Nuclear Energy in South Africa: An Opportunity for Greater Energy Efficiency and Energy Security

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Abstract: *The increasing concern raised by the overreliance on fossil fuels such as natural gas, coal and oil has pushed countries around the world to look for alternative sources such as nuclear energy. South Africa is one such country that has, in recent years, begun to strongly consider the prospects of using more nuclear energy as part of the energy mix. The current makeup of South Africa's energy use consists primarily of coal (which accounts for 75% of energy consumption), followed by oil, gas, nuclear and renewables. The inefficiency and highly polluting factor of coal, and the current strain on the power grid, have pushed South Africa to look closer at the prospects of using nuclear energy. With current initiatives of the locally developed Pebble Bed Modular Reactor being put on hold due to financial constraints, South Africa is also looking abroad for possible actors to participate in the construction of a fleet of new nuclear reactors. The development of this industry has substantial possibility to provide job creation, skills development, meeting CO2 reduction targets, greater energy security and better energy efficiency. However, safety considerations and the costs involved are major aspects to take into account. This article seeks to analyse the existing power supply sector in South Africa and note the feasibility that nuclear energy can play in South Africa's energy security and efficiency. An overview of current policy developments will also be provided in order to note the stance of the South African government with regard to nuclear energy and energy security.*

Keywords: *South Africa, policy, energy, security, nuclear, efficiency, PBMR*

Introduction

The state of energy security in South Africa is an issue of constant discussion, spanning decades. Prior to the end of apartheid in 1994 and in light of the global economic sanctions that were imposed on the country, the South African government was highly reliant on the use of domestic resources such as coal for sustainability. These restrictions also played a role in pushing the South African government towards the development of a nuclear power sector. On 14 March 1984, the first and only nuclear

power station at Koeberg in the Western Cape went operational. It has remained operational since. With the onset of democracy in 1994, and the lifting of international sanctions, South Africa became more open to importing other energy sources such as oil and gas to supplement the highly energy intensive coal sector, as well as to diversify the makeup of energy consumption in the country. Despite this, coal has remained the dominant energy source in South Africa, although, due to its levels of inefficiency and high CO_2 emissions, coal has become less desirable as an energy source. Massive power outages in 2008, alongside South African commitments to reduce greenhouse gas (GHG) emissions, initiated a renewed interest in nuclear energy.

SOUTH AFRICAN ENERGY BACKGROUND

South Africa has had a relatively secure supply of energy for a number of decades. Prior to the end of apartheid, economic sanctions forced the country to rely heavily on its domestic energy reserves in order to maintain an operational industrial and manufacturing sector. This trend has continued into the post-1994 era, but has diversified slightly due to the lifting of sanctions and the initiation of oil imports primarily from states that are part of the Organisation of Petroleum Exporting Countries (OPEC), as well as natural gas imports from neighbouring countries. By 2010, energy supplies consisted of coal (67%), oil (19%), solid biomass and waste (10%), natural gas (2%), nuclear (2%), and hydro (<1%) respectively.[1] The energy consumption by sector comprises of industry (45%), transport (20%), non-energy (17%; referring to resources such as coal, gas, wood and oil, which are converted to other products such as chemicals and paper), residential (10%), agriculture (3%), commerce (3%), and other (2%).[2]

From the above percentages, it is clear that the primary driver of energy consumption in South Africa is the industrial sector, with almost 50% of energy expended towards aspects of industry such as manufacturing. However, due to policies initiated by the post-apartheid government, residential electrification has become a primary priority in a bid to connect all South Africans to a stable power supply. This has put substantial strain on the electricity grid in recent years, with rolling blackouts being experienced throughout the country in 2008 during a power crisis.

Regardless of the power shortages and inefficiency in power generation, coal remains the dominant source of energy for South Africa. In terms of coal reserves, South Africa has the ninth largest deposit in the world.[3] In 2011, South Africa mined an

[1] Jo-Ansie van Wyk, "South Africa's Nuclear Future", SAIIA Occasional Paper, No 150, (June 2013), 1-36, accessed October 18, 2013. http://www.saiia.org.za/occasional-papers/south-africas-nuclear-future
[2] Ogunlade Davidson *et al.*, *Energy policies for sustainable development in South Africa* (Energy Research Centre: UCT, 2006), 1-223, accessed on 17 October 2013.
http://web.uct.ac.za/depts/erc/Research/publications/06Winkler-Energy%20policies%20for%20SD.pdf
[3] US Energy Information Administration, "Country Briefs - South Africa", 2, accessed October 20, 2013.
http://www.eia.gov/countries/analysisbriefs/South_africa/south_africa.pdf

estimated 282 million short-tons (MMst) and consumed 210 MMst, with the majority of supplies coming from the north-eastern fields of Witbank, the Highveld (the area of land on which a portion of the Gauteng province resides), and Ermelo (see map below).[4] The vast mining of coal and the apartheid government's isolation provided indigenous energy giant Sasol with an opportunity to initiate developments towards a new form of fuel from coal. Sasol, established in 1950, has the ability to convert coal-to-liquids, providing approximately 30% of the country's gasoline and diesel consumption.[5] This has made the mining of coal a further necessity for South Africa's energy security needs.

As a result of the substantial coal reserves, the expanded mining capacity and the further add-on necessity for synthetic fuels, South Africa's coal production accounts for nearly 90% of electricity generation and 77% of primary energy needs.[6] This translates into 243,412 gigawatt hours (GWh) generated by coal and peat.[7] However, this has had a negative environmental impact, resulting in South Africa becoming one of the biggest global emitters of CO_2, and being responsible for more than 90% of Africa's total CO_2 emissions.[8] That said, the role played by coal in South Africa's energy supply is unlikely to change much over the course of the coming decade due to a lack of viable alternatives and the costs involved in shifting the energy grid away from coal.

During the period of apartheid, South Africa also sought to develop its nuclear energy industry for both power and security needs. In the early 1960s, Pretoria commissioned the first (and only) nuclear power station at Koeberg on the Cape west coast. Koeberg has two French-supplied reactors, which became operational in 1984 and 1985 respectively.[9] At present, the station provides only 6% of total electricity generation to South Africa. In terms of electric power, nuclear energy accounts for 1840 megawatts electrical (MWe) in comparison to coal's 38,000 MWe.[10]

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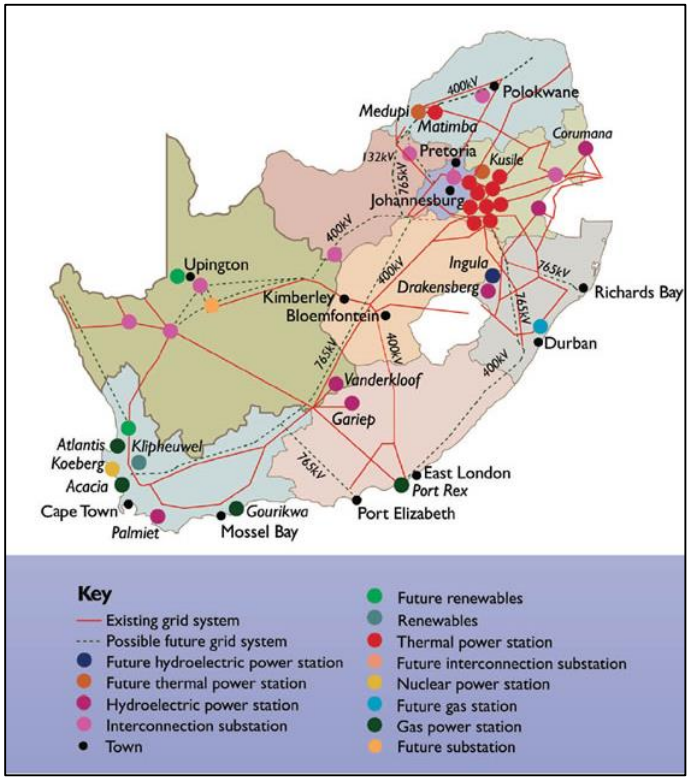
[4] US EIA, "Country Briefs – South Africa", 4.
[5] US EIA, "Country Briefs – South Africa", 5.
[6] "Basic Electricity – Overview", accessed October 20, 2013. http://www.energy.gov.za/files/electricity_frame.html;"Coal Resources – Overview", accessed October 20, 2013. http://www.energy.gov.za/files/coal_frame.html
[7] International Energy Agency, "South Africa: Electricity and Heat for 2011", accessed October 20, 2013. http://www.iea.org/statistics/statisticssearch/report/?&country=SOUTHAFRIC&year=2011&product=ElectricityandHeat
[8] Renee Greyvenstein, Michael Correia and Willem Kriel, "South Africa's opportunity to maximise the role of nuclear power in a global hydrogen economy", Nuclear Engineering and Design 238 (2008) 3031-3040, accessed October 17, 2013. doi:10.1016/j.nucengdes.2008.01.026
[9] Van Wyk, "South Africa's Nuclear Future", 4.
[10] Schalk W. Smith and P.J. Bredell, "Development of a strategy for the management of PBMR spent fuel in South Africa", *Nuclear Engineering and Design* 240 (2010), 2415-2420, accessed 17 October, 2013. doi:10.1016/j.nucengdes.2010.01.025

LOCATIONS OF POWER STATIONS IN SOUTH AFRICA[11]



Source: Eskom SA, 2014

Over the past two decades, South Africa has investigated the expansion of its nuclear energy proficiency. Since 1998, it has developed new nuclear technologies in the form of the Pebble Bed Modular Reactor (PBMR), which has the ability to provide greater energy supplies and efficiency to an electricity sector that is currently undergoing stress due to the massive growth in demand and electrification.[12] Recent statements by the South African government have also indicated that it would be pursuing a greater supply of nuclear energy through the commissioning of a fleet of new reactors to meet the goals of energy security, as laid out by the Integrated Resource Plan (IRP) of 2010.[13] The IRP mandates that by 2030, an additional 9,600 MW of nuclear energy will be added to the electricity grid in a bid to decrease South Africa's overreliance on coal as an energy source.[14] This policy has not come without criticism

[11] Eskom, "South African Grid Map", 2014, accessed at http://www.eskom.co.za/OurCompany/CompanyInformation/Pages/Company_Information_1.aspx
[12] Smith and Bredell, "Development of a strategy for the management of PBMR," 2415.
[13] Carol Paton, "State stands ground on SA's nuclear ambitions", *Business Day*, 25 April, 2013, accessed at http://www.bdlive.co.za/business/energy/2013/04/25/state-stands-ground-on-sas-nuclear-ambitions
[14] Department of Energy, "Electricity Regulations on the Integrated Resource Plan 2010-2030", 6 May, 2011, accessed 18 October, 2013. http://www.energy.gov.za/IRP/2010/IRP_2010.pdf

from sectors of academia over the costs involved in the construction of nuclear power plants, as well as the transparency mechanisms used in the procurement process.[15] Further criticism comes from the need for green energy developments such as wind and solar, considering South Africa's coastal regions that generate substantial winds, as well as the abundance of sunlight in the Northern Cape province - both methods that can be used to great effect.

POST-1994 DEVELOPMENTS IN THE QUEST FOR ENERGY PROVISIONS AND ENERGY SECURITY

There have been a number of shifts in domestic policy post-1994 concerning energy provisions and energy security in South Africa. The electrification of the country is a top priority for government, considering that, prior to 1994, a large proportion of the urban and an even larger proportion of the rural population in South Africa were without electricity. The White Paper on Energy Policy (1998) has been a backbone of the current ANC government's energy developments since inception. The objectives laid out within the paper note the need for increased access to affordable energy services, improving energy governance, stimulating economic development, managing energy-related environmental and health impacts, and securing supply through diversity.[16] Within these, special emphasis in demand sectors was placed on households; industry, commerce and mining; transport; and agriculture. Supply sectors of electricity, nuclear energy, oil, liquid fuels, gas, coal, renewable resources, and transition fuels (low in CO_2 emissions), were high on the agenda. These objectives formed the foundation for South Africa's energy policy post-1994.

Based on these objectives, certain inroads were made in further policy formulations and enactments. Integrated Energy Plans were formulated in 2003 and 2005, along with a draft Integrated Energy Plan in 2012.[17] Electricity Pricing Policy, Free Basic Electricity Policy, and Free Basic Alternative Energy Policy fell in line with the White Paper's objectives of ensuring electricity for disadvantaged households throughout the country at minimum to no cost. Other electricity acts were also developed for the regulation of electricity use, as well as the formulation of a national regulator to carry out the implementation of acts such as the Electricity Regulation Act, and the Electricity

[15] Lynley Donnelly, "Academic questions scale of nuclear ambitions", *Mail and Guardian*, 15 August, 2013, accessed at http://mg.co.za/article/2013-08-15-academic-blasts-sa-neanderthal-power-policy
[16] Department of Minerals and Energy, "White Paper on the Energy Policy of the Republic of South Africa", December 1998, 1-110, accessed 20 October 2013. http://www.energy.gov.za/files/policies/whitepaper_energypolicy_1998.pdf
[17] Department of Minerals and Energy, "Acts and Legislation – Energy Planning", accessed on 20 October 2013. http://www.energy.gov.za/files/policies_frame.html

Regulation Amendment Act.[18] A further initiative for a strong energy efficiency policy was the National Energy Act (2008), as well as an Energy Efficiency and Demand Side Management Policy to regulate energy use intensity through various supply and demand sectors. Natural gas acts were also put in force through Act 48 of 2001 (National), Act 48 of 2001 (Regulations), and Act 75 of 2002 (Levies). In 2003, a White Paper on Renewable Energy Resources was published, in line with the existing Reconstruction and Development Programme of the post-apartheid government. The huge potential of renewable energy was noted in light of wind, biomass, hydro, solar, wave energy, ocean currents, and energy from waste, which could be used to great effect to achieve the goals of managing energy-related environmental and health impacts and securing supply through diversity.[19]

South Africa joined the Kyoto Protocol and ratified it on 16 February 2005 so as to aid the future reduction of GHG's.[20] Hence, the government has initiated the necessary steps to achieve reductions in CO_2 emissions, given South Africa's high use of coal within the energy sector. Coal is the only sector within the South African economy mentioned in the 2003 White Paper on Energy Policy that has little to no regulation. This is a disturbing fact, given the precedence of coal in the growth and security of South Africa's energy needs.

The policies formulated in the aftermath of the implementation of the 2003 White Paper on Energy have been evident in a number of areas. For instance, by 2010, substantial inroads had been made in terms of the electrification of the South African population, with just over 75% of people in South Africa having access to electricity, in comparison to the 66% having access in 2001. [21] Other notable differences exist in the makeup of energy resources used within the sector. There is a notable improvement in diversity, in comparison to the make-up of the energy sector 10 years earlier in 2000, consisting of coal (79.8%), petroleum (9.8%), biomass (5.5%), nuclear (3.3%) and gas (1.5%). Hydro did not even feature in the equation.[22] Such improvements are important to note, as they are in line with the White Paper. Thus, certain objectives have been

[18] Department of Minerals and Energy, "Acts and Legislation – Electricity", accessed on 20 October 2013. http://www.energy.gov.za/files/policies_frame.html
[19] Department of Minerals and Energy, "White Paper on Renewable Energy", 1-45, accessed on 20 October 2013. http://www.energy.gov.za/files/policies/whitepaper_renewables_2003.pdf
[20] United Nations Framework Convention on Climate Change, "Status of Ratification of the Kyoto Protocol", accessed 21 October 2013.
http://unfccc.int/kyoto_protocol/status_of_ratification/items/2613.php
[21] World Bank, "Access to electricity (% of population)", accessed 20 October, 2013.
http://data.worldbank.org/indicator/EG.ELC.ACCS.ZS; Ogunlade Davidson and Harald Winkler, "South Africa's Energy Future: Visions, driving factors and sustainable development indicators", Report for Phase I of the Sustainable Development and Climate Change Project, (Energy and Development research Centre: UCT, 2003) 1-43. http://web.uct.ac.za/depts/erc/Research/publications-pre2004/03-Davidson-Winkler_SA_Energy_Future.pdf
[22] Davidson and Winkler, "South Africa's Energy Future," 2.

achieved through the implementation of various control mechanisms and policies for regulation.

Due to the lack of implementation of energy efficiency, South Africa has lagged behind in comparison to other states throughout the world and is responsible for nearly two times the global average of electricity consumption per capita (World: 2,343 kWh; SA 4,533 kWh). As a result of this inefficiency, CO_2 emissions are at 2.54kg per 2,000 US $ of GDP, in comparison to the European Union at 0.38kg, Latin America and the Caribbean at 0.59kg, the OECD at 0.43kg and Sub-Saharan Africa at 1.53kg.[23] Hence, while South Africa has developed substantially in the post-apartheid era with greater access to electricity by both the urban and rural population, stronger mechanisms to govern and regulate energy use, and greater diversity placed on the makeup of energy consumption by type, this has come at a cost of great inefficiency. This has been the partial result of rolling blackouts experienced in 2008 as a result of strain on the energy supply sector.

Despite plans for new coal-fired power stations by the national power provider, Eskom, there is still a massive void that needs to be filled due to the inefficiency of using coal as a major source for electricity. The two new coal-fired power stations currently being built, Medupi and Kusile, will account for over 9000MW of power.[24] However, long delays due to quality of boilers, issues with the instrumentation systems, as well as labour unrest have pushed the completion dates of both stations further and further back; the first unit at Medupi was supposed to be online in December 2013, and the first in Kusile in December 2014.[25] By January 2014, the first unit at Kusile was just over 50% complete. Even when both power stations become operational, conservative estimates note that should demand increase by only 4% per year, South Africa would still need to add more power to the grid at a pace of a power-station, equivalent in size to Medupi or Kusile, every five years.[26] This point was also evident in the president's 2014 State of the Nation address, when he made mention of the government's intent to build a third coal-fired power station (Coal 3).[27] Without adding this new power to the grid, South Africa would be unable to meet the growth targets of 5% set by the 2010

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[23] Kojo Menyah and Yemane Wolde-Rufael, "Energy consumption, pollutant emissions and economic growth in South Africa", *Energy Economics* 32 (2010) 1374-1382, accessed 17 October, 2013. doi:10.1016/j.eneco.2010.08.002

[24] "Is Medupi power plant deadline slipping yet again?", *The Citizen*, (5 February, 2014). Accessed http://citizen.co.za/121907/medupi-power-plant-deadline-slipping-yet/

[25] Terence Creamer, "Medupi, Kusile overruns should be probed, NPC commissioner asserts", Engineering News, (21 August, 2012). http://www.engineeringnews.co.za/article/medupi-kusile-overruns-should-be-probed-npc-commissioner-asserts-2012-08-21

[26] Sue Blaine, "SA needs 'another power station the size of Medupi and Kusile'" *Business Day*, (10 March, 2014), accessed at http://www.bdlive.co.za/business/energy/2014/03/10/sa-needs-another-power-station-the-size-of-medupi-and-kusile

[27] Carol Paton, "SA needs nuclear power, says Zuma", *Business Day*, (18 June, 2014), accessed at http://www.bdlive.co.za/national/2014/06/18/sa-needs-nuclear-power-says-zuma

National Development Plan (NDP). Former Energy Minister Dipuo Peters has also noted that using coal-fired stations as the primary source of energy is unfeasible in the long-run, due to the locations of the majority of power plants.[28] Thus, diversifying the energy makeup of the power grid has been a major area for consideration by the South African government. As a result, it has launched an initiative of building a fleet of new nuclear reactors to meet the goal of 9,600 MW of nuclear energy by 2030.

NUCLEAR ENERGY: HISTORY, ENTERPRISES, POLICIES AND OUTLOOK

As mentioned, South Africa's nuclear developments came about partially through the need for energy self-sufficiency during the apartheid era, and partially as a sense of prestige for the South African government at the time. Out of this need, the two nuclear reactors at Koeberg were commissioned to supply electricity to the South African grid during the worst period of sanctions and isolation in the early to mid-1980s. The two pressurised water reactors (PWRs) together have a net output of 1830 MW of power, which supplies the majority of the Western Cape.[29] A major aspect for the successful operation of the Koeberg nuclear power plant during the period was the extraction of uranium. In South Africa, uranium is readily found while mining for gold and is, in fact, a by-product of the process, as opposed to being mined solely on its own. Current estimated uranium reserves in South Africa are at 261,000 tons, thus leaving South Africa with 8% of global uranium resources. [30] Post-1994, South Africa had to relinquish a large portion of its existing nuclear materials as per agreement with the International Atomic Energy Agency (IAEA), and following South Africa's signing of the Nuclear Non-proliferation Treaty (NPT) in July 1991. However, the operation of its Koeberg nuclear plant was left untouched due to the low degree of enriched uranium that the plant uses to generate power. The peaceful purpose of the nuclear power plant is in line with international rules and regulations on the safe use of nuclear energy.[31]

The National Nuclear Regulator (NNR) is the sole enterprise responsible for the oversight and regulation of nuclear energy in South Africa. The NNR is responsible for

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[28] Antonio Ruffini "SA's nuclear power build programme – will it happen?", *ESI Magazine*, (24 May, 2013), accessed at http://www.esi-africa.com/sa-s-nuclear-power-build-programme-will-it-happen/
[29] Van Wyk, "South Africa's Nuclear Future", 8.
[30] Ogunlade Davidson et al., *Energy policies for sustainable development in South Africa* (Energy Research Centre: UCT, 2006), 48; Michiel J. Combrink, "Nuclear Energy Security: A critical analysis of the North-South diplomatic discourse on the nuclear fuel cycle, 2004-2011", (MDip diss., University of Pretoria: 2012).
[31] Department of Energy, "Integrated Nuclear Infrastructure review", *City Press*, (3 February, 2013), accessed at http://www.energy.gov.za/files/media/Pub/Integrated%20Nuclear%20Infrastructure%20Review%20(INIR).pdf

all assets, rights, liabilities and obligations of the Council for Nuclear Safety.[32] The predecessor of the NNR was the Atomic Energy Board (AEB) formed in 1948, which later became the Atomic Energy Corporation (AEC) in 1986 and was responsible for granting nuclear licenses.[33] The creation of the Nuclear Energy Act in 1982 tasked the soon to be AEC with all responsibility regarding nuclear matters, including enrichment. Through the amendment of the Nuclear Energy Act in 1988, a separate body was also created for the independent jurisdiction of nuclear energy, known as the Council for Nuclear Safety (CNS). "The CNS was responsible for the regulation of nuclear installations and activities involving radioactive material in order to protect persons and property against the harmful effects of ionizing radiation".[34] There was a necessity to create a distinction between legislation aimed at promoting nuclear activities, from that which was responsible for regulating safety related to nuclear installations, submarines (or other vessels) propelled by nuclear power, and actions involving the use of radioactive material. As a result, the National Nuclear Regulator was officially established in 1999 and was tasked with ensuring the safety of people, property and the environment from nuclear damage. The main subsidiary body to the NNR is the South African Nuclear Energy Corporation (NECSA). Through the Nuclear Energy Act, No 46 of 1999, NECSA is mandated to undertake and promote research and development (R&D) in the nuclear field; process source material, special nuclear material and restricted material, and also reprocess such material; and lastly to cooperate with any person or institution in matters falling within these functions.[35]

Along with the main body responsible for nuclear regulation, South Africa has, furthermore, developed a number of acts to guide the use of nuclear energy. It is a signatory to a number of international obligations for the safe use of nuclear energy. These include the Hazardous Substance Act 15 of 1973, the Convention on the Physical Protection of Nuclear Materials (PPNM) of 1980, the Safeguards Agreement of 1991, the Non-Proliferation of Weapons of Mass Destruction (WMD) Act 87 of 1993 (amended in 1995 and 1996), the Nuclear Energy Act 46 of 1999, the Zangger Committee of 2000, the Additional Protocol of 2000, the National Radio -Active Waste Act 53 of 2008, the Pelindaba Treaty of 2009, and the Nuclear Supplier Group of 2011.[36] In 2008, South Africa developed a Nuclear Energy Policy to supplement the Nuclear Energy Act 46 of 1999, thus laying out the objectives to be met through the use of nuclear energy. A number of the core objectives relating to the paper include the promotion of nuclear

[32] Department of Minerals and Energy, "Acts and legislation – Nuclear", accessed 20 October 2013. http://www.energy.gov.za/files/policies/act_nuclear_47_1999A.pdf
[33] World Nuclear Association, "Nuclear Power in South Africa", (May, 2014), accessed at http://www.world-nuclear.org/info/country-profiles/countries-o-s/south-africa/
[34] National Nuclear Regulator, "History", accessed on 20 October 2013. http://www.nnr.co.za/history/
[35] Necsa, Organisational Structure 2013, accessed on 20 October 2013. http://www.necsa.co.za/Necsa/Company-Information-499.aspx
[36] Department of Minerals and Energy, "Acts and legislation – Nuclear", accessed 20 October 2013.

energy as an important electricity supply option; the establishment of governance structures for a nuclear energy programme; the creation of a framework for safe and secure utilisation; exercising control over unprocessed uranium ore for export purposes to the benefit of the South African economy; promoting energy security for South Africa; and the reduction of GHGs.[37]

In light of the discussion thus far, it is evident that South Africa has put in place the necessary measures to regulate and govern the use of nuclear energy in a safe and responsible manner. Certain regulations developed in the late 2000s were the primary result of the rolling blackouts that the country experienced due to the strain on the power grid. In the immediate aftermath of the 2008 energy crisis, the South African government began to look more closely at the possible use of nuclear energy to provide more clean energy, as well as to ensure that energy needs are met in the medium-to-long term. The current chair of the Nuclear Energy Executive Coordination Committee, President Jacob Zuma, has made strong statements that South Africa is taking a very close look at the potential nuclear energy holds. During the 2014 State of the Nation speech, the president expressed the need to promote the standing of the South African nuclear industry in order to add more power to the electricity grid, which would allow South Africa to pursue its growth objectives through secure energy supplies.[38] One of the main reasons for this notion is the dire need for reform and a more stable energy mix in South Africa's electricity sector.[39] However, the price tag on the projects laid out in the IRP sits close to (or perhaps even over) 1 trillion Rand (US$100 billion).[40] Considering the fact that this is far outside Eskom's reach, the country will have to look towards foreign investors in order to get the nuclear projects off the ground.

Challenges exist in the face of committing to the commissioning of a number of nuclear power plants for South Africa's future energy security, but there exists substantial potential for the country to 'green up' its act and, at the same time, ensure greater provision of energy needs for the foreseeable future. Certain considerations do need to be taken into account during the decision-making process, in order to ensure that the use of nuclear power is, indeed, viable. These include issues of environmental degradation, safety concerns in light of the 2011 Fukushima disaster and previous instances of nuclear reactor meltdowns (Three Mile Island in the US and Chernobyl in

[37] Department of Minerals and Energy, "Nuclear Energy Policy of the Republic of South Africa", accessed 20 October 2013. http://www.energy.gov.za/files/policies/policy_nuclear_energy_2008.pdf
[38] Jacob Zuma, "Full text of President Jacob Zuma's state of the nation speech 2014 #SONA2014", *Times LIVE*, (17 June, 2014), accessed at http://www.timeslive.co.za/politics/2014/06/17/full-text-of-president-jacob-zuma-s-state-of-the-nation-speech-2014-sona2014.
[39] Conrad Kassier, "Behind South Africa's nuclear Ambitions", *News24*, (5 August 2012), accessed at http://www.news24.com/MyNews24/Behind-South-Africas-nuclear-ambitions-20130802
[40] Carol Paton, "State stands ground on SA's nuclear ambitions", *Business Day*, (25 April 2013), accessed at 17 October 2013. http://www.bdlive.co.za/business/energy/2013/04/25/state-stands-ground-on-sas-nuclear-ambitions

the former USSR), and storage and disposal of nuclear materials. The technology does, however, possess many benefits.

Merits of using nuclear energy, strategies for waste disposal, and current developments in South African nuclear energy initiatives

There are a number of positives linked to the use of nuclear energy that need to be taken into consideration. Nuclear energy is, by far, the least polluting, along with renewables such as wind, solar, hydro and biomass, and has a substantial lifespan. For example, the Koeberg reactors are still in operation 30 years after going critical, and have an estimated lifetime of 40 years. Thus, considerations for the use of nuclear energy should go towards efficiency and the decreased carbon footprint. In recent years, coal has contributed a vast amount of GHGs to the South African environment and polluted certain sectors of the country to a point where the air is barely breathable. In 2010, coal was responsible for 87% of CO_2 emissions, 96% of sulphur dioxide (SO_2), and 94% of nitrous oxide emissions.[41] Estimates by Greenpeace in a 2012 study conducted by the University of Pretoria, note that the negative externality costs on health, water, mining and climate change just for one coal station the size of Kusile, would amount to over R30 billion per year, potentially even double that.[42] As stated earlier, South Africa is one of the biggest emitters of GHGs in relation to other developed countries, and is far higher than the global average. At the same time, South Africa is looking to substantially boost economic growth in the coming years to alleviate the dire unemployment situation.

There is a major problem which stands in the way, however. At present, there is the belief within trade unions such as the National Union of Mineworkers (NUM), that there will be incremental job losses as a result of the increase in high-skilled nuclear energy procurement away from labour-intensive coal mining.[43] The aforementioned study conducted by Greenpeace notes that global demand for coal will drop as a result of the rise in carbon emission standards, and that this has already become evident in South Africa with annual reductions in production of roughly 5%. In the long run, this would mean that jobs in the coal mining sector (accounting for some 57,000 workers), as well as in power generation, will inevitably decrease. Thus, the South African government needs to take into consideration the feasibility of using nuclear energy as a partial alleviator to coal, in order to ensure that emissions do not escalate while the country

[41] Menyah and Wolde-Rufael, "Energy consumption," 1374.
[42] Greenpeace, "The True Cost of Coal in South Africa - Paying the price of coal addiction", 2012, accessed at http://www.greenpeace.org/africa/Global/africa/publications/coal/TrueCostOfCoal.pdf
[43] "NUM against nuclear energy", *News24*, (2 July, 2014), accessed at http://www.news24.com/Green/News/NUM-against-nuclear-energy-20140702

begins the process of creating more high-skilled job opportunities and growing the economy.

In the coming years, it will become increasingly feasible to use nuclear energy in sectors of industry to reduce dependence on hydrocarbons as a fuel source and, hence, reduce GHG emissions. An advantage of using nuclear energy for power generation is the production of hydrogen, which can be used in a new global hydrogen-driven economy. While the majority of hydrogen in the world today is produced through the burning of fossil fuels, the hydrogen produced through nuclear reaction is via water. The only challenge that stands in the way of realising a global hydrogen economy is cost-effective technologies for the production of hydrogen. By using hydrogen produced during the nuclear reaction of energy generation, and further developing storage and processing mechanisms for this hydrogen, nuclear energy can provide an alternative sector to the South African economy and, thus, ensure economic growth while maintaining carbon emissions at constantly decreasing levels.[44] The clean hydrogen can also be used in hydrogen -driven motor vehicles, which have already become available on the global market. At the same time, it can be used to produce synthetic liquid fuel cells - in which South Africa is a leader through its coal-to-liquids synthetic fuels - to generate viable alternative fuels in other sectors of the economy, such as petroleum and diesel alternatives.

The hydrogen fuel extraction process can be achieved through the use of the locally engineered and developed PBMR technology. In the short term, PBMR technology can be used as an alternative to natural gas as the main energy type needed to process heat-to-steam-methane-reforming.[45] PBMR can also use process heat (meaning heat generated from the nuclear reaction) to generate hydrogen at efficiency greater than 40%. It can also be used to generate hydrogen from hybrid sulphur while the high-steam electrolysis process can be used to generate hydrogen fuel cells for transportation. This smaller type of nuclear reactor is far more efficient in relation to other energy sources. In comparison to pressurised water reactors (PWRs) and coal-fired power plants, it is nearly 10% more efficient, with a 40 year lifespan.[46] It also provides better safety as the design rules out core-meltdown, even in the worst case scenario of all systems failing. It has the ability to produce a 400-500 MWt (thermal) energy, which is enough to power a number of towns.[47] This reactor technology is well suited for developing countries and can, in the long term, be exported to other nations. Construction time is substantially shorter, with roughly 24 months needed for the construction of each

[44] Greyvenstein et al., "South Africa's opportunity to maximise the role of nuclear power," 3032.
[45] Greyvenstein et al., 3033.
[46] Emily Grubert, Brian Parks, Erich Schneider, and Srinivas Sekar, "Pebble Bed Modular Reactors Versus other Generation Technologies: Costs and Challenges for South Africa", GLOBAL Discussion Paper, (2011), accessed at https://www.academia.edu/2014701/Pebble_Bed_Modular_Reactors_Versus_Other_Generation_Technologies_Costs_and_Challenges_for_South_Africa
[47] Greyvenstein et al., 3034.

module. In terms of costs, it also proves more feasible to procure as opposed to other energy sources. To this end, PBMR fares better and is cheaper than photovoltaic solar power (PV), concentrated solar power (CSP), and PWRs.[48] The waste disposal system is substantially better due to the silicon and graphite fuel form, both of which are materials that are geographic and stable in nature.[49]

The waste management system for the PBMR continues to undergo research and testing. It includes the interim storage of spent fuel at the reactor site (approximately 40 years), followed by either reprocessing or interim storage, and then deep geological disposal or storage at a central site, followed by spent fuel conditioning and treatment and interim storage and deep geological disposal.[50] The utility of using PBMR in the long run is highly dependent on the ability to get rid of nuclear waste as well as to ensure the least amount of environmental damage possible. While at present the PBMR project has been cut from the budget due to the high costs involved, should investors be willing to fund further R&D into PBMR technology, it could prove of great benefit to, not only South Africa, but the world at large. Skills and job creation have been evident in the running of the PBMR project. Shortly before severe budget cuts in 2010, the project employed over 700 highly skilled workers and sought to also meet equity demands. The breakdown of the workforce included some 400 Whites, over 200 Africans, nearly 30 Coloureds, and 50 Indians.[51] While this labour force is substantially lower than that employed by the coal sector, it has the ability to create further job opportunities in other areas such as microbiology, geology, botany, chemistry, physics, materials sciences and engineering. All of these are highly-skilled areas that South Africa needs to further develop. This is also consistent with the notion that South Africa seeks to use nuclear energy in sectors of health, nutrition and agriculture, which falls in line with its national obligations.[52] PBMR technology stands to change the face of nuclear energy and its benefits globally if given the opportunity to showcase its ability. There is, however, a need for support from the South African government to put the project back into commission, as well as the need for investment to continue driving R&D forward.

In the meantime, the South African government has also taken additional steps to further enhance its prospective nuclear energy developments. For the better part of 2013, South Africa initiated talks with a number of countries for the construction of six new nuclear power plants. Among bidders are Russia, China, the US, Britain and most

[48] Grubert et al., 5.
[49] Greyvenstein et al., 3034.
[50] Smith and Bredell, "Development of a strategy," 2416.
[51] PBMR Annual Report – 2010.
[52] "SA has a right to nuclear research, say minister", *News24*, (27 March, 2014), accessed at http://www.news24.com/Green/News/SA-has-a-right-to-nuclear-research-says-minister-20140326

recently, France.[53] According to former Energy Minister Dipuo Peters, the construction of the six new nuclear power plants has the potential of creating an additional 70,000 new jobs.[54] In mid-2013, Peters further affirmed that the South African government is taking a closer look at the Eastern Cape province as a possible location of the power plants, due to its proximity to the Indian Ocean and its current status as a major energy hub.[55] Greater safety measures have also been undertaken by the South African government following the Fukushima disaster in 2011. The NNP conducted safety reviews at the Koeberg nuclear power plant and the Safari-1 research reactor located at Pelindaba, west of Pretoria, both of which have had positive feedback with only minor changes required.[56]

Criticisms of using nuclear energy

Despite the notable benefits of using nuclear technology and energy to diversify South Africa's energy mix, there has been some opposition to the notion of using this type of energy. As mentioned earlier, one of the biggest hurdles is the impact that this may have on the existing labour force in the coal sector. However, as already noted, global demand for coal is decreasing, as is the production of coal in countries with the highest GHG emissions (China being one of them). Therefore, South Africa will lose jobs in the coal production sector regardless, be it the result of a drop in global demand or the procurement of other forms of energy.

Safety has been cited as a major issue. As also mentioned earlier, previous nuclear disasters are always on the minds of environmental protection groups as well as concerned citizens. However, as pointed out above, should the PBMR project receive a capital injection to continue with R&D, there is substantially less safety risks in the use of the technology as opposed to importing foreign and much larger nuclear reactors. Other countries have already seen the possibility that PBRM can offer, with offers coming in from the US and Indonesia for the purchase of the existing patents.[57] In this sense, the fact that other countries are willing to invest in the technology should signal the viability of the PBMR project and thus the need to continue with R&D.

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[53] Ayesha Ismail, "France eyes nuclear contract in South Africa", *France24*, 15 October 2013, accessed 20 October 2013. http://www.france24.com/en/20131015-south-africa-france-eyes-contract-build-nuclear-plants-hollande

[54] "Six nuclear power stations planned", *Fin24*, 8 September 2010, accessed 20 October 2013. http://www.fin24.com/Business/Six-nuclear-power-stations-planned-20100908

[55] Keith Campbell, "SA looks nearly set to start new nuclear power station build programme", *Engineering News*, 5 April 2013, accessed 20 October 2013. http://www.engineeringnews.co.za/article/sa-looks-nearly-set-to-start-new-nuclear-power-station-building-programme-2013-04-05

[56] Campbell, "SA looks set to start," 5 April 2013.

[57] Martin Zhuwakinyu, "Indonesia expresses interest in SA's dormant PBMR", *Engineering News*, (4 July, 2014), accessed at http://www.engineeringnews.co.za/article/pbmr-2014-07-04.

A final criticism which has emerged with an aim to curb nuclear development is the costs of the proposed fleet of new reactors. The R1 trillion price tag is far outside Eskom's reach and will therefore necessitate substantial foreign investment (hence the mentioned actors such as Russia and China who are very interested in developing this fleet). However, in hindsight, the costs of the Medupi and Kusile coal-fired power stations have together amounted to over R220 billion since the start of construction.[58] Considering that Kusile is only half - built, the overruns could easily amount to R400 billion, and this is for building two coal-fired power stations instead of six nuclear stations. With a simple calculation, one can note how the costs of four additional coal-fired stations (with Coal 3 to be built as mentioned by President Zuma), could easily go over the R1 trillion projected for the proposed nuclear fleet. In this regard, the price variation may not be as great as many sceptics assume.

Conclusion and Recommendations

Looking back in hindsight, there are a number of relevant issues that have been ascertained in relation to South Africa's current and future energy mix. As noted, the South African government is seeking to diversify the makeup of energy in the country for a number of reasons.

Firstly, the country is at present far too reliant on coal for energy production and power generation. The main driving factor for this trend has been the historic isolation that South Africa endured during years of apartheid. Post-1994, however, new policies sought to delve deeper into diversifying this trend. Among the factors cited for the diversification is the inefficiency of using coal for power generation. As pointed out, South Africa uses twice as much energy to produce manufactured products as the majority of the developed world (and even in some cases, the developing world). This leaves South Africa lagging behind in terms of efficiency and productivity in both the manufacturing sector (which is the largest consumer of power) as well as electricity generation. To this end, South Africa has to diversify its energy mix in order to stay competitive in the global business environment.

Secondly, the South African government is aware of the fact that in the long run using coal as the main power supply is highly polluting and costly. Current GHG emissions place the country in the upper echelon of global emitters. As a result, the ramifications to health, mining, water and the environment will prove far more costly than securing more coal-dependant power. The fact that the new coal-fired power stations of Kusile and Medupi are located near massive coal fields will compound this

[58] David McKay, "Eskom faces Medupi cost surge as project delayed", *MiningMx*, (8 July, 2013), accessed at http://www.miningmx.com/page/news/energy/1631229-Eskom-faces-Medupi-cost-surge-as-project-delayed#.U87QzZSSw2Y.

issue and are likely to elevate the noted effects. At the same time, the high costs of transmission systems to get power from the source to sectors of the economy are unfeasible and unsustainable over a long period.

Thirdly, global policies on reducing greenhouse gases are driving down the production of coal in developed (and even some developing) countries. As South Africa is looking to play a greater role in global politics as well as stand as a leader in African affairs, the government is conscious of the need to include less polluting aspects to the energy mix. At the same time, the decrease in global demand for coal has been impacting production for a number of years and thus the labour force in coal mining and power generation has decreased. To this end, the government has had to look closer at how to diversify the energy make-up of South Africa in order to provide opportunities for growth and employment in other energy related sectors (such as renewables, oil, gas, biomass and nuclear).

Lastly, the government has had to weigh its options quite carefully. While renewable energy has great potential to decrease GHGs and provide room for economic growth, it is only partly feasible. The reason for this is the base load capacity of renewable energy. It will take many years to bring up the share of renewables to levels necessary to sustain economic growth. Thus, the options left on the table are more coal-fired power plants or introducing more nuclear energy as part of the diversification. The reasons why the South African government is adamant on using nuclear energy are quite straightforward. Firstly, there is an already existing knowledge of nuclear technology in South Africa through the operational reactors at Koeberg in the Western Cape. Both reactors have been in use since the mid-1980s and have proved stable and efficient in providing 5% of South Africa's energy needs. Secondly, the base load carrying capacity of a nuclear reactor is equal to that of coal-fired power plants, yet only fractionally as polluting. To this end, the government sees the opportunity to hit 'two birds with one stone'. On the one hand, there is an opportunity to increase the contribution of alternative energy away from coal, which would be able to substitute the current output of coal-fired plants. On the other hand, South Africa would be able to decrease the current levels of GHG emissions while still providing the necessary power needed for economic growth.

Combined, the above factors have pushed South Africa closer to the procurement of more nuclear power plants in a bid to diversify the energy mix, decrease GHG emissions, provide stable power that will stimulate growth and foreign investment, and lower the overwhelming dependency on coal that currently exists. While the government has taken steps in moving this issue forward by opening up rounds of bidding by international nuclear suppliers (like China and Russia), a certain home-grown aspect has been overlooked. As mentioned, the locally developed PBMR reactor has great potential in meeting SA's energy needs while cutting out the risks of maintaining and operating larger reactors. It has been proven to be more efficient than other nuclear energy power generation units, less costly, easier to maintain and operate,

and has, in fact, been targeted by foreign investors for purchase of patents and development rights. Using PBMR as opposed to procuring from abroad would also allow for greater technological and skills transfers to the local workforce, provide room for economic development through stable power supplies, and allow for indigenous growth in other sectors of the economy such as science, physics, biology, health, and agriculture, among others.

For these reasons, as a recommendation for future initiatives, the South African government should take a much closer look at existing nuclear technology, as opposed to opening up bidding for foreign technology to infiltrate the domestic nuclear market. Rather, more effort should be placed on acquiring the necessary funding for the completion of a working PBMR module, and then replicate the process once the initial reactors come online. While it will be near impossible to secure funding for more than two reactors at first, the payoff will be evident once they start generating power and South Africa begins to increase its energy efficiency. The South African government should also strongly consider the implications of importing such technology. Without the necessary skills transfer from the prospective companies involved in the construction process, the construction of the nuclear facilities will create a dependency on imported labour to maintain the facilities and ensure the stable operation of the reactors. As a recommendation, the South African government should ensure that the contracted enterprises adequately transfer skills and knowledge to the South African workforce in order to ensure local growth within the sector.

A further recommendation would be to not let the future of a hydrogen-driven economy pass South Africa by in the same way as the commodity boom did a few years ago. The opportunity needs to be seized now, as the rewards to be reaped will be substantial. South Africa needs to take the initiative on this end rather than allowing other countries to do it and reap the benefits. This will only be realised through a strong policy for the commissioning of the PBMR through either a massive government capital injection or foreign direct investment. However, this is currently unfeasible, hence the same guidelines should apply when foreign companies enter the South African market to construct the nuclear plants. Harnessing hydrogen as an alternative clean energy source will prove of major benefit to the South African aim to decrease CO_2 emissions and ensure greater energy security. Time will tell how the aspect of nuclear energy will unfold. One thing is certain, however: nuclear energy is about to start playing a big role in South Africa's energy security.

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