Scientific Assessment of Shale Gas Development

SUMMARY DOCUMENT

CHAPTER 1: SCENARIOS AND ACTIVITIES

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What is the purpose of the Scenarios and Activities Chapter?

The purpose of the Shale Gas Development Scenarios and Activities, which forms Chapter 1 of the Scientific Assessment report, is to describe the scale and type of activities assumed for three shale gas development scenarios of increasing magnitude. The scenarios are described in the context of a reference scenario where there is no shale gas development. The scenarios are selected to cover a range of plausible futures. Chapter 1 serves as a common point of departure for seventeen other chapters comprising the Scientific Assessment report which estimate, for the issues on which they focus, the levels of risk associated with each of the scenarios and their main defining activities (see Figure 1 showing the structure of the entre Scientific Assessment report). Chapter 1 is not itself an assessment, but an input to the assessment process. It does not present any conclusions regarding how likely or desirable any of the scenarios are, neither does it outline the site specific regulatory processes which will be required for decision-making around shale gas development. Rather, it provides a shared framework from which activity- and issue-related risk is estimated for the scenarios. The outcome of the full, multi-issue assessment of impacts, risks and mitigating actions will inform responsible decision-making with respect to shale gas development, in the following phase of the Scientific Assessment, and provide recommendations for regulations and decision-making processes. The contents of Chapter 1 and all other related chapters of the Scientific Assessment report are in no way a substitute for, or pre-empt, the already regulated decision-making processes, which still need to be followed in the case of any shale gas development.

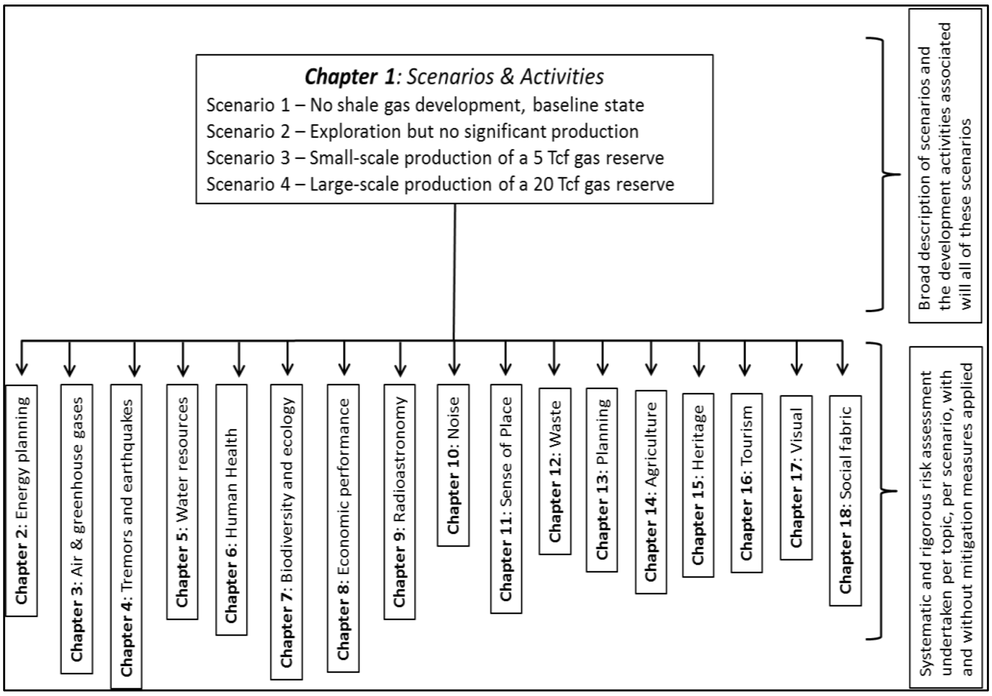

Figure 1: : The Scenarios & Activities Chapter provides the basis upon which the risk assessment is undertaken for the proceeding chapters, but is not in itself an assessment of the risks or opportunities associated with shale gas development.

What are the broad baseline trends in the study area?

Understanding baseline trends in the study area is critical to any strategic assessment. They provide the reference points from which risks resulting from new development activities can be assessed. The central Karoo (with particular reference to the Scientific Assessment study area) is not a static environment; its social, economic and biophysical characteristics are constantly changing (Figure 2).

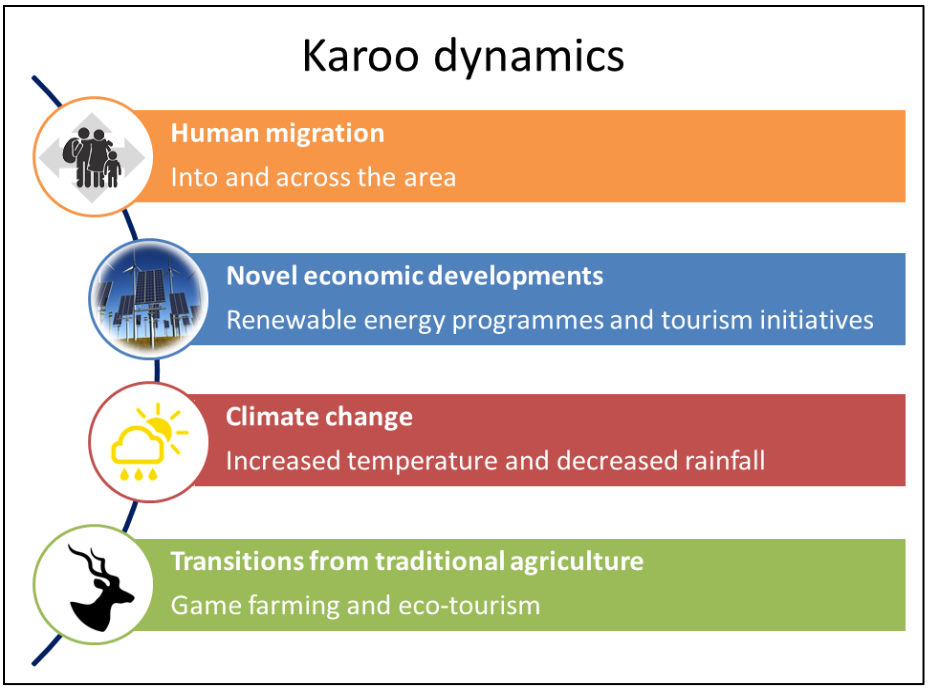

Figure 2: Current social, economic and biophysical trends in the Karoo.

For example, there are marked trends in human migration into and across the area; there are novel economic developments materialising, such as renewable energy programmes, tourism initiatives; and land-use change, including transitions from traditional agriculture to game farming and eco - tourism enterprises. Global trends, such as climate change, will also have marked effects on ecosystems and human well-being. The Scientific Assessment study area encompasses elements of several major biomes: the Nama Karoo Biome in the centre and north; the Grassland Biome to the east; the Succulent Karoo Biome in the west (which receives winter rainfall); and the Albany Thicket Biome in the south-east, which receives both summer and winter rainfall. The distribution of the biomes is mainly controlled by climate, with geology and soils also contributing. The majority of the Scientific Assessment study area receives an average of around 250 mm annual rainfall, mostly in summer. Average annual rainfall in the study area is expected to decline in the 21st century in response to climate change. Temperatures in the study area are expected to increase, in the region of 1-2° C, with a significantly higher number of very hot days likely to be experienced (temperatures are exceeding 35° Celsius). With already irregular rainfall patterns in the study area leading to unreliable runoff, most of the surface water systems (which cover roughly 5% of the study area, including their riparian fringes) do not supply human consumption. Groundwater resources are heavily relied upon for domestic supply and to sustain much of the local economic activity. The majority of the land in the study area is used for domestic livestock grazing, with smaller areas used for game farming or biodiversity protection in private or state protected areas. Intensive agriculture occupies less than 1% of the land surface, typically on alluvial soils in close proximity to major drainage lines (which are dry for most of the time). Agriculture in the western areas focuses on small livestock for meat and wool production, with a shift evident toward agri-processing and the use of crop types more resistant to lower rainfall and a changing climate. Relatively large commercial farms, various local and regional service towns, nature reserves and conservation areas characterise the economy of the Scientific Assessment study area. Household income is generally low relative to areas outside the study area. Economic growth and adaptability to change varies across the study area. There is economic growth potential in the renewable energy market, national and inter-regional transport routes, tourism and large government development initiatives such as the Square Kilometre Array (SKA).

What is shale gas, how much is there in the study area and where might it be concentrated?

Shale gas is naturally occurring methane that is trapped within shale layers deep below the Earth's surface. The shales in which gas is expected to be concentrated are the Prince Albert, Collingham and Whitehill Formations of the Ecca Group. They range in depth below surface from about 300 m to >3000 m. Gas volumes originally trapped within the shales will have been severely reduced through exposure to extreme temperatures, about 100 million years ago, when dolerite (a type of igneous rock) intruded into the Karoo Basin. The folding processes associated with the Cape Fold Belt mountains will also have reduced the volume of gas originally trapped in the shales. The Whitehill and Prince Albert formations are still considered attractive targets for shale gas, since they are known to have relatively high organic carbon contents and occur over a large part of the Scientific Assessment study area. The results of several assessments of shale gas potential within the Karoo shale sequences (with particular emphasis on the study area) are in reasonable agreement as to the total technically recoverable gas resource for the Whitehill- and Prince Albert Formations, which could range between 71 and 153 trillion cubic feet (tcf). 'Technically recoverability' does not take the economic viability of doing so into account. Conservative estimates of the economically-viable shale gas volume potentially available for downstream development and production suggest a low and high case scenario of 5 and 20 tcf respectively. The area most likely to contain viable shale gas resources extends across the central and eastern to north-eastern parts of the Scientific Assessment study area, as indicated in Figure 3.

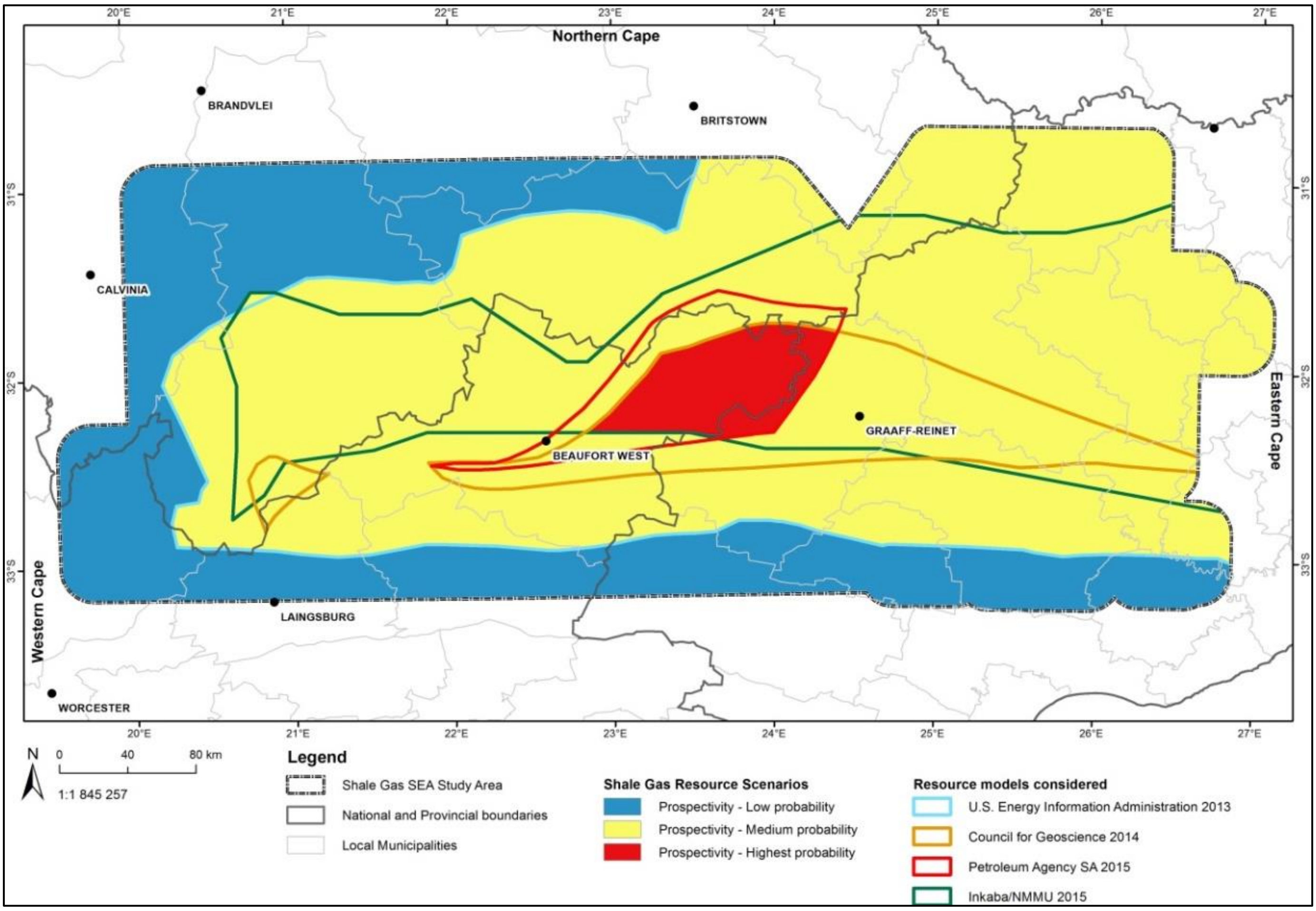

Figure 3: Relative prospectivity of gas-bearing shales, ranging from low to high, across the study area.

What is Shale Gas Development?

Shale gas development entails a broad range of activities. 'Upstream' activities refer to aspects such as seismic surveys, site preparation, drilling deep vertical boreholes and the deviation of drilling to form horizontal wells that penetrate into deep targeted shale layers. They also include hydraulic fracturing or 'fracking' of the shale and a host of other surface activities such as waste management, transportation of equipment, materials and personnel to and from areas of operations, and many other others such as 'Downstream' use in gas to power plants. Shale gas development is conceptually depicted in the following six stages in Figure 4.

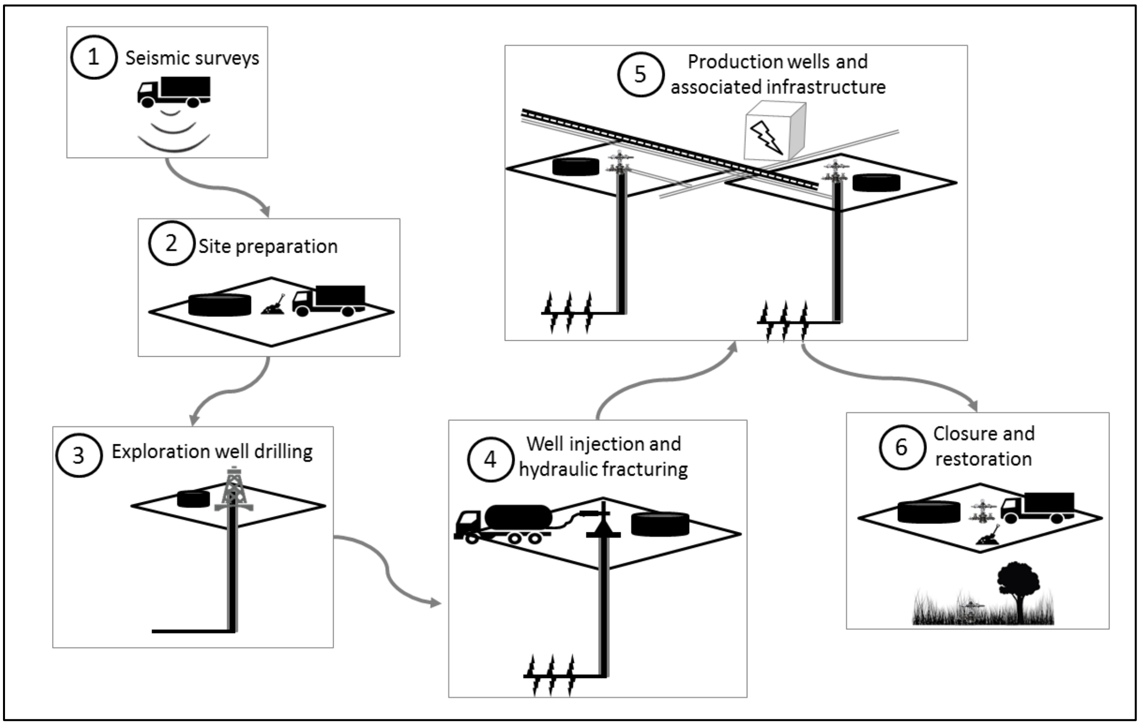

Figure 4: Key stages in the shale gas development life-cycle.

Fracking is probably the most publicised aspect of shale gas exploration and production. It is the process of using hydraulic pressure to break fractures in the shale reservoir located deep underground, through which released gas escapes via a borehole to the surface (Figure 5). The fractures are kept open by small solid particles (sand or ceramic beads called 'proppant') that are included in the fracking fluid that is pumped into the shale formation. Around 90-95% of fracking fluid is water, with 5-10% comprising proppant and other additives such as antimicrobials, hydrochloric acid, scale inhibitor and friction reducers.

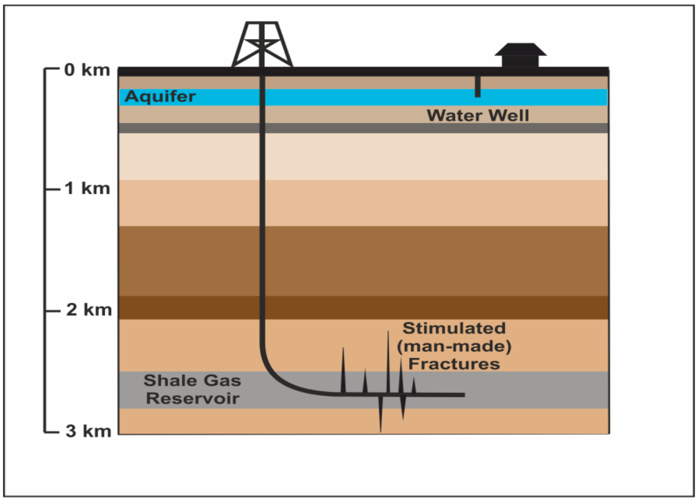

Figure 5: Fracking of the shale gas reservoir to allow methane to escape to the surface.

Exploration is the first stage of the shale gas development cycle. It is typically concentrated in the initial 2-3 years of the development cycle, but is undertaken throughout the cycle to inform the location of additional drilling and production operations. It involves geological studies, seismic surveys and drilling of stratigraphic and exploration wells. Stratigraphic wells are vertical boreholes drilled to obtain geological core samples for analysis, while appraisal wells are drilled into target formations and may be fracked to test for the presence of shale gas. The appraisal stage follows exploration, and for a single campaign also typically extends over ~2-3 years. It involves the drilling of appraisal wells (vertical wells with horizontal sections) to ascertain potential yields of shale gas within the target formation. If, during the exploration or appraisal phase, it is revealed that technically recoverable reserves cannot be economically exploited, decommissioning is implemented. Wellpads from which drilling is undertaken typically occupies 1-2 ha of land surface. Drilling, hydraulic fracturing and other equipment and materials and waste receiving facilities are contained in this area (see an example of a well pad in Pennsylvania a State, USA in Figure 6). An area of similar extent is developed for temporary accommodation of drilling crews in the region.

Figure 6: Example of a wellpad in Pennsylvania a State, USA during the hydraulic fracturing process.

Figure 7: Cluster of producing wellheads following hydraulic fracturing and removal of the drilling rig.

Where operations progress to production, the third stage of the shale gas development cycle commences. This includes drilling of production wells and the construction of surface infrastructure and facilities employed for the gathering, compression and treatment of produced gas (Figure 7 & 8). This proceeds within an initial concentrated period of 3-5 years; thereafter, operations, which might extend over 10-30 years, involve the ongoing development of production wells, gas plant operations and maintenance, and the export of produced gas for downstream uses. Together with drill cuttings, which comprise the rock particles drilled out of the wellbores, the greatest volume of waste that is managed on site is the so-called 'flowback'. This includes fracking fluid that is returned to surface together with entrained gas and, where encountered, saline fossil water. Part of the flowback is treated for re-use whilst the residual waste, including high salinity water and sludge, is dispatched for disposal. Once the production phase reaches its conclusion, decommissioning extends over a period of 5-10 years. This involves the plugging of wells, dismantling of infrastructure and site rehabilitation.

Figure 8: Example of a centralised gas compressor station. Compressed gas would be exported from this facility, via a pipeline, to a downstream facility.

How might shale gas development happen in South Africa?

There are high levels of uncertainty regarding how shale gas development could materialise. Therefore, the range of potential future outcomes has prompted consideration of four possible scenarios, which are imagined as materialising between the present and about 35 years into the future, in 2050.

Scenario I: Reference Scenario

In the reference or 'baseline' scenario, shale gas development does not materialise. Important influences on ecological and socio-economic dynamics include climate change effects and changing land-uses. Increased average annual temperatures and decreased rainfall are key change drivers in this regard. Novel approaches to commercial agriculture, including diversification, extension of product value chains and increasing access to local and international markets for products, are expected. This accompanies growth in cultural and ecological tourism and other major developments, such as renewable energy projects, uranium mining, national and inter-regional transport routes and phase 1 of Square Kilometre Array in the north-west of the study area. Long term socio-economic benefits accrue in particular as a result of the renewable energy sector (primarily solar photovoltaic based), which becomes the dominant contributor to the area's economy.

Scenario II: Exploration only

Scenario II assumes that exploration will commence in 2018 and continue until about 2025, at which point it is concluded that there are no economically viable gas reserves contained within the Karoo shales. Operations do not proceed to development and production. Only seismic surveying and exploration- and appraisal-drilling activities are carried out. The latter includes limited fracking activities undertaken at a maximum of five targeted locations, with less than 5% of the land surface impinged upon at each location. During seismic surveying, seismic waves are generated at or near the Earth's surface and travel though the rock formations, potentially up to a maximum depth of 10 km. Seismic surveys rely primarily on two types of seismic sources: explosives and mechanical sources of vibration (most commonly produced by 'vibroseis' trucks, see Figures 9 and 10). Surveys may be conducted using one or both approaches to seismic sound source generation, with the choice depending on several factors including geophysical objectives, cost and environmental constraints. Following seismic exploration, establishing the presence and potential yield of hydrocarbon reserves is achieved through drilling, evaluation of drill cuttings and cores, downhole logging and, for some operations, measurement of hydrocarbon flow through extended well testing (e.g. measurement of gas flow following trial hydraulic fracturing). In terms of drilling location, the first phase of drilling one or more stratigraphic wells is informed by the results of seismic exploration and regional geological studies. For the appraisal phases of drilling, well locations are determined by the combined results of seismic exploration and the results derived from the stratigraphic wells (more detailed information on the seismic surveys, the exploration and appraisal

Figure 9: Personnel setting up seismic data collection systems.

Figure 10: Vibroseis truck used for collecting seismic data along seismic transect lines.

drilling stages are included in the detailed Chapter 1). Considering that in this scenario, shale gas development operations do not proceed to development and production, in the absence of shale gas production, the national gas energy supply mix is supported by imported liquefied natural gas.

Scenario III: Small-Scale Production

Scenario III assumes the same suite of activities as those described for exploration and appraisal, in Scenario II; however, for this scenario, it is assumed that exploration reveals a modest economically viable shale gas reserve of approximately 5 tcf. This results in small-scale shale gas development and production concentrated in the central Karoo. Based on the most successful of the exploration and appraisal campaigns, development would occur within a target area of approximately 30 x 30 km (see Figure 11). A sustained flow of gas of ~172 million standard cubic feet (MMscf) per day is achieved, requiring approximately 550 production wells to be drilled and equipped from around 55 wellpads (i.e. 10 wells per wellpad). A central facility, supplying process water would receive flowback for treatment, allowing for re-cycling and re-use of water that is separated from the waste that is disposed of. A 1000 MW Combined Cycle Gas Turbine (CCGT) power station, situated less than 100 km from the production block, would be established and supplied with gas via a pipeline. The CCGT facility would make a modest contribution to the country's energy supply mix.

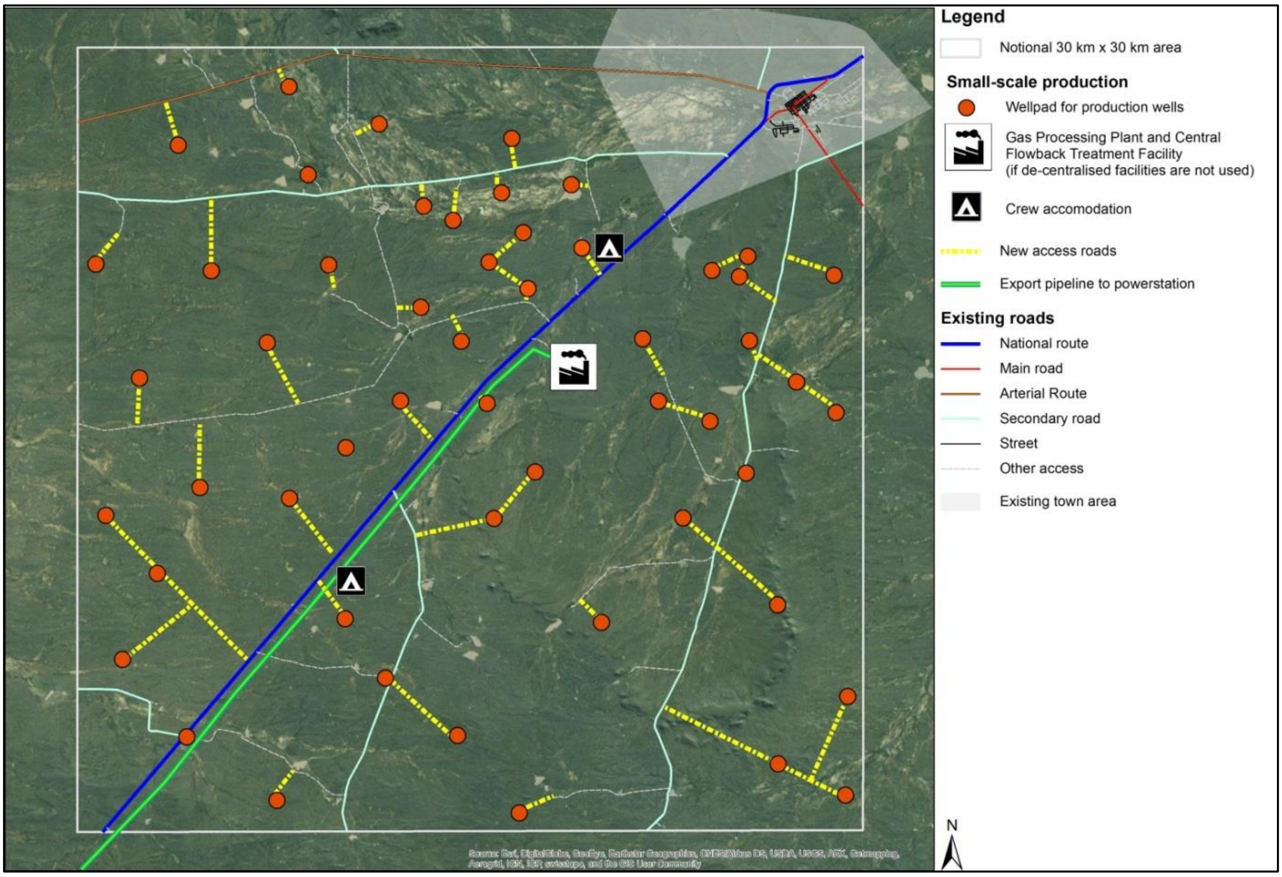

Figure 11: Notional schematic illustration of example wellpads, access roads pipeline grids and other infrastructure established in an area (30 x 30 km) notionally targeted for small-scale development and production.

Scenario IV: Large-Scale Production

Scenario IV involves a significantly larger gas discovery than for Scenario III, triggering large-scale development and production (Figure 12). This would follow several years of exploration, after which an economically viable shale gas reserve totalling ~20 tcf is confirmed for the central Karoo. The scenario assumes that two CCGT power stations are established, each with a generation capcity of 2000MW, and that these contribute significantly to the country's energy supply mix. Guided by the country's Integrated Energy Plan, a new Gas-to-Liquid (GTL) plant, with a refining capacity of 65 000 barrels (bbl) per day, is established at the coast and is supplied with gas via a pipeline from the central Karoo. The main activities of large scale development and production would occur within 4 production blocks (including the already developed small-scale production block described in Scenario III), each measuring about 30 x 30 km (Figure 13). Wells and infrastructure would be developed progressively on a block-by-block basis to meet the downstream gas demand and to compensate for diminishing gas flow from older wells. Gas supplied to the two power stations would total approximately 688 MMscf per day, with approximately 600 MMscf per day of gas supplied to the GTL plant. This combined feedstock of approximately 1200 MMscf per day would be sourced from approximately 4 100 production wells established at around 410 wellpads.

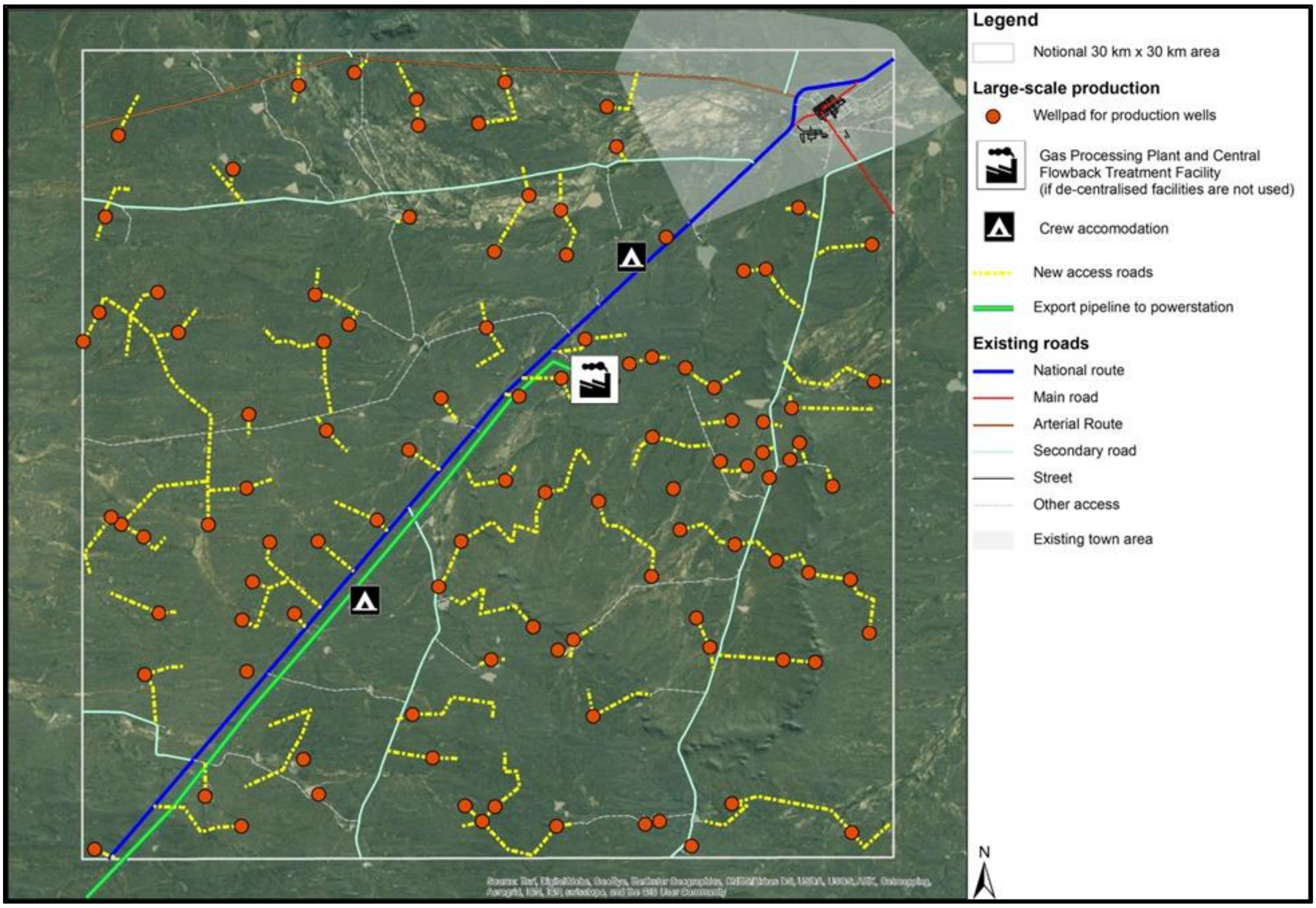

Figure 12: Notional schematic representation of gas production infrastructure within one fully developed block (30 x 30 km). Note that an additional three similar production blocks would be developed to deliver the volumes of gas required.

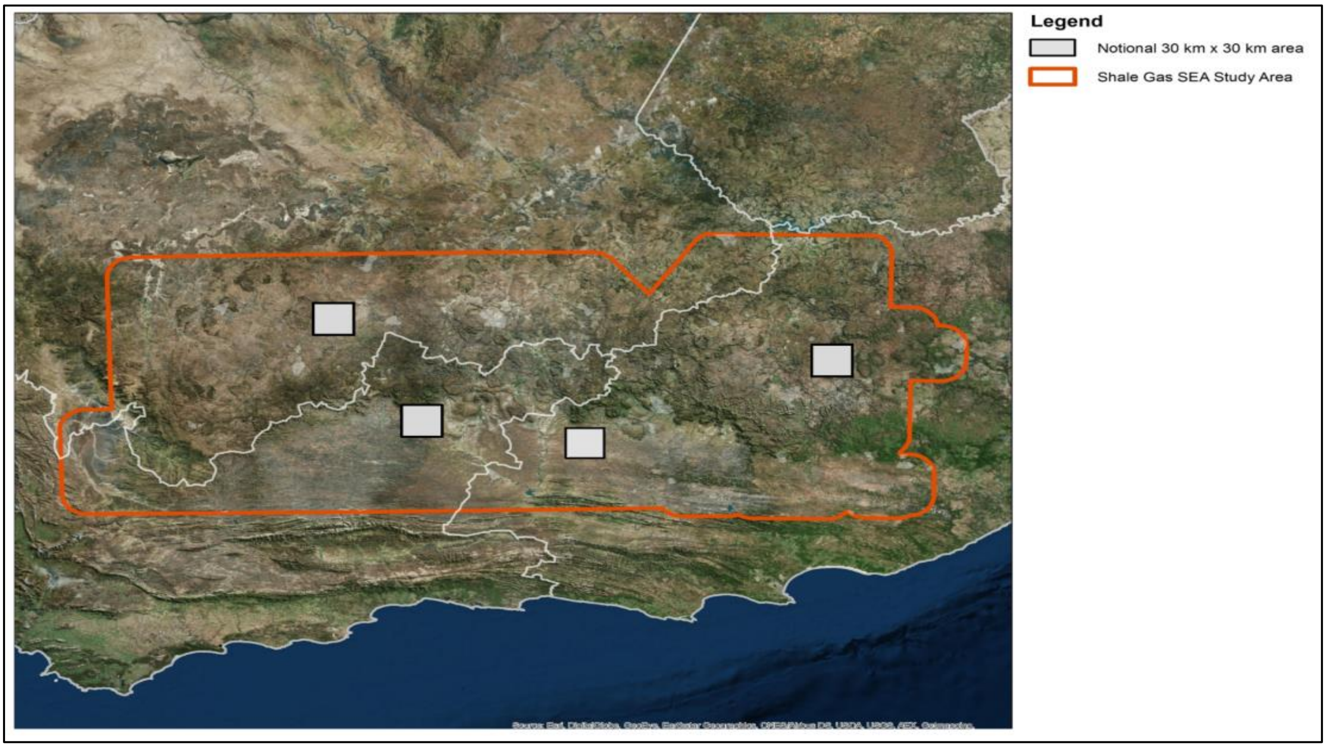

Figure 13: Four hypothetical full scale development blocks randomly spread across the study area to give a rough indication of the scale of development associated with Scenario IV.