An economic assessment of South African electricity supply systems

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Abstract

With regards to the rapid development of renewable energy resources, which is seen as sustainable electricity generating technologies. The costs analysis related to various power supply technologies are critical for business decision making. To this end, the South African government by means of its energy department has signed an agreement to add 2 300MW of renewable energy generating sources, which will be developed by the Independent Power Producer. Thus, this research paper used two different approaches (the Levelized Cost of Electricity (LCOE) and the Levelized Avoided Cost of Electricity (LACE). This latter was developed with the aim of addressing the issues left out by LCOE, which are crucial to business decision making. In this paper, at least 10 different power producing plants (coal, gas, nuclear, biomass, geothermal, hydroelectric, wind offshore, wind onshore, solar photovoltaic, concentrated solar power) were used as case study. The results indicate that of all technologies, geothermal ranks at the first place as the most economic competitive alternative, followed by coal technology. Furthermore, the results illustrate that the worse technologies in terms of economic viability are solar photovoltaic, concentrated solar power, and wind. As far as the authors are aware this study is the first example in the context of the South African energy sector.

Keywords.
Levelised cost of electricity, Levelised avoided cost of electricity, electricity generating sources, economic competitiveness.

I. Introduction

In South Africa, the history of power supply and demand started since 1881. During that century, the first electric lights were made online in western Cape by the British colony, this was just after Thomas Edison invented them in the United States. This was based on the benefits that electrical energy would have brought into human activities, therefore, the use of electricity spread quickly into the inner circle of the then Boer-ruled South African Republic. The main beneficiary was the gold mining industry. As early as 1895, first small hydro- and steam powered electricity power plants were in operation in the main cities of Cape Town, Johannesburg and Pretoria [2]. Likewise, the gold mining industry was the driving force behind the development of further power stations. In the years around 1900, the mining industry recognized that existing power plants where too small in capacity and that more energy was needed for their mining processes. This proved to be the beginning of the idea of "larger and centralized power plants" in South Africa, which provide cheap and reliable electricity supply to the industry. Soon, several mining companies bundled their forces and gave concessions to newly founded electricity companies that would provide them with the necessary electricity. Coal was then introduced for electricity generation in thermal power plants [3]. Subsequently, both private companies and municipalities started to produce electricity from a variety of technologies and under a variety of municipal laws and regulations in order to cover the increasing electricity demand. To bundle new individual power stations into a network and to deliver power to railroads and nearby cities, the Electricity Supply Commission (ESCOM) was created in the government's Electricity Act of 1922, with a mandate to supply electricity at the least cost possible. Likewise, a first regulatory body, the Electricity Control Board (ECB) was installed [3]. New licenses to private companies and municipalities were issued at a limited scope by the ECB and preference was given to ESCOM's own electricity generation projects.

Large investments were made into coal-fired power stations fueled by cheap domestic low-grade sub-bituminous coal. In this way, the state secured more and more influence in the electricity sector and was able to suppress competition, which was seen to be wasteful at that time, as [13] explains. The main political purpose of this strategy was to allow for world competitive resources and mining sectors that were very energy-intensive. As a result, South Africa soon possessed one of the cheapest sources for electricity in the world. In 1948, the National Party took over and eventually installed the apartheid regime which lasted until 1994. This time period was also crucial to how the electricity sector developed, as power stations brought online during that time are still running in many cases. In addition, energy politics from the National Party had a huge impact on the availability of electricity throughout the country and authors such as [14] claim that it was also used by the white government as a means for social control of the suppressed Black population. Around 1950, ESCOM had cemented its position as a vertically integrated monopoly by taking ownership over the national transmission grid and parts of the distribution grid. As in many other developing countries, high economic growth rates implied the need for capacity enlargements in electricity generation. Starting from the 1960s, state- guaranteed investments into a number of base load coal power plants were made through ESCOM and these were mainly located next to coal mines in the Mpumalanga Province. With the oil crisis in 1973, South Africa's economy shifted towards a substitution of oil with electricity and consequently peak demand growth rates skyrocketed

with demand increases of 6 – 16 % per year from 1972 to 1982 [14]. This situation induced yet more commitments for capacity increases and the fear of power shortages was permanent at that time. The capacity increases were not used to electrify rural areas. Instead, the electricity supply was concentrated to major cities, industries and the farms of white farmers [14]. In South Africa, energy sector is a crucial segment and parcel used by the government in order to create transformation in many lives. Since the end of Apartheid era in 1994, most of policies designed by the first democratic elected government, as well as those that govern the power supply encompass a section of radical transformation. The goal is to eliminate past discriminations based on ethnicity. Although a huge amount of poor folks lives within rural areas, there are also an important amount of them living within city zones. Throughout the Apartheid era, Black, Colored and Asian folks were not permitted to stay in the same zones as the white folks. As a result, there were areas with good service delivery and others with bad or no service delivery. Up to the present time, there are some regions that do not have basic services delivery. For example, water and easy access to electrical energy.

In addition to this, South Africa has been experiencing a rapid economic growth over the past decade. Thus, the South African government is aiming to maintain and improve this growth beyond the current trend. Nevertheless, there is a jeopardy that insufficient and defective electricity supply stays the main limitation to potential economic development. Growth related to urbanization, residents and economic cause an upsurge regarding demand for electrical energy. Nevertheless, inadequate facilities for power production, transmission and distribution, makes the country incapable in meeting the present demand for electrical energy and therefore overcomes the power demand. South Africa owns ample electricity reserve to satisfy the consumers demand, including coal, natural gas, nuclear, and renewable energy sources [13]. Whilst an amount of electricity production plants programmes has been laid in the country by decision-makers in the South African power utility. the dearth of adequate bankrolling seriously hinder the scale and pace at which electricity is supplied to the country and other African countries.

II. LEVELISED COST OF ELECTRICITY (LCOE)

Despite capital cost is a critical element that influences the cost associated with producing electrical energy by means of a power plant. There exist also others, such as fuel costs that is a key factor for fossil fuel-based power production stations. And also, costs related to operating and maintaining a power plant is also crucial, mainly in those that employ technologies such as gas turbines that necessitate recurrent important repairs. In what way, then, does one organised concerning merging all these factors to calculate the cost of producing a unit of electrical energy through a recommended power plant? Here the response is by employing certain form of financial modelling. Considering this, LCOE is the economic modelling that is widely used by many decisions makers. This includes computing the overall cost invested in the construction and operation of the plant throughout its whole lifespan, divided for every single year of its operation. The yearly outlays are afterward discounted to adapt them into the present worth. All the yearly discounted figures are then totalled in order to offer a figure in current's currency for the overall costs related to the power plant. This number is divided by means of the projected overall production of the plant during its lifespan and the resulting figure is the LCOE from the plant, once more in the current's values.

As mentioned above, the costs of producing electricity are generally evaluated according to the Levelised Cost of Electricity (LCOE) approach. Because, it shows the minimum marketing price of the electricity generated through a generating technology, assuming constant within real currency units, which can be needed to ensure all operating costs, interest and primary reimbursement obligations on debt, taxes and offering the investors an acceptable market return for the assumed risk [11, 12, 15]. LCOE is estimated as the actual cost of the electrical energy, which makes the present worth of the returns earning from the selling of the electrical energy equivalent to the present worth of all costs met throughout the plant life-cycle. LCOE is an essential key that aims at offering the break-even of sale price and it enables the costs comparison between various electricity generating technologies [6, 7, 8, 11]. Additionally, LCOE plays an important role in the context of a free market, therefore contributing to the incorporation of market uncertainties and risks in the worth of the cost of capital cast-off to discount cash-flows [9, 10]. LCOE can also be defined as an indicator of the cost incurred to producing electrical energy. It should be noted that LCOE does not consider the costs associated with transmission and distribution of electricity. However, it considers the capital investments, Operating and fuel costs. It should also be noted that LCOE may be addressed within real or nominal dollars' way. When addressing LCOE in real dollar way, the effects of inflation are removed [15, 16].

III. LEVELISED AVOIDED COST OF ELECTRICITY (LACE)

LACE is an alternative economic assessment tool to LCOE, which is designed with the aim of measuring the value associated with the electric power grid system that some technologies supply [1]. LACE represents the outlay that would be avoided to deliver the similar electrical energy to the system in case additional capacity employing a particular technology were not included and deployed. Another reason is due to the fact that anticipated operation rates, the available supply mix, and capacity rates may all differ radically throughout provinces where replacement production capacity can be required. For instance, in case a proposed additional coal-fired power plants were not built, other technologies might ought to be included or the operation rate (and fuel consumption) of available power plants might ought to be augmented to reach the electrical energy and the rated capacity, which the proposed additional

power plant would have delivered. The direct analysis by means of LCOE between different electricity generating sources is generally tricky and, in some circumstances,, may be unreliable as a tool to measure the economic competitiveness of several power production technologies [1]. Therefore, a good analysis of economic competitiveness may be reached by means of taking avoided cost into account, an amount of what it would cost the power grid to supply the electrical energy, which is then replaced by a fresh production plant, including its cost of generating a unit of electricity [7]. Avoided cost offers an alternative rate for the yearly financial worth regarding an entrant project, might be computed throughout its monetary life and converted into an extent annualized worth, which is then divided by average yearly output of the projected plant to develop its "LACE. The worth associated with LACE might therefore be weight against the worth related to LCOE about the entrant power plant project in order to offer a clue of whether or not the worth associated with the entrant plant project surpasses its outlay. In case various power plants are available to reach the load demand, judgements concerning each plant's LACE to its LCOE should be employed to identify which alternative has the potential to offer the best net economic worth.

It should be noted that the estimation of avoided costs is very difficult than the one of levelized costs since it needs data regarding by what means the system would have ran without the alternative under appraisal. In this paper, we used the avoided costs that were computed on a basis of the marginal worth linked to electricity and rated capacity, which would arise through an addition of a unit concerning a prearranged technology to the power grid as it is operational or is anticipated to be operational at a determined time in the future and characterizes the potential worth existing to the plant owner from the project's contribution to meeting both electricity and rated capacity supplies [1, 7]. As mentioned earlier, LACE offers an estimation of the electricity generating costs, as well as rated capacity replaced through a subsidiary unit of fresh capacity regarding a specific type, therefore offering an estimation linked to the worth of constructing such new capacity. This is a crucial factor that should be considered especially concerning renewable energy sources such as concentrated solar power, solar photovoltaic, and wind, which have considerably different task cycles than the conventional power plants such as coal, gas, and nuclear [1]. A power plant project is economically competitive and is when its LACE surpasses its LCOE.

IV. RESULTS

in this section, we are going to present the results based on the secondary data collected from previous works. It should be noted the reliability and validity of the data were thoroughly checked.

IV.1. Levelised cost of electricity

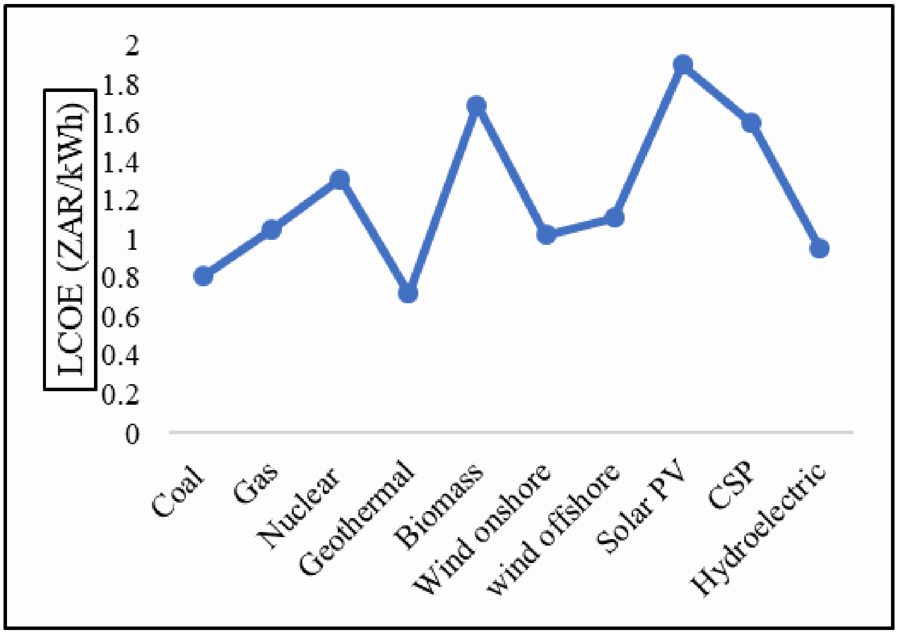

Figure 1. Levelised cost of electricity

From the figure 1 above, it can clearly be seen that the cost of producing electricity differs broadly among these technologies. For example, among thermal power plants, coal technology has the least LCOE. One possible reason may be attributed to the abundance of coal in South Africa and within many countries across the world. The results also show that gas is the second expensive option of conventional technologies. Here one possible explanation is that the load factor of gas is insignificant compared to both coal and nuclear, furthermore gas does not require high initial investment cost due to its integrated nature with many of its components brought to site ready-built. Alternatively, nuclear is the most expensive thermal technology. The reason is because due to safety issue surrounding this type of electricity technology, nuclear necessitates significant material and substantial labor cost. It can also be observed from the figure that most of renewable energy sources are costlier than conventional electricity technologies. One possible explanation may be due to their high investment costs and low load factor. That is why, they are not yet competitive with thermal technologies.

IV.2. Levelised avoided cost of electricity

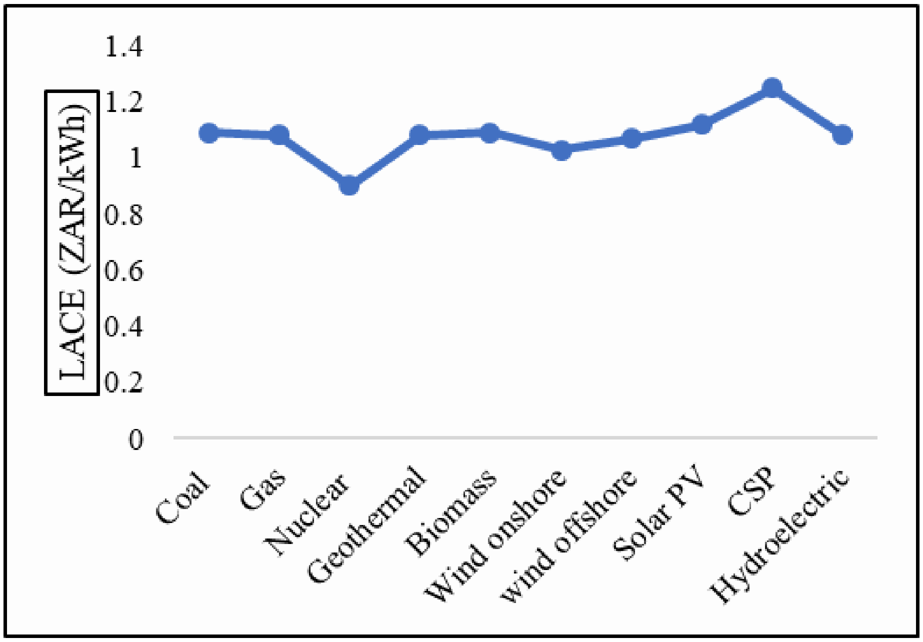

Figure 2. Levelised avoided cost of electricity

The figure 2 above shows that of conventional technologies, including coal, gas, and nuclear, coal has got the highest LACE of about ZAR 1.9/kWh, followed by gas and nuclear that have got LACE of around ZAR 1.08/kWh and ZAR 0.9/kWh, respectively. Whilst, of renewable energy sources, concentrated solar power has got the highest LACE of about ZAR 1.25/kWh, followed by solar PV with approximately ZAR 1.12/kWh, biomass, geothermal, hydro, wind offshore, wind, onshore of around, ZAR 1.09/kWh, ZAR 1.08/kWh, ZAR 1.08/kWh, ZAR 1.07/kWh, ZAR 1.03/kWh, respectively.

IV.3. Economic competitiveness of electricity technologies

The above results are based on the difference between the LACE and LCOE as presented above.

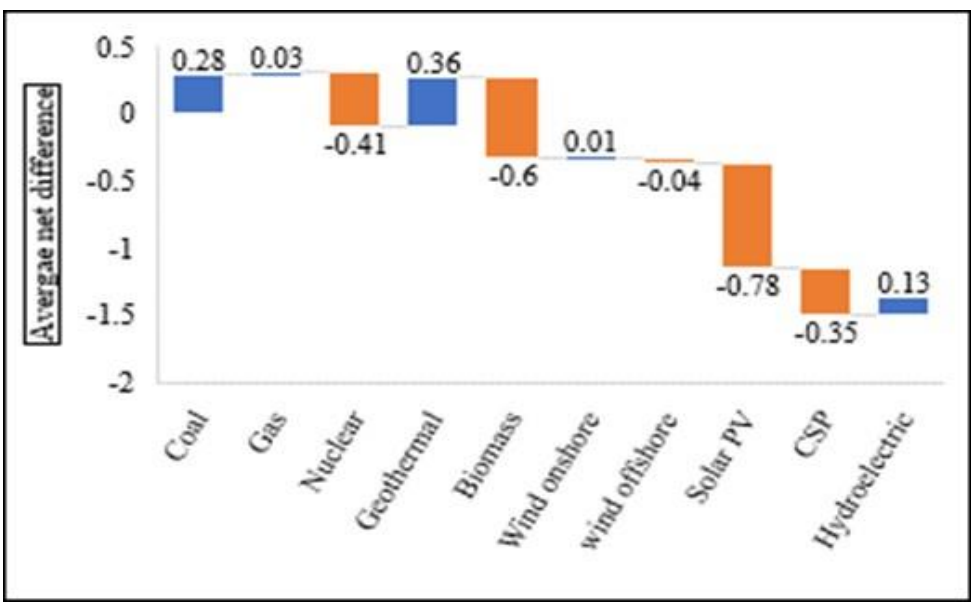

Figure 3. Economic competitiveness of power plants

The figure 3 above shows that of all electricity generating technologies, geothermal is the most economic competitive alternative. There is maybe due to the fact that electrical energy generated by means of geothermal is sufficient flexible in order to bridge the gap that maybe caused by the erratic renewable energy sources such as wind and solar. Because energy produced through geothermal may be easily augmented or reduced depending upon the demand, it may be used in maintaining the stability of the electric power grid, thus, increasing the total efficiency of the entire power production system, whilst at the same time providing reliable and clean energy. It can also be seen from the figure that coal is the second most economic completive technology. One possible explanation is due to its reliability aspect since coal technology has the potential to deliver electricity throughout peak hours, during which is often used as baseload or as off-peak power. Coal-based power plant is often used to back up the power grid system in order to avoid total blackouts. Furthermore, electricity generated from coal is cheap and affordable. Compared to nuclear technology, coal fired power plant guarantee safety. Since even if it fails it cannot produce disastrous damage such as a nuclear meltdown would. Lastly, the figure demonstrates that solar PV, wind, and CSP are the least competitive alternative. The reason is because these technologies do not supply electricity continuously, since the amount of the power generated by means of these technologies depend on the availability and strength of wind and the sun.

CONCLUSION

The main goal of this study was to assess the economic viability of different electricity technologies, which is crucial in identifying which alternative has the highest economic potential. To this achieve this objective, this study used both LCOE and LACE tools assess and compare the economic viability of 10 technologies which are: coal, gas, nuclear, biomass, geothermal, hydroelectric, wind offshore, wind onshore, solar photovoltaic, concentrated solar power. The results indicate that of all technologies, geothermal ranks at the first place as the most economic competitive alternative, followed by coal technology. Furthermore, the results illustrate that the worse technologies in terms of economic viability are solar photovoltaic, concentrated solar power, and wind. As far as the authors are aware this study is the first example in the context of the South African energy sector.

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Biography

Ndala Yves Mulongo is currently conducting a PhD degree in the Faculty of Engineering and the built environment, University of Johannesburg. He holds bachelor of engineering in extraction metallurgy and master of engineering in engineering management from University of Johannesburg, South Africa. His research interests involve life cycle approach, cost of electricity production, energy efficiency measures, green supply chain management, impact of mining operations on environment, mineral processing, manufacturing processes.

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