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The viability of biomethane as a future transport fuel for Zambian towns: A case study of Lusaka

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Abstract

The objective of the study was to determine the viability of biomethane as a transport fuel for Zambian urban towns. The study revealed good potential for biomethane production and use as a transport fuel in Zambian towns, using Lusaka as a case example. There is 3.67 million m^3 *biomethane potential from municipal solid waste alone in Lusaka. About 3 000 tonnes of organic fertiliser would replace an equivalent amount of chemical fertiliser. The replaced chemical fertiliser would lead to about 5.816* $GgCO_2eqy^{-1}$ *as avoided emissions. The study showed a positive net present value at the prevailing market interest rates of 28–40%; the project would become unviable at interest rates higher than that. It was estimated that the project would recover its initial investment in a maximum of two years. The research findings have closed data and information gaps in Zambia and have potential to contribute to academic research, policymaking, investments, financing and interested parties.*

Keywords: *biogas, municipal solid waste, environmental, social and economic benefits*

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1. Introduction

Biogas is the main product of the anaerobic digestion (AD) of organic waste and wet biomass. The organic fraction of municipal solid waste (MSW)' slaughterhouse waste, agricultural and forest residues, livestock manure, dedicated energy crops, and sewage waste are all potential feedstock types that can be used to produce biogas [1, 2]. During the AD process, a major portion of the carbon compounds are converted to methane (CH_4), carbon dioxide (CO_2) and water [3, 4]. Biogas normally contains 50–70% CH_4, 35-50% CO_2 [5] and trace gases like hydrogen sulphide (H_2S), depending on the feedstock type [6].

The co-product of anaerobic digestion is organic fertiliser, which is preferable to chemical fertiliser in terms of environmental impacts [7] and can lead to higher yields [8]. Traditionally, biogas has been used by households as a source of energy for cooking [9] and combined heat power plants to produce electric power and heat [10]. Countries like Germany, Sweden, Switzerland, Italy, Hong Kong and Ireland demonstrated that biogas could be upgraded to biomethane and used more efficiently by injecting it into the compressed natural gas grid or used as a transport fuel for both heavy and light duty vehicles [11, 12].

The main objective of this study was to assess the viability of biomethane production and use as a transportation fuel. The study first assessed the biogas potential from municipal solid waste in Lusaka, discussed the upgrading processes of biogas in general, and estimated how much biomethane could be available for light-duty vehicles weighing 0.75–3.00 tonnes. The focus was on these vehicles because they have small engines and mostly use petrol, which can easily be switched to biomethane [13]. The study then looked at the potential environmental, health and sanitation, and social and economic benefits of adopting biomethane as a future transport fuel in Zambia.

2. Methodology

The information and data used in this study was obtained from the Central Statistics Office reports, official reports from government ministries, non-governmental and community-based organisations, the Food and Agriculture Organisation statistics database, and publications on similar studies in other countries where such projects have been and are being implemented.

2.1 Biogas potential

Biogas potential was determined according to Sanches-Pereira et al. [14]) and Shane et al. [15]. Jingura and Matengaifa [16] stated the biogas potential as the product of quantity of feedstock and the biogas potential per ton of feedstock less 6% losses. The biogas potential can be estimated according to Equation 1. The population from different wards of Lusaka province was obtained from the Census of Population and Housing report [17]. The generated solid waste per capita used in the estimation was obtained from the Zambia Environmental Outlook report for which the Environmental Council of Zambia, now the Environmental Management Agency (ZEMA), carried out studies and determined this figure. The MSW collection efficiency was also obtained from studies by ZEMA and Senkwe et al. [18]. The organic matter content and the biogas potential were taken from similar studies done in sub-Saharan African countries like Zimbabwe and Uganda. A 6% biogas loss was also incorporated into the formula [19] to account for characteristic leakages in production of the biogas.

$$BP_{MSW} = \sum N_i \times Q_{pc} \times C_{eff} \times OM_f \times B_p \tag{1}$$

where BP_{MSW} is the biogas potential from municipal solid waste (m^3d^{-1}); N_i is the *i*th ward total human population; Q_{pc} is the quantity of municipal solid waste generated per capita ($kgp^{-1}d^{-1}$); C_{eff} is the municipal solid waste collection efficiency or rate of municipal solid waste collection (%); OM_f is the organic matter fraction in the municipal solid waste (%); and B_p is the biogas potential of the organic fraction of the municipal solid waste (m^3kg^{-1}).

2.2 Organic fertiliser production potential

The organic fertiliser was estimated using the estimated biogas and/or biomethane potential, the standard ratio of methane in the biogas, standard density of methane and the organic fertiliser that could be produced per unit volume of biogas generated. These parameters were obtained from similar studies on organic fertiliser production, according to Equation 2 [20-22].

$$Q_f = \frac{M_{CH_4}}{\rho_{CH_4} \times R_{CH_4} \times V_B \times D_P} \tag{2}$$

where Q_f is the production rate of fertiliser (kgd^{-1}); M_{CH_4} is the mass of methane generated within a year (kgy^{-1}); ρ_{CH_4} is the density of methane (kgm^{-3}); R_{CH_4} is the ratio of methane in the biogas; V_B is the biogas generated from a unit mass of organic fertiliser (m^3kg^{-1} of fertiliser); and D_p is the number of days per year of production.

2.3 Avoided greenhouse gas emissions

Avoided greenhouse gas (GHG) emissions that were considered were CO_2 from chemical fertiliser production, nitrous oxide (N_2O) emissions from chemical fertiliser (replaced urea and D-compound) applications to managed soils, and non-CO_2 GHG emissions such as combustion of MSW in disposal sites and emissions from fuel combustion. Managed soils are soils that undergo enhancement in terms of their performance and fertility through practices such as tiling, ploughing, and the addition of agricultural lime and fertiliser.

2.3.1 Avoided greenhouse gas emissions from fertiliser production

To estimate the amount of GHG emissions from fertiliser production, the amount of GHG emission per kg of nitrogen fertiliser produced is multiplied by the percentage of nitrogen in the fertiliser and the quantity of fertiliser produced (kgy^{-1}), according to Equation 3 [23, 24]. The amount of fertiliser was obtained from the quantified organic fertiliser, which could be replaced by the chemical fertiliser. The nitrogen content was obtained from a standard nitrogen phosphorus and potassium fertiliser used in Zambia, and emission factors are standard factors obtained in chemical fertiliser production.

$$GHG_{FP} = 365\sum_{i=1}^{n} Q_f \times P_{N,i} \times EF_i \times 10^{-6} \quad (3)$$

where GHG_{FP} = GHG emissions from fertiliser production ($GgCO_2eqy^{-1}$); Q_f = quantitate of fertiliser type *i* (kgd^{-1}); percentage of nitrogen in fertiliser type *i* (%); and EF_i is the GHG emissions per kilogram of fertiliser type *i* ($kgCO_2eqkg^{-1}$ N-fertiliser). The values of GHG emissions per kg of nitrogen fertiliser produced are given in Table 1. The fertiliser in row one was used in the calculation because of the large number of citations in the literature, which could indicate wide applications in research.

Table 1: Greenhouse gas emissions from fertiliser production.

Fertiliser type	*N*	*P*	*K*	*Source*
GHG emissions ($kg\ CO_2$-$eqkg^{-1}$ fertiliser	3.30	1.10	0.73	IFA, 2009; TGO, 2015; Lal, 2004b
	3.30	1.57	0.50	(TGO, 2015
	3.63	1.55	0.97	Kool et al, 2012

2.3.2 Avoided greenhouse gas emissions from fertiliser application to managed soils

The GHG emissions from both chemical and organic fertiliser application to managed soils were estimated according to the Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories, Volume 4 and Chapter 11 [25], Elsgaard [26] and Figueiredo et al. [28]. Equations 4 and 5 were used to calculate direct and indirect nitrous oxide (N_2O) emissions, respectively, from the nitrogen, phosphorus and potassium (D-compound), urea and organic fertiliser application to managed soils. The quantity of chemical fertiliser used in the estimation was based on the equivalent fertiliser that would be replaced by organic fertilisers.

$$N_2O_{DE} = N \times \frac{44}{28} \times EF_1 \times 10^{-6} \quad (4)$$

$$N_2O_{IE} = N\left[(F_{Vola} \times EF_4) + (F_{leach} \times F_5)\right] \times \frac{44}{28} \times 10^{-6} \quad (5)$$

where N_2O_{DE} = direct N_2O emissions from synthetic nitrogen additions to the managed soils ($Gg\ N_2O\ yr^{-1}$); N = consumption in nutrients of N-fertilisers ($kg\ N\ input\ yr^{-1}$); EF_1 = emission factor for N_2O emissions from N inputs (kg N_2O–N/kg N input); N_2O_{IE} = indirect N_2O emissions produced from atmospheric deposition of N, volatilised from managed soils (Gg N_2O–N yr^{-1}); F_{vola} = fraction of applied synthetic N-fertiliser materials that volatilises as NH_3 and NO_x (kg N volatilized/ kg of N applied); *EF4* = emission factor for N_2O emissions from atmospheric deposition of N on soils and water surfaces, kg N–N_2O/kg NH_3-N + NO_x-N volatilised; F_{leach} = fraction of applied synthetic N-fertiliser material that leaches as NH_3 and NO_X (kg N leached/kg of N additions); and EF_5 = emission factor for N_2O emissions from N leaching and runoff (kg N_2O–N/kg N).

2.3.3 Avoided greenhouse gas emissions from burning of municipal solid waste in dump sites

The methane and nitrogen oxide emissions were estimated according to the IPCC, volume 2 on energy, chapter 2: stationary combustion, under tier one as stated in Equation 6. The open air burning of the MSW considered under stationary combustion because of the immobile burning. The MSW was left to burn where it was dumped. The combusted fuel was obtained from the amount of MSW that ended up in disposal sites and the emissions factors were default emissions factors as stated in IPCC 2006 [28]. Carbon dioxide emissions accounted for the majority of the GHG emissions from open burning of MSW. However, since its source is biogenic, it was ignored in the calculations.

$$E_{GHG,F} = FCF \times EF_{GHG,F} \quad (6)$$

where $E_{GHG,F}$ = emissions of a given GHG by type of fuel *F*(kg GHG); FC_F = amount of fuel combusted (TJ); and $EF_{GHG,F}$ = default emission factor of a given GHG by type of fuel (kg gas/TJ).

2.3.4 Avoided emissions from fossil fuel consumption

The GHG emissions from fossil fuel were estimated using the average combusted fuel for each fuel types. The historical statistics on fuel consumption in Lusaka were obtained from the energy statistics report by the Central Statistics Office. Equation (7) was adopted from the IPCC [17] to estimate these GHG emissions.

$$E_{GHG} = \sum_{i=1}^{n}[F_i \times EF_i] \quad (7)$$

where E_{GHG} = GHG emissions (kg); F_i = fuel type i sold (TJ); and EF_i = emission factor for fuel type i ($kgTJ^{-1}$).

The magnitude of avoided GHG emissions from the use of biomethane in Lusaka equals the GHG emissions from petrol consumption minus the GHG emissions from an equivalent energy from biomethane that would be produced from municipal solid waste.

2.4 Economic viability

The net present value (NPV) and the payback period (PBP) [29, 30] are the two methods that were used to estimate the economic viability of the biomethane use as a future transport fuel in Lusaka. The basis for using NPV was that if the project NPV is greater than zero the project is considered to be profitable over that time period and the opposite applies for NPV less than zero [31]. The PBP considers the length of time in which the investment is recovered. Equations 8–11 were used to estimate the NPVs and the PBP.

$$NPV_n = (PV_1 + PV_2 + ... + PV_n) - IIC \quad (8)$$

$$PV_n = FV_n * PVF_{n,i} \quad (9)$$

$$PVF_{n,i} = \frac{1}{(1+i)^n} \quad (10)$$

$$PBP = \frac{IIC}{CI} \quad (11)$$

where NPV_n = NPV of a project over n years; $PV_1...PV_n$ = project cash flows from each project year one to n; IIC = initial investment cost; FV_n = the known future value of the project cash flow in year n; PVF_{ni} = a present value factor for the year (n) and the project discount rate (i); PBP is the payback period in years and CI is the cash inflow.

3. Results and discussion

3.1 Biogas potential from municipal solid waste for Lusaka

The waste generation per capita of 0.5 kgd^{-1}, MSW collection efficiency of 40% and organic matter fraction of 40% [32, 33] were used in the estimation. Biogas potential of 128 m^3t^{-1} with 6% losses was used [16] for MSW. The total estimated biogas potential was 16 777 m^3d^{-1}, bringing the total to 6 123 605 m^3y^{-1}. Taking the biogas to constitute 60% methane [21], there would be about 3.67 million m^3y^{-1} of biomethane potential in Lusaka. Table 2 presents the estimated biogas potential.

3.2 Organic fertiliser production

Using Equation 2, the co-product of biogas (bioslurry) that would be produced was estimated to be just above 3 kilotons per annum. With proper packaging and branding, the organic fertiliser could result in an income to the developer and offset some crucial costs. The price of chemical fertiliser was used as a proxy for the estimation of earning from organic fertiliser sales. A 50 kg bag of chemical fertiliser (NPK and/or urea) costs between USD 38.00 and USD 46.00 [34], yielding 0.76–0.92 USD/kg of D-compound or urea. The net income from organic fertiliser sales would be equal to the product between the quantity of the organic fertiliser produced and the unit cost less processing, storage, marketing and miscellaneous costs, which were estimated at 50% based on similar studies [35]. The net earnings from organic fertiliser sales would range from USD 1.2–1.4 million/year.

3.3 Avoided greenhouse gas emissions from chemical fertiliser production

Using Equation 3, the GHG emissions resulting from chemical fertiliser production were estimated to be approximately 2.836 $GgCO_2$ eqy^{-1}. The emission factor (EF_i) was taken as be equal to 3.30 kg CO_2eq kg^{-1} for N-fertilisers [23, 36]. The use of organic fertiliser would, consequently, not produce chemical fertilisers of an equivalent amount. Table 3 gives the calculated GHG emissions avoided from the production of urea and D-compound fertilisers.

3.4 Avoided greenhouse gas emissions from chemical fertiliser application to managed soils

Taking D-compound, urea and organic fertiliser to contain 10, 46 and 10% nitrogen respectively, a net 2.980 $GgCO_2eq$ y^{-1} was estimated (Table 4). Urea contributed the largest percentage to the net GHG emissions from chemical fertiliser application to managed soils because it has the highest nitrogen percentage [37-39].

Table 1: Daily biogas potential for Lusaka.

Constituency	*Population*	*Municipal solid waste generated (kgd^{-1})*	*Biogas potential (m^{3}d^{-1})*
Chawama	184 227	14 738	1 773
Kabwata	171 224	13 698	1 648
Kanyama	366 170	29 294	3 525
Lusaka Central	125 030	10 002	1 203
Mandevu	353 807	28 305	3 406
Matero	278 693	22 295	2 683
Munali	263 828	21 106	2 540
Total	1 742 979	139 438	16 777

Table 3: Greenhouse gas emissions from fertiliser production.

Fertiliser production	*Quantity*	*CO_2eq (Ggy^{-1})*
Urea	1 534 388	2.329
D-compound	1 534 388	0.506
Total		2.836

Table 4: Greenhouse gas emissions from fertiliser application to managed soils.

	Quantity (kgy^{-1})	*Direct N_2O (kgy^{-1})*	*Indirect N_2O (kgy^{-1})*	*CO_2eq (Ggy^{-1})*
Chemical fertiliser (D-Compound)	1 534 388	2 411	259	0.83
Chemical fertiliser (Urea)	1 534 388	11 091	1 192	3.81
Organic fertiliser	3 068 776	(4 822)	(518)	(1.66)
Total		8680	933	2.980

Note: Values in parentheses are negative.

3.5 Avoided greenhouse gas emissions from petrol consumption

Equation 8 was used to compute the GHG emissions from biomethane and equivalent amount of fossil fuel (petrol) that would be replaced by the biomethane. Default emission factors for tier 1 from the IPCC were used in the calculation. When calculating the total energy from each of the two energy sources, 39.82 and 34.20 MJm^{-3} were used as calorific values for biomethane and petrol respectively [40]. The avoided GHG emissions resulting from the use of biomethane as a transport fuel were estimated as the difference between the GHG emissions from the consumption of fossil fuel and the GHG emissions from the biomethane of an equivalent energy. Equation (8) was also used to estimate the amount of GHG emissions from petrol consumption in Lusaka and GHG emissions from an equivalent energy of biomethane that could replace the petrol. The biomethane energy amounted to 146 TJy^{-1}. Table 5 shows that the total GHG emissions from this biomethane were estimated to be 0.418 GgCO_2eqy^{-1}. This biomethane would replace an equivalent of 146 TJy^{-1} of energy from petrol. A total 11.000 GgCO_2eqy^{-1} of GHG emissions would be recorded from the use of petrol (Table 6). Using biomethane would obviate 10.582 GgCO_2eqy^{-1} of GHG emissions. This contribution from the use of biomethane as a transport fuel would be about 5% of the total GHG emissions from petrol consumption in Lusaka. This means that 95% GHG emissions from fossil petrol would be avoided if 146 TJy^{-1} biomethane from MSW is produced and used in Lusaka.

3.6 Avoided greenhouse gas emissions from burning municipal solid waste in dump sites

Waste is normally dumped in legal and illegal sites and later burnt [18, 41-42]. With MSW being used to produce biogas and biomethane, these emissions are reduced to at least half.

Table 5: Greenhouse gas emissions from biomethane consumption as a transport fuel.

	Energy	*Emission factors*		*Emissions*		*CO_2-eq*
	(TJy^{-1})	*CH_4 ($kgTJ^{-1}$)*	*N_2O ($kgTJ^{-1}$)*	*CH_4 (kgy^{-1})*	*N_2O (kgy^{-1})*	*(Ggy^{-1})*
Biomethane	146	92	3	13 432	438	0.418

CH_4 = methane, N_2O = nitrous oxide, CO_2 = carbon dioxide

Table 6: Greenhouse gas emissions from petrol consumption as a transport fuel.

	Energy	*Emission factors*			*Emissions*			*CO_2-eq*
	(TJy^{-1})	*CO_2 ($kgTJ^{-1}$)*	*CH_4 ($KgTJ^{-1}$)*	*N_2O ($KgTJ^{-1}$)*	*CO_2 (kgy^{-1})*	*CH_4 (kgy^{-1})*	*N_2O (kgy^{-1})*	*(Ggy^{-1})*
Petrol	146	69 300	25	8.0	10 117 800	3 650	1 168	11

CH_4 = methane, N_2O = nitrous oxide, CO_2 = carbon dioxide

Table 7: GHG emissions from the burning of municipal solid waste in dump sites.

	Energy (TJy-1)	*EF (kg CH4/TJ)*	*EF (kg N2O/TJ)*	*CH_4 (kgy-1)*	*N_2O (kgy-1)*	*CO_2-eq (Ggy-1)*
MSW	146	300	4	43800	584	1101

MSW = municipal solid waste, EF = emission factor, CH_4 = methane, N_2O = nitrous oxide, CO_2 = carbon dioxide

3.7 Economic benefits

Initial investment costs consist of installation of anaerobic digesters, a biogas upgrading unit and a biogas storage unit. Other costs included in the initial investment include the cost of conducting an environmental impact assessment for the proposed project and planning, and authorisation costs. Annual recurring costs include operational and maintenance, insurance, depreciation, and tax. Project life was estimated at 25 years [43–44]. The cost of anaerobic digesters, biogas upgrading units and storage, with their installation costs, were obtained from publications of similar studies where this technology is fully developed in Poland, Germany, Italy, China and Kenya [3, 45, 46–48]. According to the Environmental Management Act [49], an Environmental Project Brief costing about USD 1 000 (review fee) should be submitted to ZEMA.

The economic viability was determined by estimating the NPV and the simple payback period (PBP) of the proposed project using Equations 9 and 12. Over the years, interest rates in Zambia increased from about 17% to 28% and even higher [50–51]. Table 8 presents the important parameters with their sources used in the economic viability determination. The NPV calculations indicated that the proposed project was viable with NPV values ranging from USD 1 360 000 at 28% to USD 37 000 at 41% interest rates. At 42% interest rate, the proposed project became unfeasible as shown in Figure 1. The simple PBP estimations indicated that the proposed project would recover the initial investment cost within two years. The initial investment cost comprised the capital costs, operating expenses and corporate tax. This amounted in year one to USD 6 083 000 and the annual cash inflow amounted to USD 4 467 000. This implied that in year one there would still be USD 1 616 000 unrecovered. This balance would only be fully recovered in year two. In short, dividing the initial investment cost with the annual cash inflow gives the PBP of 1.4 years, which was therefore taken to be two years.

4. Enabling platform

Biomethane can be produced from a broad range of feedstocks suitable for anaerobic digestion, such as livestock manure, municipal solid waste, food processing wastewater, dairy processing, vegetable canning, potato processing, breweries and sugar production. Shane et al. [32] reported that feedstock for bioenergy and biogas is available in abundance in Zambia, with a surplus of 151 million kilograms of crop residues, 6.5 million cubic metres of forest residue, 304 kilotons of MSW and 4.8 kilotons of livestock manure per year. The water and sewerage companies across the country have the potential to provide wastewater as a feedstock for biogas production. Crop and forest residues can also be used for biomethane production if there is proper seeding and with wastewater having microorganisms.

Table 8: Cash flow for using biomethane as a transport fuel: Lusaka real case example.

Parameter	*Unit*	*Unit cost*	*Reference*	*Quantity*	*USD 1000*
Anaerobic digesters	USDm^{-3}	109	[108]	16 777 m^3	1 829
Biogas upgrading unit	kUSDMW^{-1}	250	[32, 45]	3 886 MW	972
Biogas storage	kUSDMW^{-1}	14.39	[44, 52]	3 886 MW	56
Environmental impact assessment	USD/unit	2.60	[53-54]	433 units	1
Planning and authorisation	%	5	]38]		204
Initial capital costs					**2 858**
Commercial insurance	%	5	[55]		143
Depreciation	%	5.5	[46]		157
Operational and maintenance	USD$_{ct}$kwh^{-1}	4	[47]	34 038 000 kWh	1 362
Total operating expenses					1 662
Earnings					
From organic fertiliser sales					1 381
Biomethane sales	USDCTm^3	84.00	[48]		3 086
Total earnings					4 467
Corporate tax	35%		[56]		1 563
Profit/(loss)					(1 616)

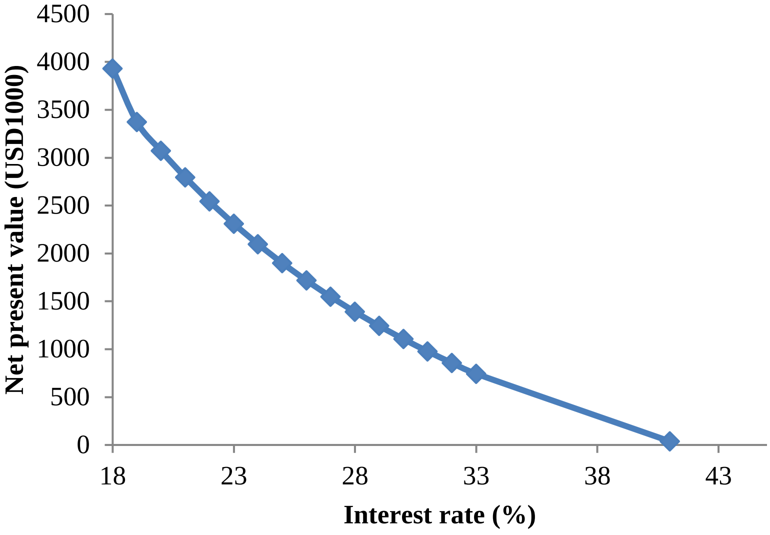

Figure 1: Net present value versus interest rates.

4.1 Biogas upgrading technology availability

For biogas to be used in a motor vehicle as a fuel, it requires processing to upgrade it to compressed biomethane gas. Once it has been compressed it can be transported to the end user or its delivery arranged. Upgrading involves removing carbon dioxide, particles, water vapour, hydrogen sulphide, siloxane, and trace gases such as ammonia, chlorine or fluorine compounds, depending on the feedstock from which biogas has been produced [57].

Figure 2 shows the biomethane upgrading technology using wet scrubbing. This technology has been used in Denmark, Sweden, Norway, USA, Italy, Brazil, Hong Kong, Germany and many other European, American and Asian countries. It is a physical process which takes advantage of the fact that carbon dioxide (CO_2) and hydrogen sulphide (H_2S) are more soluble in water compared to CH_4. The pressurised biogas if fed from the bottom and water from the top of the scrubber. The water exits

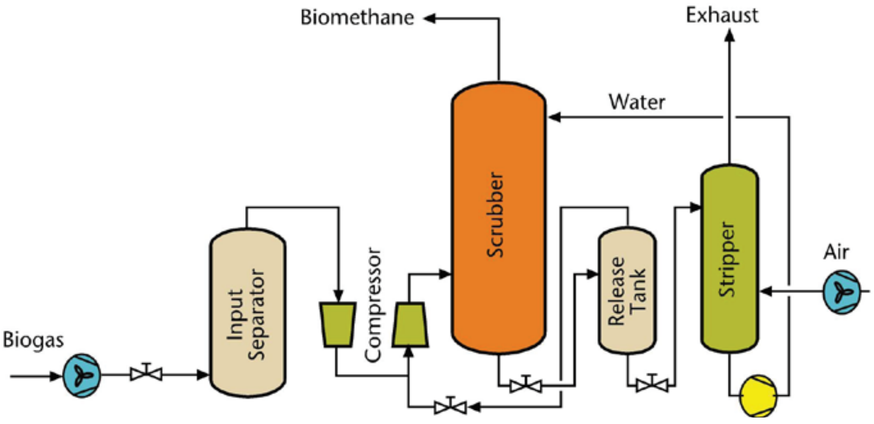

Figure 2: Biomethane upgrading technology - wet scrubbing [58].

with the CO_2 and H_2S dissolved into it at the bottom while the biomethane exits at the top of scrubber [59].

In Zambia, neither light nor heavy duty motor vehicles are ready to use biomethane with the current engine systems. The fuel system of the motor vehicle must be modified so that it can run on gasoline and biomethane, depending on which one is available. Equipment designed for converting petrol engines to use natural gas or petrol is readily available from a number of manufacturers in many countries in Europe and Asia. Technology is readily available on the market to upgrade biogas to biomethane, which could be compressed and used as a fuel for transport in both heavy and light duty vehicles in Zambia. With appropriate policy and implementation, petrol engine light duty vehicles could be targeted first. This would involve adding a biomethane conversion system to each vehicle in addition to the existing conventional one. The reason for targeting light duty petrol engines is that they have a lower fuel consumption and require less sophisticated engine modification requirements than heavy duty ones. They also commonly use petrol or biomethane, as opposed to heavy duty vehicles which mostly use diesel.

5. Conclusions

The study showed a potential to produce 3 670 000 m^3 of biomethane from municipal solid waste with 146 TJy^{-1} of energy. This would result in 10.582 $GgCO_2eqy^{-1}$ of avoided greenhouse gas (GHG) emissions from motor vehicles in Lusaka. The avoided GHG emissions accounted for 95% of emissions from petrol consumption in Lusaka if biomethane replaces fossil petrol. The biogas production process would produce 3 000 tonnes of organic fertiliser as a co-product. The replaced chemical fertiliser would lead to about 5.816 $GgCO_2eqy^{-1}$ as non-CO_2 GHG emissions from its production and application. The net present (NPV) of the proposed Lusaka compressed biogas project as a future transport fuel had a positive NPV at the prevailing market interest rates of between 28–41%, but would became unviable if interest rates increased to about 42%. A simple payback period estimation indicated that the project would recover its initial investment in a maximum of two years. The related data and information gaps that existed in Zambia were also identified, with a potential to contribute to research policymaking, investments, financing and allied parties.

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