Coal prospects in Botswana, Mozambique, Zambia, Zimbabwe and Namibia

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Abstract

Increasing demand for coal in Asia is stimulating interest in the potentially large coal resources in Southern African countries such as Botswana, Mozambique, Zambia, Zimbabwe and Namibia. These countries have been slow to utilise their coal as local demand has been limited and the means to export coal has been inadequate. The governments in these regions are now recognising coal as a strategically important commodity, capable of earning foreign revenue but also adding value to the economy by generating much needed electricity. This report looks in turn at the role of coal in the energy economies of each of these countries. As in most emerging economies, the provision of a reliable and cost-effective supply of electricity to industries and people is essential for economic growth and the welfare of communities. Demand for Africa's mineral commodities such as diamonds and copper is driving a massive need for electricity and coal will play a major role. Not only does the mining industry need power, but with these growing industries come communities and commerce which are also in need of energy.

Acronyms and abbreviations

ADGB	African Development Group Bank
AfDB	African Development Bank
AER	African Energy Resources
BAGC	Beira Agricultural Growth Corridor
BEMP	Botswana Energy Master Plan
BPC	Botswana Power Corporation
CCS	carbon capture and storage
CO_2	carbon dioxide
CFM	Portos e Caminhos de Ferro de Moçambique
CIA	Central Intelligence Agency
CFP	central processing facility
CERs	certified emission reductions
CFBC	circulating fluidised bed combustion
CDM	Clean Development Mechanism
CBEND	Combating Bush Encroachment for Namibia's Development
CBM	coalbed methane
CTL	coal-to-liquid
CVRD	Compania Vale de Rio Doce
CSP	concentrated solar power
CEC	Copperbelt Energy Corporation
DFRN	Desert Research Foundation of Namibia
DRC	Democratic Republic of Congo
DNA	designated national authority
DME	dimethyl ether
EDM	Electricidade de Mozambique
ENE	Empresa Nacional de Electricidade Angola
ERB	Energy Regulation Board
ECN	Energy Research Centre of the Netherlands
ECBM	enhanced coalbed methane
ENRC	Eurasian Natural Resources Corporation
ESI	electrical supply industry
FAM	armed forces of Mozambique
FSI	free swelling index
FRELIMO	Front for Liberation of Mozambique
FUNAE	Fundo de Energia
GDP	gross domestic product
Gt	gigatonne
GJ	gigajoule
GWh	gigawatt hour
HCB	Hidroeléctrica de Cahora Bassa
HVDC	high voltage direct current
HCC	Hwange coking coal
HIC	Hwange industrial coal
IDC	Industrial Development Corporation (South Africa)
IPP	independent power producer
JORC	joint ore reserves committee
JV	joint venture
KSE	Karoo sustainable energy
kWh	kilowatt hour
LULUCF	land use, land use change and forestry

LNG	liquefied natural gas
LHPC	Lunsemfwa Hydro Power Company
MCL	Maamba Collieries Limited
MW	megawatt
MWe	megawatt electric
MEPD	Ministry of Energy and Power Development
MEWD	Ministry of Energy and Water Development
MEWT	Ministry of Environment, Wildlife and Tourism
MMEWR	Ministry of Minerals, Energy and Water Resources
MEP	Mmamabula Energy Project
NAMCOR	National Petroleum Corporation of Namibia
NAPA	National Adaptation Plan of Action
NAMAs	national appropriate mitigation actions
NDP	national development plans
NEP	National Energy Policy
NO	nitrous oxide
OPPPI	Office for the promotion of private power investment
PEDSA	Ministry of Agriculture's agricultural sectoral development strategic plan
PER	panafrican energy resource
PRA	petroleum regulatory authority
PPA	power purchase agreement
PSDRP	private sector development reform programme
PF	pulverised fuel
RENAMO	Mozambique National Resistance Movement
REEEP	Renewable Energy and Energy Efficiency Partnership
ROM	run of mine
REA	rural electrification authority
SIRDC	Scientific and Industrial Research and Development Centre
SNEL	Société National d'Eléctricité
SACCCS	South African centre for carbon capture and storage
SADC	Southern African development community
SAPP	Southern African power pool
SEC	Swaziland electricity company
TANESCO	Tanzania electricity supply company limited
TNA	technical needs assessment
TCM	Terminal de Carvao da Matola
TWh	terrawatt hour
TFR	Transnet Freight Rail
UCG	underground coal gasification
UNIP	United National Independence Party
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework on Climate Change
WEC	World Energy Council
WHO	World Health Organisation
ZESCO	Zambia Electricity Supply Corporation Limited
ZERA	Zimbabwe electricity regulatory authority
ZERC	Zimbabwe electricity regulatory commission
ZESA	Zimbabwe electricity supply authority
ZETDC	Zimbabwe electricity transmission and distribution company
ZEEP	Zimbabwe energy efficiency project
ZPC	Zimbabwe Power Company

Contents

1 Introduction

Southern Africa has a wealth of coal resources as proven by the massive coal mining and export industry operating in the Republic of South Africa today. South Africa is well understood with its vast 200 Mt/y coal market, but less is known of the other Southern African countries listed here, which are in the early stages of growth of their respective coal industries:

- Mozambique;
- Botswana;
- Zambia;
- Zimbabwe;
- Namibia.

These countries have been slow to utilise their coal as local demand has been limited and the means to export coal has been inadequate. The governments in these regions are now recognising coal as a strategically important commodity, capable of earning foreign revenue but also adding value to the economy by generating much needed electricity.

This report looks in turn at the role of coal in the energy economies of these countries. As in most emerging economies, the provision of a reliable and cost-effective supply of electricity to industries and people is essential for economic growth and the welfare of communities. Demand for Africa's mineral commodities such as diamonds and copper is driving a massive need for electricity and coal will play a major role. Not only does the mining industry need power, but with these growing industries come communities and commerce which are also in need of energy. Issues that could spearhead a surge in coal production and consumption in these countries include:

- Economic and political environment.
- Energy and climate change policy.
- Primary energy demand and the role of coal.
- Electricity generation – current market structure and generating capacity.
- Coal-fired power – current operating capacity , technology deployed, and environmental emission equipment.
- Coal demand – trends and future projections based on newly built and planned coal-fired capacity.
- Coal resource, quality, production, and export potential.
- Application of advanced or unconventional coal technology such as CFBC, super-critical technology, gasification, other solid fuels (biomass).

Rapid growth in global demand for Africa's mineral commodities is fuelling a need for reliable and cost-effective electricity for the mining industry. Add to this the need for improved electrification in rural populations and increasing cross border trade of electricity, the provision of new electricity sources becomes challenging.

2 Mozambique

2.1 Basic facts

Population:	23.9 million
Capital:	Maputo
Currency	Metical
Total coal production (2010 estimate):	0
Total coal demand (2010 estimate):	0
Imports (2010 estimate):	0

The county has a total land area of 799,380 km^2 and a coastline of 2470 km; it is bordered by South Africa, Zambia, Tanzania, Malawi, Swaziland and Zimbabwe. The population of 23 million live in eleven provinces (CIA, 2012a). There are ten administrative provinces and the capital city Maputo forms a special administrative province. These provinces are subdivided into a total of 129 districts, which are further divided into 405 administrative posts and then into 'localities'. Figure 1 shows all the provinces in Mozambique as well as some of the infrastructure that connects the various regions of the country.

According to the World Bank (2012), in 2011 the average life expectancy for a Mozambique citizen was 50 years and per capita GDP was $982. To improve living standards and the welfare of the population, Mozambique's government aims to improve the energy infrastructure and supply to industry, local businesses and the residential population.

Figure 1 Map of Mozambique provinces, roads and power lines (Mining Journal, 2008)

Mozambique is a relatively energy-rich country with gas and coal reserves constantly being found. These energy assets will prove valuable to economic growth through the development of an export industry, particularly for coal. Hydroelectric power is also a rich source of energy in this country; there are 39 rivers flowing into the Indian Ocean including the famous Zambezi, the fifth largest river basin in the world. Biomass is also potentially a large energy source, provided it can be harvested sustainably, with 70% of the country covered by savannah and secondary forests. Around 45% of the land has potential for agriculture, and in total, 60% of the agricultural land is already classified as managed, including agriculture and permanent pasture lands (Ministry for Co-ordination of Environmental Affairs, 2003).

Mozambique's political history has been turbulent. The overthrow of the Portuguese government in 1974 resulted in the end of colonial rule in Mozambique (and Angola) with independence gained in 1975. The socialist ruling party, the Front for Liberation of Mozambique (Frelimo), became the government in 1975. Within two years, Mozambique descended into a 15-year civil war between the national resistance movement (Renamo) and the Frelimo government. During the civil war millions were killed, injured, and displaced from their homes. Opposition forces were supported by Zimbabwe and South Africa due to Mozambique's involvement in opposition activities within these neighbouring countries. The civil war pushed Mozambique into becoming one of the poorest nations in Africa. The country's infrastructure was destroyed, and consequently lack of rail and inland freight infrastructure is still a problem affecting the mobility of people, businesses, and coal exports.

In 1992, a peace agreement was signed between the Frelimo and Renamo parties and democratic elections were held in 1994. The Frelimo gained victory and has ruled the country ever since. The Renamo party and the Mozambique Democratic Movement are still the main opposition parties. Nevertheless, the government has remained politically stable under the current president Armando Emílio Guebuza (term ending 2014). The Frelimo party has greater support in the south of the country where the capital Maputo is located; the Renamo party are more popular elsewhere. Anti-white rule has dominated neighbouring Zimbabwe, and whilst some groups with similar views operate within Mozambique, they are small and no such view has been expressed by the major parties.

Economically, the government encourages investment and development by managing a favourable tax structure for foreign companies. This has led to considerable interest in the coal sector and to exploration of some of the world's largest undeveloped coal reserves in the west of the country, along with natural gas deposits in the Indian Ocean. There are currently up to 40 coal mining companies exploring and developing coal mines in the country. The largest mining concessions are held by Vale (Brazil) and Rio Tinto (UK), with smaller concessions held by the Talbot-Nippon Group (Japan) and Jindal Steel (India).

2.2 Economy and policy

Economically, Mozambique has weathered the global economic and financial crises, with economic growth dipping to 6.3% in 2009 but rising to 7.2% in 2011 and 7.5% in 2012 (World Bank, 2013). Inflation has fallen to record low levels, at 1.2% in the twelve months ending in September 2012. Infrastructure spending as well as foreign investments in new mega-projects are expected to drive economic growth to 8% over the medium-term. Former colonial influences such as Portugal mean there are strong economic ties, but China and South Africa have been leading investors in recent years (*see* Figure 2).

In 2011, GDP exceeded $12.8 billion with the economy expanding by 7.3% due to a good agricultural performance and an expanding mining sector (Reuters, 2011). GDP per capita has doubled in eight years, but still remains under $1000. Reforms in the banking and financial sectors are under way, but corruption in public institutions is still a major problem. Improvements are being made in terms of collecting government revenues through taxation and better management of receipts.

While coal and other minerals are growing industries, the main economic activity in Mozambique has traditionally been based on agricultural activities and the production of cash crops such as cotton, copra (coconut product), tea, sugar, and cashew nuts. Fishing contributes to the economy, and tourism is also being developed after years of conflict; Mozambique was once a destination for visitors from South Africa and Zimbabwe. Liquefied natural gas (LNG) is another potential energy export with a liquefaction plant due to come online in 2018. Unless coal developments happen more quickly, LNG may well take a lead in being a major export revenue earner.

Although agriculture remains a large part of the economy, major industrial operations include aluminium production which makes up 50% of the country's exports. The aluminium industry comprises chiefly of the Mozal smelter that is located in the Maputo province, southern Mozambique. The smelter is jointly owned by BHP Billiton Ltd (47.1%), Mitsubishi Corp (25%), the Industrial

Figure 2 Top 10 investors in Mozambique in 2011 (Alves, 2012)

Development Corporation of South Africa (24%), and the Government of Mozambique (3.9%). The Mozal project was commissioned in 2003 becoming the first major development in Mozambique for 30 years, producing around 560,000 tonnes of aluminium per year and employing more than 1100 people.

Amongst many pressures facing the economic development of Mozambique is education. According to the African Development Bank, Mozambique is estimated to have the lowest level of education among its adult population in the world at 1.2 years of formal education. This low skills level is a major challenge and obstacle for employers in the industrial and mining sectors when recruiting qualified labourers. The reason for the low skills level is that the majority of Mozambique's people live in rural areas, and are dependent on farming. In total, 99% of farmers subsist on small-scale, family-based agriculture which is sometimes the only source of income.

The key is to strike a balance between using mineral wealth and improving the welfare and quality of life of Mozambicans. The government is a signatory of the Extractive Industries Transparency Initiative, a programme set up by Britain and supported by the World Bank to ensure that governments and companies are honest about revenues. There has been an economic boom in Mozambique over the last twenty years. However, the country is still 184th out of 187 countries on the Human Development Index, just above Burundi, Niger and the Democratic Republic of Congo. The Index uses criteria such as life expectancy, income and education as metrics.

The Government has undertaken substantial economic reforms since the 1980s with 1200 state-owned small and medium-sized enterprises being privatised. Work is under way to privatise the electricity generation and transmission, ports, railways and telecommunications sectors (Chambal, 2010). The Government of Mozambique could hold a minority interest in these ventures, while majority ownership is retained by credit-worthy corporations improving access to lending and equity that could further boost investment, education, and training in the country.

2.2.1 Energy policy

To date, the framework for energy policy is based on the government-approved Energy Management Strategy for the Energy Sector (2008-12). The strategy establishes the policy guidelines and relevant measures for the energy sector based on principles such as:

- increased sustainable access to electricity and liquid fuels;
- sustainable utilisation of wood fuel;
- promotion of new and renewable sources of energy;
- diversification of the energy matrix;
- joint planning and integration of energy initiatives with development plans and programmes of other sectors;
- sustainable development and environmental protection;
- tariffs reflecting real costs and the incorporation of mitigation measures to protect the environment;
- promotion of the concept of the productive use of energy and enlarging the approach to energy supply to include the supply of systems and tools;
- institutional co-ordination and consultation with relevant stakeholders for better development of the energy sector;
- active participation in international co-operation forums, including the Southern African Development Community (SADC); and the efficient use of energy (Chambal, 2010).

The following sections analyse and report on how the guidelines and policy measures are working.

2.2.2 Coal policy

The Government is committed to encouraging foreign investment for its fledgling mining industry in strategic assets such as coal. All applications for exploration and mining rights are submitted to the Minister of Mineral Resources and Energy for processing by the National Directorate of Mines. So far, the biggest mining concessions are held by Vale and Rio Tinto, and there are also smaller concessions held by the Talbot-Nippon Group and Jindal Steel which are discussed later.

The most significant early mover in the coal industry was the Brazilian corporation Compania Vale do Rio Doce (CVRD or Vale); the company started its exploration and feasibility studies in 2005-06. By 2008, the government awarded a five-year development licence to Vale, which enabled it to build a $1.3 billion opencast coal mine in Moatize.

The next biggest mining company operating is Rio Tinto. The company acquired the concession from exploration company, Riversdale, in 2011. Rio Tinto holds mining concessions of 290,000 hectares for the Benga and Zambezi projects. The two sites are estimated to hold 4 Gt and 9 Gt of coal reserves respectively. Under the current economic conditions of 2013, Rio Tinto way well tentatively hold onto their shares of this business, but the long-term prospect is less certain.

2.2.3 Electricity market policy

The Mozambican power utility Electricidade de Moçambique (EDM) maintains and operates the national grid that links most of the major cities in the country. The power grid covers about 6% of the country and so most of Mozambique's homes and businesses have limited or no access to electricity; only 10.5% of households have such access. Half of those households are located in Maputo the capital and surrounding areas. Currently, electricity demand is averaging 7%/y growth and the government's objective is to reach an electrification rate of 15% by 2019 and 20% by 2020 (Chambal, 2010). Despite having an apparent deficiency in its economy, it is surprising to see that Mozambique is a *net-exporter* of electricity, supplying mainly South Africa and the Southern Africa Power Pool (SAPP).

Domestically, EDM is currently undertaking a massive electrification programme that is expanding at a rate of 100,000 new connections annually (Hankins, 2009). The electricity sector can be divided into four sectors in Mozambique. These sectors are the residential and commercial consumers, industry, off-grid consumers (managed by the Fundo de Energia or FUNAE), and finally exports to the Southern African Power Pool (SAPP).

The SAPP is an important and integral part of the Southern African power supply, but it appears to serve chiefly the needs of South Africa. The largest participant, Eskom, accounts for more than 82% of generating capacity and over 85% of peak demand (Chambal, 2010). This dominance is unlikely to change in the near future. The other representatives in SAPP include the power utilities of Botswana, Mozambique, Angola, Malawi, Swaziland, the Democratic Republic of Congo, Namibia, Tanzania and Zimbabwe. The aim of SAPP is to create one single interconnected grid in Southern Africa.

2.2.4 Climate change policy

The Mozambican government has made a commitment to global climate agreements, and is a member of the United Nations Framework Convention on Climate Change (UNFCCC) through the country's ratification of the Kyoto Protocol. The country has established a Designated National Authority (DNA) which manages activities under the Kyoto Protocol's Clean Development Mechanism (CDM) within Mozambique. One CDM project on fuel switching from coal to natural gas in a cement plant in Matola has been submitted to the CDM's executive board. Some additional project activities are emerging from different sectors. However, as the National Power Grid is arguably based mainly on hydro-electric power, there are relatively few opportunities to identify potential CDM activities in the energy sector. The recent collapse in the CDM price per unit also limits incentives for CDM activities.

The Mozambican First National Communication to the UNFCCC reported direct CO_2 emissions of 9265 ktCO_2/y (with 2004 as the reference year). These emissions were released mainly from land use, land use change and forestry (LULUCF) accounting for 83% of emissions; the energy sectors accounted for 17%. The remaining trace amounts were released by industrial processes (de Coninck and others, 2010).

2.3 Energy demand

Mozambique is rich in energy resources and the exploitation and use within the country may well lead to a rise in CO_2 emissions. With only 10.5% of the population being connected to the grid, the majority lack access to adequate lighting and refrigeration, and are reliant on traditional wood and charcoal biomass resources to meet their energy needs (*see* Figure 3). Residential biomass accounts for more than 70% of all energy consumption. Most of this is wood fuel for cooking, heating water, and heating for cold periods. Charcoal and non-woody biomass is used in almost all households. Charcoal accounts for 20% of the wood fuel demand. Biomass use has increased year on year for decades adding pressure to deforestation and habitat loss in certain areas.

Industry remains a significant consumer of biomass for raising heat but is also a major market for electricity. Industry is comprised mainly of aluminium production which accounts for the bulk of the electricity consumption for the whole country. Aluminium production in Mozambique is dominated by the Mozal aluminium plant near Maputo, responsible for 30% of the country's official exports, and consuming 45% of the electricity produced in Mozambique (Tran, 2013). The smelter consumes 960 MWe of electricity and is therefore a large load on the country's system and is sensitive to supplies from South Africa. In 2008, meeting a contractual obligation to supply electricity to South Africa's Eskom led to a 10% cut in the supply of electricity to Mozambique's smelting operations reducing exports of aluminium (Engineering News, 2008).

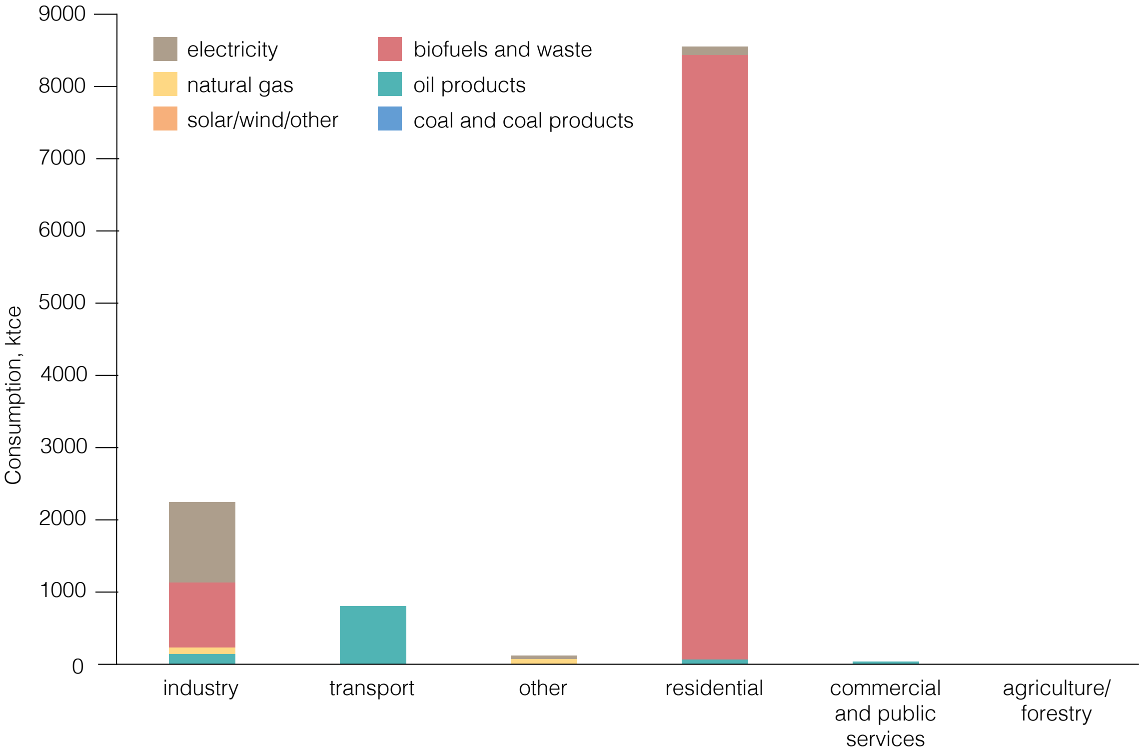

Figure 3 Mozambique primary energy demand, Mtce (IEA, 2012)

2.4 Energy resources (non-coal)

To date there has been no discovery of commercial quantities of oil.

2.4.1 Gas

The first discovery of natural gas in Mozambique was in 1961 in Pande followed by discovery of the Buzi and Temane fields. Companies drilled for oil in the 1960s, but the associated natural gas discoveries were not seen as commercial because at that time there were no markets for the gas. The proven reserves for Pande and Temane are 3.6 trillion ft^3 (128 Mtce) with probable reserves of around 4.6 trillion ft^3 (165 Mtce). There have also been further discoveries in the Buzi and Inhassoro fields.

In 2010-11 Anadarko Petroleum and ENI (Italy) announced discoveries of 33–38 trillion ft^3 (1.2–1.4 Gtce) of recoverable gas reserves in the Rovuma basin offshore of the northern province of Cabo Delgado. Additional exploration suggested that there could be potentially 100 trillion ft^3 (3.6 Gtce) of recoverable gas in the basin. Statoil of Norway and Petronas, Malaysia's national oil company both have leases to the south of the Anadarko and ENI discoveries and are undertaking exploratory drilling (ICF International, 2012).

The gas from the fields is piped to Sasol's coal-to-liquid complex at Secunda in South Africa through an 865 km pipeline. The gas contract with Sasol is for 25 years and production began in 2004. Raw gas is processed through the central processing facility (CPF) in Temane with a capacity of 120 million GJ/y. The pipeline has a capacity of about 147 million GJ/y (or 5 Mtce). There is also a small distribution network in Inhambane province, supplying gas to several localities totalling less than 200,000 GJ/y (or 14 ktce).

In 2010, production from Pande and Temane was 125 million GJ (4.3 Mtce), of which 118 million GJ

(4 Mtce) were exported (ICF International, 2012). There is an investigation under way into the construction of a $15 billion LNG plant so the gas can be processed and exported to Asia. According to a news report the CPF plant will increase production from the current 120 GJ/y up to 183 GJ/y. The additional 63 million GJ (2.2 Mtce) will be shared with the Mozambican market and South Africa with each receiving 27 million GJ (0.9 Mtce). The remaining 9 million GJ (0.3 Mtce) represents royalty gas allocated to the government (Mozambique News Agency, 2012).

2.4.2 Renewable energy

Mozambique's main source of renewable electricity is hydro-electric power. There are 20 hydro plants operating in the country; with a combined capacity of 2000 MWe; just five produce almost all of the country's electricity (de Coninck and others, 2010). These plants produce 16–17 TWh of electricity annually. In 2010, the country produced 16.7 TWh, of which 12.7 TWh was exported to neighbouring countries. Mozambique supplemented its domestic use of 11.9 TWh of electricity with 7.9 TWh of imports. This is due to poor grid connectivity and a lack of capacity to handle the full output of the hydro plants at any one time. It is more efficient to import power into the populated areas where cross border links are stronger and when hydro-electric power is less plentiful.

There is further potential for hydro-electric power development along with other renewable energy resources. According to the WEC (2010) Survey of Energy Resources, the economically exploitable reserve of hydro-electric power is 32 TWh/y, so Mozambique is already using approximately half of the hydro-electric power resource available to it. The largest portion of the hydro-electric power potential is located on the Zambezi River. Here the only potential that has been developed is Cahora Bassa South Bank, commissioned in 1975, with an installed capacity of 2075 MW. Hidroeléctrica de Cahora Bassa (HCB) is the power producer company at Cahora Bassa dam.

2.5 Coal resources and quality

Estimates of coal resources and reserves are uncertain, and a recent survey by BGR estimated coal resources at over 23 Gt with recoverable reserves quantified at 849 Mt, which comprises a mix of thermal (25–30%) and coking (70–75%) hard coal (BGR, 2011). Figure 4 shows a map of the geology of Mozambique illustrating the age of formations with the key area of interest the Tete region.

The six coal basins in Mozambique which have potential for exploration and development are:
- Zambezi Basin which incorporates the Moatize-Minjova Basin where most of the exploration work in the country has been carried out;
- Lunhu-Maniamba Basin;
- Luagua Basin;
- Luchimua Basin;
- Chemba Basin;
- Espunggabera Basin.

According to Mining Weekly (2012a), the major coal fields are found in the collection of the Zambezi basins with estimated resources of 23 Gt. Two basins are being exploited, these are the Moatize subbasin (estimate reserves of 750 Mt) and the Muchana-Vusi subbasin (600 Mt). Within the next five years optimistic forecasts could see coal production rise to 40 Mt/y and potentially to 100 Mt in ten years.

Within the basins listed above are several coalfields that have been identified and contain the majority of the coal resources. These are all in the Tete Province in the far west of the country which is believed to have one of the world's largest untapped coal resources. Tete is unusual in that the province is completely surrounded by borders with Zimbabwe, Zambia and Malawi which makes

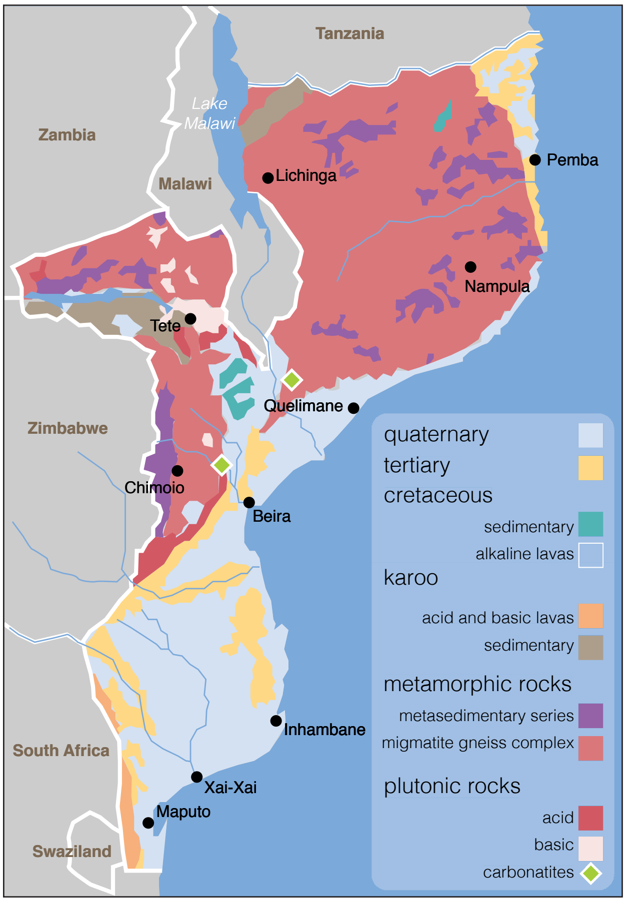

Figure 4 Map of geology of Mozambique (Mining Journal, 2008)

direct transport out of the province less straightforward. The remainder of the country's resources is found in the Manica and Niassa provinces. Niassa has not been fully explored but could potentially have bigger reserves than Tete.

The seams in the Zambezi Moatize region range in thickness from 0.4–4.0 metres, and the structure of the field is heavily faulted. The coal in this region is bituminous, low volatile and low sulphur, but high in ash. Much of the more recent interest has been in the exploration for coking coal which commands a price premium over steam coal.

Although various reserves figures for different basins are published, the exact total of coal reserves in the country as a whole is unknown as exploration is still ongoing. In the last two years, the government has granted 112 licences to 45 national and foreign companies. Rio Tinto has 22 exploration licences in Tete, including 65% of the Benga mining project (Tata Steel from India holds the other 35%) and the Zambezia project. All applications for exploration and mining rights have to be addressed to the Minister of Mineral Resources and Energy for processing by the National Directorate of Mines.

In addition to the companies listed in Table 1, other prospects are being pursued. Mozambi coal is an Australian-based coal exploration company exploring the Zambezi Basin. Company data show a summary of the country's total reserves based on projects in progress, and so will not account for the country's entire reserve or resource base. In addition to these projects are Mozambi's own licences for exploration. Based on this list of projects alone, there is a total of 21.5 Gt of coal, much of which is measured under the Joint Ore Reserves Committee (JORC) criteria, but levels of recoverable reserves may be a smaller proportion of this.

Rio Tinto has access to a vast resource of 13 Gt. Mozambi itself has three coal exploration licences, one of which is located close to the Jindal Steel & Power project and contains a reserve of 700 Mt. The company has a 70–80% interest in each lease, with the remainder held by local partners Xiluva Minerals Resources Lda and Camal & Companhia Lda.

ETA Star is a Dubai-based coal company, operating ETA Star Moçambique SA, a joint venture between Eta Star, Minas do Zambeze, and Indico Investments. Eta Star have 1.92 Gt of coal in Moatize in a concession covering 4000 ha, and hopes to produce 5 Mt/y, of which 1.5 Mt is coking and the rest thermal (Coalage, 2012). Eta Star is also operating in South Africa and the Philippines with the intention of connecting world coal reserves to customers in India.

2.6 Coal production – emergence of a new export industry

Coal has been produced from underground mines in Moatize since 1940 (Chambal, 2010). However,

Table 1 Major coal projects in Mozambique (Mozambi, 2012)	
Significant projects	Data
Vale	1.4 Gt
	Mining licence granted
	Production commenced 1H2012
	Target 22 Mt/y from 2H2014
Rio Tinto	13 Gt JORC resource
	20 Mt/y mining licence granted
Jindal Steel & Power	700 Mt resource
	Mining licence granted
	10 Mt/y production from 2012
ENRC	1.3 Gt resources
Minas de Revuboe	1.4 Gt JORC resources
Ncondezi Coal	1.8 Gt JORC resources
ETA star	1.9 Gt resources

all operations were suspended in 1981 due to the civil war. The recent exploration and development of coal blocks means that in the next decade mining will increase albeit with some delay due to lack of infrastructure.

Reports of the wealth of the country's coal reserves have been supported by the US Chamber of Commerce, stating that Tete province alone has the potential to export 25% of the world's coking coal by 2015 (USCC, 2012). Mozambique is a new entrant to the international coal market and some way off this target, but the potential exists.

In the first few years of coal export development, Riversdale changed ownership and is now owned by Rio Tinto, while Anglo Coal has approached investment in Mozambique with caution and halted its purchase of the Revuboe coking coal project. Despite Anglo Coal's caution, there remain many coal mining ventures, each at different stages of development. There are nine major projects of which three are operating coal mines, these are:

- Moatize mine (owned by Vale, Brazil);
- Benga mine (Rio Tinto, UK);
- Minas de Moatize, not to be confused with Vale's Moatize (Beacon Hill Resources, Australia).

The remaining projects are in development. At least four international companies are expected to begin operations within the next two years;

- Jindal Steel and Power;
- Eurasian Natural Resources Corporation (ENRC);
- Ncondezi;
- Minas de Revuboe (owned by Nippon Steel and Talbot Group).

In February 2012, the government announced a moratorium on new coal licences in Tete province having issued 112 licenses to 45 companies (Macauhub, 2011). Total production from the combined efforts of these companies is expected to exceed 56 Mt/y by 2020, the equivalent to the demand of more than 20 large power plants running at base load. Mozambique could offer a potentially influential and pivotal role as a major exporter in this region, which has long been dominated by South Africa.

2.6.1 Vale Moçambique Limitada

Vale is one of the most prominent foreign investors in Mozambique and is eager to set in motion the export potential of the country. In September 2011, Vale made an overseas shipment of 35,000 tonnes of thermal coal from Moatize, via the port of Beira, to the United Arab Emirates. There were plans to produce 4.6 Mt of coal from Moatize in 2012, but the company halved its output and export targets due to the limited rail capacity connecting the mine with Beira at the time (the Sena line).

Work is currently being undertaken on the Sena railway line and the company expects to be able to export around 5 Mt/y of coal by the end of 2013. Once the upgrade is finished capacity of the line will increase to 6.5 Mt (Mining Weekly, 2012b). Moatize capacity could rise to 11 Mt/y by the end of 2014, although actual production will be dependent on market factors (AfDB, 2012a). Production could increase to 22.3 Mt/y by 2017 and 26 Mt/y beyond 2017 (Lemarie, 2012).

Vale has been operating both coal mine and power facilities in Mozambique since 2004. These include the two mines, M1 and M2, the Moatize power station, the Beira port, and the Sena railway, together forming the Nacala logistic corridor. $1.88 billion has been invested in the Vale Moatize project, and $6.4 billion in the Nacala Corridor transportation project.

2.6.2 Rio Tinto

In 2012, Rio Tinto opened the Benga mine, joining Vale as one of the first foreign companies to undertake large investments in coal interests in Mozambique. Early plans to reach production levels similar to those of Vale, reaching 25 Mt/y by 2016, have been downgraded.

Rio Tinto applied to the government to carry coal by barge coal from the mines to the Zambezi River, but this proved impossible because of opposition from the government and a lack of building infrastructure (Financial Times, 2013). Plans for an independent rail network were also abandoned because of the apparently poor prospects for rail use in the country. Rio Tinto's larger financial problems will mean clawing back value from the investments that have been made in Mozambique and the company is now considering working with rival mining groups to build and share rail infrastructure.

2.6.3 Nippon steel

Nippon Steel is one of the largest producers of steel in the world, and one of the largest buyers of iron ore (50 Mt/y) and coal (30 Mt/y) participating in the seaborne market (Aoki, 2012). Nippon steel has interests in Mozambique, notably the Revuboe mine, part-owned with Talbot Group and POSCO. Production is due to start in 2016, although a projected target of 5 Mt/t is more likely in 2019. The Revuboe mine is located in the Moatize Basin, and the facility will produce high quality coking coal for export to Japan (Jamasmie, 2013).

2.6.4 Beacon Hill

Minas Moatize operates a mine in the Tete province, producing export-quality coal. The total mineable resource is some 36 Mt, but marketable reserves currently stand at just 23.5 Mt, of which 14.7 Mt is steam coal and 8.7 is coking coal (Beacon Hill, 2013). There is a development plan to produce 4 Mt/y of run of mine (ROM) coal, yielding 2.2 Mt/y of saleable coking and thermal coal (Jose, 2012).

Minas Moatize Limitada was acquired by Beacon Hill Resources Plc and is listed on the London Stock Exchange and the Australian Securities Exchange. The Mina Moatize is regarded as the company's flagship project. Beacon Hill took control of the company in May 2010 and although the mine started as an underground operation, it has since become a mainly opencast operation. The defined JORC-compliant Resource is 86.8 Mt.

The Changara Coal Project offers more potential given the larger licence area offered in the Songo Area. The project is located in a region rich in coking coal, containing in excess of 700 Mt of coking and steam coal. The proven coal reserves are located close to Jindal Steel & Power's Chingodzi Coal Project (estimated resource of 724 Mt). Initial exploration of this resource started with 17 drill holes to a depth of 200 m across a 184 km^2 area. The drill holes contain sandstone of the Matinde formation, which normally sits above coal zones within the Moatize Formation of the Lower Karoo. The next stage involves deeper drilling to a depth of 750 m. Like many foreign investments, the project involves local community and infrastructure development to enhance community welfare. Education, rehousing and road projects are necessary as families are being affected by the mine project.

2.6.5 Jindal Africa

Jindal Africa runs a 25-year concession to mine 10 Mt/y of coking coal, although an initial target for the first year of production (2013) is 3 Mt/y. The parent company, Jindal, is an Indian steel and power company whose interest in mining of iron ore, coking coal, through to steel production is growing, and is a competitor to Sail and Tata. Jindal has a wide business presence in Southern Africa, notably in South Africa, Botswana, Mozambique, Namibia, Zambia, Tanzania and Madagascar.

2.6.6 Mine and associated power projects

Coal-fired power is discussed in greater detail later in the report, but this section summarises the mine and associated power projects that are being planned. The status of these power stations and mines are subject to change or even cancellation pending funding, corporate strategies, and authorisations.

As Table 2 shows, domestic steam coal demand could increase by 2.4 Mtce (or 3 Mt/y) as new power plant units are commissioned over time. Some plants could be as large as 1800–2640 MWe leading to an ultimate coal demand of more than 17 Mtce (21 Mt/y). Mine developments such as Vale's Moatize Phase 1 would produce enough coal to supply a 1 GWe power station, so the full power project at 1800 MWe would require Phase 2 of the mine (assuming a subcritical station running at base load).

To meet this potential rise in demand, mining companies operating in Mozambique are aiming to expand production capacity to export both coking and steam coal. Few countries in this region have this much commitment from foreign-owned corporations to mine, utilise and export coal to the international market. However, the slow progress in expansion of inland freight, in part due to government intervention, has proved costly for some firms as seen from the Rio Tinto write down of asset values.

2.7 Coal export prospects

Inland transportation is one of the biggest challenges to the development of the mining industry across the whole of Mozambique (Resenfeld, 2012). Without an adequate and cost-effective rail system with loading and offloading facilities capable of handling coal, many of these projects will be slow to reach fruition. This challenge is partly being met by the state-owned company Portos e Caminhos de Ferro de Mocambique (CFM) which oversees the country's rail and port systems. The current coal export network comprises of three main links (*see* Figure 5):

- Nacala railroad (CFM Norte);
- Beira railroad (CFM Centro);
- Maputo railroad (CFM Sul).

Table 2 New and planned coal mine operations with associated power projects, as of 2012 (Resenfeld, 2012)

Mine	Owner	Production start date	Max. coking coal production capacity, Mt/y	Max. thermal coal production capacity, Mt/y	Proposed power projects associated with mine	Planned initial power plant capacity, MWe	Planned ultimate power plant capacity, MWe
Minas Moatize	Beacon Hill	2011	0.72	1.64			
Moatize Phase I	Vale	2011	8.58	2.6	Moatize	300	2400
Benga (formerly Riversdale)	Rio Tinto	2012	6	4	Benga	300	2000
ENRC Estima	ENRC	2013	6	4			
Jindal	JSPL	2013	3	2	Jindal	300	2640
Revuboe	Revuboe (Talbot, Nippon Steel, POSCO)	2015	5.1	3.4			
Ncondezi	Ncondezi	2014	0	10.5	Ncondezi	300	1800
Zambeze	Rio Tinto	2015	13.5	9			
Moatize Phase II	Vale	2015	8.58	2.6			
Total			**51.48**	**39.74**		**1200**	**8840**
Estimated coal demand, Mtce						**2.4**	**17.68**

Each of these connects the country's major mines to the key ports located on the Indian Ocean (*see* Figure 5). CFM manages infrastructure through a concession where CFM has an equity share of at least 33% in various assets. The company is investigating several rail line and port development options to deal with the expected increase of volumes of coal. The government expects coal exports to exceed 56 Mt/y by 2020 with overseas companies involved in coal development investing in excess of $6 billion by 2014.

An economic corridor also links South African coalfields to the port of Maputo in southern Mozambique (also commonly known as Matola). The Maputo Corridor initiative was launched in the 1990s between South Africa, Mozambique, and Swaziland. The goal was to develop better transport

Figure 5 Rail route options from Moatize coal basin to various ports

links with road, rail, ports and communication. There is an expansion of Maputo's seaport capacity from 100 Mt/y to 700 Mt/y, although not exclusively for coal (AfDB, 2012a).

Matola has been used by South African coal exporters operating from the country's major producing region, the Witbank. Whilst Richard's Bay Coal Terminal (RBCT) in the south of the country has a larger throughput, the rail distance of 627 km is longer than that to the Mozambique port. Matola is 437 km distance by rail, and so offers a useful alternative to the massive dedicated coal port of RBCT (Ferreira, 2012).

Matola is a 6 Mt/y coal terminal jointly owned by the port terminal companies Grindrod and Vitol, the former of which operates in Namibia. Matola has the capability of taking panamax vessels, and plans to invest in a $800 million upgrade to increase capacity to 20 Mt/y are under way involving excavation and reclamation to expand the footprint of the port, along with the addition of two berths, a stockyard and railway infrastructure.

While Matola has several established 'corridor' links with regions in South Africa, elsewhere, the Mozambique coal operators are looking to other ports further north up the Mozambique coast. All the coal developments occurring in the Tete region have three possible ports for exports. The only train link to date is the Sena rail link, some 600 km long and terminating at Beira. The Sena line is being upgraded from a throughput capacity of 2 Mt/y to 6 Mt/y. In 2013, the Sena Line is targeted to export at least 4.5 Mt of coking coal by Vale and Rio Tinto (MCR, 2013b).

Road transport is possible and offers flexibility but, at three times the cost of rail, road haulage from Tete to the coast is not economic. Even with the Sena upgrade, the country still lacks enough rail capacity to other ports which will affect coal export prospects. Another option is river barge, but Rio Tinto's plans to utilise the Zambezi River faced government opposition. In addition, a failed attempt at a dedicated rail link forced the company to consider sharing rail facilities with Vale. While rail infrastructure needs to be improved further, regular severe weather conditions, notably flooding, can force the existing Sena railway to close. The development of alternative routes would be beneficial.

The ports of Beira and Nacala (*see below*) must be expanded and improved to handle the rising volumes of coal passing through in coming years. A lack of cranes, tugs and general inefficiencies means that these ports have been operating at 35% of their capacity. Also, vessel waiting times can be as high as 26 days, which coal buyers might consider unsatisfactory (Kotzé, 2012). Recent dredging at the Port of Beira has permitted 60,000 dwt ships to be loaded. It would therefore require relatively little investment to further boost the throughput capacity of these ports.

As mentioned, the Moatize (Sena) rail line to Beira is currently the only operational rail line that can handle any significant quantities of coal. The Government is currently investigating expansion of the line from 6.5 Mt/y to 20 Mt/y by 2015 although a target of 2017 or beyond is more probable. Rail capacity is shared by Rio Tinto and Vale, but cannot achieve the 6 Mt/y nameplate capacity, therefore restricting the actual production and export performance of Mozambique (Woodley, 2012).

The port of Nacala is an interesting option for coal exports, situated on the northern coast of Mozambique. Capacity at Nacala is currently limited to around 1 Mt/y, but the Brazilian mining corporation Vale is planning an increase to 18 Mt/y at a cost of $4.4 billion which could be completed by 2015. A feasibility study undertaken by Mott MacDonald found the rail route to the coal terminal at Nacala could transport volumes of 40–60 Mt/y, but would require major capital investment. A throughput capacity of 40 Mt/y would require 27 trains travelling at 60 km/h every week. If successful, Nacala could soon be the largest coal port in Mozambique. The Mott Macdonald study also found that the volumes could be increased at a future date up to 120 Mt/y with third-party access. Nacala benefits from being a natural deep water port capable of loading capsize vessels (Bishop, 2012).

While Nacala holds a great deal of promise, a direct route between the port and the mines in Tete is not possible without entering Malawi. This would require two border crossings and complicate auditing of the coal as it enters and re-enters the Mozambique rail system, but Nacala and Malawi are already connected with an existing rail route which should ease any potential administrative issues. The Eurasian Natural Resources Corporation (ENRC) coal rail route connects Tete with Nacala, but entirely within Mozambique's borders. The planned track route would follow the Zambezi River south and then veer north east across a number of rivers to reach Nacala. Ironically, while this new rail route avoids Malawi, Malawi is already connected to Nacala via a direct 931 km rail link, although a track upgrade from Malawi to Tete would be required.

Other infrastructure plans included Rio Tinto's plans for the Greenfield and Chinde rail and port projects with the view of expanding capacity to 25 Mt/y (at Greenfield) and 3 Mt/y (at Chinde). However, given Rio Tinto's infrastructure plans were setback in early 2013, it is possible these rail and port plans may be shelved indefinitely. Chinde is perfectly situated in terms of distance from the coalfield, and is effectively the mouth of the Zambezi River.

Macuse offers yet another possibility to export coal, north of Chinde. In 2013, Rio Tinto announced possible plans for a 525 km rail line from Tete to Macuse. Macuse is located close to the town of Quelimane, approximately 350km north of Beira in the Zambezi province and is the location of an existing port (MCR, 2013a). The expansion in coal exports from Mozambique raises opportunities for other landlocked countries in Southern Africa to export commodities. However, expansion plans will be dependent on the rail arrangements and third-party access terms. While this may affect outgoing export traffic, it will also provide opportunities to enhance import traffic and boost the domestic economies of southern African states.

2.8 Power generation and supply – dominance of hydro-electric power

Previous sections have discussed the production and export potential for many coal projects, but most of them integrate new coal-fired capacity within the plans. The interest in expanding coal-fired power in Mozambique is made clear once the existing structure of the Mozambique power market and the dominance of hydro-electric power are better understood. There are three key electricity suppliers in Mozambique. They are Electricidade de Mozambique (EDM), Hidroeléctrica de Cahora Bassa (HCB) and MoTraCo. The main electricity authority is EDM, which is responsible for generation, transmission and distribution.

Hidroeléctrica de Cahora Bassa (HCB) is a company jointly owned by the governments of Mozambique and Portugal (18%) that manages the Cahora Bassa hydro-electric power station (2075 MWe) which provides most of the electricity in Mozambique. Despite reports that Mozambique is facing a power shortage, the output from Cahora Bassa is almost entirely contracted to supply South

Africa. The dam was constructed with a high voltage direct current (HVDC) transmission line that runs south from Tete province in the west to the South African border, and passes close to the capital city Maputo. Nine tenths of the production is contracted to the South African energy company Eskom through a long-term agreement.

Cahora Bassa has a colourful past, being subject to (unsuccessful) guerrilla attacks and until recently, almost fully-owned by the Portuguese. The dam is located on Africa's fourth largest artificial lake. The Mozambican civil war led to power lines being attacked almost 2000 times, yet the dam itself remained intact throughout the 15-year civil war. The plant itself comprises of 5 x 415 MWe turbines.

MoTraCo is a joint venture company formed by the state power companies in Mozambique, South Africa and Swaziland to provide power from South Africa to the Maputo-based Mozambique Aluminium Smelter (Mozal) plant. MoTraCo manages the transmission lines in the three countries and was created in 1998 (Chambal, 2010).

Mozambique is one of the largest power producers in the region and a member of the Southern African Power Pool (SAPP) through which the country exports its power to South Africa and a number of other countries. Power demand is growing at a high rate of 8%/y and efforts are being made to electrify more households. The current peak capacity of the country is 600 MWe, but projections suggest that a peak of 1554 MWe is needed which could grow to 2338 MWe in 2030 (HMN, 2013).

Figure 6 illustrates the country's power generation mix, and the almost complete reliance on hydro-electric power with negligible amounts of power produced from small gas and oil plants. In 2009, Cahora Bassa produced a record output of almost 17 TWh of electricity (BE, 2011). This boost in output over previous years was largely a product of refurbishment works and increased output and availability of the turbine units. Hydroelectricity in Mozambique runs at unusually high utilisations, averaging more than 70–80%.

Despite the impressive performance, the current generating capacity will not be able to supply the

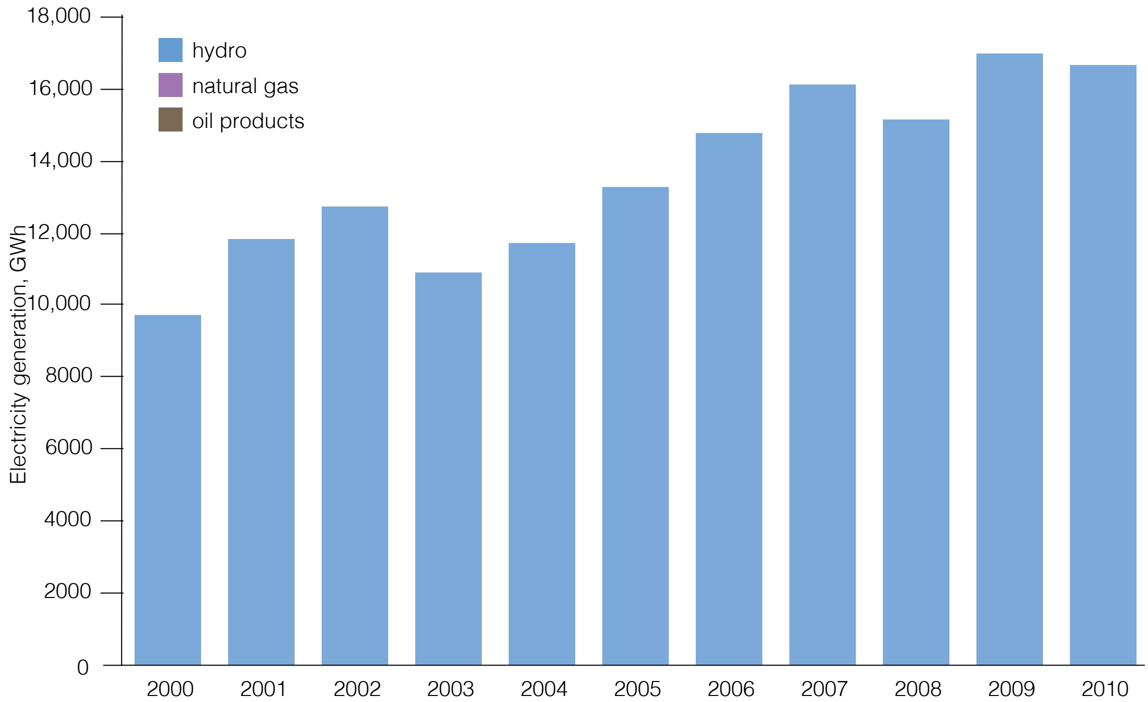

Figure 6 Electricity generation in Mozambique, GWh (IEA, 2013

expected increase in demand from the mining sector, as well as fulfil the export demand to the SAPP. Hydro projects in the planning stage include a second Cahora Bassa station, the Norte, which could add four units of 311 MWe at a cost of $800 million, but funding is still being sought. The project would lie upstream of the Zambezi River while improvements to the DC substations, hydro spillways and transmission upgrades are ongoing.

Another major hydro dam project is planned, called the Mphanda Nkuwa, comprising of 4 x 600 MWe units. The plant is expected to be completed by 2015 at a cost of $2 billion (Hydroworld, 2010). Unless a power agreement with Eskom of South Africa is concluded, the date may well slip. The Mphanda Nkuwa plant could become the largest hydro plant, delivering 2400 MWe output (double that of the planned Cahora Bassa Norte 1–4). It is likely most of the output will be supplied to South Africa, perhaps retaining 20% of the output for Mozambique.

Despite this apparent drive towards continued reliance on hydro-electric power, Table 2 shows the interest in coal mining companies in building coal-fired generating capacity. Although not shown in the table, even gas-fired power generation capacity could increase with the construction of a 140 MWe gas-fired power plant in Ressano Garcia due for completion in 2014.

2.9 Electricity demand scenarios

Power demand is expected to remain high for some years with Mozambique having some of the highest rates of growth of any country in Southern Africa, or indeed the world. Domestic Mozambique load could grow at a rate of 20%/y between 2011 and 2016, but then drop to 4%/y between 2016 and 2026.

Figure 7 shows the projected rise in the country's load between 2011 and 2026, showing a near trebling from 500 MWe to 1500 MWe in 2017, and then a further rise to 2000 MWe by 2026. This rise excludes the load of 950 MWe taken by the Mozal aluminium smelter discussed earlier.

Previous sections suggest that the continued building of hydro-electric power stations could meet much of this increase in load growth, but Table 2 shows an equal commitment to push forward a different, yet parallel, path to develop coal-fired capacity which is discussed in the next chapter. Electricity tariffs may need to escalate further to encourage much needed injection IPP investment in this sector. In two years, Mozambique has seen tariffs increase by 10.3% (Ncondezi, 2012).

Other forecasts show a similar trend, with 18.9%/y growth between 2013 and 2017, reaching a demand of 39.7 TWh (BMI, 2013). However, it is difficult to compare forecasts as electricity consumption within Mozambique (12.96 TWh in 2012) differs from electricity generation (17 TWh in 2010). Investment in transmission links and substations in South Africa, Malawi, and SAPP may drive an increase in electricity exports, irrespective of demand within the Mozambique. The power sector could see net exports rising to 16 TWh in 2017 but drop to 7.4 TWh by 2021. Combining demand and (net) exports implies that total generation would rise from 17 TWh in 2012 to 37.5 TWh in 2021.

2.10 Coal-fired power generation – an emerging fleet?

There are currently no coal-fired power stations operating in Mozambique but there are a number of plans for new projects that could be built and commissioned before 2020. There are initially four projects, all associated with coal mines. These include:

- Benga (Rio Tinto) 300 MWe scaled up to 2000 MWe;
- Moatize (Vale) 300 MWe scaled up to 2400 MWe;
- Jindal (Jindal Steel & Power) 300 MWe scaled up to 2640 MWe;
- Ncondezi (Ncondezi) 300 MWe scaled up to 1800 MWe.

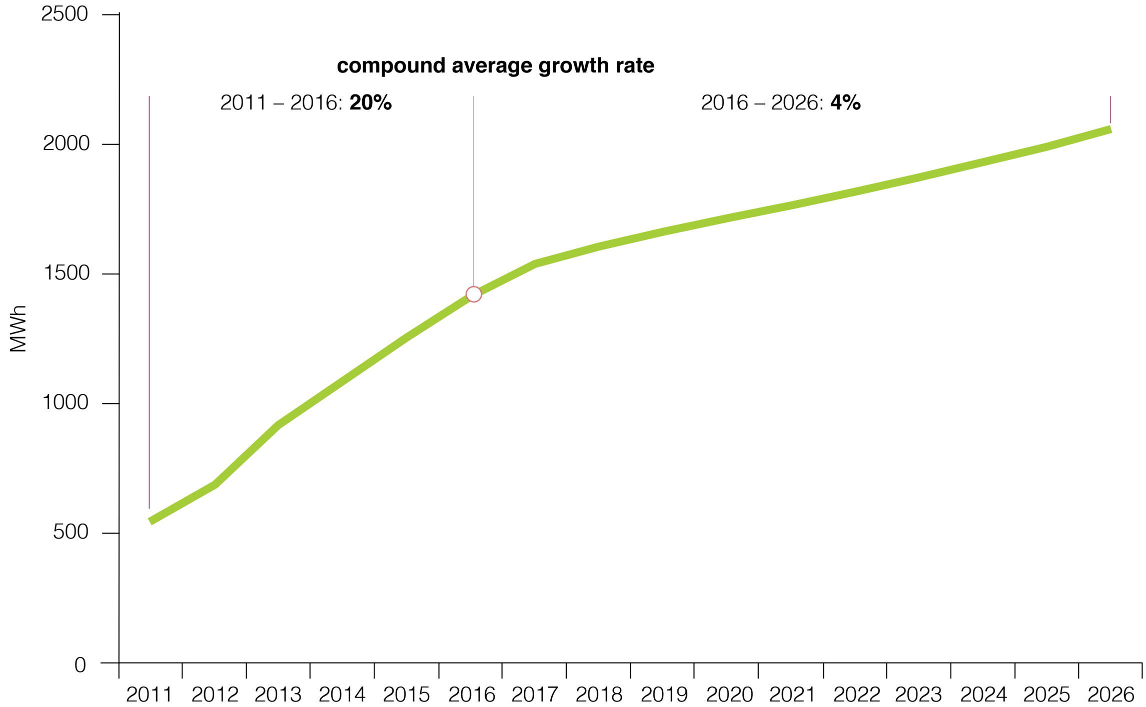

Figure 7 Forecast electricity load of Mozambique (Ncondezi, 2012)

Table 2 lists the new power projects that are associated with the various coal mine projects. These plants have yet to reach the construction stage, and much of the success could depend on the agreements with Eskom.

Both the Cahora Bassa Dam and the working coalfields are in the northwest province of Tete. This places a considerable focus of electricity production in the Tete province, making this an extremely important region for the country. A vast proportion of the power that is generated is exported. That is not to say the country is self-sufficient or enjoying a surplus of power. The grid system is not fully integrated and so the generation in one region will not necessarily be able to supply other regions. The government has pledged to improve electrification in the country. The HVDC transmission line that links the Cahora Bassa hydro station to Maputo and the South African border substations offers an ideal outlet for the new coal-fired stations; until the grid system permits a greater flow of electricity around the rest of the country, much of the power may still flow out of Mozambique. The stations are all planned to start at a small scale of roughly 300–400 MWe, and scale up to larger plants with the incremental addition of 300 MWe units or similar.

In 2012, Rio Tinto issued a call for expressions of interests for potential developers and operators of its Benga power plant (Creamer, 2012). In 2008, plans for commissioning were targeting 2013, but mine expansion plans and transportation infrastructure for the coal export business have been lagging, and so the power plants may well be delayed. Nevertheless, the Benga facility would be located on Rio Tinto's Benga mining concession, and have an initial capacity of between 400 MWe and 600 MWe; environmental sanction is secured for a 2000 MWe facility. If developed, the plant will deliver power to Rio's coal-mining operations in the territory as well as to regional off takers, including the State-owned EDM.

Indian power and steel company Jindal (Africa) announced plans to invest $3 billion in a power plant to produce 2640 MWe, but the project is currently at the feasibility stage (Jindal Steel & Power, 2012).

In September 2012, Ncondezi Coal Company Limited (NCCL) completed a feasibility study for a 1800 MWe minemouth power plant. The study confirmed the project's economic and technical viability. The project is located in the Tete Province of Mozambique and could consume 7.2 Mt/y of coal. The proposed site for the power plant is approximately 6 km from the planned coal processing facilities at the proposed Ncondezi mine. The facility is around 95 km from existing power transmission infrastructure; a further $500–600 million investment may be required as well as an agreement with EDM to supply the grid.

The power plant is expected to be built in phases of 300 MWe units using domestic grade coal. The technology selected is circulating fluidised bed (CFB) technology due to its suitability to the quality and composition of the domestic grade coal. The Ministry of Energy has approved the building of the plant. However all the projects in the Tete region are highly dependent on the success of the coal mine and export business which could delay the power project for some years.

2.11 Future coal demand trends

As of 2012, coal demand was limited to a small amount for heat raising in the industrial sector, but the commissioning of new coal-fired stations, if they come to fruition, will boost steam coal demand greatly. To meet the demand as well as export potential, the major companies operating coal mine facilities, including Vale, Rio Tinto, ENRC, Jindal Steel and Power, Ncondezi Coal Company, Nippon Steel are expected to produce 56 Mt/y by 2020. Most of this is destined for export, but Table 2 shows how coal demand in the power/mine sector from these projects could give rise to a local demand of 2.4 Mtce, expanding to more than 17 Mtce in coming years. Some of this coal demand may well be a 'sink' for utilising middlings and reject coal which has a high ash content (>20–30%), and so less suited to the seaborne export market. Some of the coal will be from better quality steam coal blocks, adjacent to coking coal blocks, with much of the coal export business likely to be coking coal.

Mozambique is well placed to export coal to India and China in the Pacific market, but also to Brazil in the Atlantic market. Mozambique's natural gas industry is in its infancy, but the future development of gas-fired power may affect growth in coal-fired generation. There is no coking coal consumption, and any steel that is manufactured in Mozambique makes use of domestic natural gas as the primary fuel. Prospects for coking coal are unclear; a metals explorer, Boabab Resources is seeking partners and finance to build a pig iron operation producing 1 Mt/y. The project, which could start in 2016 would be located in the Tete region, a region rich in coking coal. The prospect is in response to the natural gas industry, which will demand many tonnes of steel for pipeline projects from Mozambique's gas fields (Antonioli, 2013). Whether the pig iron facility uses gas or coal is not yet confirmed.

2.12 Advanced coal technology prospects

Currently, details of the coal-fired stations intended for the region are unclear. Ideally, these stations should be adopting the latest technology, namely supercritical or ultra-supercritical steam conditions, fitted with FGD and ESP as minimum criteria. It is unlikely these stations will be fitted with SCR for NOx reduction due to cost. The adoption of supercritical technology may be limited by the weakness of the transmission grids. Often supercritical stations are most economic at large sizes and when delivering base load power, but in the case of southern Africa, smaller, multiple units can react more quickly to grid problems. Another option is subcritical CFBC (although supercritical CFBC is possible) if the station intends to burn coal of higher ash content. Coal washery plants may well have a product high in ash that is not suitable for exporting to the world market. CFBC may therefore play a part while also reducing emissions of SO_2. The 300–1800 MWe integrated power plant (with the associated coal mine – *see* Table 2) will use CFB technology in 300 MWe units. Scaling up in successive 300 MWe units should be straightforward provided funding is available and tariff agreements with EdM are agreed (Ncondezi, 2013).

The details of the Vale Moatize plant are scant, but Vale is building a new coal-fired station in Brazil, the Barcarena, which is due online in 2013 and will be a subcritical PF station fitted with FGD and ESP. This plant will use steam turbine equipment supplied by Chinese manufacturers, with steam turbines supplied by Dongfang and a generator system supplied by Harbin. It is possible that the Moatize plant will be similar.

2.12.1 Coal to liquids

There is currently a pre-feasibility study being undertaken on whether to proceed with construction of a $9.5 billion coal-to-liquids plant in Mozambique's Tete province (Kotzé, 2012). The Ministry of Energy and the joint venture Clean Carbon Industries (CCI) are due to submit Phase 2 of a pre-feasibility study to the government for the development of the 65,000 bbl/d coal-to-liquids (CTL) plant. In addition to the CTL plant there is also a plan to develop a pipeline from Tete to the coastal town of Savane just north of Beira where the products might be exported. The agreement would provide Mozambique with 20,000 bbl/d for use within the country; the remaining 45,000 bbl/d of synfuel would be exported to Tanzania, Malawi, Zambia and Botswana, and possibly Europe (Mining Weekly, 2012a).

2.12.2 Biomass

Boosting agricultural output and exports is part of the government's aim. In 2010 the Ministry of Agriculture's Agricultural Sector Development Strategic Plan (PEDSA) was introduced. While aluminium dominates Mozambique exports, agriculture dominates the country's economy as a whole, employing 80% of the workforce, and contributing 32% to GDP in 2011 (USCC, 2012).

Sugarcane production has grown from 386 kt in 1998 to an estimated 4 Mt/y in 2012/13. The Biera Agriculture Growth Corridor (BAGC) is a joint venture (JV) with the government of Mozambique and private investors and international agencies. The Biera corridor will also be close to the rail link that will connect the Tete province to Biera port. The growth in agricultural products could increase biomass production either from waste or from direct crop production. As such, there may be potential for biomass cofiring in the coal-fired power stations that will be built in Tete. Just 3% of 10 million ha of arable land in the BAGC is used for commercial farming. Irrigation systems, and in turn increased access to the grid and increased supply from coal-fired stations, could provide an opportunity to adopt cleaner coal-fired plants through a biomass combustion plan.

2.13 Comments

Mozambique is one of the poorest countries in the world, ranked 184th on the UN Human Development Index out of 187 countries. Life expectancy is 50 years and GDP is under 1000 $/y. The mineral wealth of the country is an opportunity, if effectively used, to bring millions out of poverty and to improve the overall quality of life.

Until relatively recently Mozambique was a backwater for coal. The estimated 23 Gt of high quality coal and accessibility to international markets has resulted in a coal rush. Several international mining companies are involved in the assessment and development of coal resources, along with the development of coal-fired power associates with some of these projects.

There are several obstacles, such as a weak transport infrastructure, that must be resolved. Work is under way to increase the capacity of the rail lines from the coal-rich Tete province to the ports. There is also work on expanding the port terminals for coal exports. A barrier to expansion is the lack of skilled labour for the mining industry. The government is aware of these obstacles and is working with the private sector to improve the transport and port infrastructure as well as train local people in the skills needed to develop the mining sector.

The key issue for mining companies is not financing activities but rather developing a transport infrastructure that can cope with the projected large volumes of coal for export. The Government's favourable tax regime is attractive for overseas companies and encourages investment. The next few years will see several large projects being built in Mozambique including a LNG terminal to process raw gas for export to the Asian markets. Mozambique has a promising future with the revenue that could be generated from its mineral resources.

3 Botswana

3.1 Basic facts

Population:	2.1 million
Capital:	Gaborone
Currency	Pula
Total coal production (2010 estimate):	0.7–0.9 Mt
Total coal demand (2010 estimate):	0.7–0.9 Mt
Imports (2010 estimate):	0.0 Mt

Since 1966, Botswana has been governed by a civilian government and undergone peaceful development with free and democratic elections. Prior to 1966, the country was a British protectorate called Bechuanaland. Namibia is to the west of Botswana, but the Caprivi strip protrudes into the northern part of Botswana leading to a long-running dispute with Namibia over the northern border region (*see* Figure 8).

Figure 8 Map of Botswana (CIA, 2012a)

Geographically, the country is 582,000 km^2 (48th largest country by area) with a population of just two million. Botswana is equivalent to the size of Texas (USA) and is therefore one of the most sparsely populated countries with a GDP per capita of approximately $14,000.

The country is landlocked with access to the coast via Mozambique and its ports. A great deal of Botswana is dominated by the Kalahari Desert, while the majority of the population lives in the south east where the land is more fertile. Half of the population lives within 100 km of the capital city Gaborone. Drought is a major problem, with water supplies relying heavily on boreholes into groundwater resources. This makes arable farming difficult; most of the farming is based on raising cattle and livestock.

3.2 Economy and policy

The economy has a stable and transparent banking system, and the Stock Exchange is thriving. Mining is responsible for 35% of the country's GDP, with retail and leisure accounting for 14%. Diamond mining is of massive importance to the country's economy; diamond exports accounted for 76% of export receipts in 2011 (AEO, 2012a). Robust demand from India and China helps boost Botswana's export fortunes. From 2013, trading of Botswana's diamonds will be carried out in the capital Gaborone, instead of London. The Government may also market and trade up to 15% of the diamonds outside De Beers' channels. In time, diamonds from South Africa, Namibia, and Canada will also be sold from Gaborone.

Botswana's diamond industry has enabled the economy to weather the global economic downturn since 2007-08. There are three diamond mines, Orapa, Lethlakane, and Jwaneng where the Botswana government is a joint shareholder with South Africa's De Beers. Botswana is also rich in copper, nickel and gold. The Government wants to diversify away from metal mining and coal is a key prospect for economic growth in years to come.

Part of the appeal of investing in Botswana is the favourable tax regime, with a tax on profits for private sector investment of 19.5%, compared with an average of 68% across Sub-Saharan Africa, and 43% for OECD countries. This makes private investment attractive in Botswana, and one reason why the private sector employs 50% of the workforce. However, being landlocked and located in the heart of the African continent, the country incurs high transport costs to move goods from the border to the ports, and vice versa. Costs can be 30% higher for exports and imports than all other southern African countries.

Social and health issues remain priorities for the Botswana government, and economic development is considered an essential tool to tackle these. With an economy dominated by mining commodities, resource development is important for economic wealth. While diamonds remain important, coal resources are a strategic asset for meeting domestic energy needs. Coal has a much wider impact on society, being a potential foreign revenue earner and provider of electricity and heat to the mining industry and other sectors of the economy.

Botswana's population is young with some 57% of people under the age of 25 years. The percentage of people living below the poverty line is just over 20% and unemployment is around 17%. Despite these figures, the GDP per capita (2005 US$) is high for the region at 5902 $/head. This is in part due to the low population, but Mozambique and Zimbabwe are considerably worse off at around 400 $/head. In Botswana, more than 95% of the population has access to a health centre within a radius of 8 km, and access to drinking water and sanitation are roughly 96% and 80% respectively.

3.2.1 Energy policy

The Department of Energy Affairs is a government organisation in the Ministry of Minerals Energy and Water Resources (MMEWR), tasked with the formulation, direction and co-ordination of the national energy policy. The Department was established in 1984 as the focal point of all energy related matters. The Botswana Energy Master Plan (BEMP) is the basis for successive National Development Plans (NDPs). Amongst a set of policies to promote sustainable energy and energy efficiency is the improvement of the accessibility and quality of Botswana's coal. Surprisingly little attention is paid to wind and hydro.

In January 2012, the government of Botswana lifted a moratorium on prospecting licences for coal and coalbed methane (CBM). The moratorium was issued in the summer of 2011 while the roadmap study of the country's coal potential was carried out with UK-based consultancy Wood Mackenzie (World Coal, 2012). The study recommended the most effective way of exploiting the country's coal reserves, and assessed a potential for a 90 Mt/y export industry.

The country's single largest power station is Morupule, which supplies a small proportion of the country's needs; the remainder of electricity is supplied by South Africa. Oil is imported. Developing indigenous energy sources is paramount for the country, as is ensuring reliable and affordable energy for its citizens.

3.2.2 Climate policy

Botswana ratified the UNFCCC Convention in January 1994 and the Kyoto Protocol in November 2003, but as a developing economy Botswana has no fixed mitigation targets and is under little pressure to reduce CO_2 emissions. There is a National Committee on Climate Change consisting of members from government, private sector/business community, academia and civic society. There are plans to form a high level technical committee that can support the private sector to develop low carbon technologies and/or the Clean Development Mechanism (CDM).

The World Bank provided technical assistance to support the Botswana Designated National Authority to identify and promote several CDM projects, including energy efficiency in mines, and in households. The World Bank also proposed a Carbon Partnership Facility to help examine coalbed methane (CBM) and carbon capture and storage (CCS) potential; CCS ventures are unlikely to occur, while the prospects for CBM are more positive.

A key to mitigating climate change is the development and implementation of the BEMP which sets out policies, regulatory mechanisms and institutions to guide the energy sector in reaching the national economic and social goals. The Botswana Government and the United Nations Development Programme (UNDP) also undertook a technical needs assessment (TNA) in 2004. Some of the key findings for energy of the TNA which still apply today, were that the country had potential for applying several environmental technologies including:

- coal washing to improve quality and use;
- utilisation of CBM resources for transport fuels and power generation;
- using landfill, abattoir and manure waste to generate biogas for domestic and industrial use;
- growing and producing oil bearing plants such as Jetropha for biofuels;
- using solar PV for off-grid power and water pumping;
- increasing the use of energy efficiency and demand side management through use of compact fluorescent lighting, passive solar design and energy management systems.

Since the TNA, little progress has been made with many of the recommendations. Coal washing and CBM were two of the biggest opportunities, although progress has been slow. Coal washing is costly and lacks investors, while CBM needs infrastructure to store and distribute the methane gas. One area the Botswana Government is exploring to mitigate CO_2 emissions is the use of National Appropriate Mitigation Actions (NAMAs). The Government intends to embark on a series of voluntary measures that will include sustainable policies and measures with:

- energy efficiency;
- emissions from the transport sector;
- standards in the building sector;
- energy performance standards in household appliances.

3.2.3 Coal policy

In 2011, the government developed the coal road map. The roadmap provides a coal market strategy that incorporates developments in the mining and the electricity sectors through to 2018, and also identifies possible candidates to implement the preferred strategic options.

Several countries are interested in developing the huge coal resources in Botswana. In August 2012, President Zuma (South Africa) signed a bilateral energy agreement with the Botswana President, Ian Khama, to supply coal to South Africa from Botswana. Depletion of coal deposits in the main South African coal region, the Witbank, has prompted Eskom, the state South African power utility, to seek coal from Botswana if coal generating expansion plans by Eskom are to be successful.

As well as supplying coal to its southern neighbour, the Botswana government is exploring options to build rail lines to export coal to the seaborne market, in possible competition (or co-operation) with South Africa and the other southern African coal producers with similar aspirations. The two major options open to Botswana are the 1500 km TransKalahari route to Walvis Bay in Namibia for exports to Europe, and via Zimbabwe and Mozambique to Ponta Technobanine (south of Maputo). The latter route is 400 km shorter than the Namibia proposal and, being on the coast of the Indian Ocean, better placed to serve the expanding markets in Asia.

3.3 Energy demand

Primary energy supply to Botswana comprises three fuels used in three distinct sectors (*see* Figure 9):
- biofuels for residential cooking and heating;
- coal for power generation;
- oil products for road transport and industry.

There is little demand for any other fuel in significant quantity. Coal use in power generation is discussed in detail later.

Figure 10 shows how 45% of all primary energy in 2010 was for oil products, three quarters of which is for road transportation; little is used for aviation purposes. Around 16% of oil products are used in industry, almost all of which are used in the mining sector for likely use as fuel in mine trucks and diesel generators. Diesel is often used for operating water borehole pumps and LPG can be used as a household fuel.

Biofuels account for 24% of primary energy. This is significant but it is less than that of other Southern African countries covered in this report. Wood fuel has a high rate of use and completely dominates energy use in residential households. Electricity and LPG are growing in use, especially amongst affluent sectors of the community. Amongst the rural and urban low-income groups, switching away from wood fuel is less easy.

Women and children tend to collect wood fuel, and depletion rates are high around homesteads, leading to gatherers spending more time collecting fuel. Fuel wood, if used more efficiently, can help reduce the time spent collecting the fuel, as well as improve the health of households where smoke and fumes from cooking in an enclosed space are detrimental. Exposure to smoke from traditional cooking stoves and open fires causes 1.9 million premature deaths every year (UNDP, 2012). One such solution includes the use of heat-retention bags which permit longer cooking times for the same amount of fuel.

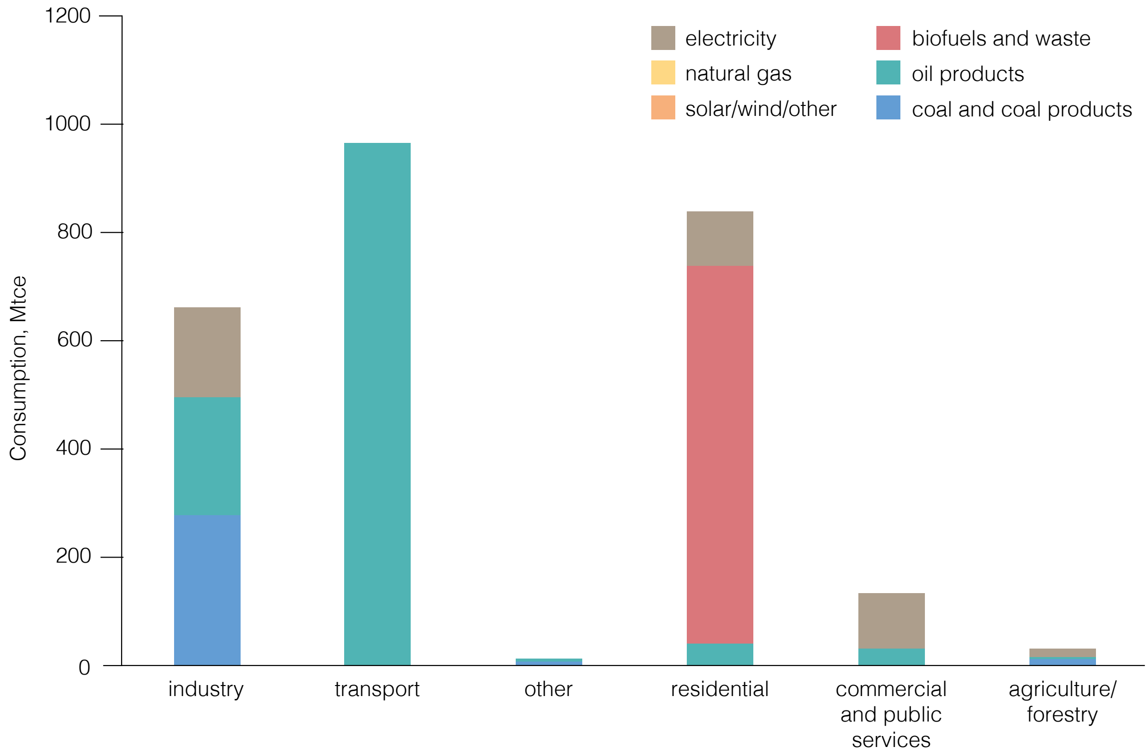

Figure 9 End-user energy consumption in Botswana, Mtce (IEA, 2012)

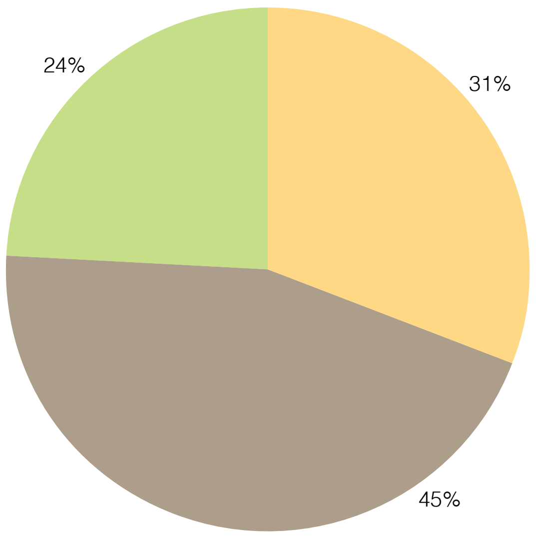

Figure 10 Total primary energy supply by fuel in 2010 (IEA, 2012)

Fuel wood management is carried out by the Ministry of Environment, Wildlife and Tourism (MEWT), and the Ministry of Minerals, Energy and Water Resources (MMEWR). Inventories and accurate feedstock measurements are needed to understand biomass fuel use and the associated depletion rates. Furthermore, measures to improve biomass management might include selective pruning of green wood, which permits better plant growth.

Solar (photovoltaic) is an attractive energy option with resources estimated at 22 MJ/h for 3200 h/y, but the adoption is low. The UNDP and the Global Environment Facility have assisted in solar projects, but the low electrical output, high capital cost, and lack of storage means it is unlikely to replace wood fuel on any meaningful scale for some time. Solar could provide electricity to communities isolated from the main grid but Government incentives seem geared towards grid power more than distributed (solar) power. Hybrid solar/biogas generation may prove a better option for remote communities, but the same lack of financial capital and technical expertise to maintain these technologies remain a challenge (UNDP, 2012).

While end-user demand for energy includes oil and biomass, coal is the sole source of domestic power generation. However, with a national peak demand of 553 MWe in 2010 and an available capacity of 190 MWe (from 202 MWe of generating capacity), the nation's electricity market needs to obtain 363 MWe elsewhere, namely imported power transmitted via the SAPP. Such excessive reliance on imported power is not an ideal position for the country's economy, and a much greater drive towards domestic generation must be pursued. The country's indigenous energy resources are therefore being investigated to improve energy supply.

3.4 Energy resources and reserves

Based on UN analysis (UNDP, 2012), local energy resources are considered to be bountiful in Botswana, including coal (200 Gt), solar radiation (3200 h at 22 MJ/m^2), biogas (2.2 million cattle, 3 kg dung per animal per day) and fuel wood (200 t/y). Petroleum products (LPG, petrol, diesel and paraffin) are imported. The main resources are discussed in greater detail in this section.

3.4.1 Oil and gas

Botswana has no known petroleum reserves and the country imports all its petroleum product requirements from South Africa. As such, Botswana must focus its efforts on other energy reserves that can be exploited quickly and provide financial returns with immediate effect. For Southern Africa and especially Botswana, this could be coal. Botswana has around 5.6 Gtce of gas in place sourced within coal structures (as coalbed methane) and also as shale gas deposits. These are discussed in more detail later on in the report.

3.5 Coal resource and quality

According to the US Chamber of Commerce, Botswana has 66% of Africa's identified untapped coal reserves (ABI, 2012). The coal deposits allegedly cover 70% of the country, so if confirmed would indeed prove to be a major energy resource for the region. Estimates of coal resources vary widely with speculative resources put at a high of 212 Gt resources. These estimates are based on figures quoted in the early 1990s. Actual recoverable reserves also vary significantly with the Botswana government suggesting 3.3 Gt. However, others put economically recoverable reserves as high as 40 Gt (WEC, 2010). Several geological surveys are being undertaken to reduce the uncertainty. Reserves generally contain bituminous coals; there is so far little or no lignite or subbituminous reserves.

Botswana coals were formed as part of the vast Permian Gondwana coals located in the Karoo Basin which is found throughout southern Africa. These deposits originated from the late Carboniferous to early Jurassic periods. In Botswana, coal is found in sedimentary rocks that form part of the Karoo Supergroup and are largely preserved in the centrally located Kalahari Karoo Basin that also extends into southeastern Namibia and western Zimbabwe. Botswana coal exists in 12 coalfields, with current workings at the Morupule Colliery. The average thickness of the main No 1 seam is 8.5 m, containing 23.2 MJ/kg, and 20.8% ash (air dried).

Botswana coal qualities are well within standards expected of export coals being traded from countries like Australia and South Africa (*see* Table 3). Lower quality coal tends to have high ash content and is better suited as a power station fuel.

Coals produced and consumed in India are similar to the higher ash Botswana products, and so there may be a market for these coals in India thus opening up a massive export opportunity. One of the largest companies undertaking exploration is Continental Coal Limited through its Botswana subsidiary Weldon Investment (Pty) Ltd. Weldon Investment holds three coal prospecting licences that cover an area of approximately 475 km^2. The two areas being prospected are called the Serowe Coal Project and the Kweneng Coal Project.

Table 3 Comparison of representative Botswanan coals with Australian and South African coals (Paya, 2012)

	Botswana (high)	Botswana (low)	Australian Newcastle benchmark	South African Richards Bay benchmark
Heating value, kcal/kg	6000	5400	6322	6300
Moisture, %, as received	8	10	15 max	15 max
Inherent moisture, %, air dried	4	5		
Ash, %, air dried	13	20	14 max	16 max
Fixed carbon, %, air dried	58	50		
Sulphur, %, air dried	0.45	0.80	<0.75	<1.0

3.6 Coal production

The main source of coal in Botswana is the Morupule colliery located in Palapye which has been in operation since 1973. Morupule is an underground operation owned by the Debswana Diamond Company (jointly owned by De Beers and the Botswana government), which runs some of the largest and most valuable diamond mining assets in the world. The coalfield is immense and as already mentioned, contains good quality coal.

The possible reserves at Morupule could be as high as 9 Gt (out of 40 Gt for the country as a whole) but whether these are recoverable or measured is not clear. Coal production in Morupule increased steadily over the years from 0.2 Mt/y in 1973 to 1 Mt in 2005 but has since dropped to around 0.8 Mt/y.

A number of key industries in Botswana depend on coal supplies from Morupule. More than half of the mine's current annual production is supplied directly by overland conveyor to the adjacent Morupule A power station, while the BCL Mine at Selebi-Phikwe and the Botswana Ash plant at Sua Pan remain major customers (Ecosurv, 2007a,b).

Coal is extracted from an 8 m seam using the room and pillar method of extraction. These operations are carried out 85 m below ground and accessed through a single shaft. Four continuous miners operate with two stages of crushing are carried out. The coal then enters a 1 Mt/y coal washing plant which was built in 2008. Particles of <15 mm are separated using a dense media separator (DMS) and high calorific coal is separated from lower calorific particles.

In October 2010, Morupule Colliery Ltd underwent a $218 million (Pula 1.7 billion) expansion and by June 2012, the expansion project was commissioned. The project which boosted both coal production and power generation was entirely financed within Botswana, with bank loans from Stanbic Bank of Botswana, First National Bank of Botswana and Barclays Bank Botswana and $65 million of shares.

Two further expansion plans include Phase I (MCL 2) mine expansion to supply the Morupule Power station expansion, which would push production of the existing underground mine from 3.2 Mt/y to 8.5 Mt/y and cost $700 million. The next expansion plan (MCL 3) will create an opencast mine with a production capacity of 5 Mt/y.

Separately, the Sese Coal & Power project is being developed by the mining company African Energy Resources Ltd (AER); this coal mining operation has access to 2.6 Gt of coal, of which 0.6 Gt is measured. The Sese coal project is located in the eastern part of the country, 50 km south of the mining transport hub of Francistown, close to the border of Mozambique (*see* Figure 11). Sese is split into three Blocks, A/B/C, covering more than 100 km². The Sese Export Project will extract steam coal from the Sese Block-B and, after passing through a preparation plant, will export a 5000–5500 kcal/kg (21–23 MJ/kg) product to Asian buyers. Exploration at Sese West (PL197/2007) indicates coal seam thicknesses up to 19 m at a depth of just 150 m (AER, 2012a).

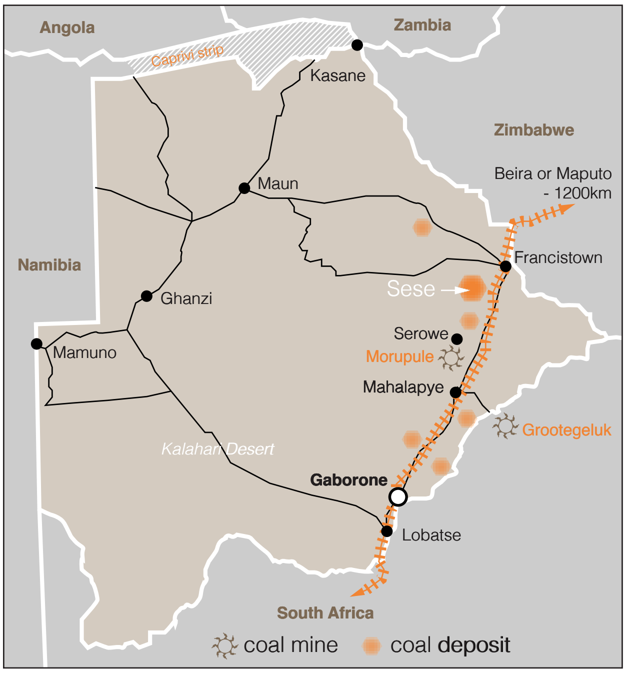

Figure 11 Map of Botswana coal export infrastructure (AER, 2013a)

The rail distance between Francistown and Maputo is 1300 km (AER, 2012a), a lengthy journey compared with perhaps some of the 200–300 km distances from Australian export mines to port distances. The mine could export up to 20 Mt/y, provided the port capacity allows, and further investment could see rail and port infrastructure expand to 50–100 Mt/y.

It is estimated that Block-C of the measured resource could fuel a 2.4 GWe station for more than 30 years, although initially, Botswana's government has announced IPP tenders for a 2 x 300 MWe plant, in which African Energy could compete. Sese Power Ltd is a subsidiary of African Energy, and could raise limited recourse finance and equity. Power purchase agreements, equipment manufacturers and O&M contracts are being negotiated and could be commissioned in 2016 provided $800 million of funding for both power station and mine can be raised ($500 m debt and $300 million equity).

Another project is Mmamantswe, located just 70 km north of the capital Gabarone. Indicated reserves of 895 Mt were identified out of a resource of 1.3 Gt. Mmamantswe is being developed by an Australian resource company Aviva and Mawana Minerals Pty Ltd (Botswana), although Aviva were in the process of selling its share to AER in 2013 (Dodson, 2013). The project could feasibly supply 200 Mt/y of export steam coal and 100–150 Mt/y for the domestic power market. The project could yield 20–22 MJ/kg export coal at a cost of 9.1 $/t and around 14–17 MJ/kg of a middling product (Aviva, 2012). The operation would have a coal preparation plant costing $149 million with a 45% yield for ROM to sellable coal. Existing infrastructure could link the coal deposit to planned South African power plants or supply a local power station of up to 2000 MWe for 40 years.

The sulphur content of the fuel is low at just 0.38% and the production costs are low because of the accessibility by opencast mining with a low stripping ratio of 1:1 billion m^2/t giving the coal deposit a considerable advantage (Aviva, 2012). At the time of the annual report publication for 2012, the Botswana coal licence moratorium was enforced, but has since been lifted. Production targets of 90 Mt/y of export coal and 30 Mt/y of domestic coal would make this a considerable facility, producing as much coal as Colombia.

Weldon Investment Pty Ltd (subsidiary of Continental Coal Ltd) holds three prospecting licences, two at the Serowe Project and one at Kweneng. Serowe is located north of the Morupule coal mine while

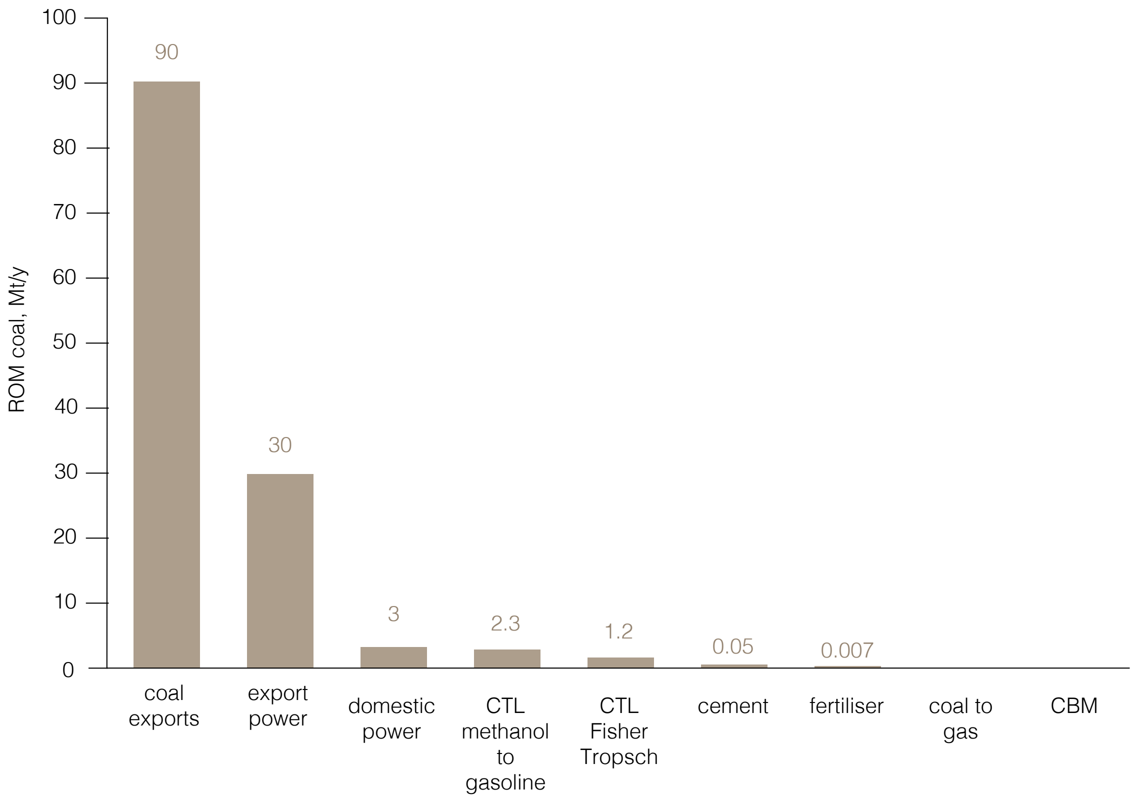

Figure 12 Potential ROM coal demand by option, Mt/y (Paya, 2012)

Kweneng is near the Mmamabula Coal Project (CIC Energy) which was recently purchased by Jindal Steel and Power Ltd of India for $116 million (ESI, 2012). In August 2012 the company completed Phase 1 of a drilling programme discovering an inferred resource of 2.2 Gt on the Kweneng Coal Project. So far, the exploration and geological modelling has confirmed that the Serowe Coal Project is suitable for opencast mining, and with sufficient washing has the potential to produce an exportable low grade steam coal. A Phase 2 drilling programme and further exploration for both Kweneng and Serowe Projects could confirm a resource of 9 Gt.

In terms of the total market for all of these Botswana projects, Figure 12 shows the export market has the greatest potential given the coal is located close to the country's borders and linked by rail to South Africa and Mozambique. Interestingly, the market for coal in the power generation sector could be 33 Mt, but 30 Mt/y of this would be for power exports, while just 3 Mt/y would be for the Botswanan customers. Coal-to-liquid (CTL) might also demand around 3 Mt/y to steer the country away from its dependency on oil imports.

3.7 Prospects for coal exports

In order to expand the supply of Botswana coal to the international seaborne market, the current mineral policy needs to encourage more private sector involvement (Paya, 2012). Jordaan and Eita (2009) investigated the causal relationship between exports and economic growth. Exports of goods and services are essential for foreign exchange reserve accumulation and reduce any balance of payments problems. A reliance on diamonds for foreign exchange reserves is perhaps not the ideal situation. Other exports in meat, copper, nickel and textiles form a smaller percentage of trade. Agriculture and manufacturing account for 9% of GDP (versus 40% of GDP from diamonds).

Experts suggest that policymakers must continue to strive for export expansion. The research does not explicitly highlight coal as a particular commodity. However, it is clear with the correct investment in infrastructure in place, the coal industry could contribute greatly in the future wealth of Botswana (Fichani, 2003).

The growth of the Indian and Asia-Pacific markets has renewed the potential for Botswana exports, but with export shipments going from the Eastern coast of Africa. The coalfields of eastern Botswana are linked to Maputo (Mozambique's largest port), but transporting coal by rail to Richards Bay or Durban in South Africa is too costly. Other possibilities include a new port development in Ponta Techobanine, south of Maputo in Mozambique. The project would require $11–14 billion of investment and would mean a 1300 km rail trip.

A third option is Namibia, but distance and a lack of a rail link prohibits any chance of transporting coal across to the Atlantic coast directly at the current time. Taking coal by rail through Namibia requires an overland rail trip over 1500 km to Namibia's Walvis Bay (Reuters, 2013). The construction of the TransKalahari Railway is expected to take five years and cost $5–9 billion. The line would link Mmamabula to Walvis Bay as well as a possible connection to the South African Waterberg coal field. The first problem to be faced is the prospect of the Atlantic market requiring this extra coal. The EU may well see a rise in imports as domestic supplies dwindle, but Russia appears already set to fill any gaps. Whether a private company could see any return on investment is problematic; it is more likely that investment will prioritise rail to the East coast of Africa, towards the Asian market.

For now, it appears that using existing rail infrastructure to Mozambique ports will lead to quick wins as far as Botswana coal exports are concerned (Baxter, 2012). In April 2012, a small 25 t trial cargo of coal was transported north by AER through Francistown using the Mozambique rail network to Maputo. In November 2012, a larger cargo of 1600 t was exported using the same route, and sold onward to an overseas customer. The export trial was partnered with the Morupule Coal Mine, Grindrod Mozambique Limitada, Vitol Coal South Africa, Botswana Railways, National Railways of

Zimbabwe, and Caminhos de Ferro de Mocambique. Botswana's ambition to export 115 Mt of steam coal by 2020 will rely heavily on the development of a dedicated rail link including track, signalling, loading and rail discharge facilities at the port.

3.8 South Africa – potential key partner in coal development

While a rail route through Mozambique is the preferred option at present, there is a feasibility study under way for a coal rail link between Botswana and South Africa. The line would run between the Waterberg reserve in South Africa to the Botswana-run network, running close to the Mmamabula coalfields. The line could potentially have a capacity of 80 Mt/y (Mining Weekly, 2012a).

South Africa's rail company Transnet Freight Rail (TFR) confirmed it was seriously considering linking the Richard's Bay Coal terminal (RBCT) to the coalfields of Botswana by extending the existing rail line that serves the South African mining company, Exxaro operating in South Africa close to the Botswana border (Baxter, 2012).

3.9 Power generation and supply

Botswana Power Corporation (BPC) is a state-owned company for electrical power generation, transmission, and distribution. It was established in 1970 and is the sole electricity supplier to the country. In 2011, BPC produced 372 GWh of electricity, while demand was estimated to be almost ten times this at 3552 GWh (BPC, 2011). The mining sector alone consumed 1117 GWh, while the residential sector used 873 GWh sector and commercial and public sectors 1128 GWh. The massive shortfall in supply was mainly filled by Eskom (South Africa) with more than 2400 GWh of cross border electricity representing 68% of the total system demand in Botswana. Another 10% was supplied by local emergency generators, with further imports from Nampower (Namibia), Electricidade de Mocambique (EDM), and the Société Nationale d'Eléctricité (SNEL) of the DRC. Transmission losses are high at 12% and add to the problems of shortages.

Electricity imports are becoming costly, from 2 ¢/kWh in 2007 to 5 ¢/kWh by 2010 (de Coninck and others, 2010). Imports are also uncertain as electricity exporting countries give priority to national demand, and there are transmission constraints in some SAPP countries. According to an African Development Bank Report (AfDB, nd), the expansion of coal-fired power generation in Botswana is essential to produce base-load electricity as alternatives, such as renewable power with storage, are not proven commercially. Clearly, the addition of new coal-fired power capacity is long overdue. The AfDB also recommended the adoption of circulating fluidised bed combustion (CFBC) over conventional pulverised coal (PC) for the following reasons:

- CFBC burns a wider range of fuels (for example biomass and waste tyres);
- it is suited to low grade fuels, enabling the export of higher grade products;
- decreased NOx and SOx relative to PF assuming a given low grade fuel;
- higher combustion efficiency;
- space saving and improved maintenance.

Botswana's power capacity is limited to one coal-fired station that is comprised of a modest 4 x 33 MWe units built between 1984 and 1989 (*see* Figure 13). The Morupula A is a subcritical bituminous fired station with a boiler supplied by Parsons, and equipped with ESP particulate matter control. The ash content of local coal products can reach 14–20% (before cleaning). Being in an area where water shortage is a problem the units were designed with air-cooled condensers. Figure 13 illustrates the increase in coal-fired power generating capacity due to the commissioning of the Morupule B (or II) units to push coal capacity above 700 MWe.

A Concentrated Solar Power (CSP) installation of 50 MWe is expected to be developed by 2016, with the

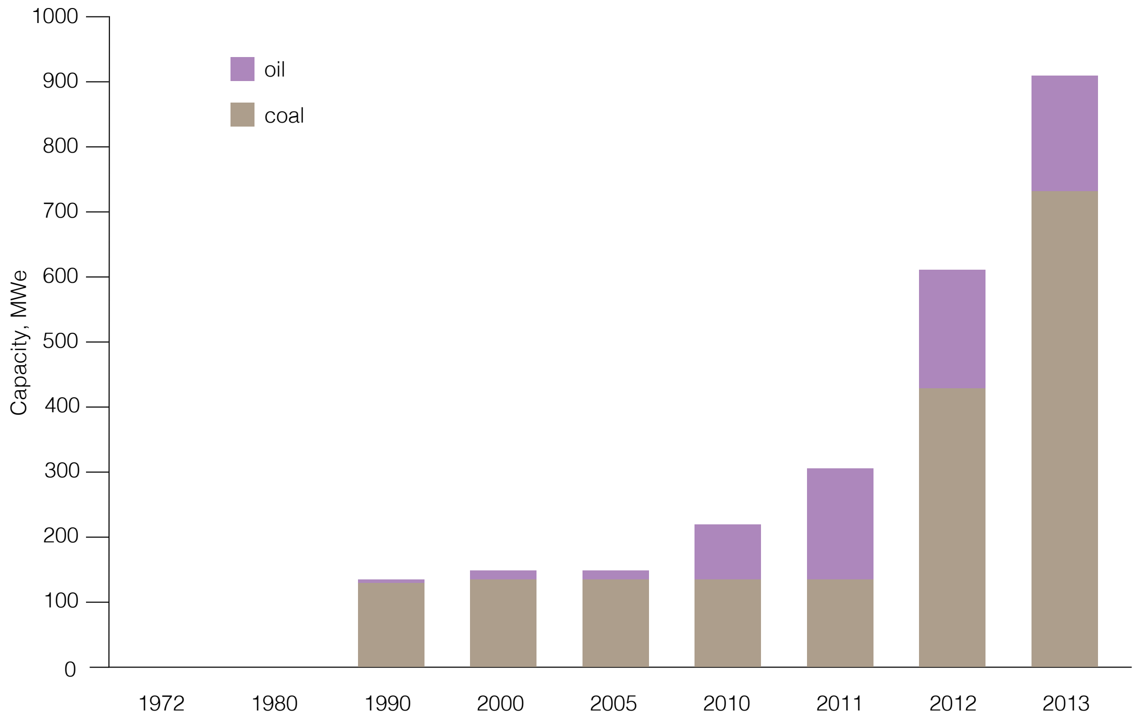

Figure 13 Power generating capacity in Botswana (Platts, 2012)

target to reach 200 MWe by 2020. Similarly, gas turbine capacity of 50 MWe based on coalbed methane is expected on stream by 2016 also reaching 200 MWe by 2020. According to the SAPP Plan, up to 3000 MWe of new coal power station capacity is to be built in Botswana. Even the addition of these solar and gas stations may not be enough to avert future power shortages if demand continues to grow.

3.10 Electricity scenarios

TLOU Energy is an Australian exploration company which specialises in drilling and testing for CBM and unconventional gas resources. The TLOU (2012) report describes how peak electricity demand is expected to reach 890 MWe by 2020 (*see* Figure 14), and even with the new coal-fired output from Morupule B, the country may face a growing power crisis. The additional gas-fired generation and solar plant and another two 300 MWe coal-fired stations could stave off a crisis until the end of the forecast period. Investment and support for coal could therefore provide an extremely valuable driver for the economy.

The forecast does not account for the Mmamabula Energy Project (MEP) planned by CIC Energy (owned by India's Jindal BVI Ltd), a 300 MWe plant associated with the adjacent coal mine for power supplies to the BPC. If financing can be finalised, construction of the 300 MWe plant could be completed in as little as two years. Another, and more ambitious, project is a 1200 MWe plant for exporting electricity to South Africa (Jindal, 2013). Engineering design and project co-ordination are being provided by Aurecon. If Botswana attracts investment to build additional power capacity then in the future the country could become a net exporter of electricity to the SAPP.

3.11 Coalbed methane (CBM)

The Government's Coal Roadmap, described by Paya (2012), identifies coalbed methane resources.

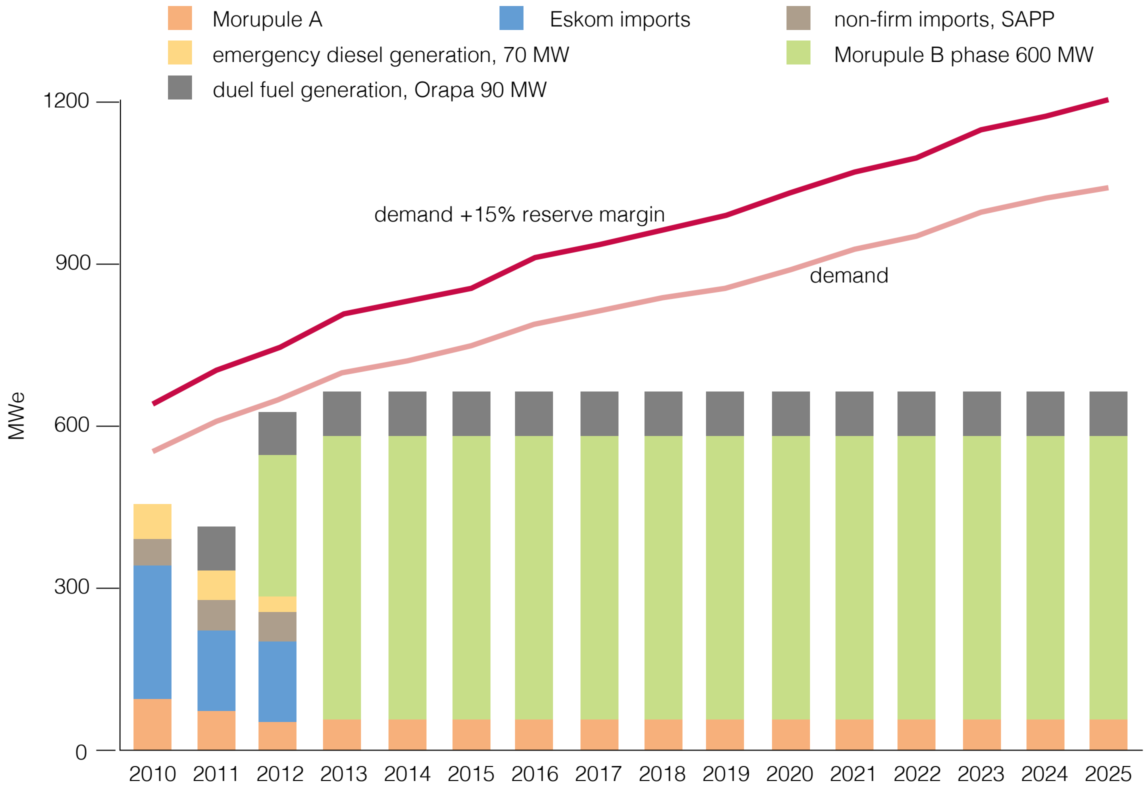

Figure 14 Electricity supply and peak demand for Botswana (TLOU, 2012)

Phase 1 (of 3) is a literature review and detailed project planning. Phase 2 is a technical resource assessment and evaluation, and was ongoing in 2013; Phase 3 is a techno-economic evaluation.

In terms of project proposals, the Karoo Sustainable Energy (KSE) company is considering a 180 MWe power station fuelled by CBM. This would be a 4 x 45 MWe station, with turbines provided by GE (Platts, 2012). The power purchase agreement (PPA) could be a first of its kind, creating a 15-year deal as a build, own and operate station (BOO) to be built in Mmashoro, with power destined entirely for the BPC. The PPA is denominated in US$ and comprises of a capacity and energy charge. In addition, the agreement features a take-or-pay system, with an expectation that the plant will operate for 15 hours a day (equivalent to 63% annual utilisation). The technology will be similar to the newly built 2 x 45 MWe Orapa station that is fuelled with diesel and gas, and commissioned in 2011. This diesel plant is operated by KSE under an asset management agreement with BPC, and could switch from diesel to CBM in the future.

The project will comprise of production wells, transportation and gas storage. Kalahari Energy is the holding company of KSE, and the company's lease area in the Central District could provide enough gas from CBM for 30 years to a 1300 MWe generator. The target of 1000 MWe from CBM by 2020 of CBM could make this an extremely promising prospect. According to Platts (2012), the Kalahari project could be the largest CBM power project in planning at the moment anywhere in the world.

Nationwide, CBM is extremely attractive. According to Sloss (2005), the Karoo coal basin in Southern Africa is well defined as extensive exploration programmes have been carried out by Shell, BP, Anglo-American and other companies. The Karoo basin lies under much of South Africa, Botswana and Zimbabwe, although it also stretches into Mozambique on the east and Namibia on the west. The high gas content of the coal seams is evident from methane bubbling and blowouts from boreholes. The gas content of the seams has been estimated at 2.8–5.1 m^3/t. However, the gas content may be adversely affected by igneous intrusions into the coal seams. The permeability of the seams also appears suitable from initial studies (Kelafant, 2004).

The Botswana Department of Geological Survey studied the prospects for CBM for the National Development Plan 8 (NDP8). The works for the project were carried out under consultancy by Advanced Resources International Inc (USA) in association with Scales Associates (Botswana). The drilling, coring, and testing works conducted during this project indicate that the coal beds within the study area contain an estimated gas resource of 1700 billion m^3 (1714 Mtce). The associated carbonaceous shales are estimated to contain an additional 3851 billion m^3 (3885 Mtce), resulting in a combined total of 5550 billion m^3 of gas-in-place (5600 Mtce). Reservoir modelling of the results obtained indicates that a reasonably large percentage (15–20%) of the CBM gas-in-place could potentially be developed at a gas price of 70 \$/thousand m^3 at the wellhead (roughly 85 \$/toe).

3.12 Comments

Botswana has potentially the largest coal resource in Africa. There are several estimates of up to 212 Gt of resources. Actual economically recoverable reserves are also wide ranging from as little as 3.3 Gt to as high as 40 Gt. To reduce the uncertainty over these numbers several geological surveys are being carried out by mining companies to confirm the actual economically recoverable reserves. All the coal exists in 12 coal fields, with current working at the Morupule Colliery. To utilise this resource and encourage economic development the Government has published the Botswana coal road map focused on delivering three core businesses;

- export coal;
- export electricity;
- domestic electricity.

The small population, lack of rail infrastructure and access to the coal fields will make any development of the coalfields difficult and costly. However, Botswana has a favourable tax regime, with a tax on profits of 19.5% for private sector investment, compared with an average of 68% across Sub-Saharan Africa, and 43% for OECD countries. This makes private investment attractive in Botswana. Several companies are investing and examining the opportunities of developing coal resources, mainly for export to Asia.

There is also consideration of a 180 MWe power station fuelled by CBM, expanding the Morupule B (or II) units to push coal-fired generation capacity above 700 MWe and a potential 1200 MWe plant for exporting electricity to South Africa. If these projects come to fruition, coal may have a promising future in Botswana.

4 Zambia

4.1 Basic facts

Population:	13 million
Capital:	Lusaka
Currency: US$	Kwacha
Total coal production (2010 estimate):	1 Mt
Total coal demand (2010 estimate):	estimated 1 kt *(grossly underestimated)*
Imports (2010 estimate):	

As Figure 15 shows, Zambia is landlocked, surrounded by seven countries: Angola, Democratic Republic of the Congo, Malawi, Mozambique, Namibia, Tanzania, and Zimbabwe. Zambia covers a land area of 752,618 km^2 and has a generally dry climate for much of the year and is prone to drought, yet has a wealth of hydro-electric power potential.

Figure 15 Map of Zambia (CIA, 2012b)

The population is estimated to be 13.3 million (2010) and is projected to increase to 15.5 million by 2015; roughly 60% live in rural areas. The country is mostly high plateau of woodlands and savannah. The southern border with Zimbabwe runs along the middle of the Zambezi River and Lake Kariba. Tourism is growing in Zambia since Zimbabwe's internal troubles started, especially in the southernmost region where the tallest (single drop) waterfall in the world is located (108 m), the Mosi-oa-Tunya or Victoria Falls.

Zambia is made up of ten provinces which are each divided into districts. Zambia is highly urbanised with 44% of the population concentrated in a few urban areas. The so-called copperbelt is in the north of the country.

4.2 Economy and policy

In recent years, the country has recorded around 6.0–7.6%/y growth in GDP, however, two thirds of the population lives below the poverty line. According to the African Energy Outlook (AEO, 2012c) Zambia's economic growth slowed to 6.6% in 2011 from 7.6% in 2010 as a result of a slightly weaker mining sector. Other sectors are showing growth with expansion in the agriculture, construction, manufacturing, transport and communications sectors.

Copper is essential for foreign earnings and, at the prices seen in recent years, a highly profitable venture for the largely private firms that now operate the copper industry. Agriculture is a key sector providing employment to the more than 80% of Zambians involved in the production of maize and other crops. The outlook for the economy is expected to improve with roughly 7% growth in 2012-13, while inflation should be around 8%/y. The country remains vulnerable to commodity prices, not least from agricultural and copper prices. Reducing high youth unemployment and poverty reduction remain priorities which could impair growth in the future.

4.2.1 Constitutional issues

Zambia was colonised by Britain in the 1800s and was ruled as Northern Rhodesia until its independence in 1964. The transition from colony to nation was peaceful unlike the majority of Zambia's neighbours. Over the three further decades the country was led by Kenneth Kaunda and his United National Independence Party (UNIP). There were no other parties until 1991 when constitutional change resulted in a multi-party system and a change of leadership. During President Kaunda's tenure there was central planning and the government nationalised key sectors including copper mines which were a major revenue earner for the country when prices were high. However, the drop in copper prices led to economic turmoil in Zambia. Since 2004, the government has implemented institutional reforms in line with the Zambia Private Sector Development Reform Programme (PSDRP), aiming to improve the business environment and encourage competition and drive export diversification (AfDB, 2012c).

4.2.2 Energy and electricity policy

In 1995, the Government set up two new institutions; the Energy Regulation Board (ERB) and the Office for the Promotion of Private Power Investors (OPPPI) to regulate operations and pricing, and promote new players to the electricity market respectively. There is also the Rural Electrification Authority (REA) which deals with increasing access to electricity in the rural areas. Other participants in the industry include small-scale generators and solar-based energy services companies supplying power to some rural areas.

Development of the modern energy policy was started in 1991 during the formation of the multi-party (democratic) system of government. Other Ministries include the Ministry of Mines and Mineral Development which guides coal production, as well as a multitude of other commodities mined in the country.

All petroleum is imported via a 1706 km pipeline which runs from Tanzania to Ndola, a petroleum refinery. The mining industry accounts for a significant proportion of oil demand (27%) while the leading indigenous energy source is biomass, then hydro-electricity, and lastly coal (*see below*). Energy policy mostly covers the electricity market, and the electrification of the country, as well as the supply either through domestic generation or imports.

In spite of the potential of Victoria Falls, it was not until 1938 that hydro-electric power was first generated at a small station in the third gorge below the falls. In the early part of the 20th century, power development was associated with the copper mines where several independent thermal stations were constructed. Currently there are three major players in the ESI including

- Zambia Electricity Supply Corporation (ZESCO) Limited. ZESCO Limited was formed in 1970 through the Zambia Electricity Supply Act. This Act brought together the electricity sector, previously managed by the local authorities, under one umbrella.
- Copperbelt Energy Corporation (CEC) based in Kitwe which is a net transmitter of electricity purchased from ZESCO at high voltage and distributed to the mining industry based on the Copperbelt,
- Lunsemfwa Hydro Power Company based in Kabwe, an independent power producer, is generating 48 MW of power that it sells to ZESCO Limited under a Power Purchase Agreement.

The Zambian National Energy Policy (NEP) aims to promote indigenous energy and reform the power sector, yet the Government remains the sole shareholder of ZESCO Limited which is a vertically integrated utility that generates, transmits, distributes and supplies electricity. ZESCO is also responsible for all electric power imports and exports in the country.

The power supply to Zambia's largest load centre, the mines of the Copperbelt Province, is provided by a private company, the Copperbelt Energy Corporation (CEC). CEC purchases power from ZESCO and supplies the mines, smelters and refineries via its own transmission system. CEC is ZESCO's single largest customer with contractual commitments securing a large proportion of the company's revenues. By 2009, the CEC accounted for 36% of ZESCO's sales.

The Lunsemfwa Hydro Power Company (LHPC) is a consortium made up of local investors Degarnier and Wand Gorge Investment. LHPC has an installed capacity of 38 MWe and is the only private generator of electricity in Zambia (excluding emergency and rural generating units). The Zambian electricity power system is operated as part of an interconnected powergrid linking South Africa, Zimbabwe, and Democratic Republic of Congo (DRC). The Zambian power system is connected to the DRC grid to the north and to the power systems of Namibia and Zimbabwe to the south. These interconnections enable power imports and exports, but more crucially position Zambia as the gateway for the flow of power from the DRC to South Africa (via Zimbabwe), the largest consumer of electricity in Africa.

4.2.3 Climate change policy

Environmental matters are overseen by the Ministry of Tourism, Environment and Natural Resources (UNFCCC, 2007). Zambia suffers from drought, and so the effects of climate change are felt. Food and water security are of great concern.

Zambia has developed a national adaptation plan of action (NAPA) to cover agriculture and food security, human health, and natural resources and wildlife. In the NAPA plan, the impact of drought on hydro-electricity and the subsequent impact on the economy were noted.

Zambia signed the UNFFFC Convention on 11 June 1992 and ratified it on 28 May 1993. The Convention entered into force on 21 March 1994. As a non-Annex I party, Zambia is not legally bound to reduce CO_2 emissions, but its economic development is driven by a need for a more diverse portfolio of electricity sources. The use of renewables is insignificant, aside from the use of biomass in the residential sector.

The Kyoto Protocol offers opportunities for developing countries such as Zambia to access financial resources for implementing projects aimed at reducing greenhouse gases (GHGs) under the clean development mechanism (CDM). There is an institutional framework for CDM in Zambia with the establishment by the Zambian Government of a designated national authority (DNA). The DNA has adopted an inter-ministerial model where relevant government ministries are integrated into the DNA as permanent members and facilitates the CDM process and project evaluation.
The opportunities for CDM projects in this sector are twofold:

- On the supply side, switching to cleaner and renewable energy sources such as wind power and run-of-river hydro-power presents an opportunity for CDM projects. Zambia's tropical/subtropical location gives it moderate to gusting winds, which tend to support generation of wind energy.
- Replacement of diesel generator power supply with mini-hydro where there is potential offers further opportunities for developing CDM projects, particularly in an off-grid context. This opportunity has been enhanced by the Government's introduction of an energy policy that promotes the use of renewable energy resources through private sector participation.

Just as there are opportunities, there are also several challenges associated with implementing CDM projects. The use of clean and renewable sources of energy such as wind power has not been fully investigated in Zambia while the use of solar power has its own technical and maintenance complications relating to PV solar panels, although some potential has been identified. The bulk of electricity generation in Zambia is from hydro-generation, which has very low greenhouse gas emissions. This limits the development of CDM projects for on-grid applications in this sector. The low price of CDM credits is also likely to also lessen the interest in developing small-scale CDM projects in Zambia.

4.3 Energy demand

Zambia has a range of primary energy sources, including hydro-electric power, oil, coal, and biomass. Primary energy demand across the country's economic sectors is overwhelmed by traditional woodfuel, for cooking and heating (*see* Figure 16). According to the Renewable Energy and Energy Efficiency Partnership (REEEP) only 16.7% of households in Zambia have access to electricity (REEEP, 2012). The majority of the population relies heavily on charcoal and firewood for heating and cooking using candles and kerosene lamps for lighting.

Traditional wood fuels from natural woodlands and agricultural lands dominate energy consumption in Zambia. According to the Energy Services Delivery in Zambia Report 2004, the present consumption of wood fuel exceeds the potential sustainable supply (Sooka, 2007). This is a serious threat to the total forestry land cover, which is currently estimated at 66% of the total land area. Industry also makes use of these traditional fuels. The Zambian population is similar to all the other countries examined in this report in that the majority of the population are subsistence farmers living on minimum incomes with little or no access to modern energy services. As a result, especially outside the cities, people rely on biomass for their source of energy. Oil products are used widely across most sectors, while some electricity is used in industry and households.

Figure 17 shows the split of primary energy demand by source, based on IEA (2013) data. Coal

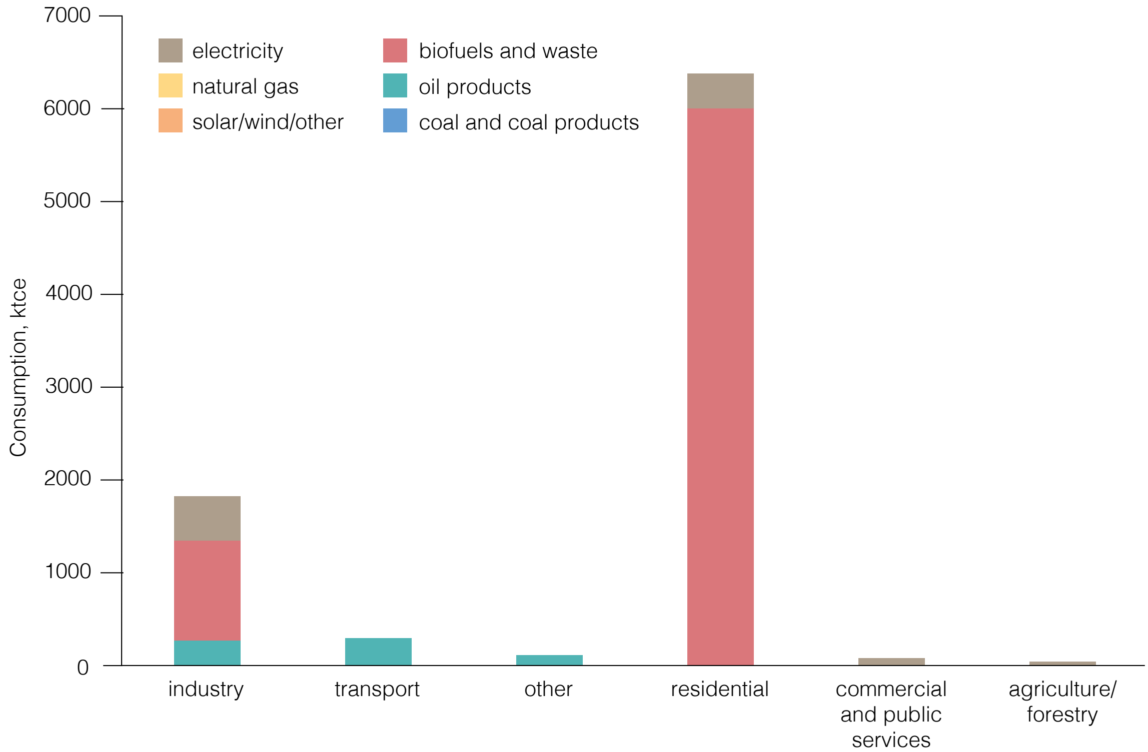

Figure 16 End user energy consumption in Zambia, ktce (IEA, 2013)

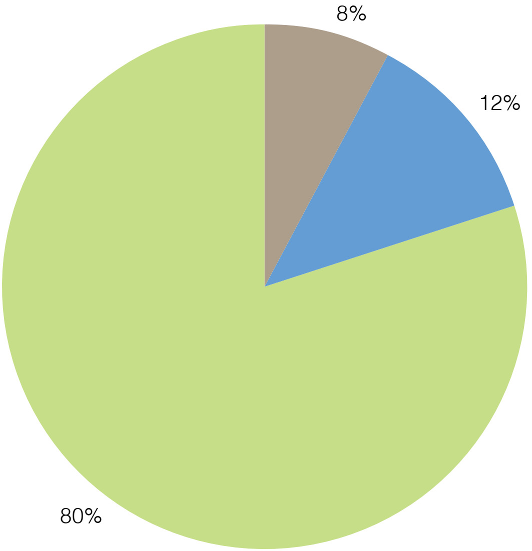

Figure 17 Total primary energy supply by fuel in 2010 (IEA, 2013)

consumption in recent years appears to be minimal at little more than 1 kt/y in 2008-10, which barely shows in the chart and comprises locally produced coal. The country's electricity is predominately consumed by the mines.

Copper mining is a major source of revenue for the country, accounting for 75% of Zambia's foreign exchange earnings (AEO, 2013c). In terms of energy, the copper industry uses 55% and 37% of the country's electricity and oil demand respectively. With so much of the country's foreign revenues and GDP underpinned by the price and volume of sales of copper, the industry is also sensitive to other factors that affect the day-to-day operation of the copper mines. In 2013, state utility ZESCO urged companies in 2013 to cut back on electricity consumption due to shortages. Peak demand is estimated to be 70 MWe above the 1746 MWe of available generation. A new fleet of power stations should help ease the burden on the currently ageing hydrostations.

4.4 Coal demand

Coal demand in Zambia is low, coming mainly from the mining industry which consumes more than half the coal (54%), with commerce and industry (37%) and the government and service sectors (9%) consuming the remainder. Maamba supplies 20–30 kt of coal every month to Zambian cement factories, steel plants and fertiliser manufacturers, but most coal is used by the copper producers.

Coal consumers such as Lafarge PLC (formerly Chilanga Cement PLC) import coal from Zimbabwe, despite higher transport costs than for local products. It is likely that, to ensure security of coal supplies, Lafarge maintains a portfolio of different sources and presumably has ongoing contracts to fulfil. One example is the long-term supply contract with Hwange Coal Mines of Zimbabwe.

Some of this market competition within Zambia is for low grade fines. The large amount of coal preparation required to treat the coal throughput leads to a production of fines, which are subject to degradation during periods of heavy rainfall in Zambia. A market for fines still exists in Zambia with reports of Lafarge cement purchasing fines from the Wankie Coal mine in Zimbabwe thus displacing some Zambian coal (Ngombe, 2009).

4.5 Energy resources (non-coal)

To date no discoveries of oil and gas have been made in Zambia. Hydropower is the country's leading conventional resource of energy alongside biomass. According to the WEC (2010), the gross theoretical generation is 53 TWh/y, of which 20 TWh/y is economically exploitable. Actual generation in 2008 was 9.7 TWh/y, so Zambia has used a large proportion of its hydro resources, but upgrades to existing plants are helping to maintain a healthy output. Exploitation of hydro has to be carefully managed to ensure there is no disruption to irrigation in farmlands.

According to the WEC (2010), Zambia has 22 kt of uranium of indicated resources as of 2009 based on a price <130 $/kgU. Production thus far has been 86 tonnes so the life of reserves under these circumstances looks good. Zambia itself does not appear to have any plans to pursue nuclear power generation.

4.6 Coal resources and quality

According to the WEC (2010), Zambia has a small coal reserve of just 10 Mt; this apparently tiny reserve of coal is in contrast to other estimates. Sooka (2007) quotes a proven resource of 30 Mt/y. According to reports the Maamba mine, one of two operating mines, has at least 20 Mt of potentially mineable reserves. This figure already doubles the WEC recoverable reserves data, but Maamba estimate the company has access to 78 Mt of low-grade coal reserves, as well as 102 Mt of high grade coal reserves (MCL, 2013). A total reserve base for this one company could be as high as 200 Mt. The exploration of just a small area of the larger coal basin has yielded results, but even amongst these explored blocks, ongoing work is required to confirm the wealth of reserves.

In 2012, African Energy Resources Ltd reported a new coal discovery at Sinazongwe in the Gwembe Valley of southern Zambia, located close to the two existing operations, Collume and Maamba (AER, 2012b). The raw calorific value ranges 10–26 MJ/kg, indicating a massively broad rank and quality of coals available to the region. The ash content is in the range 24.3–61.5% (air dried) and the inherent moisture is 0.1–2.4% (air-dried). At least 17 out of some 20 or so drilling rig samples were determined to have a free swelling index (FSI) above 4.5. Maximum FSI was 8.5, with a mean FSI of 6.1, indicating some potential for medium to hard coking coal (AER, 2013b). These tests do not appear to confirm the tonnage of recoverable reserves as yet.

4.7 Coal production

Zambia has produced coal since 1967. The majority of the coal is from the aforementioned Maamba coal mine, an opencast operation near Lake Kariba located 352 km from Lusaka in the Southern Province. The country's coal supply comes almost entirely from domestic suppliers, the two key producers being the Maamba Collieries Limited (MCL) and Collume Coal Mine. In the 1970s, coal production was in excess of 0.8 Mt/y (little more than that seen in Botswana in recent years), but has since plummeted as the industry restructures and attempts to modernise (*see* Figure 18). Data from the IEA (2013) shows 1000 t of production since 2008. Other reports suggest that perhaps 20–35 kt of coal is being produced from the two operations in Maamba and Collume. African Energy Resources is also exploring coal deposits close to these operations. These domestic coal operations are located in Southern Province. Also small quantities of coal and coal fines are imported from Zimbabwe on contract.

Domestic production has also been affected by industrial relations between Zambian mine workers and foreign management. In recent years, Collume has been marred by disputes which have resulted in fatalities and injuries. In 2013, the Chinese-owned Collume coal mine had its operating licence revoked by the Zambian government (Jamasmie, 2013). The Collume mine remains workable, but improvements in safety and environmental protection, and a possible change in ownership, will be required before operations resume. Other issues such as problems with paying mineral royalties to the government were also claimed. The mine was privately-owned by a Chinese developer Xu Jianxue, but not registered or affiliated to any official Chinese authorities.

Despite decades of decline, production is expected to increase with the rise in investment and the plans to build new power stations within the country. More recently the Maamba company literature reported that the mine operation reached its highest production ever from one of two of its pits, the Izuma Pit B (Nulacha, 2012). The future growth of the coal mine will depend on the successful operation of the newly built Maamba power plant.

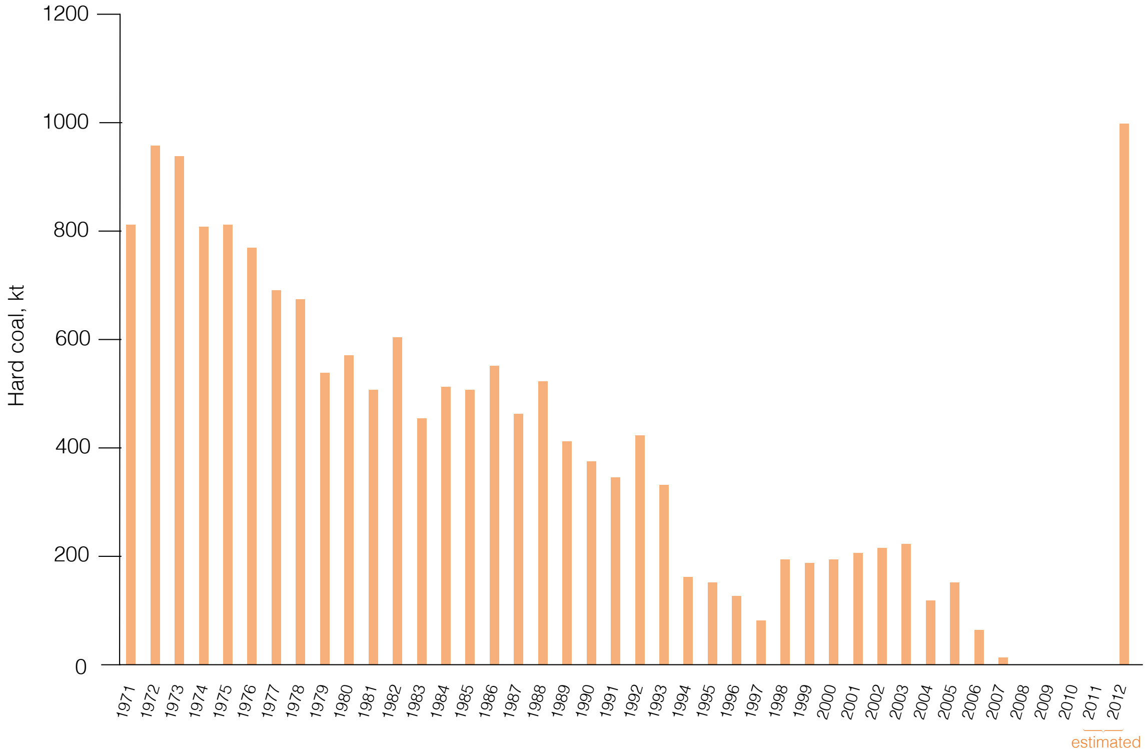

Figure 18 Hard coal production in Zambia (IEA, 2013)

MCL mining operations are outsourced to an Indian-based company GRN Construction Ltd which is responsible for overburden removal and coal extraction. Up until 2010, MCL was a state-owned company until it was sold in 2010 to a Singapore-based Indian company Nava Bharat Ventures (65%), with 35% owned by ZCCM (Zambia). A new coal handling and preparation plant was installed by EPE Engineering Pvt Ltd (South Africa) to produce washed coal with ash content less than 20% and sulphur content less than 1% (Maamba, 2013b).

Maamba coal product qualities are as follows: heating value 6294–6482 kcal/kg, sulphur 0.7–1.5%, total moisture 3–9%, ash 18–21% with a volatile matter 18–20% (Maamba, 2013b). Unwashed coal fines and slurry of <10 mm have a heating value of 5353–6200 kcal/kg, which is high for material that might otherwise be discarded if no market is found for them. Sulphur contents of these less marketable coals are much higher at 1.6–3.0%, ash contents 21–30%, and total moisture content averages around 20%.

Private investment and management is also being injected into the Zambian coal industry, particularly from non-OECD countries where agreements have been fast tracked with little scrutiny from international financial institutions. Zambia has adopted a proactive approach to engage with foreign financiers and project developers from Indian and Chinese corporations which have invested heavily in the country's mining and energy sector.

4.8 Power generation

The country's total installed generating capacity is 1931 MWe, of which ZESCO operates seven hydro-electric power stations with a total capacity of 1752 MWe (most of which are listed in Table 4) and one thermal power plant of 8 MWe. Oil-fired stations account for 93 MWe consisting of distillate fired gas–turbines and emergency diesel generators. Small units, 2 MWe, operated by the sugar industry are fuelled using bagasse.

Table 4 Major power stations in Zambia (Platts, 2012)

	Capacity, MWe	Type	Commissioned
Kafue Gorge	930	Hydro	1972-77
Kariba North Bank	720	Hydro	1974
Victoria Falls	108	Hydro	1938-72
Lunsemfwa & Mulungushi	38	Hydro	1925-20

In 2013, a new hydro power station is due to come on line, the Itezhi-Tezhi plant with 120 MWe capacity. In terms of energy demand by end users, electricity is the second most important energy source, after woodfuel, contributing 10% of the national energy supply. The country's hydro-electric power resource potential stands at an estimated 6000 MWe while the installed capacity is 1831 MWe.

Many of these units are old with the most recent, 11 MWe, being built in 2008-09. Hydroelectric plants represent 99% of electricity production in the country. Other than a handful of small stations, no bigger than a few megawatts, the next new projects include the 120 MWe Itezhi-Tezhi plant and the Kafue Gorge Power plant amounting to 800 MWe (2017). These are under construction, and should boost power supply. The Kafue Gorge power plant will be owned and operated by ZESCO Ltd. Other forms of power generation such as natural gas and solar are not planned as yet.

There are inherent risks associated with a market dominated by hydro-electric capacity. In the period 1991-92, a serious drought led to a decrease in gross generation output of nearly 30% (Tiffen and Mulele, 1994). There were also intermittent droughts during 2000-05 (Nyambe and Feilberg, 2009). The impact of drought has not been as severe as experienced by the other countries discussed in this report partly due to electricity imports from the SAPP network. Steps are being taken to diversify the electricity mix. One example is the $60 million oil-fired power station in Ndola, which is being funded and constructed by the Ndola Energy Company (BMI, 2012). As the first energy generation project to be constructed entirely by private funds, this could be the start of a shift towards private power initiatives in the country.

BMI (2012) also reported that the government announced plans to invest in the electrification of rural areas in the Luapula province with a proposed $63.8 million project to connect the Lwangwa district to the grid. Additionally, the World Bank has signed a financing agreement with the Zambian government to fund a transmission line. On an international scale, the Zizabona interconnection project, which involves five southern African nations, is also advancing.

4.9 Coal-fired power generation – a new beginning

Zambia has no coal-fired generation as yet, but to meet the growing demand for power, MCL is planning a minemouth, 300 MW (2 x 150 MWe) coal plant, which will utilise the thermal grade coal from the coal mine as fuel. The power plant could employ circulating fluidised bed combustion (CFBC) technology, a technology common across this region for burning low grade coals.

In 2011, MCL appointed SEPCO Electric Power Construction Corp (China), a large supplier of power generating plants, substations and transmission lines, for implementation of this power project. Works on the construction of the power plant are progressing with the first 150 MWe planned to be commissioned in September 2014 and the second 150 MWe to be commissioned by December 2014 (MCL, 2013). If power demand increases there are plans to increase capacity up to 600 MWe.

The Energy Regulation Board (ERB) has granted authority to Maamba Collieries Ltd to sell

265.5 MWe of the electricity generated from its coal-fired plant to ZESCO for a period of 20 years. In common for other southern African nations mining in the Karoo Basin, the power station is adapted to burn lower grade coals, often as ROM coal or as middlings from coal preparation plants, while washed coal is usually reserved for export or higher value markets (coking coal).

4.10 Power scenarios

The Zambian Sixth National Development Plan (SNDP), 2011-15, sets out plans to expand electricity generation and transmission capacities and enhance cost-effectiveness in fuel supply. Following an estimated increase in real GDP of 7.0%/y in 2012, growth is expected to continue at this rate between 2013 and 2021 (BMI, 2012). Economic growth driven by mining expansions and electrification is likely to be a major driver for electricity demand, some of it fuelled by new coal stations.

Equally, economic growth could be curtailed if new reliable generating capacity cannot keep pace with consumption. Power outages continue to have a negative impact on Zambia's businesses. In October 2012, the telecoms company Airtel expressed its concern about the irregularity of electricity supplies and therefore its ability to maintain a service. In addition, other reports stated that Zambia's main airport experienced blackouts lasting over four hours (BMI, 2012).

To help meet the country's need for power, BMI (2012) estimated that power generation may increase by 4.2%/y between 2013 and 2017, reaching 13.85 TWh. Another avenue for demand is the possibility of coal export by rail to the Democratic Republic of Congo (Hill, 2013). Exports could double the market for Zambian coal. Zambia Railways Ltd plans to invest $1.5 billion to boost the rail network, whereby Konkola Copper Mines will transport copper by rail from mines in Chingol to Tanzania for the first time in five years. This boost in interest in Zambian commodities and potentially increased revenues could provide funds to further expand the rail network and rolling stock to accommodate coal movements.

Electricity tariffs are among the lowest in the world. For many years, the government of Zambia was reluctant to allow tariffs to rise; with tariffs below economic levels. Obtaining the necessary funds to invest in refurbishment and system expansion is therefore difficult. Both the ERB and government

Table 5 Planned power generating capacity in Zambia (GSB,2010)

	Capacity, MWe	Cost, $millions	Developer	Funding
Kafue Gorge Lower (hydro)	600–750	1500	Joint venture ZESCO (35%) and China-Africa Dev. Fund with SINOHYDRO (65%)	Export credit ($1 billion) plus other
Kariba North Bank (hydro)	360	420	Wholly-owned ZESCO subsidiary SINOHYDRO as EPC	China Exim bank ($360 million) plus Dev. Bank of Southern Africa
Itezhi-Tezhi (hydro)	120	230	Joint venture between ZESCO (50%) and Tata (50%)	Concessional loan from Indian government plus others
Maamba (coal)	300	420	Nava Bharat	Financing proposals under discussion
Kabompo Gorge (hydro)	40	140	CEC	Financing proposals under discussion
Kalungwishi (hydro)	220	800	Lunzua Power Authority	Financing proposals under discussion

have since recognised the need to raise tariffs to levels that will make the electricity supply industry more sustainable from a financial standpoint. Above-inflation increases were awarded in 2008 and 2009, and a path towards cost reflective tariffs has been established.

The Rural Electrification Authority (REA) has the ambitious target of increasing rural access to electricity to 51% by 2030. If achieved, this would improve the overall electrification rate in the country from 23% to 66%. As would be expected, the funding required for an electrification programme of this size is significant. Current estimates are that in order to reach the target a total of $1.1 billion will need to be spent at an annual rate of $50 million making tariff increases necessary.

Foreign investors are increasing their influence on Zambia's power market. These Chinese-supported projects, financed primarily through export-credit arrangements, are providing an alternative to traditional project financing (*see* Table 5). Though not competitively bid, what appears to be attractive to government is the swiftness of project preparation and speed of financial closure, thus increasing the likelihood of a quick start to construction.

4.11 Coalbed methane

No systematic exploration for coalbed methane (CBM) has been done; however, recently companies have expressed an interest in searching for methane. Methane gas has been discovered in neighbouring countries (Mozambique and Tanzania) and the geological environment of Zambia offers potential for this. Furthermore, there are reports of gas emissions in the coal exploratory wells in the Maamba area that need to be further investigated.

Coalbed methane is potentially a very rich source of methane for supplying gas into gas-fired power station. In 1999, the IEA conducted a study to assess global CBM resources and southern Africa was one of the regions covered. The Zambezi basin contains possibly 108 billion m^3, with a CO_2 storage possibility of 400 Mt (IEA, 1999). The Zambezi CBM region straddles northern Botswana, southeastern Zambia and north western Zimbabwe. The Zambezi basin is a Karoo sub-basin which extends over 80,000 km^2.

Prospective gas in place is estimated at 1350 billion m^3 (48 trillion ft^3), with an average resource concentration of 75 million m^3/km^2 (6.9 billion $ft^3/mile^2$). The surface area, which is sparsely populated, is estimated to be 20,000 km^2 of which 18,000 km^2 is considered non-minable.

4.12 Comments

Similarly to the other countries examined in this report two thirds of the population live below the poverty line. The main employment is in agriculture through subsidence farming. One of the key priorities of the government is to improve the economy and infrastructure. In order to do that energy will play a key role with coal one of the areas the government is supporting. Although Zambia is not a large coal user with reserves of 10 Mt and coal resources of up to 200 Mt there is potential to increase this. The construction of a 300 MWe coal-fired plant is an interesting development although the technology is subcritical. There are several plans to expand mining and use of coal resources within Zambia with the Government supporting several initiatives.

5 Zimbabwe

5.1 Basic facts

Population:	12.6 million
Capital:	Harare
Currency:	US$, SA rand, Botswana pula, €, £ sterling
Total coal production (2011 estimate):	2.58 Mt
Total coal demand (2010 estimate):	2.73 Mt
Imports (2010 estimate):	0.046 Mt

Zimbabwe has a land area of 391,000 km^2 and is land locked (*see* Figure 19). The country has land borders with Mozambique, Botswana, Zambia and South Africa. Formerly known as Rhodesia, when the Zimbabwe Liberation War ended in 1980, the country became independent from the UK and was renamed Zimbabwe. It is made up eight provinces and two cities, Harare and Bulawayo which have provincial status. The other provinces are Manicaland, Mashonaland Central, Mashonaland East, Mashonaland West, Masvingo, Matabeleland North, Matabeleland South, Midlands (CIA, 2012c).

Figure 19 Map of Zimbabwe (CIA, 2012c)

The geography of the country comprises a high central plateau known as the high veld. This forms a watershed between the Zambezi and Limpopo river systems. The Zambezi River forms a natural boundary with Zambia and in full flood the Victoria Falls on the river forms the world's largest waterfall. The Limpopo and the lower Zambezi valleys are broad and relatively flat plains. The eastern end of the watershed terminates in a north-south mountain spine, called the Eastern Highlands. The Kalahari Desert is on the southwest edge of the country.

5.2 Economy and policy

Historically, Zimbabwe was known as the bread basket of Africa with a vibrant economy. Robert Mugabe was elected the country's first prime minister in 1980 and since 1987 has been the president. The introduction of a land distribution campaign resulted in an exodus of white farmers and the collapse of the economy due to rapid inflation and widespread shortages of basic commodities. Zimbabwe's current economy is driven by agriculture and mining. In 2008 agriculture accounted for 18% of gross domestic product and mining for 22%.

The government is trying to encourage foreign investment in manufacturing, mining and infrastructure development for tourism. Foreign investors could take up to 100% ownership. However, in 2007 the government introduced an Indigenisation Bill that mandates, over time, 51% indigenous ownership of business and this has proved unpopular with overseas investors.

The country's population and businesses faced some of the worst economic conditions, and the country is still recovering. Since 2000, the controversial land reform policy to seize land formerly owned by ethnic white Zimbabweans, and the violence that often accompanied the drive, caused continuing economic decline.

5.2.1 Constitutional issues

The Zimbabwe Constitution has a president and a prime minister as the heads of state and government, respectively. The president is elected for a five-year term by popular majority vote whilst the Prime Minister has no specified term limit. Parliament has 120 members elected by the common-roll electorate, ten tribal chiefs, twelve presidential appointees, eight presidentially-appointed provincial governors, the Speaker, and the Attorney General. It may serve for a maximum of five years.

5.2.2 Energy policy

Broader energy policy is overseen by the Ministry of Energy and Power Development (MEPD) (www.energy.gov.zw). The mandate of the Ministry includes policy formulation, performance monitoring and regulation of the energy sector. The MEPD also mandates research and promotion of new and renewable sources of energy and energy conservation (AfDB,2011). The Ministry supervises and oversees the performance of the parastatal energy companies (those part-owned by government) ZESA Holdings and NOCZIM (REEEP, 2012).

In 2012, the government launched its National Energy Policy (NEP) with strategies and measures to extend and increase electricity transmission and generating capacity. Zimbabwe has set a target of 10,000 MWe of installed capacity by 2040. To achieve this goal, the NEP called for a capacity expansion of 800 MW at the Batoka Gorge hydro-electric power station by 2020, 300 MWe at the Kariba South hydro-electric power station by 2016, as well as other smaller hydro-electric power plants (Mining Weekly, 2012c).

The Rural Electrification Fund Act (13:20) created a Rural Electrification Agency funded by electrification levies and government stipends. The main functions of the agency are to plan electrification projects, raise funds, manage rural electrification finance, and monitor project implementation.

The Zimbabwe Electricity Regulatory Commission (ZERC, www.zerc.co.zw) was established under a 2003 amendment of the Electricity Act, (Chapter 13:19) No. 4 of 2002, becoming operational in August 2003. The Petroleum Act, passed in 2006, provided for the establishment of the Petroleum Regulatory Authority (PRA), to license and regulate the petroleum industry. Zimbabwe is almost entirely dependent on oil imports and the new Authority is aimed at promoting the development of efficient procurement, sales and distribution of petroleum products.

Most of the country's energy supply comes from woody biomass, resulting in deforestation in some areas of the country. Forest loss is almost directly linked to poverty, which is partly a consequence of having poor access to reliable electricity supplies and fossil fuels. Often, this deforestation is hard to record where the wood fuel is illegally felled and traded, often below market prices. While wood fuel supplies mainly the residential sector, a great deal of forest is also cleared for agriculture, but also used in industries such as tobacco for curing.

The Forestry Commission is proposing a Statutory Instrument provision under the Tobacco Wood Energy Programme where farmers facilitate sustainable forest management which would establish their own sustainable source of wood in the form of fast-growing exotic trees which are renewable compared to indigenous varieties. In addition, there are plans to establish a supply chain of coal from the country's major producer to offer affordable coal to small-scale farmers.

5.2.3 Electricity market policy

The Zimbabwe Electricity Supply Authority (ZESA) is separate from the Ministry of Energy and Power Development. ZESA is an important organisation that provides the majority of electricity based on subsidiary companies which handle the core services of generation and transmission/distribution. ZESA is a statutory corporation established by the Electricity Act of 1985. A Board of Directors, appointed by the Minister in charge of energy, is responsible for the management of ZESA. The electricity market is currently operating with two key companies that generate, supply, and import electricity: Zimbabwe Power Company (ZPC), responsible for all generating stations and for the supply of power to the transmission grid, the Zimbabwe Electricity Transmission and Distribution Company (ZETDC)

In 2002, the new Electricity Act was implemented, which restructured the power sector from a vertically integrated utility into three separate companies under Zimbabwe Electric Supply Authority (ZESA) Holdings. The separate companies were ZPC and the ZETCO (former transmission company) and ZEDC (the former distribution company), the latter two being merged in 2010 to form the ZETDC.

Based on REEEP (2013), ZESA oversees the trade in electricity with other countries, chiefly imports as the country exports little power. Zimbabwe often needs to import electricity, leading to trade imbalances, with ZESA in debt to power suppliers from power-exporting countries. This partly contributed to ZESA's relatively poor financial performance, suffering annual net losses of $270–418 million in the years 2003-05. By 2008, ZESA owed $417 million to the Mozambican supplier Hidroeléctrica de Cahora Bassa alone. These losses occurred early during the newly restructured power market – which will require further reforms. The financial losses are due to a variety of problems. Theft of equipment such as transformers and cable and a shortage of spares continue and was estimated to cost 400,000 $/month during 2009.

One of the major restrictions on raising cash flow to ZESA is the controlled pricing of domestic electricity by capping. This limits the cost recovery and, when combined with poor billing/collection efficiency (estimated at 60% cost recovery in 2009), cash flow is unduly low compared to the cost of operating the system. Tariff caps also reduce confidence amongst financial agencies to loan funds to the company.

ZESA also operates the Hwange power plant which provides the bulk of the country's thermal power generation, and is fuelled using coal from the Hwange Colliery. Coal from the colliery is subsidised, but the power plant itself is unable to raise enough funds to pay for the subsidised fuel. This in turn weakens the cash flow of Hwange Colliery which relies heavily on the supply contract with the power station to remain in business (Pushak and Briceño-Garmendia, 2011).

A restructuring of the electricity market and tariff inflation will be necessary over the long term, and is essential to stimulate the much needed investment in this sector. However in the short term, whilst increasing revenue, higher tariffs may worsen poverty in Zimbabwe in some sectors. Better electricity infrastructure will be needed for long-term economic growth, which itself should lead to rising incomes. The government endeavoured to increase some tariffs, while offering free power for a limited amount of kWh to prepaid customers. In addition, businesses receive a discounted tariff structure.

5.2.4 Climate change policy

The Ministry of Environment and Natural Resources Management (formerly Mines, Environment and Tourism) is responsible for climate change policy in Zimbabwe as leader in a thirteen member institution. The adoption of cleaner energy such as solar and bio-ethanol should be seen as a solution to marginalised rural communities with little access to conventional grid networks. To co-ordinate climate change activities the Ministry has also established a Climate Change Office.

Zimbabwe is likely to feel the impact of climate change, but its economic situation and low per capita incomes makes action on greenhouse gas emission reduction difficult. Realistic action to combat climate change may come in the form of mitigation plans to protect the agricultural sector and the general population from drought or flood.

5.2.5 Clean development mechanism (CDM)

The UN FCCC understands the untapped potential for CDM projects in Africa. Much of the work currently involves removing the barriers to foreign investment and repatriation of profits to stimulate CDM investments in Africa. The first CDM project to earn Certified Emission Reductions (CERs) involved the avoided emissions of nitrous oxide (NO) from a fertiliser plant in Kwekwe.

The facility is owned and operated by Sable Chemicals. Some 3.4 million CERs were expected to be generated, which would be purchased by Standard Bank Group (Kitogo, 2011). The abatement facility would catalyse NO into N and O, using a NOx reduction facility. Replacement of the electrolysis plant (presumably electricity intensive) with a coal gasification plant is possible, but Maguwu (2012) believes this would lead to increased CO_2 emissions. However, half of the country's power generation comes from coal, and with 12% losses in the grid, greenhouse gas abatement requires more research. Sable Chemicals requires 115 MWe of power and is considered the single largest consumer of electricity in the country.

5.2.6 Energy efficiency

The government's International Energy Initiative runs programmes to promote energy efficiency, notably through the Zimbabwe Energy Efficiency Project (ZEEP). Under ZEEP, industrial efficiency has improved and government standards for efficient appliances and equipment, for example, lighting, water heaters and refrigerators are being applied (REEEP, 2012). Transmission and distribution losses in the country are considerably lower than in many African nations, standing at approximately 12%. Demand-side efficiency could be further encouraged in the country, as electricity tariffs remain amongst the lowest in Africa, at roughly 0.06 $/kWh, due to heavy subsidies. The low non-technical losses in the transmission and distribution system have been attributed to the exceptionally low power tariffs.

5.3 Energy demand

Zimbabwe's economy consumes around 11 Mtce (9.6 Mtoe) of energy, the majority of which is consumed in the residential sector which is completely dominated by biomass. This is a common picture seen across this whole region and unlikely to change for some years (*see* Figures 20 and 21).

Energy consumption per capita in 2009 stood at 0.76 toe, which is higher than the African average of 0.67 toe/person. The residential sector accounts for roughly 70% of the total energy consumption in the country; in the residential sector biomass supplies >90% of this energy (in energy terms).

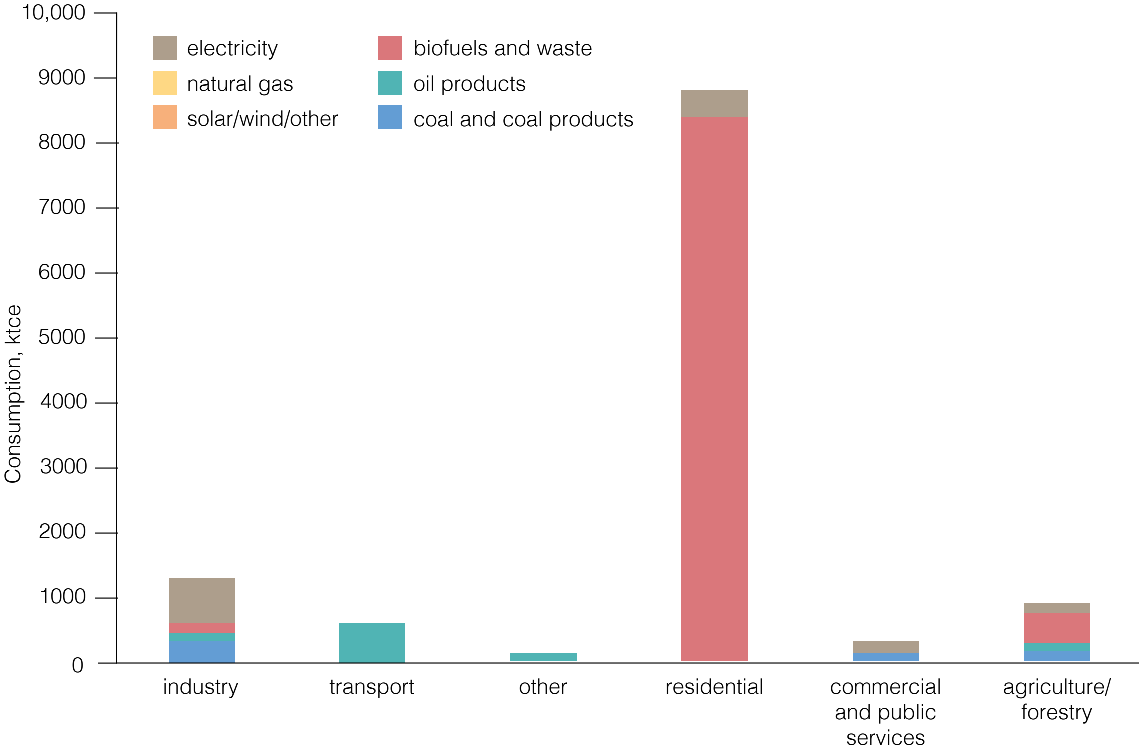

Figure 20 End user energy consumption, ktce (IEA, 2013)

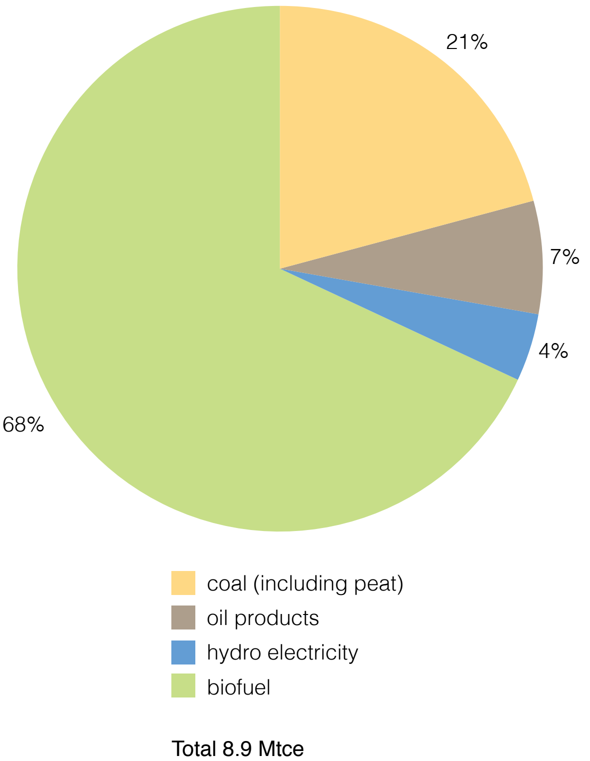

Figure 21 Total primary energy supply by fuel in 2010 (IEA, 2013)

Access to electricity is estimated nationally at nearly 40%, with urban access standing at nearly 80%, but access to electricity in the rural areas of the country is much lower, at about 19%, due to the prohibitive costs of extending national electricity grids. In rural Zimbabwe, 80–90% of people are heavily dependent on wood fuel for cooking, kerosene for lighting; processing tasks, such as milling grain, often make use of use of diesel-powered systems.

5.4 Coal demand

The current coal market is limited with few minemouth power stations able to use the low grade coals produced by coal preparation plants. Sometimes, if the power station demand drops, these products (with heating values) end up as backfill in the mine pits.

According to Mosuwe (2012), both steam and coking coals are supplied to various customers in Zimbabwe. Apart from the Hwange power station, the heavy industry sector (chiefly cement production) makes use of coal. Other markets include the small overland export market of coal fines to Zambia. Coal fines are discussed in more detail by Lewitt (2012).

The agriculture sector also provides a valuable market for coal, such as tobacco industries which require heat for curing from coal-fired industrial boilers (Matyanga, 2012). Coke products are used mainly by the Zisco steel company. Coke is used in foundries and by other steel customers in Zimbabwe, Zambia and the DRC. Zumchem Refineries makes use of Hangwe's tar and crude Benzol products.

Hangwe Colliery Company Ltd or HCCL (2013) reported improvements in the manufacturing and agricultural sectors, while demand for coke exports is also strengthening. Reduced demand from the Zimbabwe Power Company (ZPC) led to a fall in sales of coal by 25% over the year to 2012. Total coal and coke sales for the year were 2.5 Mt in 2012, down from 1.9 Mt in 2011 (ZPC, 2013a).

Table 6 Coal sales by HCCL in 2011-12, kt (HCCL, 2013)

Product	2011	2012
HPS coal	1450.2	901.5
HCC/HIC coal	815.5	546.3
Coal fines	190.9	233.5
Total coal	**2456.6**	**1681.3**
Coke (incl breeze)	74.9	228.2
Total	**2531.5**	**1909.5**

The ZPC Hwange power station accounted for 54% of coal sold in 2012 (*see* Table 6). Hwange Coking Coal (HCC) and Hwange Industrial Coal (HIC) were also major contributors to the company's revenues. Investment in mining amounted to $32 million, part of which was for the acquisition of mining equipment from South Africa valued at $6.35 million destined for the Hwange Chaba pit. Export sale increased in 2012 by 28% to 261 kt.

5.5 Energy resources (non-coal)

5.5.1 Oil and gas

Zimbabwe has no indigenous sources of oil and natural gas. Oil product imports in 2009 were estimated at 13,140 bbl/day, with consumption approximately the same. There is no oil refinery within the country. As a result all refined petroleum products, including gasoline are imported. Fuel import spending in 2009 stood at $454 million, or 15.7% of total import expenditure. Almost all oil is consumed within the transport sector, piped over 280 km via the Mozambique port of Beira to terminals in Zimbabwe. Oil is transported another 260 km to the key consumption market of Harare.

5.5.2 Renewables

The leading energy resources in the country are fuelwood and hydro-electricity. Forests cover 20% of the land area and represent a stock of 320 Mt, with a sustainable yield of 13 Mt/y (AfDB, 2011). Regional resource depletion occurs, but nationally the fuelwood resource is adequate to meet the country's needs sustainably. Intra-regional trade in fuel-wood is developing in order to supply surplus to other regions in deficit.

As part of the biomass and waste fuel market, fuelwood is produced alongside waste products such as timber waste, urban waste, bagasse, and biogas. Some 70 kt of biomass waste is produced from timber plantations, and 2.5 Mt/y of household and industrial waste from urban areas.

Some of the fuel has the potential to fuel power plants. Bagasse is currently used to generate 72 MWe in the Lowveld, while biogas could supply households and the agricultural industry. More than four hundred biogas digesters have been installed in Zimbabwe.

Other renewable resources include hydro-electricity, with the powerful Zambezi River offering a shared resource with Zambia, estimated at 37 TWh of which roughly 10 TWh has been harnessed. Small-scale hydro-electric power is made available in the eastern part of the country due to terrain and rainfall, but offers marginal power in comparison to the Zambezi. Solar radiation could offer 10 TWh of power with an efficiency of 20%, given the annual 2000 kW per hour per sq km resource available for 3000 hours per year. This output could be achieved by harnessing just 1.3% of Zimbabwe's total surface land area.

5.6 Coal resources and quality

There is a wide range of basins, subbasins, and coalfields which are part of various geological structures, making understanding coal reserves a complex task in Zimbabwe. Estimates for coal reserves and resources vary considerably, and not all state whether they are economically recoverable.

Table 7 List of coal deposits in Zimbabwe (Holloway, 2012)

Coal deposit	Approximate resource, Mt	Number of drill holes
Zambezi-Hwange area		
Hwange	418	3900
Chaba	103	150
Western area	952	26
Entuba	532	34
Sinamatella	96	6
Sub-total	*2101*	
Zambezi-Lubimbi area		
Lubimbi	1742	124
Hankano	571	12
Dahlia	699	5
Sub-total	*3012*	
Other Zambezi Basin		
Lusulu	1900	185
Sengwa	1500	450
Lubu-Sebungu	83	5
Marowa	14	3
Sessami-Kaonga	1000	12
Sub total	*4497*	
Save-Limpopo Basin		
Bubye	60	13
Save area	569	12
Tuli	15	5
Sub total	*644*	
Total	**10254**	**4942**

Figure 22 Map of Zimbabwe coal resources (Holloway, 2012)

Table 8 Representative coal qualities for Zimbabwe (Moyo, 2012)

Coal properties air-dried basis	Composition
Calorific value, MJ/kg	29.8
Inherent moisture, %	0.8
Ash, %	9.8
Volatile matter, %	23.4
Fixed carbon, %	64
Volatile matter, % (daf)	26.3
Sulphur, %	1.3
Free swelling index, %	2.0

According to the World Energy Council (WEC, 2010) at the end of 2008 there were 502 Mt of proven recoverable reserves. The country's coal deposits are being explored and surveyed and according to the AfDB (2), they believe coal reserves are in the range 10.6–26 Gt in twenty-one deposits (presumably both proven and probable), of which 2 Gt are mineable using opencast methods, but there is little indication of the quantity of proven recoverable reserves from underground seams as yet.

Holloway (2012) believed the country's coal resource to be around 10.2 Gt, but the amount of reserves was not specified. This figure was established by some 5000 drill hole surveys. In some regions, coal surveys are supported by sophisticated geophysical mapping of the geological structures (*see* Table 7).

Coal resources are found all over the country, with large reserves in the mid-Zambezi region in the northwest of the country where the current production is concentrated, although large deposits are also found in the southern region of the country in the Save-Limpopo basin (Hawadi, 2012). The Zambezi area contains the richest resources, with 2101 Mt in the Hangwe area and a further 4497 Mt in 'other' Zambezi regions (*see* Figure 22). The Hwange coal deposit has large reserves of both coking and thermal coal (Hawadi, 2012). Hwange currently mines one seam, at depths ranging from outcrops to 360 m below ground with seam thicknesses of 10–12 m.

Coal resources outside Hwange, notably those in the Lubimbi, Lusulu and Sengwa regions, are potentially the most abundant, each having 1500–1900 Mt. These coal deposits are generally easier to mine as the geology is more favourable than around Hwange. There is less intrusion by igneous features, the seams are thicker and the coal is lower in ash (Matyanga, 2012).

Moving away from the Zambezi region, the southern coal deposits of the Save-Limpopo basin demonstrate more faulting and igneous intrusions, and contain coals with high ash contents and numerous dirt bands. As such, the coal is less suited to the world seaborne (export) market, but could have considerable potential serving local needs.

The coal quality being mined by the Hwange Colliery Coal Company Ltd ranges from steam quality to coking coal (Moyo, 2012). At the base of the seam, the lower ash and lower volatile coal is produced for coking markets. Here the ash content is no more than 15% and the volatile content is upwards of 23.5%. The rest of the seam is marketed as steam coal, with ash contents reaching 24% and a creditable heating value of 24–26 MJ/kg. The metallurgical coal qualities are shown in Table 8.

The coal qualities are similar to the coals found in Waterberg coals and Botswanan coals. The run-of-mine coal can have ash contents as high as 50%.

5.7 Coal production

Coal has been produced in Zimbabwe in Hwange since 1895. As Figure 23 shows, production peaked in the 1990s at around 6 Mt/y, comprising of predominantly steam coal. Production in recent years has been closer to 3 Mt/y, with steam coal still accounting for most of the production. Mosuwe (2012) states that the partially state-owned Hwange Colliery operates at 60% of its nominal capacity. A lack of capital, poor logistics and low prices prevent any major expansion or drive to increase productivity.

Mining prior to independence in 1980 was mainly underground by bord and pillar; opencast mining was limited. Soon after independence, the commissioning of a 905 MWe Hwange power station created enough demand to stimulate more production at the associated coal operation. This brought about the need for an opencast mine employing a dragline system and strip mine method. In the underground operations the No. 3 colliery was upgraded in the late 1990s using a continuous miner, three shuttle cars and mechanical roof bolters. With sales set at 2.5 Mt in 2011, Hwange Colliery Company Ltd accounted for at least 76% of the country's production, not including any coal that is produced for stockpiles or lost in transformations such as coke making.

The remainder of the country's production, some of which is coking coal, comes from other smaller operations. RioZim operates the Sengwe coal company with a small production of around 25 kt per month from an opencast operation. In the past, coal mining licences were issued to few companies, but deregulation has opened more opportunity to apply for coal blocks. There are four mining special grants, these are: Hwange Colliery Company Ltd, RioZim, Makomo Resources, Steel Makers Zimbabwe, KW (Chibonde). In addition, there are 19 Special Grants for exploration and one 'Special Grant' for coalbed methane (*see below*).

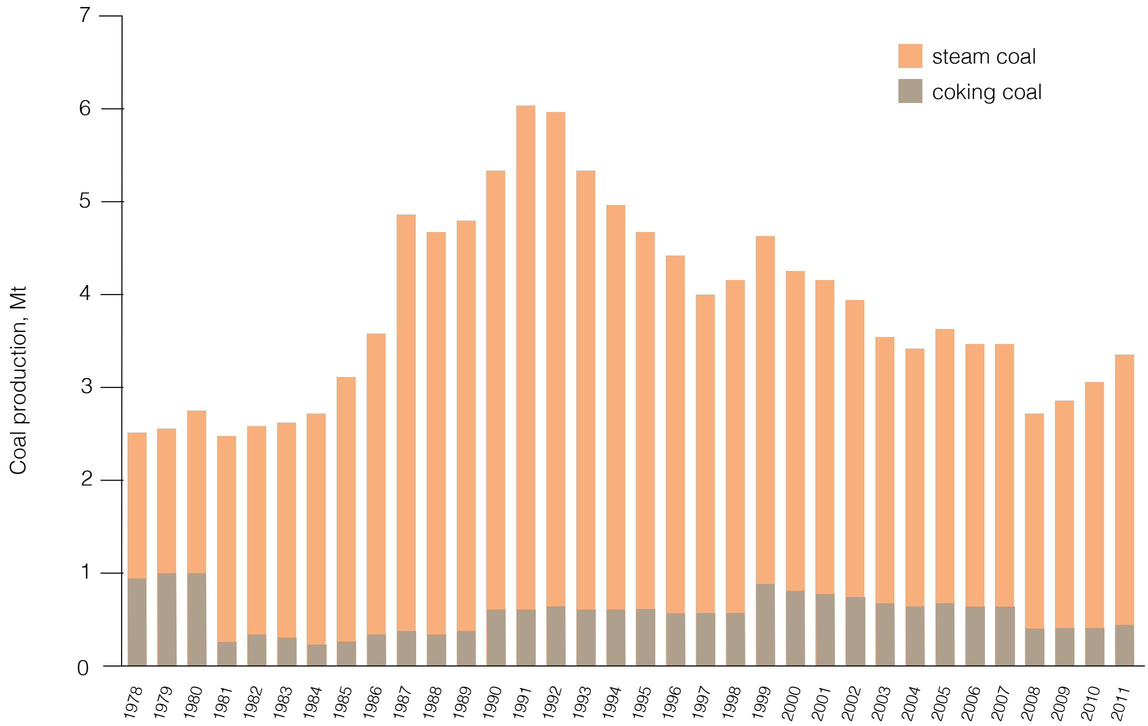

Figure 23 Zimbabwe coal production since 1978, Mt (IEA, 2013)

Mining royalties paid to the government have increased from 3.5% to 4%. The government may well benefit from the rise in the number of private companies intending to expand operations, and benefit further from export. The government has also set up a fund to acquire 51% of the shares of all mining companies for black Zimbabweans by 2012. Makomo Investments, WK Blasting, Clidder, Apex and Liberation Mining are mining coal in Hwange, Deka, Gwayi, and Binga. According to Mosuwe (2012) there are ten companies operating in the Zimbabwean coal industry. The main ones are:

- Hwange Colliery Company Ltd (Zim) – Hwange Coalfield;
- RioZim – copper producer operating the Sengwe Colliery with 0.5 Gt proven reserves, producing 25 kt per month; $3 billion plans to build a 2400 MWe IPP power plant using local coals;
- LontohCoal Limited (South African-based) – investment in the Lubimbi Coalfield possibly containing 1.25 Gt of steam and coking coal available from opencast production;
- Monaf Investment 80% owned by Sable Mining (UK) – Lubu Coalfield in Hwange, currently undergoing drilling and confirming 0.3–0.5 Gt of potentially opencast mined coal;
- Cluff Africa Associates (UK) – Lubimbi Coalfield in Hwange;
- Zimasco (Zim) – ferrochrome producer currently drilling to explore CBM prospects;
- IDC (SA) Industrial Development Company;
- Coal Videsh Ltd (China) – bidding for exploration and drilling licences with ZESA;
- India's Essar Group – a major industrial conglomerate could team up with Hangwe Colliery to supply coal, coal waste and coke products if Essar successfully bid for Zimbabwe's Ziso iron ore and steel company.

The Lubimbi coalfield is around 80 km east of Hwange with a potential resource of 3.2 Gt, although higher estimates of 22Gt have been reported. There are plans to develop it as a series of large-scale open pits serving power generation and/or coal-to-liquids operations. In addition, there is an intention to export the low ash steam coal and high volatile blend coking coal. ROM output from the first pit is projected to be 4 Mt/y annually, with 2 Mt to a power station and about 0.8 Mt of export semi-coking coal.

5.8 Coal exports

Existing rail networks can be used to transport coal from western Zimbabwe where the coalfields are being developed to the ports of Beira and Maputo (Mozambique) and Richards Bay and Durban (South Africa). The latter could provide direct routes or coal could be transported via Botswana's rail network that also goes close to the Botswana coalfields. A number of coal opportunities are being considered aside from coal production, such as power generation, coke production, coal-to-liquids (CTL), coalbed/mine methane (CBM), gasification (although not underground gasification or UCG as yet). These issues are discussed later.

Previous exports by rail to Zambia may well continue, but growth could be squeezed until Zambia develops the current railway network. To rehabilitate the 2583 km railway network would cost around $1.1 billion and a further $870 million to replace or upgrade rolling stock. One of the key challenges is that the coal deposits that are being worked are in the west of the country, while the market is in the east of the country, hence railway transportation is key to connecting these two development regions. Exports are currently only via the ports located on the Indian Ocean, these ports are in Mozambique and South Africa (*see* Table 9).

Distance is a major obstacle. Hwange coalfield is close to the Zambian border, which itself is landlocked. The Mozambique coast offers a number of export ports. However the Hwange producing region is a distance of 1389–2218 km from the east coast ports, a similar distance to the transport of Russian coals to the Baltic ports, where the cost of inland transportation is half the export cost of coal. Access to suitable ports will ned to be taken in account by the Zimbabwean coal developers. Namibia is a possible route but less practical as the rail links are still undeveloped, and the key market for

Table 9 Rail distances from Zimbabwe regions to export ports, km (Moyo, 2012)				
	Beira	Maputo	Durban	Richards Bay
Gweru	869	967	1764	1684
Bulawayo	1051	1083	1880	1800
Hwange	1389	1421	2218	2138
Mutare	290	1546	2641	2561
Beitbridge	1333	745	1598	1518
Chicualacuala	1300	536	1879	1799

Zimbabwean coal lies in Asia. It is likely that coal exports will only go to neighbouring countries. The market is likely to be mainly domestic.

The Africa Development Bank reported that Hwange Colliery is securing an export supply contract to India and Europe as part of the company's strategy to diversify its portfolio of customers. While it is recognised that the majority of customers will be in the domestic industry and power sector, 40 kt of coal was transported via Mozambique from an unspecified port. Coal exports have traditionally been with neighbouring countries such as DRC, Zambia and South Africa, but with an international price of 100 $/t, seaborne shipments are increasingly attractive (AfDB, 2012).

The US-based company Steelmakers Zimbabwe operates the Chiredzi mine and announced the possibility of exporting coal to India after a $6 million investment at the Chiredzi Ores Anthracites Lignites Zimbabwe (Coal) colliery (Kazunga, 2013). Coal is crushed and screened in a preparation plant capable of screening 200 t/h. December 2012 saw production reach 60 kt, supplying local customers in construction, and agriculture. Steelmakers Zimbabwe applied for a Mining Special Grant in 2004 to mine coal as Hwange Colliery was unable to fulfil supply commitments, which had a negative impact on the Steelmaker Masvingo sponge iron plant.

Hwange avoided the process of obtaining foreign currency in order to make coal purchases from the world market, although initial investments required importing capital equipment for mining. The coal mining venture was intended to help drive the expansion plans for the group's steel interests in Zimbabwe, and produce low-S low-P coal from a 2500 ha area which could contain 500 Mt of coal.

5.9 Power generation

The country's power supplies come chiefly from two forms of generation, hydro-electricity and coal-fired power, with some net imports necessary to supplement these sources. The Zimbabwean grid is connected to the South African Power Pool. In 2000, power generation supply was around 12,000 GWh, with a large proportion coming from imports, and just 7000 GWh coming from the small fleet of stations (*see* Figure 24). By 2005, the output from these stations increased to more than 10,000 GWh, but by 2008 it dropped back to 2000 levels. Net imports also plummeted from 5000 GWh in the early 2000s to below 1200 GWh a few years later.

Fulfilling electricity demand with more generation is key to supporting the growing economy. However the economy is currently supplied by a few old power stations. The electricity generating sector is made up of few power stations (*see* Figure 25). The overall electricity industry infrastructure is outdated and dilapidated due to vandalism, theft and neglect. The stations are in need of refurbishment and upgrading to improve efficiency. Figure 25 shows the power capacity in Zimbabwe.

Power generation is controlled by the Zimbabwe Power Company Ltd (ZPC), a wholly-owned

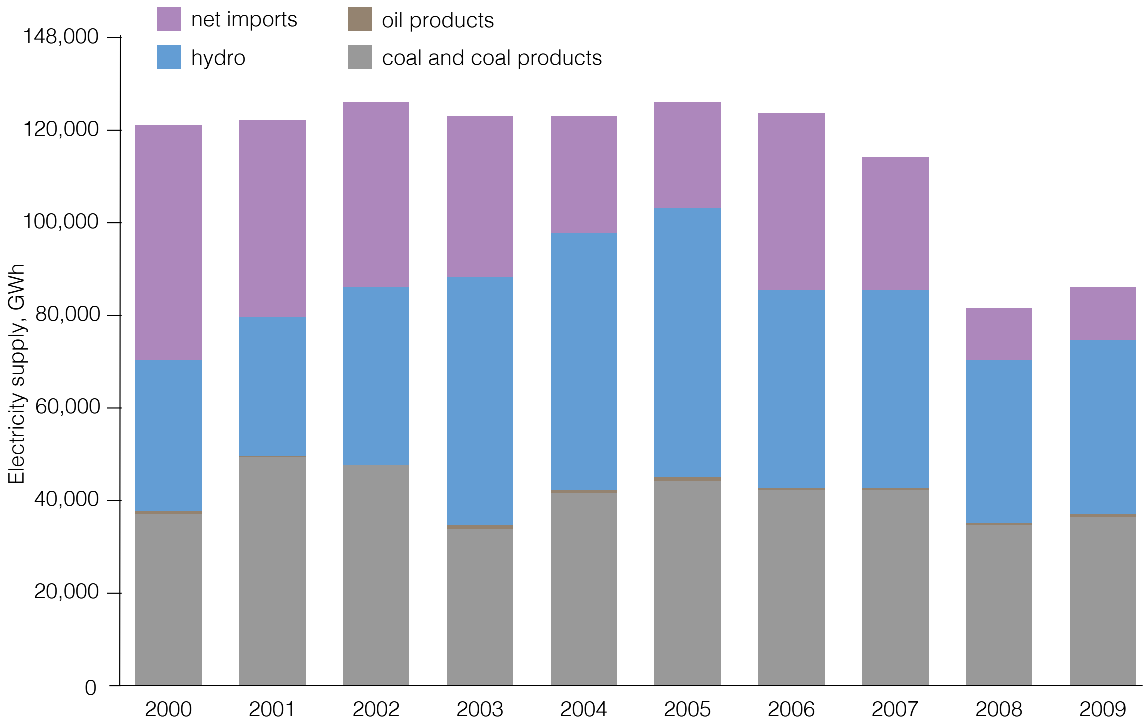

Figure 24 Power generation in Zimbabwe, not including 12% system losses from transmission (IEA, 2013)

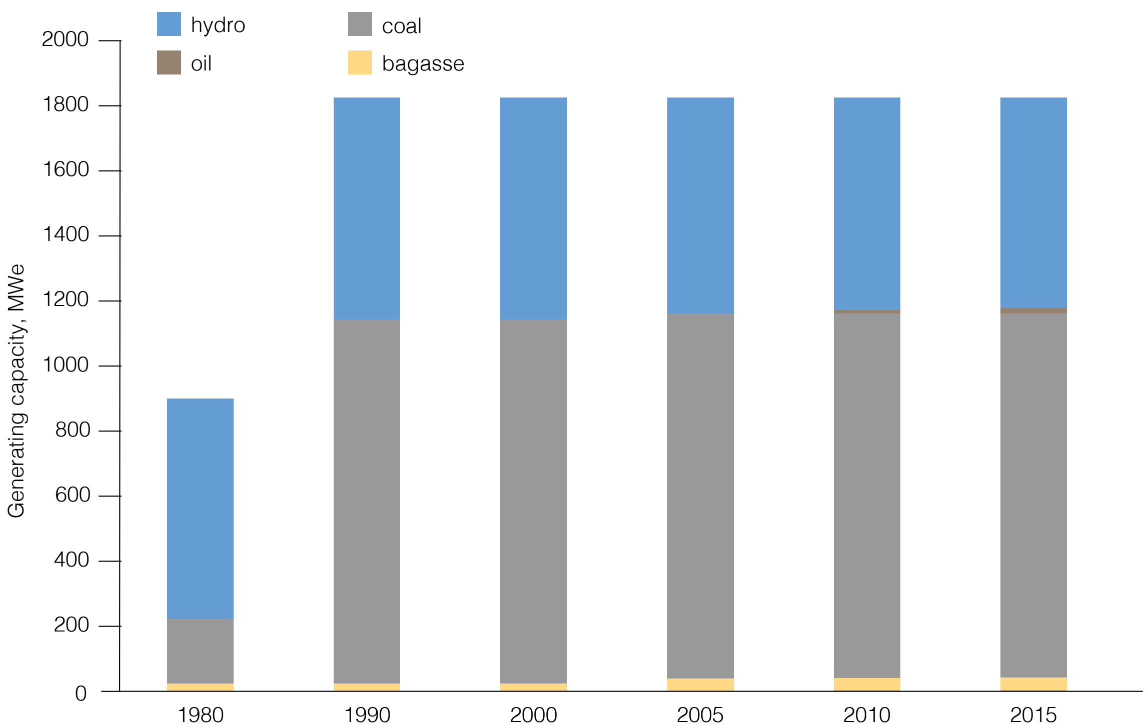

Figure 25 Power generating capacity in Zimbabwe, excluding import capacity (Platts, 2012)

subsidiary of Zimbabwe Electricity Supply Authority (ZESA) Holding group of companies. ZPC was incorporated in 1996 and became operational in 1999 as the power generating investment arm authorised to build, own, and operate (and maintain) power generation stations. ZPC itself operates four coal-fired power stations, they are: Hwange, Bulawayo, Munyati and Harare. In addition there is one large hydro power station, Kariba South Power Station. These five stations amount to a total of 1960 MW as installed capacity. Each power station holds a generation licence from the Zimbabwe Electricity Regulatory Authority (ZERA). ZPC supplies about 1200 MWe of electricity to the network, against a demand of 2200 MWe (ZPC, 2013b). Transmission losses in the network system are around 11–12% and the infrastructure requires investment.

Frequent power shortages lead to a significant under-utilisation of production capacity in manufacturing, mining and agriculture. In 2009, the country experienced 15 days of (non-consecutive) outages. The Kariba hydro station is more reliable with available capacity of 746 MWe while the Hwange coal plant has frequent outages which occasionally can limit the output to 100 MWe.

The available capacity changes from year to year. According to the AfDB (2011) only 1000 MWe out of 2000 MWe of installed generation capacity is currently available, although the ZPC (2013b) would claim that this figure is closer to 1200 MWe. In May 2010, the country's generation was just 940 MWe, although the actual dependable capacity at the time was reported to be 1700 MWe.

The SAPP plays an important role in helping to fill any shortfalls in generation within the country. Without imports, there would be a greater failure in the country's electricity system. Like Zimbabwe, more neighbouring countries are looking to build coal-fired capacity to ease these shortages.

Zimbabwe has a significant amount of potential hydro-electric power resources. Most of these locations are on the Zambezi river and require international agreement with Zambia. The average wind speeds in Zimbabwe are in the range of 2–4 metres a second m/s, insufficient for large turbines, but suitable for small-scale turbines.

Biomass provides 50% of energy used with coal providing around 13%. Fuelwood is the most important domestic fuel in the country supplying 80% of the population for cooking, heating and lighting. However, biomass is not used in the power market.

5.10 Coal-fired power generation

Out of the small number of power stations in the country, only the Hwange power plant is of significance in terms of overall output to the public grid. The 920 MWe Hwange Power Station operates as a base load station and meets approximately 40% of the country's electricity supply. According to the ZPC (2013a), the plant availability averages 80% and has a load factor of 65%, but as observed before, reliability can be an issue.

The station design largely represents technologies of the late 1960s and some of the equipment such as the boiler controls has had to be replaced with modern digital process controls. Stage 2 is however of more modern design. The plant was built in two stages and consists of four units of 120 MWe each and two units of 220 MWe each. Stage 1 units were commissioned from 1983 to 1986 and the Stage 2 units in 1986-87.

Coal is transported to the station by a 3.5 km conveyor from the Wankie Colliery opencast mine. Coke oven gas is used as an alternative to imported diesel fuel on Stage 1 units. The coke oven gas, which used to be flared to the atmosphere, is a by-product of the coking process at the nearby Wankie Colliery coke ovens. The station uses ESP for particulate control but is not equipped with FGD for SOx reduction.

The Harare Power Station is located in the capital city of Zimbabwe and consists of three units with coal supplied by Hwange Colliery Company by rail.

The Munyati power plant, built between 1946 and 1957, is situated in the Midlands province. The station originally had a capacity of 120 MWe, comprising of multiple 20 MWe units, but the station is currently generating 30 MWe. The station uses stoker boilers, burning bituminous coal under subcritical conditions. The operators of Munyati aim to use lower sulphur products to limit SO_2 emissions, but particulate and NOx control are not installed, in common with all of the smaller thermal plants.

The Bulawayo station is situated in the city of Bulawayo, Zimbabwe's second largest city. The plant was commissioned between 1947 and 1957 as an undertaking for the Municipality of Bulawayo. It joined ZESA in 1987 after the amalgamation of all the Local Authority Electricity Undertakings. Unbundling of business units has resulted in the plant joining Zimbabwe Power Company. It has an installed capacity of 120 MWe but is capable of generating 90 MWe due to the deactivation of 2 x 15 MWe units. The station has been operating as standby capacity. Bulawayo Power Station is also ISO 9001:2008 certified.

5.11 Scenarios

Zimbabwe is in a state of uncertainty – with numerous plans but little or no progress on the construction of plants. However, three new projects are under construction and were due online in 2013, while many combined coal mine and power projects are at a stage of licence approvals or in the application process for either coal exploration or for IPP development. Business and regulatory confidence needs to increase. Some signs of this have come from the tariffs and takeoff agreements signed to enhance hydro-electric power, but the coal-fired power industry needs assurances that coal supply infrastructure and a stable and secure network system will be developed.

In 2011, AfDB (2011), reported power tariffs as being very low for the region at 8–9 ¢/kWh due to price controls effectively acting as a subsidy. The power tariff model should increase power tariffs from 13 to 15 ¢/kWh to encourage IPPs. There are $5.6 billion worth of projects in planning to add 20.7 GWe of power generating capacity (AfDB, 2011).

To bridge the huge gap between supply and demand, ZPC has a generating capacity expansion target of 10,000 MWe by 2040 to support a vision of growing the economy to $100 billion (Mining Weekly, 2012c). To achieve this, the company embarked on a number of projects. In addition, the government has set a target of boosting the electrification rate of the general population to 85% by 2020. The regulator has licensed various large electricity generation projects, investing in eleven new projects with a combined capacity of 5400 MW and value of $10.1-billion. All new projects would trade in the Southern African Power Pool (SAPP).

ZPC outlined plans to build another coal-fired power plant with a capacity of 1400 MW, expand capacity at the Hwange coal-fired station by 2 x 300 MWe, and add 2 x 150 MWe to the Kariba hydro-electric power plant (REEEP, 2012). The three smaller thermal power stations, Harare, Munyati and Bulawayo will be repowered by replacing the current boiler plants with new circulating fluidised bed (CFB) technology which is expected to enhance the small thermal stations' generating capacity to 340 MWe.

The ZPC invested $2 billion in many of these new projects, including the construction of a 30 MWe Gairezi hydro plant, the development of the Lupane gas fields for a 350 MW plant and a $500 million transmission integration project (ZPC, 2013b). The Hwange and Kariba projects could add 900 MW to Zimbabwe's power mix by 2016. As of 2011-12, Hwange and Kariba South were 80% and 90% complete, with Lupane standing at about 10%.

Zambia and Zimbabwe are planning the construction of the Batoka Gorge hydro-electric power station, located about 50 km downstream from the Victoria Falls, between the two countries. When operational, the $2.4 billion plant will have the capacity to produce up to 1600 MWe. Continued development of the nation's transmission infrastructure includes the uprating of the Hwange coal plant's infrastructure (REEEP, 2013).

Sengwa Coalfields of RioZim Ltd is planning an IPP project which has been approved and licensed at 2400 MW (in two phases), and follows from the earlier abandonment of a 1400 MWe with a UK partner. However, the perceived risk arising from the political and economic status of Zimbabwe meant that financial closure was delayed for two years after confirmation of the licences (Gata, 2012).

Panafrican Energy Resource (PER) is planning to develop a thermal power station in four phases of 500 MWe each, using partners with mining licences on fields north-east of Hwange, beginning with the Lusulu coalfield and using a mothballed pulverised fuel power plant from France. The power station will be at an exceptionally low cost, as the French equipment will be free. No cooling towers will be needed as the plant is being sited on the banks of Lake Kariba, using the lake water for cooling (Nicolas, 2012).

Figure 26 illustrates the planned rise in capacity, but as yet only the 600 MWe Hwange expansion will be operational in the coming years. Assuming a modest 6% rise in projected demand, forecast demand could double from 9.6 TWh to 17.2 TWh (Nicolas, 2012). This would mean peak demand could rise at a similar rate, from 1.6 GWe to roughly 3 GWe. The stations under construction could add 1400 GWe, some of which will be hydro-electricity, which may not be available during drought years. Nevertheless, at full output this could almost cover a peak demand of 3 GWe.

The additional 3000 MWe of coal-fired power that is planned up to 2020 could push coal demand up to beyond 6 Mt/y, compared with the current 3 Mt/y or so being produced. Plans to expand production are being drawn up. Figures quoted by Mining Weekly (2012b), suggest similar projections with plans

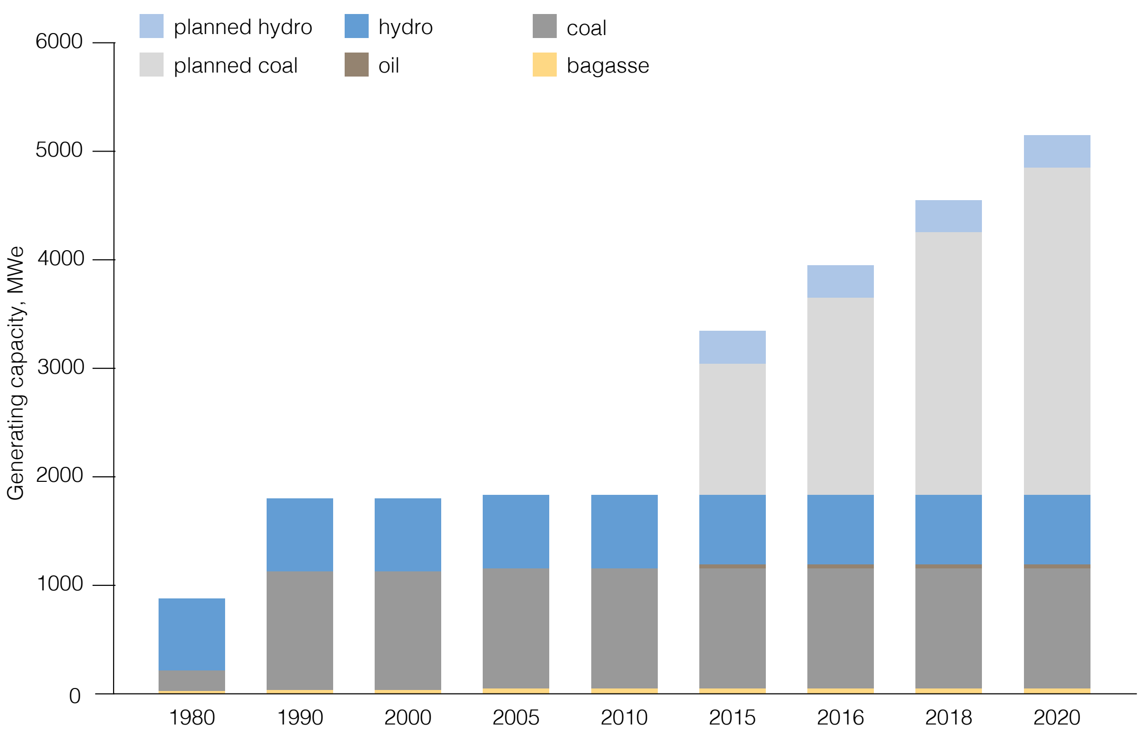

Figure 26 Planned coal-fired generating capacity in Zimbabwe, MWe (Platts, 2012)

to increase coal production to 7 Mt. While some of the key markets will be minemouth power stations, served by conveyor belts from coal processing plants, reaching the wider market is another logistical challenge. In order to promote coal development, the government will need to invest in the transport infrastructure which will be governed by the Ministry of Transport, Communications, and Transport Infrastructural Development.

Liberation Mining, which has a Special Grant 4977 for access to an estimated resource of 1 Gt (in situ), 1.9 Gt inferred in potentially opencast seams, and an additional 6.2 Gt (inferred) mineable by underground seams (Mutsinya, 2012). Projected ROM production could be 4 Mt/y for 22 years for the first pit. The production would comprise 2 Mt/y of marketable thermal coal for local markets and 0.8 Mt/y of semi-coking coal for export. This infers that 30% of the ROM coal will be discarded during coal preparation. The anticipated price for delivered coal is 30 $/t for steam coal at the power station, and 280 $/t for coke (2011 financial analysis).

5.12 Advanced coal technology prospects

All the new coal-fired stations are designed with subcritical technology; supercritical stations are not yet planned. One prospect for the utilisation of coal in an unconventional manner is coal-to-liquids (CTL). One example of this is the Sengwa CTL plan. Other plans for non-conventional coal energy abstraction include CBM. Both routes are in the infancy stage of planning,

5.12.1 Coal-to-liquids

The Sengwa coal field is located in the far north of the Midlands province. The coalfield is located almost on the Sengwa river, close to two national parks. The measured coal reserve is as much as 525 Mt, with a further 513 Mt indicated, and more inferred available for opencast mining. The coal analysis suggests a 16.7 MJ/kg heating value, with a 0.3% S content, and 18.7% vol, and 29.2% ash (ash fusion 1400°C, and <0.5 swelling), and so is not necessarily a good exportable product, but otherwise acceptable for short transportation to local markets. The coal is not considered suitable for PF boilers and has no coking quality and is not of a high enough standard for residential use. One target market could be gasification and production of bulk chemicals, such as ammonia, and liquid fuels, and has been tested for suitability.

However the opportunity for CTL is dependent on private funding from a foreign investor. One possibility that has been considered in the past is Sasol, the oil products giant of South Africa and a specialist in the production of liquid fuels from coal.

5.12.2 Coalbed/mine methane (CBM/CMM)

All coal mines contain a certain amount of methane trapped in the seam bed and surrounding rock. CBM gas mining exploration activities in Zimbabwe date back to more than ten years ago and the exploration work done to date indicates extensive deposits of coalbed methane gas. It is estimated that the Hwange/ Lupane basins have over 765 billion m^3 of sulphur-free methane gas, equivalent to 966 Mtce (ZHC, 2013). According to the exploration reports, some of the following key requirements for mineable gas are present in the basin's methane gas deposits: gas content, coal seam thickness, lateral continuity, high gas saturation, and adequate permeability. Zimbabwe's CBM reserve parameters compare favourably with commercially producing CBM basins in the USA. The exploration and tests were performed to international standards. However, there is need for further feasibility work to move from a proven gas resource to a commercially mineable gas reserve. The project is set to move to the next stage of establishing a mini gas field to prove that the resource is a reserve which can be mined commercially. The cost of establishing the gas field is estimated at

$12 million. Funding for this development is being sought by the Industrial Development Corporation of Zimbabwe.

5.13 Comments

Zimbabwe is in a state of uncertainty – with numerous plans but little or no progress on the construction of new plants. However, three new projects are under construction and were due online in 2013 with delays likely. There are several combined coal mine and power projects at the stage of licence approvals or in the application process for either coal exploration of for IPP development.

Investors' lack of confidence in the business and regulatory environment will lead to delaying energy sector development and investment. There are signs of progress with tariffs and takeoff agreements signed to enhance hydro-electric power. The coal sector will also need these assurances to develop a supply infrastructure and a stable and secure network.

6 Namibia

6.1 Basic facts

Population:	2 million
Capital:	Windhoek
Currency:	Namibian dollar
Total coal production (2011 estimate):	0 Mt
Total coal demand (2010 estimate):	0 Mt
Imports (2010 estimate):	0.1 Mt

Namibia is one of the smaller energy economies in the Southern African region, yet its role as a logistics centre in Southern Africa could be important. The economy is heavily dependent on minerals extraction and processing for exporting, a common feature of all the southern African states. Mining accounts for 8% of GDP and half the foreign exchange earnings. Diamonds are a major contributor to GDP while Namibia is also the world's fourth largest uranium producer (CIA, 2013). GDP is estimated at $12.15 billion, and growth in 2012 was 4.6%.

The country's energy white paper has committed to the development of renewable energy. The bulk of the country's generation comes from hydro-electric power, but solar, wind, biomass and even wave power are being considered. However, the high cost of renewables is a major obstacle. Distributed solar generation to extend power supplies to remote communities is an option that could obtain funding more readily than large-scale (non-hydro) renewables. Currently, there is no coal production.

6.2 Climate change policy

Namibia's greenhouse gas emissions in 2000 were mainly from agriculture (6.7 Mt) and energy (2.2 Mt) sectors. At the time, Namibia was a net carbon sink, sequestering a total CO_2 equivalent of some 1.4 Mt per annum. Some major developments will influence this status, such as:

- harvesting of 80 kt/y of biomass from invader bush species, to be used for wood gasification power plants, coal-fuel replacement for cement production and export of wood pellets;
- commissioning of a cement factory in 2010 with an annual coal consumption of 120 kt.

In 1995, Namibia ratified the United Nations Framework Convention on Climate Change and established the country's Designated National Authority (DNA) at the Ministry of Environment and Tourism. By March 2010, the DNA had issued several 'Letters of No Objection' to project developers wishing to initiate activities relevant to the Clean Development Mechanism (CDM).

The DNA provides guidance on CDM procedures relating to projects that seek to reduce emissions and/or sequester carbon in Namibia. As yet, Namibia does not have a registered CDM project, although several Project Idea Notes have been developed. In 2009, Namibia compiled its first climate change policy. Namibia has also signalled its agreement with the Copenhagen Accord, and has a multi-sector stakeholder group – the Namibia Climate Change Committee – which advises government on strategies and policies relating to climate change.

Project developers wishing to tap into international carbon markets remain cognizant that the country offers some CDM and voluntary carbon sequestering opportunities. However, as a sparsely populated country with very limited industrial activities generating greenhouse gases, the scope and scale of such projects remains limited.

6.3 Electricity

Unlike many other African countries, there have been no issues with power shortages in Namibia. This has a lot to do with the small population. Namibia imports more electricity than it produces with total consumption being 3.6 TWh, of which 1.6 TWh is produced domestically. Developing indigenous power is a priority for the country, and if possible, export power to the SAPP.

In 2008, maximum demand was 533 MWe, but installed generating capacity was less than 400 MWe, hence the need for imported electricity from neighbouring countries. Maximum demand in 2012 reached 614 MWe and even with the addition of new hydro generating capacity was still only 508 MWe. Two thirds of the electricity is derived from hydro-electric power, the remaining third is from coal (*see* Figure 27). Like the rest of Southern Africa, the mining sector is a large end user. The largest single consumer of coal, the Skorpion Zinc mine, uses 80 MWe.

In 2010, Namibia had more interconnector capacity with foreign countries than it had generating capacity, and therefore imports have become the mainstay supply of power to Namibia. These transmission lines draw electricity from South Africa (450 MWe), Zambia and Zimbabwe (300 MWe combined) with a 350 kV HVDC line (Namibian, 2010).

6.4 Coal reserves

According to the GSN (2013), coal potentially exists in extensive sedimentary basins like the Owambo, Huab, Waterberg and Aranos basins. The Aranos basin, which has been investigated in detail for coal, contains in situ resources of about 350 Mt of high-quality metallurgical coal at a depth of up to 300 m, the largest known coal deposit in the country. Gecko Coal (Pty) Ltd holds four Exclusive Prospecting Licences (EPLs) in the Aranos area. The coal is described as being low in sulphur with workable seams averaging 2 metres in thickness (Gecko, 2013). One of the key obstacles to development is the seam being surrounded by a groundwater aquifer. Deposits are also found in

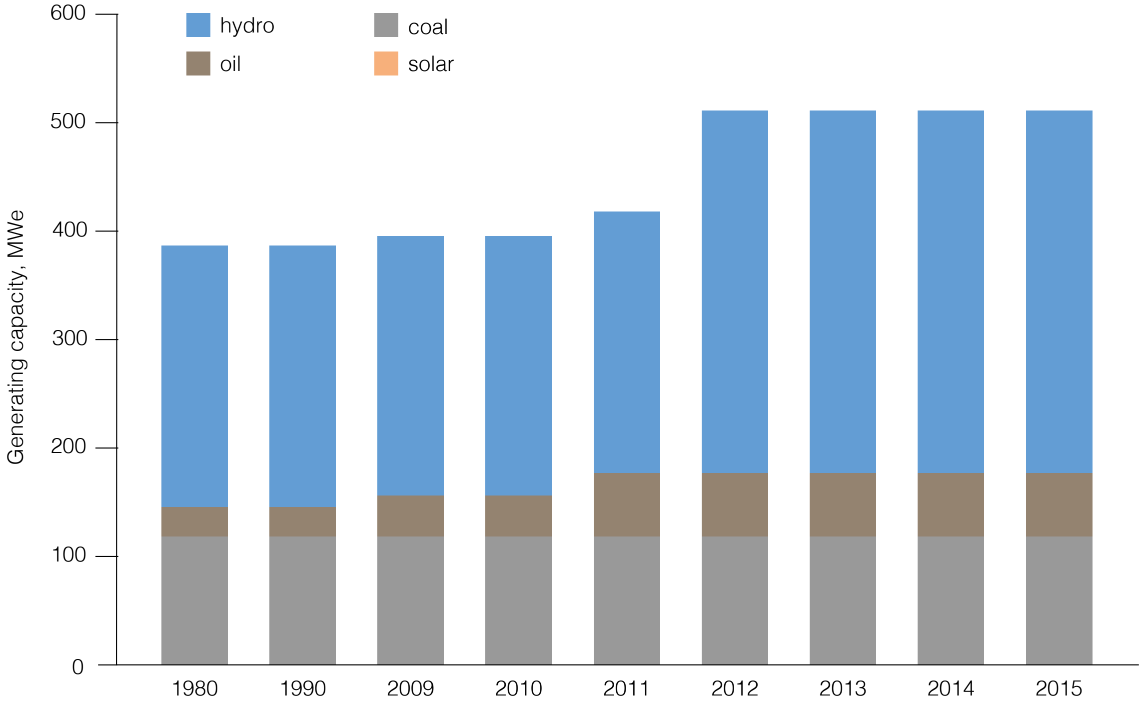

Figure 27 Power generating capacity in Namibia, MWe (Platts, 2012)

Ovamboland, Waterberg and Toscanini areas. Although coal is present in Namibia, there are no operating coal mines in the country.

6.5 Coal-fired power

Alternative methods of power generation were assessed with coal-fired power deemed the most effective addition to the country's small fleet of stations. All the coal that is consumed in the country goes to the single power plant that operates in the city of Windhoek, in the state of Khomas. This coal-fired power plant is operated by the Namibian state power utility, Nampower.

The 4 x 30 MWe Van Eck coal-fired station was built in the 1970s. It is a subcritical plant with no emission control systems. The plant was the first to implement dry cooling in Southern Africa using fans forcing air through radiators to cool the steam. The coal is fed using the grate method, which sprays coal onto a moving floor, or grate, moving forward at a specific speed. Roughly 570 kg of coal is consumed per MWh.

One of the biggest developments could be the planned Erongo power station by Nampower. The plans specify 2 x 150 MWe units. The plant would be located close to the proposed coal export terminal at Walvis Bay. The potential to expand this to 800 MWe is also being considered.

According to the Environmental and Socioeconomic Impacts Assessment, the Erongo region experiences fog, and so acidic emissions combining with the fog could create an acidic smog (Aurecon, 2012). The proposed station is planned to run at baseload, as well as have the flexibility to ramp output up and down to smooth grid fluctuations. The proposed station will include a circulating fluidised bed boiler, steam turbine and a direct dry cooling system. The absence of water for parts of the year means that water abstraction cannot be relied upon.

CFBC means that SO_2 emissions can be suppressed in-bed by adding limestone. NOx reduction could be achieved by staged combustion at temperatures of 850°C. Particulate capture could be by ESP or fabric filters. It is envisaged that coal of equivalent quality to South African Richards Bay export coal could be supplemented by biomass. Imported coal would come in via the TransNamib rail line. Coal consumption could be as high as 1.1 Mt/y for the 300 MWe plant, while the 650 MWe plant could consume 2.7 Mt/y. The construction period is expected to be 28–33 months with operations starting before 2016. The increase in greenhouse gas emissions from an 800 MWe coal-fired plant would double the current GHG emissions produced from the energy sector in Namibia. It was recognised that the emissions increase is small, less than 1% of global emissions.

There are predicted air quality impacts in terms of PM and SO_2 (associated with the 800 mg/m^3 emission limit scenario) for the 300 MWe power plant. However, any exceedance of emissions will mostly be confined to the site boundary (for predicted ground level concentrations). The highest daily and the annual averages are predicted to fall below the required guideline value off-site. Only the SO_2 ground level concentration (800 mg/m^3) is predicted to exceed the more stringent World Health Organisation (WHO) 24-hour guideline of 20 µg/m^3 on-site. It is not expected that the communities living in Arandis will be affected, as they are located nearly 10 km away, and the area around the plant is not inhabited. Furthermore the dominant winds will not carry pollutants in the direction of the town.

6.6 New port capacity and associated power projects

Botswana's Transport and Communications Minister signed an agreement for a $11 billion railway deal in April 2013, which has moved into the bid tendering stage (Ramokopelwa, 2013). The 1500 km Trans-Kalahari Railway will link the Botswana coalfields of Mmamabula to the Namibian port of Walvis Bay on the Atlantic coast. The line will cost $9 billion and require five years to complete. The connection could extend to the Waterberg coalfields in South Africa freeing up the Richards Bay Coal Terminal for Asia bound shipments.

Namibia's port could be an important infrastructure route for southern African producers in Botswana, providing access to the Atlantic coast for shipments to NW Europe and the Mediterranean and North African markets.

Walvis Bay is operated by Namport, the National Port Authority in Namibia. It is the country's largest commercial port handling roughly 5 Mt/y of cargo. The bulk terminal is used for salt exports, handling 500 t/h. The dry bulk terminal is privately run by Grindrod Terminal, the company that also operates the Maputo Coal terminal in Mozambique. NamPower has an obligation to provide electricity for all its citizens (Vision 20304), with due consideration of the international perspective in terms of global warming and its Agenda 21 commitments (Nampower, 2011). Earlier plans for a coal-fired plant in Walvis Bay appears to have been shelved, but an environmental and socioeconomic impact report assessment was done for stations of units 200/400/800 MWe.

The recommendations of the report included choosing the smallest possible units to minimise the impact of coal-fired power, decommissioning of the Paratus oil-fired plant (or switch it to standby), and the decommissioning of the Van Eck station in Windhoek once the new capacity is installed.

A 900 MWe Sirtentu CCGT plant is being proposed. If commissioned, the station could be expanded to 4000 MWe. The developers include the Groot Group and SDS Group with development partners Siemens, Aurecon, and Mott Macdonald.

6.7 Coalbed methane

While coal reserves are limited in terms of economical recoverability, another option to access energy from these coal seams is to extract the trapped gas reservoirs that exist within and around these deep seams.

The company Instinct Energy (Australia) has been awarded two CBM projects in Namibia (iZambia, 2012). The Huab block is located on the Atlantic coast, while the Caprivi block is located in the Kongola in the far north eastern region of Katima Mulilo. Instinct is one of the first to venture into onshore drilling for CBM in Namibia, but a date for commercial production has not yet been confirmed. The permit covers an 11,582 km^2 area in the Huab where Instinct will undertake exploration drilling activities.

The coal basins have not been previously mined due to their depths and basalt cover which has adverse cost implications in the case of coal extraction. Namibia's coal resources are as yet not recoverable economically using conventional means. The CBM resources could offer valuable energy security given the country's dependence on imports. Instinct is also exploring opportunities in the Mid Zambeze Basin and has been awarded permits in the Caprivi area.

6.8 Comments

Early exploration of coalfields suggests Namibia has around 350 Mt of coal reserves, but the seams occur in difficult hydrogeological conditions. CBM is being investigated and shows more promise. One of the largest coal related developments is the 300 MWe Erongo coal-fired station located near Walvis Bay, a potential coal export terminal. There is no domestic coal industry – all coal supplies are imported. Coal supplies to Erongo could come by rail from Botswana, but investment in and development of rail links are only in the planning stage.

7 Summary of Southern Africa

The Southern African countries of **Botswana, Mozambique, Namibia, Zambia, and Zimbabwe** are rich in ore and mineral reserves. However, relatively little attention has been paid to the possibility of mining coal on a large scale until recently. Domestic coal markets are in their infancy, and coal reserves remain relatively unsurveyed. However, the demand for coal from Asia could ensure coal production in Southern Africa follows an upward trajectory.

Some of the unifying themes that seem to connect the countries of Southern Africa in terms of energy demand and the role of coal are as follows:

- Energy use per person and electrification in most regions are low, and will probably remain so unless personal incomes and GDP improve considerably.
- Most of the countries possess considerable mineral wealth. The development of these mineral extraction industries will be a key driver for electricity demand. Coal-fired power may well feature strongly in this growth area.
- Any growth in coal-fired power generation could boost local coal mining industries.
- Coal exports are an exciting prospect for mining developers in Southern Africa, but with a shortage of cost-effective rail and port capacity, large-scale exports will remain a challenge.

Understanding the region's reserves, infrastructure and future markets for coal is fraught with uncertainty. While the geology is well known and coal is found across the region, detailed exploration is ongoing and drilling activity in some regions has yet to confirm the amount of recoverable reserve. Both steam and metallurgical grade coal are found in Southern Africa. Whilst metallurgical coal will probably be exported, steam coal will serve the export and domestic markets.

Coal exploration and surveying is limited to the regions where coal production has already started, or been operating for many decades. Recoverable reserves are still being measured and so the region's true potential will remain uncertain for some years. Many newly-licensed coal blocks are close to each other, therefore creating the potential for partnerships and shared infrastructure. This reduces risk and promotes a greater degree of co-operation amongst the interested parties.

The largest known reserves (40 Gt) are found in Botswana (based on individual company data), but the amount that is economically recoverable may be much lower. Mozambique could have between 16 and 22 Gt while Zimbabwe could range between 2 and 26 Gt. Reserves in Zambia and Namibia are much lower; in Zambia there appears to be as little as 0.1 Gt.

Overall production in these countries is less than 4 Mt/y, yet the potential is considerable, particularly in Mozambique and Botswana. Surprisingly, Zimbabwe has been the largest producer of this group of countries with an output of 2 Mt/y, while output from each of the other countries is below 1 Mt/y. In Botswana and Zambia, the coal production will increase to fuel the increased demand coming from newly expanded coal-fired plants. Mozambique's prospects will come from both new generating capacity and demand for coal in the international seaborne market.

To date, there has been virtually no coal production in Mozambique, yet it is geographically poised to supply the Asian market through its major coal port at Maputo. Other coal export terminals are being planned to take advantage of the export opportunity, and Mozambique could improve rail and port links making Mozambique a major hub for southern African coal exports. Development of entire coal supply chains from mine to port (or local end users) are being planned simultaneously. Co-ordinated plans are now including mines, coal preparation plants, coal-fired power plants, inland transport and port upgrades. To achieve these plans foreign investment is being widely encouraged, with companies from countries such as the UK, Brazil, Japan, India and China all active in the region.

Some of the key drivers in the growth in local coal demand will come chiefly from minemouth power generation. This demand is being spearheaded by mining companies, which are looking for an outlet for coal by-products from associated coal preparation plants, and using the power generated to supply other mining and industrial facilities.

As a region, the five Southern African economies covered in this report operate just two coal-fired stations of any significant size, amounting to a modest 1.2 GWe. These are the Morupule power plant in Botswana, and the Hwange power plant in Zimbabwe. Zimbabwe also operates several small units as standby plants. Some 2.1 GWe of hydro-electric and coal-fired plants are being built, some with investment from the private sector.

The most interesting picture is the planned capacity that this region of Africa aspires to build. Out of 15.7 GWe of new plants being considered, just 4.5 GWe are hydro-electric plants, with some 10.6 GWe of coal-fired projects on the drawing board. This could lead to a demand of more than 20 Mtce/y of coal products. As mentioned earlier, some of this demand may be fulfilled by coal preparation plant by-products.

Coal-fired power generation appears to be favoured on cost and reliability grounds, two of the most important criteria for the fledgling economies in Southern Africa. Coal investment prospects are therefore good, provided the funding can be secured, adequate coal supply contracts put in place and financial returns secured with appropriate tariff structures.

Botswana, Zambia, and Namibia are turning to fluidised bed technology, along with air-cooled condensers to cope with water shortages. Coalbed methane is being investigated, and underground coal gasification may feature in the future. However, coal-to-liquids has less appeal.

The future of coal and coal-fired power in Southern Africa is dependent on the co-operation between foreign investors and local government or international organisations. Botswana and Mozambique have favourable taxation regimes for foreign investors. In contrast, the taxation system in Zimbabwe presents an obstacle for foreign investment. Ownership rights, taxation, and the rights to repatriate profits may be necessary, but in return, investment into local communities, social, health and education is essential. In Zambia, social tensions have arisen between foreign-owned mining firms and local workers, and industrial disputes are increasingly common. Whether this spreads across the region is uncertain but the future of Southern African mining should be based on modern, world class operations.

In terms of climate change mitigation, the Southern African governments all endorse sustainable practice in energy production and aim to ensure minimal impact on the global environment. However, these aims must also consider the immediate needs of the economy and the population where a large proportion still lack access to basic power and are reliant on subsistence biomass. Coal may well play an increasingly important role in the long-term future of this region.

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