Technological Feasibility and Cultural Acceptability Study of Solar Power Systems for Microwave Assisted Sandstone Artisanal Mining

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Abstract--**This paper investigates the technical feasibility of microwave assisted artisanal mining in the production of Sandstone from QwaQwa in South Africa. It further discusses the cultural acceptability by the rural community of the synergetic application of the emerging technology (microwave energy) and the renewable resource (solar). Sandstone in QwaQwa, Free State is artisanally mined using chisels and hammers. This form of mining is extensively laborious and is normally accompanied by numerous casualties.**

The paper demonstrates the existence and the possible utilization of alternative methods including emerging technologies which are more productive, efficient, effective and sustainable. The solar energy systems are used to trigger the microwave magnetron which results into high energy microwave dosage. The dosage causes differential or selective heating on the rocks which culminate into rock breaking along the interfacial grain boundaries between the different constituting minerals. The data used in the analysis was collected by administering questionnaires to the artisanal mining community in QwaQwa and from observations made on site as well as desk top information obtained from secondary sources. The paper contributes to knowledge by drawing on the solar energy systems to generate the dosage required to trigger the microwave magnetron used to facilitate a more efficient and economical artisanal mining of sandstones.

In conclusion the paper recommends to policy makers the application of microwave energy in mineral artisanal mining and processing instead of the manual chisel and hammer currently being utilized country wide. It then gives a detail analysis of the technical, scheduling and economic analysis of the sandstone artisanal mining in QwaQwa.

I. INTRODUCTION

In undertaking the technological feasibility and cultural acceptability study of the synergetic application of renewable resource (solar) and the emerging technology (microwave energy) the paper evaluates and analyses the artisanal mining of sandstone in QwaQwa Free-state province, figure 1 below.

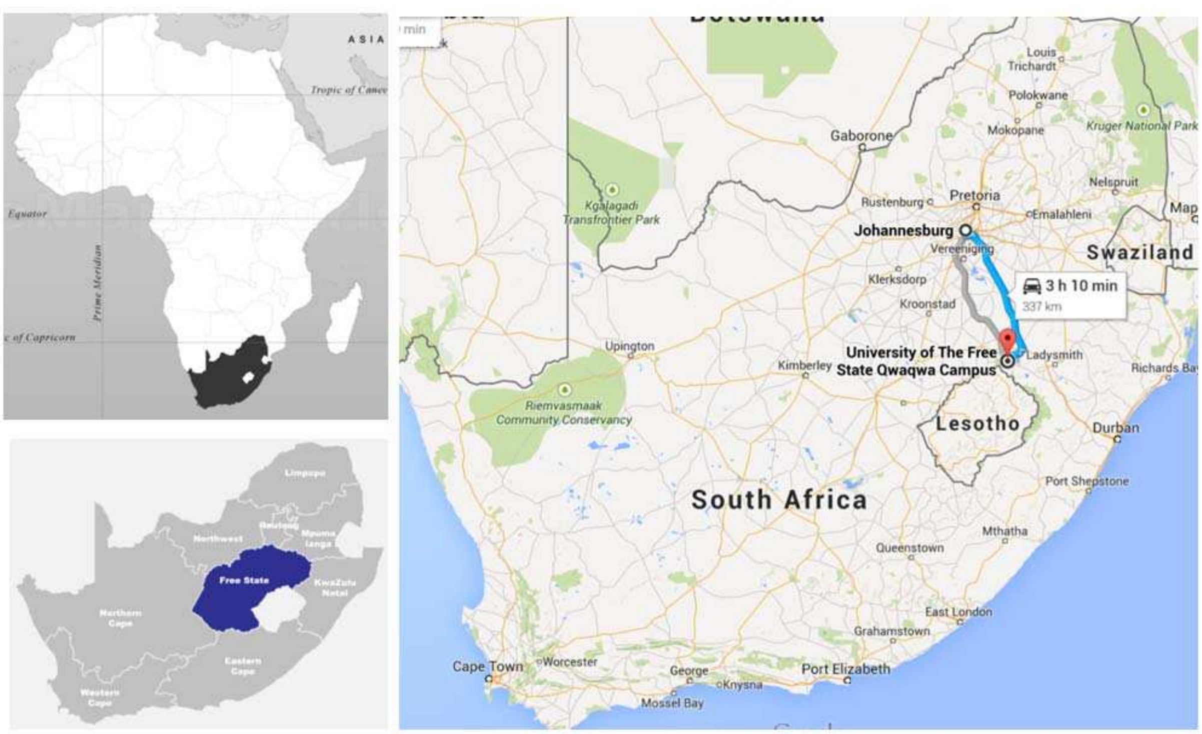

Figure 1: Maps of Africa; South Africa; and Free State. Source: Google Map Retrieved: 12/02/2015 World Wide Web.

II. METHODOLOGY, OBSERVATION ON SITE AND DATA DESCRIPTION

A case study was used as one of the methodology in developing this concept. The researcher visited the QwaQwa site and carried out a detailed extensive tour of the mining area in conjunction with the community. Questionnaires were administered by the researcher to 45 mine owners and mine employees. This was meant to obtain their views about the current methods of mining and possibility of another method of mining, of which 65% of it was completed correctly and were in support of an alternative means of mining. An extensive literature review was done in order to capture existing data based on earlier academic studies, and on secondary data sources on the sandstone mining in Southern Africa and the neighbouring countries. A SWOT analysis and Score Card Tools were used in the analysis. This helped the researcher to bring out the strengths, weaknesses, opportunities and threats of the technological alternatives. The findings were then triangulated by observation.

III. RESULTS AND DISCUSSION

In this section of the paper, a brief description is given of the observations made and data gathered from the questionnaires and interviews with mine owners in QwaQwa. During the field visit the researchers interviewed sandstone mine owners, artisanal sandstone mine operators and traditional councillors. The interactions with the above led to an explanation on the history of sandstone mining in QwaQwa as well as on the current artisanal mining processes. Figure 2 below shows that majority of the artisanal miners interviewed started operation long time ago (more than five years) and therefore have been in the business for long time with a wealth of indigenous and trained skills, knowledge and a long exposure to the sandstone mining practices.

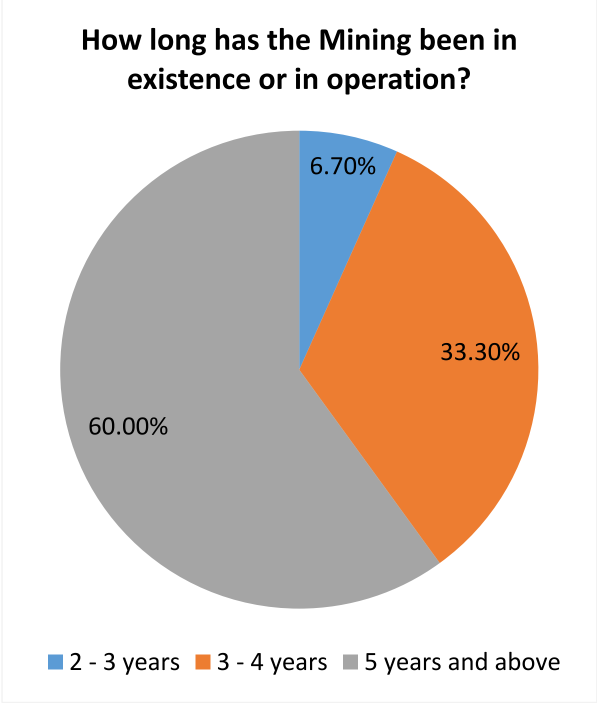

Figure 2: Artisanal mining exposure of respondents from the field work.

A. Artisanal mining of sandstones in QwaQwa

The analysis focuses on the technological aspects of rock breaking possibility using microwave energy ability to selectively heat mineral constituents of the sandstone rock Chen et al, [3], Scott, [14]. As shown in the figure 3 below artisanal sandstone miners in QwaQwa (Free State, South Africa) employ hammers, picks, shovels to mine and wheelbarrows to transport their products.

Figure 3: Rock breaking using Hammers and chisels in QwaQwa. Source: Tshabalala [15].

Training and getting them to use solar energy (renewable resource) and microwave devices (emerging technology) to cut sandstone plaques from the mountain surface would assist in educating them to operate safely in an environmental friendly way while productivity and safety are improved. The technological feasibility assessment was directed at gaining an understanding of the proposed technical resources to be used in the artisanal mining and their applicability to the expected needs of the proposed system. It involved the evaluation of the solar system and the microwave energy technology to be used in the artisanal mining process.

A description of sandstone as a mining product would include its presentation as a form of sedimentary rock composed of quartz sand, which may also sometimes contain significant amounts of feldspar as well as silt and clay. The argillaceous sandstone normally has a grey to blue color and therefore is also called the bluestone. The most common sandstones have various shades of red caused by iron oxide and in some instances purple caused by manganese. Sandstone initially in majority of cases began as large deposits of beach or river sands that were then compacted and citified into stones. The grain of sand of which sandstone is composed is the mineral quartz (SiO_2). The quartz grains come from the effect of weathering and the erosion as well as natural exposure of the rocks.

In QwaQwa different forms of sandstones are available namely the yellowish, blackish, reddish, greenish, greyish and whitish, figure 4, which are artisanaliy mined using inadequate tools for processing the sandstones. These stones have two major applications as crushed stone and as dimensioned stone. Dimensioned stone is any rock material that is cut into specific sizes typically as blocks or slabs. The crushed stones are used for general construction purposes mainly in roads and highway construction and maintenance.

B. Historical background of Sandstone Mining in QwaQwa

QwaQwa, situated in the Thabo Mofutsanyane district municipality in the Free State South Africa, and is a mountain town located at about 325 kilometers south of Johannesburg the economic hub for Africa. QwaQwa means “whiter than white” in the San language and links the town to the sandstone hills of the Drakensburg Mountains, figure 5.

QwaQwa has a wealth of sandstone deposits which are being mined artisanally using chisel and hammer under enormous risks e.g. rock fall, being bitten by mountain snakes, sliding of unsupported roofs and surfaces etc…. Artisanal mining (AM) is always associated with informal, illegal, unregulated, undercapitalized and under equipped operations where technical management skills are lacking Lungu and Shikwe, [8]. However, research on AM in Africa suggests that it is a livelihood activity with poverty reduction potential Noetstaller et al., [12], Eleanor, [4]. In QwaQwa, the sandstone artisanal mining activities are being seen as one the ways to raise the standard of living for the villagers, Tshabalala, [15]. It is also argued that a worldwide artisanal mining activities in general has been identified as an important economic opportunity for people in rural areas, for the provision of income for household livelihoods

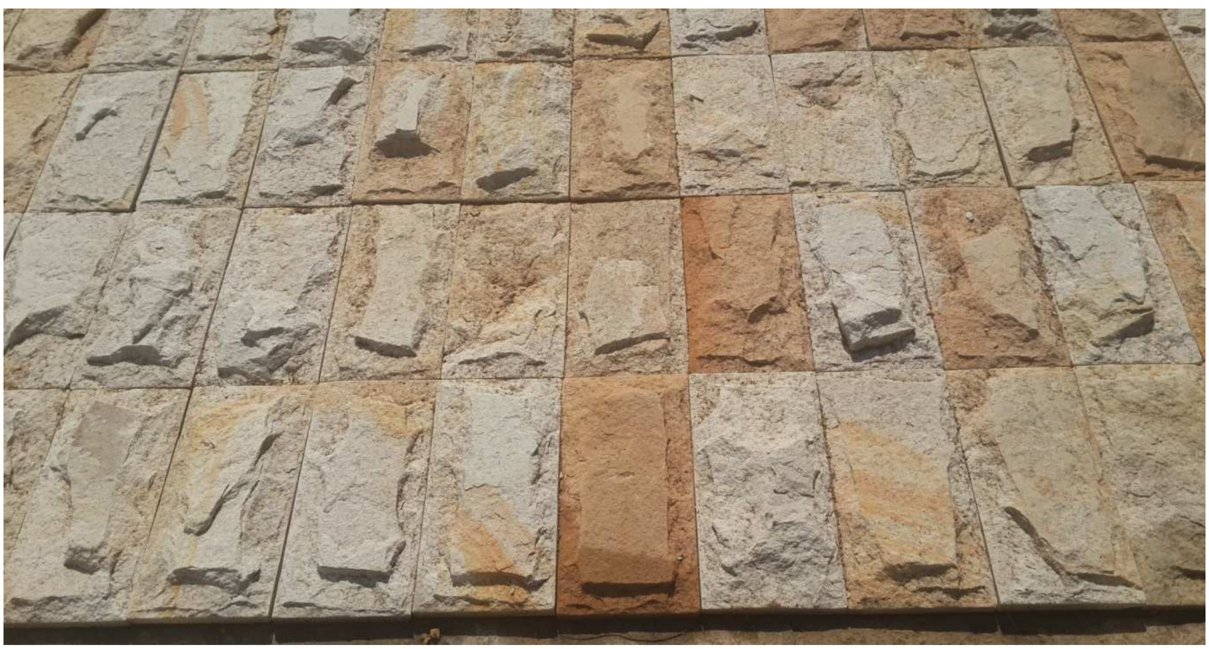

Figure 4: The sample of sandstone pieces mined in QwaQwa, January 2015.

Figure 5: Part of the Drakensberg mountain chain including mining landscape located in QwaQwa, January 2015.

C. Mineralogical and physico-chemical properties of sandstones

According to Lurie, [9] sandstones are generally medium-grained clastic rocks composed of rounded or angular fragment of quartz in a cementing material. The most common cements are silica, iron oxide, calcium carbonate and clay. Most of these rocks are named according to the cementation. A hard rock named Roth-quartzite is formed by cementing with silica which completely fills the pore spaces making it very compact. Sandstones have contributed a great deal in the construction industry worldwide and are still used for this purpose Jens and Heiner, [6]. They added that even though sandstones show similar appearance and properties; a geological background may cause differences in colour, granulometric properties, mineral composition, pressure strength and weathering behaviour. On the other hand, mineralogical properties of sandstones could predict their mechanical properties such as the uniaxial compressive strength. According to Zorlu, [17] the uniaxial compressive strength of sandstones is controlled by several natural and environmental parameters. The natural parameters can be characterized by petro graphical properties. The mineral composition, the void space, the degree of grain interlocking, the packing density and the grain size are known to be affected by the petrographic characteristics. It has been reported that rocks containing quartz as binding material are the strongest materials followed by calcite, and ferrous minerals; but rocks clayed binding materials are the weakest Zorlu et al, [17].

The shape of grains usually expressed in terms of roundness or sphericity, roundness being distinct from sphericity in that it is concerned with the curvature of corners. In fact, sphericity represents a quantitative means of expressing the departure of a grain from equidimensiality. The findings by Zorlu et al., [17] also found that there is a fairly strong relationship between the uniaxial compressive strength and the percent of angular grains. However, Fahy and Guccione cited by Zorlu et al. [17] obtained no meaningful correlation between the uniaxial compressive strength and the roundness while they found an extremely strong relationship between the uniaxial compressive strength and sphericity.

IV. POTENTIAL OF MICROWAVE ENERGY IN ROCK BREAKING

Microwaves lie between infrared and radio waves in the electromagnetic spectrum with a typical wavelength in the range of 1mm – 1m. Microwaves have a frequency band of between 300 MHz and 300 GHz. Scott, [14]. Dielectric properties are central to the theoretical understanding of microwave-heating processes. Knowledge of the dielectric properties of a substance as a function of temperature can be used to predict how microwave radiation will heat the material Kay, [7]. Any homogeneous, isotropic, and linear dielectric material is characterized by a frequency-dependant absolute complex permittivity Chan and Reader, [3].The research conducted by Chan and Reader, [3] states that when assessing the relative dielectric constant. The value obtained is used as a relative measure of the microwave energy density in the material. The imaginary part usually has a relative loss factor, which accounts for all the internal loss mechanisms.

These constants indicate how well a material absorbs energy from the electric field passing through to where it is converted to heat. Within the material, electromagnetic energy is transformed into heat by means of several complex mechanisms such as dipole rotation, stretching of large molecules, and ionic conduction. Above 1 GHz, the release of heat involves mainly rotation of dipole material. The loss tangent is used to provide an indication of how well an electric field can penetrate into a material and how it dissipates the energy in the heat. The power dissipation in a load is proportional to the square of the applied electric field density Metaxas, [10], Scott, [14]. Thus the time average for the power dissipated per unit volume in a dielectric material, under the influence of a time dependent electric field can be calculated. In general, the penetration depth of microwave at frequencies allocated to industrial use are small, and thus the size of any materials to be treated must be taken into account. If the width of the material is several times larger than the diameter non-uniformity heating will occur Scott, [14]. Microwave heating is the transfer of the power to the applicator containing the material to be heated in waveguides at frequencies between 300MHz to 300GHz. In conventional oven, gas charcoal fire, or an electric heating element, heat is generated from outer surface of the material to be heated. The outside and the inside of the material are heated by convention and conduction respectively. In the microwave heating by contrast, the inside of the material is heated first. The process through which this occurs primarily involves the conduction losses in material with large loss tangents. Loss tangent of any foods decreases with the increasing temperature, so that microwave heating is to some level self-regulating Mohamed and Yusuf, [11].

The mechanism of microwave heating is a classical phenomenon and not related to microwave spectroscopy in which gas phase molecules absorb photons at pointed bands in the frequency range 3-60 GHz due to transitions between quantised rotational energy levels Kay, [7]. Microwave energy and Microwave technology usage have already shown a lot of benefits with success in a number of applications including the food and telecommunications industry. Ever since microwave heating was discovered, the load is one of the issues that have attracted much interest in the microwave heating uniformity. Uneven field distribution creates the so called hot and cold spots. Hot spots could, for example, contribute to the phenomenon of thermal runaway typical for ceramic materials. Therefore, a more uniform heating is generally desirable Chan and Reader, [3]. Many researchers have developed ways of improving the heating distribution with varying degrees of success by changing the source, the feeding system, the cavity, or the environmental surrounding and the load. Advanced packing material, referred to as a dual-mode susceptor is described in the literature by Chan and Reader, [3] as exhibiting uniform heating. According to Wroe, [16], the magnetic field maximum occurs at an even temperature profile throughout the load when a combination of conventional heating (also known as hybrid heating) is used. The conventional heating minimizes losses from the surface of the load by proving heat to its surroundings, and the volumetric heating provided by the microwaves heats the load inside.

V. SOLAR AS A SOURCE OF ENERGY FOR ARTISANAL MINING

Solar energy is an alternative energy source that involves harnessing the radiant light energy emitted by the sun and converting it into electrical current.

Our primary source of clean, abundant energy is the sun. The sun deposits 120,000 TW of radiation on the surface of the earth, far exceeding human needs even in the most aggressive energy demand scenarios. Covering 0.16% of the land on Earth with 10% efficient solar conversion systems would provide 20 TW of power, nearly twice the world's consumption rate of fossil energy and the equivalent 20,000 1-GWe nuclear fission plants. These comparisons illustrate the impressive magnitude of the solar resource, providing an energy stream far more potent than present-day human technology can achieve Renee, [13]. In South Africa, an average of 24 GWhr/m² of solar radiation is received per annum. The country has a large potential to tap solar energy with an open land mass of 1.2 million Km² which has a desert covering a big portion Bugaje, [2]. Therefore, the energy policy document of SA seeks to attain 15% renewable energy contribution to national energy mix within the next ten years, Bugaje, [2]. On the other hand, it is known that artisanal mines including artisanal mining of sandstones are located mostly in rural areas, where access to electricity is minimal Lungu and Shikwe, [8]. Leveraging on the high solar radiation on the mountains and around the tropics, the artisanal mining operators in QwaQwa would make use of solar energy to trigger the magnetron which generates microwave as described in the figure 6 below.

VI. SOLAR ENERGY AND MICROWAVE FOR ARTISANAL MINING OF SANDSTONE

A possible flow diagram of the synergetic combination between solar energy and microwave is depicted in figure 6 here below.

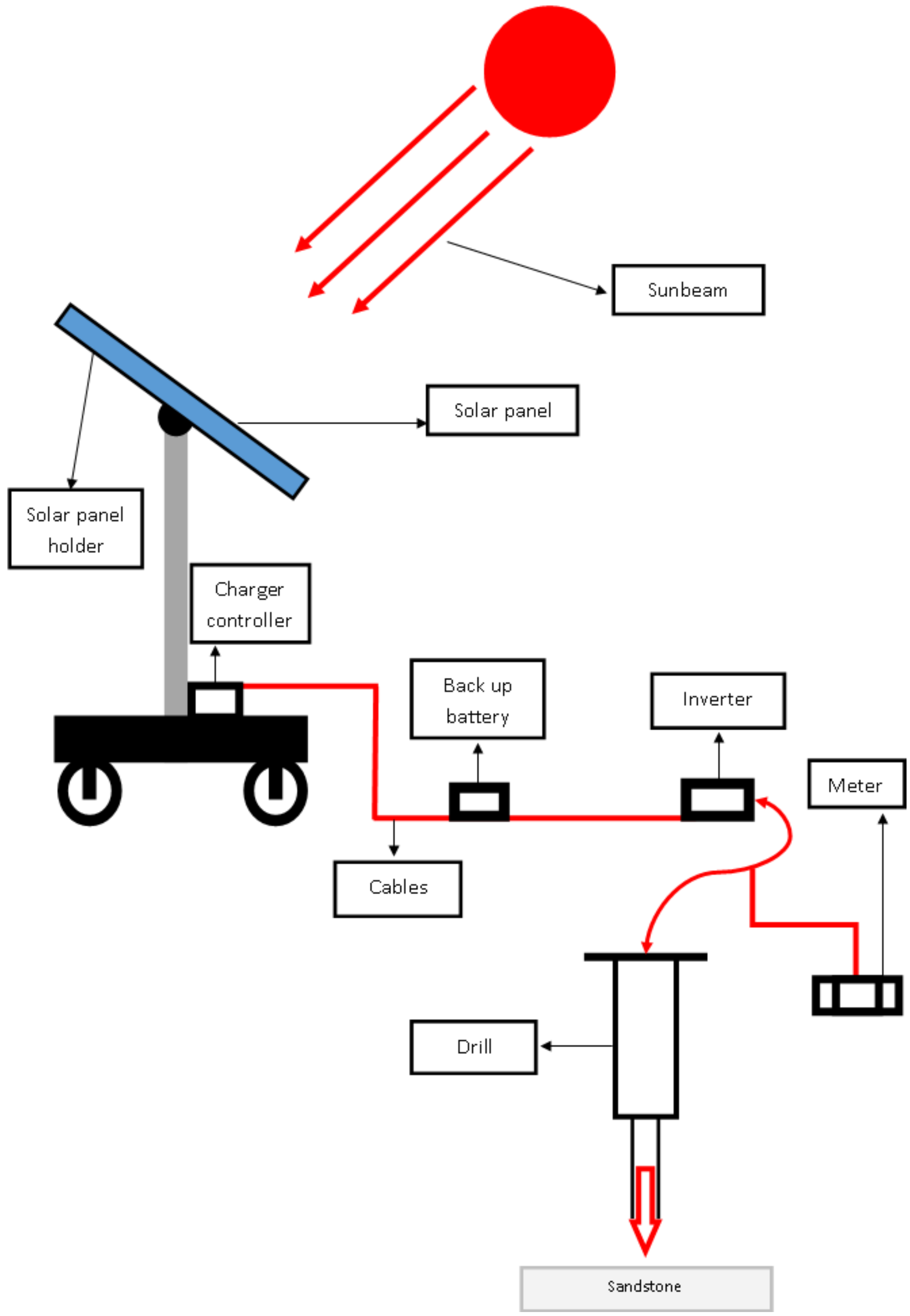

Figure 6: Diagrammatic representation of solar system powering the microwave sandstone driller. Source: Mukuna P.M, [11].

VII. ARTISANAL MINING OF SANDSTONE AND THEIR POTENTIAL ENVIRONMENTAL IMPACT

In many African countries, sustainable development has been the center of recent development plans. This is a pattern of development that delivers basic environmental, social and economic services without threatening the viability of natural, built and social systems upon which these services depend. In terms of development guide, energy consumption is a recognized indicator. However, according to Bugaje, [2] across the globe, as many as two billion people have no access to electricity. In other words, energy has become a top priority and the main concern of our societies. It is important therefore to note that electrical generation is typically provided by fossil fuels, coal, natural gas, and oil as well as nuclear power. Most of today's serious environmental problems can be linked to world electricity production based primarily on the use of non-renewable resources Berger, [1]. In order to meet the electricity needs of an expanding global population and simultaneously reduce negative environmental impacts, it is of vital importance to make the transition from dependence on non-sustainable, non-renewable fossil fuels to incorporate renewable energy as a source of electricity production. An adequate and uninterrupted supply of electricity is critical to the functioning of modern society.

VII. CULTURAL ACCEPTABILITY OF MICROWAVE POWERED ARTISANAL MINING IN QWAQWA

The use of microwave energy in artisanal mining appears to be a novelty. Any new technology which would assist in improving productivity would be welcomed by the mining community in QwaQwa. Such should be the case for the use of microwave for sandstone mining and the triggering of magnetron by solar energy. In QwaQwa a fraction of the community believes in preserving the natural landscape of the Drakensberg Mountains. Reducing or reserving mining areas would meet their needs. This would be in line with Hetor el at, [5] who examined the balance between the environmental risks, cultural safeguarding and economic development. Their findings revealed that a balanced approach should normally be encouraged where the mining activities could be considered as an alternative [industrial] site that enables the geology and topography of the mines to be viewed as an architectural landscape with an economic opportunity for tourism. As shown in figure 7 here below artisanal mining in QwaQwa is heavily male dominated. Child labor was not observed.

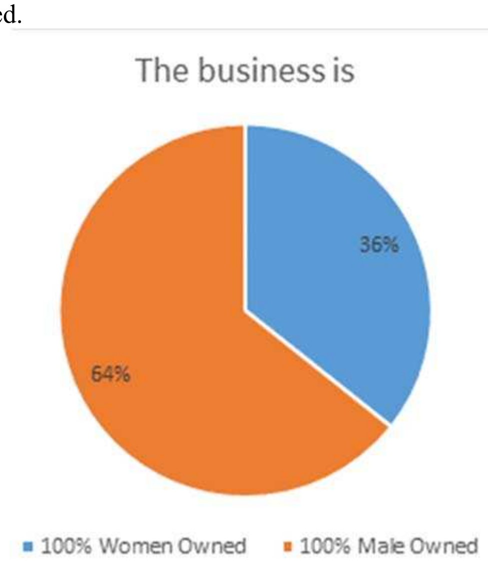

Figure 7: The proportion of sandstone mines owned by male only from the field work.

VIII. CONCLUSIONS

Artisanal mining activities have been found as supplementary ways of improving household incomes in rural areas of Southern Africa. In QwaQwa activities around the sandstone artisanal mining were noticed. About less than 10 % of the community mainly composed of males are legally and/or illegally invested in the artisanal mining of sandstones. The, in-to-outwards selective heating of dielectric components of sandstone minerals facilitates the grain boundary cracking of the layered geological sedimentary structure. The natural high abundance of solar influx calls for the use of solar energy to generate electricity triggering the magnetron of the portable microwave sandstone driller. The research's contribution to knowledge is based on the drawing together the solar energy dosage to trigger the microwave magnetron and facilitate a more efficient, sustainable and economical artisan mining of sandstone. Similarly this knowledge will be used by academicians and policy makers for research and improvements in production of sandstone.

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