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## FRACKING FOR SHALE GAS IN SOUTH AFRICA: BLESSING OR CURSE?

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### SUMMARY

As the first country to reverse a moratorium<sup>1</sup> on hydraulic fracturing – more commonly known as ‘fracking’ – South Africa is now poised to move forward with the controversial process, exploring what experts believe to be the eighth largest shale gas reserve in the world. For a country that is almost wholly dependent on coal production, shale gas development could be a game-changer. Yet, the possible environmental impacts could also be devastating.

Despite the government’s current plans for exploration, many environmental groups still hold on to the hope that a fracking-free status quo may continue. We explore this possibility in our Base Case scenario, which offers the most promise for preserving the water and natural resources of the Karoo, but the least potential for the country’s economy. Our alternative Shale Boom scenario allows for shale gas development and could significantly boost economic growth, reduce poverty and provide more resources for spending on education, health and infrastructure. Yet, with these gains come steep costs. Widespread fracking could lead to significant water contamination, destruction of natural habitats, increases in earthquakes and no long-term reduction in carbon emissions.

Is there a way to harness the positive power of fracking, reduce its negative impact and move towards a greener future? Our Blue Bridge scenario levies a small tax on fracking that is then invested

in renewable energy infrastructure and production. In this scenario, strong economic growth drives reductions in poverty and increased spending on education, health and infrastructure. It also moves South Africa to a renewable energy-based economy, lowering shale production relative to the Shale Boom, reducing carbon emissions, producing more overall energy and damaging fewer natural resources in the long term.

### THIS SERIES

This paper is the third in a three-part series, the goal of which is to test the central planning assumptions that inform South Africa’s National Development Plan (NDP) 2030. The first paper in the series analysed the feasibility of the NDP’s economic growth rate targets and explored some of the associated human development targets. The second paper explored reasonable population scenarios for South Africa at the national and provincial levels to 2030 by analysing trends in fertility, mortality and migration. This paper examines the implications of exploring and developing South Africa’s shale gas reserves in light of emerging global energy technologies, namely hydraulic fracturing and horizontal drilling.

### STRIKING A BALANCE IN THE FRACKING DEBATE

Earlier this year, when asked by a *Financial Times* blogger about her government’s stance on gas produced from hydraulic fracturing – or fracking – South Africa’s Mineral Resources Minister Susan Shabangu expressed little reserve. ‘We cannot worry that it is controversial,’ she said. ‘We are confident, and we have taken a decision as

government that we are going to go the fracking route.<sup>2</sup> Indeed, just more than a year after lifting its moratorium on the politically charged energy production process, South Africa's government recently announced it would start granting exploration permits for shale gas in early 2014. The pivotal move has sent a strong message to those on both sides of the ongoing fracking debate. Yet, for South Africa itself, the decision is still only an early step on a very uncertain path forward.

Whether or not the government intends to worry about it moving forward, the fiery controversy over shale gas production in South Africa won't just subside once permits are issued. According to the United States (US) Energy Information Administration (EIA), the country possesses the eighth largest shale gas reserve in the world. Former Energy Minister Dipuo Peters has called the resource a 'blessing' from God and other advocates are calling it a potential 'game-changer' for the now coal-dependent country.<sup>3</sup> On the other side, vocal opposition groups highlight the potentially damaging impacts of fracking on the local environment, particularly in the water-scarce Karoo, the region where the bulk of South Africa's shale gas is located.

This paper explores what might happen if policymakers strike a balance between these two sides, one that allows South Africans to take advantage of their rich shale gas reserves in the shorter term, even while protecting their natural resources and environment long into the future. How might such policies impact South Africa's overall economic development? Could they reduce carbon emissions in the long term? How would they measure up to other alternative paths – including a future with no fracking at all?

To help answer these questions, this brief begins by assessing South Africa's current energy profile and elucidating the arguments on both sides of the fracking debate. Then, using the International Futures (IFs) integrated modelling system, the authors compare the long-term impacts of potential energy production scenarios as they relate to South Africa's development goals. Ultimately, this integrated analysis suggests that, with proper management of shale gas production and profits, a route that includes *some* investment in fracking could, in fact, bring South Africa into a sustainable, accessible energy future even more quickly than would a route that doesn't.

## **SOUTH AFRICA'S ENERGY MIX**

Coal dominates the South African energy portfolio, accounting for more than 70 per cent of primary energy production, more than 90 per cent of electricity generation and a third of liquid fuels.<sup>4</sup> High levels of coal

production, an inefficient electricity infrastructure and the fact that a fifth of South Africa's coal goes to the only commercial coal-to-liquid plant in the world<sup>5</sup> make South Africa the sixth most carbon intense economy<sup>6</sup> in the world and the 18th largest energy producer, while ranking only 27th in terms of Gross Domestic Product (GDP).<sup>7</sup> This dependence on coal production not only fosters an unsustainable energy sector – both economically and environmentally – but also means that South Africa could face globally imposed carbon emission restrictions in the future.

While a majority of South Africans likely desire a transition away from coal, a reduction in energy production must be reconciled with the development and energy needs of the poorest South Africans. The country has already achieved great gains in electricity access. Between 2002 and 2012, for instance, the number of households with access to electricity increased from 77.1 per cent to 85.3 per cent.<sup>8</sup> However, to date, more than 10 per cent of the population still does not have any access to electricity. Around 15 per cent of the population relies on solid fuels – such as wood or animal products – as their primary source of domestic energy for cooking and heating.<sup>9</sup> Solid fuels produce high levels of indoor air pollution, causing health issues like pneumonia and chronic obstructive pulmonary disease (COPD).<sup>10</sup> Owing to population growth, an aging energy infrastructure, climate change mandates and a national development plan that emphasises infrastructure investments, energy demand will only increase.

Already, given such expectations for continued growth in demand, the South African government has plans for increasing capacity in both coal-driven and nuclear power. The state owned utility company Eskom has begun construction of two coal plants – Medupi and Kusile – which are expected to come online next year and the National Development Plan (NDP) discusses the possibility of building more nuclear capacity.

## **THE NATIONAL DEVELOPMENT PLAN 2030**

The NDP, developed by South Africa's National Planning Commission (NPC), aims to eliminate poverty and reduce inequality by 2030. These two overarching goals and the targets set to help achieve them are the result of a long process of analysis and consultation undertaken by the Commission. Its diagnostic report outlined its view of South Africa's achievements and shortcomings since 1994.<sup>11</sup> According to the report, the primary challenges to the country's future growth include high unemployment, poor quality of school education for black people, deficiencies in infrastructure, spatial divides that compromise inclusive development,

overreliance of the economy on natural resources, shortcomings in public health and services, high corruption levels and a divided society.

The NDP has also identified key policy issues and planning priorities for the energy sector alone, which include: growth in coal exports balanced against the need for domestic supply; gas exploration as an alternative to coal; a greater mix of energy sources and a greater diversity of independent power producers (IPPs) in the energy industry; improvements in municipal electricity-distribution services; electricity pricing and access that accommodates the needs of the poor; and the consideration of a new nuclear power and/or a new petrol refinery. The NDP has set these targets for 2030 and outlined the steps needed to achieve them as a series of short-, medium- and long-term priorities.

Among its many goals, the NDP has set as a target that more than 20 000 MW of renewable energy will be contracted by 2030 and at least 90 per cent of South Africans will have access to grid electricity during the same time horizon. The government itself has stated even more aggressive targets, aiming for universal access to modern energy (both grid and non-grid) by 2025.<sup>12</sup> In addition, the NDP encourages stakeholders to better understand the extent of economically recoverable coal-bed seam gas and shale gas reserves within the country.

The NDP expands on the gas target by stating, ‘Subject to acceptable environmental controls, these gas resources, supplemented by liquefied natural gas imports, will begin to supply a growing share of power production. This could avoid the need for further base-load nuclear generation.’ The NDP also addresses shale gas specifically in its guiding document. ‘South Africa should seek to develop these resources, provided the overall economic and environmental costs and benefits outweigh those associated with South Africa’s dependence on coal, or with the alternative of nuclear power.’<sup>13</sup> Nonetheless, the weights of these costs and benefits are difficult to measure and it’s these very uncertainties that continue to fuel both the global and domestic debate.

## THE BIG DEBATE: TO FRACK OR NOT TO FRACK

The ongoing dispute over fracking is not exclusive to South Africa, nor will it likely cease there. A 2013 EIA report<sup>14</sup> estimated global technically recoverable shale gas resources at 7 299 trillion cubic feet (tcf) (1 387 billion barrels of oil equivalent (BBOE)) – 32 per cent of total estimated natural gas resources. The report indicated that the largest basins are located in China, Argentina,

Algeria, the US, Canada, Mexico, Australia, South Africa, Russia and Brazil, respectively. In response to the shale boom experienced in the US, some countries like China and Poland are actively investing in shale gas production. Much of the rest of Europe has been more resistant. France and Bulgaria, for instance, have altogether banned fracking and the United Kingdom’s governmental promotion of it has been met with protest.<sup>15</sup>

To give some context, the process of fracking involves pumping water, sand and chemicals deep below the surface of the Earth at high pressures to access gas trapped in small pockets of shale rock – reserves previously thought to be uneconomical or impossible to exploit. The US has been at the forefront of this technology, which has allowed the nation to become the largest natural gas producer in the world, all while decreasing its short-term energy-related carbon dioxide (CO<sub>2</sub>) emissions. CO<sub>2</sub> emissions in the US have decreased by 12 per cent since 2007. Of this reduction, 27 per cent (198 million metric tons of CO<sub>2</sub>) came from electricity generation shifting from coal to gas.<sup>16</sup>

For better or for worse, the US shale gas boom has been hailed as a true energy revolution, one that affects not just production but energy consumption as well. In the US, for example, this so-called revolution in production has led to a decrease in the price of domestic gas, which has incentivised increased consumption. Meanwhile, as history demonstrates, the price of fossil fuels often does not reflect the long-term environmental costs of their production or use. While individual energy companies pay for more immediate production and distribution, the environment and the larger ecosystem are frequently forced to absorb increased carbon emissions,<sup>17</sup> increased exploitation of other natural resources, like water, and more frequent micro-earthquakes.

A similar story could be true for South Africa, especially if it continues down its current route. Yet, as the US and other countries around the world have faced their own challenges in this area, South Africa’s unique political and natural environments require strategic policy choices that no other country’s experience, nor any other energy revolution of the past, can entirely inform.

## WHAT WOULD FRACKING MEAN FOR SOUTH AFRICA?

Understanding how natural gas production is likely to unfold in South Africa is complex. The country is estimated to have 390 tcf (74.1 BBOE) of shale gas resources,<sup>18</sup> yet no wells have been drilled. In response to public outcry concerning issues like water and other environmental effects, the South African Minister of



Mineral Resources issued a moratorium on exploration licences in February 2011.<sup>19</sup> This moratorium was lifted in August 2012, however, making South Africa the first country ever to end a ban on fracking.<sup>20</sup> Though many companies have been granted technical cooperation permits, this does not allow any actual drilling in the Karoo. Minister Susan Shabangu has stated that the government plans to issue permits in the first quarter of 2014.<sup>21</sup>

The following subsections outline some of the biggest uncertainties related to this type of energy development. While many are political in nature, the environmental factors are just as, if not more, important to consider.

## Water

To date, the strongest environmental objection to fracking concerns its use, disposal and potential to contaminate water. In the semi-arid Karoo Basin of South Africa, increased use and possible contamination of freshwater resources could further strain the availability of water for the population that relies on these resources and increase the susceptibility of the region to drought.

### *Water use: How much water is in South Africa?*

Hydraulic fracturing, as the name implies, requires water; each well in the US, for instance, requires between 7.5 and 15 million litres of water.<sup>22</sup> While this is not much on a national level (the 27 000 new gas wells completed in the US in 2011 accounted for only 0.3 per cent of total US freshwater consumption)<sup>23</sup>, since the water is required at the drill site, the problems associated with water use in fracking tend to be localised.

South Africa, and especially the Karoo region, is marked by low annual rainfall and high evaporation, making it the 30th driest country in the world.<sup>24</sup> Average annual rainfall in South Africa is only 495 mm,<sup>25</sup> compared to the world average rainfall of 860 mm.<sup>26</sup> The Karoo Basin itself receives less than 100 mm of rain in a year on average.<sup>27</sup>

While water is not abundant in South Africa, it is extensively used for domestic purposes and for irrigation of crops.<sup>28</sup> In addition, 21 per cent of the rural South African population still does not have access to an improved water source.<sup>29</sup> The need exists to supply these people with water services. Owing to population growth, urbanisation and the requirements of the agricultural and mining industries water demand in South Africa will increase.<sup>30</sup> Using freshwater in the Karoo for fracking could increase the vulnerability of

the rural population's access to water and increase the region's susceptibility to drought.

The total volume of freshwater available on a reliable basis is called the 'yield' – expressed in terms of volume of water per year.<sup>31</sup> The South African National Water Resource Strategy (NWRS) 2004 (using 2000 data) estimated total potential freshwater yield to be 13 227 Mm<sup>3</sup>/year and total consumption to be 12 871 Mm<sup>3</sup>/year.<sup>32</sup> This implies that a surplus of freshwater existed in South Africa in 2000, yet more than half of the Water Management Areas (WMAs) had water deficits that year.<sup>33</sup> Water deficits can increase a region's susceptibility to drought and possibly damage the ecological health of the aquatic system on which humans depend.<sup>34</sup>

Both the Vaal WMA and the Orange WMA, two of the largest inland WMAs, have already reached their yield limits. The Vaal River System serves the economic heartland of South Africa, supplying water to 20 million people and 60 per cent of the national economy – mostly mining operations. According to the NWRS 2013, 'All water resources within the catchment are fully used and no further development of any of the tributaries can be contemplated.'<sup>35</sup> Owing to population growth, migration to Gauteng and economic growth, the NWRS forecasts that an extra 229 Mm<sup>3</sup>/year will be needed by 2035. Since the Vaal River System has reached its potential yield, any increase in water supply will have to come from either water conservation and water demand management (WCWDM) or from the Orange River upstream.

The Orange River is the longest river in South Africa and potentially has more available water than current yield.<sup>36</sup> Even so, using this water requires additional investments in storage infrastructure. Phase 2 of the Lesotho Highlands Water Project (LHWP) is set to be completed by 2020, which will increase the yield of the Orange WMA by 475 Mm<sup>3</sup>/year. Yet, more than half of this water is reserved for the increasing demand of the Vaal WMA downstream. There is also the possibility of increasing the Orange yield through the construction of the Boskraai Dam, which has the potential capacity of 8 000 Mm<sup>3</sup>/year. The South African Department of Water Affairs is now conducting a water resource reconciliation strategy to assess possible future water demands and potential yield for the Orange River System.

While water resources are strained in the inland of South Africa, industrial mining operations and power plants that are more water intensive than fracking can still operate. Access to freshwater will be a major constraint on fracking, not necessarily because of the amount of water consumed but because of the location

of consumption.<sup>37</sup> Shale gas wells tend to have faster decline rates than conventional natural gas wells. This means that many wells have to be drilled over a larger area to reach the same levels of production as conventional gas. Unlike coal mines or power plants, shale gas production cannot receive all of its water needs from a centralised location.

To reduce localised water shortages that result from fracking, water can be transported from areas with surplus. The Vaal Gamagara scheme, for example, has a main pipeline distribution network of 370 km, abstracting water from the confluence of the Vaal River and the Harts River and taking it as far as Black Rock in the Kalahari.<sup>38</sup> These pipeline networks, however, require heavy investment. Re-used or brackish water may prove viable alternatives to fresh water. The NWRS outlines a national desalination strategy and a national strategy for water re-use. The Department of Water Affairs is currently investing in the treatment of acid mine drainage from aquifers in the Vaal River Catchment for possible re-use.

The proximity to available freshwater resources and the ability of the gas industry to use other water sources will determine the constraints on production regarding water use. Proper regulations need to be put in place. This will ensure that the water requirements for fracking do not detract from the domestic or municipal water needs of the South African people now or in the future and that the water requirements for fracking do not detract from the ecological reserve required to protect aquatic ecosystems. Water withdrawal must consider present and future demand, available yield and fluctuations in yield.

### *Wastewater disposal*

Even if gas companies have enough water, they will still need to find a way to dispose of the wastewater. Hydraulic fracturing fluid contains harmful chemicals, some of which are known carcinogens.<sup>39</sup> After a well is drilled, some of this fluid returns to the surface and must be disposed of, either by re-injecting into an old well or at a wastewater treatment plant (WWTP).<sup>40</sup> WWTPs in South Africa are already operating at 80 per cent capacity and a significant portion of the surplus capacity may not be ready due to inadequate maintenance.<sup>41</sup> The WWTPs are also located hundreds of kilometres away from the Karoo Basin.<sup>42</sup> WWTPs, even when operational, are not perfect. Wastewater discharge from a WWTP in Pennsylvania in the US, for instance, was found to have levels of radium above the radioactive waste disposal threshold regulations and with isotopic compositions suggestive of shale gas-produced waters.<sup>43</sup>

Moreover, while fracking routinely causes micro-earthquakes (with a magnitude of less than 2 on the Richter scale), wastewater disposal into deep wells can induce larger and more dangerous seismic activity.<sup>44</sup> Hydraulic fracturing and deep well injections can weaken pre-existing faults by increasing the subterranean fluid pressure. Wastewater from fracking must be managed responsibly for the health of the Karoo and its inhabitants.

### *Contamination*

Water resources can also be contaminated from the fracking process itself. While methane gas has been recorded as occurring naturally in groundwater,<sup>45</sup> a recent study has found concentrations of methane in drinking water to be six times higher in homes less than 1 km from natural gas wells. The isotropic signatures of the contaminated groundwater suggest that the methane originated deep beneath the aquifer.<sup>46, 47</sup>

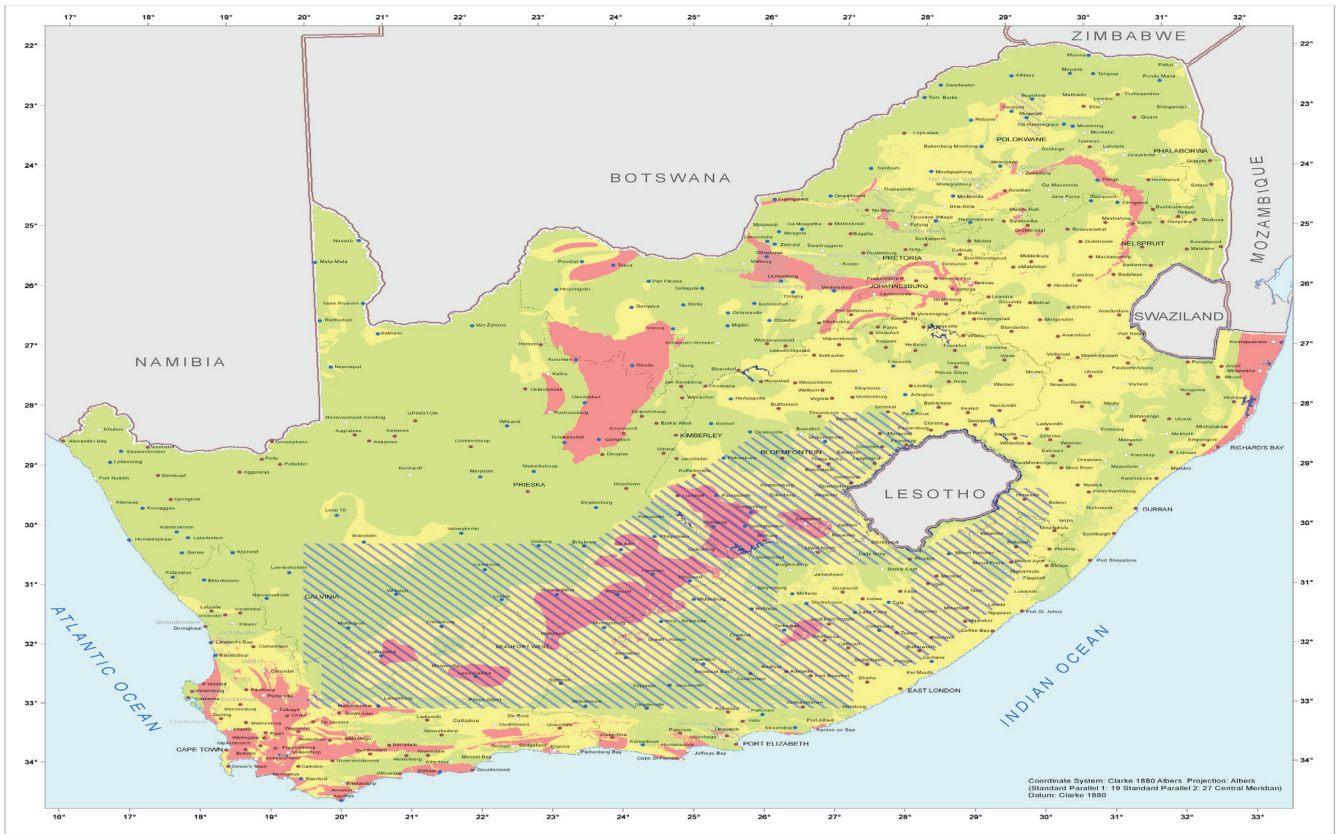
Some aquifers in the Karoo Basin are especially vulnerable to contamination. The map below juxtaposes two sets of information. The Department of Water Affairs of the South African government identifies three different levels of water vulnerability.<sup>48</sup> Red areas identify water sources particularly vulnerable to surface pollution. The shaded areas – taken from an EIA publication – identify where technical cooperation permits have been granted in the Karoo.<sup>49</sup> The map shows that the majority of the land set aside for fracking contains aquifers that are either moderately or extremely vulnerable to pollution.

The responsible management of South Africa's freshwater resources could be the largest physical constraint on fracking in the Karoo. To avoid putting strain on the freshwater requirements of other sectors, the country will need to build additional infrastructure or explore other sources, such as re-used or brackish water. It must also construct wastewater treatment centres to handle the residual fracking fluid. Although it would constrain the amount of land available for fracking, policymakers could also work to ensure that companies avoid drilling in the most vulnerable aquifers.

### *The shale gas effect on emissions and exports*

Many see natural gas as a cleaner alternative to the country's current primary energy source: coal. As in the other countries, it's reasonable to expect that shale development in South Africa could lead to a short-term decrease in CO<sub>2</sub> emissions. Even so, it's important to understand that, while natural gas burns cleaner than coal, a reduction in overall greenhouse gas (GHG) emissions is not a given. The process of natural gas

**Figure 1: Map of aquifer vulnerability in South Africa, Department of Water Affairs,<sup>50</sup> with horizontal line overlay from US EIA showing operator permits in the Karoo Basin<sup>51</sup>**



extraction can release methane into the atmosphere (fugitive methane emissions), a GHG much more potent than CO<sub>2</sub> in driving climate change.<sup>52</sup>

Also, an increase in natural gas production does not necessarily translate into a reduction of coal production. There is very little natural gas infrastructure in South Africa currently and very few natural gas power plants. As a result, critics argue that any natural gas produced in the short term will be exported and coal will still remain the primary energy source. If this were the case, there would be few opportunities for jobs or domestic access. Thus, it's entirely possible that the production of natural gas would not reduce coal production, oil imports or CO<sub>2</sub> emissions. In short, without dedicated policy to manage potential gains effectively, the potential upside of fracking would be largely diminished at the domestic level.

Alternatively, some claim that shale gas can be a 'blue bridge to a green future' – the blue flame of methane could decrease production of coal and oil and give renewables time to become more economically competitive. For example, the shale gas boom in the US has indeed driven down coal consumption, resulting in a reduction in CO<sub>2</sub> emissions. Still, there are several problems with this argument. Increased supply of gas

tends to drive down the domestic price of natural gas, which does lower investment in coal and oil production, resulting in a reduction in annual CO<sub>2</sub> emissions relative to the Base Case over the short term. Yet, some point to the fact that the low price of gas might also reduce investments in renewables, further delaying the transition to a clean energy sector.

### **Regulatory structure and investment**

Shale gas offers private sector investors significant short-term returns on investment, making it a potentially large source of government revenue through taxation. However, the government could shoot itself in the foot, effectively turning these private investors away, if it is not careful with its regulatory structure. To be sure, the largest uncertainty regarding shale gas production in the Karoo will ultimately come down to the policy stance of the South African government.

One example is mineral rights. Under the Mineral and Petroleum Resources Development Act (MPRDA), the government owns all mineral rights.<sup>53</sup> Thus, unlike in the US, landowners in the Karoo would not be able to profit off the volume of shale gas under their land, effectively removing their incentives to sell to energy developers. An amendment to the MPRDA<sup>54</sup> currently being debated



in parliament will put more control over mineral rights into the hands of the government by allowing the mines minister to declare certain minerals ‘strategic’ at whim.<sup>55</sup> Nevertheless, it remains unclear what a ‘strategic’ mineral might mean.

On top of domain issues, the South African government has tabled legislation that would allow it to take a minimum 20 per cent stake, in the form of ‘free carried interest,’ in new gas and oil exploration and production plays. If the law is passed as introduced, the government would potentially have the ability to take as much as 50 per cent of each venture. This complicates the investment environment, as the government would essentially have the right to nationalise major parts of projects without taking on the risks or compensating the owners, likely major oil and gas companies.<sup>56</sup>

In addition to the political framework put in place to facilitate exploration and production, shale gas production in the Karoo will require heavy investments in infrastructure. Midstream infrastructure such as natural gas pipelines, roads and possibly water pipelines will be required as will downstream refineries, power plants and distribution networks, depending on the end-use.

### **Below the surface**

Even if investments are made in the Karoo, production is not guaranteed. Since no wells have been drilled, geological uncertainties still exist. The EIA shale gas resource estimate was lowered from 485 tcf in 2011 to 390 tcf in 2013 because ‘the (Karoo) basin contains significant areas of igneous (sill) intrusions that may impact the quality of the shale resources, limit the use of seismic imaging, and increase the risks of shale exploration.’<sup>57</sup> Until substantial drill-hole knowledge is collected, the amount of the shale resource that is economical to extract remains unknown.

## **FORECASTS**

### **International Futures**

International Futures (IFs) is large-scale, long-term, highly integrated modelling software housed at the Frederick S. Pardee Center for International Futures at the Josef Korbel School of International Studies at the University of Denver. The model forecasts hundreds of variables for 186 countries to the year 2100 using more than 2 500 historical series and sophisticated algorithms based on correlations found in academic literature. As the acronym implies, IFs allows policymakers to ask ‘what IF?’ questions about the future and then suggests aggressive yet reasonable policy targets. While

the future is uncertain, there are different degrees of uncertainty depending on the questions we ask. An inability to know everything about the future does not equate to an inability to know anything about the future. The IFs software allows us to structure this uncertainty using three main functionalities.

First, IFs allows us to see past relationships between variables and how they have developed and interacted over time. Second, using these dynamic relationships, we are able to build a Base Case forecast. This represents where the world seems to be going given our history and current circumstances and policies, and an absence of any major shock to the system (wars, pandemics, etc.). Third, scenario analysis augments the Base Case by exploring the leverage that policymakers have to push the systems to more desirable outcomes.

The IFs software consists of 11 main modules: Population, Economics, Energy, Agriculture, Infrastructure, Health, Education, Socio-political, International Political, Technology and the Environment. Each module is tightly connected with the other modules, creating dynamic relationships among variables across the entire system.

The energy module is a partial equilibrium model, which uses differences in production and consumption for each country to calculate energy prices each year. These prices, along with technological advances and drawdown of total resources, are used to determine levels of investment in each energy type for each country. Energy production is calculated using these levels of investment. Carbon emissions for each country are calculated using total fossil fuel energy production.

The energy module is disaggregated into six different fuel types for each country: oil, coal, gas, hydro, nuclear and renewables. Production of each fuel type for each country is forecasted. Yet, since the model assumes that energy types are relatively fungible in the long-term, energy price, energy demand and energy trade for each country are not disaggregated into fuel type.

### *IFs forecasts*

Using the IFs forecasting software, we have constructed two different scenarios, in addition to the IFs Base Case. In general, the IFs Base Case forecasts a future that is based primarily on historical trends and the implications of already implemented policy. It does not account for any major policy shifts or exogenous shocks to the system. Note that the IFs Base Case, as is now developed, is mostly optimistic about the onset of renewables globally; this factors significantly into

the analysis at hand. For instance, in the Base Case, as renewable energy production increases, we expect growth in coal production in South Africa to begin to slow as early as 2020; in this scenario coal production would then peak in the early 2030s and begin to decline in subsequent years. The Base Case also forecasts a peak, then a plateau in South African carbon emissions, with a significant decline not likely until the early 2030s.

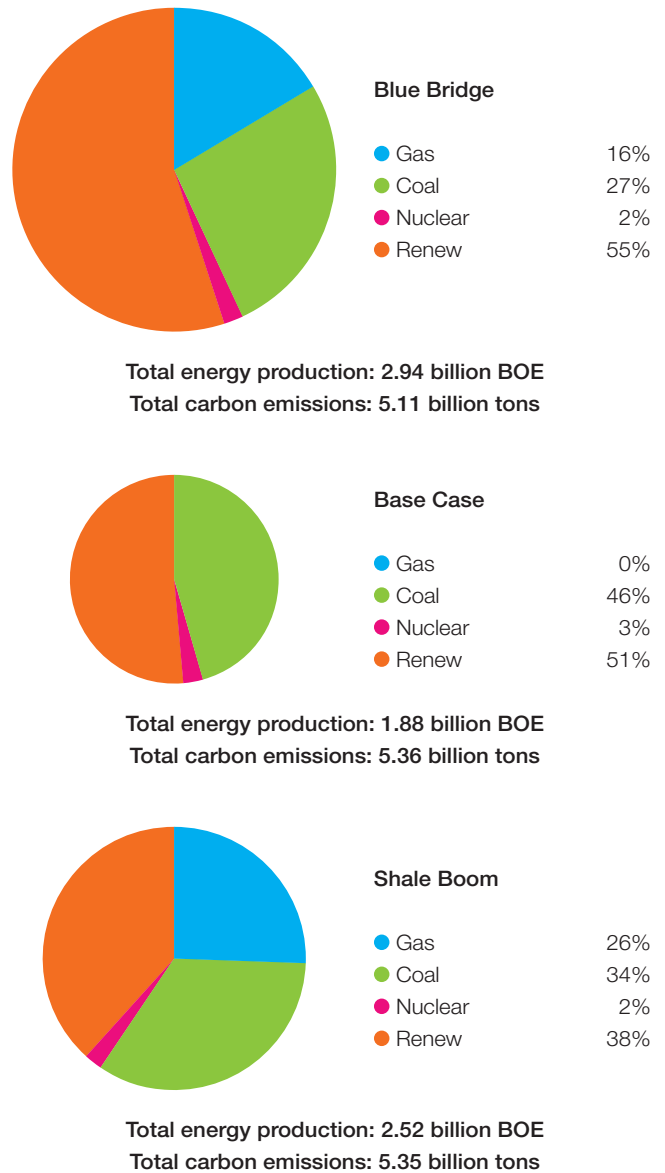
Additionally, despite the increasing likelihood of its adoption, the Base Case here assumes no shale gas production. This provides a basis for comparison to the other scenarios – both of which include shale gas – and also accounts for the still existing possibility that fracking won’t advance as the South African government now intends. By contrast, the model and Base Case do account for increased nuclear capacity at a basic level. According to the country’s integrated resource plan, a total 9 600 MW of power should be generated from nuclear sources by 2030.<sup>58</sup> Finally, the Base Case does not include South Africa’s intentions to meet the carbon emissions targets, which were set as part of its participation with the Copenhagen Accord. If these targets are met, then coal production will likely peak sooner than in the model’s Base Case.

To better understand what might happen if South Africa pursued limited levels of fracking in the Karoo, we created a second scenario that represents a Shale Boom.<sup>59</sup> In this scenario South Africa increases its natural gas production to 644 million barrels of oil equivalent (MBOE) by 2050, reaching the same levels of coal production observed at the end of Apartheid. Here, the South African energy production portfolio is much more diversified than in the Base Case, with natural gas, coal production and renewables comprising most of the energy output. Under this scenario, an increase in natural gas production is partially consumed domestically and partially exported.

This boom in natural resource production leads to an increase in overall GDP, along with an increase in per capita production by over ZAR 12 156 (USD 1 200) in 2050 compared to the Base Case. Relative to the Base Case, these positive spillovers reduce the number of people living in extreme poverty by 400 000 (comparing scenarios in 2050). They also allow the government cumulatively to spend ZAR 912 billion (USD 90 billion) more money on healthcare, education and infrastructure, and increase government revenue generation by ZAR 3 394 billion (USD 335 billion).

While the benefits are apparent, certain trade-offs exist that may affect the nation as a whole. For instance, the increase in natural gas exports would make the exports

Figure 2: South African energy scenarios 2050



Individual pie chart size based on total energy production. Radius used to scale pie charts.

of goods and services from other parts of the South African economy more expensive. This phenomenon is called the ‘Dutch Disease’. While energy exports increase by 69 per cent (from 3.8 per cent of GDP in the Base Case in 2050 to 6.1 per cent in the Shale Boom scenario), the exports of services, manufactured goods, agriculture and ICT all decline.

In addition, while the move to shale gas would initially have a slight downward impact on South African emissions (reducing them in the first four decades of the Shale Boom scenario relative to the Base Case by 1 per cent), the long-term impacts would be negative for climate change. In the short run, emissions are reduced because energy production substitutes gas



for coal, which is more carbon intensive. However, in the long run, extra natural gas should drive down energy prices, leading to increased energy demand and enough additional gas being consumed means that the aggregate carbon emissions are greater. In addition, the lowered energy price delays investment in renewable energy production.

Producing 644 MBOE of shale gas in 2050 will require 23 million m<sup>3</sup> of water.<sup>60</sup> At just 0.2 per cent of total water consumption in 2004, this is not much on a national scale. But, as stated above, the location of water use will be a constraint to fracking. In addition, by placing restrictions on fracking near vulnerable aquifers, the government could significantly decrease the potential land area under production. Companies engaged in fracking will have to dispose of this wastewater appropriately, requiring additional investments in wastewater treatment and management (WWTM). Fracking can also become costly rather quickly if even just small amounts of water are polluted across time. If only 1 per cent of all water used in fracking is polluted and accumulates, the Shale Boom scenario will lead to 2.8 million m<sup>3</sup> of water polluted. That is the equivalent of 1 100 Olympic-sized swimming pools.

In response to the negative effects of a shale gas boom in South Africa, we have built a third scenario: the Blue Bridge Scenario. In this scenario, South Africa capitalises on the economic gains from a shale gas boom by investing in renewable energy, which will drive long-term sustainability.

One of the largest barriers to renewable energy production in South Africa lies in the nature of renewable energy itself. It is decentralised and intermittent, restricted to locations where the resource is abundant and can only generate electricity when wind or sun is present. By contrast, traditional industrial power plants operate and distribute electricity from a centralised location. From this central hub, power companies can control the generation, transmission and distribution of electricity for the entire grid, increasing or decreasing generation as demand fluctuates.

One solution to this barrier to renewable energy penetration involves the use of backup gas turbines to supplement renewable energy generation. Gas turbines are more suited to integration with renewables than coal power plants.<sup>61</sup> They can be built on a smaller and more modular scale and have shorter start-up times. This means they can be more easily integrated into a diverse electricity sector that includes renewable energy like wind and solar. South Africa already enjoys abundant wind and solar resources, and natural

gas could be an ideal fuel to help the country take advantage of them.

Adding upon the Shale Boom Scenario, the Blue Bridge Scenario introduces an excise tax on the production of natural gas from fracking, in addition to standard energy taxes. The transition tax – beginning at 0.05 ZAR in 2017 and ramping up to 0.30 ZAR per million cubic feet of gas produced by 2050 – would be invested in renewable energy production and infrastructure.<sup>62</sup>

With this tax in place, the annual investments in renewable energy could drive production up to over 1.6 BBOE by 2050, making it a larger source of South African energy than even coal today. Natural gas production would grow at the beginning of this scenario but, because the transition tax increases over time, gas production plateaus in the 2040s as the cost effectiveness of fracking declines.

The increase in production also drives economic growth, which surges from ZAR 15.4 trillion (USD 1.52 trillion) in 2050 in the Base Case to ZAR 16.51 trillion (USD 1.63 trillion) in the Blue Bridge scenario. This is also higher than the Shale Boom scenario by ZAR 401 billion (USD 39.6 billion). Such an increase in GDP leads to increases in health, education and infrastructure spending, along with reductions in extreme poverty and those with no access to water and sanitation.

Although the Shale Boom and Blue Bridge scenarios provide similar benefits to human development, their environmental impacts are different. The Shale Boom shows a slight decline in carbon emissions relative to the Base Case early in the time horizon, but overall growth in emissions later. In the same way, the Blue Bridge scenario also shows a relative decline in emissions early in the time horizon, as natural gas production in part replaces dirtier coal production. However, in contrast with the Shale Boom, long-term emissions remain below the Base Case, due in large part to the significant, long-lasting increase in overall renewable production. In addition to potentially limiting South African contribution to climate change over time, the Blue Bridge scenario would also put less water at risk and involve less drilling in the Karoo across time. The Blue Bridge scenario uses 14 per cent less water relative to the Shale Boom. Even so, there remains a significant likelihood that some water resources would still become significantly polluted. Assuming, again, that only 1 per cent of water used in fracking remains polluted across time, this would leave the Karoo with the equivalent of 945 Olympic-sized swimming pools of polluted water by 2050.

## LIMITATIONS OF THIS ANALYSIS

While these IFs forecasts offer a valuable way to think about potential policy, the model is still limited in many ways. For one, because so many effects are unknown, it's impossible to model all of the environmental impacts that fracking and shale gas development might have in South Africa. Groups like the Treasure Karoo Action Group (TKAG) have been outspoken about the dangers that shale gas exploration might bring to South Africa's Karoo. In addition to their concerns over water usage and contamination – which this analysis does consider – anti-fracking activists worry about the broader environmental costs, including the disruption of animal habitats and a reduction in biodiversity, not to mention the aesthetic damage caused by drill sites in a destination known for its beautiful landscapes. In addition, the model exclusively deals with carbon emissions when considering the impacts of energy production. Therefore, any increase in methane (a more powerful GHG) cannot be modelled.

On top of the environmental concerns, it's difficult to capture the effects of increased shale gas production on other factors, such as access to electricity or unemployment – both major domestic issues for South Africa. Even with increased energy production within the country, there's no guarantee that South Africans will have access. It's up to policymakers to ensure that proper infrastructure exists and that those without access – many who live in conditions of poverty – can afford the newly available electricity. Likewise, we still do not know the impact that a transition from coal production to fracking and then to renewables would have on unemployment. For instance, one might anticipate an inflow of foreign experts when fracking begins, while jobs for lower-skilled workers might decrease as coal production decreases. Similarly, employment prospects also depend on the end-use of new energy resources. If domestic industry can leverage the country's increased energy supply, then employment might jump in the long term; yet, if the energy resources are exported abroad, then the prospects won't likely be the same. Meanwhile, overall GDP is forecasted to increase, which might lead to more jobs in other areas of the economy.

## CONCLUSION

South Africa is poised to frack. This decision will require an evaluation of major trade-offs between economic growth and environmental protection. This brief suggests that fracking can be used to move towards a greener future. But this is far from guaranteed. Difficult decisions about water resources, taxation and investment must still be made.

Owing to the potential damage fracking could have on South Africa's scarce water supply, the brief argues that water use, disposal and possible contamination should be among the primary constraints on shale gas production moving forward. Uncertainties over regulation may also limit private sector investment. In addition, other factors – both positive and negative – undoubtedly exist that we can neither measure nor forecast. It's important that if the South African government continues to push for fracking within the country, it must do so fully aware of not just the measurable costs and benefits but also the potentially unforeseeable consequences that models like IFs cannot address.

The Blue Bridge Scenario seems to offer the most promise for South Africa in the long term. Under this scenario, which anticipates constraints on water as well as a gradually increasing tax on shale gas production, the South African government could both limit the negative environmental impacts of fracking and use the revenue it gains from the process to jumpstart the use of renewable energy. Shale gas production, coupled with a strategic diversion of tax revenues, could offer both the short-term financial benefits that private investors seek now and the long-term sustainability that might improve South Africa's prospects overall.

However, the story doesn't end there. Even despite the improvements that the country's leaders could achieve through a scenario like this one, South Africa will have to do much more, even to fall in line with the 'green' targets already set. For instance, while South Africa set carbon emission reduction goals – as part of the Copenhagen Accord – at 34 per cent below a 'business-as-usual' growth trajectory by 2020, even the Blue Bridge Scenario only anticipates a reduction of 5 per cent in cumulative carbon emissions by 2050 compared to the Base Case.

A transition away from coal and towards a clean energy sector with universal access to electricity is possible. As this brief illustrates, shale gas development could either facilitate or hinder this transition – it can be a blessing or a curse.

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## NOTES

- <sup>1</sup> Sylvia Pfeifer, South Africa's struggle for power, *Financial Times*, 4 November 2012, <http://www.ft.com/intl/cms/s/0/f2f1942a-1dce-11e2-8e1d-00144feabdco.html#axzz2LfwyWUJl> (accessed 18 September 2013).
- <sup>2</sup> Eleanor Whitehead, South Africa: no frack back track, *Financial Times*, 8 November 2013, <http://blogs.ft.com/beyond-brics/2013/11/08/south-africa-no-frack-back-track> (accessed 10 November 2013).
- <sup>3</sup> South African Press Association, Minister touts shale gas fracking, 17 May 2012, <http://www.news24.com/SciTech/News/Shale-gas-a-gift-from-God-minister-20120517> (accessed 19 August 2013).
- <sup>4</sup> National Development Plan 2030 (NDP), *Our Future – make it work*, 2012, p. 164.
- <sup>5</sup> Anton Eberhard, *The future of South African coal*, 2011, [http://iis-db.stanford.edu/pubs/23082/WP\\_100\\_Eberhard\\_Future\\_of\\_South\\_African\\_Coal.pdf](http://iis-db.stanford.edu/pubs/23082/WP_100_Eberhard_Future_of_South_African_Coal.pdf) (accessed 20 August 2013).
- <sup>6</sup> Standard Bank, *Commodities: special report, part 3: drilling down into South Africa's shale gas prospects*, 2013.
- <sup>7</sup> International Futures, 2013, ifs.du.edu.
- <sup>8</sup> Stats South Africa, GHS Series Volume V, Energy 2002–2012, 2013. <http://beta2.statssa.gov.za/publications/Report-03-18-04/Report-03-18-042012.pdf> (accessed 22 October 2013).
- <sup>9</sup> International Futures, 2013, ifs.du.edu.
- <sup>10</sup> World Health Organization, *Indoor air pollution and health*, 2011, 'http://www.who.int/mediacentre/factsheets/fs292/en/' (accessed 18 September 2013).
- <sup>11</sup> National Planning Commission. *Diagnostic overview*, 2011, <http://www.npconline.co.za?pebble.asp?relid=206> (accessed October 2013).
- <sup>12</sup> Integrated National Electrification Programme: briefing by Department of Energy, 10 September 2013, <http://www.pmg.org.za/report/20130910-integrated-national-electrification-programme-briefing-department-energy> (accessed 18 September 2013).
- <sup>13</sup> National Development Plan 2030 (NDP), *Our Future – Make it Work*, 2012, p. 167.
- <sup>14</sup> EIA, *Technically recoverable shale oil and shale gas resources: an assessment of 137 shale formations in 41 countries outside the United States*, June 2013, <http://www.eia.gov/analysis/studies/worldshalegas/>.
- <sup>15</sup> *The New York Times*, As drilling practice takes off in US, Europe proves hesitant, October 2013.
- <sup>16</sup> EIA, *US energy-related carbon dioxide emissions*, 2012, October 2013, <http://www.eia.gov/environment/emissions/carbon/> (accessed 3 November 2013).
- <sup>17</sup> Our findings show that, while natural gas is less carbon intensive than coal production, the reduction in price incentivises enough consumption to increase overall carbon emissions.
- <sup>18</sup> EIA, *Technically recoverable shale oil and shale gas resources: an assessment of 137 shale formations in 41 countries outside the United States*, June 2013, <http://www.eia.gov/analysis/studies/worldshalegas/> (accessed 24 August 2013).
- <sup>19</sup> David Fig, *Fracking and the democratic deficit in South Africa*, 2011, <http://www.tni.org/sites/www.tni.org/files/dfig64.pdf> (accessed 18 September 2013).
- <sup>20</sup> Charles H Warren, *Shale gas in South Africa: toward an understanding of the security implications*, March 2013, <http://www.tandfonline.com/doi/abs/10.1080/10246029.2013.766443#tabModule> (accessed 18 September 2013).
- <sup>21</sup> Kevin Crowley, South Africa to issue shale-gas permits in first quarter of 2014. *Bloomberg*, 23 October 2013.
- <sup>22</sup> Patricia Els, et al. *Frack water treatment challenge*, (May 2013), 41.
- <sup>23</sup> Jesse Jenkins, *Energy facts: how much water does fracking for shale gas consume?* *The Energy Collective*, April 2013, <http://theenergycollective.com/jessejenkins/205481/friday-energy-facts-how-much-water-does-fracking-shale-gas-consume> (accessed 9 September 2013).
- <sup>24</sup> Republic of South Africa: Department of Water Affairs, National water resource strategy: water for an equitable and sustainable future (NWRS), 2013, 8.
- <sup>25</sup> The World Bank, World DataBank, 2013.
- <sup>26</sup> South African Water Research Commission, Regional water statistics, 2013, [http://www.wrc.org.za/Pages/Resources\\_Regionalstats.aspx](http://www.wrc.org.za/Pages/Resources_Regionalstats.aspx) (accessed 3 November 2013).
- <sup>27</sup> Food and Agriculture Organization of the United Nations (FAO) Aquastat Country profiles South Africa, [http://www.fao.org/nr/water/aquastat/countries\\_regions/south\\_africa/index.stm](http://www.fao.org/nr/water/aquastat/countries_regions/south_africa/index.stm) (accessed 16 August 2013).
- <sup>28</sup> Republic of South Africa: Department of Water Affairs, National water resource strategy: water for an equitable and sustainable future (NWRS), 2013, 27.
- <sup>29</sup> World DataBank, World development indicators.
- <sup>30</sup> Jackie King and Harrison Plenaar, *Sustainable use of South Africa's inland waters. A situation assessment of resource directed measures 12 years after the National Water Act*, 2011, 4, <http://www.wrc.org.za/Pages/DisplayItem.aspx?ItemID=9519&FromURL=%2FPages%2FDefault.aspx%3F> (accessed 3 November 2013).
- <sup>31</sup> National Water Resource Strategy, 2004, Chapter 2, 21, <http://www.dwaf.gov.za/Documents/Policies/NWRS/Sep2004/pdf/General.pdf> (accessed 3 November 2013).  
Because of fluctuations in stream flow throughout the year, the amount of readily accessible water available year round cannot exceed the lowest flow of the river in that year. Since the water flows fluctuate from year to year the yield also fluctuates from year to year. Thus, yield is often calculated in terms of an assurance of supply. The amount of water that can be abstracted 98 out of 100 years is called the 'yield' at a 98 per cent assurance of supply.
- <sup>32</sup> National Water Resource Strategy, 2004, Chapter 2, 29, <http://www.dwaf.gov.za/Documents/Policies/NWRS/Sep2004/pdf/General.pdf> (accessed 3 November 2013).
- <sup>33</sup> Republic of South Africa: Department of Water Affairs, National water resource strategy: water for an equitable and sustainable future (NWRS), 2013, Chapter 4.
- <sup>34</sup> Jackie King and Harrison Plenaar, *Sustainable use of South Africa's inland waters*, 20.
- <sup>35</sup> National Water Resource Strategy, 2013, 2, from "Annexure A: Perspectives per water management area" from that report.
- <sup>36</sup> National Water Resource Strategy, 2013, Annexure A: Perspectives per Water Management Area, <http://www.dwaf.gov.za/nwrs/LinkClick.aspx?fileticket=kt6Knl3auk%3d&tabid=91&mid=496> (accessed 3 November 2013).
- <sup>37</sup> To reduce localised water shortages that result from fracking, water can be transported from areas with surplus, though this does increase other environmental costs by requiring more energy for gas production, among other potential problems.
- <sup>38</sup> National Water Resource Strategy, 2013, Annexure A: 1.
- <sup>39</sup> Shona Walter, A fracking nuisance. *Environmental Policy and Law*, 2012, <http://iospress.metapress.com/content/k53g12828008232/>.
- <sup>40</sup> Ibid.
- <sup>41</sup> Republic of South Africa: Department of Water Affairs, Green drop report, 2011, <http://www.dwaf.gov.za/Documents/GD/GDIntro.pdf> (accessed 22 October 2013).
- <sup>42</sup> Accenture, *Water and shale gas development*, December 2012, <http://www.accenture.com/SiteCollectionDocuments/PDF/Accenture-Water-And-Shale-Gas-Development.pdf> (accessed 22 October 2013).
- <sup>43</sup> Nathaniel R. Warner, et al. Impacts of shale gas wastewater disposal on water quality in Western Pennsylvania, *Environmental Science & Technology*, September 2013.
- <sup>44</sup> William Ellsworth, *Injection-Inducing Earthquakes*, Science, 12 July 2013, <http://www.sciencemag.org/content/341/6142/1225942> (accessed 22 October 2013).
- <sup>45</sup> Shell, *Protecting water resources*, July 2012, <http://s04.static-shell.com/content/dam/shell-new/local/country/zaf/downloads/pdf/karobasin/Water.pdf> (accessed 19 September 2013).
- <sup>46</sup> Robert B. Jackson, et al. Increased stray gas abundance in a subset of drinking water wells near Marcellus shale gas extraction, *Proceedings of the National Academy of Sciences*, December 2012, <http://www.pnas.org/content/early/2013/06/19/1221635110.abstract> (accessed 22 October 2013).



- <sup>47</sup> The study also found that distance to valley bottoms and tectonic deformation (the natural factors influencing methane in water) were not statistically significant in the contamination of drinking water by methane.
- <sup>48</sup> Republic of South Africa: Department of Water Affairs, Aquifer vulnerability of South Africa, July 2013, [http://www.dwaf.gov.za/groundwater/documents/Aquifer%20Vulnerability\\_1.pdf](http://www.dwaf.gov.za/groundwater/documents/Aquifer%20Vulnerability_1.pdf). (accessed 8 August 2013).  
From the original image, which has been altered: "This map indicates the tendency or likelihood for contamination to reach a specified position in the groundwater system after introduction at some location above the uppermost aquifer. Green represents the least vulnerable region that is only vulnerable to conservative pollutants in the long term when continuously discharged or leached. Yellow represents the moderately vulnerable region which is vulnerable to some pollutants, but only when continuously discharged or leached. Red represents the most vulnerable aquifer region, which is vulnerable to many pollutants except those strongly absorbed or readily transformed in many pollution scenarios."
- <sup>49</sup> EIA, *Technically recoverable shale oil and shale gas resources: an assessment of 137 shale formations in 41 countries outside the United States*, June 2013, <http://www.eia.gov/analysis/studies/worldshalegas/>.
- <sup>50</sup> Republic of South Africa: Department of Water Affairs, Aquifer vulnerability of South Africa, July 2013, [http://www.dwaf.gov.za/groundwater/documents/Aquifer%20Vulnerability\\_1.pdf](http://www.dwaf.gov.za/groundwater/documents/Aquifer%20Vulnerability_1.pdf).
- <sup>51</sup> EIA, *Technically recoverable shale oil and shale gas resources: an assessment of 137 shale formations in 41 countries outside the United States*, June 2013, <http://www.eia.gov/analysis/studies/worldshalegas/>.
- <sup>52</sup> EIA, *Methane (CH<sub>4</sub>) has 21 times the 'Global Warming Potential' as Carbon Dioxide (CO<sub>2</sub>)*, 2013, <http://epa.gov/climatechange/ghgemissions/gases/ch4.html> (accessed 8 October 2013).
- <sup>53</sup> Mineral and Petroleum Resources Development Act, October 2002, <http://cer.org.za/wp-content/uploads/2010/08/MPRDA-2002.pdf>. (accessed 22 October 2013).
- <sup>54</sup> Mineral and Petroleum Resources Development Amendment Bill, 2013, <http://cer.org.za/wp-content/uploads/2013/07/MPDA-Amendment-Bill-15-2013-mineral-and-petroleum-resources-development.pdf> (accessed 3 November 2013).
- <sup>55</sup> *Brief overview of the main amendments proposed in the Mineral and Petroleum Resources Development Draft Amendment Bill*, 2012, <http://www.bowman.co.za/FileBrowser/ArticleDocuments/MPRDA-Amendments.pdf> (accessed 22 October 2013).
- <sup>56</sup> Wendell Roelf, *UPDATE 1-South Africa eyes free 20 pct stake in new oil, gas ventures*, Reuters, November 2013, <http://www.reuters.com/article/2013/10/29/safrica-oil-idUSL5N0J1XG20131029> (accessed 3 November 2013).
- <sup>57</sup> EIA, *Technically recoverable shale oil and shale gas resources: an assessment of 137 shale formations in 41 countries outside the United States*, June 2013, 536.
- <sup>58</sup> South African Department of Energy, *Integrated resource plan for electricity*, March 2011, [http://www.energy.gov.za/IRP/irp%20files/IRP2010\\_2030\\_Final\\_Report\\_20110325.pdf](http://www.energy.gov.za/IRP/irp%20files/IRP2010_2030_Final_Report_20110325.pdf) (accessed 22 October 2013).
- <sup>59</sup> In the following two scenarios, we assumed constraints on production due to measures similar to those presented in a special report from the IEA's 2012 World Energy Outlook, titled "Golden Rules for a Golden Age of Gas." [http://www.iea.org/publications/freepublications/publication/WEO2012\\_GoldenRulesReport.pdf](http://www.iea.org/publications/freepublications/publication/WEO2012_GoldenRulesReport.pdf) (accessed October 2013).
- <sup>60</sup> Erik Mielke, *Water consumption of energy resource extraction, processing, and conversion*, October 2010, <http://belfercenter.ksg.harvard.edu/files/ETIP-DP-2010-15-final-4.pdf> (accessed 22 October 2013).
- <sup>61</sup> April Lee, et al. *Opportunities for synergy between natural gas and renewable energy in the electric power and transportation sectors*, National Renewable Energy Laboratory, December 2012.
- <sup>62</sup> To model the effects of this 'transition tax,' we built a new parameter for the IFs system. The parameter is initialised as zero and the user has the ability to adjust it over time. Each year gas production is calculated for each country. Production is multiplied by the tax to calculate revenue. Given the tax revenue, an increase in renewable energy production is calculated using a capital-output ratio. We calculated the capital-output ratio for renewable energy in South Africa using the newly built Sere wind farm in the Western Cape as a benchmark. The wind farm cost ZAR 2.7 billion (USD 270 million) to build and is expected to produce 233 000 MWh (146 852 BBOE) of electricity per year. This comes out to be about USD 1 837 per barrel oil equivalent. The capital-output ratio is decreased by 1.5 per cent each year to represent exogenous advances in technology.

## AFRICAN FUTURES PROJECT

The African Futures Project ([www.issafrica.org/futures](http://www.issafrica.org/futures)) is a collaboration between the Institute for Security Studies (<http://www.issafrica.org>) and the Frederick S. Pardee Center for International Futures ([www.ifs.du.edu](http://www.ifs.du.edu)) at the Josef Korbel School of International Studies, University of Denver. The Institute for Security Studies is an African organisation, which aims to enhance human security on the continent. It does independent and authoritative research, provides expert policy analysis and advice, and delivers practical training and technical assistance. The Pardee Center is the home of the International Futures modelling system, an integrated approach to exploring and understanding human development and the broad implications of policy choices. These organisations leverage each other's expertise to provide forward-looking, policy-relevant material that frames uncertainty around human development in Africa.

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