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The Impact of Electricity Trade on the Environment in South Africa

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ABSTRACT

In the early 1990s, about two-thirds of South Africans were without electricity, relying on dirtier and less convenient fuel such as coal. As a result, urban air is severely degraded, with health guidelines for concentration of particulate materials being exceeded. Eskom dominates the electricity market of sub-Saharan Africa generates about 95% of South Africa's electricity. Electricity generation has been showing an upward trend in South Africa, with an increase of approximately 40% between 1990 and 2000. More than 85% of the coal produced in the country is used to generate electricity. Energy prices in the country do not reflect the impact of pollution and other externalities, and hence undermine investment decisions that could favour less polluting technologies.

The study will investigate factors determining the demand of energy in the electricity sub-sector and evaluate the main environmental issues associated with electricity production in the country. The research will also investigate possible long run shifts in production technology.

EXECUTIVE SUMMARY

Introduction

The issue of the relationship between trade, sustainable development and the environment has gained momentum over the last couple of decades, especially with the global climatic changes and massive environmental degradation that have been occurring over a long period of time. Energy environmental issues in South Africa, as in many parts of the world, have to do with atmospheric pollution caused by the burning of fossil fuels. As a signatory to the Kyoto protocol on climate change, South Africa is committed to the reduction of greenhouse gases.

Eskom, the state-owned energy utility of South Africa, began as the Electricity Supply Commission in 1923, and is now one of the largest utilities in the world. Eskom dominates the electricity market of sub-Saharan Africa, generating about two thirds of the electricity produced on the African continent.

What is the problem under investigation?

The production, transformation and use of energy generate substantial environmental impacts in South Africa. In the country, the coal fuel cycle is the dominant source of air pollution and overall waste generation. Coal mining, processing and conversion into power have various adverse effects on the environment, ranging from direct health hazards, to accidents, ecosystem disruptions, and air and water pollution. The burning of coal releases large quantities of sulphur dioxide, nitrogen oxide, particulates and carbon dioxide into the air, which damages the ozone layer.

With the advent of the Kyoto Protocol, the global trend has been a movement away from the burning of fossil fuels (coal, oil, gas) so as to reduce the emission of greenhouse gases and decrease global warming. The objective of the UNFCCC is to stabilise greenhouse gas concentrations to levels that would prevent dangerous anthropogenic (human induced) interference with the climate change system.

Coal is the main fuel produced and consumed in South Africa, with more than 85% of the coal produced being used to generate electricity. Coal is also used by other sectors including gold mining, the cement industry, the brick and tile industry, the metallurgical industry and for domestic use as a source of energy.

Concerns for the environment can however collide with goals for expanding economic activities in a country like South Africa. Carbon dioxide emissions are closely related to economic growth, industrialization and overall energy consumption. Until the last decade, the advanced countries were the largest contributors to the carbon dioxide emissions.

The study will therefore investigate factors determining the demand of energy in the electricity sub-sector and evaluate the main environmental issues associated with electricity production in the country. The research will also investigate possible long run shifts in production technology.

Electricity Trade

Up to two-thirds of the electricity generated in South Africa goes to parts of the continent. Exports are showing an increasing trend, reaching a peak in 1997, before dropping a little. They have been constant since. Imports started picking up in 1998 and are expected to continue in light of Southern African Power Pool (SAPP), which was established in 1995 with a view to cooperation in terms of electricity generation and distribution within the SADC region. Most of the exported electricity goes to Botswana, Lesotho, Mozambique, Namibia, Swaziland and Zimbabwe. South Africa has a long history of active trade in electricity with its neighbours.

The environmental impact of Eskom's electricity production and trade

South Africa ranked 14th out of 170 countries on a cumulative aggregate tonnage of CO_2 emissions for the period 1950-1995, and ranked 22 out of the same number of countries in terms of energy consumption per unit GDP. One of the reasons for such a high-energy intensity is the country's reliance on thermal power.

There was an annual increase in Green House Gas (GHG) emissions during 1993 to 2000. This can be attributed to an increase in the amount of coal burnt during the electricity production process. The high volume of water used during electricity production is attributed to the wet cooling system. Dry-cooled power stations use relatively less water than wet-cooled ones but emit more particulates.

Alternative Energy Sources

With the advent of the Kyoto Protocol, South Africa is under pressure to consider other forms of energy, besides thermal coal-fired energy, which are less harmful to the environment. The South African Bulk Renewable Energy Generation (SABRE-Gen) research programme was initiated in 1998 by Eskom with a view to evaluating the feasibility of multi-MW, grid connected generation systems and to determine whether they could provide viable solutions to South Africa's future electricity needs. The long term energy demand in South Africa is driven by rapid urbanisation and the growth of energy intensive industries. Coupled with growing export demands, this places pressure on South Africa to seek more environmentally friendly sources of energy. SABRE-Gen, is focused on the adoption of multi-megawatt renewable-energy generating technologies. There are many forms of renewable energy sources, namely solar energy, wind energy, wave energy, tidal energy, biomass, geothermal energy and hydro power. However the most likely sources of economical, efficient and safe energy at present are solar, nuclear, micro-hydro and wind.

The Research Programme

The implications of energy trade and sectoral transformation on the environment is largely unexplored territory in South Africa. This research aims to investigate the forces driving pollution emissions in the country and assess the implication of shifting from thermal electricity generation source to another, in particular, the nuclear energy option. This will enable us to determine the implications for policy formulation and implementation. The following are some of the models to be developed in this study:

1. The first model will relate variations in per capita emissions of different pollutants to key indicators of the weight of different energy types in the country's energy systems. In the process, we will determine whether nuclear power has a role to play in reducing pollutants emissions in the country.
2. The second will be a model of emissions linking four key variables as instruments to achieving reductions in greenhouse gas emissions.

The study will analyse the driving factors of energy-related carbon and other emission patterns using the "Kaya Identity" decomposition format.

1. INTRODUCTION

The issue of the relationship between trade, sustainable development and the environment has gained momentum over the last couple of decades, especially with the global climatic changes and massive environmental degradation that have been occurring over a long period of time. This has led to the polarisation of relations between North and South, government and civil society, trade and environment (Law & McDaid: 2001). In December 1997, more than 160 nations met in Kyoto, Japan, to bind themselves to limit the emissions of greenhouse gases for the developed nations, pursuant to the objectives of the United Nations Framework Convention on Climate Change (UNFCCC) of 1992. The result of the meeting was the Kyoto Protocol, in which the developed nations agreed to limit their greenhouse gas emissions, relative to the levels emitted in 1990. Energy environmental issues in South Africa, as in the rest of the world, have to do with atmospheric pollution caused by the burning of fossil fuels. As a signatory to the Kyoto protocol on climate change, South Africa is committed to the reduction of greenhouse gases.

2. INDUSTRY BACKGROUND

Eskom, the state-owned energy utility of South Africa, began as the Electricity Supply Commission in 1923, and is now one of the largest utilities in the world. Eskom dominates the electricity market of sub-Saharan Africa, generating about two thirds of the electricity produced on the African continent, even though South Africa accounts for just 4% of the continent's land mass and 8% of the population. It generates about 95% of South Africa's electricity, with private generators and municipalities producing the remainder between them.

With a production cost of 2 cents per kilowatt-hour, Eskom is one of the lowest-cost producers of electricity in the world. The company operates 20 power stations with a generating capacity of 35,200 MW. Nominal generating capacity for the company is 39,154 MWe, with generating capacity of 4,201 MWe currently mothballed (USDOE:2002). In 1998 Eskom generated about 192.0 billion kilowatt hours of electricity, of which 176.8 bkwh was thermal, 13.6 nuclear and 1.6 hydroelectric. Electricity generation has been showing an upward trend in South Africa, with an increase of approximately 40% between 1990 and 2000.

Table 1: Electricity Generation and Consumption in South Africa, 1990-2000
(in billion kWhr)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Net Generation	247.6	256.2	247.3	258.4	272.3	288.4	297.1	324.6	322.0	320.2	326.1
Hydroelectric	1.0	2.0	0.8	0.1	1.1	0.5	1.3	2.1	1.6	0.7	1.3
Nuclear	8.4	9.1	9.3	7.3	9.7	11.3	11.8	12.6	13.6	12.8	13.0
geo/solar/wind/biomas	n/a	n/a	n/a	N/a	N/a	n/a	N/a	n/a	n/a	n/a	n/a
Conventional Thermal	146.6	147.8	147.1	155.9	160.0	164.2	173.9	181.1	176.5	173.3	180.0
Net Consumption	143.8	146.1	144.6	149.4	156.2	160.9	168.3	175.6	175.8	176.0	181.5
Imports	0.3	0.3	0.3	0.1	0.1	0.1	0.0	0.0	2.6	6.7	5.3
Exports	1.6	1.9	1.8	2.6	2.6	3.0	5.6	6.6	5.1	4.5	4.5

Source: DOE/EIA

n/a - not applicable ; generation components may not add to total due to rounding.

Among Eskom's domestic customers are commercial farmers, a large number of residential consumers, local municipal authorities who distribute to consumers within their boundaries, manufacturing and mining industries. Manufacturing is the largest consumer of electricity in South Africa, accounting for 44% of consumption. Mining and residential customers each account for 18% of demand, with another 9% going to commercial customers. Residential consumption is experiencing the fastest growth due to the country's success with rural electrification. Having more residential consumers connected to the grid has in turn heightened demand during peak periods and has had the biggest effect on the shape of the country's load profile.

In the early 1990s, about two-thirds of South Africans were without electricity. The situation varied significantly from region to region; whereas about 80% of households in the Gauteng Province had access to electricity, under 20% of households in parts of Kwazulu Natal were connected. Van Horen, Eberhard, Trollip and Thorne (1993) attribute the variation in electrification to the politics of the country. They suggest that the high level of inequality which characterises the South African political economy is reflected in the country's patterns of energy use and consequent environmental impacts. In spite of the significant overcapacity of the national electricity grid, two-thirds of households do not have access to electricity, and rely on dirtier and less convenient fuel such as coal. As a result, urban air is severely degraded, with health guidelines for concentration of particulate materials being exceeded. Adverse effects on resident's health have been observed. On the whole, the impacts of national electrification initiatives are likely to be positive, although a complete switch to electricity may not occur immediately.

It is the policy of the government to extend the benefit of electrification as rapidly as possible. The aim was to electrify some 2.45 million households in the country between 1994 and 2000, raising the rate of electrification from 36% to 72%. In order to meet this objective, an annual connection rate of 450,000 homes through 1999 was required. The rate of connections was expected to decline after the year 2000 such that by the year 2012, about 79% connection was expected to be achieved.

Table 2: Eskom's electrification plans

Year	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
New connections(000)		254	300	300	300	300	300
270							
Operating cost(Rm)	260	308	375	430	479	495	523
Operating cost/ customer/month(R)	28	23	21	20	19	17	16
Capital(Rm)	885	1008	945	828	719	690	621
Capital cost/connection(R)	3484	3360	3151	2761	2396	2300	2300
Sales/customer/month(kWh)	80	81	89	96	104	111	114

Source IEA (1996)

Estimates of the total cost of the electrification programme ranges from R12 billion to R14 billion. It is expected that most of this will be provided by the industry assuming a limited degree of cross-subsidization. The substantial subsidies which exist in South Africa not only drain the economy but also negatively affect the environment. The impact of which will be the focus of the study.

By ensuring that energy prices fail to reflect the impact of pollution and other externalities, they undermine investment decisions that could favour less polluting technologies.

3. THE ENERGY SECTOR AND THE ENVIRONMENT IN SOUTH AFRICA

The production, transformation and use of energy generate substantial environmental impacts in South Africa. In the country, the coal fuel cycle is the dominant source of air pollution and overall waste generation. Liquid fuels in the transport sector are the second major source of air pollution whereas in the rural areas the major pollution related problem among households is related to indoor pollution resulting from the inefficient burning of low quality fuels, mainly wood and coal which affect health and visibility adversely.

Coal mining, processing and conversion into power have various adverse effects on the environment, ranging from direct health hazards, to accidents, ecosystem disruptions, and air and water pollution (TIPS: 1999). The burning of coal releases large quantities of sulphur dioxide, nitrogen oxide, particulates and carbon dioxide into the air which damages the ozone layer.

With the advent of the Kyoto Protocol, the global trend has been a movement away from the burning of fossil fuels (coal, oil, gas) so as to reduce the emission of greenhouse gases and decrease global warming. The objective of the UNFCCC is to stabilise greenhouse gas concentrations to levels that would prevent dangerous anthropogenic (human induced) interference with the climate change system. South Africa is classified as a non-annex 1 signatory to the Convention, that is, as a developing country it is not subject to the same commitments as developed countries. One of the main obligations placed on developed countries, such as the USA, EU 15, Australia, and Canada, is to reduce their greenhouse gases (GHGs) to an average level of 5% below the 1990 levels by 2012. The first three greenhouse gases are carbon dioxide (CO2), Methane (CH4) and Nitrous Oxide (N2O) (USDOE: 2002).

Table 3 Fossil Fuel-related Carbon Dioxide Emissions in South Africa, 1990-2000 (in millions of metric tons of carbon)

Component	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CO_2 – Coal	93.85	69.67	69.75	71.36	71.19	78.19	73.48	89.74	94.23	85.62	86.12
CO_2 – Natural gas	0.00	0.00	0.02	0.96	1.04	1.04	0.98	0.96	0.85	0.82	0.82
$C0_2$ – Petroleum	14.93	15.96	16.43	16.11	16.25	16.52	16.85	16.39	17.46	18.34	18.91
Total CO_2 Fossil fuels	108.79	85.63	86.20	88.43	88.48	95.75	91.31	107.09	112.54	104.79	105.85

Source: DOE/EIA
note: components may not add to total due to rounding

Table 3 above shows that burning coal releases the highest amount of carbon dioxide relative to other fossil fuels. Although there was a decrease in coal-related carbon dioxide emissions between 1991 and 1997 before peaking in 1998 and dropping again in 1999 and 2000, the levels are still relatively high in international terms.

Table 4: Coal Production and Consumption in South Africa, 1990-2000 (in millions of short tons)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Production	247.58	256.20	247.28	258.41	272.30	288.39	297.12	324.56	322.00	320.15	326.08
Anthracite	6.05	4.90	6.08	5.72	4.45	3.60	3.92	4.41	2.90	2.72	3.41
Bituminous	241.53	251.29	241.20	252.69	267.85	284.79	293.20	320.14	319.10	317.44	322.67
Lignite	n/a	N/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Consumption	193.48	153.13	151.79	156.23	158.09	172.83	165.71	178.13	186.99	174.62	176.30

Source: DOE/EIA
n/a - not applicable

South Africa is regarded as a comparatively energy and carbon intensive country in relation to other African countries as well as relative to many developed countries. Of the total energy consumption in 1998, 78% was from coal. This shows a high reliance on a highly carbon-intensive fossil fuel with negative impacts on the environment (EIA: 2001). Table 4 shows the total amount of coal produced and consumed in South Africa between 1990 and 2000. As shown in the table, coal is the main fuel produced and consumed in South Africa, with more than 85% of the coal produced being used to generate electricity. Coal is also used by other sectors including gold mining, the cement industry, the brick and tile industry, the metallurgical industry and for domestic use as a source of energy.

South African coal is in demand, making the country the second largest coal exporter in the world after Australia and the second lowest-cost producer behind Indonesia. Up to 60% of the coal exported goes to the European export market. Countries along the Pacific Rim buy the remainder (USDOE: 2002). The coal industry generated sales in 1998 of US$3 billion, contributing 16.5% of South Africa's mineral exports and 4.3% of the GDP. This makes coal the country's second largest foreign exchange earner after gold. As shown in Table 4, Bituminous coal production is higher than the other types and remains South Africa's main export coal, with anthracite having to be imported, due to diminishing reserves. The latter type of coal has a low ash content which makes it attractive in terms of the environment.

While South Africa has considerably reduced particulates emission from power plants over the past decades, the country's sulphur dioxide and nitrogen oxide levels are considerably higher than those of any other country in the African continent. South Africa produces one-third of Africa's total energy-related carbon dioxide emissions though the country produces less than 1.5% of the global total. As a simple function of increased energy use alone, pollution levels may grow rapidly over the next few decades despite improving efficiency and enhanced production techniques.

Concerns for the environment can however collide with goals for expanding economic activities in a country like South Africa. Carbon dioxide emissions are closely related to economic growth, industrialization and overall energy consumption. Until the last decade, the advanced countries were the largest contributors to the carbon dioxide emissions. In due recognition of this, policies and instruments for reducing carbon dioxide emissions were instituted in several advanced industrialised countries resulting in their share of carbon dioxide emissions declining. Since 1991, the developing countries have been responsible for more than 50% of the world's carbon dioxide emissions. This share is expected to increase with greater industrialisation and increased energy use per capita that accompanies the process.

The ability of developing countries, like South Africa, to respond to concerns about climate change are complicated by the fact that a greater majority of South Africans need to increase their living standards and this may depend on increased energy use per capita and this may depend on increased reliance on fossil and other solid fuel like woods which have large carbon dioxide emissions.

In order to implement policies that can benefit both development and the environment, it is important to understand the various subcomponents of the process causing the increase in carbon dioxide emissions as well as the trends in fuel mix due to the positive correlation between energy use and living standards.

4. ELECTRCITY TRADE

Up to two-thirds of the electricity generated in South Africa goes to parts of the continent. Exports are showing an increasing trend, reaching a peak in 1997, before dropping a little. They have been constant since. Imports started picking up in 1998 and are expected to continue in light of Southern African Power Pool (SAPP), which was established in 1995 with a view to cooperation in terms of electricity generation and distribution within the SADC region. Most of the exported electricity goes to Botswana, Lesotho, Mozambique, Namibia, Swaziland and Zimbabwe. South Africa has a long history of active trade in electricity with its neighbours. In 1999, Eskom exported 1 564 GWh to Lesotho, I 564 GWh to Zimbabwe, 934 GWh to Botswana, 562 GWh Namibia and 68 GWh to Mozambique. Electricity export sales from South Africa increased by more than 100% between 1990 and 2000 (EIA: 2001).

5. ALTERNATIVE ENERGY SOURCES

With the advent of the Kyoto Protocol, South Africa is under pressure to consider other forms of energy, besides thermal coal-fired energy, which are less harmful to the environment. The South African Bulk Renewable Energy Generation (SABRE-Gen) research programme was initiated in 1998 by Eskom with a view to evaluating the feasibility of multi-MW, grid connected generation systems and to determine whether they could provide viable solutions to South Africa's future electricity needs. The long term energy demand in South Africa is driven by rapid urbanisation and the growth of energy intensive industries. Coupled with growing export demands, this places pressure on South Africa to seek more environmentally friendly sources of energy. SABRE-Gen, is focused on the adoption of multi-megawatt renewable-energy generating technologies (Gordon: 2002). There are many forms of renewable energy sources, namely solar energy, wind energy, wave energy, tidal energy, biomass, geothermal energy and hydro power. However the most likely sources of economical, efficient and safe energy at present are solar, nuclear, micro-hydro and wind.

5.1 Nuclear

South Africa is presently the only country in Africa that has a commercial nuclear power plant. The Koeberg Nuclear Power Plant, operated by Eskom, is located near Cape Town and was commissioned in 1984. Koeberg accounts for about 7% of South Africa's electricity generation. The plant utilizes pressurized-water reactor (PWR) technology and has a licensed generating capacity of 1,840 MWe. The National Nuclear Regulator is the government agency responsible for overseeing South Africa's nuclear industry. The primary objective of the agency is worker and public safety, and its control extends over installation safety, fuel, radioactive waste, and the mining and processing of uranium.

Eskom is in the process of developing and testing a nuclear reactor for distributed applications. The pebble-bed modular reactor (PBMR) is a relatively small (110 MWe) nuclear power station, utilising helium coolant, a graphite moderator, and ceramic fuel pellets, which allow the reactor to operate at higher temperatures, thereby increasing its efficiency. The PBMR theoretically also creates less spent fuel than PWRs like Koeberg. There have been estimates that the technology could result in a US$3 billion industry. A half-scale model of Eskom's PBMR is operating at the Kurchatov Institute in Moscow.

Law & McDaid (2001) look at the role of the proposed Pebble-Bed Modular Reactor (PBMR) in the sustainable development of South Africa. They contend that since there is not enough demand for PBMRs in South Africa, the key variable in the equation is the export market. Eskom's long term demand projections are banking on a switch to nuclear power as a way of moving away from fossil fuel-dependent energy. However there are arguments that substituting nuclear for thermal is as good as substituting one environmental problem with another. There is strong opposition from environmental lobbies in South Africa to the development of another nuclear plant. Critics are also questioning both the practicality and overall expense of the PBMR project (since South Africa currently has excess generating capacity), and that there is no market for the reactors given South Africa's rich reserves of coal, abundant wind and solar resources, and recent discoveries of offshore natural gas deposits.

Among the benefits of nuclear energy, Robinson (nd) lists the following:

1) it is environmentally friendly- does not produce greenhouse gases like coal, oil and natural gas
2) it is cheap – this owes to large supplies of uranium and the stability of nuclear energy prices. Oil prices fluctuate all the time
3) it is safe – few deaths have been directly linked to nuclear energy use – as compared to deaths from coal mining and oil well exploration.
4) Nuclear waste products are sealed and confined for permanent storage or until reprocessing – waste particles from fossil fuels are released directly into the atmosphere
5) The volume of waste from nuclear energy is relatively small compared to fossil fuels.

Stoppard (2000) on the other hand argues against the use of nuclear technology with specific reference to the South African context for the following reasons:

1) It produces a lot of dangerous radioactive waste. This is supported by Law and McDaid (2001) who contend that nuclear energy generates up to 4 to 5 times more greenhouse gas than renewable technologies over its full life cycle
2) over and above radio active waste, nuclear stations also release low, intermediate and high-level solid and liquid waste.
3) the capital outlay required for a nuclear power plant can run into billions of rands, making the initial investment much higher for a nuclear power plant than for any other kind of power plant
4) the projected job creation and foreign currency earnings are speculative and cannot be guaranteed
5) nuclear plants in developing counties are seen as 'white elephants'.
   the projects usually span long periods of time before operations can start

5.2 Hydroelectric Power

South Africa has a great potential for renewable energy with 10% of its current primary energy supply considered to be renewable. The South African government fully supports efforts aimed at developing renewable energy technologies both on a small and large–scale application. The Orange river that flows westward into the Atlantic ocean and the Limpopo river flowing eastward into the Indian ocean form the two major river systems in South Africa. There are many other small rivers and tributaries which allow the construction of dams for water conservation. This makes possible the application of micro-hydro systems. There is an estimated 6000 to 8000 potential sites for small hydro projects with a capacity of about 100Mwe, most of them located in KwaZulu Natal and the Eastern Cape. The largest hydroelectric power plant in South Africa is the Drakensberg Pumped-Storage Facility, which is part of a larger scheme of water management bringing water into the Vaal watershed from the Tugela River. It is a 1,000 Mwe facility. The second-largest pumped-storage hydroelectric power plant is located on the Palmiet River not far from Cape Town.

5.3 Solar Energy

Eskom has proposed the launch of a solar dish engine system. The solar dish-engine systems are said to convert sunlight into electricity at higher efficiencies than any other solar technology (Gordon: 2002). Solar energy is considered ideal because it is cheap and environmentally friendly. Most areas in South Africa receive an average of more than 2,500 hours of sunshine per year. Solar radiation levels range between 4.5 and 6.5 kilowatthours (kWh) per square meter, on average, every day. A solar equipment industry is taking off with a number of companies involved in manufacturing solar water-heaters. The solar part of the SABRE-Gen program, the SABRE-Gen Solar Thermal Project, is evaluating the potential for using solar for electricity generation, for both grid-connected and off-grid applications. South Africa has the potential to produce the lowest cost solar electricity in the world. In November 1998, Shell Solar South Africa and Eskom began a multi-million dollar project to supply solar energy to 50,000 low cost housing units. These two companies will provide the infrastructure, while the communities will establish various ventures for supply and maintenance. As of the end of 2000, the joint venture has installed 6,000 solar home systems, bringing electricity to an estimated 30,000 people in the area. To make the systems affordable for residents, the joint venture is charging customers $10 a month rather than billing customers for the cost and installation of the units.

5.4 Wind Energy

The first experimental wind-energy farm is under construction at Klipheuwel in the Western Cape. Wind energy has grown enormously worldwide and can be a competitive source if the wind cost premium is reduced. Generating electricity from wind requires the same principle as used in windmills, except the use of a generator. The advantages of using wind energy are that it is cheaper than other forms, it is safe, saves energy and coexists peacefully with wild life and other natural resources. South Africa does not yet commercially generate electricity from wind power. The government is currently looking into wind farms as a means of addressing peak loads on the national electricity grid. Current uses of wind power include about 300,000 wind pumps for livestock and community water use.

5.5 Biomass

The main non-hydro renewable energy source in South Africa is biomass. One-third of the population depends on firewood for their household heating and cooking needs. Firewood collected from forests as well as waste from sugar and lumber processing are the main supplies. There are five relatively small power stations in South Africa that use process waste (bagasse) mixed with coal as fuel. These are all cogeneration facilities located at the sugar mills, and produce steam and electricity for captive use by those sugar mills; they produce about 0.2% of the electricity consumed in South Africa.

6. ESKOM'S ENVIRONMENTAL POLICY

The White Paper on Energy Policy for South Africa, points out that South Africa is blessed with an abundance of natural resources such as coal and that it will continue to use coal in the long term, whilst exploring diverse energy options. The commitments placed on the developed countries in terms of the Kyoto Protocol have a direct impact on the South African economy in terms of the coal export market, and thus an effect on the job market dependant on the coal industry. Developing countries are more vulnerable to climate change because of limited infrastructure measures. Typical impacts for South Africa of burning fossil fuels include:

- • " The migration of diseases that thrive in warmer climates, such as malaria and yellow fever with the expansion of mosquitoes and other disease-carrying organisms

- • Erosion of beaches and coastal wetlands, and increased vulnerability of coastal areas to flooding from storm surges and intense rainfall due to rising sea levels

- • Intensification of the water cycle will produce more severe drought in some places and floods in others. Africa's ability to adapt to climate change impacts, like flooding, is severely limited by its poor infrastructure, such as dam walls. In addition, severe drought will have a knock-on effect on industries and other activities largely dependent on water

- • A warmer climate would reduce flexibility in crop distribution and increase irrigation demands. Agricultural systems in the developed countries are highly adaptable and can probably cope without dramatic reductions in yield. It is the poorest countries in Africa, already subject to hunger, that are the most likely to suffer significant decreases in agricultural productivity " (Eskom: 1999).

7. THE ENVIRONMENTAL IMPACT OF ESKOM'S ELECTRICITY PRODUCTION AND TRADE

South Africa participated in and ratified the United Nations Framework Convention on Climate Change (UNFCCC) in 1998 wherein government delegates, NGOs, businesses and civil society bound themselves to reducing and stabilising greenhouse gas (GHG) emissions below levels that would prevent dangerous human-induced climate change. Eskom identified focus areas for immediate attention including: the development of a climate change policy; the evaluation of potential Clean Development Mechanism (CDM) projects and the adoption of an integrated electricity planning, among other things. Many studies in the literature find that dangerous gas emissions cause changes in temperature and precipitation with serious consequences for ecosystem functions and huge losses of terrestrial and marine biodiversity.

Aridification will cause a shrinkage of those regions well suited for the country's biomes to almost half their current size. Infrastructure damage is also likely to occur owing to sea-level rise and the increased threat of storms. Increased hydrology is a breeding ground for malaria and other water-borne diseases. These effects will feed into the tourism sector which may be affected by climate change due to a loss of habitats and biodiversity, and due to changes in temperature, humidity and malaria risk. The burden of an increased incidence of diseases on state healthcare expenditure will be enormous. Consequently, productivity and therefore economic growth are likely to decline.

South Africa ranked 14^{th} out of 170 countries on a cumulative aggregate tonnage of CO_2 emissions for the period 1950-1995, and ranked 22 out of the same number of countries in terms of energy consumption per unit GDP. One of the reasons for such a high-energy intensity is the country's reliance on thermal power. It can be argued that in the presence of international multilateral agreements such as the Kyoto Protocol, potential barriers to trade and restricted access to markets via the application of environmental standards as well as civil resistance to products on environmental grounds, industries could be motivated to use cleaner electricity, and Eskom might be compelled to adopt technologies for cleaner energy.

Table 5 indicates major emissions and consumables used in the production of 1kilowatt-hour of electricity. This is an equivalent of using a 100 watt light bulb for ten hours or ten 100 watt light bulbs for one hour. The table shows a slight decrease in the amount of elements used or emitted in the production of 1KW hour of electricity from 1999 to 2000 except for Nitrogen dioxide.

Table 5: Environmental Implications of Using 1 KW Hour of Electricity

Element	1999	2000
Water usage	1.25litres	1.21itres
Coal usage	0.5kg	0.49kg
Ash produced	1.34g	130g
Ash emitted	0.37g	0.35g
SO2 Emissions	8.0g	7.95g
NO2 Emissions	3.0g	3.56g
CO2 Emissions	0.96kg	0.85kg

Source: Adapted from Eskom Environmental Reports 1999 & 2000

Table 6 shows an increase in GHG emissions from 1993 to 2000. This can be attributed to an increase in the amount of coal burnt during the electricity production process. The high volume of water used during electricity production is attributed to the wet cooling system. Dry-cooled power stations use relatively less water than wet-cooled ones but emit more particulates.

In 1998, Eskom's coal-fired power stations consumed a total of 228 759 mega-litres of water from government water schemes to produce 189 307 Gigawatt-hours of electricity, compared with 223 650 mega-litres of water that was used to produce 154 260 Gigawatt-hours of electricity in 1993. The mining of coal impacts negatively on the environment, through the leaching of chemical substances from coal dumps which might contaminate water (Eskom: 1998). Water pollution also comes from oil spills and ash spills. For instance, in 1998 Eskom had eight water-related contraventions of legislation. There were four ash spills, two oil spills from substations and two underground cable oil spills (Eskom: 1998).

Eskom operates an air quality management system with a network of 43 particulate emissions monitors. The ability to keep track of particulate emissions on a continuous contributed to a 46% reduction in particulate emissions from 1993 to 2000.

Table 6: Other environmental aspects of Eskom's activities

Operations	**Unit**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Electricity produced by stations	Giga w-hours net	154260	160293	164834	178855	187811	183093	181818	189307
Total electricity sold	Giga w-hours	143800	149443	153547	165370	172550	171454	173422	178192
Coal burnt in power stations	Million tons	75.9	76.9	79.4	85.4	90.2	87.2	88.5	92.3
Water consumed by power stations	Million litres	223650	213220	214329	215199	224754	224457	226387	228759
Emissions from Coal Fired Power Stations									
Nitrous Oxide N20	Tons	N/a	N/a	1864	2004	2085	2031	2010	2093
Carbon dioxide CO2	Million tons	141.0	143.0	147.0	159.0	169.0	163.0	159.4	161.2
Sulphur dioxide SO2	Thous tons	1134	1167	1198	1295	1382	1583	1506	1505
Nitrogen oxide NO2	Thous tons	582	582	603	647	688	669	673	674
Particulate Emissions	Thous tons	122.2	122.0	115.3	112.1	83.43	65.21	67.08	66.08
Ash at Coal Fired Power Stations									
Ash produced	Million tons	20.9	22.1	23.0	22.2	23.7	24.7	24.3	24.6
Ash sales	Million tons	N/a	0.818	0.943	0.995	1.117	1.175	1.114	1.126
Koeberg Nuclear Power Station									
Radiation release (target less than 0,0025 mSv)	Millisieverts	0.0297	0.0005	0.0004	0.0006	0.0006	0.0006	0.0006	0.0005
Low level waste (steel drums)	Cubic metres	100.80	85.47	73.29	109.06	107.54	61.25	70.77	68.81
Intermediate level waste (concrete drums)	Cubic metres	37.65	43.00	28.76	35.69	23.10	22.77	41.21	27.6

Source: Adapted from Eskom Environmental Reports 1998-2000

8. STATEMENT OF THE PROBLEM

South Africa, like many other countries, has had a history of not including all costs, including external costs, into the pricing of production inputs and the determination of national accounts. Such an omission in the past has had distortionary effects and in the future could potentially have far reaching implications with regard to achieving the goals and objectives of sustainable equitable growth anticipated by the South African government's Growth, Employment and Redistribution (GEAR) strategy.

The energy sector is central both to improving societal well-being as well as enhancing economic performance. It has significant impacts upon the macro-economy, through enhanced or deteriorating production and social consumption and productivity, as well as the environment not only in its own right but also in terms of the effects of the relationship between the sector and an array of other sectors which use energy as a significant input.

Efficient energy production, reliable availability and ease of utilisation in the industrial, mining and other sectors are crucial to sustained growth in the economy. In the South African context 'cheap' electricity derived from coal combustion has been and will continue to be for the foreseeable future the preferred option. The environmental impact of the energy production and consumption 'chain' is considerable, in terms of air and water pollution, and associated health hazards.

At macro policy level pricing and regulation are two instruments available to guide practice towards these objectives. However if maximum social and economic utility is to be obtained from these instruments then much greater clarity around key issues needs to be forthcoming.

A new and more specific plan to distribute electricity was unveiled by the government in August 1997. Under this plan, South Africa would be divided into five regional electricity distributors (REDS), which would be joint ventures formed by Eskom (which already currently distributes nearly 60% of the electricity it generates directly to end-users) and local authorities. The REDS would purchase electricity from generators (Eskom and independent power producers) on the basis of wholesale purchase tariffs established by the NER. To help finance the REDS, the Electricity Restructuring Inter-departmental Committee (ERIC), which formulated the REDS proposal, has suggested that a tax be placed on electricity charges; this levy would only last until the electrification programs are completed.

9. THE RESEARCH PROGRAMME

The implications of energy trade and sectoral transformation on the environment is largely unexplored territory in South Africa. This research proposal aims to investigate the forces driving pollution emissions in the country and assess the implication of shifting from thermal electricity generation source to another, in particular, the nuclear energy option. This will enable us to determine the implications for policy formulation and implementation.

10. SPECIFIC OBJECTIVES OF THE STUDY

The study objectives will be as follows:

(i) The first section of our research will provide a description of the current status of energy provision and demand in the electricity sub-sector of the country.

(ii) The research will also investigate factors determining the demand of energy in the electricity sub-sector. In the process, we would conduct econometric analyses and test appropriate hypotheses on the possible implications of the sectoral reform.

(iii). The research will determine the main environmental issues associated with electricity production in the country and identify ways of mitigating them. We will analyse trends in emissions of the key pollutants in terms of their annual pollution flows, these pollutants being selected in terms of their environmental relevance and data availability. This will later lead to a decomposition of factors driving the historical trend of the selected environmental pollutants.

(iv). The research will also investigate possible long run shifts in production technology, output level and composition that may be consequent on these macroeconomic reforms. South Africa has a specific commitment to limiting greenhouse gas emissions in terms of the requirements of the agreements of the Kyoto convention on climatic change. The research will model key indicators of energy to ascertain the weight that nuclear, hydro, solar and thermal energy sources have in the South African energy system and in the process examine the implications of shifts from one energy source to another.

(v) We would draw appropriate policy implications from the findings of the study.

11. RESEARCH METHODOLOGY

Data will be collected on various variables of interest including those on electricity-generating sector output, inputs, pollution, the degree of subsidization and their potential influence on the environment. Price and output indices will be calculated for the sector. These would assist us to calculate price and income elasticities which would enable us better understand overall sectoral responses to the proposed macroeconomic reform.

12. TESTING FOR UNIT ROOTS AND EVIDENCE OF COINTEGRATION

Regressions based on levels of variables of interest may produce spurious results. A valid reason for estimating in first differences rather than levels is that the variables included in the regressions may be non-stationary variables. If each of the variables possesses a single unit root, then first differencing would render them stationary, and regression based on changes in the variables would not exhibit the spurious correlation problem. Our research will test for unit root tests in the variables included in our model with a view to determining the order of stationarity and similarly test for cointegration among them. Where evidence of cointegration is found, our model will employ the technique of error correction in order to arrive at the short and long run solutions to the models specified.

13. SOME OF THE MODELS TO BE DEVELOPED

The energy sector in South Africa has a significant environmental impact at local, regional and global levels. At the local level, the issue of air pollution in the domestic sector is extremely serious, even where electrification has occurred. In many such areas, electricity use remains low, as consumption habits have not altered. Research has indicated that suspended particulates and sulphur dioxide in non-electrified homes exceeded acceptable levels by a massive margin. Acute respiratory disease is a major cause of child mortality for African children, at a rate 720 times that of children in Western Europe. Deforestation in rural areas is a second environmental problem arising from lack of electrification.

At a global level, the most significant environmental impact of the energy sector is that it contributes half of South Africa's substantial emissions of greenhouse gases. South Africa is responsible for 1.5% of the global total emissions, the 3rd highest contributing country on a per capita basis.

The following are some of the models to be developed in this study

1 The first model will relate variations in per capita emissions of different pollutants to key indicators of the weight of different energy types in the country's energy systems. In the process, we will determine whether nuclear power has a role to play in reducing pollutants emissions in the country. Other studies suggest that nuclear power have played an important role in the reduction of carbon dioxide emissions in Spain while increased use of thermal energy provides the opposite result (Roca, et al, 2002). Similar exercises will be carried out to ascertain the role that hydroelectric and solar energy sources can play in the reduction of greenhouse gas emissions in South Africa.

2 The second model will be a model of emissions linking four key variables as instruments to achieving reductions in greenhouse gas emissions. Various climate change policies affect emissions through their effect on one or more of these variables. In simple algebraic terms, emissions are a product of total energy use and emissions per unit of energy. The literature on the demand for energy suggests that real GDP, the price of energy and an autonomous time trend explain variations in energy use. A reduced form equation will be formed to enable us generate income and price elasticities of demand for electricity energy for South Africa. The trend variable represents the composite influence on energy use of all non-random variables, other than energy price and real GDP. This trend reflects the influence of

changes in the structure of the economy, such as shifts away from the more energy intensive industries to less energy intensive ones. It also reflects the influence of policy variables such as energy conservation programmes and the adoption of new technologies encouraged by research and development programmes. Attempts will be made to decompose this trend element by separately examining evidence of structural breaks in the data and capturing such structural breaks by means of dummy variables. Similarly, the adoption of new technologies, which are less energy intensive will be captured by the specification of own dummy variable.

3 Kaya Identity: Decomposition of Carbon and other pollutant emissions

In many fields of social sciences, decomposition techniques are used to help disentangle the impact of various contributing factors. An analysis of the driving factors of energy-related carbon and other emission patterns can provide useful information for further policy studies on national strategies and the use of flexible instruments in climate policy. This study will introduce the "Kaya Identity" and work through the four contributing factors or components i.e, carbon/electricity energy, electricity energy/GDP, GDP/population and population) over the period for which data are available. For small to moderate changes in the Kaya variables between any two years, the sum of the percentage changes in each of the variables closely approximates the percentage change in the pollutant emission between these two years. Kaya identity will be summarised over the 1970 – 2001 period by determining the factors affecting emissions during 1970-1980, 1981-1993, 1994-2002 periods.

Transformation within energy, involving changes in pricing and regulatory regimes, will impact on sectors within the "MEC" which rely on energy as a significant input. These same sectors - mining, manufacturing and transport - are the focus of current trade and industrial policies aimed at increasing the growth rate of the economy, enhancing outward orientation and increasing exports, especially of manufactures. These policies are embodied in the Spatial Development Initiatives (SDIs), which are a set of clearly demarcated regions within which government is actively encouraging investment projects. Several of these projects - planned or already initiated - are large capital-intensive, and energy-intensive, materials processing plants, so that the SDI process, if successful in raising the economic growth rate, can be expected also to significantly increase the demand for energy, and the reliance of South African industry on cheap electricity.

The first two 'Kaya Identity' factors therefore, will later be decomposed over five economic sectors namely, agriculture, mining, manufacturing, transport, and services. The aim is to reveal the importance of distinct sectoral components that drive historical pollution emission data. The relative weight of each factor in the observed change can provide relevant information for policy measures. Examples of the use of this method are contained in Dougher (1999) and Albrecht (2001), among others.

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