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# Investigating the Environmental and Economic Benefit of Waste to Energy Project: a Case Study of Methane Gas at the Thohoyandou Landfill Site

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## 1 ABSTRACT

The increasing power outage in South Africa and other developing countries, coupled with the global challenge of fossil fuel depletion, highlights the need for urgent alternative energy sources. Despite various studies being conducted, there is minimal application of waste-to-energy projects. The waste-to-energy projects have emerged as a potential solution to address both waste management and energy provision challenges. This study aims to investigate the environmental and economic benefits of using methane gas from the Thohoyandou landfill site in the Thulamela local municipality as an alternative energy source to the coal-powered grid. The research methodology was a content analysis to examine the sustainability benefits. The results suggest that the technology is economically feasible, considering the sales of electricity generated and Certified Emission Reductions (CER) (carbon credits). In addition, the project has the potential to reduce greenhouse gases (GHGs) from coal-power stations, resulting in improved air quality in nearby communities. This paper recommends that the Thulamela Local Municipality should scale up the innovative waste-to-energy projects as they offer best practice solutions.

Keywords: Sustainable Benefit, Methane Gas, Landfill Site, Environment, Waste to Energy

## 2 INTRODUCTION

Municipality solid waste management challenge is experienced in both developed and developing countries. This challenge continues to grow with population growth, which is rapid, as a result of no proper stringent methods to divert the waste from the landfill so that it can be processed into other by-products or recycled. Despite that waste reclaimers and waste management services, either public or private are available at the disposal of the municipality, the challenge is still widely experienced. The lack of public-private partnerships hinders tons of waste from being diverted from the source. Referring to Jeff Delmon (2015) states that the solid waste sector is not naturally fit for public-private partnerships as compared to other sectors due to the fact that the fees for waste collection are relatively low. In some instances, in developing countries such as South Africa, residents do not pay service fees for waste collection, which results in the emergence of illegal dumping sites.

The concern when it comes to fast-growing illegal dumping sites is due to the population. It poses a lot of strain on the local government because of the lack of development, provision of energy, and waste management. Supported by Hoornweg and Bhada-Tata (2012), Municipal Solid Waste (MSW) production globally is currently over 1.3 billion tons per year, with projections of 2.2 billion tons per year by 2025. Therefore, there is an urgent need to properly manage and recycle waste. This cannot be overstated, because the increase in tonnages of waste annually causes the local government to encounter a crisis of airspace in the landfill site. Landfill site airspace, also known as landfill capacity is defined as the amount of volume a site has for disposal (J. Collins, 2020). The shortage of airspace makes it difficult for municipalities to render their waste management services. The difficulties in the management of landfills emerge from the lack of resources, and funds to sustain and manage the waste (Viljoen, et al., 2019). This results in the creation of backlogs which influence open dumping and burning of the waste by community members especially those that are residing in the informal settlements and rural areas.

In the Vhembe district municipality, 18470 tons of waste is left in open spaces, without any collection (District, 2021). This shows that there is a need for alternative solutions to the waste left in open places, which poses social and environmental threats such as contamination of soil and underground water. The contamination of the environment is also experienced in the landfill site, due to a lack of proper management and innovative strategies to utilize wastewater, methane, and waste by-products (Shareef & Abdelazim, 2019). In most small landfill sites, the facility for leachate collection and treatment is often not part of the design of landfill sites.


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Relatively within the energy provision, there is a challenge of service delivery because innovative strategies are not implemented. The fossil fuels globally are decreasing due to a lack of management of the natural resources, lack of infrastructure, and development of alternative energy to supplement that which is already being supplied to the citizens. Thus Baraka Obama (2017) stated that the current generation is still utilizing the energy infrastructure that was developed to cater to the 19th-century population, which puts a strain on production The lack of improvement of the energy system especially in Africa has resulted in countries experiencing power outages or load-shedding over 24 hours per day (Agency, 2020). In the local concept of South Africa, the citizens experience six hours daily without electricity (Aljazeera, 2022), this is not applicable to those communities without electrification at all in remote areas. With this challenge expected to increase, it calls for urgent implementation of alternative energy such as waste-to-energy which will address both the waste and energy crisis that the country is currently experiencing daily. Wasteto-energy (WtE) projects are defined as projects that recycle substances and energy from solid waste through particular management methods and technical processes (UNECE, 2018).

The waste-to-energy projects are an essential solution globally through addressing the challenge of waste. Despite that more research has been conducted but there is less implementation of this project. For instance, a feasibility study for the waste-to-energy project has been done across the 62 political territories in Africa. That mentioned only 7 territories have installed the technology and have the potential to advance their project whilst in South Africa the WtE project has been implemented in 3 metropolitan cities of the country: Cape Town, Durban, and Johannesburg (Chrtina, 2013). This raises concerns about why this technology is not being replicated in other cities of the country. The WtE project can be produced in a thermal or non-thermal way, where the thermal is used to heat or for the combustion to treat wastes such as incineration, whilst the non-thermal is a process whereby the methane and carbon dioxide are produced and then captured using anaerobic digestion (Purser.R., 2011). The diagram below illustrates the different stages of waste-to-energy projects and the area where the energy can be utilized. This shows how the municipality can implement this WtE project.

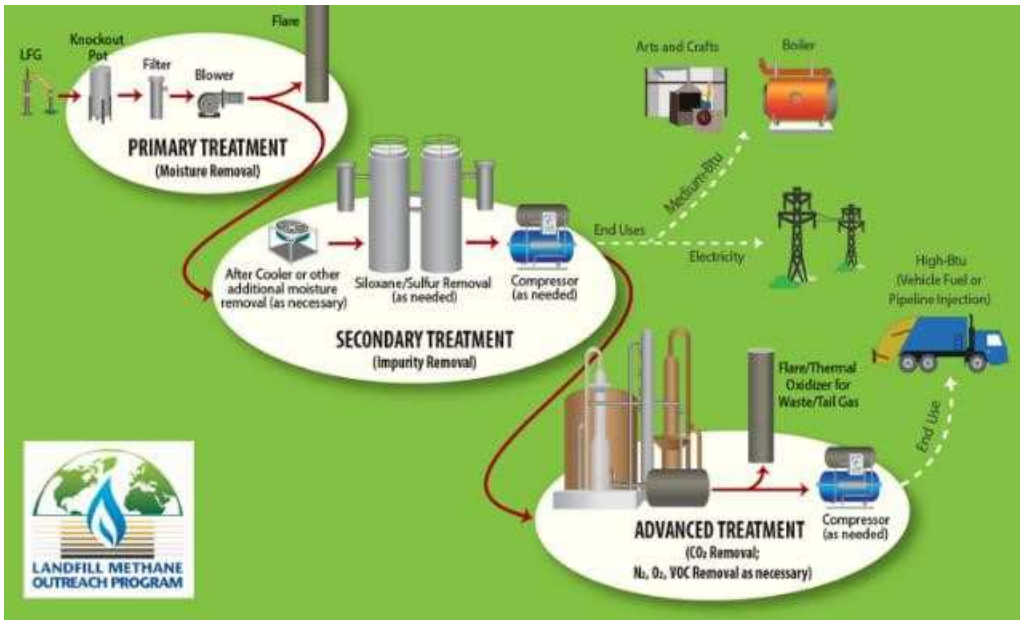


Figure 1 WTE potential usage by Landfill Methane Outreach Program

## 3 LOADSHEDDING IN SOUTH AFRICA

As the population in our township and industries continue to increase on a daily basis, the demand is increasing resulting in ESKOM not being able to cater to the energy demand. The Electricity Supply Commission (Eskom) is a state-owned company that was established in 1923. The company is responsible for supplying 90% of its electricity to South Africa and 30% to other African countries. It generates, transmits, and distributes electricity to industrial, mining, commercial, and agricultural sectors (BASE, 2023). This illustrates that this organization provides a vast amount of energy across the country, hence the challenge in providing electricity. In the past couple of years, South Africa has been facing a lot of challenges of power cuts, which are caused by various factors of corruption and lack of maintenance of

power plants. These power cuts are also referred to as load shedding. Load shedding is a deliberate shutdown of electric power in parts or parts of a power distribution system, generally to prevent the failure of the entire system when the demand strains the capacity of the system (Reporter, 2023).

This occurs because there is a shortage of coal to generate electricity or failure in power plants. For instance, in September 2022 South Africa had a bout of load shedding and this has continued till date resulting in 3.9 THw of energy being shed. This is double the electricity shed in 2021 (CSIR, 2022).

With all the different stages of load shedding experience, this is how communities are affected by the power cuts. Stage one load shedding means consumers will be deprived of electricity 3 times in 4 days at an interval of every 2 hours or 3 times in 8 days at an interval of every 4 hours. Stage two involves depriving consumers of electricity 6 times in 4 days at an interval of every 2 hours, or 6 times in 8 days at an interval of every 4 hours. Stage three involves depriving consumers of power supply 9 times in 4 days at an interval of every after 2 hours, or 9 times in 8 days at an interval of every after 4 hours. Stage four involves depriving consumers of electricity 12 times in 4 days at an interval of every 2 hours or 12 times in 8 days at an interval of every 4 hours. Stages five to eight indicate consumers not having electricity 12 times in four days at an interval of 4 hours. This is a clear depiction of how the electricity is shedding through the different stages.

There are various factors that affect the production of energy, which are the electricity generation capacity storage, where the organization is not able to meet the demand required due to the high demand. This is also affected by the delay in the construction of new power plants and updating of old power plants (Omarjee, 2022), thus people are still dependent on the old plants which is no longer efficient to cater to the current generation. There is a cause of financial strains due to the fact that the operation cost is really high, whilst the revenue is low (Pueyo, 2018). The low revenue collection is a result of illegal connections by communities and the debts owed by local municipalities. Lastly, the other factor causing load shedding is environmental concern (Courses, 2023), as the plants rely heavily on coal for electricity generation leading to environmental concerns and climate change.

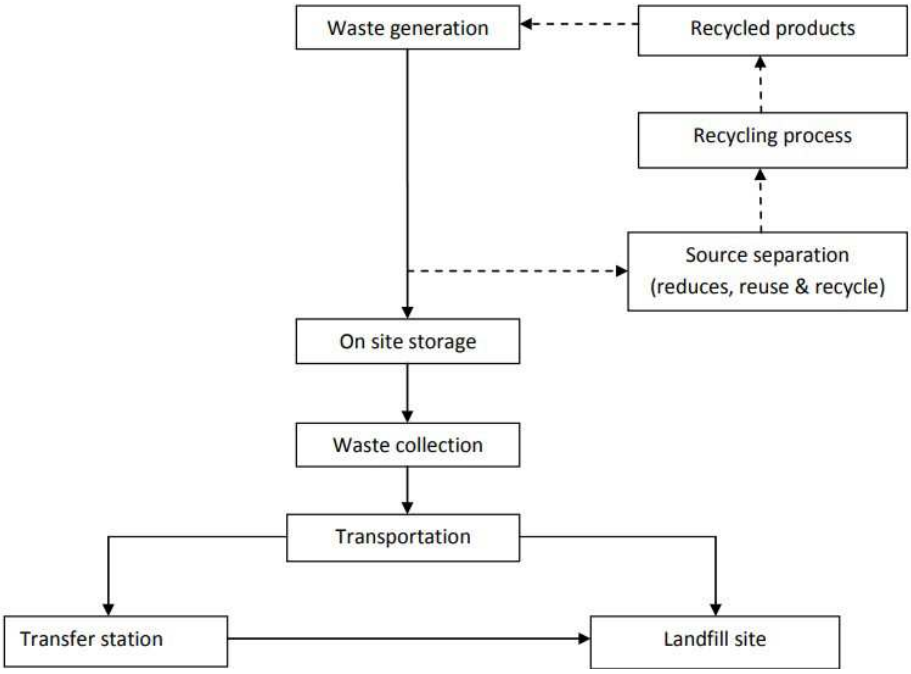


Figure 2 Flow Diagram of the Solid Waste Management In South Africa, Author University of Pretoria

## 4 MUNICIPAL SOLID WASTE MANAGEMENT

South African municipalities have the mandate to provide basic services to their community members as per the constitution of the republic. These services form part of the constitution of the country, which includes the right to clean water, sanitation, a clean environment, electrification, and waste management just to mention a few. The provision of services has a great potential to assist in the achievement of the National Development Plan 2030 as well as the Sustainable Development Goals related to the conservation of the environment, such as goal number 3 of clean energy (Nkosi, 2014). The Thulamela local municipality


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provides waste management of collection, disposal and transportation of waste. Covering a surface area of 2 893.936 km² from 59097 households (Municipality, 2022). The Municipal Solid Waste Management (MSWM) performs activities related to the generation, storage, collection, transfer, transporting, processing, and disposal of solid waste which requires efficient and effective management (Bonolo, 2016). Below is a systematic flow chart of how the waste management service by municipalities is conducted in South Africa commencing from the collection till the last stage of disposing the waste at the landfill site.

One of the strategic objectives implemented by the municipality is to provide quality basic services and infrastructure to the citizen to enhance the quality of life of individuals residing in the community, which include solid waste management services (Tshwane, 2015). As of Schedule 5 Part 8 of the South African constitution, each municipality of the country has a mandate for refuse removal, refuse dumping, and solid waste management.

## 5 THOHOYANDOU LANDFILL SITE

The use of renewable energy has been on a prominent rise since the 19th century by governments and organizations, thus in most countries globally there have been various experiments when it comes to the utilization of renewable energy such as wind, kinetic, nuclear, solar, and biogas energy. This aims to diversify the energy sectors through having various alternatives and to address the environmental problem (Panwar, et al., 2011). The urgent need to find sustainable solutions when it comes to energy is critical because the power outage is affecting the economy and infringing on the basic rights of South African citizens. As it infringes on the constitutional right the provide clean energy and stay in a clean environment so that they could be able to perform and develop effectively in their settlement (Mannak, 2015). As a way to find a solution to the issue of power outages, it is with this objective that the paper aims to investigate the potential environmental and economic benefits of using methane at the Thohoyandou Landfill Site.

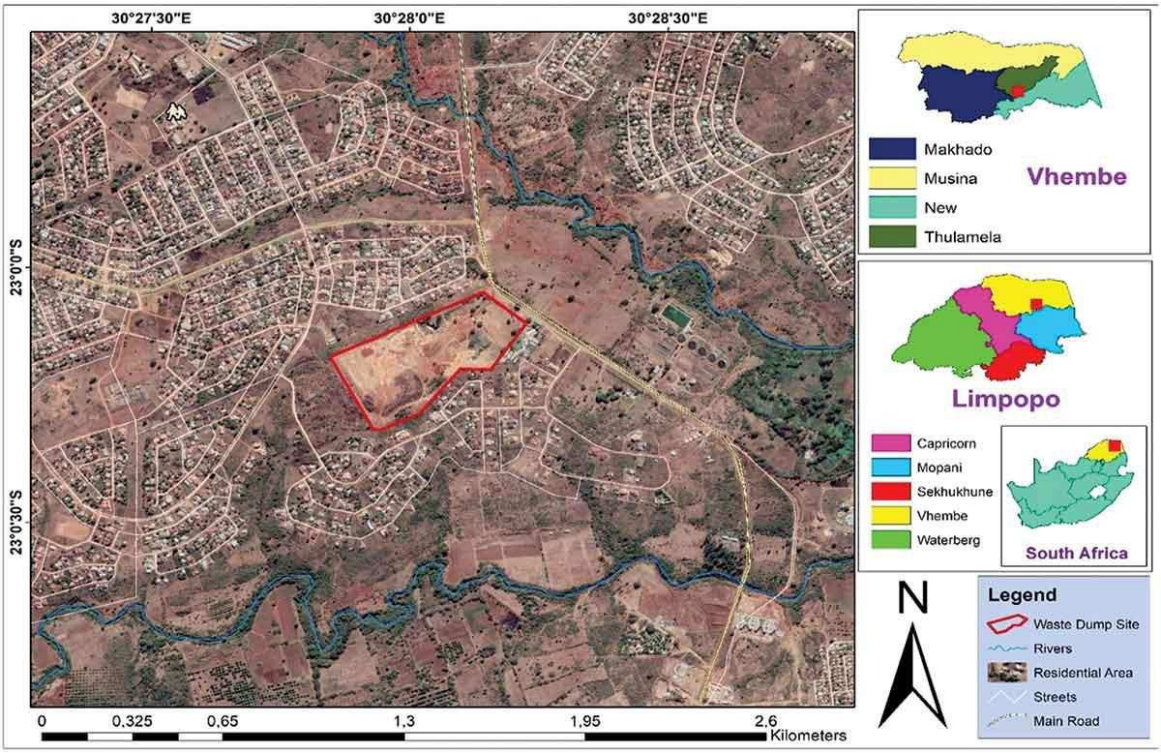


Figure 3:Map of Thohoyandou Landfill Site, Author Google Maps

The Thohoyandou landfill site is situated within the Vhembe District municipality under the Thulamela local municipality. This landfill site has been in operation since 2004 and is located 180km from Polokwane and in the gateway to Kruger National Park (Njoku, et al., 2020) and it remains the main landfill for the local municipality. It lies on the geographic coordinates of 23°00’12.0” S longitude and 30°27’55.3” E. latitude (Edokpayi, 2018). Despite the municipality having four licensed landfill sites, the Thohoyandou Landfill Site, also known as Tswinga Mulendane landfill site is the one that carries the most capacity of waste because it caters to many urban and rural settlements and industrial areas (District, 2021). For instance, in

2014, the landfill site was able to receive 210000 tons of waste. This landfill site is located adjusted to the Thohoyandou wastewater treatment and residential areas just around the facility, which imposes environmental and health hazards to the community. This harm is also influenced by the fact that the Thohoyandou landfill site has 4 cells but currently only one is functional (Njoku, et al., 2020). Below is the map of the landfill sites, with legends the man-made and environmental elements found near the landfill site.

## 6 THE OBSTACLES OF WASTE TO ENERGY PROJECT IN THE MUNICIPALITY

The use of WtE possess so many advantages in terms of the economy and the environment, hence the need to shift into the utilization of the WtE in the different municipalities. WtE is defined as a technology that consists of any waste treatment process that creates energy in the form of electricity or heat from several types of waste (Change, 2020). This is waste such as organic waste, waste water, human excreta and landfill waste. Despite that the benefits of this have been illustrated from various decades and also from other countries implementing them such as Indian and Germany. The government has not been increasing its interest in the use of energy, despite that there is a desperate need to supplement electricity provision especially due to the power cuts. In the various municipalities despite that they owe ESKOM a lot of money, the policies and bylaws for using methane are not implemented (Victoria O'Regan, 2022). The other challenge obstacle in the implementation of the WtE projects is that there is a lot of substrate to utilize in the generation of the waste but unfortunately, the lack of separation at the sources hinders the local municipality from implementing the WtE (Wang, 2023).

New technology is emerging and has great potential to assist the municipality in reaching its service delivery. There is a need to further conduct studies on how it will assist in assist in reaching the mission and vision of the municipality when it comes to energy supply and waste management (S. Matos., 2013). Unfortunately, the local municipality has limited research when it comes to the WtE project, especially focusing on the landfill site, this lack of research in terms of the project makes it difficult for the municipality to venture into WtE as they are not much concrete data that would be used in supporting that the WtE benefits (P. Mukumba, et al., 2016). Furthermore, there is inadequate expertise for construction and maintenance, for instance, within the local municipality a lot of this WtE is mostly being monitored by the University of Venda. This illustrates that there is a gap of expertise within the WtE in the municipality. This is furthermore supported by the fact that there are no technical or vocational schools that provide such training so the market can be diverse (P. Mukumba, et al., 2016). New technology comes with a new design that needs to be procured by the local municipality. One of the obstacles that the Thulamela local municipality faces is the high initial cost required for the construction and installation of the WtE digester. This is a challenge as most departments are under-financed. This is mostly the challenge in developing countries which are struggling with waste management and lack of energy supply (A., et al., 2021).

## 7 THE ENVIRONMENTAL BENEFIT OF USING METHANE AT THOHOYANDOU LANDFILL

Landfill sites will remain the final destination for waste collected that is not being recycled, thus despite being supposed to be a solution to avoid waste being disposed of in open spaces, it also has a few challenges such as the contamination of the underground water and soil decay. To combat some of the reactions that are occurring at the landfill site with regards to greenhouse gases. it is best to utilise the resources effectively such as methane gas and carbon dioxide, which will have a benefit to the environment. Environmental benefit is defined as the economic appraisal of policies and projects concerned with the improvement in the provision of environmental services or actions that have a direct impact on the environment and community members (Atkinson & Mourato, 2008). When waste is disposed at the landfill site by the municipality, a process occurs whereby gases are emitted. The gas that is emitted is referred to as landfill gases (LFG), which is defined as a natural by-product of the decomposed organic material in the landfill, which compromises 50% methane, 50% carbon dioxide, and a small component of nonmethane compound (Agency, 2023). This LFG can be captured and used as renewable energy, because of the high potential of methane that is found. If the LFG is captured in the Thohoyandou landfill site, it will assist in reducing the odor especially because they are settlements located 80m away from the landfill site, which is not environmentally acceptable (Agency, 2023).

According to Dudek (2010), the LFG provided a lot of opportunities such as being used directly using it in the landfills for bowlers, generating electrical power, bio-methane production, and lastly for automobile fuel.


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This opportunity contributes immensely towards the sustainable development goal and usage of natural resources in a sustainable manner. This is an agreement made during the Brundtland Commission conference. Another environmental benefit of using the methane gas from the Thohoyandou landfill site is that it will reduce the emission from the MSW landfill to achieve the near-term beneficial impact in the mitigation of global climate change, especially with the municipality vision for 2030 of achieving a City Status through urban regeneration and comprehensive rural development. As South Africa is facing the challenge of landfill sites reaching their airspace, the capturing of methane possesses the great benefit of extending its lifespan. especially because this is the main landfill site, the airspace has reached a capacity that a study conducted by Nelwomondo stated that by the year 2022, the airspace would be at 16391m³. Therefore, the use of methane could help in avoiding the construction or extending the landfill site, In terms of the Thulamela local municipality, the landfill site tender bid has been projected to be costing R16000000 (Municipality, 2022).

## 8 ECONOMIC BENEFITS OF USING METHANE GAS AT THOHOYANDOU LANDFILL

Economic benefits are defined as tangible benefits that can be measured in terms of the revenue generated or money saved through the implementation of policies or innovative strategies (Wells, 2021). The need to generate revenue through the utilization of wasteto-energy projects, especially with the economic state of the country and the Eskom crisis. Henceforth the utilization of methane gas in the Thohoyandou landfill site as will provide the economic benefit of providing a reliable energy source because landfill gas is generated 24 hours a day, every day of the year. This will be reliable energy because according to the LFG calculator done by (Njoku, et al., 2020), stipulated those simulations from Afvalzorg's model CH4 peak emissions for Thohoyandou landfill were 3336 Mg/year. Which is sufficient for providing energy. The world is facing the depletion of fossil fuel, which makes the buying prices high, thus using methane will reduce the demand and dependence on fossil fuel and nuclear energy. This when it comes to the municipality will be beneficial because according to Daily Maverick (2022), the Limpopo local municipalities already owe ESKOM R1062095. The reduction in the dependence can lead to the selling of greenhouse gas offsets, through the carbon credit method (Guy, 2016). Table 1 illustrates how to leverage the methane.

| | REIPPP Feed in Tarriff (FIT) unit rate (2015) | Eskom Avg Mega flex unit rate (2016) | Units |
|---|---|---|---|
| Average output per MW installed | 7 095 600 | 7 095 600 | KWh/year |
| Average capacity/load factor experienced in SA projects | 81 | 81 | % |
| Anticipated/global average capacity factor | 92 | 92 | % |
| Tariff for landfill gas | 1 | 0.85 | ZAR/KWh |
| Annual income/MW installed | 7 095 600 | 6 031 260 | ZAR/MW |
| Annual income minus op costs | 4 967 600 | 3 903 260 | ZAR/MW |
| Revenue over 15 year lifespan (12 – 20 years avg lifespan) | 106 434 000 | 90 468 900 | ZAR/MW |
| Capital cost/MW (estimated avg. including wells) | 19 300 000 | 19 300 000 | ZAR/MW |
| Operational costs per year (figure indicative) | 2 128 000 | 2 128 000 | ZAR/MW |
| Operational costs (over 15 years) | 31 920 000 | 31 920 000 | ZAR/MW |
| Revenue minus costs (over 15 years) | 55 214 000 | 39 248 900 | ZAR/MW |
| Revenue minus costs (average annual) | 3 680 933 | 2 616 593 | ZAR/MW |
| Payback/break even – number of years | 3.89 | 4.94 | Years |

Table 1 Simple payback analysis for LFG to electricity project by Ferry et al 2016.

The other economic benefits are available from the potential to use the methane from the landfill site. Making reference to Njoku's Study (2020) indicates that the engine generator set will generate an average electricity of approximately 9,366,635.263 KWh/year and will supply an average of approximately 4130 households every year. This will help to reduce the pressure on the coal-powered grid. In a municipality with a high number of unemployment, this equates to 47.7% (District, 2021). The use of the waste-to-energy project in the landfill site can assist with job creation in the municipality through having engineers, operators, maintenance officers, and various employment opportunities. This will be beneficial to the

municipality by making this project localized by employing local people procuring from local shops and working in partnership with the University of Venda and Makwarela Tvet College with their experts. This is because the WtE projects turn to source people from abroad to come and assist in design and assembling. The utilization of methane by the municipality can be used directly in the municipal vehicle fleet, as a way to have an alternative to the use of gasoline for their vehicle. The use of this gas possesses more benefits to the municipality as it solves environmental problems whilst generating revenue for the operation of the municipality which they have the opportunity to leverage on it.

## 9 CONCLUSION

At the rate the population is growing and the vision that Thulamela local municipality aims to achieve by 2030 will require stringent measures to be implemented. This will assist in addressing the issue of waste management and energy delivery within the landscape. Thus, this paper recommends that Thulamela local municipality should implement the waste-to-energy project at the Thohoyandou landfill sites, as it poses more environmental and economic benefits to the municipality and makes the municipality contribute towards the common goal set by the United Nations to achieve sustainable usage by the year 2030.

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