Progress or Proliferation?
South Africa's Nuclear Future

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Introduction: Progress or Proliferation?

The present and future of South Africa's nuclear capabilities are inextricably bound up with the social and political history of apartheid. However, while South Africa is known as the only country in the world to have voluntarily given up a well-developed nuclear program, the history of uranium mining and the genesis of the nuclear program go back to the very beginning of the Cold War. In 1944, Winston Churchill asked South African Prime Minister Jan Smuts to survey South Africa's uranium deposits.[1] The study, which included findings from geological papers from the 1920s, revealed the existence of large deposits of low-grade ore on the Witwatersrand, home of the rapidly growing South African gold mining industry.[2] The Combined Development Agency (CDA) was established by the United States and the United Kingdom that same year to procure uranium for the US and UK nuclear weapons programs. This was the beginning of a bumpy relationship between South Africa and the West on nuclear issues. Viewed in the context of the current debate over nuclear fuel supply and domestic enrichment, South Africa's dramatic turns as a pariah state, NPT signatory, and Non-Aligned Movement leader highlight the difficulties of using political criteria to designate privilege in the nuclear arena.[3]

In 1951, the CDA established the South African firm Calcined Products (Pty) Limited (Calprods) to produce uranium as a by-product of the country's gold mining operations.[4] The CDA financed Calprods and managed the firm in cooperation with South Africa's Chamber of Mines. The uranium produced was owned by the South African Atomic Energy Board (established in 1948 as the successor to a "Uranium Committee"), which approved the sales to the United States and the United Kingdom. In July 1957 under the "Atoms for Peace" program, South Africa and the United States signed a bilateral 50-year agreement for nuclear collaboration. Under the agreement, South Africa acquired the Safari-1 reactor and an assured supply of highly enriched uranium (HEU) fuel for the reactor.[5] South African scientists also studied physics in the United States, later becoming important players in the nuclear program that began in earnest in the 1970s. By June of 1985, the US House of Representatives had adopted an amendment to the Anti-Apartheid Bill that banned nuclear cooperation of any kind with South Africa.[6]

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[1] Fischer, David, "South Africa: As a Nuclear Supplier," in W.C. Potter, ed., *International Nuclear Trade and Nonproliferation: The Challenges of the Emerging Suppliers*. Toronto: Lexington Books, 1990, p. 273.
[2] Fig, David, "Political Fission: South Africa's Nuclear Programme", *Energy & Environment,* Vol. 17 No. 3, 2006, p. 460.
[3] The United States appears to be making politically motivated preliminary "special rules" about which countries would be allowed to enrich uranium under various proposals to establish multinational nuclear fuel centers and subsidized fuel-supply arrangements to limit enrichment capability to a more easily monitored group. See Ferguson and Potter, "Lining up to enrich uranium," *International Herald Tribune,* September 12, 2006.
[4] IAEA South Africa Country Profile, accessed online at http://www-pub.iaea.org/MTCD/publications/PDF/cnpp2003/CNPP_Webpage/PDF/2002/Documents/Documents/South%20Africa%202002.pdf
[5] Minty, Abdul, "South Africa's Nuclear Capability: The Apartheid Bomb," in P. Johnson and D. Martin, eds., *Destructive Engagement: Southern Africa at War*. Harare: Zimbabwe Publishing House, 1986, p. 205
[6] "The House Has Voted to Ban Nuclear Trade with South Africa," *Nuclear News*, July 1985, p. 17; *Nuclear Developments*, 25 February 1988, pp. 1-3.

After fifty years encompassing the rise and fall of apartheid, official United States sanctions against South Africa[7], and the changing landscape of the Nuclear Nonproliferation Treaty (NPT), there is growing domestic and international concern that the country has come full circle in its stated desire to restart a domestic uranium enrichment program.[8] Although South Africa has been very careful to specify that any such program would take place commercially and respecting all international obligations,[9] the suggestion of uranium enrichment in Africa is sensitive in the context of the current debate over Iran's domestic centrifuge enrichment and a climate of conflict between nuclear "haves" and "have-nots" under the NPT.

South Africa values its principled voice in the international arena, but also its leadership position in the Non-Aligned Movement and as a strong advocate for disarmament and NPT Article IV "inalienable rights" to the peaceful uses of nuclear technology. These two positions have presented conflicting challenges during the United Nations Security Council's debate over Iran's nuclear program and the Nuclear Suppliers' Group's (NSG) consideration of the US-India nuclear deal. South Africa's credibility in the non-proliferation regime is important because of its potential to influence the direction of the global non-proliferation for developing countries: either positively, by promoting a multilateral and responsible approach to nuclear technology and material, or negatively, if it chooses a defensive and nationalistic path towards domestic enrichment that threatens efforts to prevent nuclear proliferation.[10]

This paper argues that attempting to enrich uranium through the development of domestic centrifuge technology would be neither cost effective nor well received in the international arena. South Africa should choose alternatives that promote multilateralism and transparency, such as collaborating with an established enrichment program or investing jointly in a potentially much more proliferation-resistant enrichment technology such as Argentina's SIGMA. Additionally, South Africa should take a farsighted view towards supporting international institutions that would curb the proliferation of costly, inefficient, and risky domestic enrichment start-up programs. As the only economic and political powerhouse in Africa with deep nuclear experience, South Africa should be especially mindful of the costs involved with domestic centrifuge programs when the majority of South Africans do not have affordable access to electricity. Popular backlash against the Pebble Bed Modular Reactor has recently gained steam, with a South African television documentary presenting the issue as one of wasteful government spending.[11] There are more efficient and equally secure ways to provide power to the continent while promoting a strong non-proliferation regime, including regionally through a revival of the

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[7] The Comprehensive Anti-Apartheid Act was passed by the U.S. Congress in 1986.
[8] "South Africa: Uranium Enrichment," Business Day, August 29, 2006. "South Africa Explores Revival of Uranium Enrichment," Financial Times, August 29, 2006.
[9] Ibid. Financial Times: "[Minister of Public Enterprises Alec] Erwin stressed that any enrichment activities would be conducted commercially under the country's international obligations."
[10] This theme is explored in Boureston, Jack and Lacey, Jennifer, "Shoring Up a Crucial Bridge: South Africa's Pressing Nuclear Choices," *Arms Control Today,* Jan/Feb 2007.
[11] *Carte Blanche,* 8 June 2008, transcript available at http://www.mnet.co.za/Mnet/Shows/carteblanche/Story.asp?Id=3516

1996 Pelindaba Treaty for an African Nuclear-Weapons Free Zone.

Apartheid-Era Nuclear History

In 1965, the Atomic Energy Board (AEB) moved its headquarters from Pretoria to a farm on the Crocodile River west of the city and expanded to include a full-scale research complex called Pelindaba, meaning "the talking is over."[12] The following year, Prime Minister Hendrik Verwoerd was assassinated in parliament, and B.J. Vorster came to power. Vorster was a hard-liner who oversaw the expansion of the nuclear program outside the realm of peaceful purposes. This process arguably began with his decision to split the AEB into two separate entities in 1970; the Atomic Energy Corporation (AEC) continued to conduct research at Pelindaba, while the Uranium Enrichment Corporation (UCOR) constructed the country's first enrichment facility (known as the "Y-plant") at an adjacent site, Valindaba.

The 1970s were marked by a worldwide oil crisis that affected South Africa as a perceived supporter of Israel in the 1973 Yom Kippur war.[13] As the decade progressed, independence movements began taking control of neighboring countries, most notably Angola and Mozambique in 1975 and Zimbabwe in 1980. Domestically, the Soweto students' uprising of 1976 made international headlines and the worldwide anti-apartheid movement began isolating the South African government. It was a moment of great insecurity for the apartheid regime, and in this context the enriched uranium produced at Valindaba was put to use not only at the Koeberg power station, which began operating in April 1984,[14] but also for a weapons program officially approved by Vorster in 1978.[15] In 1977 the South African government broke off negotiations with the International Atomic Energy Agency (IAEA) over safeguards at the semi-commercial Valindaba plant (sometimes known as the "Z-plant", not to be confused with the "Y-plant"), and in June of that year the IAEA removed South Africa from its Board of Governors as worldwide pressure against apartheid grew.

On September 22, 1979, a United States Vela satellite detected a bright flash of light "near the Southern tip of Africa" that American officials estimated could have been the detonation of a nuclear device with a 2-4 kiloton yield. Suspicion immediately fell upon South Africa, which denied involvement through the president of the AEB, J.W.L. De Villiers. However, perhaps hoping to gain deterrence value from the incident (consistent with South Africa's stated objectives in developing nuclear weapons) Foreign Minister Pik Botha refused to deny South Africa's involvement. Israel was also suspected of

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[12] Fig, David, "Political Fission: South Africa's Nuclear Programme", *Energy & Environment,* Vol. 17 No. 3, 2006, p. 461.
[13] Ibid.
[14] NTI South Africa timeline, accessed online at http://www.nti.org/e_research/profiles/SAfrica/Nuclear/2149_3276.html
[15] The weapons program was active as early as 1971, however, as referenced in statements by the IAEA and former South African president FW DeKlerk after the end of the weapons program. "De Klerk Tells World South Africa Built and Dismantled Six Nuclear Weapons," *NuclearFuel*, Vol. 29, March 1993, p. 7. See also Masiza, Zondi, "A Chronology of South Africa's Nuclear Program," *The Nonproliferation Review,* Fall 1993.

conducting a test, either alone or with South Africa's cooperation. The results remain inconclusive, even though South Africa later pointed to their timeline of development as proof that this was too early for them to have acquired a bomb.[16]

The National Party and the ANC: Termination, Transition, and Renaissance

Explanations vary as to why the South African government decided to abandon its very well established nuclear program in 1990. One argument is that with the release of Nelson Mandela in 1990 and the imminent probability of majority rule, the white government did not want nuclear weapons or technology passed on to the African National Congress (ANC), which as a liberation movement had planted bombs to stall the progress of Koeberg while it was being built. Another common theme, and often the one presented as a lesson for promoting nuclear rollback, is that South Africa built its nuclear weapons program out of insecurity and a desire for protection from the West, and then relinquished it to build political and economic ties when that was made the more expedient option.[17] In either case, with the fall of the Berlin Wall and the collapse of the Soviet Union, which had provided the threat requiring deterrence, the political climate would not sustain continuation of the program.

On February 11, 1990, the De Klerk government lifted the ban on the ANC and Nelson Mandela was released from prison. Two weeks later on February 26, De Klerk issued written instructions to begin dismantling the nuclear weapons program. According to Waldo Stumpf, former president of the AEC, this should be considered the official date that the program ended, even though earlier steps had been taken[18] (a test site in the Kalahari was completely abandoned by 1989, and the Y-plant stopped producing Highly Enriched Uranium that year in response to an "Experts Committee" recommendation).[19] In June of 1991, the dismantling of the weapons program was almost complete, and on July 10 South Africa acceded to the NPT as a non-nuclear weapon state. On September 16, 1991, the government signed a full-scope safeguards agreement with the IAEA, and by September 1993 disarmament was officially concluded when the IAEA General Conference accepted "the completeness of South Africa's inventory of materials and facilities." The General Conference also accepted South Africa's declarations on the dismantlement and destruction of equipment for its nuclear weapons, on transfer of dual-use equipment and facilities to non-nuclear or civilian nuclear uses, and on destruction of two Vastrap test shafts under IAEA supervision.[20] The two enrichment plants were mothballed.

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[16] Stumpf, Waldo, "South Africa: Nuclear Technology and Nonproliferation," *Security Dialogue,* vol. 4, 1993, p. 458

[17] Horton, Roy, "Out of (South) Africa: Pretoria's Nuclear Weapons Experience." *USAF Occasional Paper 27,* August 1999. Accessed online: http://www.fas.org/nuke/guide/rsa/nuke/ocp27.htm

[18] Stumpf, Waldo, "South Africa's Nuclear Weapons Program: From Deterrence to Dismantlement," *Arms Control Today* 25, December 1995/January 1996, p. 6

[19] Reiss, Mitchell, "South Africa: Castles in the Air," in *Bridled Ambition: Why Countries Constrain Their Nuclear Capabilities*. Washington, DC: Woodrow Wilson Center, 1995, pp. 11 and 17

[20] Blix, Hans,"Director General's Statement on the Occasion of the Presentation by the Minister of Foreign Affairs of South Africa," 7 April 1994, *International Atomic Energy Agency,* http://www.iaea.or.at/worldatom/inforesource/dgspeeches/dgsp1994n05.html

This marked South Africa's unique place in history as the only country ever to have built and then dismantled a nuclear weapons program. By the time the first democrat election was held on April 27, 1994, most documents from the program had been destroyed, and the ANC was left not only as a non-nuclear weapon state, which was necessary for building goodwill in the region, but also without any of the infrastructure or documentation of the commercial aspects of uranium enrichment. After taking office, the new ANC government promoted the idea of making Africa a nuclear weapons-free zone and the Treaty of Pelindaba was finalized in 1996, although it has not come into force because many African states have not signed on. South Africa also joined the Nuclear Suppliers' Group and the Conference on Disarmament, and was reinstated to the IAEA Board of Governors.

However, critics were quick to point out that the ANC quickly adopted a non-consultative pro-nuclear stance once in power, abandoning the idea of an annual "Energy Summit" after the first event and promoting an increase in the use of nuclear technology for electricity generation. David Fig has argued that this was both politically and financially predictable: previously excluded groups (blacks and women) wanted to be part of the industry, and newly free black entrepreneurs had stakes in nuclear infrastructure investments. He asks:

What is the reason for this irresolute approach? Has there been a forging of common interests between the former nuclear bureaucracy and key elements of the new political elite? Clearly there are those in the new political elite who felt cheated by De Klerk's decision to dismantle the country's weapons capability. Among many of those who opposed proliferation, there is nevertheless support for the notion that useful commercial nuclear technologies should be retained and made available to potential consumers in the rest of the continent.[21]

The simultaneous development of South Africa's international posture as a principled and unique voice on disarmament and its promotion of peaceful nuclear technology domestically characterized its participation in the predicted nuclear "renaissance" of the early 21st century and led to a complex position in the world of post-9/11 international politics.

A Principled Voice: South Africa in the Current Nuclear Landscape

Political Position

South Africa takes has established itself as a bridge between developed and developing countries, playing a critical role in negotiations on the United Nations Security Council (UNSC), as chair of the NSG, and at the Conference on Disarmament. A Business Day article writing for the domestic South African audience waxed Shakespearian about South Africa's role as (rotating) President of the UNSC:

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[21] Fig, David, "Apartheid's Nuclear Arsenal: Deviation from Development," in *From Defense to Development: Redirecting Military Resources in South Africa,"* eds. Cock, Jacklyn and McKenzie, Peggy. IDRC/David Phillip 1998. Available online: http://www.idrc.ca/en/ev-9376-201-1-DO_TOPIC.html

> Some are born great, others achieve greatness, and some have greatness thrust upon them.' By assigning SA the presidency of the United Nations (UN) Security Council, this body has thrust greatness upon the government and people of our country. By giving SA this responsibility, the security council sends the message that the world has confidence in the ability of the government and the people of SA to contribute meaningfully to the maintenance of global peace and security.[22]

The article goes on to define South Africa's role with regard to the Iran controversy as a mandate "to guide the council towards consensus." And yet, South Africa's leadership of the NAM and its insistence on the "inalienable rights" of all countries to use nuclear technology (interpreted to include enrichment) for peaceful purposes under Article IV of the NPT has created a diplomatic tightrope. A month after the trumpets of optimism blared in the article above, the same newspaper published a more sober note of caution from a South African non-governmental analyst, Thomas Wheeler of the South African Institute of International Affairs, who said that "SA should remain aware that there is an international lack of trust in Iran" and that instead of leaning towards support of its President, Mahmoud Ahmadinejad, South Africa should be pushing Iran to follow Pretoria's lead (presumably regarding openness to inspection and renouncing of nuclear weapons).[23]

Politically, however, South Africa's strong endorsement of Article IV rights stem from a strongly held argument about the country's own domestic energy security. Minerals and Energy Director-General Sandile Nogxina said, "SA needs to ensure that its abundant uranium resources are not exploited for the benefit of the nuclear development strategies of other countries," and that the draft nuclear strategy submitted to the cabinet was "partly designed to guarantee the security of uranium supply" as South Africa embarks on an accelerated nuclear development program to meet energy demand and reduce greenhouse gas emissions.[24] In fact, South Africa's uranium ore is low grade and largely a byproduct of gold mining. Nonetheless, there is an almost panicky note in the statements by countries currently considering or pursuing enrichment technology, inspired at least partly by the US-government inspired Global Nuclear Energy Partnership (GNEP) and similar initiatives aimed at limiting enrichment "rights" to countries that are already fuel suppliers (plus other countries whose nonproliferation credentials are approved by the Bush Administration). Nucleonics Week quoted Australian sources as saying that country, not currently a supplier of enrichment services, "wants to be in the club of recognized enrichers if and when the US-led GNEP initiative carves the world into enrichment 'haves' and have-nots'".[25] Non-aligned states, led by South Africa and Brazil, were reported to have told an IAEA meeting on the subject in October 2006 that any such initiative "must not result in a new cartel of Western supplier states that could control the world nuclear fuel market."[26]

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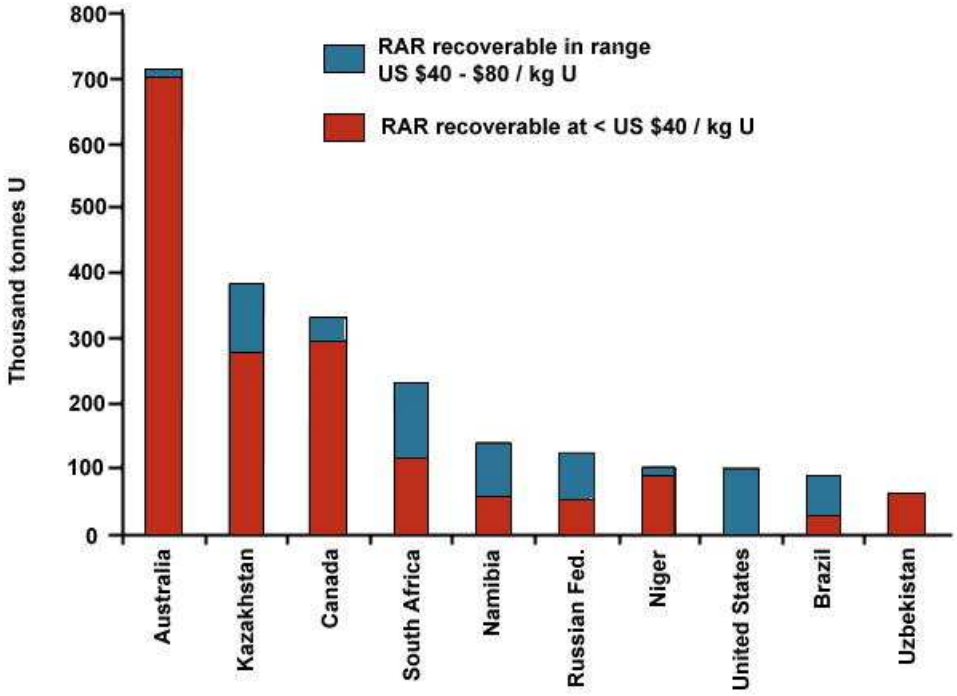
[22] "A Great Chance Thrust Upon SA", *Business Day,* March 7, 2007.
[23] "SA Cautioned on Attitude To Iran Nukes," *Business Day,* April 11, 2007.
[24] "Must Secure Uranium Supply," *Business Day,* May 9, 2007
[25] "Argentina, South Africa studying revival of enrichment programs," *Nucleonics Week,* August 31, 2006.
[26] "South Africa seeks joint venture in gas centrifuge enrichment," *Nuclear Fuel,* October 9, 2006.

Economic Position

Many of the reasons given for the consideration of enrichment technology, however, are put into economic terms. Alec Erwin, the Minister of Public Enterprises who confirmed South Africa's plans on August 28, 2006, said:

Given South Africa's position as a leading producer of uranium, it is only logical for it to assess the economic potential for adding value to the resource. This would include, but not exclusively so, possible uranium enrichment for use as fuel in conventional nuclear-energy plants as well as for the emerging pebble bed modular reactor (PBMR) technology.[27]

South Africa has somewhere between the world's fourth and sixth largest uranium reserves. Some estimates have placed the reserves as making up 10 percent of the world's total.[28]



Reasonably Assured Resources plus Inferred Resources, to US$ 130/kg U, 1/1/05, from OECD NEA & IAEA, Uranium 2005: Resources, Production and Demand, ("Red Book").
http://www.world-nuclear.org/info/inf75.html

[27] "Argentina, South Africa studying revival of enrichment programs," *Nucleonics Week,* August 31, 2006.
[28] "South Africa seeks joint venture in gas centrifuge enrichment," *Nuclear Fuel,* October 9, 2006. Quote by Rob Adam, CEO of NECSA.

WESTERN URANIUM SUPPLY - 2015

	WNA Reference	WNA Upper	Existing & Planned Capacity
Primary Supply:			
Australia	17,702	18,042	13,800
Canada	16,567	16,567	15,380
Kazakhstan	11,219	11,219	8,000
Namibia	4,038	4,038	4,850
Niger	3,282	3,282	3,500
South Africa	2,295	2,295	2,000
USA	3,328	4,098	3,260
Uzbekistan	2,516	2,516	2,500
Other	2,265	4,065	1,800
Total Primary Supply	**63,212**	**66,122**	**55,090**

From Thomas Neff, Center for International Studies, MIT and the World Nuclear Assocation (WNA). Units in metric tonnes/year.

In March, South Africa declared uranium a strategic mineral as it develops an energy strategy that includes the possibility of uranium "beneficiation". Alec Erwin, South African Minister of Public Enterprises, has said, "It would be very strange for any country of South Africa's uranium capacity - and we've done enrichment before - not to beneficiate its uranium deposits."[29] The declaration has been framed in terms of controlling production and export in light of South Africa's potentially expanding nuclear energy program. An economic cost-savings argument has been advanced as well, citing the benefits of rand-based fuel costs not tied to foreign exchange. Echoing the supply-guarantee concern, Rob Adam, CEO of the Nuclear Energy Corporation of South Africa (NECSA) said "If the 'club' [of suppliers] wants to set up a wonderful service, that's fine, but if it's the only service in town, that is not good. The question is, is the rest of the 'club' prepared to have all of the front end of the fuel cycle in South Africa?" He added that the front end would only be undertaken if it was economically justifiable, but that if South Africa does conclude that enrichment is good for the future, "we might do R&D" on a "more economic centrifuge process."[30]

As part of the strategic mineral designation, Minerals and Energy Minister Buyelwa Sonjica has indicated that export of uranium might be restricted under South Africa's new energy plan. This would clearly harm domestic uranium interests given worldwide rising prices and demand. Uranium prices are at historic highs because of 20 years of under-investment in primary uranium production capacity, the end of inventory liquidation throughout the 1980s and 1990s, and expectations of growth, as well as the flooding of Cameco Corporation's Cigar Lake mine, one of the world's biggest developing uranium

[29] Pearson, Natalie Obiko, "Will investors latch onto Africa's Nuclear Plans?" *Globe and Mail (Canada)*, 13 November 2007.
[30] Ibid.

mines that will not begin producing again until around 2013.[31] While mining and export of uranium is a domain where South Africa is already poised to succeed, the competition in enrichment services is fierce. It may not make financial sense for South Africa to enter the enrichment market at all. In fact, according to Charles Ferguson of the Council on Foreign Relations and William Potter of the Center for Nonproliferation Studies at the Monterey Institute of International Studies, "current global enrichment capacity exceeds demand," and "the projected boom in nuclear-energy development in most countries has yet to be matched by major new orders." In addition to the start-up costs of such an endeavor, "the ability of newcomers to supplant the entrenched suppliers is problematic."[32]

Supply and demand in domestic and regional terms form the basis of the government's confidence in expanding the nuclear program. Eskom, the state-owned electricity provider, supplies about 95 percent of South Africa's electricity and more than 60 percent of Africa's. In 2008, regional electricity demand already exceeds supply capacity, and South African power exports are being curtailed. Government officials report that although nuclear energy currently represents between 4 and 6 percent of South Africa energy generation, the government wants to build a new base load nuclear plant by 2017. NECSA expects nuclear capacity to increase by 20 GWe in 2025 so that nuclear contribution to power would rise from 6 percent to more than 25 percent and coal's contribution would fall from 87 percent now to below 70 percent. The new program will start with up to 4 GWe of PWR capacity to be built from 2009-10, with the first unit commissioned in 2016. The environmental assessment process is under way, and selection of technology will follow in the first half of 2008.[33] The government's estimates are probably ambitious, especially because of environmental protest factors (more on that below). Still, the short-term shortage of demand capacity in the next 10-15 years (less than 10GWe of output) for enriched uranium makes domestic enrichment economically unviable in any country, South Africa included (see Appendix A). By even the most conservative estimates, a domestic centrifuge program with little hope of competing efficiently with established technology like URENCO's would take ten to twelve years to develop. The startup cost and time to operation, compared to the margins of technical capacity for a new program and an uncertain demand capacity do not make domestic centrifuge enrichment a viable choice.

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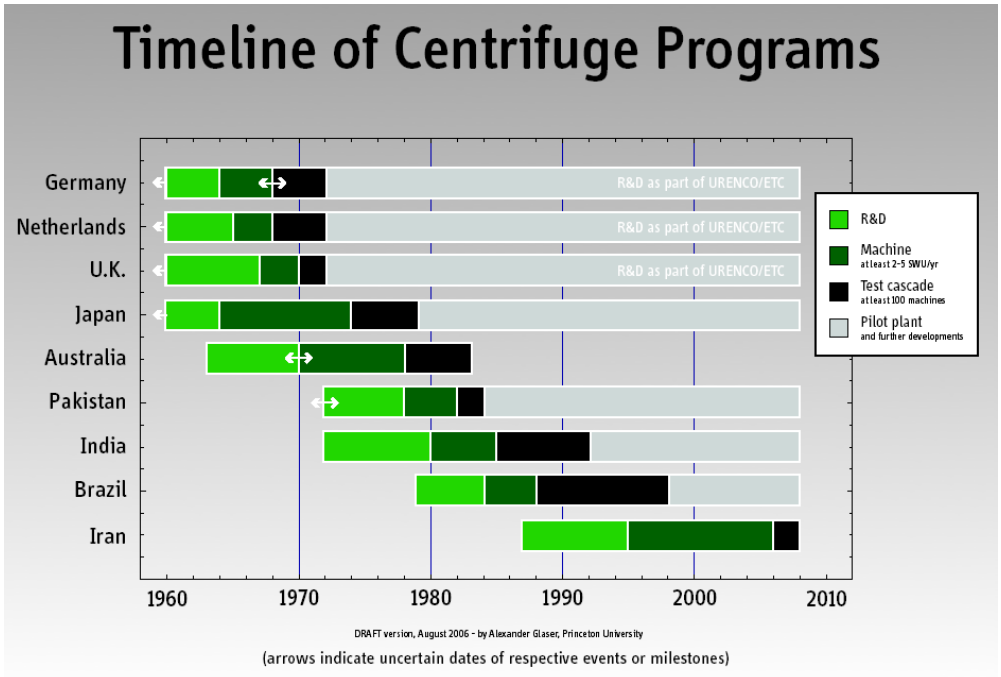
[31] "Cameco reveals Cigar Lake Failures," *World Nuclear News* online, May 9, 2007: http://www.world-nuclear-news.org/explorationNuclearFuel/090507Cameco_reveal_Cigar_Lake_failures.shtml

[32] Ferguson, Charles and Potter, William, "Lining up to enrich uranium," *International Herald Tribune,* September 12, 2006.

[33] Uranium Information Center, Melbourne, Australia, "Nuclear Power in South Africa," Briefing Paper 88. Accessed online: http://www.uic.com.au/nip88.htm



From A. Glaser, "The Gas Centrifuge and Nuclear Proliferation," presentation on March 11, 2007.

Environmental Position

A 2002 study showed that South Africa produces more than 90 percent of the continent's greenhouse gas emissions and 3.4 percent of world energy-related carbon dioxide emissions.[34] Reliance on coal-based energy sources explains South Africa's proportionally larger carbon dioxide emissions in comparison with many other industrializing countries. Seventy-four percent of primary energy consumption comes from coal, and another 20.9 percent from oil. Climate change is on the government's agenda, and nuclear energy is considered to be part of the solution. This characterization is disputed by at least one active non-governmental organization, Earthlife Africa, which runs a campaign titled "Nuclear Energy Costs the Earth". The NGO has cost NECSA in real terms: the Corporation spent 3.5 million South African rand (around half a million US dollars) on a probe in 2005 after Earthlife Africa went public with claims that former workers at the Pelindaba complex suffered from lung cancer and other radiation-related illnesses. The report cleared NECSA of the most egregious radiation charges, but did significant damage to its public image. Such accusations and follow-up reports have continued.[35]

In 1999 in response to environmental lobbyists, NECSA admitted that its Pelindaba complex inadvertently discharged higher than allowed amounts of radioactive liquid material into the Crocodile River in the second quarter of 1999. The National Nuclear Regulator (NNR), which monitors South Africa's nuclear industry, found no negative

[34] Energy Information Administration, U.S. Government, "South Africa: Energy and Environmental Issues," accessed online: http://www.eia.doe.gov/cabs/safrenv.html

[35] Campbell, Keith, "Radiation not responsible for illnesses – Necsa", *Engineering News,* 20 March 2007

impact on the environment from the radioactive discharge, but gave NECSA 24 hours to demonstrate that it had implemented all necessary measures to remedy the situation.[36]

Eskom has also been a target of Earthlife Africa campaigns, most notably a lawsuit over an Environmental Impact Assessment (EIA) that makes it unlikely that the next large conventional nuclear plant could be online by 2013 or 2014, or even the revised 2017 estimate as Eskom has claimed. One source told Nucleonics Weekly in February that the EIA process hasn't even begun, and there was no way to tell how long it could last. PBMR Ltd. (the company responsible for the pebble bed modular reactors) sought an environmental go-ahead on the demonstration PBMR for more than six years, waiting for the Department of Environmental Affairs and Tourism to issue a record of decision (ROD) on Eskom's EIA covering the project at Koeberg. The department's initial positive ROD was successfully challenged in court by Earthlife Africa on grounds that public comment had been insufficiently taken into account. The administration decided to redo the process rather than appeal.[37]

Taken in total, the challenges of developing domestic uranium enrichment would seem to outweigh the benefits; but as Ferguson and Potter point out, "other factors are at play."[38] Weighted more heavily than economic and environmental concerns are the drive for energy security and the fear of a nuclear fuel supply dependent on a "cartel" of Western states or on being designated politically acceptable by the enrichment "haves". This poses a problem both for South Africa in taking a leadership role, and for the IAEA in promoting an agenda that guarantees access to nuclear fuel for all states in good standing with the NPT while preventing the spread of nuclear weapons.

Summary: Domestic Centrifuge Technology

Attempting to enrich uranium through the development of domestic centrifuge technology would be neither cost effective nor well received in the international arena. South Africa has suggested that energy security, potential cost savings, and even job creation are good reasons to pursue this route. However:

1. South Africa's current nuclear power capacity is under 10GWe. Domestic centrifuge enrichment technology cannot cost-effectively be used to secure a nuclear power program at this stage. This negates the immediate energy security and cost savings arguments.

2. While enriched uranium can also be sold on the international market, this can be done through means other than domestic centrifuge technology, which will not involve significant job creation for the South Africans who are most in need of employment. Alternative sources of "clean" energy, such as wind, have much more job creation potential. Furthermore, an enrichment program is not required to foster talented scientists,

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[36] "Nuclear Waste Pumped into S. Africa River Exceeds Legal Limit," *Agence France Presse,* May 30, 2000

[37] "South Africa's near-term plans include up to 3,000 MW of nuclear", *Nucleonics Weekly,* February 15, 2007

[38] Ferguson and Potter, "Lining up to enrich uranium," *International Herald Tribune,* September 12, 2006

even in the nuclear arena.

3. Getting centrifuge technology up and running domestically would take at least a decade by conservative estimates, using other countries' timelines as a guide.

4. If South Africa decides to act alone it will face heightened international suspicion and squander its credibility in the non-proliferation regime. As the current chair of the NSG and a non-permanent member of the United Nations Security Council, it is in a unique position to use its moral and strategic weight to strengthen the non-proliferation regime, specifically with regard to Iran and the US-India nuclear deal. Beginning a domestic centrifuge program after having given up its nuclear program would severely weaken South Africa's standing in the world.

Policy Recommendations: Alternatives to Domestic Centrifuge Technology

1. Collaborate with an established enrichment program. There are two possibilities: partner with Russia by buying a share of a Russian enrichment plant, or use black box technology from either Russia or URENCO. Both of these options would remove both the long-term burden of developing indigenous centrifuge technology and the international condemnation sure to accompany such a move. Both would create the possibility of energy security for future nuclear power expansion. The South African government has expressed interest in a possible partnership, and should focus this to the exclusion of rhetoric about centrifuge development.

2. Invest in proliferation-resistant enrichment technology. If South Africa wants to keep the domestic enrichment option open, indigenous development of centrifuge technology should not be considered. Instead, South Africa should invest now in the research and development of a proliferation resistant enrichment technology such as Argentina's SIGMA. South Africa and Argentina are currently strengthening trade ties. Both are members of the Nuclear Suppliers' Group (NSG) and both formerly had nuclear weapon programs but are now prominent nonproliferation voices. Cooperating with Argentina on new proliferation resistant enrichment technology would lend international credibility to South Africa's developing energy security plans.

Proliferation Resistant Enrichment Technology: SIGMA

If South Africa, after completing all of the necessary cost-benefit analyses, chooses to pursue a domestic uranium enrichment program, it should be at the forefront of supporting and investing in proliferation-resistant technology. The SIGMA technology, developed by the Comision Nacional de Energia Atomica in Argentina, is based on the gaseous diffusion method. (For a comparison of the proliferation dangers of various enrichment technologies, see Appendix B.) It is widely accepted that gaseous diffusion methods are more proliferation resistant than centrifuge technology. Although centrifuge plants may be less costly to operate than classical gaseous diffusion plants, research and development is still ongoing and SIGMA is poised to compete in the world technology market. In particular, the developers of the SIGMA technology evaluate their technology

taking into account the cost of external safeguards, making a strong argument for a holistic, societal approach to costing enrichment methods based on proliferation resistance, IAEA costs, and enrichment operators' bottom line. This is an approach that South Africa should support.

Conclusion: the Larger Implications of South Africa's Decisions

South Africa is at a crossroads, and must critically examine its history in order to chart a farsighted and strategic course in the energy and nuclear arenas. Historically, South Africa experienced political isolation under apartheid and saw the HEU fuel supply for its Safari-1 research reactor suspended by the United States in 1976 under pressure from the anti-apartheid movement. The peaceful transition to a democratically elected government brought to power a liberation party, the ANC, which embraced the opportunity to participate in the nuclear technology opportunities generated during the apartheid years. Perhaps ironically, the current government seems to have taken on the collective fears left from South Africa's historical insecurities rather than rejecting them outright in favor of multilateral solutions. The ANC also shares the fears of other uranium mining countries that they may be permanently excluded from the enrichment "club" if the US or Russian programs to curtail enrichment go forward, and those fears extend to the politicization of nuclear fuel supplies.

There is an opportunity now for South Africa to take the lead in pursuing a peaceful nuclear power program that does not rely on domestic centrifuge technology, however. With other African states expressing interest in nuclear power,[39] South Africa should be mindful of its role to either lead positively or create destabilizing factors. When one state pursues a domestic enrichment program, it can unbalance an entire region, as is happening in the Middle East in response to Iran's diplomatic intransigence.[40] The question remains whether South Africa's nationalist tendencies on energy security will hold sway over its principled stands on nonproliferation in defining its international policy voice on uranium enrichment, nuclear fuel supplies, and nonproliferation.

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[39] Kanhema, Tawanda, "Is Africa ready for nuclear energy?" *The Statesman,* Ghana, December 4, 2007

[40] Broad, William, and Sanger, David, "With eye on Iran, rivals also want nuclear power," *New York Times,* April 15, 2007

Appendix A. Worldwide Installed Nuclear Power Requiring Enriched Uranium

Table 1: Worldwide Installed Nuclear Power Requiring Enriched Uranium

States with nuclear power	GWe requiring enrichment
USA	97.8
France	63.5
Japan	47.7
Russia	21.7
Germany	20.3
South Korea	14.3
Ukraine	13.2
United Kingdom	9.6
Sweden	8.9
Spain	7.6
Belgium	5.7
China	5.3
China (Taiwan)	4.9
Czech Republic	3.5
Switzerland	3.2
Bulgaria	2.7
Finland	2.7
Slovak Republic	2.5
Brazil	1.9
South Africa	1.8
Hungary	1.8
Mexico	1.3
Lithuania	1.2
Slovenia	0.7
Netherlands	0.5
Armenia	0.4
India	0.3
Pakistan	0.3

Blue: more than 10 GWe installed
Green: part of multinational consortium with >10 GWe total

Table 1 illustrates the impact of the 10 GWe criterion. The figures given show installed nuclear power that requires enriched uranium for fuel as of 2005.[14] The states marked in blue already have 10 GWe of installed power. Out of these, South Korea and Ukraine do not have enrichment plants. Note that Canada, although it has over 10 GWe of capacity, does not need an enrichment plant because its reactors are fueled with natural uranium. Note also that Brazil, Argentina, Iran, South Africa, China and Pakistan have enrichment facilities but not 10 GWe of installed nuclear power. United Kingdom and the Netherlands, shown in green, meet the criterion based on the multinational-facility criterion discussed below.

From Habib et al, "Stemming the Spread of Enrichment Technology: Fuel-Supply Guarantees and the Development of Objective Criteria for Restricting Enrichment," January 2006 Woodrow Wilson School report.

Appendix B. Proliferation Sensitivity of Enrichment Techniques

Note: SIGMA is a small facility and therefore differs from the gaseous diffusion plants whose characteristics are shown here. It would therefore have a smaller inventory and it would be easier to do batch recycle.

Table 2.1. Important enrichment technique property ratings according to their contribution to proliferation sensitivity

	Separation factor	Equilibrium time and inventory	Size of dedicated facility	Ease of batch recycle	Reflux chemistry and criticality problems
Gaseous diffusion	3	3	3	3	1
Centrifuge	2	1	1	1	1
Aerodynamic					
Nozzle	3	1	2	2	1
Helikon	3	1	2	1	1
Chemical					
Solvent extraction	3	3	3	3	2
Ion exchange	3	3	3	3	2
Laser					
Molecular (MLIS)	1	1	1	1	1
Atomic (AVLIS)	1	1	2	3	3
Electromagnetic					
Calutron	1	1	3	2	3
Ion cyclotron resonance	1	1	2	2	3

Rating 1 implies that the factor presents a low barrier to misuse of the technique; rating 3 a significant obstacle to misuse; and rating 2 somewhere in between.

From Krass et al, "Uranium Enrichment and Nuclear Weapon Proliferation," SIPRI, 1983, p. 19, available online at http://www.sipri.org/contents/publications/Krass83.html