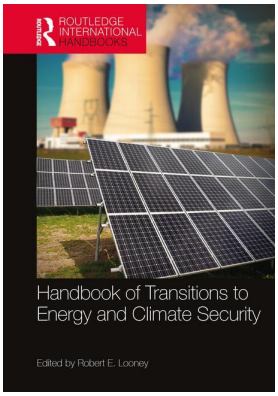

Handbook of Transitions to Energy and Climate Security

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South Africa's pragmatic transition

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Introduction

South Africa accounts for slightly under two-thirds of Africa's total power-generating capacity.[1] The country is richly endowed with sources of energy generating resources, particularly coal. With its large coal reserves, South Africa was able to take advantage of its comparative advantage in developing an energy intensive mining sector through the provision of low cost electricity. The resulting economic development model has been characterized as a powerful "minerals-energy-complex."[2] For years, this model served the country well, generating relatively high rates of economic growth with price stability and more than adequate levels of foreign exchange needed to supply essential imports.

In recent years, however, this energy paradigm has come under increasing criticism as being no longer economically or environmentally sustainable.[3] After years of underinvestment in the nation's power supply, demand for electricity began to noticeably outstrip supply in 2008.[4] Subsequently, the country has experienced sharply rising power tariffs and frequent periods of load-shedding, brownouts and even blackouts.

Energy shortfalls and rising electricity costs are particularly detrimental to the mining industry, which uses 15% of all electricity for drilling and pumping water from mines. In December 2015 one of the country's largest mining companies, Anglo American, announced[5] it would reduce its staff by over 50% and sell off many of its assets in an attempt to remain profitable. Moody's rating agency has downgraded its debt to junk status.[6]

The decline in mining, with mineral exports historically making up around 60% of total exports, has put additional pressure on the already large current account deficit. The manufacturing sector also suffers[7] from the adverse effects of power-shortfalls, with foreign investment falling off due to investors' perception of deterioration in the country's business climate. As things stand, energy in South Africa is increasingly seen as a major constraint on growth, new firm development and broad based employment creation. Recent research suggests energy shortages are one of the major factors impeding South Africa's micro, small and medium firms' growth.[8] Studies[9] for Sub-Saharan Africa suggest that these economies suffer a fall in their potential growth of nearly 2% because of inadequate power supplies.

Normally the South African government would have responded to the energy crisis in a conventional manner – massive investments in new coal generating capacity.[10] And to a certain extent this has been the case, although the new plants are falling behind their completion schedules. In energy trilemma terms the country would, as in the past, opt to increase its energy affordability and energy security at the expense of environmental sustainability. However, increased concern in recent years over greenhouse gas emissions and the consequences for the country of increased global warming have forced attention not only on energy affordability but also on water supplies and environmental sustainability.[11]

Currently South Africa ranks[12] 130 out of 130 countries on the World Energy Council's index of environmental sustainability. This stems from the country's extremely high greenhouse gas emissions due to the country's almost complete reliance on coal for electricity generation. The South African government is well aware of the environmental situation, and has made a number of international pledges[13] to reduce carbon emissions. In addition to an improved environment, South Africa is also trying to provide affordable energy to as many low income households as possible. Some 15% of the population still lacks access to modern energy services.[14]

With the decline in the country's mining sector due to falling commodity prices, rising costs, labor strife, and falling investment, South Africa is finding a new development model will be necessary if growth and employment creation are to be restored. Simultaneously making major changes in its development strategy and energy priorities will present major challenges. The sections that follow attempt to identify the complex factors that are likely to come to bear as South Africa attempts its energy transition away from coal and a new development model away from mining.

Energy patterns and trends

As might be expected South Africa's energy trilemma pattern shares several similarities to the four other (Saudi Arabia, Canada, Russia and Mexico) carbon-producing countries examined in the current volume. But because the country is a coal producer and the others largely reliant on oil, a number of notable differences also occur.

Relative to other carbon-producing countries, South Africa scores considerably below the others in overall energy performance defined in terms of balancing the three main dimensions of the energy trilemma: energy security, energy equity and environmental sustainability. Nor has there been an improvement on this key energy dimension over the available data period, 2011–2015 (Table 12.1). As with the other carbon-producing countries, South Africa, as noted, demonstrates a priority of energy security and energy equity at the expense of environmental sustainability.

The deterioration in the country's energy equity score in recent years is reflective of the rapid rise in energy prices brought on by the growing gap between electricity supplies and demand. As discussed below, the recent improvement in energy security can be attributed to the encouraged expansion of renewable fuels to help fill the country's electricity shortfalls.

These general patterns are supported by another trilemma-type assessment of the energy sector, the World Economic Forum's Energy Architecture Performance Index (EAPI).[15] The EAPI provides a measure of the relative performance of the energy sector in national energy systems. The EAPI consists of eighteen indicators reflective of progress in three trilemma-like sub-indexes: (a) economic growth and development, (b) environmental sustainability, and (c) energy access and security.

In the EAPI framework, economic growth and development captures the impact of the country's energy sector on the country's economic expansion. Environmental sustainability

Table 12.1 The energy trilemma: carbon-producing countries

	2011	*2012*	*2013*	*2014*	*2015*	*2011/2015*		*Score*
						Difference	*Average*	
South Africa								
Energy performance	93	97	93	96	93	0	94.4	
Energy security	52	55	43	42	30	22	44.4	B
Energy equity	73	75	78	85	87	−14	79.6	C
Environmental sustainability	129	129	128	129	130	−1	129	C
Saudi Arabia								
Energy performance	57	57	57	67	54	3	58.4	
Energy security	32	38	45	68	49	−17	46.4	B
Energy equity	18	14	12	7	7	11	11.6	A
Environmental sustainability	124	124	124	125	120	4	123.4	D
Canada								
Energy performance	8	9	8	4	9	−1	7.6	
Energy security	2	2	1	1	1	1	1.4	A
Energy equity	2	2	2	2	2	0	2.0	A
Environmental sustainability	61	66	60	56	71	−10	62.8	C
Russia								
Energy performance	53	48	46	40	43	10	46.0	
Energy security	1	1	2	2	15	−14	4.2	A
Energy equity	65	57	61	44	37	28	52.8	B
Environmental sustainability	102	102	99	104	108	−6	103.0	D

	2011	2012	2013	2014	2015	2011/2015		Score
						Difference	Average	
Mexico								
Energy performance	51	47	38	37	55	−4	46.0	
Energy security	28	35	29	30	37	−9	31.8	B
Energy equity	62	52	47	43	61	1	53.0	B
Environmental sustainability	71	73	75	74	80	−9	74.6	C

Source: World Energy Council, Energy Trilemma Index, 2015, https://www.worldenergy.org/data/trilemma-index/country/.

depicts the impact of energy production and consumption on the environment. Finally, energy access and security measures the degree to which the country's energy supply is secure, accessible and diversified. Scores for each are assigned on a scale from 0 to 1 with the EAPI a composite of the three sub-indexes.

The EIPA and related sub-indexes for South Africa show several interesting patterns relative to other carbon-producing countries (Table 12.2). On the overall EAPI summary index, South Africa scores the second lowest, above Saudi Arabia. On the other hand, South Africa ranks above the group average in terms of economic growth and development and environmental sustainability. Energy's relatively high economic impact in South Africa probably stems from the fact that the country's energy sector has more linkages with the domestic economy than is usually the case for oil based economies. However, because of its oil import dependency South Africa scores considerably below the group average on the energy access and security dimension.

In the last several years (2013–2015) South Africa has made the greatest improvements in its weakest area, energy access and security. Progress occurred to a lesser extent in environmental sustainability, while the country suffered a decline in the energy sector's contribution to economic growth and development. No doubt rising energy tariffs and shortfalls account for this decline and highlight the importance of expanded energy production if the country is to break out of its current economic slump.

Both the World Energy Council's Energy Trilemma Index and the World Economic Forum's EAPI index represent the culmination of past patterns of both energy usage and production. In this regard the composition of South Africa's energy mix shows some similarities and differences with those found in the other energy-producing countries. As expected all four countries have a predominance of fossil fuels in energy use, with South Africa's averaging in the high 80% level, with a slight upward trend since 2000 (Table 12.3).

Combustible renewals and waste account for slightly over 10% of the country's total energy use with a downward trend of 7.3% between 2000 and 2012. This was considerably less of a decline than found in Saudi Arabia, Russia and Mexico. Because it has only one nuclear plant, the 30-year-old 1,800 MW Koeberg facility near Cape Town,[16] alternative and nuclear energy only accounts for around 2.5% of South Africa's energy mix and this has been declining simply because nuclear generating capacity has remained constant.

At least through 2012 renewable energy has also been declining as a share in South Africa's final energy consumption. This source accounted for 18.5% in 2000, but by 2012 this had fallen to 16.9% for a decline of 8.5%. However as discussed below, this trend is likely to be reversed in the near future as the country is turning to renewables as a way to close the current electricity shortfall.

Other aspects of South Africa's energy environment relevant for future policy discussion include the fact that the country's energy exports as a percentage of energy use (Table 12.4) have been falling[17] rather sharply since 2000. In 2000 the country exported about a third of its energy, largely coal, but by 2012 this had fallen to 18.6% for a decline of 44%.

Of the energy-producing countries surveyed here, South Africa had by far the greatest CO_2 intensity (Table 12.4) measured in terms of kg per kg of oil equivalent energy use. In other words, South African energy use to date is one of the worst in terms of contributing to global warming. While there has been a slight downward trend in CO_2 intensity, South Africa lags considerably behind the other energy-producing countries in reducing greenhouse gas emissions.

South Africa's energy use per capita is considerably below the average for the energy-producing countries examined here. No doubt this stems largely from the fact that per capita incomes are

Table 12.2 Global Energy Architecture Performance Index 2013–2015

Country	*Country rank*		*EAPI index*		*Economic growth and development*		*Environmental sustainability*		*Energy access and security*	
	2015	*2013*	*2015*	*2013*	*2015*	*2013*	*2015*	*2013*	*2015*	*2013*
South Africa	*66*	*59*	*0.58*	*0.54*	*0.59*	*0.60*	*0.53*	*0.49*	*0.65*	*0.54*
Saudi Arabia	112	82	0.47	0.46	0.39	0.30	0.19	0.28	0.82	0.78
Canada	25	23	0.69	0.63	0.59	0.61	0.61	0.47	0.89	0.82
Russia	39	27	0.66	0.61	0.60	0.58	0.50	0.54	0.80	0.71
Mexico	55	39	0.62	0.59	0.57	0.61	0.54	0.50	0.76	0.67
Average	59.4	46.0	0.60	0.57	0.55	0.54	0.47	0.46	0.78	0.70
% Change: 2013–2015										
South Africa			*7.41*		*−1.67*		*8.16*		*20.37*	
Saudi Arabia			2.17		30.00		−32.14		5.13	
Canada			9.52		−3.28		29.79		8.54	
Russia			8.20		3.45		-7.41		12.68	
Mexico			5.08		-6.56		8.00		13.43	
Average			6.71		1.48		3.95		11.36	

Source: Global Energy Architecture Performance Index, *Report 2015*, December 2014.

Note: Scores are on a scale of 0 to 1.

Table 12.3 Energy producing countries: composition of energy mix

	200	*2005*	*2010*	*2011*	*2012*	*2013*	*200–2012 % Change*
Fossil fuel energy consumption (% of total)							
South Africa	84.3	87.1	87.5	87.1	87.0		*3.2*
Saudi Arabia	100.0	100.0	100.0	100.0	100.0		*0.0*
Canada	76.8	75.4	74.4	73.5	73.4	72.3	*−4.4*
Russia	91.1	90.7	90.7	91.1	91.1		*−0.1*
Mexico	86.8	87.9	89.3	89.2	90.2	89.4	*3.9*
Combustible renewables and waste (% of total energy)							
South Africa	11.6	10.7	10.2	10.4	10.7		*−7.3*
Saudi Arabia	0.0	0.0	0.0	0.0	0.0		*−26.8*
Canada	4.6	5.0	4.8	4.9	4.9	5.0	*6.3*
Russia	1.1	1.1	1.0	1.0	1.0		*−11.8*
Mexico	6.2	5.3	4.8	4.5	4.5	4.6	*−27.6*
Alternative and nuclear energy (% of total energy)							
South Africa	3.2	2.4	2.4	2.7	2.6		*−17.8*
Saudi Arabia	0.0	0.0	0.0	0.0	0.0		*0.0*
Canada	19.8	20.4	21.7	22.7	23.3	24.5	*17.5*
Russia	7.8	8.4	8.5	8.1	8.1		*3.3*
Mexico	7.0	6.9	6.0	6.3	5.6	6.3	*−20.2*
Renewable energy consumption (% of total final energy consumption)							
South Africa	18.5	16.9	16.9	17.1	16.9		*−8.5*
Saudi Arabia	0.0	0.0	0.0	0.0	0.0		*−23.6*
Canada	20.5	21.5	20.7	20.7	20.6		*0.4*
Russia	3.5	0.36	3.3	3.2	3.2		*−7.2*
Mexico	12.4	10.7	10.0	9.6	9.4		*−24.9*

Data from database: World Development Indicators. Last updated: December 22, 2015.

Table 12.4 Energy-producing countries: aspects of energy use

	2000	*2005*	*2010*	*2011*	*2012*	*2000–2012 % Change*
Energy imports, net (% of energy use)						
South Africa	−33.3	−23.1	−14.8	−15.0	−18.6	*-44.0*
Saudi Arabia	−386.2	−365.9	−186.7	−232.9	−212.1	*-45.1*
Canada	−48.2	−48.6	−57.4	−61.4	−67.1	*39.3*
Russia	−57.9	−84.6	−83.8	−78.0	−76.0	*31.2*
Mexico	−52.1	−44.7	−21.4	−16.2	−19.1	*-63.3*
CO_2 intensity (kg per kg of oil equivalent energy use)						
South Africa	3.4	3.1	3.2	3.2		*0.3*
Saudi Arabia	3.0	3.2	2.9	2.9		*-3.7*
Canada	2.1	2.1	2.0	1.9		*-9.7*
Russia	2.5	2.5	2.5	2.4		*-2.7*
Mexico	2.6	2.6	2.5	2.5		*-3.8*
Energy use (kg of oil equivalent per capita)						
South Africa	2,483.3	2,710.5	2,808.8	2,752.2	2,674.8	*7.7*
Saudi Arabia	4,574.5	4,952.6	6,600.0	6,184.1	6,789.2	*48.4*
Canada	8173.7	8,378.8	7,390.4	7,366.6	7,225.7	*-11.6*
Russia	4,224.3	4,541.0	4,925.1	5,165.8	5,283.4	*25.1*
Mexico	1408.6	1537.1	1486.0	1525.4	1543.3	*9.6*
Energy intensity level of primary energy (MJ/$2011 PPP GDP)						
South Africa	250.2	243.5	232.4	223.9	216.2	*-13.6*
Saudi Arabia	5.5	5.4	6.2	5.5	5.8	*5.7*
Canada	9.2	8.7	7.6	7.5	7.3	*-20.7*
Russia	320.7	250.6	227.3	228.9	226.8	*-29.3*
Mexico	320.7	250.6	227.0	228.9	226.8	*-29.3*

Data from database: World Development Indicators. Last updated: December 22, 2015.

relatively low with some individuals not yet receiving access to electricity. South Africa's precipitate energy use closest resembles that of Mexico with both showing a steady increase in per capita energy use.

Finally, South Africa's energy intensity level is quite high, but still in the same range as that found in Russia and Mexico. Still, South Africa remains by far the most energy intensive economy in Africa, contributing to the country's now chronic power shortfalls. For the longer term, this ratio is likely to fall as the country continues to move away from mining and towards a more diversified manufacturing and service oriented economy.

In sharp contrast to the other energy-producing countries surveyed here, South Africa generates its electricity almost exclusively with coal. Coal is responsible for nearly 94% of South Africa's electricity generation, and this has increased slightly (0.8%) since 2000 (Table 12.5). The next largest coal generating country is Russia at 15.6% and Mexico at 15.0% in 2012, but both countries have been experiencing a relatively rapid decline (2000–2012) in coal usage for electricity generation – 16.9% for Russia and 24.6% for Mexico.

Next to Saudi Arabia, renewables in South Africa account for the lowest share in electricity generation for the countries surveyed here. Percentage wise there has been a 41.1% increase (2000–2012) in electricity generated by renewables, but in 2012 this source accounted for only 1.0% of electricity generated in South Africa.

One of the South African government's main goals has been the spread of electricity access to most of the population. The program has been quite successful with access to electricity increasing by 29.2% from 66.1% in 2000 to 85.4% by 2012. While most urban residents now have access, the rural areas are lagging with access there increasing by 80.2% from 37.1% with access in 2000 to 66.9% by 2012.[18] These additions took place without additional power stations being built. The rapid increase in household access to electricity has significantly contributed to the surge in electricity demand that is currently outrunning available supplies.

Energy plans and resource shifts

The energy situation in South Africa has created several paradoxes. In November 2015 a headline[19] appeared arguing that the recent hiatus in load-shedding was actually bad news because it was a reflection of the stagnation that has been plaguing the South African economy. Between 2014 and 2015 South Africa's peak demand for electricity has shrunk between 1,500MW and 3,000MW because of the economic stagnation that has set in. Even more worrying the peak power demand in 2011 was 3,6000MW whereas in 2015 peak demand was only 3,0000MW. Clearly electricity shortages have taken a tremendous toll on the economy.

Empirical research[20] has identified a statistically significant causal relationship linking South Africa's economic growth to the country's energy supply, with energy consumption a determinant of economic growth. Clearly the country will have to find ways to rapidly expand the supply of electricity if it has any hope of restoring strong economic growth and reducing the high level of unemployment which now stands at around 22% of the labor force.

In order to expand the country's supply of energy, the South African government has developed several comprehensive energy plans, some of which focus on the shorter term, while others are oriented towards reaching longer-term targets. In doing so the South African government no longer leaves the country's power plans exclusively with Eskom, the state-owned utility company. The reasons behind this move lie largely with the size of the task involved in revamping the country's energy system. It also is an attempt to overcome some of the limitations associated with Eskom's coal-orientation and the company's energy stewardship since the days of apartheid.

Table 12.5 Energy-producing countries: aspects of electricity

	2000	*2005*	*2010*	*2011*	*2012*	*2000–2012 % Change*
Electricity production from coal sources (% of total)						
South Africa	93.1	94.6	94.2	93.8	93.8	0.8
Saudi Arabia	0.0	0.0	0.0	0.0	0.0	0.0
Canada	19.4	16.2	13.8	12.2	10.0	−48.3
Russia	19.9	17.3	16.0	15.5	15.7	−20.8
Mexico	9.5	13.6	12.0	11.5	11.7	22.7
Renewable electricity output (% of total electricity output)						
South Africa	0.7	0.7	1.0	0.9	1.0	41.1
Saudi Arabia	0.0	0.0	0.0	0.0	0.0	0.0
Canada	60.6	59.6	61.3	62.0	63.2	4.4
Russia	18.7	18.2	16.1	15.8	15.6	−16.9
Mexico	19.9	15.6	17.6	15.9	15.0	−24.6
Access to electricity (% of population)						
South Africa	66.1		82.7		85.4	29.2
Saudi Arabia	90.9		94.1		97.7	7.5
Canada	100.0		100.0		100.0	0.0
Russia	100.0		100.0		100.0	0.0
Mexico	98.0		99.0		99.1	1.1
Access to electricity, rural (% of rural population)						
South Africa	37.1		64.1		66.8546	80.2
Saudi Arabia	86.9258		90.1		92.8546	6.8
Canada	100.0		100.0		100.0	0.0
Russia	100.0		100.0		100.0	0.0
Mexico	92.5		97.5		97.2	5.1

Data from database: World Development Indicators. Last Updated: December 22, 2015.

Eskom

Eskom and the coal industry began to prosper in 1948 when the apartheid regime came to power. At the time the apartheid government viewed the country's vast coal reserves and the provision of cheap energy as the key to rapid growth. The coal reserves also provided energy security against the anticipated imposition of UN sanctions over the country's racial policies. With the country's post-war economic boom, Eskom grew into the world's fourth-largest power utility as it implemented a strategy that gave preference in electricity deliveries to factories, mines, and white households.

Eskom's expansion stopped in 1985 as anti-apartheid sanctions began to cripple the economy and reduce the demand for electricity. By the time the African National Congress took power (1994) the economy had contracted to the point that Eskom's reserve margin had increased to nearly 30%, or twice the international average.

Understandably Eskom's management viewed the company's backup capacity as adequate for years to come. But post-apartheid governments adopted policies that represented a major shift from their predecessors. Most importantly, these governments placed a high priority on connecting neglected black households, schools and clinics to the grid. In a relatively short period, hookups jumped from 5 million to 12 million.

At the same time, the end of sanctions opened up the economy to foreign investment, and growth, particularly in manufacturing, surged. From 1985–1993 GDP growth had averaged 0.73% per annum with private consumption increasing at an annual average rate of 1.27% and investment declining at an average annual rate of 3.02% per annum (Table 12.6). Manufacturing also contracted at an average annual rate of 0.35%. In sharp contrast, with the end of apartheid, from 1994–2007 GDP accelerated to 6.66% per annum, private consumption rose to 4.46% per annum and investment rose to 7.22% per annum. Manufacturing also expanded sharply at an annual average rate of 3.50% per annum.

Eskom, as often is the case with monopolies, was unprepared for the shift in priorities towards bringing electricity access to communities for the first time during a period of sharply accelerating economic growth. It wasn't until May 2007 that the utility finally reacted to the country's dwindling reserves by authorizing the construction of the Medupi and Kusile mega coal-fired plants to add 10,000MW to the grid.

Originally scheduled to be up and running and providing ample capacity by 2011, both plants are way over budget and years behind schedule. Inadequate planning, skills shortages, labor disruptions and technical issues have hindered the arrival of both coal plants, causing significant delays. The Medupi power station was not supplying the grid until one unit came online in August 2015. The plant will not be at full capacity until at least 2018. The completion of

Table 12.6 South Africa: growth sub-periods (period average, constant price percentage)

	1985–1993	*1994–2007*	*2008–2015*
GDP	0.73	3.66	19.1
Private consumption	1.27	4.46	2.03
Investment	-3.02	7.22	2.43
Agriculture	4.56	1.68	2.44
Manufacturing	-0.35	3.50	0.34
Services	1.16	4.21	2.57

Source: Compiled from EIU South Africa data base.

Kusile's first 800MW unit has been pushed back from 2011 to the first half of 2017, with the plant complete by 2021.

Eskom's other problems stem from the manner in which it responded to the blackout and load-shedding crisis of 2008. At that time, Eskom's management opted for a strategy of "keeping the lights on at all cost." But postponing maintenance for seven years led to an increase in plant breakdowns. After running its 25- and 30-year-old plants at full capacity for seven years, trouble began in January 2015 with multiple equipment breakdowns. Afterwards, Eskom juggled 21 days of rolling blackouts in the first three months of the year as it struggled with plant shutdowns. This stifled production, and manufacturing fell 2.4% in the first quarter of that year.

The country's electricity shortages took a heavy toll on the economy. Specifically, ESKOM's power-shedding program in early 2015 cost the economy between R 20,000m. (US $1,600m.) and R 80,100m.[21] ($6,500m.) per month. Analysts estimate shortfalls in power supplies have cost R 300,000m. ($24,700m.) over the seven years prior to 2015. Other estimates suggest power shortages reduced the potential growth of the economy during 2007–14 by 10%, while also costing more than 1 million jobs.[22]

By the end of August 2015, the country had experienced 99 days of load-shedding leading to significant drops in manufacturing and mining in particular. South African GDP contracted 1.3% in the second quarter of 2015. It was estimated that power cuts had cost the economy between $1.7bn and $6.8bn per month, depending on the load-shedding stage implemented.[23]

Eskom's problems have been amplified due to the accelerating maintenance requirements of its ageing plants, most of which have been run continuously since the 2008 crisis. As things stand, the company is seriously burdened with debt, and based on the Medupi and Kusile experiences, has shown little capability in managing major infrastructure investments.

Integrated Resource Plan (IRP)

After the 2008 load-shedding crisis, the South African government realized the country would experience a recurrent pattern of energy shortages and crisis if it did not take a more active role in planning, particularly for the period following completion of the Medupi and Kusile plants. At the time this was expected to have occurred by 2011 or 2012.

To reduce dependence on coal and improve energy security, the government pledged to increase exploration to find domestic gas feedstock, identified as critical, in the National Development Plan (NDP). The authorities also developed and released a 20-year Integrated Resource Plan (IRP)[24] in 2010 to diversify the energy mix by increasing nuclear, natural gas and renewable power generation capacities.[25] In this regard, the IRP marks a clear departure from the country's traditional reliance on coal-fired power. In 2011, the government also released its Renewable Independent Power Producer Procurement Program in 2011.[26]

The IRP is revised every two years to take into account changes in the energy market and new technological developments. The implementation of the IRP has been a critical component of the country's push to improve supply, opening up space for private sector-led renewable energy. The plan calls for coal-fired electricity to account for less than 15% of all new generation capacity added through to 2030, and for the commodity to provide under 50% of the total grid capacity. Renewables are set to take up 42% of all new generation capacity, which would see the construction of 9.6 GW of nuclear energy and 11.4 GW of renewables, including solar and wind by 2030.

The IRP anticipates that natural gas will also play a larger role, through both imports by pipeline and proposed liquefied natural gas terminals, possibly as well as from domestically

produced sources such as the country's shale gas and coal-bed methane reserves. It is also anticipated that the lives of Eskom's ageing coal-based generators will not be prolonged by retro-fitting pollution control mechanisms. This will require additional new generation capacity to come on-stream, as these stations are to be mothballed from 2018 until 2050.

Shifts of these magnitudes away from coal towards other sources of energy are difficult even under the most favorable of circumstances. Clearly much will depend on the amounts of investment available from both the public and private sectors along with the costs of expansion. On the surface, South Africa would appear to have a number of viable options. A closer look, however suggests a limited range of choices that are economically and/or politically feasible.

Coal

As noted, the IRP marks a clear departure from the country's traditional reliance on coal-fired power. While at first glance this shift may seem to be based largely on concerns over global warming, future profitability in coal projects may be playing a much larger role.

Currently South Africa possesses the world's ninth-largest recoverable coal reserves, with 3.4% of the global total as of the end of 2015.[27] Current coal production comes largely from the mature Witbank, Highveld and Ermelo fields in the Central Basin near the eastern border with Swaziland. Coal production was 145.3m tons of oil equivalent (MTOE) in 2013, increasing to 147.7 MTOE in 2014 after having experienced a brief 0.8% contraction from 2012 to 2013.

While coal has historically proved to be an easily accessible input for South Africa's power sector, this may not be the case for much longer. In 2012 Eskom was anticipating that it would consume 4bn tons of coal from then until 2040.[28] However, investment in new coal projects has been slow to materialize. Eskom is concerned over the possibility of a 17m-tonne coal shortfall at its Matla, Tutuka and Hendrina power stations in 2015 and at the Kriel and Arnot power stations in 2016. In June 2015, Eskom officials began to predict that the company could start running out of coal in 2015. Indeed, by 2020 it could see a deficit of between 60m and 100m tons per year.[29]

With their reserves expected to run out in less than a decade, the industry has turned its attention to inland coalfields in the Limpopo Province and around the resource-rich Waterburg Basin. Commercial viability for exploration depends on overcoming water, transportation and infrastructure constraints. The poor financial health of mining companies – due principally to rising power costs, shortfalls in productivity and steep declines in global coal prices down to $50 per metric tonne – could inhibit large-scale capital investments in exploration programs and greenfield projects. Another factor that may curtail investment is new rules on Broad-Based Black Economic Empowerment (BBBEE). A new supplier of coal now has to have a 50% plus one share empowered.[30] This is up from the 26% figure incorporated in the Minerals and Petroleum Resources Development Act.[31]

Shale

Following the shale boom in the US, unconventional exploration and production has increased around the world and has met with some success in South Africa – although it has not been without its challenges. In 2013 the EIA estimated South Africa's technically recoverable shale gas reserves to be 390 tcf, the eighth-largest reserves in the world.

The Whitehill formation, located in the Karoo Basin and thought to be among the most prolific reserves in the country, holds an estimated 36 tcf of recoverable shale gas, or roughly 30

times that of PetroSA's Mossgas project. In 2009 and 2010 PASA awarded technical cooperation permits to four international energy companies to conduct geological surveys of potential shale reserves in different areas of the Karoo Basin. Following this, the government placed a 19-month ban on fracking as it conducted environmental impact assessments amid concerns over its potential impact on aquifers and ecosystems. The ban was later lifted and the government announced its intention to proceed with the issuing of licenses once the shale regulations are published. The Department of Energy will process existing applications first and will issue new licenses in three years. However, water will remain an issue if only in the form of a premium price that producers will have to pay, given the limited supplies throughout the prime shale bearing districts.[32]

The drop in oil prices has slowed shale activity worldwide, including in South Africa. Shell, which holds three of the five shale blocks, announced in March 2015 the redeployment of its senior staff to outside of South Africa.

Nuclear

South Africa has had 30 years of experience in producing nuclear power, and given the country's pressing need for additional power supplies, nuclear power has a number of strong advocates.[33] Officially the government, based on its 2010 IRP, would like to have 9,600MW of new nuclear power by 2030. President Zuma confirmed the country's commitment to nuclear power in his February 2016 State of the Nation Address[34] when he announced that the country hopes to install 9,600MW of nuclear power over the next 15 years.

However, nuclear advocates face a number of questions concerning the economics of a major expansion in South Africa's generating capacity. In addition to the usual safety concerns, these include the construction costs, length of time between approval and full generating capability, the impact such a large increase in capacity will have on electricity prices, and the terms that the country is negotiating with potential builders. More fundamentally, with Eskom's new projects coming on line in a few years, and the recent surge in investment in renewables, it is not clear that additional nuclear plants will even be needed.[35] Proponents of the program believe this nuclear expansion will unlock South Africa's industrialization potential and secure its energy security. At an estimated cost of between $60bn and $100bn, critics believe it will bankrupt the state and permanently endanger the country's credit rating.

To date South Africa has had exploratory talks with five countries, China, Russia, France, the U.S. and South Korea on collaboration. However, these talks have been very opaque, leading many in the country to suspect corruption and kickbacks to the country's political elite.[36]

Given the uncertainty surrounding nuclear energy in South Africa, major decisions should, no doubt, be postponed until it is determined whether renewable energies have the potential to provide sufficient base-load power in addition to that coming on line during the next several years.

Renewable energy

Until quite recently, and given the country's abundant deposits of coal, renewable energy had played a very minor role in South Africa's energy mix. Yet in a very short period of time, the country has become one of the fastest growing incubators of renewable energy.

This somewhat surprising development came about as a result of two quite unrelated developments. First, the 2008 energy crisis and Eskom's need to rapidly expand the energy supply, and second the fact that South Africa has the largest carbon footprint in Africa: it's responsible

for 40% of the total CO_2 emissions in the continent. At the COP 15 climate conference, the country pledged to reduce its carbon emissions 34% by 2020, and 42% by 2025.[37] By the 2015 Paris COP 21 South Africa was pledging to "peak, plateau, and decline" by 2030.[38] How best to manage both tasks? The South African government concluded the only feasible solution was to expand the supply of renewable energy.

As early as 2009, the government had begun exploring the best way to proceed with renewable energy development. Initially the use of feed-in tariffs (FITs)[39] seemed the best for renewable energy, but ultimately the country settled for a system of competitive tenders. Because of Eskom's financial constraints the government had little choice but to turn to the country's independent power producers (IPPs) for additional amounts of clean power.

To the surprise of many, the resulting program, the Renewable Energy Independent Power Producer Procurement Program (REIPPPP),[40] has been a major success[41] proving to be an efficient and innovative approach to a country-specific renewables policy; it relies on private sector actors – as opposed to the South African government – to realize renewable energy projects. To this end, the policy uses a very clear international bidding process known as renewable energy auctions through its Independent Power Producer Program, which has been praised by the International Renewable Energy Agency (IRENA). Furthermore, the policy not only reduces borrowing and funding burdens that would have otherwise fallen on the South African government, but also promotes off-grid and small-scale renewable projects that the public utility company ESKOM has little incentive to pursue. The policy also aims to reduce corruption risks known to be prevalent in such projects.

The workings of the program are straightforward and transparent. The process is set up to procure renewable energy through bid windows for the IPPs. Each bid window specifies the maximum amount of power that can be purchased for a set price.

And what are the results? The first phase, Bid Window 1, was initiated in 2011 and saw a total of 1,190.34MW auctioned. Of those projects, 99.4% (or 1,182.62MW) have been brought to a commercial stage. This outstanding success – in just a year – led to second, third and fourth bidding windows being announced in 2012, 2013 and 2014 respectively. In total, the government has awarded 3,634.42MW worth of projects. According to IRENA, the number of bidders at the renewable auctions has increased by 50%, while solar and wind costs have shrunk by 39% and 23% respectively. Furthermore, since 2011 – when the first bid was announced – the private sectors, comprising both domestic and international players, have invested a total of $13 billion in South Africa's renewable energy sector.[42]

The South African government has contracted for 3,725MW of renewable energy by 2016. The bidding process will continue until the required amount of energy is available. So far, if recent progress can be sustained the program is on track to meet the renewable target for 2030.[43]

While boosting renewables is the program's main goal, it also pays attention to the country's rampant unemployment and economic inequality. (13% of the South African population does not have access to electricity.) REIPPPP has thus encouraged partial community ownership of the renewable projects, and a share of generated revenue is being diverted towards enterprise development, including hiring locals and transferring skills.

Conclusions

The South African experience is one of pragmatism under stress. Facing a major short-fall in electricity, a government that in the past has shown ambivalence toward the private sector, designed an innovative program to draw on that sector's expertise and financing. The success of

the government's REIPPPP has surprised most observers and is drawing wide-spread attention as an option to improve both energy security and environmental sustainability without major sacrifices in energy affordability.

The transferability of REIPPPP to other settings will depend largely on the willingness of local and international private sectors and financiers to actively participate. The South African case suggests a necessary requirement will be one where a well-designed and transparent procurement process exists, there is a reasonable level of profitability, and where the government is willing to mitigate key risks.

The South African experience also sheds additional light on the energy trilemma. Specifically, by improving incentives or introducing innovative institutional changes previously conflicting objectives can actually be made complementary.

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Part III

Energy transitions in the intermediate carbon-producing/ consuming countries

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