# 31 SOUTH AFRICA

## 31.1 Summary of Coal Industry

### 31.1.1 ROLE OF COAL IN SOUTH AFRICA

South Africa is the world's seventh largest coal producer and dominates the African coal industry, producing 250 million tonnes (Mmt) of coal in 2009 (BP, 2010). It is the third largest coal exporter in the world (GCIS 2010), and responsible for about 99 percent of all coal production in Africa (BP, 2010). South Africa's coal resources are estimated at 115 billion tonnes, based on a survey conducted in 1987 (DME, 2010a). As seen in Table 31-1, its reserves are estimated at about 30.4 billion tonnes which consist almost entirely of hard coals (i.e., anthracite and bituminous) (BP, 2010).

**Table 31-1. South Africa's Coal Reserves and Production**

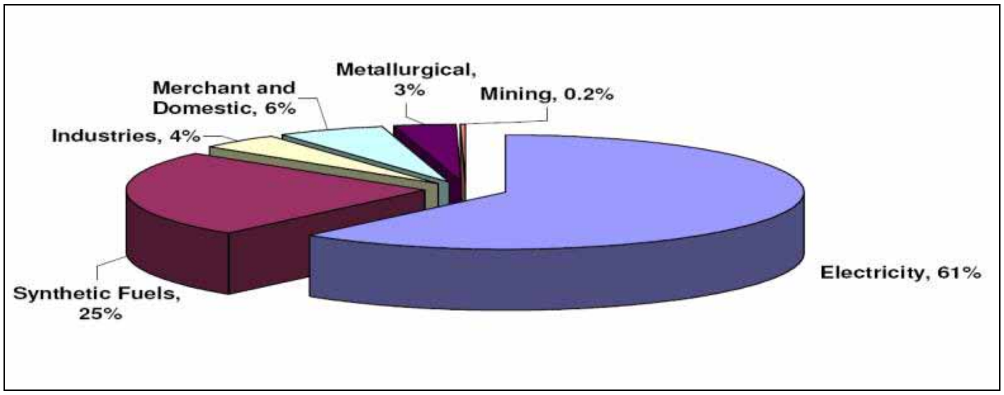
| Indicator | Anthracite & Bituminous (million tonnes) | Sub-bituminous & Lignite (million tonnes) | Total (million tonnes) | Global Rank (# and %) |
|---|---|---|---|---|
| Estimated Proved Coal Reserves (2009) | 30,408 | 0 | 30,408 | 8 (3.7%) |
| Annual Coal Production (2009) | 250 | 0 | 250 | 7 (4.1%) |

Source: BP (2010)

Coal is the primary fuel produced and consumed in South Africa, accounting for 72 percent of total primary energy supply in 2007 (IEA, 2009). Three quarters of its production is consumed internally and one quarter is exported to the European Union and East Asia (EIA, 2010). The industrial sector, including mining, consumed 4.2 percent, the metallurgical industry used 3 percent, and merchants bought 6 percent of domestic coal (Figure 31-1) (DME, 2008). Internal consumption is primarily for electric power generation (about 61 percent of locally sold coal in 2007). The second most important use is conversion to synthetic liquid petrol and diesel fuels (25 percent).

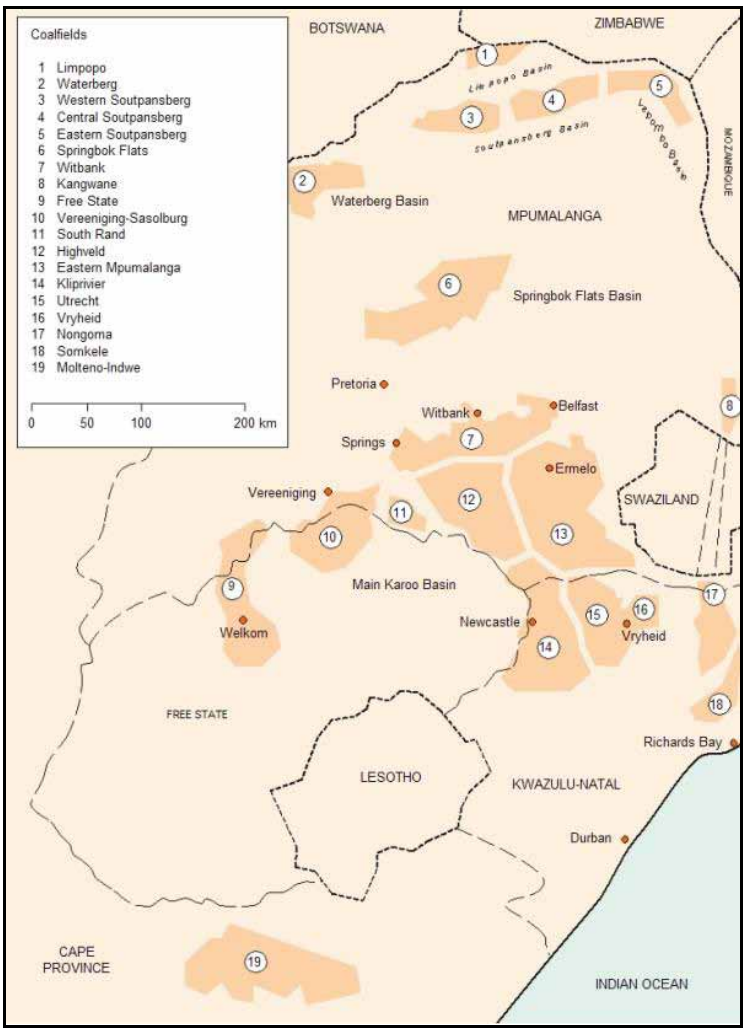
Figure 31-2 illustrates the distribution of coal deposits in the country. Seventy percent of South Africa's recoverable coal reserves lie in the Highveld, Waterberg, and Witbank fields. The great bulk of the coal reserves are concentrated in 19 Karoo (Permian) coalfields in the Mpumalanga region of the country and underlay an area of about 115,000 square miles (EIA, 2005).

**Figure 31-1. South Africa's Domestic Coal Consumption by Sector**




Source: DME (2008)

**Figure 31-2. South Africa's Coal Basins**

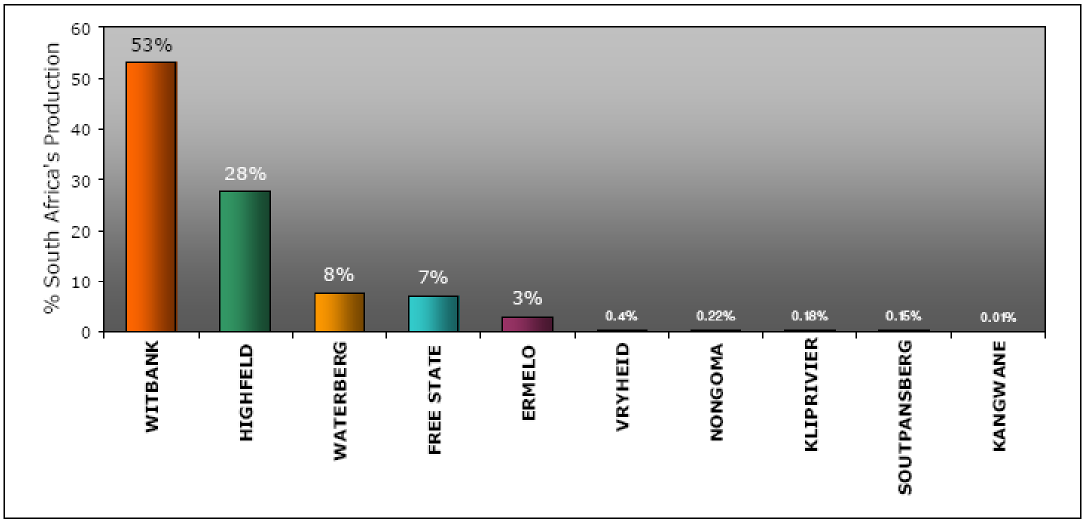



Source: Walker (2000)

In 2007, South Africa's production of bituminous coal increased by 0.5 Mmt (0.2 percent) and exports by 1.4 Mmt (2.1 percent). Due to very high international prices, revenue from exports increased by 11.9 percent. South African coal was exported to 34 countries in 2007, of which 84.5 percent went to European nations, with Great Britain, Spain, France and Germany as the largest customers. South Africa's coal exports to Europe decreased by 3.5 percent, but exports to the Middle and the Far East increased from 7 percent of total exports in 2006 to 11.8 percent in 2007, with South African coal exports to India increasing by 403 percent (DME, 2008).

In 2007, South Africa's run-of-mine (ROM) coal production was 312.3 Mmt, 236 kt less than in 2006. Some 247.6 Mmt of this production were of saleable quality (DME, 2008). ROM output for 2006 by coalfield is illustrated in Figure 31-3 (Ntlou, 2008). As seen in the figure, the Witbank Coalfield remains the largest producer, followed by the Highveld Coalfield, both in the Central Basin. They produced more than 80 percent of the total country's output for 2006 (Ntlou, 2008).

**Figure 31-3. 2006 Coalfields Run-of-Mine Production**

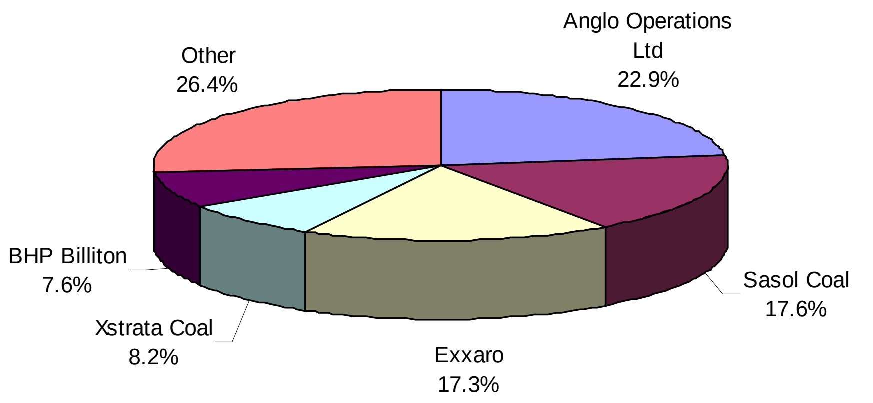



| | | | | | |
|---|---|---|---|---|---|
| Field | Witbank | Highfeld | Waterberg | Free State | Ermelo |
| Production (Mmt) | 174 | 70 | 36 | 19 | 11 |
| Field | Kliprivier | Nongoma | Vryheid | Soutpansberg | Kangwane |
| Production (Mmt) | 1.5 | 0.7 | 0.6 | 0.3 | 0.01 |

Source: Ntlou (2008)

In 2008, almost 74 percent of the saleable coal production was supplied by mines controlled by the five largest mining groups: Anglo Coal, BHP Billiton, Exxaro, Sasol, and Xstrata (see Figure 31-4) (CM, 2008).

**Figure 31-4. 2008 Saleable Coal Production by Mining Company**




Source: CM (2008)

## 31.1.2 STAKEHOLDERS

The coal mine methane (CMM) industry has significant potential to develop as deeper, gassier seams are targeted for mining. Table 31-2 lists potential stakeholders in CMM development in South Africa.

**Table 31-2. Key Stakeholders in South Africa's CMM Industry**

| Stakeholder Category | Stakeholder | Role |
|---|---|---|
| Mining companies | ▪ Ingwe Colliers Limited<br>▪ Anglo Coal<br>▪ Xstrata<br>▪ Eyesizwe<br>▪ SASOL<br>▪ Exxaro Coal | Project host |
| Government Groups | ▪ Department of Minerals and Energy | Licensing |
| Developers and Consultancy | ▪ See http://www.epa.gov/coalbed/networkcontacts.html | Project opportunity identification, planning and technical assistance |
| Organizations | ▪ Chamber of Mines of South Africa<br>▪ South African Mining Development Association | |
| Universities, Research Establishments | ▪ (See Table 26-6) | |

Source: DME (2010a, 2010b)

## 31.1.3 STATUS OF COAL AND THE COAL MINING INDUSTRY

There are currently 93 operating coal mines as per recent statistics for coal mining in South Africa (see Table 31-3). Forty operations use only surface mines, 18 combine surface and underground mining operations, and 35 are solely underground mining operations. (DME, 2009). About 47 percent of South Africa's coal production is from underground mines and about 53 percent is from surface mines (GCIS, 2009).

**Table 31-3. South Africa's Recent Production and Mine Statistics**

| Type of mine | Production (million tonnes) | Number of mines |
|---|---|---|
| Underground | NA | 35 (2008) |
| Opencast / Surface | NA | 40 (2008) |
| Combined Opencast and Underground | NA | 18 (2008) |
| Total production | 239.3 (2003) | 93 (2008) |

Source: DME (2009)

The coal mining industry is operated by private companies. Increasingly these companies are consolidating and multinational coal mining companies are joining large domestic companies. Forty-two companies currently operate coal mines in South Africa (DME, 2009), although only six companies—Anglo Coal, BHP Billiton, Kumba Resources, SASOL Mining, Exxaro Coal and Xstrata Coal—are responsible for about 90 percent of the country's saleable coal production. The eight largest mines account for 61 percent of output (GCIS, 2009).

Asset sales have been conducted to achieve government-set targets for black ownership under South Africa's black economic empowerment program (BEE). For example, South Africa's procurement policies for Eskom, the parastatal electric utility, grant preferences to companies owned by previously disadvantaged communities. In November 2000, Anglo Coal and Ingwe sold assets for US$222 million to the black empowerment group Eyesizwe Coal, creating what was at the time South Africa's fourth largest coal mining company. Subsequent deals included the splitting of Kumba resources and the formation of Exxaro Resources, which contains assets from both Kumba and Eyesizwe (DME, 2008b). Exxaro is now the largest black mining firm and the fourth largest coal producer in South Africa (DME, 2006).

Future new coal developments are expected to be located mainly in the northern provinces of Limpopo and Mpumalanga. Anglo and Sasol began operation of the Kriel South coalfield, Mpumalanga province in 2005 and produces 5.0 Mmt per year (Anglo, 2005). Coal of Africa (COA, 2009) is progressing with plans for two mines in the Limpopo province, which at full capacity will produce a total of 10 Mmt per year (combined investment US$755 million). ESKOM estimate that 40 new mines will be necessary over the next decade to produce enough coal to fuel future electricity demand (SAinfo, 2009).

The percentage of operating mines considered "gassy" is very low. It is estimated that in the shallower fields, methane loss could have approached 80 percent of initial gas content in the coalification process (UNFCCC, 2000). However, newer underground mines that may be developed in deeper zones are likely to be gassier.

## 31.2 Overview of CMM Emissions and Development Potential

In the mid-1990s, South Africa was ranked as one of the world's top five CMM emitters attributable to its high coal production and estimates placed the gas content of South Africa's coals on a par with Australia's. Since then, it has been shown that these original estimates were overstated. In 2008, its rank in worldwide CMM emissions dropped to ninth with estimated emissions of almost 10 million tonnes of carbon dioxide equivalent (Mmt$CO_2$e) (EPA, 2008).

The Global Methane Initiative (formerly Methane to Markets Partnership) International CMM Projects Database currently identifies one CMM recovery project in South Africa (M2M Projects, 2010). The recovery project is a flaring project at Anglo American Thermal Coal's New Denmark colliery near Standerton. The operation involves the incorporation of two enclosed Swiss-designed mobile flares into the mine's methane drainage system. A small diesel blower delivers the methane to four flaring nozzles, where the gas is mixed with air to a concentration that enables it to be safely burnt. The process can be monitored remotely via the flare's solar-powered communication system. The project reportedly cost US$1.2 million and the project developers are pursuing carbon credits under the Clean Development Mechanism (Creamer, 2010).

### 31.2.1 CMM Emissions from Operating Mines

A national greenhouse gas (GHG) inventory for South Africa was initially prepared for the years 1990–1994 for South Africa's First National Communication Report to the UNFCCC, published in 2000. Work is currently underway by the Climate Change Division of the Department of Environmental Affairs and Tourism (DEAT) to design a process and approach for preparation of an updated inventory (DEAT, 2010).

In the energy sector, fugitive emissions contributed 323 gigagrams (Gg) (475 million cubic meters [$m^3$]) of methane in 1990 and 327 Gg (481 million $m^3$) in 1994, which represents about 16 percent of the total methane emissions. In 1990, methane emissions from coal mining contributed almost 100 percent of the fugitive emissions and 97 percent in 1994 when emissions from natural gas processing were included in the total. Of the coal mining fugitive emissions, 88 percent were from underground mines (UNFCCC, 2000). Methane emissions for South Africa are summarized in Table 31-4.

**Table 31-4. South Africa's CMM Emissions (million cubic meters)**

| Emission Category | 1990 | 1994 | 1995 | 2000 | 2005 | 2010 | 2015 |
|---|---|---|---|---|---|---|---|
| Underground coal mines – drained emissions | 418 | 423 | | | | | |
| Surface mine emissions (total) | 57 | 58 | | | | | |
| Total emitted (= Total liberated – recovered & used) | 471* | - | 466* | 495* | 519* | 520* | 521* |

Source: UNFCCC (2000); *USEPA (2006) – estimates and projections

A detailed industry-funded study, *Coal Tech 2020*, was conducted in 2004, to more accurately assess South Africa's CMM emissions. This study, conducted by the Council for Scientific and Industrial Research (CSIR), measured ventilation air methane concentrations from most major mines (USEPA, 2004a). The final report is only available to CoalTech members, but a summary of its principal results by study participants Alan Cooke and Philip Lloyd provides key insights as to South Africa's likely CMM emissions levels. An excerpt from their findings is provided below in Figure 31-5.

**Figure 31-5. *Coal Tech 2020* Summary Results**

During the course of this work most of the production shafts on underground mines have been sampled repeatedly. In total there were 243 measurements of methane in the return air from 27 different shafts. As we have seen, a wide scatter was observed, but taken as a whole the results give us some measure of the quantities involved. For each shaft the average methane concentration was multiplied by the known ventilation rate, which gave a contribution to the total methane emission of 40.8 Gg $CH_4$/a (with an error of ±30.2 Gg).

Seam gas contents had been determined for about 72% of the coal production. Assuming 50% was lost underground, and contributed to the methane in the return air, and that the mines for which data were missing were represented by the mines for which there was data, then the total lost after leaving underground mines was about 28.6 Gg $CH_4$/a (with an error of about 24 Gg).

Thus the best present estimate of the release of methane from South African coalmines is:

- 40.8 Gg $CH_4$/a in ventilation air from underground mines;
- 28.6 Gg $CH_4$/a from coal after it has left the mine; and
- <3 Gg $CH_4$/a from surface mining operations,

or approximately 72 Gg/a.

However, there are very large errors associated with these estimates. The source of these errors is largely the physical processes responsible for the release of much of the methane from South African coalmines, particularly the sporadic release of free methane. This causes huge fluctuations in the measurable concentrations of methane in the return air. To improve the estimates will require effectively continuous measurements over several weeks on each shaft. Further errors arise from the considerable variation in the seam gas content of the coal, and it will require repeated measurements of the residual gas in coal coming from underground in each mine before these errors can be reduced significantly.

Source: Excerpted from Lloyd and Cook (2004)

The coal seams of the main Karoo coalfields—being relatively shallow—are generally not regarded as being very gassy. Accordingly, little attention has been paid to CMM recovery and end-use. There are, however, several individual examples of gassy mines in South Africa. The most noted example is the Majuba Colliery, which has experienced higher than expected levels of methane in the mine workings. Gas desorption tests showed that the coal contains up to 300 cubic feet per ton. In the early 1990s, several in-mine horizontal wells were drilled to degasify the coal in advance of mining. The mine operators were contemplating various CMM drainage and end-use scenarios, but the mine was eventually closed due to other reasons (USEPA, 2004b).

Some South African mines have been known to drain methane prior to mining through surface holes and the feasibility of recovering this methane for use in local heating has been widely investigated (UNFCCC, 2000).

### 31.2.2 CMM Emissions from Abandoned Mines

South Africa has a number of abandoned coal mines, the number of operating mines having declined by about one half between 1986 and 2004 (Limpitlaw and Aken, 2005). No data quantifying emissions from abandoned mines in South Africa were found. However, the percentage of gassy mines is thought to be low as most of the gassy areas of South Africa's coal resources have not yet been developed. It does not appear that any company is currently extracting methane resources from abandoned mines. Key barriers are legal and regulatory constraints; many companies are concerned that once they have received a mine closure certificate, further work in and around the mine could expose them to legal liabilities.

### 31.2.3 CBM from Virgin Coal Seams

The country's coalbed methane (CBM) resource is estimated to be 0.14–0.28 trillion $m^3$. Currently there is no commercial CBM production reported for South Africa; however, there is significant discussion about possible future projects, and several pilot wells have been installed and are undergoing testing. Moreover, adoption of CBM/CMM technologies could become increasingly likely as additional mines are expected to open in gassy coal fields.

The most promising areas for CBM are the deeper, thicker, and gassier coal resources. The Waterberg Basin in the northwest Mpumalanga region of the country and the southwest portion of the Highveld coalfield near Paardekop-Amersfoort are deeper (> 1,000 feet) and gassier (4–10 $m^3$/tonne at 1000–1200 ft) and appear to have the best potential for CBM development (ARI, 1992).

Anglo Coal has been conducting a CBM exploration program in the Waterberg Basin for the past several years. As part of this program, a series of core wells were drilled and tested and a five-well pilot production project is currently underway. Barriers to project progress include its remote location, delays in rights conversions, lack of prior experience among government authorities, and lack of incentives (DME, 2006; Merwe, 2007). Other CBM licenses are held by Badimo, NT Energy Africa, Molopo/Highland Energy, Msix, and numerous smaller companies, but little work has been done to date.

While there is only one active CMM recovery and end-use activity in South Africa, there are several reports from the gold mining sector of companies utilizing methane coming from gold mine shafts. For example, at the Harmony Gold Mine in the Free State province, the kitchen stoves and bath houses were fueled by captured mine methane for more than 20 years (USEPA, 2004b). The Beatrix Gold Mine, also in the Free State province, has applied for a methane capture project under the Clean Development Mechanism (CDM) of the Kyoto Protocol (Le Roux, 2007). Methane emanates from faults and fissures intersected during normal mining operations and a pipeline drainage system is currently being installed to capture the methane at source underground and transport it to the surface where the gas will be flared (Creamer, 2010b). The mine estimates that for an initial outlay of US$5.5 million, US$27 million in carbon credits will be earned over 7 years through flaring alone, with resultant emission reductions estimated to be 2.6 $MmtCO_2e$. Plans are also in place to begin construction of a methane-fueled 5 megawatt (MW) power plant in 2011.

## 31.3 Opportunities and Challenges to Greater CMM Recovery and Use

As reflected in Table 31-5, South Africa is a signatory to both the UNFCCC and the Kyoto Protocol. As a non-Annex 1 country, South Africa is eligible to host CDM projects that reduce GHG emissions. Carbon credits could be available if South Africa reduces total emissions below 1990 levels (USEPA, 1998).

**Table 31-5. South Africa's Climate Change Mitigation Commitment**

| Agreement | Signature | Ratification |
|---|---|---|
| UNFCCC | June 15, 1993 | August 8, 1997 |
| Kyoto Protocol | --- | July 31, 2002 (Accession) |

Source: UNFCCC (2004); UNFCCC (2005)

### 31.3.1 Market and Infrastructure Factors

Significant research and development (R&D) organizations exist in South Africa to assist in the assessment of CMM emissions, recovery potential, and technology. Coaltech 2020 is an industry-led consortium of coal mine research and technology organizations (see Table 31-6).

**Table 31-6. Coaltech 2020 Consortium Members**

| | |
|---|---|
| Anglo Coal | Kumba Resources |
| CSIR Mining Technology | National Union of Mineworkers (NUM) |
| Department of Minerals and Energy (DME) | National Research Foundation (NRF) |
| Department of Trade and Industry (DTI-THRIP) | Sasol Coal |
| Xstrata (producer) | The Chamber of Mines of South Africa |
| Eskom (state utility) | Total |
| Eyesizwe | University of Pretoria |
| Ingwe | University of Witwatersrand* |

*Note: The University of Witwatersrand has for more than a decade conducted research on coal seam gas content, gas emission rates, permeability, and other coal properties (Schwochow, 1997).

The potential end uses for CMM in South Africa include electric power generation, boiler fuel, transportation fuel, and petrochemical feedstocks. CMM could offset or reduce growing requirements for gas imports to meet growing gas demand. It could also provide an effective fuel substitute for coal and firewood.

Where mines are shallow and less gassy, collected CMM could be used for local heating purposes, but infrastructure would be required. In new areas, where virgin seams are deeper and gassier, CBM development could precede mining. Higher gas volumes from CBM and subsequent CMM in commercial quantities would require infrastructure investments for development of deeper mines, installation of gas collection technologies, and construction of gas pipelines to move the methane to markets.

Evidence of the gas potential in South African coals has evolved from a long record of gas-related mine explosions. Mines experience problems with gas and dust explosions and fires because the coals are hard and highly prone to sparking, as are the sandstone roof rocks. The proportion of mine deaths related to explosions increased from 3 percent in 1955 to 21 percent in 1993 (Schwochow, 1997).

### 31.3.2 Regulatory Information

In South Africa, CBM is defined by law as a unique mineral, so rights to its exploration and development can be separate from those of coal in the same seam. Under the latest Minerals Act, all mineral rights are vested with the government. Companies that held mineral rights under old orders, however, can apply for an extension to retain those rights. Technically, development licenses are required by law after commercially successful exploration, but many mines currently operate under exploration licenses. Licensing requirements and applications are available for review on the Department of Minerals and Energy's website (www.dme.gov.za).

Electricity, petroleum pipelines, and piped gas including CBM are regulated by the independent National Energy Regulator of South Africa (NERSA), which—among other things—issues licenses for construction and operation of gas transmission, storage, distribution, liquefaction, and re-gasification facilities (Gas Act, 2001). The piped gas industry is regulated by the Gas Act as amended by the National Energy Regulatory Act, which was brought into operation in 2005. Prior to 2005, the gas industry was not regulated and companies had to negotiate a regulatory agreement with the South African Government. The Piped-Gas Regulations Act came into effect in 2007. The Act is continuously reviewed by NERSA with the aim of suggesting possible amendments to the Minister of Minerals and Energy should these be deemed necessary (NERSA, 2009).

## 31.4 Profiles of Individual Mines

A comprehensive inventory of coal mines and coal production in South Africa can be found on the DME website (DME, 2010c). Detailed spreadsheets of mines and contact information are also available online at http://www.dme.gov.za. Profiles for individual mines are not available.

## 31.5 References

Anglo (2005): Production starts at Anglo American's Isibonelo coal mine in South Africa. AngloAmerican press releases, July 2005. http://www.angloamerican.com/aal/media/releases/2005pr/2005-07-04/

ARI (1992): Coalbed Gas -2: Vast Resource Potential Exists in Many Countries, Kuuskraa, Vello A., and Jonathan R. Kelafant., *Oil & Gas Journal*, November 2, 1992. (Reprint)

BP (2010): Statistical Review of World Energy June 2010. http://www.bp.com/productlanding.do?categoryId=6929&contentId=7044622

CM (2008): Facts and Figures 2008. Chamber of Mines of South Africa. http://www.bullion.org.za/Publications/Facts&Figures2008/Text2008.pdf

COA (2009). Coal of Africa Limited, Annual Report 2009. http://www.coalofafrica.com/-Annual-Reports-.html

Creamer (2010). "Methane flaring mitigating climate change – Anglo Thermal Coal." Mining Weekly, 12 May 2010. http://www.miningweekly.com/article/methane-flaring-mitigating-climate-change-anglo-thermal-coal-2010-05-12

Creamer (2010b). "Gold Fields turns killer-gas methane curse into R200m Beatrix revenue stream." Mining Weekly, 26 May 2010. http://www.miningweekly.com/article/gold-fields-turns-killer-gas-methane-curse-into-r200m-beatrix-revenue-stream-2010-05-26

DEAT (2010): National Greenhouse Gas Inventory - Department of Environmental Affairs and Tourism climate change web page. Accessed July 2010. http://www.environment.gov.za/ClimateChange2005/National_Greenhouse_Gas_Inventory.htm

DME (2005a): "Aggregate Energy Balances" South Africa Department of Minerals and Energy, 2005, http://www.dme.gov.za/energy/documents.stm#6..

DME (2006): South Africa's Mineral Industry 2005/2006. South Africa Department of Minerals and Energy, 2006

DME (2008); South Africa's Mineral Industry 2007/2008. South Africa Department of Minerals and Energy, 2007. http://www.dme.gov.za/pdfs/minerals/SAMI%202007%202008.pdf

DME (2009): Operating Mines and Quarries and Minerals Processing Plants in the Republic of South Africa, 2009. Pretoria: South Africa Department of Minerals and Energy, 2009. Also available online at http://www.dme.gov.za/pdfs/minerals/D1%20Information%202009.pdf

DME (2010): "Aggregate Energy Balances" South Africa Department of Minerals and Energy, 2006. Accessed 16 June 2010. http://www.dme.gov.za/pdfs/energy/statistics/Me/Ag.xls

DME (2010a): "Coal" South Africa Department of Minerals and Energy, http://www.dme.gov.za/energy/coal.stm

DME (2010b): "Overview of the Minerals Industry," South Africa Department of Minerals and Energy, http://www.dme.gov.za/minerals/mineral_info.stm

DME (2010c): "Mineral Directories," South Africa Department of Minerals and Energy, http://www.dme.gov.za/minerals/minerals_information.stm

Dykes (2006): Information provided by Arthur Dykes, advisor to NERSA, 2006.

EIA (2007): Data obtained from *International Energy Annual 2005*. U.S. Energy Information Administration, Washington, DC, table posted June 21, 2007 at http://www.eia.doe.gov/pub/international/iea2006/table82.xls (reserves)

EIA (2010): U.S. Energy Information Administration, "South Africa Country Analysis Brief" March, 2010. http://www.eia.doe.gov/emeu/cabs/South_Africa/Coal.html

Gas Act (2001): Act No. 48 of 2001, Published in the Government Gazette of the Republic of South Africa. February 21, 2002.

GCIS (2009): *South Africa Yearbook 2008/2009 – Minerals, Energy and Geology*. Government Communication and Information System, 2009. http://www.gcis.gov.za/resource_centre/sa_info/yearbook/index.html

Hill (2007): "Government Teams up with Private Firm to Develop New Methane Projects," *Mining Weekly Online*, Mathew Hill, Dec 2007. http://www.engineeringnews.co.za/article.php?a_id=123548

IEA (2005): *International Energy Agency Energy Statistics – Coal*. International Energy Agency, Paris, France, table posted at http://www.iea.org/Textbase/country/index.asp

IEA (2009): International Energy Agency Energy Statistics – Share of total primary energy supply in 2007. International Energy Agency , Paris France. Accessed 15 June 2010. http://www.iea.org/stats/pdf_graphs/ZATPESPI.pdf

IEA (2010): International Energy Agency Energy Statistics – Coal and Peat in South Africa in 2007. International Energy Agency , Paris France. Accessed 14 June 2010. http://www.iea.org/stats/coaldata.asp?COUNTRY_CODE=ZA

Limpitlaw and Aken (2005): "Post Mining Rehabilitation, Land Use, and Pollution at Colliers in South Africa, Presented at the Colloquium: Sustainable Development in the Life of Coal Mining, Boksburg, 13 July, 2005. http://www.csmi.co.za/library_research/papers/2005/Post_mining_landuse_Collieries_jul05.pdf

Le Roux (2007); "Gold Mine Pursues Carbon Credits for Methane Capture," *Mining Weekly Online*, Helene Le Roux, May 2007. http://www.miningweekly.com/article/gold-mine-pursues-carbon-credits-for-methane-capture-2007-05-04

Lloyd and Cook (2004): Methane Release from South African Coal Mines, Lloyd, Philip and Alan Cook, http://www.erc.uct.ac.za/publications/Methane%20release%20from%20South%20African%20coal%20mines.pdf

M2M Projects (2010): Methane to Markets International Coal Mine Methane Projects Database, Methane to Markets, accessed July 2010. http://www2.ergweb.com/cmm/index.aspx

Merwe (2007): "Interest in Coal Bed Methane on the Increase," Mining Weekly Online. Christy van der Merwe, March 2007. http://www.miningweekly.com/article/interest-in-coalbed-methane-on-the-increase-2007-03-16

NERSA (2009): NERSA Annual Report for 2008/09. http://www.nersa.org.za/Admin/Document/Editor/file/News%20and%20Publications/Publications/Current%20Issues/NERSA%20Annual%20Report%202009.pdf

SAinfo (2009): South Africa 'needs 40 new coal mines'. August, 2009. http://www.southafrica.info/news/business/832012.htm

Schwochow (1997): The International Coal Seam Gas Report, Cairn Point Publishing, Steve Schwochow, editor, 1997

UNFCCC (2000): South Africa "Initial National Communication to UN Framework Convention on Climate Change," October 2000, p.77. http://unfccc.int/resource/docs/natc/zafnc01.pdf

UNFCCC (2004): United Nations Framework Convention on Climate Change - Status of Ratification, May 24, 2004, http://unfccc.int/resource/conv/ratlist.pdf

UNFCCC (2005): Kyoto Protocol - Status of Ratification, September 19, 2005, http://unfccc.int/files/essential_background/kyoto_protocol/application/pdf/kpstats.pdf

USEPA (1998): "South Africa Country Fact Sheet" World Bank / U.S. EPA Seminar and Roundtable on Coalbed Methane Development Potential, September 1998.

USEPA (2004a); Coalbed Methane Outreach Program South Africa Trip Report, March 1–13, 2004

USEPA (2004b): International Activities – South Africa, U.S. Environmental Protection Agency, Coalbed Methane Outreach Program.

USEPA (2006): *Global Anthropogenic Non-$CO_2$ Greenhouse Gas Emissions: 1990–2020*, Draft, U.S. Environmental Protection Agency, Office of Atmospheric Programs, Climate Change Division, June, 2006. Available at http://www.epa.gov/nonco2/econ-inv/international.html.

USEPA (2008): Coal Mine Methane Project Development: Global Update. Presentation by Franklin, P., at the UNECE Ad Hoc Group of Experts on CMM, Geneva, October 2008. http://www.unece.org/energy/se/pdfs/cmm/4ahge_cmm/4_Franklin.pdf