ENERGY TECHNOLOGIES FOR CLIMATE CHANGE MITIGATION - WHAT IS APPROPRIATE FOR SA?

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ABSTRACT

Climate change is emerging as one of the most challenging problems confronting the humankind in the 21st century. Global warming is almost proportionally interrelated with the pace of industrialization over the past 200 years. This paper reviews emerging and available energy technologies for applicability to energy production, transport and household sectors with the view of climate change mitigation in South Africa

1. INTRODUCTION

Scientists and policy makers are debating about probable changes brought about by increased anthropogenic greenhouse gas emissions, along with strategies for mitigation and adaptation. It is widely agreed that the risks associated with these changes are real and highly uncertain. Developing countries are the worst affected because they lack adaptive capacity, financial resources and the resilience to deal with vulnerability to the risks associated with climate change. The situation is worsened by their dependence of resources that a sensitive to changes in climate such as agriculture.

The last 200 years witnessed massive economic growth supported by technological development in the utilisation and exploitation of fossil fuels. The impacts on climate are phenomenal with atmospheric carbon dioxide concentrations rising from 280 ppm in the pre-industrial era to current levels of about 367 ppm [1].The 1998 have also been cited as the warmest decade in 1000 years [1]

Total greenhouse gas emissions are the product of population, economic activity per capita, energy use per unit of economic activity, and the carbon intensity of energy used. Although greenhouse gas emissions can be limited by reducing economic activity, this option obviously has little appeal to both developed and developing countries. Focus has then been drawn the role that technological improvements can play in mitigating greenhouse gas emissions and in lowering the cost of those reductions.

New and renewable energy technologies (RETs) play an important role in the energy mix aimed at green house gas mitigation. However, there is no single technology that will provide a comprehensive solution to mitigate climate change. Therefore, there is a need for cross-sectoral solutions, all contributing towards sustainable energy use (including energy efficiency) and generation.

This paper assesses energy technologies that have a huge potential to mitigate climate change in the South African context. This paper is not meant to provide a conclusive argument on this, but just raises a few discussion points. The thrust of the paper is however on creating an enabling policy environment that will facilitate the adoption of these technologies.

2. ENERGY PRODUCTION

Arguably, fossil fuels are the largest contributor to greenhouse gas emissions, the primary cause of global climate change. South Africa, with a large endowment of coal, has an electricity production system that is highly carbon intensive generating two-thirds of Africa's electricity, more than 90% of which is generated from coal (Figure 1).

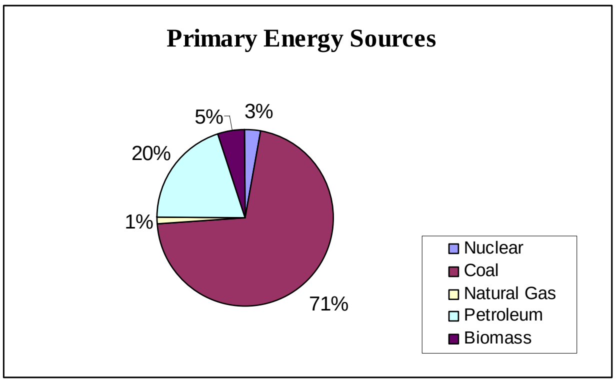

Figure1: Primary energy sources for South Africa [2].

The country is one of the four cheapest electricity producers in the world. Resultantly, the electricity production sector is the largest contributor of carbon dioxide (Figure 2).

2.1 CLEANER FOSSIL FUEL TECHNOLOGY

Despite the environmental impacts of fossil fuel use, South Africa will continue depending on fossil fuel power utilisation. Coal in particular will remain the main source of electricity generation in the foreseeable future. However, its environmental performance needs to be improved if coal is to continue dominating the energy economy of the country.

Advances in clean coal technology (CCT) have led to development of cost-competitive advanced technology coal-fired power plants. The emphasis has been reducing the three major pollutants from coal firing: sulphur dioxide (SO_2), nitrous oxide (NOx), both of which cause acid rain, and carbon dioxide (CO_2).Continued development of CCTs will lead to a number of technology options (zero or near-zero emissions technologies – ZETs) that emit very low levels of all emissions

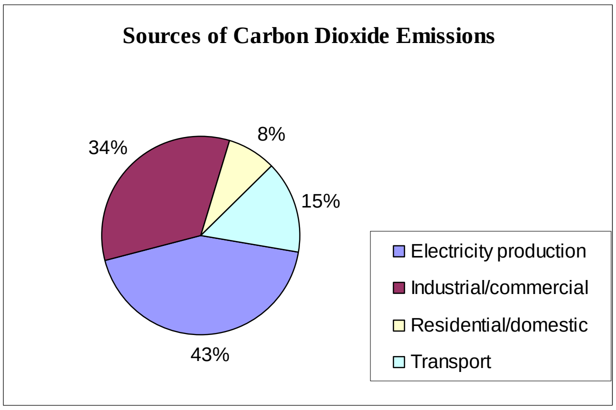

Figure 2: Sources of CO_2 emissions in South Africa [3].

Available CCTs with the options of retrofitting to conventional power plants include:

a) Pulverised Coal Combustion(PCC) with Flue Gas Desulphurisation,
b) Circulating Fluidised Bed Combustion,
c) Integrated Gasification Combined Cycle,

Even though the CCTs have the potential to make significant CO_2 emissions reductions, an enabling regulatory framework that encourages their development and deployment is required for the country to ensure their success. There is need for collaborative effort by research centres, academics, government and industry to initiate and establish focussed research and action to develop and demonstrate CCTs. CCTs may, however, increase electricity production cost; and this may impact on the current and future electrification programmes.

2.2 RENEWABLE ENERGY TECHNOLOGIES DEVELOPMENT

The White Paper on Renewable Energy commits the country to a 10 TWh target of renewable energy contribution to final energy consumption by 2012 [4]. This would be produced mainly from biomass, wind, solar and small-scale hydro resources. There is little done currently to meet this target, and no detailed plan of action has been put forward to this effect

South Africa has invaluable experience in the utilisation and promotion of RETs, and noted successes in solar and wind energy. In the past, however, South Africa has neglected the development of renewable energy applications. A review of previous implementations of RETs highlights the need to overcome numerous barriers to implementation. Such barriers include the following [5]:

a) High initial cost,
b) Subsidies for coal fired power,
c) Poor market acceptance,
d) Imperfect capital market,
e) Regulatory and institutional factors
f) Low utilisation of funding mechanisms such as clean development mechanism (CDM)

South Africa has about 5 MWp PV of installed capacity of which nearly half is used in telecommunications [6]. Solar power also played an important contribution in South Africa's National Electrification Programme. To date, an estimated 50,000 to 80,000 PV systems have been installed, plus a number of small-scale pilot projects [6]. The full available resource capacity is not been fully utilised. This applies to solar-thermal applications where there is no obvious government driven programme. To this effect, these applications are limited to a few domestic solar water heating (DSWH) with installed capacity over 484,000 m^2, representing less than 1% of the potential market.

Hydro-electric power contributes less than 1% of electricity generation, and most of that is pumped storage. The largest hydroelectric power plant in South Africa is the 1 000 MW Drakensberg Pumped-Storage Facility, which is part of a larger scheme of water management that brings water from the Tugela River into the Vaal watershed. The country's second-largest plant is situated on the Palmiet River outside Cape Town. It is however estimated that there are 6 000 to 8 000 potential sites in South Africa suitable for small hydro-utilisation below 100 megawatts, with the provinces of KwaZulu-Natal and the Eastern Cape offering the best prospects

Wave energy has significant potential wave energy along the Cape coastline and is estimated at 56 800 MW [16]. However, wave power is not a fully commercial RET. The possibility of a Hydrogen Economy will also see South Africa becoming "the new Saudi Arabia", as it has vast platinum reserves. Despite this potential, there is little research and development, as well as supporting policy on the use of hydrogen and related technologies (fuel cells). Platinum is used as a catalyst in fuel cells, which holds the key to unleashing the power of the universe's simplest and most plentiful element - hydrogen.

Other untapped mitigation option is landfill gas utilisation, the conversion of municipal solid waste-to-energy and commercial biomass to electricity initiative. Currently landfill gas is either collected for flaring or just emitted to the atmosphere. Potential also exists in wind energy where two notable instalments are:

a) The Klipheuwel Wind Farm has a total capacity of 3.2 MW,
b) Darling wind farm 5.2 MW installed power for the first stage which came into operation at the end of 2005

RETs also improve energy delivery in rural and low-income urban households with high dependence on traditional biomass, about 15% of energy use [7]. This have a multiplier effect on the associated benefits, as biomass is linked to numerous health concerns due to resultant poor indoor and outdoor air quality..

2.3 NUCLEAR

Nuclear energy, hydroelectricity, plus "renewables" like solar and wind, emit no carbon..

Table 1. Energy production comparison

Source	Output
1 kg coal	3 kWh
1 kg oil	4 kWh
1 kg uranium	50 000 kWh (3 500 000 kWh with reprocessing**)**

Eskom operates one nuclear power plant (Koeberg), which produces 6% of national electricity, with installed capacity of 1800 MW. Furthermore, South Africa has the world's fourth largest uranium reserves, and is leading the way in developing the new generation nuclear power plants: the Pebble Bed Modular Reactors (PBMR).

The PBMR plants are one-tenth the size (100 megawatts) of current plants (1,000 megawatts), and have been cited as safe and reliable, which further reduces operational risks. South Africa, thus, has great potential to reduce CO_2 emissions by utilising the immerse uranium and human capital resources it has.

Despite the favourable conditions for nuclear use in South Africa, this technology has negative public perception. This due to concerns about the safety of nuclear fission reactors include the possibility of radiation-releasing nuclear accidents, the possibility of contributing to nuclear weapon proliferation, and the problems of radioactive waste disposal. Radioactive waste require safe disposal (and aftercare) running into hundreds of thousands, and sometimes millions of years. This alone outweighs the immediate benefits of nuclear use.

3 ENERGY STORAGE

Renewable sources of energy have irrefutable advantages over conventional electricity generation methods. At the same time, they present new challenges. The output of traditional methods is easy to adjust according to the power requirements of users. The new energy sources are based more directly on harnessing the power of nature and, as such, their peak power outputs may not match the power requirements of human users. In addition, they may exhibit large fluctuations in power output in diurnal, monthly or even annual cycles. Similarly, the demand can vary diurnally or annually. There is a need to buffer power, that is, store energy when an excess is produced and then release it when production levels do not meet the requirements. Only then can one rely on, say, wind or solar power as our primary sources of energy. There are other reasons why it is necessary to store large amounts of energy. Depending on how storage is distributed, it may also help the network to withstand peaks in demand. Storing energy allows transmission and distribution to operate at full capacity, decreasing the demand for newer or upgraded lines. Storing energy for shorter periods may be useful for smoothing out small peaks and sags in voltage. There is certainly a need for energy storage, especially energy storage on a larger scale than ever before. DCs need to build capacity in the area of development and utilisation of innovative energy storage devices. The following energy storage technologies are available:

- Fuel cells,
- Mechanical alternatives (flywheel),
- Pumped hydroelectric energy storage,
- Underground thermal energy storage,
- Compressed air energy storage,
- Superconducting magnetic energy storage, and
- Super capacitors.

The specific energy storage options that are available will vary according to the end-user sector. However, fuel cells have great promise in a wide variety of applications. In terms of their capacity, they are flexible, partly because there are a number of technologies under the umbrella of fuel cells. Eskom operates two pumped storage hydro-power plants (Palmiet – 400 MW and Drakensberg – 1000 MW) with installed capacity of 1400 MW.

4 ENERGY CONSUMPTION

The two dominant energy consumption sectors for South Africa are: Industry and Commerce; and the Transport sectors (Figure 3). These two account for nearly 70 % of annual energy consumption.

Energy efficiency provides the cheapest "cost free" route in terms of both emissions and energy savings whilst meeting the same energy demand. This is recognized by the Energy Efficiency Strategy of South Africa which advocates for a final energy demand reduction of 12% by 2015 [8].

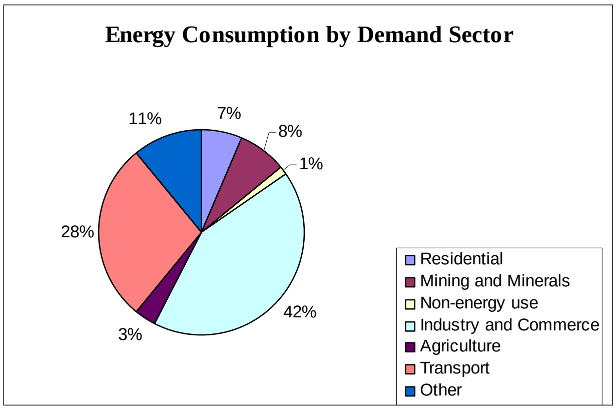

Figure 3: South Africa's energy consumption by demand sector [2].

Typical energy efficiency technology oriented measures in some of the energy demand sectors may include:

- Households – efficient space cooling, lighting, cooking, heating (solar water heaters), integrated solar facades (thermal & photovoltaic) etc.
- Industry – improved energy converters (burners), process improvements, increased recycling, RETs, cogeneration, waste gas scrubbing technologies, carbon management/sequestration, etc.

- Agriculture – use of RETs: solar/wind water pumping, solar drying, bio-energy as fuel.

There are several mitigation options and those discussed below relates to the transport and household sector only.

4.1 TRANSPORTATION

Transport is the leading economic sector in terms of its growth in oil use over the past 30 years, and will likely to continue this pattern in the near future. In most countries, oil accounts for over 97% of transportation fuel utilisation. [9]. Typical of other economies, the transport sector in South Africa is fossil fuel intensive contributing 28 % of the overall annual energy consumption (Figure 3) and 15% of CO_2 emissions (Figure 2). Apart from electric trains the entirety of transport depends on fossil fuel. Road transport is discussed below as it is by far the most used transport option.

possibilities for change in design, engineering and alternative fuels, but there are concerns that efficiency increases will translate into increased power rather than increased economy. Fuel cells were presented as the ultimate solution over the long term.

Mitigation and improvement options for road transport include:

- Nearly two-thirds of the energy in the fuel is lost as rejected heat, or frictional and pumping losses in the engine. Figure 4 illustrates the types and relative magnitudes of energy losses for typical engine-propelled vehicles today [10]. Reduction of these losses and improved energy efficiency is an integral part of greenhouse gas mitigation in transport use.
- Hybrid drives – combining electric motors and combustion engines. These systems still need require battery capacity improvements, charging process and charging stations. Hybrid drive cars are already available on the market at competitive pricing.

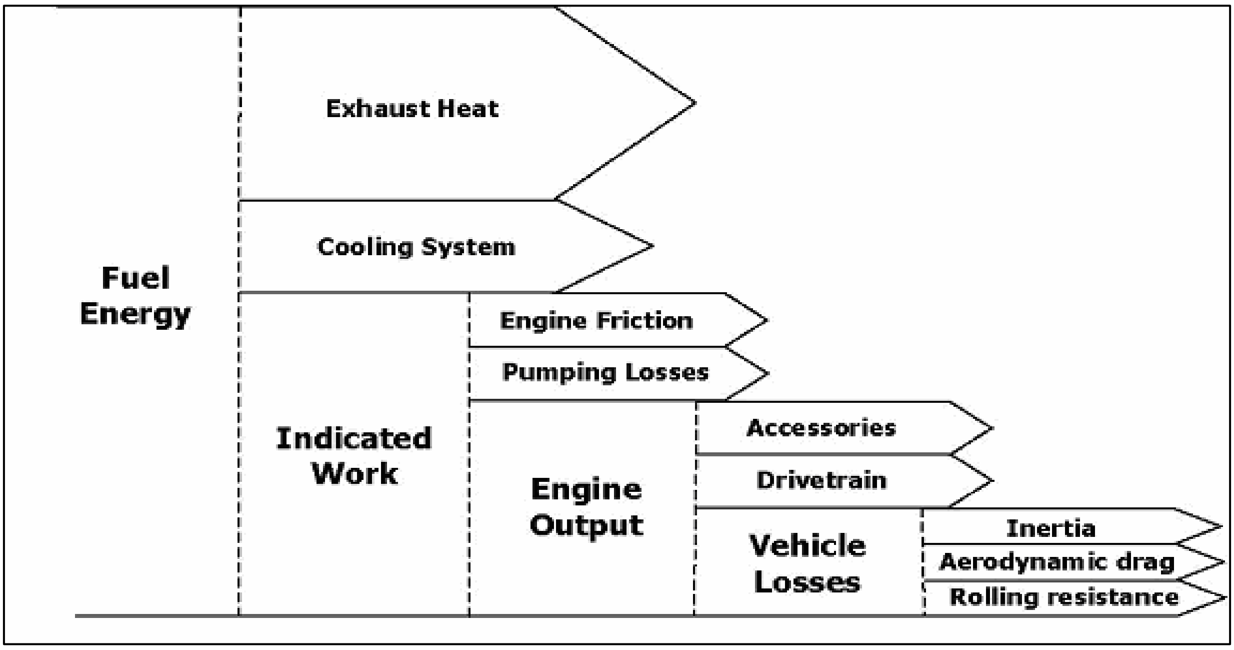

Figure 4: Diagrammatic representation of energy losses in vehicles

Road traffic exhaust emissions result in local air pollutants and greenhouse gas emissions. Vehicle exhaust emissions are a major contributor to the creation of smog and carbonaceous particulate matter in the air. The exhaust emissions from vehicles using oil-based fuels include toxic complex compounds (NO_x, HCs and heavy metals) that also lead to formation of tropospheric ozone (photochemical smog produced by the action of sunlight on NO_x and HCs). Such detrimental effects on urban air quality have important negative effects on human health.

With public transportation in an unsustainable state, there is an increase in personal transport adding to emissions. There has been a notable improvement in engine designs aimed at higher fuel economy and less air pollution. There are many

- Drive systems with renewable energy (biofuels) – biogas, biodiesel, ethanol, CNG, LPG, methanol and hydrogen. Biofuels are generally designed as straight replacements for fuels derived from fossil sources, and are available as liquids, solids or gases. They consequently provide more flexibility than most other forms of renewable energy, and are easier to use in existing systems, markets and infrastructures A major concern for these are the implications of biofuels on land use to food production.

- Efficiency improvement – optimized conventional drive systems e.g. weight and rolling resistance reductions
- Fuel cell driven vehicles – The major limitation of this technology is the high-energy consumption during H_2 production, hydrogen storage problems and lack of infrastructure. Currently this technology is not fully commercial.

Transport plays a pivotal developmental role, despite having several negative impacts on the environment. The challenge is then challenge is to enable mobility while reducing consumption of fossil fuels until such a time where alternative energies are commercially proven.

4.2 HOUSEHOLDS

There is potential for mitigation in the household sector in the existing households and those to be constructed. Rural electrification has had the effect proving service delivery and mitigation as well. The later benefits has however not been enumerated.

Mitigation options in households sector mainly relates to:

a) Efficient endues devices –such as efficient light bulbs, improved cooking utensils (micro-wave etc.) and efficient cooking stoves in rural households,
b) Solar thermal applications to meet thermal loads – solar water heaters, solar assisted air-conditioning,
c) Architectural designs for housing maximising passive solar designs heating and cooling. For example: Kutlwanong Energy Efficient Housing, Kuyasa Housing Project.
d) Integrated solar facades – both thermal and photovoltaic,
e) Innovative technologies in – lighting, insulation, space heating, refrigeration, air-conditioning, building controls, infiltration reduction, etc.

The implementation of the Efficient Lighting Initiative ELI supported by the International Finance Corporation (IFC) and funded by Eskom and the Global Environment Facility (GEF), hastened the dissemination of energy-efficient lighting technologies into emerging markets in South Africa.

Table2: Benefits of the ELI to South Africa [11]

Emissions	Savings per year
CO_2	3.6 Mt
SOx	29.4 kt
NOx	14.65 kt
Water use	4.8 Gl
Coal use	1.92 Mt
Ash	505 kt

Compact Fluorescent Lamps (CFLs) save up to 80 % of the energy consumed by a conventional light bulb and last 6-15 times longer. The potential for replacing conventional light bulbs has been estimated to 31.5 million. Over a 15-20 year period, savings in peak load are estimated to up to 810-820 MW of new capacity [11]. Derived environmental benefits from the Efficient Lighting Initiative include CO_2 savings of 3.6 Mt (Table 2)

5.0 BEYOND TECHNOLOGY

5.1 INTERNATIONAL COLLABORATION

Climate change and greenhouse gas mitigation are global phenomena requiring international collaboration to deliver solution going beyond national borders. International collaboration enhances national greenhouse gas mitigation efforts by risk sharing, resources and knowledge exchange, harmonising standards, capacity building and technology transfer.

South Africa stands to benefit from technological in-roads made elsewhere, particularly by Annex 1 countries. Technology collaboration also provides a framework for long-term co-operation on climate change and energy challenges with both Annex I and Non-Annex I Parties can participate.

5.2 POLICY AND LEGISLATION

South Africa, a non-Annex 1 member, is not compelled by the Kyoto protocol to reduce carbon emissions. However as participant in both domestic and international policies focusing primarily on greenhouse gas mitigation, the country has to comply with these international protocols. These policies serve to (particularly domestic policies) guide mitigation strategies implementation and response from both public and private sector. Despite the existence of policies there has been very little implementation of any strategy. Typical example is the little implementation drive in RETs as cited by the White paper on energy.

Further policy driven mitigation options include:

- Energy and resource use policy and legislative tools (e.g. standards, labels, incentives or mandatory Minimum Efficiency Performance Standards, mandatory energy audits and energy tax incentives for businesses and industry). The major limitation of this is that they require high technical and legal capacity to implement
- Prohibitive Pollution tax accounting for externalities in fossil fuel power generation – this will promote efficient fuel use and R&D in cleaner technology to cut costs, and RETs
- Improved urban planning and improved urban transport systems
- Strengthening government policies toward RE with respect to R&D, deployment, financing, etc

The present mitigation polices were formulated with a short-term focus. These include the 2012 renewable energy contribution and the 2014 energy efficiency targets. There is need to develop policy and strategy in the long-term framework as the span of climate change mitigation surpasses the current policy and strategy. Such long-term policy will guide investment, business decision and R&D strategy in emerging and future RETs such as hydrogen. Long time scales further serve to provide for gradual transition of economies towards sustainable energy and resource utilisation

6.0 CONCLUSION

Under the Kyoto Protocol, the world's wealthier (Annex 1) countries assumed binding commitments to reduce greenhouse gas emissions. As with other developing countries (Annex 2), South Africa is not compelled to reduce greenhouse gas emissions. However South Africa's emissions are comparable and even well above some of the Annex 1 countries. Government efforts in terms of policy and strategy delivery are at the core of mitigation.

To enhance greenhouse mitigation efforts there is need for stronger stakeholder participation and awareness about climate change and available mitigation options. Partnerships and international collaboration will also aid mitigation efforts particularly in the technology side (RETs). Improvements in the ability to initiate and undertake The CDM projects will also go a long way in providing greenhouse gas mitigation solutions.

There is need for increased R&D in mitigation technologies at both academic and industrial levels. Presently little academic research is directed at RETs as such services are not available in most academic institutions in South Africa.

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