EVALUATION OF WASTE-TO-ENERGY GRATE INCINERATION POWER PLANT DRIVERS AND BARRIERS FOR A SMALL SOUTH AFRICAN CITY: A SWOT ANALYSIS APPROACH

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ABSTRACT

The global share of energy from waste is approximately 0.4% of global energy consumption. The average amount of municipal solid waste generated in South Africa is equivalent to 11 GWh wasted energy. This paper focuses on the drivers and barriers to the establishment of a waste-to-energy (WtE) grate incineration power plant for a small South African city in the North-West Province. It employs strength, weakness, opportunity and threats (SWOT) analysis to analyse the drivers and barriers to implementation of such a plant. Strengths and opportunities were acknowledged as drivers to the establishment of such a plant and weaknesses and threats as barriers. A holistic investigation using a SWOT analysis showed significantly more drivers than barriers. The study proved that SWOT analysis can be used as both a preliminary technology selection tool and an investment decision-making tool.

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1. INTRODUCTION

South Africa is currently facing power shortages due to increase in demand, failure to invest in additional capacity and limited maintenance. Simultaneously, over the years, municipal solid waste (MSW) generation and management problems have escalated [1, 2] in response to constant population growth and expansion of urbanization.

A significant amount of energy is wasted in South African landfill, as over 90% of MSW is disposed of in landfill and dumped illegally without energy recovery [2]. Landfill poses a number of environmental problems, such as greenhouse gases (methane and carbon dioxide) emissions, leakages into groundwater and inefficient space utilization [3].

The global trend is that the focus in waste management strategies has shifted to harmonize with the goal of sustainable development through electrical power generation and minimization of the adverse effects of landfill [4, 5]. MSW can now be viewed as a useful resource and can be used as an alternative renewable energy source.

Waste-to-energy (WtE) thermal technologies have the potential to meet the goal of sustainable waste management [6]. Developed countries that have implemented WtE thermal technologies have boosted their recycling rates, minimized the adverse impacts of landfill and increased the renewable energy generation level [4, 7].

South African cities are faced with power shortages, high unemployment rates and MSW generation and management problems, with landfill and illegal dumping dominating waste management strategies. WtE thermal technologies can be used to harness energy wasted in the landfill of South African cities, at the same time creating employment.

Maisiri [8, 9], performed technological and performance evaluation of four WtE thermal technologies and financial analysis of WtE grate incineration power plant. This paper is a continuation of this work and its objective is to carry out a SWOT analysis for a WtE grate incineration power plant for a small South African city in the North-West Province.

The paper is organized as follows: firstly, an overview on WtE grate incineration power plant is presented in section 2. Small city WtE grate incineration power plant SWOT analysis (Section 3) is discussed next. Small city internal drivers and barriers to WtE grate incineration power plant is deliberated in section 4. This is followed by a discussion on external drivers and barrires to WtE grate incineration power plant in section 5. A discussion on SWOT analysis results (Section 6) and conclusion (Section 7) are presented last.

2. WASTE-TO-ENERGY GRATE INCINERATION OVERVIEW

WtE grate incineration technology, commonly know as mass burn, is a conventional technology used to thermally treat MSW and other waste streams in a suststainble manner. Waste is treated with the objective of recovering energy inform of heat and electricty [10, 11, 12].

Oualitative and quantitative analysis evaluations carried by Maisiri [8, 9] proved that WtE grate incineration is the dominant and commercialy accepted technology over other WtE thermal technologies. The investigation further indicates that grate incineration remains the preferred and most economical thermal technology in view of its reliability, capability to incinerate assorted waste, lower operational complexity and higher power efficiency [13].

WtE grate incineration has been in use for more than 130 years and more that 90% of European WtE plants use grate incineration, and there are more than 1000 operational WtE plant installations across the world [9,14]. Figure 1 shows WtE grate incienarion power plant process flow diagram. Selected existing WtE grate incineration power plants are presented in Table 1.

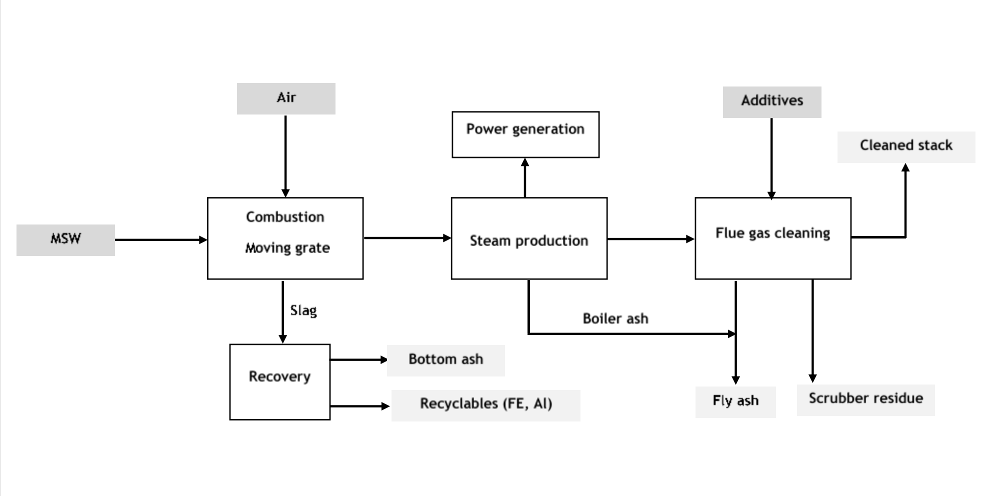

Figure 1: WtE grate incineration process flow diagram [14].

Table 1: Existing WtE grate incineration power plants [14].

Plant	**Country**	**Discription**	**Capacity** (Ton/year)
AEB, Amsterdam	The Netherlands	The largest plant in the Netherlands. Produces electricity with a total thermal efficiency of 30%.	1,370,000
Lakeside, London	UK	A recently commissioned merchant incinerator developed by a major UK waste management company. The plant processes residual MSW and other waste	410,000
Spittelau, Vienna, Austria	Austria	Relatively old conventional moving grate combustion plant. The first facility that used architectural treatment to gain public acceptance.	250,000
Issyles Moulineaux, Paris	France	The newest and largest incineration plant in France.	460,000
Reno Nord, Aalborg	Denmark	Modern incinerator in CHP mode and providing district heating to the local city.	160000 (line 4)

3. WASTE-TO-ENERGY GRATE INCINERATION SWOT ANALYSIS

SWOT analysis is a tool used for analysing internal and external environments in order to ensure a systematic approach and support in making decisions. Strengths and weaknesses are regarded as internal factors, while opportunities and threats are external factors [15].

In this study, SWOT analysis is applied by regarding WtE drivers and barriers for the small city case study as internal factors, while drivers and barriers outside the small city but within South Africa are regarded as external factors. Table 2 summarizes the strengths, weaknesses, opportunities and threats associated with establishing a WtE grate incineration power plant for a small city in the North-West Province.

Table 2: South small city WtE grate incineration power plant SWOT analysis [13].

Small city internal WtE investment drivers and barriers	
Strengths • Average MSW generation growth rate 3.04% per annum (Section 4.1.1) • MSW characterized by more than 80% of combustible material (Section 4.1.2).	**Weakness** • Dominance of wet months in a year in the small city (Section 4.2.1). • MSW yearly tonnages fluctuations (Section 4.2.2).

• Significant percentage of metals promotes material recovery (Section 4.1.2). • 98.3% dominance of landfill as MSW management strategy for the small city (Section 4.1.3). • Increased illegal dumping in the small city (Section 4.1.3).	• Absence of landfill diversion measures evidenced by no cost to dump waste at the landfill (Section 4.2.3). • Local culture of non-payment for service especially in the African and colored settlements (Section 5.2.4).
Small city external WtE investment drivers and barriers	
Opportunities	**Threats**
• 90% dominance of landfill as MSW strategy at national level (Section 5.1.1). • National waste generation growth rate estimated 3.0% per annum (Section 5.1.2). • 34% of non-recyclable combustible waste in the national MSW characterization (Section 5.1.2). • Non-energy recovery methods used to treat health care risk waste (HCRW) (Section 5.1.2). • National power crisis, promotion of renewable energy (Section 5.1.3) • Intermittent nature of solar and wind energy (Section 5.1.3). • Accumulation of waste vehicle tyre (WT) stockpile nationwide (Section 5.1.4). • Anticipated implementation of carbon tax and offset incentives in the country (Section 5.1.5)	• WtE thermal technologies are not allocated generating capacity in the REIPPP (Section 5.2.1). • Lack of enforcement of environmental legislation in the country hampers technological innovation in the waste sector (Sections 5.2.2). • High capital cost that requires access to investment subsidy from government institutions (Section 5.2.3). • Local culture of non-payment for service especially in the African and colored settlements (Section 2.4).5.

The small city internal and external drivers and barriers to investment in WtE grate incineration power plant are further explained in section 4 and 5.

4. SMALL CITY INTERNAL DRIVERS AND BARRIERS TO WASTE-TO-ENERY PLANT

An MSW management survey was performed for a small municipality in the North-West Province. Data were collected through interviews with representatives from the department of waste management. The collected data were analyzed and this section presents the drivers and barriers to implementation of WtE grate incineration plant identified from data analysis results.

4.1 Internal drivers to the implementation of WtE grate incineration

4.1.1 Municipal solid waste generation trends

MSW generation is on an upward trend due to the expansion of the small city and population growth. Figure 2 shows MSW generation trends for the small municipality. The average MSW generation growth rate was calculated at 3.04% per year [13].

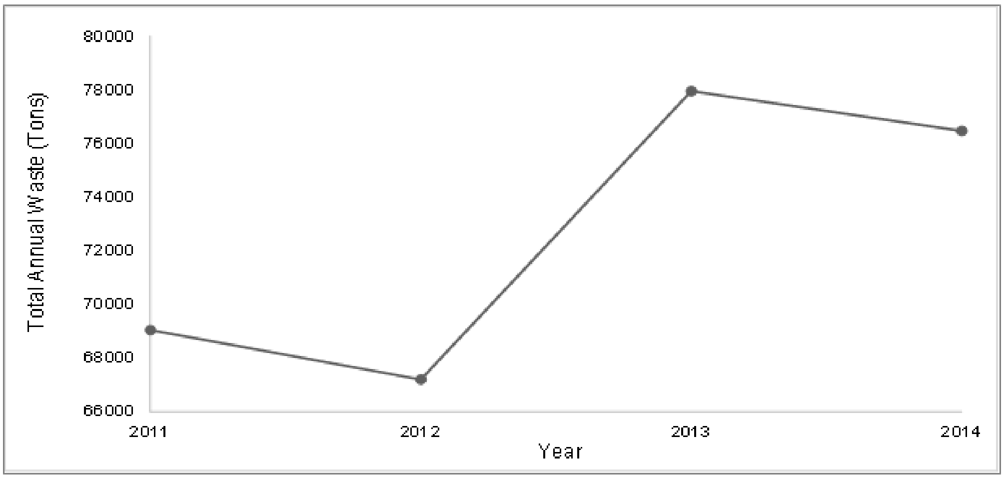

Figure 2: Small city MSW generation trends [9].

4.1.2 Municipal solid waste characterization

Table 3 shows MSW characterization for the small municipality investigated. MSW is characterized with more than 80% of combustible material of which plastic makes the highest percentage. The lower heating value (LHV) of MSW is estimated at 8.0 MJ/kg. There is significant percentage of metals which can promote metal recovery [13].

Table 3: Small municipality MSW characterization [9].

Waste Type	**Percentage (%)**
Builders rubble	2
Plastic	30
Paper	28
Organics, garden waste	8
Metals	6
Glass	13
Other (textile, disposable nappies, tyres, residue and miscellaneous)	13
TOTAL	**100**

4.1.3 Municipal solid waste management strategies

Landfill was identified as the dominant MSW management strategy for the small municipality investigated. On average 98.3% of the waste generated is landfilled while 1.7% is recycled. Figure 3 shows the contribution of landfill and recycling to the overall waste management strategy of the small city. Investigations proved that there is increase in illegal dumping in the small city [13].

4.2 Internal barriers to the implementation of WtE grate incineration

4.2.1 Municipal solid waste dampness

Data analysis results showed that the small city has five dry months in a year. Figure 4 shows the rainfall patterns recorded at the landfill. Damp MSW dominates because of wet months recorded [9].

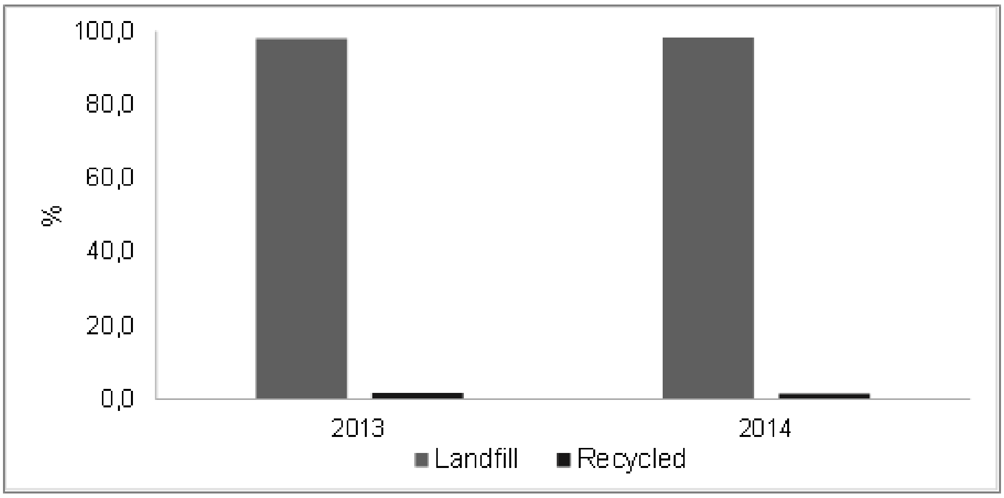

Figure 3: Contribution of landfill and recycling to the overall small city waste management strategy [9].

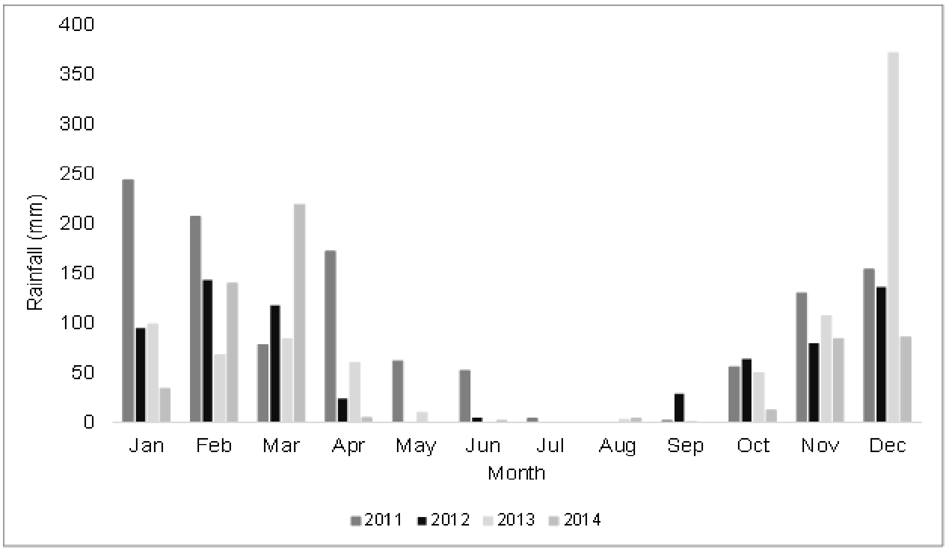

Figure 4: Monthly rainfall trends for the small city [9].

4.2.2 Municipal solid waste generation trends

Figure 2 shows variations in MSW generation trends from the year 2011 to 2014. The trends show significant fluctuations in the amount of MSW generated for the state period. This presents uncertainty in the availability of the waste stream to run the WtE grate incineration plant for the small city [13].

4.2.3 Landfill diversion measures

In developed countries landfill diversion is a major driver of WtE technologies [4]. Measures such as high fees charged on waste managed through landfill have been instituted. WtE grate incineration power plants' gate fees are relatively low compared to landfill gate fees. This leaves waste producers with no other option than using the WtE grate incineration plant as an alternative waste management strategy.

Contrary to this, investigations by Maisiri revealed that no landfill gate fee is levied by the small city in the North-West province and in South Africa at large. This makes landfill the cheapest waste management option and waste producers consequently choose this method. Local residents only pay an insignificant flat fee, embedded in their property bills, to local municipalities. Refuse collection fees vary with residential areas.

5. SMALL CITY EXTERNAL DRIVERS AND BARRIERS TO WASTE-TO-ENERGY PLANT

5.1 External drivers to implementation of waste-to-energy grate incineration

5.1.1 Municipal solid waste management trends

Investigations reveal that landfill dominates other waste management strategies in South Africa, regardless of the amendment of the waste hierarchy in 2011 [2, 16]. Landfill accounts for approximately 90.1% of waste generated in the country. It was noticed that MSW accumulation in uncontrolled dumpsites is rampant in South African cities [2].

Surveyed literature indicate that WtE thermal technologies make no contribution to the country's current MSW management strategies [17]. The current MSW management trends in South Africa offer an opportunity to implement WtE thermal technologies.

Significant waste divergence from landfill can be achieved in the country through WtE thermal technology initiatives. Figure 5 reflects the experience of countries that have implemented WtE thermal technologies. Noticeable decrease in landfill usage and boost in recycling levels can be seen [6].

WtE thermal technologies can boost recycling activities in the country considerably. Countries that have implemented WtE thermal technologies attest that WtE facilities appreciably improve material recovery. WtE facilities promotes recycling through metals recovered from air pollution control and bottom ash residue and in the feedstock preparation stage [6].

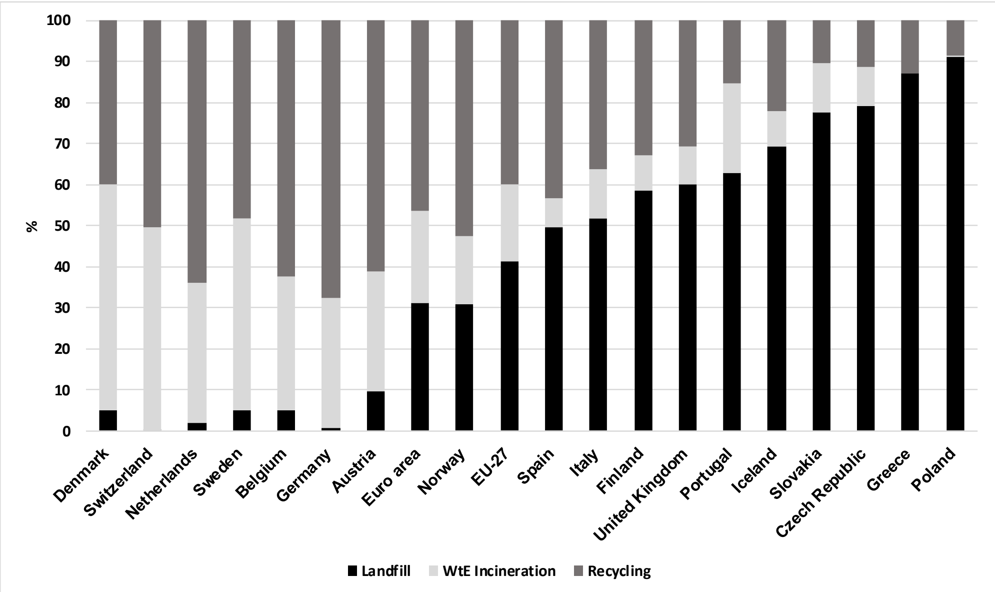

Figure 5: Percentage contribution of WtE incineration, recycling and landfill in managing MSW in EU [7].

5.1.2 Municipal solid waste generation trends.

MSW national generation was at 59 million tonnes in 2011. The national waste generation growth rate is estimated at 3.0% per annum [1]. The MSW composition is dominated by combustible non-recyclable waste with a percentage contribution of 34%. Table 4 shows South Africa's general waste composition by 2011.

In South Africa health care risk waste (HCRW) generation was estimated at 45 232 tonnes per annum in 2011. Gauteng province made the highest percentage contribution to HCRW [1, 18]. HCRW treatment facilities are not decentralized and there is no energy recovery during incineration [18, 19]. Significant illegal dumping of HCRW has been witnessed, with Gauteng recording most HCRW illegal dumping incidents [18].

Table 4: General waste composition [1].

Waste type	Percentage contribution (%)
Glass	4
Plastics	6
Paper	7
Tyres	1
Combustible non-recyclable MSW	34

Organic waste	13
Construction and demolition waste	21
Metals	14

5.1.3 South Africa's energy scenario

In 2014, South Africa was hit with blackouts in its major cities due to a shortfall in electrical energy generation capacity [20]. The shortfall in generation capacity was a result of increased demand, failure to invest in additional supply and limited power plant maintenance.

The renewable energy mix in South Africa comprise wind, solar energy, small-scale hydro generation, biomass and bagasse. MSW is also listed as a potential source of energy in the country. It is estimated that MSW equivalent to 11 000 GWh is wasted in South African landfill per annum [21].

The wasted energy in the landfill can be harnessed through direct incineration and by using methane gas. WtE thermal technologies best suit urban areas where a large amount of waste is produced and the costs of landfill sites are relatively high [22].

International Energy Agency statistics point out that residual MSW has the potential of replacing 2% of fossil fuel in South Africa [4], thus WtE technology can make a significant contribution to the country's renewable energy mix.

South Africa's renewable energy sector is dominated by wind and solar energy. Increasing the share of wind and solar power in the national grid might result in a long-term crisis. A large amount of intermittent renewables in the grid causes grid crush [23]. This is due to their spasmodic nature, which is unable to supply power at all times and when it is needed most.

Unlike wind and solar energy, a WtE grate incineration power plant has load flowing characteristics and has no intermittency problem. A WtE grate incineration power plant can be classified among peaking technologies and can operate 24 hours a day. The capacity factor of a WtE power plant is approximated at 90%. Implementation of WtE grate incineration technology can significantly boost renewable energy and increase national grid security in South Africa.

5.1.4 Waste vehicle tyre management

Muzenda [16] maintains that South Africa is currently faced with problems in waste vehicle tyre (WT) management. It is stated that there are over 60 million WT in South Africa. The illegal dumping and disposal of WT poses significant environmental problems. Landfill and stockpiling are the commonly used WT management strategy in South Africa [16].

The millions of WT lying in stockpiles, landfill and scattered in residential, industrial and rural areas are posing serious environmental and health problems. WT stockpiling causes significant problems such as breeding of insects and rodents, as well as risk of uncontrollable burning, which cause air pollution [16].

Including WT as a supplementary feedstock to a WtE grate incineration power plant has the potential of improving its financial model performance. This is possible through improving the feedstock LHV, thus boosting power generated.

5.1.5 Carbon tax

The Department of National Treasury states that carbon tax will be introduced to facilitate transition to a low-carbon economy. The government of South Africa is moving towards cutting green-house emissions by 34% and 42% in 2020 and 2025 respectively [24]. The move is significantly subject to the availability of sufficient financial, technological and capacity-building support by developed countries.

In order to include the cost of pollution on goods and services, carbon tax will be used as instrument that will ensure polluters, both producers and consumers, held accountable [24]. To this end, major consumers of electricity such as municipalities will incur large carbon tax. The use of alternative green energy such as WtE grate incineration can assist in offsetting such huge amount carbon tax.

WtE grate incineration reduce green-house gas emissions by approximately 13 000 tonnes carbon-dioxide equivalent for every 100 000 tonnes of MSW processed. For combined heat and power systems, green-house gas emissions are lowered by roughly 23 000 tonnes carbon-dioxide equivalent [4]. This means for a 200 000 tonnes capacity WtE grate incineration plant, carbon credits equivalent to 26 000 tonnes carbon-dioxide equivalent can be earned.

5.2 External barriers to implementation of waste-to-energy grate incineration

5.2.1 Renewable energy independent power producer procurement program allocations

Renewable energy independent power producer procurement program (REIPPP) is competitive tender procurement process, designed to promote renewable energy to match global trends and uphold the goal of sustainable development [25]. Table 5 shows summarized results of RIEPPP generation capacity allocation in bidding windows 1 to 4. WtE thermal technologies were not allocated generating capacity in the REIPPP. There has thus been no participation in WtE thermal technologies [26].

Table 5: RIEPPP total allocated and remaining generation capacity [27].

Technology	Total allocated and remaining generation capacity (MW) in bidding windows 1 to 4					
	1	2	3	4	Total allocated	Total remaining
Solar photovoltaic	632	417	435	415	1899	626
Onshore wind	634	563	787	676	2660	660
Concentrated solar power	150	50	200	0	400	0
Small hydro (< 40MW)	0	14	0	5	19	116
Landfill gas	0	0	18	0	18	7
Biomass	0	0	16	25	41	19
Biogas	0	0	0	0	0	60
WtE thermal technologies	0	0	0	0	0	0

5.2.2 Legislative framework

National environmental management in South Africa facilitated the development of regulations that support the Waste Act. These regulations are aimed at supporting innovation and divergence of waste streams from landfill [2]. However, lack of enforcement of environmental legislation has hampered technological innovation in the waste sector.

Investigations show that the authorization of waste management licenses has been hindering novelty and implementation of new technologies in the waste sector. The authorization process is expensive and unrealistically long. Reports of corruption in the system have been received [17].

Enforcement of environmental legislation will encourage different stakeholders to implement alternative technologies in the waste management sector. An effective, efficient and transparent authorization process will attract innovation in the country's waste management sector.

5.2.3 Waste-to-energy thermal technologies high capital investment

WtE thermal technologies involves high capital investment, operational and maintenance costs. In comparison with other renewable energy technologies, the capital cost of a WtE power plant makes it an unfavourable investment option. South Africa has no operating WtE thermal technologies at present. The capital-intensive nature of WtE thermal technologies calls for long-term security to investors.

The capital cost of WtE technologies in South Africa has not been well researched [19]. The capital investment figures used are taken from the experience of other countries that use WtE thermal technologies. Because of the availability and low cost of material, the estimated capital cost of WtE thermal technologies in South Africa might be significantly lower.

5.2.4 Local culture

The financial viability of a WtE grate incineration power plant in developed countries is noticeably influenced by the MSW gate fees. A negative price on waste has resulted in the success of many WtE grate incineration power plant projects. This means that waste producers must pay a fee to the plant operator for their waste to be processed [4].

The local culture of non-payment for service, mainly encountered in African and colored communities [28], promotes failure of the waste negative price model. This adversely affects the financial viability of a WtE power plant.

The local culture might necessitate a WtE plant financial model that will have a positive price on waste. This means that the WtE plant operator will have to pay waste generators for their waste to be processed. This decreases the anticipated revenue streams and may cause financial instability in a WtE grate incineration power plant. Nevertheless, that model will grantee residual waste stockpile for the plant.

6. SWOT ANALYSIS DISCUSION

SWOT analysis was applied in this study by considering small city case study drivers and barriers to the establisment of WtE grate incineration power plant in South Africa as the strenghts and weakness respectively. Drivers and barriers outside the small city but within South Africa were regarded as oppotunities and threats correspondingly.

According to Table 2, the identified strengths are more than the weakness while the opportunities acknowledged are significantly more than the threats. Thus the drivers to the implementation of a WtE grate incineration power plant are considerbaly more than the barrriers.

The drivers identified include an average of 90% dominance of landfill over other MSW management strategies, average MSW generation growth rate of 3% per annum, national power shortages, the intermittent nature of solar and wind energy and non-energy recovery methods used in treating health care risk waste (HCRW).

However, obstacles to execution, such as the legislative framework, lack of landfill diversion measures, high capital investment involved and local culture were acknowledged.

7. CONCLUSION

The purpose of this paper was to perform a SWOT analysis for a WtE grate incineration power plant for a small South African city. The analysis proved that the drivers to WtE grate incineration power plant implememenation are significantly more than the barriers identified. Thus SWOT analysis results proved that investment in a WtE grate incineration power plant for a small South African city is feasible. The investigations in this study proved that SWOT analysis can be used as both a preliminary technology selection tool and an investment decision-making tool.

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