The great shale debate in the Karoo

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Over the last year, rumours of vast cheap energy wealth stacked away beneath the Karoo have reached fever pitch. Apparently gas (methane – CH_4) from shale is there for the picking – and they're said to be rich pickings. The extraction industry believes that we all will benefit from this fortune if we harvest it soon: indeed, it has been presented as a proverbial win-win situation.

Alas, nothing could be further from the truth. Firstly, it is not known with any degree of certainty how much gas may be beneath the Karoo, and secondly, if there is enough, it is also uncertain whether the gas can be tapped without damaging other subsurface resources, particularly scarce potable water reservoirs, or without full rehabilitation of inevitable surface damage around the gas taps (or well heads).

Two camps have emerged in the Karoo's 'great shale debate'. Conservationists argue that extraction of the gas will leave massive irreparable environmental scars on one of South Africa's iconic landscapes. And some of them have pointed to possible human health hazards from associated chemical pollution. According to this camp, we would all be better off leaving the gas in the ground – in a world of trade-offs, there are plainly none here.

The flip side of this coin is engraved with the strong empirical correlation between energy use and wealth, and with the theoretical fact that gas burns almost 50% cleaner than coal. It might have been expected then that such a new potential bonanza of 'cleaner' energy would be welcomed in the light of two professed South African priorities. The first is the country's projected inability to meet the 2015 UN Millennium Development Goal target of poverty reduction. The second concerns the stringent 2020 UN carbon-emission targets the country set to reduce its carbon footprint in an economy committed to nearly doubling its use of coal as a primary source of energy over the next two decades.[1] With access to local shale gas, South Africa could easily meet these goals.

But heated debates between those that fret about the environment of the Karoo and those that regard Karoo shale as delivering new solutions to meet intergenerational equity, are part of a wider ethical debate about looming global environmental challenges – climate change – building up to what has ironically been called 'a perfect moral storm'[2]. This paper is interested in asking and answering this question: should we not at least find out what we have in our own backyard that might help us meet the challenges posed by the perfect storm? There are signs that externality costs of harvesting shale gas are being seriously assessed by government departments, energy companies and civil society. But environmentalists, Karoo landowners and lawyers are not convinced.[3] This tension has lead to another, more narrow, subsidiary question: how can we weigh up these issues to the satisfaction of all concerned and arrive at sure-footed conclusions that will support sound policy outcomes?

On the one hand, decisions about the possible harvesting of shale gas in South Africa and elsewhere (predominantly in North America) have to be made in the wake of legitimate public mistrust of corporations. The truth is this: the extractive industries are not well known for transparency. Fossil fuel companies, like their pharmaceutical cousins, are seldom upfront with their knowledge, information and financial dealings, especially so in the wake of their environmental mismanagement: witness their extensive, long-term destruction of ecosystems in the Niger Delta, the Gulf of Mexico, and many other, more cryptic side effects of their operations across the globe. Transnational energy controllers are secretive and release vital data that can help value the real costs of their exploitation of our natural resources only when ordered to do so. Part of this reluctance to comply is surely as a result of their ever-optimistic faith in their own engineering skills to fix unpredicted problems and other hiccups 'on the fly'.

On the other hand, conservation groups want assurances up front that nothing during the harvesting of gas will potentially damage natural habitats. But, and here lies a largely unaccepted truth, uncertainty is a fact of life. Certainty eludes us because of intractable problems

– in mathematics, physics and in both natural and social systems. All these require infinite (and therefore unrealistic) information to predict precisely how nature's networks will evolve into the future. Because of this unpredictability, it surely makes good sense to err on the safe side – but, and this is the policymakers' conundrum, in the case of Karoo gas, which is the safer side?

Projections make it abundantly clear that a gap must be bridged over at least the next four decades to facilitate change-over from energy production by heavy carbon dioxide (CO_2) polluters (coal and oil) to renewables[4] (solar, wind, wave, perhaps hydrogen, nuclear and, who knows, eventually artificial photosynthesis). Shale gas, because of its cleaner burning, offers a bridging-fuel towards these renewable energy sources; and a time-window of opportunity to wean society off coal, the most serious environmental offender. This approach will require holistic valuations that are yet to be attempted in either of the Karoo camps because, above all, they will need to know how much gas there is and, thereafter, how it might be safely harvested.

In the past 10 years, shale gas has become the new fossil fuel resource in the USA; it is unsurprising then that what was once primarily a North American activity has rapidly gone international.[5,6,7] Today it is believed that shale gas may produce more fossil energy than all global oil and coal combined, and even China is likely to become a major shale gas producer. It has been calculated that, on the back of shale gas, the USA can become self-sufficient in fossil fuel for the first time since the Middle East, South America, Mexico and Africa became its main external suppliers – sometime in the 1970s.

In April 2011, President Obama urged the USA to turn in this direction in earnest, also because, when burned, gas is theoretically a cleaner energy, producing 50% of the emissions from coal and 30% of those of oil. If it took the turn, the USA could easily meet its carbon reduction targets, for the next 20 years or more, without further economic penalties. It is estimated that the Marcellus Shale, stretching from Tennessee to New York, an area about one-third of the Karoo, may hold enough gas to heat US homes and power electric plants for two decades, making it the world's second-largest gas field in the world. And there are plenty other shale gas deposits elsewhere in the USA.[8]

In 2010, shale gas output in the US was nearly 5 trillion cubic feet (TCF) or 25 billion barrels (BB). A trillion cubic feet equals about 5 BB or about 28 trillion litres (TL). That is close to a 60% increase from just over 3 TFC in 2009, and more than 10 times the production in 2000, then just under 0.4 TFC; and it has been projected that shale gas will account for about 46% of US natural gas production in 2035.[8]

Estimates of total gas global reserves range widely, from 800 TCF to 30 000 TCF.[9] This wide discrepancy is related in part to dynamic technological developments. Whereas, in the recent past shale layers needed to be 100 m thick for efficient gas extraction, today it is technically possible and economically feasible to harvest gas from layers as little as 10 m – 15 m thick. So, potentially pregnant Karoo shales can be up to 200 m thick, but their thickness varies considerably: sometimes to less than a few metres. On this basis it is estimated that the Karoo has perhaps 500 TCF. But this is indeed a big thumb-suck because we know far too little about Karoo gas shales at depth; and geologically at the surface, Karoo Shale appears less potent than Marcellus Shale.

So what exactly are gas shales and how are they tapped for gas? Shale is a sedimentary rock that is predominantly composed of consolidated clay-sized particles deposited as muds in low-energy environments, such as tidal flats and deep-water basins where the fine-grained clay particles once fell out of suspension in the quiet waters. When the muds accumulate, accompanying organic matter derived from algae and plant and animal remains oxidises and disperses relatively rapidly. However, in reducing environments where the water lacks oxygen, such as in stagnant lakes and wetlands, the organic debris provides the muds with decaying riches (including trapped biogenic gas) that, under elevated pressures and temperatures, eventually metamorphose to organic oil and gas (thermogenic gas) when the sediments are buried at the depths of many kilometres. Previously, shale was regarded only as a source rock for 'free' gas that accumulates in adjacent porous sandstone and limestone reservoirs (this is known as 'conventional' gas), and as having the impervious shale layers that prevented the escape of gas from these more porous units. The very fine sheet-like clay mineral grains and laminated layers of shale result in a rock with permeability that is limited horizontally and extremely limited vertically. Thus, any gas trapped in shale is 'tight' and does not move easily within the rock except over geologic expanses of time – millions of years – unless it is artificially stimulated (e.g. fractured). Shale layers therefore function as 'strong-rooms' for natural gas. In terms of its chemical make-up, shale gas is typically a dry gas composed primarily of methane (at least 90%), but some formations produce a more water-rich mixture known as wet gas.

Some 275 million years ago, the Karoo was a vast anoxic lake, much like the present Black Sea. Under its panoramic surface, organic muds accumulated that were buried and 'cooked-up' some 25 million years later to form oil and gas. The free gas and oil have long since leaked naturally out of the rocks of the Karoo system, but pockets of 'tight' gas may remain preserved in shale sequences – geologists know these as the Prince Albert and White Hill Formations. Throughout the southern Karoo these grey–black shales that were once deeply buried have been uplifted and exposed at the surface, close to the front of the Cape mountains. Outcrops can be sampled along the N1 highway, for example, just outside Laingsburg. But from these surface samples even tight gas has mostly escaped during depressurisation and oxidation.

How do we know then where (and how deep) shale formations with possible tight gas occur in the Karoo – perhaps beneath a farm near Beaufort West or a township adjacent to picturesque Graaff Reinet? In 2004, academic geophysical probing serendipitously located these shales using natural electric currents, as part of a study to understand the origins of the Karoo Basin and the Cape mountains.[10] Because of the highly conductive properties of the black, organic-rich shales they are relatively easily found using a technique called magnetotelluric (MT) imaging. This technique requires the placement of a few electrodes in the ground and measuring the interference of electric currents through different rocks induced by natural electric charges in the atmosphere. A second technique uses sound waves generated by small artificial explosions (charges of 15 kg per site buried at 12 m below the surface were used in our 2004 study), and then monitors how fast these waves pass through the rocks by using listening devices called seismometers. Some of the waves are reflected back from the deeply buried impermeable shales to the seismometers at the surface; and from the speed of the sound waves, the depth of the reflecting shales can be calculated. The MT and seismic experiments provided similar results, allowing a detailed picture which showed the depth variations in the shales in a section that traverses the Karoo in a region where new exploration licenses are pending.[11] Moreover, depth estimates were tested against samples of shale retrieved from deep holes drilled in the Karoo by SOEKOR (Southern Oil Exploration Corporation) in the 1960s, when they were searching for oil and gas. Because of a lack of success – gas leaked from one of the deep drill holes for only a day – these searches were soon abandoned. The samples and data are now managed by PASA (Petroleum Agency, South Africa).

From our academic work then, the Karoo shales are likely to be found at a depth of 2 km – 4.5 km below the surface – a perfect depth for tapping tight gas should it be present in sufficient quantity.

Companies that have applied for exploration rights in the Karoo, like Shell International B.V. (i.e. Shell), will use these same exploration tools to image shale layers in greater detail.[11] But in the long run, remote imaging techniques are not enough to test for 'tight' gas in the shales. The chemistry of shale is crucial to decide not only if there may be sufficient gas, but also to determine what natural constituents might be brought back to the surface once the shale is drained of its gas. For example, naturally radioactive uranium and thorium, and some of their decay products like radium and radon (a gaseous decay product of radium) can be brought to the surface with the retrieved water, gas and rock cuttings. Although this may sound alarming, greater concentrations of these elements actually occur in many natural surface exposures of Karoo sedimentary rocks than in the deep shales. Nevertheless, to evaluate the potential of the shales, rock samples will have to be brought to the surface and this can be achieved only with drilling. So, no fracturing will be required during this early phase of exploration.

The final stages of determining if gas can be liberated and economically harvested from these depths will require breaking up the shale *in situ*. This is done by pumping water under immense pressure down the drill holes to cause hydraulic fracturing – commonly known as 'fracking': this of course is the signature word that has generated strong emotion across the Karoo. Fracking is mostly based on scientific and technical developments and operational management in North America,[12] although since 2004, the Anglo American Corporation has used fracking in the Waterberg to liberate gas from coal and other companies are doing the same in Botswana.

Fracking is a stimulation technique to create additional permeability through fractures (fractures are open spaces) in a producing reservoir, which allows gas to flow more readily to the well head. It has been used in the USA for more than 60 years. It was first used in Fredonia in New York, in a crude form, in the 1820s, by placing gunpowder down a well to liberate the gas. By 1988, fracking had already been used nearly one million times in the USA (about 90% of wells) and more than one million wells in operation today have been fractured, at an ongoing rate of about 35 000 wells per year.[8,12] Hydraulic fracturing is now responsible for producing 30% of US domestic oil and natural gas, and has aided in the extraction of more than 600 TCF of natural gas and 7 BB of oil. According to the US National Petroleum Council, 60% to 80% of all US wells drilled in the next decade will require fracking to remain viable.

Two arenas suggest how fracking has revolutionised both the oil and gas industries over the last decades. Firstly, modern refinements in hydraulic fracturing technology make it an extremely sophisticated engineering process, computerised to emplace predetermined fracture networks into specific rock layers as thin as 1 m at up to 5 km below the surface. Injecting a pressurised fluid does the hard work of breaking apart rock beds, and is then in part recovered (depressurised) to allow oil and gas to drain to the surface.[12,13]

Secondly, modern drilling technology allows the drill to turn corners at depth by making the drill hole extend from the vertical along a horizontal track whilst accurately staying within a narrow layer at any depth. Because the horizontal portion is easily controlled, the well is able to harvest shale gas resources from a geographical area that is much larger than a single vertical well in the same shale formation. For example, a vertical well may only drain a cylinder of shale 400 m in diameter and as little as 15 m high. By comparison, a horizontal well may extend up to 2000 m in length and drain a volume up to about 4000 times greater than that drained by a vertical well. Horizontal drilling in a number of different directions reduces the number of well sites (pads) located at the surface by an order of magnitude from what it was even 3–4 years ago. This means that less general construction is needed and fewer natural habitats are disturbed, but the trade-off is more commercial industry per pad,[14] in which case the potential negative environmental effects of the drilling operations may pale in comparison to those of surface operations. For example, more than 100 000 large truckloads of solid and liquid materials might be needed to support a 10-pad fracking well operation: 100 000 in and 100 000 out. Whilst these figures may vary significantly depending on local circumstances, new and sustainable transport infrastructure is needed to control such a new industry of truckers and their needs.

Fracturing of wells may also present a realistic threat to subsurface aquifers, the porous and permeable rock layers where important groundwater resources are located, with the threat from horizontal wells exceeding that of the less-extensive vertically-fracked wells.[15,16] This is a second legitimate reason for those interested in preserving Karoo environments and social cohesion to be concerned. Horizontal hydrofracturing of shale strata is not dissimilar from exploding a massive horizontal pipe bomb underground, creating an explosion capable of producing seismic events up to about 3 on the Richter scale, although generally much less.[17] Fracking has not triggered larger earthquakes in tectonically active regions in the USA and, whilst it cannot be excluded, is unlikely to do so in the relatively stable Karoo. It is relevant to note too, that many large-scale oil and gas extraction activities result in little or no recorded seismicity.[18]

Because shale deep underground is hard to break (fracture), the rock underground may be under confining pressures of over 1 kilobar (1000 times the surface atmospheric pressure) and require some 4 million litres of fluid (in the order of 50 residential swimming pools) to complete a fracked well in a single direction. Moreover, the low permeability of the gas requires that the well has to be fractured repeatedly: horizontal wells are fracked up to 10–20 times in one direction. With multiple directions, the well might be pressurised 30 times or more at pressures designed to pulverise rock. Because the fractured area in horizontal wells extends over large distances, there are risks of the induced fractures intersecting existing vertical faults or natural fracture systems in the surrounding rocks, permitting gas and fracking fluids to escape upward, perhaps into aquifers.[19] Even more likely is the possibility of gas and fracking fluid escaping through broken casing in the drill holes as a result of rupturing from multiple episodes of fracking. Overlying aquifers and shallow groundwater systems are vulnerable to such potential leakages. Not only can fracking fluids and gases infiltrate the aquifers, but natural aquifers of significantly different water quality (e.g. fresh and brack) could start to interact through new fractures, potentially degrading the quality of local groundwater supply. Little is known in detail about the density of fractures or the geometry of aquifers in the Karoo, but their host rocks, particularly those adjacent to the shales, are known to be riddled with joints and fault systems that are still largely geologically uncharted.

To avoid leakage into the surrounding rocks and into water reservoirs, drill holes are cemented (cased) during and after drilling, and before the hydraulic fluids are withdrawn (typically 40% of the fracking fluids are recovered) when the gas is tapped. As wells are fracked multiple times to prolong their productive life, casing failure may increase with time. The long-term integrity of the casing cannot be guaranteed and poor well casing is a likely source of contamination, especially when all gas has been extracted. This is one of the reasons why a moratorium has been imposed on fracking in Quebec (not Canada, as is often wrongly reported, as all types of natural gas and oil production in Canada are regulated at the provincial level). Casing failure can also occur during operations at low pressures, as happened during the Gulf of Mexico oil spill in 2010. Prevention through high-quality cements and, likely in the near future, less brittle materials, requires a non-negotiable research and development phase and expense that energy companies still have to address.

To date fracturing processes have been relatively free of accidents.[12,17] In the USA, less than 1% of wells has caused detectable fracture-fluid leakage or contamination. But there have been worrying incidents.[20] Emerging academic studies at reputable universities have documented that leakage of thermogenic methane, including into local water reservoirs,[21] may be more common than suspected, and that such leakage into the atmosphere has the potential to make gas a greater contributor, over short time spans, to global warming than coal.[22] The methodology of Howarth et al.'s[22] study has been called into question by leading experts, but it is clear that leakage risks must be significantly further reduced through preventative action ahead of fracking, for example by using 3D seismic monitoring and rigorous borehole control. These well-established methods are often neglected because they are expensive. In short, well operations must be monitored continuously by independent forensic experts.

Leaking wells can be tested for in real time: fluids can be spiked with tracer chemicals and gases can be fingerprinted using their indigenous isotopic signatures.[23] Such chemical forensics, perfected at the University of Alberta, Canada, can differentiate methane sources, as was done to show that gas in burning tap water[24] was mostly contaminated by shallow derived biogenic methane sources and from coal, and not from shale gas.[25] Chemical forensics must also be used to identify contamination by industrial 'chemical additives' added to the fracking fluids to facilitate efficient harvesting of the gas.

What is in these fracking fluids then, and why? Fracking fluid generally comprises up to 95% water and from 4% to 5% sand (or ceramics). Its main job is to deliver sand grains into the fractures so that they remain open. To help ensure effective delivery, guar is added to the water to make it more gel-like. Guar is made from beans found in many processed foods. Foamy mixtures flow easily, so nitrogen gas is sometimes added to help the fluid travel down the well faster. Once the fluid is ready to be removed, an enzyme or oxidiser 'undoes' the work of the guar to make it more fluid. In addition, there are small amounts of other chemicals added to the water–sand mix. Each chemical compound serves a specifically engineered purpose, such as reducing viscosity or preventing bacterial growth from bio-fouling fracture surfaces. The make-up of fracturing fluid varies from one basin to another and from one contractor to another. The relative amounts of the components in a fracture fluid vary considerably depending on the different shale compositions even from one well to another in the same shale. A recent report contains the first comprehensive inventory of chemicals used by hydraulic fracturing companies during the drilling process in the USA. Between 2005 and 2009, 14 leading oil and gas service companies used more than 3000 million litres of hydraulic fracturing products and more than 2500 hydraulic fracturing products containing 750 different chemicals and other components.[26]

These 'additives' are a major concern because, just like in the food business, some are potentially dangerous to human health. Whilst these potentially harmful additives make up only a small percentage of the mixture, their total volume is enough to constitute a threat to drinking water should they ever contaminate reservoirs or surface water.[14,15] Usually the additives are removed during the extraction process of production water to prevent their migration through the rock bed into the water table, but this process may not be 100% efficient. Biodegradable substances are also now available and should in future be substituted.

Companies have been reluctant to share knowledge about their 'magic potions' of additives, listed as 'proprietary' or 'trade secret', but this is now recognised as counterproductive. In the USA, companies list their additives on a voluntary basis online.[27,28] In the Karoo, Shell has promised to fully disclose their additives publically this way; and they have stated that unacceptable additives will not be used.[11] Still, future legislation should insist upon the capability for on-site testing for banned substances and leakages, in a process similar to mandatory drug testing of athletes.

No rock drilling operations – anywhere – are dry. Drilling and hydraulic fracturing of a horizontal, multidirectional shale gas well is estimated to require between 10 and 20 million litres of water (equivalent to about 150 domestic swimming pools; the Vaal Dam holds about 25 trillion litres), most of which typically stays underground. Operators need this water only when drilling, perhaps for a month or so, after which some is withdrawn as waste (called production water). The costs and risks associated with lifting, treating and disposing (or recycling) of production water are significant. Even for simple fracking during an exploration phase, on the order of 350 heavy-duty water tanker trucks per well will be needed,[14] giving a figure of up to 5600 trucks, 'in and out', for up to eight exploration wells (2 x 8 x 350) across each one of the three Karoo exploration areas, as proposed by Shell (possibly up to 24 wells in total). Access to and equitable sharing of this scarce resource raises legitimate concerns in the drought-prone Karoo.

Exploration companies must all learn to show greater understanding of the looming water crisis in South Africa than they have shown to date. This is particularly so because the new thirst for fracking fluids comes right after the shocking disclosures of nearly irreversible water contamination in the Gauteng area, the greater Olifants River Basin and farther afield, through acid mine drainage systems created by the extraction industries – South Africa's traditional money earners, but also its greatest polluters, whose externality debts have become near uncontrollable.[1,29] Karoo farmers and municipalities are right to be extra alert over their water rights.

However, fracking technology has also moved on over the last 2–3 years; less water is now needed and today water with a salinity of up to 60 g/L – 80 g/L (seawater has a salinity of about 35 g/L) can be used. Brackwater reservoirs exist at deep levels in the Karoo, and our recent MT work has located large saltwater reservoirs at a depth greater than 1 km. In some instances, water is now dispensed with in the later stages of fracking and the gas is used to continue the fracking. Many technologies and best practices that can minimise the risks associated with shale gas development are already being used by some companies, and more are being developed.[17]

Whilst land values in parts of the Karoo have soared with the gas news, a well might cost R100 million to drill and secure safely with good quality cementing to prevent leakage, and a small field might cost on the order of R2–3 billion to develop, although the costs per field vary greatly as the exploration costs are not scale invariant. These are significant investments that will not be made without a better cost–benefit valuation of the resource. And this can be made only once the expenditure on a strict regulatory framework and operational network is factored in.

There are many business pressures on companies to cut corners, and this is no different in the energy business: their own past actions frequently indicate that they cannot be trusted to take on and perform reliable self-monitoring. Regulators, policymakers and the public need an objective source of information on which to base decisions to manage the challenges that may accompany shale gas development. In North America, strict regulations need to be met before a well is started and strict regulations apply when the well is finished and sealed.[30,31]

Shale gas extraction without reliable independent policing is clearly not an option for South Africa. There is no reason to believe that we cannot strive to achieve this in South Africa. But, unless systematic and independent baseline data on seismicity and groundwater quality, including isotopic compositions collected well before drilling operations start in the Karoo, are made available for public scrutiny, environmental safety and scientific knowledge, public confidence will remain compromised.

One of the things that struck me during a recent tour through Canada and the USA is that concerns about shale gas exploitation are as emotional, and at times as irrational, as they are in South Africa. Yet there are fundamental differences that apparently help to self-organise the debate about shale gas. One is closely tied to public education, access to modern communications, bandwidth and networks, none of which, it can be argued, are in place throughout South Africa, let alone in the Karoo.

In the USA, the debates are constructive: environmental issues are interactively debated online on a daily basis across a wide range of websites of NGOs and governmentsponsored agencies; and there is a serious *You-Tube* movie on almost every aspect of the discourse. For example, the Environmental Protection Agency (EPA) has disclosed (online)[30] before a US Senate Environment and Public Works Committee hearing in early April 2011 that most scholarly scientific studies show that fracturing fluids do not pose a threat to subsurface contamination. The main environmental concerns in North America relate to the use of large volumes of nonsaline water in some locations, the discharge of water of higher salinity to surface waters (not permitted in Alberta) and gas migration to unwanted locations during and after fracking. The main research on fracking technology is related to improving control over the micro-rock and macro-rock make-up and casing during harvesting.

Yet even with our restricted communications bandwidth, a US-style, open-access, online debate is being mimicked here in South Africa, but with yet another important difference: the debate here appears more confrontational. I suspect this is because of a lack of technical expertise and innovation. Good, reliable scientific information and critical evaluation sustains the discourse in North America at a structurally sound level, facilitated through their immense well-trained workforce in relevant fields. This enables many sharp independent 'watchdogs' to monitor and sound alarm bells and then act accordingly. Protection, monitoring and fixing are successful in North America, by and large, because of these interactive processes with independent 'watchdogs'. Environmentalists and federal and state officials might say, for example, that fracking taints drinking water, and comment that energy companies like Halliburton use diesel in their fracking fluids and are flouting the law. North American expertise can confront and buffer energy companies with confidence and clout. Responses are quick and professional. The EPA, for example, is under orders from Congress to study the effects on drinking water of shooting pressurised water and chemicals into rock to free gas. Progress can be followed on a weekly basis – online.[26,27,30,31] The EPA expects first results late next year and complete results in 2014. In the mean time, fracking proceeds under the watchful eye of an increasingly knowledgeable public.

Throughout North America there is sustained pressure on scientists and lawyers to produce answers and plug loopholes. Everywhere I travelled I met with colleagues genuinely involved in this process: some see this as part of their community service; some professors in top universities adjust curricula seamlessly to accommodate these communal needs; and professionals in state institutions like the Geological Survey of Alberta, and in federal agencies like the US Geological Survey, are drawn in. World-class expertise is involved in this debate, often via remote conference-sites or chat-sites, from hydrologists monitoring Canada's water resources to seismologists who have cut their teeth on studying earthquakes in California. Even studies of human-induced microseismicity by a world-leading US seismologist, who originally started triggered-earthquake research (at the University of the Witwatersrand), in our own self-induced 'fractured' backyard – the deep goldmines – are included.[18] His is expertise that we severely lack in South Africa, yet expertise we need to ensure that 'the wool is not pulled over our eyes' by the sophisticated resources of international capital and commerce.

By contrast, in South Africa we move mostly in a mode of 'tit for tat': academic studies that show some of the dangers are criticised as unscientific by industry representatives, whilst government agencies are powerless to evaluate the arguments. Research on shale gas gets one-sided responses from environmentalists when it does not suit agendas.[32] There is an apparent lack of cohesion and a lack of genuine community-oriented interest in many discourses, including this one.

If South Africa is to benefit from possible shale gas bonanzas – there is no doubt about the immense potential economic and social returns – it must be able to evaluate its options realistically. And for this it needs to build a new infrastructure that can dynamically monitor exploration activities on a number of fronts, by means of independent research and evaluation teams. But where do we begin when there is no academic infrastructure in South Africa at present that deals competently with this? We have no independent expertise in gas shales, fracking or horizontal drilling. And we have neither integrated groundwater and gas units at our institutions nor national and provincial agencies that can test if fracking products are entering subsurface water reservoirs and affecting public health. Without the help of expensive overseas consultants, we could not enforce banning orders. Only the largest exploration companies in South Africa have 3D seismic equipment and the funds to run it; there is no national instrument pool to monitor seismic pulses related to fracking, and a severe lack of academic training of geophysicists to use such instruments and interpret the data; we cannot undertake rare gas analyses to monitor leakage; and we barely have a minimum laboratory capacity in the way of isotopic fingerprinting of methane or radiogenic isotopes. Add to that the fact that our academic and research institutions do no work at the cutting edge of this rapidly evolving science and technology: we lack the capacity to gather the empirical data and to evaluate the potential for techniques like hydraulic fracturing to effect contamination of underground sources of drinking water from injection of hydraulic fracturing fluids into gas shale wells, or its potential effects on astronomical observatories. This requires a new phase of Science and Technology investment.

In the interim, we must base our debates on examples from North America and Europe. The fact that our government has placed a moratorium on all fracking until a recently appointed multidisciplinary government team has been overseas and reported on their research (within two months) about the full implications of fracking, including its potential effect on the astronomical observatories located in the Karoo,[33] illuminates both the lack of expertise and the reliance of future decisions on these important issues by people who have attended some short courses as, for example, PASA employees have to do. Is an African shale gas 'bonanza', managed by foreign captains and inexperienced local crews, déjà vu?

Our universities are not training young people with the right skills to evaluate new important projects like shale gas exploitation and its implications. This is as much a failure by the universities – and the state – to contribute to intergenerational equity, as by the very companies we accuse of focusing solely on short-term returns. In this respect our academy is failing badly and needs to think hard about why that might be so: 'We need to talk'[34], because in South Africa we are failing in our capacity building – our best technicians have left the country; the best professors become administrators, consultants, or join the industrial army; and our most talented young graduates are lured to better jobs and training grounds provided by energy exploration companies such as Shell, Tullow Oil and PetroSA. Our public institutions like the Council for Geoscience and government agencies like PASA, are too understaffed and underfinanced to undertake these tasks, and hard pushed to invest in the ever-steepening learning curves of today and tomorrow. Technically we have already been caught with our proverbial pants down in acid mine drainage: we have failed to properly monitor acid mine drainage; we have failed to understand it and we cannot contain it.[1,28] Will shale gas go the same way as the acid mine drainage debacle?

We are blessed in South Africa by a great pool of ecologists and biologists and even Karoo specialists who could monitor and advise on surface effects, plus a world class research unit that could track deep subsurface bacterial activities and biofouling. But strangely, these are not the people that Shell has chosen to help with their environmental management plan. What is that about?

Companies are secretive and do not share their data or concerns with the wider community. Therein lies the crux of how companies like Shell apparently fail to understand why the public and environmental lobbies mistrust their motives and plans – no matter what they say or promise. In my general conversations with Shell's employees, some of whom are extremely competent scientists and technicians, they are unable to listen with the care it requires to understand the deep anxieties and needs of those living in the Karoo. Instead, Shell has hired a consultancy – Golder Associates – to do this for them. Early this year, as a first step towards harvesting shale gas from the Karoo, Shell needed to submit an Environmental Management Programme (EMP) to PASA within 120 days of completing an application for an exploration licence. In fact they had to produce three such EMPs, because they chose to apply for licences in three distinct areas, each 30 000 km^2. This enormous task was undertaken by Golder, who produced a two-volume report, with many appendices, adding up to some 4000 pages.[11] The report is available online (or on CD by request), and the material at first glance appears technically sound. But it is cumbersome; it took me more than a long weekend to plough through Volume 1, a mere 15% of the total report. The public was given 3 weeks to respond to this report. In that amount of time, no Karoo farmer would have read it, let alone would a shack-dweller in a township in Graaff Reinet been able to download it. Only the very-rich landowners were able to hire lawyers to critically evaluate the plans for them, and judging from some of their responses published with the final Shell report to PASA, even these lawyers were pushed beyond their limits.[35]

The ecological sections of the report are lacking in detail and tend to be superficial compilations based on very limited sources and formulaic in the extreme. Golder consultants did a poor job of considering the real interests of the people living in the Karoo. In particular, they appear to be unaware of, or choose to ignore, existing environmental legislation, the extensive conservation planning work that has been undertaken in this very area and the fact that there is a new Red List[36] for plants of South Africa. This is inexcusable in South Africa, which is teeming with excellent and qualified ecosystem and geosystem experts. To advance into the Karoo for the benefit of all, Shell should know better than to rely on this sort of consultation without independent peer review. Their excuse that the authorities allowed too little time to prepare is not plausible: it was their own decision to apply for extraordinarily large exploration areas. Still, at least Shell has shown a measure of transparency in facing the public square on. Others with vested interests have shied away from that. Why?

We must also try to better understand the motives of large landowners to halt Shell's progress. The fact that such landowners are no longer owners of the natural resources in the ground, as they were before the minerals and petroleum laws changed in 2004, now means that they cannot legally prevent others – and the nation – from benefitting from subsurface resources beneath their properties.

The Karoo is a place of unique biodiversity, stark beauty, wide open vistas and unsurpassed night skies. No one should want to set out to ruin that. But the Karoo is also a place of intense poverty, with marginalised structurally unemployed people and some of the greatest chasms between the rich landowners and those who own nothing. Moreover, this is not the first time that the 'natives of the Karoo' have been challenged, or their landscape altered by commerce without their consent: 'the economic impact of international markets was carried into the interior, not in the waggons of the Voortrekkers, but upon the backs of the merino sheep'[37], and wind-pumps, first invented in the USA in the mid-19th century and then introduced into South Africa during the time of new mineral discoveries, spread fast throughout the Karoo as an integral part of the country's industrial revolution.[38] Ironically, today, wind-pumps – dotted all over the Karoo – are now revered as part of its cultural heritage and wire models of them are sold along its byways.

So, should we permit Shell and others to carry out the exploration they need to complete in order to assess the risk of possible shale gas exploitation? Shell's exploration will in effect pay for determining the extent of some of the nation's hidden wealth, something our own national agencies, like PASA, the Council of Geoscience, the Council for Scientific and Industrial Research or MINTEK, are unable to do.

Our ecological economists, and we have some good ones, could then use the data to value the real state of our natural bank account. Moreover, we could insist that Shell explore, in parallel with their shale gas efforts, for shallow water reservoirs that have been poorly explored in the Karoo and that they leave a legacy of trained African professionals.

Will such valuation of Karoo shales allow moral dilemmas to be more openly debated? Should Mr Johan Rupert and Princess Irene of the Netherlands wish to 'sterilise' the subsurface of their Karoo farms from legitimate mineral exploration, and prevent the Karoo community around them from realising wealth and job creation, then surely there is a trade-off to consider? Surely there is a price to pay to balance the costs of keeping valued wealth in the ground against eradicating poverty and absorption of the marginalised in the flanking townships; to stave off potential land invasions or re-appropriation; and to help reduce potential climate change? Should Mr Rupert and his neighbours – all beneficiaries of the Karoo's free and wider ecosystem services – invest instead in renewable energy and water services for those around them that do not have access to such basic amenities?

Such schemes represent microcosms of the world: the governments in South America likewise try to leverage (and protect) their natural resources with Europe in exchange for poverty alleviation when they say they will keep their oil in the ground and their forests and ecosystems intact to help avert further global climate change, if Europe pays for the development costs and debt servicing of their countries,[39] an arrangement first set forth by the Kyoto Climate Protocol.[40] That, it appears, is a sound exchange to meet both the rights of the environment to retain its ecosystem services and human rights to uplift living standards around large wealthy farms. But this needs careful management – and herein hides another important caveat: even if gas is extracted from the Karoo it may not necessarily do anything for the poor – 'trickle down' is not one of South Africa's strengths, as commerce also has a reputation of flirting with corruption.

In the light of what has been said above, can we then expect ethical wisdom to deal with a Karoo shale gas bonanza? All indications point to decisions in South Africa about shale gas rights being similar to those of the USA, where all the people own the wealth beneath private land, and which is regulated under a complex set of federal, state and local laws that address every aspect of exploration (including shale gas), rights of ecosystems and other common wealth, under general community rights-to-know acts. (In Canada, where all land belongs to the Crown, the rules are subtly different as there are no *de facto* private landowners).

Already, the South African government has invoked a moratorium on licences in the Karoo where fracking is proposed. Cabinet has made it very clear that a clean environment together with all the ecological aspects will not be compromised.[41] The energy industry must therefore learn to work better with government agencies, environmental organisations, academic research groups and local communities to develop innovative technologies and practices that can reduce the environmental risks and impacts associated with shale gas development. They should stimulate continued study and improved communication of the environmental risks associated with shale gas development to allow society to make well-informed decisions about its energy future.

But to ban all potential fracking at this stage, as radical environmentalists propose, is the kind of thing we should think about more deeply if alleviating poverty and climate change, and avoiding social unrest are agreed targets.

Perhaps our universities are not focused on the moral issues of energy and the environment because they require a change to transdisciplinary approaches in all they do: most of our professors shy away from taking these risks. But the lessons for the academic community – researchers and bureaucrats – are clear: do your homework well and focus on our grand challenges. The lessons for government are clear too: provide the funds for centres of excellence where such work can be done in earnest, and do not take half measures. Shell too should be held accountable to our nation's needs and, like the energy giant Petrobras in Brazil, should be required to redistribute a more significant slice of the company's profits into educational and regulatory institutions.

How much information then do we need to justify exploiting shale gas and to assess the risk of such a decision? That sounds like asking, how would you measure the amount of knowledge stored in Nelson Mandela's autobiography *Long walk to freedom* as a prerequisite to guarantee averting a blood bath? South Africa seems to know these things intuitively, but it cannot yet quantify the moral dilemmas of its intergenerational 'buck passing'. Neither, as I have argued, can it yet quantify the value of its shales.

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