ASSESSMENT OF EFFECTIVENESS TO REDUCE GREENHOUSE GAS EMISSION OF BIOGAS DIGESTERS IN LIVESTOCK MANURE TREATMENT AT VAN CU RICE NOODLE CRAFT VILLAGE, THUA THIEN HUE PROVINCE

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ABSTRACT

This paper used some calculation techniques of IPCC to quantify the economic and environmental benefit from greenhouse gas (GHG) emission mitigation at Van Cu rice noodle craft village, Huong Toan commune, Huong Tra town, Thua Thien Hue province. The resulting calculation showed that the GHG emission amount of Van Cu rice noodle craft village was 1,572.3 tonnes of CO_2e/ year, in which the GHG emission of households who had activities of swine breeding and rice noodle producing had accounted for 78% of total emissions of the whole village. There were 24 biogas digesters in 31 households had built biogas works that were working well and creating biogas for usage as fuel to service of life. Therefore, this study surveyed at 24 households were using biogas works efficiency. Before using biogas works, average GHG emission reached 51.0 tonnes CO_2e/ household/ year. After using biogas digesters, total GHG emission of 24 households reduced 267.6 tonnes of CO_2e/ year. Thus, the total GHG emission amount was cut down 956.5 tonnes of CO_2e/ year, corresponding to revenue from the sale of certified emission reductions (CERs) was 13.04 million dong/ year.

Keywords: biogas, certified emission reductions (CERs), emission, Van Cu rice noodle craft village.

1. INTRODUCTION

Van Cu rice noodle craft village had 162 households that joined in rice noodle production with 20,330 kg/day in 2016. Wastewater from rice noodle production was 216.5 m^3/day. Furthermore, community at this village had recycled by-products to swine breeding with 43.3 kg/day. This village had 264 households joined in swine breeding in the total of 342 households of village. The number of swine was 2,568 heads. A wastewater of swine breeding was about 230.7 m^3/day. Wastewater about 403.0 m^3/day that is not treat, and discharge into received sources to cause environmental pollution. Furthermore, there were 88 % of total households of village that had composted or collected in to tanks. And there were 31 households of 264 households (accounted for 11.7 %) that had biogas digesters. Thus, solid waste from rice noodle production and swine breeding was also concerned at this village.

2. MATERIALS AND METHODS

2.1. Collecting data

Surveying socio- economic information of Van Cu rice noodle craft village, the status of swine breeding, the demand of fuel at village. Van Cu village had 342 households. Collecting and surveying information at 264 households that had swine breeding (77.2 %) and 162 households that had rice noodle production (47.4 %) of total households at Van Cu village. This village had 10 sub villages and 30 biogas digesters, in which there were 24 works that were going good active and create gas. Thus, we choose 24 good biogas digesters to study.

2.2. Estimation of greenhouse gas emission

Using some calculation techniques (Tier 2 method) of the Intergovernmental Panel for Climate Change (IPCC) [1] and United Nations Framework Convention on Climate Change (2009- 2010) [3, 4] to quantify GHG emission at Van Cu village.

Table 1. GHG were used to calculate [1]

	Emission sources	GHG	Use
Before using biogas digester	(1) Emissions from stool vaults	CH_4, N_2O	X
	(2) Emissions from fuel	CO_2, CH_4	X
After using biogas digester	(3) Leakage emissions from biogas digester	CH_4	X
	(4) Emissions from fuel	CO_2, CH_4	X

2.2.1. Calculating average GHG emission before using biogas digester

Step 1: According to IPCC [1], we might determine the CH_4 emission factor from swine manure corresponding to climate conditions in Thua Thien Hue province following some equations (from equation (1)- CH_4 emission factor from manure management and equation (2)- annual excretion rates):

$$EF_{CH4} = VS * 365 * (B_o * D_{CH4} * \sum \frac{MCF_i}{100} * MS) \quad (1); \qquad N_{ex} = N_{rate(T)} * \frac{M}{1000} * 365 \quad (2)$$

where: EF_{CH4} (kg/head/year) is annual CH_4 emission factor for swine waste; VS (kg dry matter/head/day) is daily volatile solid excreted for swine waste per day; 365 (day/year) is the number of days in the year; B_o (m^3/kg VS) is Maximum CH_4 producing capacity of swine manure; D_{CH4} = 0.67 kg/m^3 (conversion factor of m^3 CH_4 to kilograms CH_4); MCF_i (%) is methane conversion factor provided in Table 2 that is CH_4 yield from the stool pit, depending on regional climate (MCF_i= 65 - 80 %, choose MCF_i = 65 %); MS (%): the percentage of swine waste disposed of in the waste tank; i is the number of household; N_{ex} (kg N/head/year): N is annual excretion of livestock; $N_{rate(T)}$ (kg N/head/day) is the default amount of N for swine in Thua Thien Hue province. $N_{rate\ (T)}$ = 0.24 kg N/head/day (1,000 kg) ($N_{rate\ (T)}$ is default value for nitrogen excretion rate); M (kg/head) is Average mature weight of swine, choose M = 185 kg/head.

Surveying at 264 households that had swine breeding, the average mature weight of swine was about 185 kg/head. The Tier 2 method in IPCC [1] is applicable when manure management is a key source or when the data used to develop the default values do not correspond well with the country's livestock and manure management conditions. Because swine characteristics and manure management systems can vary significantly by country. The Tier 2 method relies on two primary types of inputs that affect the calculation of methane emission factors from manure such as manure characteristics and manure management system characteristics. Regional assessments of manure management systems are used to estimate the portion of the manure that is handled with each manure management technique. A description of manure management systems is included in Table 2. With the climate of Thua Thien Hue province, average temperature is 25°C, we collected and chose some calculation coefficients according to IPCC were shown in Table 2.

Table 2. Coefficients used to calculate GHG emissions. [1]

Temperature (°C)	VS (kg/head/day)	B_o (m^3/kg VS)	D_{CH4} (kg/m^3)	MCF (%)	MS (%)	EF_{CH4} (kg/head/year)	EF_{N2O} (kg N/ head/year)	N_{ex} (kg N/ head/year)
25	0.3	0.29	0.67	65	100	13.83	0.005	16.2

Step 2 and 3: CH_4 and N_2O emission loading is emitted by composting

$$BE_{CH4} = GWP_{CH4} * LN_1 * EF_{CH4} * \frac{1}{1000} \quad (3); \quad BE_{N2O} = GWP_{N2O} * LN_1 * EF_{N2O} * N_{ex} * MS * \frac{44}{28} * \frac{1}{1000} \quad (4)$$

Step 4: CO_2 and CH_4 emission loading is emitted by burning fuel

$$B_{CO2} = \sum (BG_j * NCV_j * EF_{CO2,j}) * \frac{1}{10^6} \quad (5); \quad B_{CH4} = \sum (BG_j * NCV_j * EF_{CH4,j}) * \frac{1}{10^6} \quad (6)$$

The heat energy and emission coefficients of some fuels were shown in Table 3.

Table 3. The heat energy and emission coefficients of some fuels. [4]

Fuel	Heat energy NCV_j (MJ/kg)	Emission coefficients (tonnes CO_2e/TJ)	
		EF_{CO2} (tonnes CO_2e/TJ)	EF_{CH4} (tonnes CO_2e/TJ)
Wood	30.5	112	0.3
Gas	47.3	63.1	0.001
Biogas	14.9	54.6	0.001

(Source: [4]. United Nations Framework Convention on Climate Change, 2010).

Step 5: Average GHG emission loading before using biogas digester

- For household:

$$BE_i = BE_{CH4} + BE_{N2O} + B_{CO2} + B_{CH4} \quad (7)$$

- For Van Cu village:

$$BE = ND * BE_i \tag{8}$$

where: BE_{CH4} (tonnes CO_2e/year) is the CH_4 discharge from household silos; GWP_{CH4}= 21 is greenhouse effect of CH_4 compared to CO_2; LN_1 (head/year) is the average number of swine of the household before using biogas digester. BE_{N2O} (tonnes CO_2e/year) is the N_2O discharge by compost; GWP_{N2O}= 298 is the Greenhouse effect of N_2O gas versus CO_2; N_{ex} (kg N/head/year) is Volume N emissions; EF_{N2O} (kg/head/year) is the N_2O emission factor from swine waste; MS (%) is the percentage of swine waste disposed of in the vault; 44/28 is the conversion factor of emission from N to N_2O. B_{CO2}, B_{CH4} (tonnes CO_2e/year) are CO_2, CH_4 emissions from household fuel combustion, respectively; BG_j (kg/year) is the average volume of fuel while j is consumed annually by the household use the biogas digester; NCV_j (MJ / kg) is heat energy of fuel; BE_{N2O} (tonnes CO_2e/year) is N_2O discharge by compost; $EF_{CO2,j}$ (tonnes CO_2e/TJ) is CO_2 emission factor of fuel j; $EF_{CH4,j}$ (tonnes CO_2e/TJ) is CH_4 emission factor of fuel j. BE (tonnes CO_2e/year) is the average GHG emissions of the village; BE_i (tonnes CO_2e/household/year) is the average GHG emissions per household; B_{CO2}, B_{CH4} (tonnes CO_2e/year) are correspondingly the CO_2, CH_4 emissions from household fuel combustion; and ND (household) is number of households using biogas of Van Cu village [1].

2.2.2. Calculating average GHG emission after using biogas digester

Step 1: CH_4 emission loading due to leakage from biogas digester

$$PE_{CH4} = LF_{CH4} * [GWP_{CH4} * B_o * D_{CH4} * VS * 365 * LN_2] * \frac{1}{1000} \tag{9}$$

Step 2: CO_2 and CH_4 emission loading due to burning fuel

The formula for calculating CO_2, CH_4 emissions from burning coal and firewood was similar to the case of no biogas digester. For fuel is biogas, the formula for calculating CO_2 emissions was followed:

$$PE_{Biogas} = [H * B_o * D_{CO2} * VS * 365 * LN_2] * \frac{1}{1000} \tag{10}$$

Step 3: Total GHG emissions by using biogas digesters

For household:

$$PE_i = PE_{CH4} + P_{CO2} + P_{CH4} \tag{11}$$

for Van Cu village:

$$PE = ND * PE_i \tag{12}$$

where: PE_{CH4} (tonnes CO_2e/year): CH_4 loading was leaked from biogas digester; LF_{CH4} = 0.1: Leakage coefficient CH_4 from biogas digester; LN_2 (head/year): Average number of swine per household. PE_{Biogas} (tonnes CO_2e/year): CO_2 emission from biogas combustion; LF_{CH4} = 0.1: CH_4 leakage coefficient from biogas digester; D_{CO2} (kg/m^3): Specific gravity of CO_2, D_{CO2}= 1,977 kg/m^3; H(%): CH_4 gas yield. PE (tonnes CO_2e/year): Average GHG emissions of village; PE_i (tonnes CO_2e/household/year): Average GHG emissions per household; P_{CO2}, P_{CH4} (tonnes CO_2e/year): CO_2, CH_4 emissions from household fuel combustion.

2.2.3. The average GHG emission loading is reduced by using biogas digesters

For household:

$$ER_i = BE_i - PE_i \quad (13)$$

for Van Cu village:

$$ER = ND - ER_i \quad (14)$$

where: ER (tonnes CO_2e/year) is average GHG emission reduction of village; ER_i (tonnes CO_2e/household/year) is average GHG reduction of a household; and ND (household) is the number of households using biogas of the village.

3. RESULTS AND DISCUSSION

3.1. The status at Van Cu rice noodle craft village

According to livestock department, the solid waste from swine breeding was 2.0 kg/head/day [2], thus the estimation of solid waste of Van Cu village reached 5,136 kg/day. The average fuel used to 1,952,750 kg/year of wood and 20,578 kg/year of gas in 2016. There were 24 households of 30 households that had biogas digesters was used to effectively and had been created gas to serve human life, swine breeding and rice noodle production. In 24 surveyed households, there were avarge of 5 persons/household, 15 heads/year, 148 kg rice noodle/day. Thus, the total of using fuel at 24 households reached 322,295 kg/year of wood and 1,828.8 kg/year of gas. Therefore, the demand of using fuel from wood accounted for 99 % of total fuel demand.

3.2. The estimation of GHG emissions at Van Cu village

3.2.1. The estimation of GHG emission before using biogas digesters

Figure 1 showed the GHG emission due to composting at 24 house holds. Table 4 showed that total GHG emission of village was 7,593.1 tonnes CO_2e/year. The GHG emission due to burning fuel accounting for high rate with 88.9 %, in which 88.7 % of CO_2 emission. The GHG emission due to composting only reached 11.1 %, in which 9.8 % of CH_4 and 1.3 % of N_2O emission.

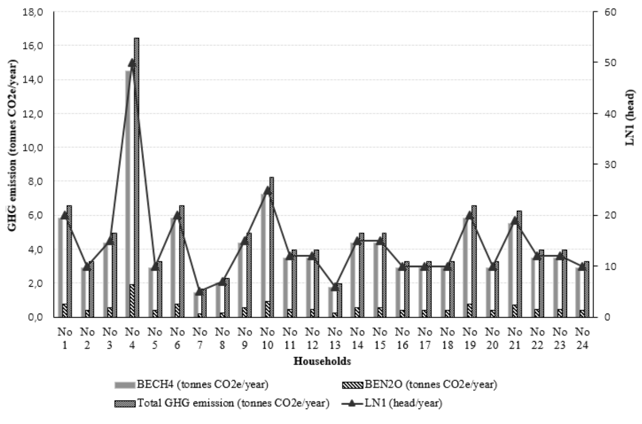

Figure 1. GHG emissions due to composting at 24 households.

Table 4. GHG emissions at Van Cu rice noodle craft village.

	GHG emission due to composting		GHG emission due to burning fuel		Total GHG emission
	BE_{CH4} (tonnes CO_2e/year)	BE_{N2O} (tonnes CO_2e/year)	B_{CO2} (tonnes CO_2e/year)	B_{CH4} (tonnes CO_2e/year)	BE_i (tonses CO_2e/year)
Total	745.79	97.44	6,732.01	17.87	7,593.1
Average	74.58	9.74	673.20	1.79	759.3

This result was higher than the study in Hunan province, China (United Nations Framework Convention on Climate Change, 2010). This difference might be due to the average annual temperature and average number of swines per farmer in Thua Thien Hue province, Vietnam higher than in Hunan province, China [4]. Therefore, composting temperature has a great impact on GHG emissions.

3.2.2 The estimation of GHG emission after using biogas digesters

According to survey data, households used to mainly fuel from wood and gas to serve cooking, breeding and producing rice noodle before they had biogas digesters. With H = 0.8 %; VS = 0.3 kg dry weight/head/day; B_o = 0.29 m^3/kg VS; D_{CO2} = 1.798 kg/m^3, LN_2 = 16 heads/year, total GHG emission of households that used to biogas digesters was 267.6 tonnes CO_2e/year, average GHG emission of every household was 11.2 tonnes CO_2e/year; in which the rate of GHG was 6.4 % of using biogas, 87.3 % of using wood and 6.2 % of reaching from biogas digesters. Total GHG reduction was 956.7 tonnes CO_2e/year, average GHG emission was 39.9 tonnes CO_2e/year/household. Thus, the output of CERs sale reached 12,922,034 VND/year, average of houshold saved to 538,418 VND/year/hosehold (see Table 5). Van Cu rice noodle craft village had 264 households to join in swine breeding. If all of households in this village will build biogas digester, total GHG emission may be reduce 10,523.9 tonnes CO_2e/year, coressponding to the outcome of CERs sale will reach 142,142,379 VND/year.

Table 5. GHG reducing by using biogas digesters at 24 households.

	Total GHG emissions			CERs price (EUR/tonnes CO_2e), in 2013	Outcome	
	BE_i (tonnes CO_2e/year)	PE_i (tonnes CO_2e/year)	ER_i (tonnes CO_2e/year)		(EUR/ year)	(VND/ year)
Total	1,224.3	267.6	956.7	0.5	516.6	12,922,034
Average	51.0	11.1	39.9	0.5	21.5	538,418

Notes: 1 EUR = 25.012,31 VND on 26 April, 2017.

4. CONCLUSIONS

Rice noodle production and swine breeding not only brought economic effectiveness for households but also caused environmental pollution issues (such as wastewater, solid waste, GHG emission etc.) that was concerned at Van Cu village, Thua Thien Hue province. When households at village enhance some solutions to recycling by-products to serve breeding and saving fuel by using biogas digesters that will reduce GHG emission. Total GHG emission was reduced 956.7 tonnes CO_2e/year. Therefore, the outcome of CERs sale reached 12,922,034 VND/year, every household will save 538.418 VND/year/household. Total GHG emission of Van Cu village will reduce 10,523.9 tonnes CO_2e/year, equivalent to CERs cost will reach 142,142,379 VND/year.

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