Developing green energy projects in Southern Africa—a mining investment approach

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Synopsis

The demographics and the growing numbers of people provide a strong signal that the demand for electrical power in Southern Africa will grow considerably over the foreseeable future. Without a steady and increasing supply of electricity development of the continent is likely to be constrained. The inventory of solar, wind, hydrothermal, geothermal and biomass resources will probably provide sources of energy for the future The parallels between extraction of natural resources in the minerals industry and the green energy industry is striking, and the well-established project development process in the minerals industry provides an ideal and useful template for comparing the establishment and development of green energy projects. The potential levels of power generation and carbon savings are described.

Keywords
African energy, renewable energy, natural resources, electrical power, mineral development, carbon saving, mining investment.

Introduction

Levels of economic development across the Southern African region are extremely diverse with countries ranging from the significantly industrialized South Africa, to recently rapidly developing countries such as Mozambique and Angola, to the poorest countries in the world, such as Zimbabwe. However, the greatest need among countries in the southern portion of the continent for fostering economic development, industrialization, rural development and advancement is the common need for electrification. The status quo of the extent of Africa's need for electrification is evident when one flies south across the vast continent at night. The fading European lights are replaced by uninterrupted darkness with a few pinpricks of light, until one reaches the towns north of Johannesburg as shown in the night-time image of southern Europe and Africa in Figure 1. Yet the African continent is home to approximately 900 million people, the majority of whom are located in Southern Africa, and are less than 25 years of age. These people all have aspirations of being educated, of watching MTV, and of being connected to the world via cell phones, e-mail, and the Internet.

The future challenge for the suppliers of energy is to bring sufficient supplies of energy to Africa in order to meet the demands that are now arising across the continent. The staged, step-function development of a power station network and provision of energy resources that brought supplies of energy to Europe and South Africa, are not available soon enough, or in sufficient abundance, to meet the rising demand for energy. Although many regions of Africa lack coal and nuclear energy resources and technology, the continent hosts vast potential resources of solar, wind, biomass, and geothermal energy. Such sources of 'green energy' or 'clean electrons' is essential as the

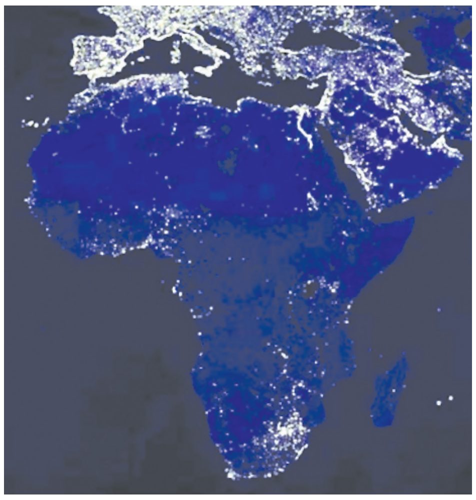

Figure 1—Southern Europe and Africa at night showing the density and distribution of lights as a proxy for electrification networks[1]

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demand for energy is counteracted by an increasing demand for environmentally friendly solutions to the energy conundrum. Energy providers should consider the continent's ability to attract capital, technology, and expertise to develop large-scale mining operations, despite the perceptions of risk associated with capital and foreign direct investment in Africa. A potential solution suggested here is that environmentally friendly, large, medium, and small-scale solar power, wind power, biomass, hydropower, and geothermal energy projects be developed to electrify the continent.

Furthermore, the authors believe that the stages involved in the development of energy projects have much in common with the well-established and publicized procedures associated with mineral developments. This arises from the fact that many stakeholders are involved in mineral developments, including investors (local and foreign), government, policy makers, financiers, NGOs, environmental interest groups, and local communities. The question posed here is, 'What can green energy project developers, financiers and policy makers learn from the mining sector to facilitate the rapid development of renewable energy projects?' This paper explores the parallels between energy and a mineral development, recognizing that 'green' is not only the idealists' vernacular. Engineers and investors recognize that green energy is about meeting market demands, application of technology, developing skills, meeting financial and investment criteria, and satisfying the requirements of environmentally sustainable future.

The electricity dilemma of Southern Africa—the need to develop green energy projects

Installed electrical capacity in South Africa is approximately 40 000 MW, with this country and the Southern African region currently deriving the bulk of electrical power from coal-fired power stations located in South Africa's Witbank coalfield. These belong principally to South Africa's electricity supply monopolist, Eskom. The rapid depletion of the Witbank coal reserves means that future supplies will be replaced by the deeper and more remote coal reserves of the Waterberg coalfield that will cost more to mine, and require substantial infrastructural development.

In 2008, Eskom could not meet the rapidly growing electricity demands and was faced with the reality of having to shut down electricity supply to industries and cities across South Africa in order to avoid a complete regional black out and power collapse.[2] These power cuts, termed 'load shedding', resulted in a series of blackouts, a shutdown of the mining sector, reduced productivity, and traffic chaos in cities across South Africa. In the neighbouring countries, allocated electricity was compromised, and these countries were faced with large-scale electricity shutdowns.[3]

South Africa's energy supply dilemma is illustrated simply in Figure 2 which compares the rising rate of demand for energy with the current available supply capacity from coal-fired power stations and the opportunity that exists for renewable, green-energy plants to take up a portion of the energy supply shortfall. The figure illustrates that the increasing demand for energy outstripped supply capacity in 2008 and that the electricity generating capacity of coal power plants will remain stable until 2025. Thereafter, unless the current technology is replaced or improved, the supply from coal fired power plants will rapidly decline due to the depletion of South Africa's coal reserves. The replacement of current electrical supply from coal power plants together with the rising demand for power into the future, means that the development of large-scale green energy plants is an imperative for South Africa and the sub-Saharan region.

Green energy projects 101

Green energy is sourced through large industrial, medium, or small-scale projects that harness sun, wind, water, hydropower, biomass and geothermal energy resources. In some senses the development and harnessing of these naturally occurring energy resources follows the route taken in the development of most nonrenewable mineral resources in that they must be quantified through a process akin to mineral exploration. If the early scoping and feasibility studies of the resource suggests that it may be viable, a power plant is designed to extract or harness (mine), the energy resource (electrons), and to produce a commodity (product), that can be marketed and sold. These electrons are sold into the electrical grid or to private customers. The sale of electricity occurs in $/kWh, a feed in tariff that is agreed upon for the life of the project between producer and customer.

Most of the current green energy projects are located in Europe, with significant projects being developed in the USA, China and Australia. Southern Africa needs to look at these projects for reference purposes and benchmarking. Below are some examples:

- *Denmark*—large-scale on and offshore wind parks, owned by private individuals
- *Germany*—large-scale solar power projects of up to 50 MW
- *Spain*—host to the largest solar thermal power park at 100 MW
- *Tasmania*—wind and hydropower projects produce power in excess of the country's power own requirements
- *Iceland*—multiple geothermal power projects facilitating the growth of the aluminum sector

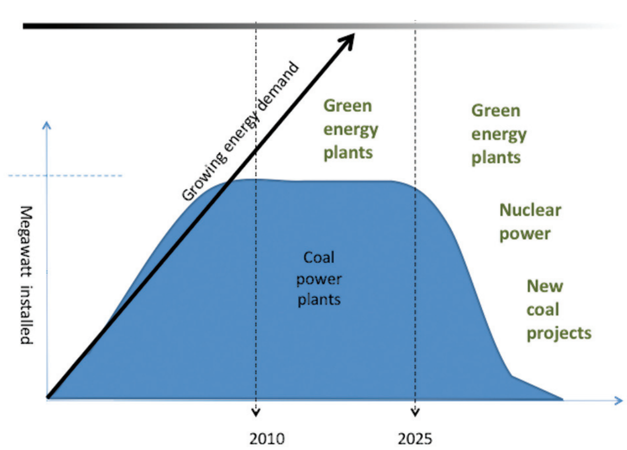


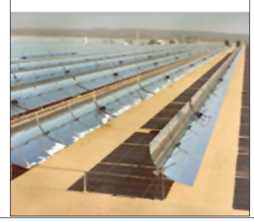
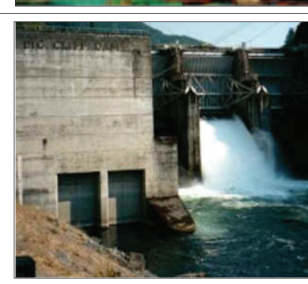
Figure 2—Energy demand and the supply capacity from coal powered plants

- *USA*—establishment of wind farms on Indian tribal indigenous land
- *Germany and Denmark*—establishment of energy independent villages that produce multiples of their own energy consumption and have become profitable ventures in their own right
- *Peru*—mini-hydro power project generates electricity for a remote small-scale village that has induced industrialization and a new hub of commercial activities, as well as a link into the global community.

The main green energy technologies are briefly described in Table I.

Table I

Green enery technology

Solar power Energy generation from solar emissions include the use of photovoltaic and solar thermal technologies. Photovoltaic technologies convert sunlight into electricity using solar modules mounted on a frame on rooftops or in free fields. Installation is small scale on rooftops 0.2 MW, medium scale 5 MW, or large scale 50MW. Solar thermal energy plants use parabolic reflectors that direct solar radiation onto an absorber tube that lies along the focus and generates temperatures of 400°C. Plants sizes range from 50 MW to 200 MW.	 
Wind power Wind turbines on towers between 35 m and 135 m in height convert wind into electricity. Capacities range from 0.2 MW to 5 MW capacity per windmill. The majority of wind mills are installed on land, but there is an increasing number being number installed offshore. There are more than 20 windfarms off the coast of Denmark, Sweden, the UK, Ireland and the Netherlands.	
Biogas Biogas consisting of 55–60% methane is produced by fermenting organic substances in an environment free of air and oxygen. The gas drives generators of electricity. Biogas can be obtained from agriculture waste material, landfill sites, municipal wastewater, energy crops, and domestic organic waste. Typical plant sizes range from 0.2 MW to 2 MW.	
Geothermal Geothermal power is power extracted from the heat in subsurface reservoirs located in the earth below surface. Depending on the temperature, geothermal energy is used to generate electricity or for heating purposes. Around the world 33 000 MW of thermal and 10 000 MW of electrical capacity has been installed. The most common system entails drilling boreholes into the hot aquifer or strata and creating a hot water circuit. The hot water or steam is fed into a power plant, where it drives a turbine that generates electricity. The used, cooled water is pumped underground back into to the reservoir, to be heated up again.	
Hydropower Around 16% of the electricity generated worldwide is produced by hydropower. Hydrower plants require areas with reliable and useable water. The water is stored in a natural or artificial lake and fed via a penstock to the lower lying power stations, where the flowing water drives the turbines. Hydropower dams have capacities ranging from 0.5 MW to +1000 MW. The construction of large-scale hydroelectric power plants has considerable environmental impacts and the focus lies on the smaller, more environmentally mini hydro systems.	

The mining investment approach to the development of green energy projects

The approach taken during the development of a mining project or mineral development investment is suggested here as a methodology for planning, structuring, developing, financing, and implementing green energy projects. Mining projects are based on exhaustible natural resources that are identified through exploration and evaluated by means of technical and financial analysis. Such quantification allows available resources to be evaluated in terms of the cost of developing, extracting, beneficiating, and marketing the product. The evaluation process is usually carried out by specialist teams that use a range of technologies to provide resource estimates that are reported according to internationally acceptable codes for reporting mineral resources and mineral reserves. The extractive industries are beset by time-consuming legal structuring and environmental permitting stages through interaction with host government agencies. Mineral developments are by nature capital intensive and such investment is often irreversible and therefore risky, but despite this risk, Southern Africa hosts many medium and large-scale gold, coal, platinum, base metals and diamond mining projects and operations.

A highly integrated and useful approach to the development of mining ventures, was outlined by Seeger, (2009), using a game plan for junior mining ventures. The game plan comprised a foundation of technical information, a number of developmental steps, and a final analysis of the potential for success or failure of the project, represented in a scoring matrix. This approach can be applied to all natural resource evaluation and specifically to green energy ventures.

The first of the three foundational elements in any mining investment process includes the assurance that the mineral resource is of adequate quantity and quality (grade) to warrant the development of the mine. Secondly, one should ensure the existence of a long-term market for the mineral commodity as well as projected mineral prices sufficiently attractive to ensure long-term investment. The third imperative for successful mineral development is to ensure that the mineral policy of the host country allows security of tenure, a clearly defined and transparent prospecting and mining right application process, and tax incentives that constitute an enabling policy environment.

The developmental steps of a mining project entail the activities that will allow the available resources and reserves to be defined. This includes the exploration, drilling, or excavations necessary to establish a geological model, and to estimate and report according to a code, the resources and reserves. The next stage includes the feasibility study, in which the mining and processing methods, logistics, markets, human resources, risks, and legal structure are outlined and defined. If such a study provides the necessary assurances that the project will provide acceptable returns on investment, net present value (NPV), internal rates of return (IRR) and payback period, a stage of construction and commissioning may begin. This will involve clearing the site of the mine, establishing the required maintenance and administrative, training of personnel, recruiting and training, appointment of mining and processing contractors, establishing the initial boxcut, and commissioning the processing plant. Finally, once the mine is in operation, the mine is managed on a day-to-day basis by a dedicated mine management team, cost are controlled, maintenance procedures are adhered to, and customer relationships are entrenched.

The final step in the method as suggested by Seeger (2009) is the scoring. The key measurement, i.e. the score in mining investment terms, is the IRR and NPV. A mining project needs to meet the IRR and NPV investment hurdle rate set by investors and banks in order to secure financing; the general level of acceptance for mining projects to proceed is that the IRR should usually be in excess of 25%.

Mining ventures require the interplay of skills, technology and finance, all in complex host country setting. Any successful mining venture is a product of such components. Mines are established in remote areas, often politically complex areas in Africa. Mines range in capital expenditure from $10 million to +$200 million and are located in diverse, often hostile areas. Despite all the risk perceptions, there are multiple medium and large-scale mining projects are on the continent.

Applying the mining investment approach to green energy

In order to satisfy the energy requirements of Southern Africa, and in particular the need for the rapid deployment of green energy plants, the model for mining sector business investment can be applied since it provides the ideal combination of inputs, operation, and outputs, as illustrated in Figure 3. A typical business investment model in the mining industry requires as a primary input the ores to be found in mineral resources containing gold, coal, platinum, base metals. The operation is represented by the mine and processing plant, and the output, which is sold to the customer, is the metal or mineral. In the green energy business model, the input is the green energy resource (wind,

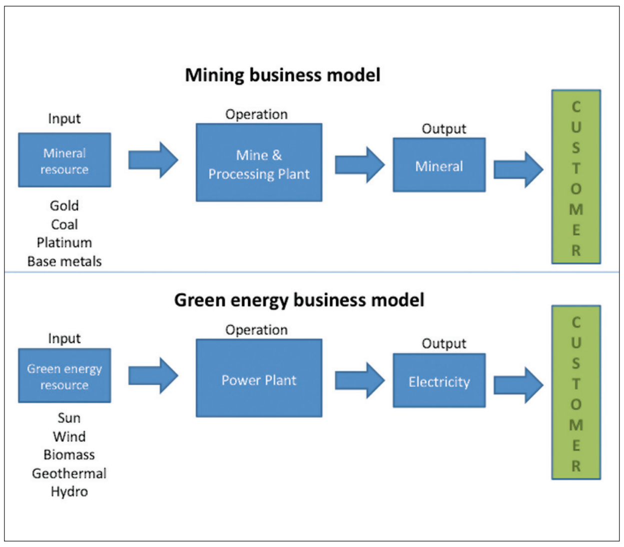


Figure 3—Comparison of the mining investment business and the green energy business models

solar, biomass, geothermal, hydropower resources), which is converted via the power plant (operation) to a supply of electricity (output) for the customer.

The close correspondence in terms of the use, extraction, processing and product delivery from the exploitation of natural resources for the mining and energy business models provides a definitive template for the means by which green energy projects can be initiated, evaluated, financed, and brought to productive account. The well-established progression in the minerals industry that allows one to develop sustainable, productive, and environmentally sensitive natural resource extraction can be duplicated in the renewable energy sector, namely through establishing a foundation, following the appropriate developmental steps, and evaluating or scoring the potential value of the project.

Foundation

Resource assessment

Just as mineral resources can vary in character, grade, quality, and composition, so renewable, green-energy resources also vary and may include wind, sun, biogas, geothermal, or hydropower. In the same way as the demand for minerals and metals is usually a derived demand, so the first requirement for renewable resources is that they should be able to produce sufficient electricity. The energy resource needs to evaluated and quantified through field trials and detailed measurement in much the same way as exploration campaigns are conducted in the mineral resources sector; the equivalent meter is shown in Table II.

Market structure

As with mineral commodities, the renewable energy market requires a reliable and sustainable product supply that is matched by consistent customer demand for the green energy (kWh), product. The off-take or demand for electricity generated in such a way must be such that the product can be sold at commercial rates (in R/kWh), which support the appropriate payback of investment. The market for renewable energy in South Africa is currently being established through the determination of REFIT tariffs that will be implemented in due course. In the absence of the regulated feed-in tariff, independent power producers will negotiate the feed-in tariff with the customers.

National policy

The way in which policy is implemented has seriously affected the minerals industry over the years and it is likely to influence the viability of renewable energy production in Southern Africa. The equivalent policy in green energy is the feed-in tariff as set by the regulator. Attractive feed-in tariffs have led to the establishment of large-scale wind farms, solar parks, and biogas installations in Germany.

Development steps

The development steps for the establishment of a green energy plant are illustrated in Figure 4, and are similar to those for mineral projects in the mining industry.

Feasibility study

The initial step here would mean that a plant that adequately captures the generated electricity be designed. As with all

Table II

Measures of natural renewable resource output

Renewable natural resource	Measurements	Units of measure
Wind energy	Maps of wind velocity and consistency	m/s
Solar energy	Annual solar irradiation tests at the site	kWh/m^2
Hydropower energy	Water flow rates	m^3/s
Biomass, biogas	Chemical and biological composition of the biomass an tons available	t
Geothermal	Flow rate for hydrothermal liquids and geothermal gradient	l/s & C^0/m depth

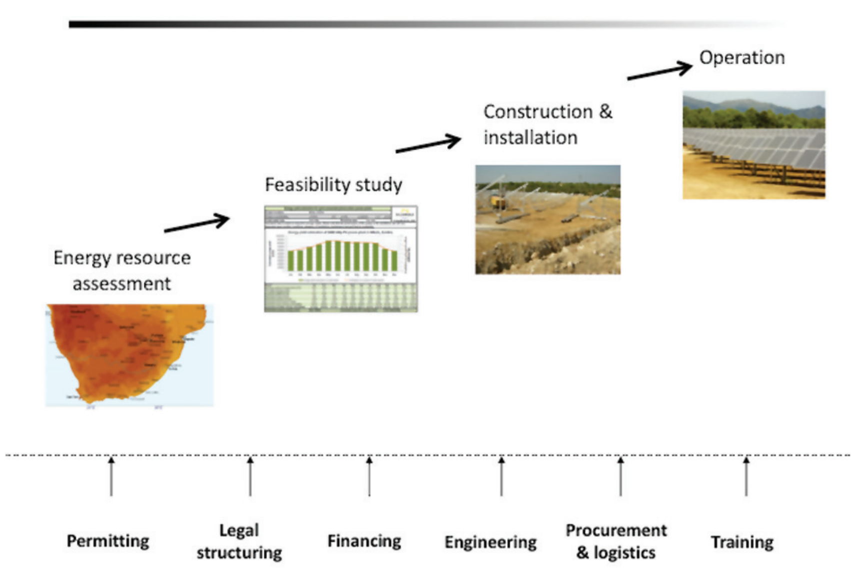


Figure 4—A schematic illustration of the developmental steps in renewable energy projects

project development, the environmental impact assessment (EIA) and environmental management progress report (EMPR) are governmental imperatives. A further design for the way in which the power is to be distributed through an integrated grid and network, and then be integrated with the existing network, is essential. The planning of equipment transportation and installation, determining capital and operating budgets, determining the economic viability of the project, and developing a risk management approach, are also essential.

Legal structuring

A special purpose vehicle (SPV) company is established to house the project, with project rights, shareholder agreements, a power purchase agreement, contractor agreements and surface rights.

Financing

Typically renewable energy resource developments are financed by raising a combination of equity capital (20–30%) and debt capital (70%–80%) for the project. Equity is sourced from venture capital funds, carbon funds, and private individuals, with debt capital being drawn from investment banks and development banks.

Construction and commissioning

This comprises ordering of the plants and components, transport of plant to site, training of local staff, site clearance, site security, plant insurance, earthworks, and installation of plant, grid integration and commissioning of plant.

Operation

Day to day operational control of the plant remotely or on site, plant maintenance and repairs, sale of electricity to customers, invoicing, administration.

Scoring

The evaluating the financial feasibility or score in green energy investments is twofold, namely the internal rate of return (IRR) and the levels of carbon saving. Generally investors in any projects require a minimum internal rate of return for the investment and a fixed payback period which may reflect the levels of risk associated with the project. Green energy projects tend to have an IRR less than that of mining projects and ranges between 12% and 20%, while the loan payback period is about 10–15 years.

Renewable energy has the added benefit that it has zero carbon emissions. The electrons generated in this way are 'clean' and replace electricity that would have else wise been generated using fossil fuel based energy; the tons CO_2 saved is the key indicator of the feasibility of the project. As an example, a 10 MW solar power plant, producing 19 GWh per annum could save approximately 17,000 tons of CO_2 per annum.

A solar power project example

The idea that the progressive development for renewable energy starts finds a strong and useful parallel in non-renewable mineral resource development can best be illustrated by considering the establishment of a hypothetical 5 MW solar power project. Let us assume a 5 MW capacity installation that produces 9 500 MWh per annum, located near a coal mining project in Mpumalanga Province, South Africa. The technology includes photovoltaic modules, assembled in a locally manufactured ground mounting systems, requiring a capital outlay of approximately R155 million, made up of 30% equity and 70% debt. Based on realistic figures, such a project would require about 6 months to install and have a productive life of 25 years. Details of the project are summarized in Table III.

Green energy resources in Southern Africa

As with the exploration and discovery of mineral resources on the African continent, so the development and implementation of green energy projects must be based on information about the distribution and quality of renewable energy resources. Seeger has revealed the rich endowments of green energy resources that Africa hosts, as illustrated in Figure 5 and listed in Table IV.

Conclusion

The region of Southern Africa will face an increasing shortage of energy due to growing demand and depleting coal reserves, but there exists the potential for extensive establishment of small green energy plants to make up for some of the anticipated shortfall and to help address the electricity needs. Despite its historically higher risk profile, Africa has attracted large-scale mineral investment, and by taking heed of the lessons learnt from mining investment, green energy plants that harness solar, wind, biogas, hydro, and geothermal energy resources, can be successfully established in the region. The similarities between mineral extraction and exploitation of green energy resources is striking since both rely on naturally occurring resources, one renewable and one nonrenewable, for their primary inputs. The early stages of natural resource extraction, in this case renewable energy, rely on the enabling business environment determined by access to, and appropriate policy surrounding the resources. It also implies that supply and demand are sufficient to generate an open market in the product and to allow trade to establish competitive price formation.

Green energy development will involve energy resource assessment, a detailed feasibility study, legal structuring, financing, construction and commissioning, and operation. A solar power plant described here can be used as reference for other projects.

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Table III

Solar project example

No.	Item	5 MW solar power plant
Foundation		
1	Energy resource	The solar farm is located in Mmpumalange Province. The solar irradiation is 1900 kWh/ KWp installed, which is excellent by comparison to European solar values at 1000 kWh/ kWp.
2	Market	The market for the electricity generated is a new coal mining project that is planned to be developed. The mine requires an installed power capacity of 10 MW, and the 5 MW solar farm will supplement electricity from Eskom. A R/kWh power purchase agreement is being negotiated between the solar farm operator and the mining company.
3	Policy	The renewable energy feed in tariff (REFIT) for solar power from a photovoltaic plant is R3.94 /kWh. However, this feed in tariff has not yet been implemented.
Development steps		
1	Green energy resource assessment	The solar energy resource is determined using available solar irradiation maps, as well as by conducting on site solar radiation checks and shadow analysis.
2	Feasibility study	The solar farm and grid integration are designed by experts and an EIA is conducted on the area. Duration: 6 months
3	Legal structuring	The project is housed in a special purpose vehicle. The company has BEE credentials, has a power purchase agreement in place with the mine, a surface lease agreement, and is registered as an independent power producer.
4	Financing	The project capital is R155 m. R38.5 m of equity capital has to be raised. A loan of R116.5 m has to be secured.
5	Construction and commissioning	A local team is assembled which is trained by the solar power plant manufacturer. A project management company is employed to project manage the installation. The plant consisting of modules, the mounting frame and inverters is ordered both form Europe and South Africa. The site is cleared of bush, a high level security fence is installed and the plant is installed on site. Once installed, the plant is connected to the grid. Up to 70 people are involved in the installation.
6	Operation	Once in operation, the solar plant generates 9 500 MWh per annum. The plant is monitored via satellite and the internet. Breakdowns are immediately reported and logged and an electrician is immediately deployed to replace the defunct parts when required. A strict maintenance schedule is complied to. A security company is employed on a 24/7 hour basis. The grass is kept short to eliminate the risk of veld fires. The customer is billed monthly.
Scoring		
1	IRR	The project has an IRR of 17% based on the feed-in tariff negotiated with the mine.
2	Carbon reduction	The project saves 8 500 tons of CO_2 per annum. Over the life of project this is 212 500 tons of CO_2.

Table IV

The location and description of some of the green energy resources[5]

Energy type	Location and description
Solar resources	An abundance of unutilized solar resources are found in South Africa, Botswana, Namibia, Zambia and Angola.
Wind resources	Wind resources are mostly to be found along the western coastline of South Africa, Namibia, and Angola as well as in Madagascar
Hydropower resources	An abundance of untapped hydropower resources occur in Zambia, the DRC and northern Mozambique
Biogas	Huge vegetation growth for biogas production is to be found in the eastern and coastal regions of South Africa, Mozambique, Madagascar and Tanzania. In addition, the waste product of the large cities of the respective countries is an untapped resource.
Geothermal resources	The African Rift Valley extends from Ethiopia into Zambia, and this is an area where electricity can be generated from geothermal power plants.

Figure 5—The distribution of solar, geothermal, wind, hydropower and biomass resources in Africa