



## Production of Biogas and Bio-fertilizer from Abattoir Waste as Sustainable Management, Eastern Ethiopia, 2019

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**ABSTRACT:** Our environment facing by serious problems of high volumes of waste, inadequate disposal system particularly in developing countries worldwide. There is also lack of studies on quantification of abattoir waste and lack of workers awareness towards abattoir waste. Therefore, the purpose of the study was to estimate abattoir waste for bio-energy potential as sustainable management. A cross-sectional study was conducted in four selected abattoirs of Eastern Ethiopia from January 1<sup>st</sup>, 2018 to December 30<sup>th</sup>, 2018. The magnitude of abattoir waste composition were computed based on Aneibo mathematical computational from the actual number of slaughtered livestock. The study demonstrated that four selected abattoirs generates 1,606,403kg of abattoir waste per year and using Fed batch Aerobic digester about 85,139m<sup>3</sup>/year of biogas and 111,249kg/year of bio-fertilizer can be produced. The biogas or energy from the waste can replace firewood and charcoal and the expensive fossil fuels. Using Banks mathematical computation about 85,139.20m<sup>3</sup>/year of biogas estimated, could cover 36097.43kg of liquefied gas or 48129.89kg of kerosene or 280757.68kg of charcoal or 32086.59kg of furnace oil or 56151.5kg of petrol or 40108.2kg of diesel per a year in same functions. The current estimated bio-fertilizer (111,249kg/year) from four abattoir sites can cover about 2,225 hectares per a year with its advantage and efficiency of soil. When in turned into cost, about \$55,645 per a year of price could estimate from biogas and bio-fertilizer. The study concluded that huge amount of biogas and dry bio-fertilizer yields could produce from abattoir waste through fed batch anaerobic digestion. Therefore, install fed batch anaerobic digestion plant is recommended to ensure environmental safety and public health.

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Abattoirs are where animals such as cattle or goat or sheep and others are slaughtered in for consumption as food and it is also known as slaughterhouse. Livestock production in abattoirs is considered a potential food for the world's needy people and during meat production huge amount of abattoir wastes are generating from them (FAO, 2010). In this way, abattoir waste management is a major challenge in urban areas throughout the world. Here, threat of abattoir waste resulted from improper managements of abattoir waste can therefore exert oxygen demand on the receiving environment or breed large population of decomposers (microorganism) some of which may be pathogenic (Gauri et al., 2006). Especially, low-income countries show rapid urban growth that is putting extraordinary pressure on gigantic amount of abattoir waste in the urban (Ezeoha and Ugwuishiwu, 2011). The production of meat, from farm to fork, includes not just meat for human consumption and useful by-products like leather and skin, but also waste. Abattoir operations produce a characteristic highly organic waste with relatively high levels of

suspended solid, liquid and fat (Aneibo et al. 2009). These countries are the worst it given the deficient waste management programs (Fearon et al., 2014). In most of them haven't organized strategy for disposal of solid as well as liquid wastes generated in abattoirs (Akinro et al., 2011). As FAO (2010) reported, these dumped as solid abattoir wastes without any further processing or composting, or they are washed away. The nature and quantity of the waste varies at each stage, but includes the carcasses of dead animals, parts of animals which are treated as inedible, bones, hides and blood. Approximately 50–54% of each cow, 52% of each sheep or goat, 60–62% of each pig, 68–72% of each chicken and 78% of each turkey end up as meat consumed by human beings with the remainder becoming waste after processing (Alonge, 2005). Moreover, of abattoir waste, the volume of waste water from abattoirs is 70 – 75% of the abattoir water that contributes to a high organic load as well as a considerable amount of suspended material in the waste (Roberts et al, 2011). This causes pollution has potential to pollute air, water and soil leading to health

hazards (FAO, 2009). Abattoir wastes affect air quality, agriculture, potable water supplies, and aquatic life, which are also pose risks to human and cause methaemoglobinaemia (Adeyemi and Adeyemo, 2007). Yet, huge amount of wastes generating from selected Eastern Ethiopia abattoirs and they simply discharging and releasing their wastes into open environment without any management system or treatment pond. The authors observed that abattoir wastes are not properly treated and managed. Moreover, there was no data available regarding quantification of abattoir waste for sustainable management. Therefore, the purpose of the study was to estimate abattoir-waste generate from selected abattoirs and estimate its potential for bio-energy as sustainable management.

## MATERIALS AND METHODS

*Study Settings:* The study areas are found in Eastern Ethiopia; the first three study areas are Harar Abattoir; Haramaya University Abattoir Enterprise and Haramaya abattoirs, which are found in Harar; Haramaya University and Haramaya towns; about 503 km, 508km and 527km, respectively far from the national capital Addis Ababa. They are characterized by subtropical highland climate, throughout the year, afternoon temperatures are warm to very warm, cool at mornings and rain falls between March and October (<https://en.wikipedia.org/wiki/Harar>). The second study is Dire Dawa abattoir, which is found in Dire Dawa Admiration and far 453km from Addis Ababa. It has 9°36'N41°52'E latitude and longitude with Coordinates of 9°36'N41°52'E. The city is characterized by hot semi-arid climate. The region has two rain seasons; that is, a small rain season from March to April, and more rain season from July to August ([https://en.wikipedia.org/wiki/Dire\\_Dawa](https://en.wikipedia.org/wiki/Dire_Dawa)).

*Study Design:* A cross sectional study was conducted in selected abattoirs of Eastern Ethiopia, namely, Haramaya, Haramaya University enterprise, Harar and Dire dawa abattoirs

*Abattoir Waste Estimation Methods:* All number of slaughtered livestock such as cattle, goats and sheep were collected from January 1st, 2018 to December 30, 2018 from each registry municipalities. For abattoir waste generation Aniebo et al (2009) mathematical model was applied. "One cattle could produce 12.6kg of blood waste, 8.0 kg of intestinal content waste, 6.4kg of waste tissue waste and 11.8kg of bone waste (total 38.8). Similarly, One slaughter Goat/sheep/ could generate 0.72kg (blood waste), 1.25 kg (intestinal content waste), 0.8kg (tissue waste) and 2.06kg (bone waste (total 4.83kg).

$$\Sigma(bLw + Bnw + Icw + Tw) * N \quad (1)$$

Where: BLw= blood waste, Bnw=bone waste, Icw=intestinal content waste and Tw=tissue waste; "N" is number of slaughtered livestock.

*Estimation of Biogas production from Abattoir waste:* In this study, biogas production was calculated following the model of Rao et al. (2000), in which it states 1ton (1000kg) of abattoir waste produces 53m<sup>3</sup> biogas that is 1Kg of abattoir waste can produce 0.053 m<sup>3</sup> of biogas. Hence, the volume of biogas produced (VBP) may be obtained using the following formula (eqn. 2):

$$VBP = AWG * 0.053m^3/kg \quad (2)$$

*Estimation of Energy from Biogas:* According to Ngumah et al. (2013), the energy potential of biogas generated is based on the calorific value (high heating value) of the methane content and Rohstoffe (2009) stated that the average calorific value of biogas is 21-23.5 MJ/m<sup>3</sup> (approximately 22.0 MJ/m<sup>3</sup>). Commonly, energy is expressed as Kilo Watt hour (KWh) and 3.6 MJ is equal to 1KWh. If the 22.0 MJ/ m<sup>3</sup> of biogas is converted to KWh, 1m<sup>3</sup> of biogas has an energy potential of 6.1 KWh. Energies (electricity and heat) potential of biogas was estimated based on the energy conversion methods formulated by Banks (2009). According to Banks (2009), the efficiency of biogas to be converted to electricity is 35% and hence, 6.1 KWh X 0.35 equals to 2.14kWh (i.e. production potential of 1m<sup>3</sup> of biogas is 2.14 KWh. Therefore, the Electricity production potential (EPP), (KWh), may be obtained using the following formula:

$$EPP = VBP * 2.14kWh \quad (3)$$

Similarly, Banks (2009) indicated that the efficiency of biogas to be converted to heat energy is 50% and, thus energy potential of 6.1 KWh X 0.5=3.1kWh. The heat production potential (HPP), (KWh), may be estimated as:

$$HPP = VBP * 3.1Kwh \quad (4)$$

*Estimation of Cost from biogas energy:* Amount of energy produced was estimated based on the current Ethiopian Electric Power Corporation /EEPC/ (2018) into cost; i.e the minimum cost (tariff) of 1 KWh of electricity or heat is 0.021USD (0.57 ETB).

$$Cost = (Eq.3 * 0.021USD) + (Eq.4 * 0.021USD) \quad (5)$$

*Reduction of GHGs using Biogas technology:* To know the Greenhouse emission from dumping sites

calculated based on IPCC, 2000; B-Sustain 2013a; JGCRI, 2018) mathematical computation, which are summarized as follows:

$$\text{GHGs emission} = [(Q \times \text{DOC} \times \text{DOCF} \times F1 \times 1.336 - R) \times (1 - \text{OX})] \times 25 \quad (6)$$

where, Q = Quantity of abattoir waste expressed in tones/kg/ from waste records; DOC= Degradable Organic Carbon of abattoir waste proportion ( default value(DV)=0.12) ; DOCF= Fraction of degradable organic carbon dissimilated for the abattoir waste (DV=0.7) ; F1= Methane fraction generate from dumping gas (DV = 0.50) ; 1.336= Conversion rate of carbon to methane; R= Recovered methane during the year, measured in kg or tones (here no recovered methane); OX=Oxidation factor (DV= 0.1 for well-managed and (DV= 0 for un managed ); and 25=CH<sub>4</sub> global warming potential used to convert the quantity of methane emitted to CO<sub>2</sub>-e from the quantity of abattoir waste produced

$$\text{GHG emissions (tCO}_2\text{e)} = Q_j \times \text{EF}_j \quad (7)$$

Where: t is unit for waste (kg or tone); CO<sub>2</sub>e is carbon dioxide in equivalence; Q<sub>j</sub> is the quantity of waste by type j (here is only abattoir waste); EF<sub>j</sub> is the emission factor of waste type j for biogas (0.02kgCO<sub>2</sub>-e). Hence, emission of reduction of GHGs using Biogas (R\_GHG\_B) will be calculated:

$$R\_GHGs\_B = \sum \text{Equation 6} - \sum \text{Equation 7} \quad (8)$$

*Equivalence of Biogas with expensive fossil fuels:* As Blotnitz (2010) and B-Sustain (2013a) energy estimation , utilization 1m<sup>3</sup> of biogas equivalent (Eq\_B) to coefficient factor of 0.45kg Liquefied Petroleum Gas(LPG) or 0.6kg kerosene(K) or 3.50kg charcoal/fire wood or 0.4kg furnace oil (F) or 0.7kg petrol (P) or/ and 0.5kg diesel(D) in the same activities. Thus equivalence biogas with other fossil fuels could be calculated as:

$$\text{Equivalence Biogas} = \sum \text{CFF} * N \quad (9)$$

Where, CFF: Coefficient factor for above fuels; N: Volume of biogas produced (i.e. Equation 2)

*Bio-Fertilizers Yield Potential Estimation Methods:* According to Ngumah et al. (2013), the coefficients used in estimating bio-fertilizer yields were based on the fraction of the dry mass (DM) portion of organic waste that is not converted to biogas. Therefore, in this study, bio-fertilizer was estimated based on the coefficient fraction of the Dry Mass (DM) and Volatile Solid (VS) portion of abattoir waste. According to Dublein and Steinhauser (2008), the DM percentage of

fresh organic wastes was given as 15% for abattoir waste, while the Volatile Solids(VS) is the potentially dry mass (DM) of abattoir waste converted into gas (i.e. dry mass minus mineral content), which was calculated by multiplying 85% with DM of abattoir waste. In this study, the following formulas were used for calculating DM and VS.

$$\text{DM} = \text{AWG} * 0.15 \text{ (15\%)} \quad (10)$$

$$\text{VS} = \text{DM} * 0.85 \text{ (85\%)} \quad (11)$$

Bio-fertilizer production was estimated from abattoir waste based on Dublein and Steinhauser (2008) coefficient fraction model as following equations of the dry mass portion (DM) and therefore, based on this principle, the Bio-Fertilizer Yield (BFY) of the abattoir waste was calculated considering DM and VS. But according to Burke (2000), 60% of VS is the actual fraction taken to be converted to biogas and the remaining 40% portion of VS was considered in BFY computation. Hence the potential of BFY was deduced as:

$$\text{BFY} = (\text{DM} - \text{VS}) + (40\% * \text{VS}) \quad (12)$$

*Estimation of Cost from bio-fertilizer Production:* Based Ethiopian Agriculture Ministry Report (2017/18) report, 50kg of UREA and DAP fertilizers are equals to 1230 Ethiopian Birr (ETB) and 1, 1455ETB, respectively. We assumed that the price of Bio-fertilizer yields (BFY) was reduced by half (≈50%, i.e.50kg of UREA and DAP equals to 600 Ethiopian Currency or 23.70 US dollar from current price of chemical fertilizers. This Reduction was assumed that, the bio-fertilizer and its benefits among our farmers may low acceptance due to limited awareness about it.

$$\text{Cost of BFY} = \text{NBFY} * 23.70 \text{ (USD)} \quad (13)$$

Where NBFY is stands for Production of bio-fertilizer in kilogram

*Dissemination of the study:* The findings of the study was disseminate to Haramaya University Research Office, Haramaya, Harar and Dire Dawa abattoirs. In Addition, attempts to be made to publish of the study.

*Data Analysis:* Data was entered in to SPSS, Version 20 for analysis. Descriptive statistics such as frequency (F), range, mean (M), sum, percentage and standard deviation (SD) for numerical to summarize and describe the data to make them more graspable

*Ethical Consideration:* Permission to conduct this “Grant research coded “HUKT-2018-01-03-63” was provided by Haramaya University Research Partnership and Group Directorate. The reviewer of proposal and Ethics Committee of Haramaya University were approved this research project. Then, Haramaya University Health and Medical Sciences was written the formal letter to Haramaya town, Haramaya University Enterprise, Harar town and Dire Dawa Municipality Authority abattoir service for realization of legal research.

## RESULT AND DISCUSSION

*Slaughtered Livestock:* The study was sought to focus on abattoir waste generation from selected Eastern Ethiopia abattoirs namely: Harar Abattoir, Dire Dawa Abattoir, Haramaya Abattoir and Haramaya University Enterprise Abattoirs. About 18/day and 6,339/year, 110/day and 10,170/year, 28/day and 39,281/year, and 12/day and 4,490/year of livestock were slaughtered in Harar Abattoir, Dire Dawa Abattoir, Haramaya and Haramaya University Enterprise (HU-E) abattoirs, respectively. From total 169 and 60,170 of slaughtered livestock, more than 9, 227kg/day and 3,315,357kg/year of meat could distribute for surrounding community with year of 2018/2019 (Table 1).

*Abattoir Waste Composition and Generation:* Aneibo (2009) mathematical computation approach was used to estimate abattoir waste composition generated from the abattoirs during meat production due to its complexity and difficulty of abattoir waste. The main principal abattoir waste compositions considered in this study were blood waste, bone waste, intestinal content waste and tissue were considered in this assumption. During production of meat about 224,366kg/year, 1,015,59kg/year, 192,253kg/year and 174,193kg/year of abattoir wastes was estimated from Harar abattoir; Dire Dawa city; Haramaya town; and Hu-enterprise abattoirs, respectively (Table 2). From total abattoir waste generated, the percentage of abattoir waste compositions weight is generated from each abattoirs is varied separately. For instance, 30%, 30%, 31% and 41% of bone composition and 32%, 32%, 31% and 21% of blood waste was estimated from Harar, HU-Enterprise, Dire Dawa and Haramaya abattoirs, respectively (Figure 1). However, the percentage of these abattoir waste compositions was varied generated among selected abattoirs (Figure 1). That means the proportion of abattoir waste compositions generated from selected abattoirs were not be same. This is because of slaughtered livestock type (such as cattle, goats and sheep). For instance,

when high number of goat and sheep slaughtered in abattoir it was resulted high amount of bone was estimated and followed by blood, intestinal content and tissue waste, respectively. Such type of waste composition estimation was observed in Haramaya and Dire Dawa Abattoirs. But, blood waste composition was highest among abattoir waste compositions in Harar and Haramaya University enterprise where purely cattle were slaughtered; and then followed by bone, intestinal content and tissues waste composition, respectively (Figure 1). The study indicated abattoir waste generation produced the throughout the year was varied among months due to livestock slaughtered were varied as the result of different fasting and meat-eating holidays. This can result high amount of abattoir waste generation could be obtain from abattoirs was resulted from high number of slaughtered livestock. The study revealed that half percent of abattoir waste generated during study period was from Dire Dawa municipality abattoir. While Harar town municipality, Hawassa University enterprise municipality and Haramaya town municipality was accounted the remaining percentage of abattoir waste compositions in decreasing order (Figure 1). The present study indicated that more than sixth thousand kilogram (more than six ton) of abattoir waste was generated per a day; annually more than two million kilogram (more than two thousand ton) of abattoir waste was estimated from four selected Eastern Ethiopia abattoirs (Table 2). As contrast, the current abattoir waste estimated (1,440,755.26kg/year) generated from Dire Dawa Municipality abattoir is higher than with finding (923,995kg/year) obtained from Hawassa Town municipality found in south Ethiopia reported by Tolera et al. (2019). Similarly, it higher than the abattoir waste could generate from Elfora Kombolcha abattoir (1, 234, 434kg/year) found in North Ethiopia, Adama town abattoir (895, 621kg/year) found in South-East Ethiopia and Mekele city abattoir ( 8345678kg/year) found in Northern Ethiopia, at which raw data (i.e. slaughtered cattle were reported by Yesihak and Edward (2015). Moreover, it is also higher that the data recorded in Minna abattoir, Abuja Nigeria (873,810 kg/year) reported by Ahaneku et al (2015); Tamale municipality abattoir, Ghana (778,910 kg/year) reported Frederick et al (2010). However the finding obtained from Harar town municipality abattoir (494,819.04kg/year); Haramaya municipality abattoir (432,639.80kg/year); Haramaya University enterprise abattoir (424,860.00kg/year) was smaller than the finding reported by (Frederick et al., 2010; Yesihak & Edward, 2015; Ahaneku et al., 2015; Tolera et al., 2019). Moreover, the current abattoir waste generate could contrasts with other organic municipality wastes that are generating from the



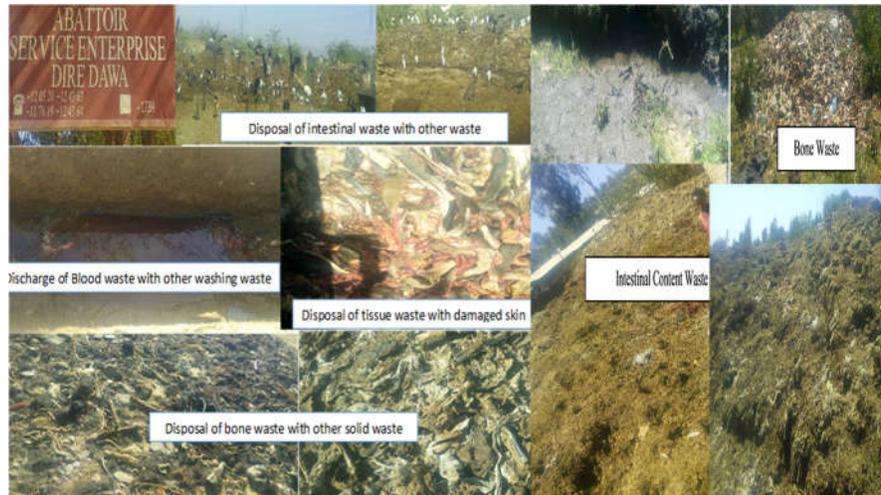


Fig 2 Waste disposal site of abattoir waste from selected municipality abattoirs, March, 2019

Table 3 Annual Estimation Greenhouse gases emission from disposal sites of abattoirs, 2019

Name of abattoirs	GHGs Emission From Dumping Sites(*kgCO <sub>2</sub> e)			
	Daily	Weekly	Monthly	Annually
Harar	73.76	516.35	2212.91	26942.22
Dire Dawa	333.89	2337.18	10016.14	118,941.44
Haramaya	63.21	316.42	1283.08	15,353.80
HU-Ent.	57.27	400.88	1718.06	20,393.28
Grand total	528.13	3570.83	15230.19	181,630.74

**NB:** \*kgCO<sub>2</sub>e= A kilogram of carbon dioxide equivalent, also abbreviated as **kgCO<sub>2</sub>e** is a metric measure used to compare the emissions from various greenhouse gases on the basis of their global-warming potential (GWP).

As many scholars reported improper disposal of wastes like abattoir waste is one of the big problem for climate change over all the world due to greenhouse gases/GHG/ emission from their disposal sites (Chukwu, 2008). Thus, to estimate greenhouse gases emission from disposal sites, the authors used IPCC (2000) and GWPs coefficient factors. These coefficient factors, it is possible to estimate the amount of GHGs emission from four disposal sites of the selected abattoirs. Table 3 shows that more twenty six thousands of kilogram of carbon dioxide equivalence of greenhouse gases (Table 3) was emitted from almost two hundred twenty four thousands of abattoir waste disposed site of Harar town abattoir per a year (Table 2); while more than one hundred eighteen thousand and nine hundreds kilogram of carbon dioxide equivalence of greenhouse gases (Table 3) was estimated from one million and fifteen thousand kilogram of abattoir waste disposed at sites of Dire Dawa administration city municipalities (Table 2). As combined, more than one hundred eighty one thousand and six hundreds kilogram of carbon dioxide equivalence of greenhouse gases emission (Table 3) was estimated from one million, six hundred thousand and six thousands kilogram of abattoir waste estimated from the disposed sites of four selected abattoirs found in Eastern Ethiopia (Table 2). Hence, such amount of gases contribute to climate change and could enhance

greenhouse effect, contribute on the sea-level rise and changes in rainfall patterns with implications for floods and droughts; and changes in the incidence of climatic as Anthony et al (2009) reported. Hereby, these amount of greenhouse gasses emission from the disposal sites of selected municipal abattoirs are one of the significant sources of air pollution at surrounding cities fully and at national level particular.

*Potential of Abattoir Waste: Biogas Production, Heat and Electricity and its cost:* The table shows about 11892m<sup>3</sup>/year, 53826m<sup>3</sup>/year, 10189m<sup>3</sup>/year and 9263.87 m<sup>3</sup>/year of biogas production was estimated from Harar; Dire Dawa; Haramaya; and HU-E abattoirs, respectively (Table 4). Using energy conversion coefficient equations, about 104336.99 kWh/year, 282049.65kWh/year, 282049.65kWh/year and 48,542.68kWh/year of electricity and heat energy was estimated from Harar town municipality, Dire Dawa administrative municipality city administration, Haramaya town municipality and Haramaya university enterprise abattoirs, respectively (Table 4). When converted biogas into cost, about \$1254.3(35823ETB), \$5624.2(160627ETB), \$1072.2(30623ETB) and \$971.1(27734 ETB) cost was estimated annually from Harar Abattoir; Dire Dawa Abattoir; Haramaya Abattoir; and HU-E abattoir, respectively (Table 4). The first product of

Feed batch Aerobic digester is that it produce biogas, which is environmental friendly product. The current finding revealed that more than two hundreds cubic meters of biogas production was estimated (Table 4) from four selected abattoirs and which could use for cooking, lighting, and heating. From this daily biogas production more than one thousand kilo watt per hour about of energy was estimated and when in turned into cost, more than twenty five dollar or more than six hundred in Ethiopian currency (Birr) price was estimated from these selected abattoirs (Table 4). Our country, Ethiopia has trying to install big project for anaerobic breakdown of organic matter (e.g., animal or human waste, food waste or plant material) ultimately alternative energy in which from to biomass. The country has been started the biogas implementation in the first Growth Transformation Program (GTP-I) and in the phase two (GTP-II) of strategic plan. This strategic plan has multitude of advantages to society and for forming sustainable environment, the wider dissemination of the technology (NBP, 2007). While, GTP-II: Alternative

energy strategic to achieve national biogas programs development goals of the second Growth and Transformation Plan (GTP-II) of the country should be a considerable focus on exploiting and initiating abattoir waste as raw materials that generated from other different abattoir operations found in the parts the country (GTP II, 2016-2019/20). Therefore, our finding was inline and encourage this strategic plan in order to any organizations or institutions found in the country could apply bioenergy from organic waste like abattoir waste as sustainable rather than disposing elsewhere.

*Possible Reduction of Greenhouses gases Using IPCC (2000), B-Sustain (2013a) and JGCRI (2018) mathematical computation model was applied. In case of Harar abattoir, from 26,942kgCO<sub>2</sub>e/year of Greenhouses gases/GHG/ estimated from disposal sites, could reduce 22,437kgCO<sub>2</sub>e/year of GHGs emission using AD and only 4,486kgCO<sub>2</sub>e/year of GHGs was estimated from fed batch anaerobic digester (Table 5).*

**Table 4** Annual Estimation of Energy from estimated biogas of selected abattoirs; Jan, 2019

Name of abattoirs	Estimated waste(Kg)	Estimated Biogas (*m <sup>3</sup> )	Estimated energy from produced biogas and its cost			
			Heat (**kWh)	Electricity (kWh)	Total energy(kWh)	Estimated Cost (*\$)
Harar	224,366	11,891.61	25,448.1	78888.94	104336.99	1254.3
Dire Dawa	1,015,591	53,826.27	115,188.2	166861.4	282049.65	5624.2
Haramaya	192,253	10,189.25	21,805.00	31,586.7	53,391.67	1072.2
HU-Ent.	174,193	9,263.87	19,824.68	28,718.0	48,542.68	971.1
Grand total	1,606,403	85,139.20	182,197.9	263,931.5	446,129.41	8901.6

\*m<sup>3</sup>: Cubic Meter=1000kg; \*\*kWh: Kilowatt- hour; \*\*\*United State Dollar (USD):1 = 28.5163: Ethiopian Currency (ETB); April, 2019

**Table 5** Estimation of potential reduction of GHGs emission using anaerobic digester per a year

Name of abattoirs	Annual Reduction of GHGs(kgCO <sub>2</sub> e) using Anaerobic Digester			
	Estimated waste (kg)	GHGs Estimated from dumping	Estimated of GHGs from AD	Potential of AD reduction
Harar	224,366	26942.22	4,486	22,437
Dire Dawa	1,015,591	118,941.44	20,312	101,558
Haramaya	192,253	15,353.80	3,843	19,225
HU-Ent.	174,193	20,393.28	3,482	17,418
Grand total	1,606,403	181,630.74	32,127	160,640

**Table 6** Equivalence of estimated biogas with other fossil fuels from selected abattoirs, 2019

Name of abattoirs	Estimated Biogas(m <sup>3</sup> )	Annual substitution of expensive fuels by utilization of biogas					
		Liquefied Gas (kg)	Kerosene (kg)	Charcoal (kg)	Furnace oil (kg)	Petrol (kg)	Diesel (kg)
Harar	11,891.61	5354.77	7139.69	41648.18	4759.79	8329.64	5949.74
Dire Dawa	53,826.27	23640.1	31520.16	183867.6	21013.44	36773.5	26266.8
Haramaya	10,189.25	3050.42	4067.22	23725.45	2711.48	4745.09	3389.35
HU-Ent.	9,263.87	4052.12	5402.82	31516.45	3601.88	6303.29	4502.35
Grand total	85,139.20	36097.43	48129.89	280757.68	32086.59	56151.5	40108.2

\* Indicated unit for biogas is cubic meter; while \*\* indicated unit for all fossil fuels is kilogram

As showed in table5, the second benefit of AD through biogas is that it can lesser impact of waste from surrounding climatic change (i.e. lesser emission of greenhouse gases into environment), which is currently the issue of world population and government politics. Thus do this, implementation of

AD is significant. For example, Table 3 shows that more than one hundred eighty one thousand and six hundreds kilogram of carbon dioxide equivalence of greenhouse gases emission (181,630.74kgCO<sub>2</sub>e) (Table 3), which could avoid about one hundred sixty kilogram of carbon dioxide equivalence of greenhouse

gases (160, 640kgCO<sub>2</sub>eq) using fed batch anaerobic digester and almost only thirty (Table 5) two thousand kilogram of carbon dioxide equivalence of greenhouse gases (32, 127 kgCO<sub>2</sub>eq) emitted by fed batch anaerobic digester when it implement based on this baseline. Biogas could substitute other fuel fossil: The following table shows that from 85,139.20m<sup>3</sup>/year of biogas estimated, could cover 36097.43kg of Liquefied Gas or 48129.89kg of Kerosene or 280757.68kg of Charcoal or 32086.59kg of Furnace oil or 56151.5kg of Petrol or 40108.2kg of Diesel per a year in same functions (Table 6). As illustrated above table, substitution of biogas instead of other expensive fossil fuels is third vital benefits of biogas. The second benefits of biogas is to substitute the other expensive fossil fuels such as liquefied petroleum gas, kerosene, charcoal, furnace oil, petrol and diesel fuel with the equivalence functions and because biogas is a “cleaner” than these fuels(Charles,2009). For example, almost eighty five thousand of estimated biogas could cover an average per capita consumption more than two hundreds eighty thousand kilogram of charcoal (Table 5). Essentially charcoal and wood fire is common in immediate household those are living in surrounding. So that implement this biogas project for each municipality abattoir could help more than 200 head of households for their daily activities such as cooking, heating and boiling water. Therefore, biogas has the potential to substitute the most expensive finite

fossil fuels and charcoal with their drawback with the community. The fourth significant of AD by means of biogas is that it is a supplementary for economy prosperity, social and for country development. In this study, the current finding shows that more than eight thousands of United States dollar (\$8901.6) was estimated from biogas estimated from four selected abattoirs per a year. Scholars confirmed biogas improving economic of the country or abattoir itself through the means of creating markets for surrounding community by leading to lesser the cost (Chukwu et al., 2011).

Bio-Fertilizer Production and with its Cost: Table 7 shows 45.20kg/day and 16,502.11kg/year; 204.51kg/day and 72,851.63kg/year; 38.71kg/year and 9,404.20kg/year; and 35.08kg/day and 12,490.88kg/year of bio-fertilizer was estimated from Harar, Dire Dawa, Haramaya and Haramaya University enterprise abattoirs, respectively(Table 7). When in turned in to cost, about 19.0(542ETB)/day and \$6933.7(198,025 ETB)/year; \$85.9(2,454ETB)/day and \$30609.9(874,220 ETB)/year; \$16.3(465ETB)/day and \$3951.3(112,850 ETB)/year; and \$14.7(421ETB)/day and \$5248.3(149,891 ETB) of bio-fertilizer was estimated from Harar town abattoir, Dire Dawa administration of abattoir, Haramaya abattoir and Haramaya University enterprise abattoir, respectively (Table 7).

**Table 7** Estimation of bio-fertilizer production from abattoir waste of selected abattoirs, 2019

Name of abattoirs	Estimated Abattoir waste	Estimated Residual for Bio fertilizer and Its Cost Benefits			
		Dry Mass/DM/	Volatile Solid/VS/	Bio fertilizer(Kg)	Estimated Cost (US dollar)
Harar	224,366	33,677.77	28,626.10	16,502.11	6933.7
Dire Dawa	1,015,591	148,676.80	126,375.28	72,851.63	30610
Haramaya	192,253	19,192.25	16,313.41	9,404.20	3951.3
HU-Ent.	174,193	25,491.60	21,667.86	12,490.88	5248.3
Grand total	1,606,403	227,038.42	192,982.65	111,248.83	46,743.2

AD\*: Fed batch Anaerobic Digester for Abattoir waste digestion; \*\*: United State Dollar (USD) 1= 28.5163 Ethiopian Currency (Birr); April, 2019

Production of bio-fertilizer, the residual part of abattoir waste is considered the second product of anaerobic digester. The current study shows that about more than one hundreds tones of bio-fertilizer was estimated per a year from four selected abattoir (Table 7). As land coverage, from annual the current estimated of bio-fertilizer, almost two thousands, two hundred and twenty five hectares can cover per year that increased from 15% to 25% of total crop yield with advantage and efficiency of soil which was described under website and deal “Agronomies” (Renuka, 2013). Now day, such benefits are important considerations both by government or users. Essentially, bio-fertilizer reduces water and soil pollution, loss of micro-organisms and beneficial insects; overall reduction in soil fertility is some of the ill effects of chemical fertilizers. So that this study give

a clue of bio-fertilizers significance which hold promising future in reducing soil quality problems with optimum crop yield for users and farmers as well (Renuka, 2013). When in turned into price, more than forty six thousands United States dollars (\$46,743.2) was estimated from four selected abattoirs found in Eastern Ethiopia (Table 6). The estimation was based on current chemical fertilizer price by considering market feasibility, was considered how bio-fertilizer is perceived in terms of value offered for money spent by customers. In such circumstances, the researchers have decided the price of bio fertilizers along with the risk and responses was weighed. In fact, the current price of chemical fertilizers or inorganic fertilizer used at national level was less halved (<50%) to estimate the cost of the current bio-fertilizer. That means such amount of price from inorganic fertilizer was reduced

by half and the present estimated bio-fertilizer cost, which could be covered two times of hectares as compare to inorganic chemical coverage. In other hands, this income generation is also supplementary of internal revenue for the abattoirs themselves. Therefore, using anaerobic digestion for abattoir waste can provide subsequent generations a more healthy economy, a fairer, a more inclusive society and a cleaner environment (Chukwu et al., 2011). So that present finding encourage 2nd GTP targeted, that recommended as “Every governments’ organization should increase their internal resource mobilization of income benefits not less than five percent of their governmental allocation (i.e. >5% of normal budget allocation from government) (NPC, 2<sup>nd</sup> GTP, 2015/2016-2019/20). Moreover, AD is a potential to reduce pollutions, greenhouse gases emissions as compared to other waste treatment. In addition, it has a benefits to mitigate global climate changes and optimize and keep soil health.

*Limitation of study:* The research didn’t deal with number of livestock slaughtered around homes or outside the selected abattoirs including slaughtered camels in these abattoirs. In addition, the magnitude of abattoir waste was estimated based on assumptions that was adopted from other African scholar context, which might be leads either lower or higher abattoir waste estimation record in these study areas due to size of cattle, sheep and goats.

*Conclusion:* The present study shows that large quantity of abattoir waste was generated as compared to other waste generated, which was directly disposed into the surrounding environment without any disposal system. The study also indicated that huge amount of biogas and bio fertilizer yield obtained through anaerobic digestion indicated that abattoir waste have a potential benefits to ensure environmental safety and public health as means of sustainable management. Thus, the municipality should design abattoir waste treatment technology as sustainable management to safeguard the environment and ensure public health for the as long term plan, while proper abattoir waste disposal will forward as short term.

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