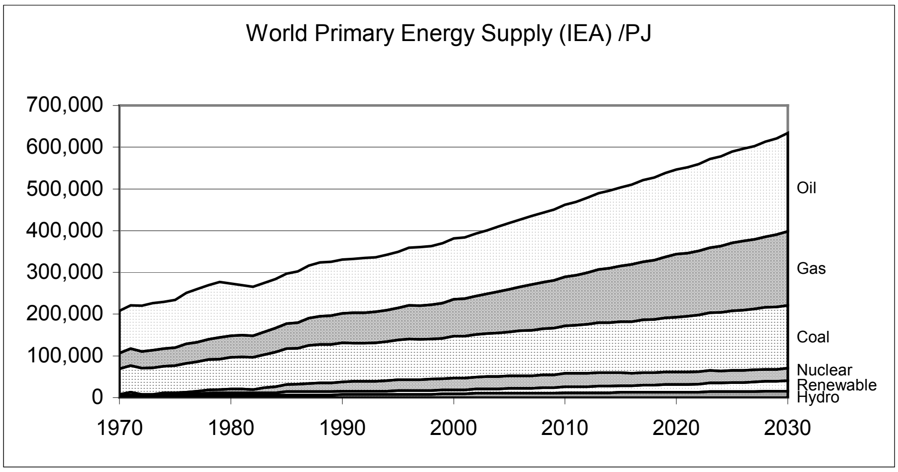

Figure 13:International Energy Agency's (IEA) forecasts for world primary energy supply

According to the World Energy Outlook 2002 the International Energy Agency has projected that fossil fuels will remain the primary source of energy, meeting more that 90% of the increase in energy demand by year 2030. However the demand for natural gas will rise more strongly than for any other fossil fuel – again this is in concert with the increasing part that natural gas will play in South Africa. The consumption of coal will also grow but at a slower pace than that of oil and gas. Whereas the World Energy

[8] (Energy Bill addresses a National Energy Advisory Committee, National Energy Data Base and Information System, Integrated Energy Planning, Renewable Energy, Energy Efficiency, Energy and safety Health and Environment, Energy Research)

Outlook states that the role of nuclear power will decline, because few nuclear reactors will be build and some will be retired, the outlook in South Africa for the Pebble Bed Modular Reactor is still contingent on the ongoing feasibility studies. In line with the World Energy Outlook, renewable energies will play an increasing role in energy supply.

The World Energy Outlook states that energy demand will rise fastest in developing countries (such as South Africa) and that transport uses will outstrip all other uses.

Increases in coal production are likely to be concentrated where extraction, processing and transportation are lowest - in South Africa, Australia, China, India, Indonesia, North America and Latin America.

8. IDENTIFIED GAPS

The present integrated energy planning is the first such process to be undertaken in South Africa and was primarily based on basic techno-economic modelling. Notwithstanding the legitimacy of the results as projections, the undertaking has, however, identified a number of gaps (that are being addressed for future endeavours) that include:

(a) <u>Governance:</u> The present process did not consider in any detail the legislative, regulatory and institutional aspects in the energy sector for the implementation of the recommendations. Where decisions are based on considerations other than only economic, and in a changing environment where previous monopolies are being replaced by a multitude of players, the government needs to intervene for example to facilitate the expansion of renewable energy and energy efficiency measures.

(b) <u>Stakeholder Participation:</u> The present process included inputs from the Department of Trade and Industry, Treasury, Department of Environmental Affairs and Tourism as well as other interested and affected parties through two workshops. Future endeavours should intensify the participation of relevant government departments as well as other stakeholders, especially when it comes to fixing assumptions such as growth rates etc.

(c) <u>Energy Data:</u> The modelling processes required large amounts of accurate energy and other (eg economic growth, exchange rates, population growth, sector inflations) data. Some data were not available (eg the provision of energy data is not currently mandatory) and some available data were inconsistent. Data quantities vary from source to source, and energy balances are not well disaggregated. The exception is electricity, which is well described by Eskom.

(d) <u>Models Programs:</u> During the current integrated energy planning process, the development of optimal calculation programs were traded off against the need to expedite results. This has been identified is a major gap in the current process. To advance the process, the calculation programs should be optimised to allow more ready facilities to change driver parameters and baseline data both up-front and over the planning period.

(e) <u>Environmental Externalities:</u> The present process did not explicitly include environmental externalities because of the uncertainty of current policy developments in this regard, reliable local data and uncertainty as to how such external costs would be constituted in a policy void.

(f) <u>Environmental Funding:</u> Environmental funding (especially international funding) was not included in the modelling because; policy regarding national environmental taxing/funding is not yet resolved and some uncertainties with international funding.

(g) <u>Industry Restructuring:</u> The effect of privatisation costs and security of supply was not addressed directly. The calculations were based on providing the most economic energy system for the country. This was assumed to be realisable, and did not take into account investment patterns of various sectors. This means that the calculated result might require policy instruments beyond simple deregulation.

(h) Other: For example the trade off between least cost energy production and other factors such as job creation and social development.

The gaps listed above are scheduled to be addressed in Phase II of the integrated energy planning programme.

9. FURTHERANCE OF INTEGRATED ENERGY PLANNING

The core of any planning process is the ability to accurately predict the principle drivers or parameters of any enterprise. It should also be borne in mind that the projections of the drivers become less tenable and consequently the outputs of the scenarios the less reliable the further in time one projects. Hence, integrated energy planning is a process that is updated periodically to address:

(a) changing market circumstances;
(b) re-appraised energy resources;
(c) changing global considerations;
(d) changing driver parameters (eg growth rates, exchange rates, discount rates);
(e) changing energy demand profiles; and
(f) cost benefit analyses of individual energy projects.

The cycle time of such a process is approximately eighteen months.

As an output of this first South African integrated energy plan, a number of gaps have been identified – Section 8 - that will be addressed in the second phase. Gaps that are currently undergoing deliberation include:

(a) Energy data gaps that are being addressed in the forthcoming reassessment of South Africa's energy data base and information system and the forthcoming Energy Bill.
(b) Re-appraisal of South Africa's coal reserves and resources.

The integrated energy plan provides a strategy framework with which certain trade-offs need to be made on a project-by-project basis. Notwithstanding program limitations, the current model with its extensive data base can provide a decision making support tool to assist in project-by-project trade-offs.

The current work has identified the significant potential for reducing the cost of an energy project while increasing it's health and environmental performance. The computer based model can now also be used to investigate specific policies and measures for energy efficiency, energisation, large scale energy investments and the potential of new technologies, such as energy efficient appliances. The model also does this in the context of the whole energy system, thus looking at the total effect of a measure, in terms of costs and environmental loading.

In furthering the integrated energy planning process, the current study will be appraised and inter alia the above gaps addressed.