Design of a Food Waste Management Method Case Study the Cafeteria in Mae Fah Luang University

P. Dokinagam and N. Laosipojana

***Abstract*—The residual food waste is one source of greenhouse gas, which results in climate change and directly increases the risk of water-, food-, vector- and rodent-borne diseases. This research aimed to develop an alternative approach for food waste management at Mae Fah Luang University (MFU). The appropriated way was evaluated based on the quantity of generated food waste together with the chemical and physical properties. The amount of food waste was collected from the canteens at MFU and then sampled to analysis. All information was evaluated to propose the proper food waste management method for MFU. The food waste generation at MFU, during academic year 2009-2013, was around 603.72 kg/day. The greenhouse gas emission from this food waste degradation was approximately 12678.015 KgCO$_2$-eq/day and increasing every year. When using COWTEC®, this generated food waste could be converted to electricity around 10.8 MWh/year with 23104.5 kg/year of fertilizer. Moreover, carbon emission is also reduced around 6058.80 KgCO$_2$-eq/year. As the economic consideration, the payback period for this investment is around 4 years. Based on economic and environment health considerations, the appropriated way of food waste management at MFU is used as power generation.**

***Index Terms*—Food waste, greenhouse gases, cost analysis, power generation.**

I. Introduction

Food waste causes the environmental problem for both community and waste management system. Increasing of population is also resulted in higher amount of food waste. Nellemann, Programme [1] found that the world food production generated food scraps waste around 1/3 or 1,300 million tons. This is the influence factor for generate greenhouse gases (GHG). Andersen, Boldrin [2] measured the GHG emission form organic house waste decomposition in Denmark. This data was used to compute the emission factor of methane and nitrogen dioxide which are 4.2 kg CH_4/Mg wet waste (ww) and 0.30-0.55 kg N_2O/ Mg.ww. These were equaled to 100-239 kg CO_2-eq/Mg.ww. Meanwhile, Kim and Kim [3] studies the environmental effect from 4 different types of food waste deposal which are dry feeding, wet feeding, composting, and landfilling. By using the LCA technique, they found that GHG emission from dry feeding, wet feeding, composting, and landfilling produced are 200 kg CO_2-eq, 61 kg CO_2-eq, 123 kg CO_2-eq and 1010 kg of CO_2-eq, respectively. Now a day, the desired solution for food waste management is energy production or related product instead of landfill or incineration [4]. As the work of [5] the current food waste-to-energy technology are divided into 3 categories: biological (such as anaerobic digestion, ethanol fermentation), thermal and thermochemical technologies (such as incineration, pyrolysis and gasification, hydrothermal carbonization). Based on environmental and energy-economic and health aspects, they suggest that the advantage of biological treatment process is simple and low investment cost. However, it has the essential limitation of a long treatment period and the possibility of bacteria inhibition when contact to contaminants in food waste.

In Thailand, MSW is mainly from residential, commercial, institutional and municipal services [6]. The institutional sector is one of the influence part that generated food waste. This the source of greenhouse gas, such as methane and carbon dioxide, from organic fermentation. There are many solutions that are developed to utilize the food waste in the university such as compost and biogas [7]. In this study, MFU was selected as the case study since this is small to medium scale of university in Thailand. Furthermore, the number of student is increased simultaneously. MFU is in the northern of Thailand. From statistic, the total of students were 17,249 in year 2009 and increased to 22,358 in 2013. When the number of population increasing, the problem food waste become significant. Then, this research aimed to evaluate the greenhouse gas emissions from food waste and calculate energy generation from food waste fermentation. Finally, the alternative ways for utilized food waste in MFU would be proposed.

II. Introduction Characters of Food Waste in MFU

In MFU, the food waste is collected in 50 Liters plastic tank which is the mixture of liquid and solid organic waste. As the Thai food style, there are many herbs, such as galanga or lemon grass. These are the main components of solid part in the food waste. Then the collected food waste from all cafeterias is transferred outside the university twice a day. Therefore, the quantity of food waste was calculated from the density of mixture of waste in the plastic tank and total amounts of the tank in MFU. At the same time, the number of dishes and amount of students and staffs in MFU were also recorded during academic year 2014-2016. These data were then used for predict the quantity of food waste generation in MFU.

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A. Review Stage Energy from Food Waste

Now a day, there are many methods to utilize the food waste instead of sent to landfill or incineration. As work of Pham, Kaushik [5], the current technologies of food waste management include animal feed, anaerobic digestion. Furthermore, it can used as fertilizer [8]. In Thailand, the organic waste is mainly used for produce compost and energy [6]. Note that the food waste from MFU is normally used as animal feed. Moreover, the food waste is benefited for power generation.

One of the favored waste to energy technology from food waste is an anaerobic digestion technology. In this technology, food waste could be digested to generate electricity via anaerobic condition. It is a complicated biochemical process for digest organic waste to biogas. Biogas is a gas typically comprised of 60% methane (CH_4) and 40% carbon dioxide (CO_2). This can be used as fuel instead of natural gas. Mao, Feng [9] recommend that the nutrition is suitable for the growth of anaerobic microorganism. Furthermore, the residue from this process could be used as fertilizer. Moreover, biogas plants could reduce the methane emissions that cause greenhouse effects on the earth’s atmosphere. However, impurities gases in biogas are corrosive to the metal parts of the utilized engines. Now a day, one of technology the suitable for small scale biogas generation from food waste as called COWTEC®. It is a machines that generated biogas and compost via the Hi-solid Dry Continuous Fermentation Process. For this process, organic wastes are converted into useful by-products by microorganisms via "anaerobic digestion". In essence, the Hi-solid Dry Continuous Fermentation Process simply reduces nature’s process of creating renewable energy & organic fertilizer from many months to a matter of one day.

Anaerobic digestion of microorganisms in COWTEC® are summarized in Fig. 1. Firstly, solid waste is hydrolyzed into a water-soluble. Then soluble organics is digested to organic acids. Then, this acids is converted to methane gas. At the meantime, the residue solid could be used as compost. The interested advantage of the COWTEC® is available for small scale organic waste. Its capacity is around 100 kg/day of food waste that would be converted to biogas 1000 liters/day and generated compost around 150 - 250 kg / day.

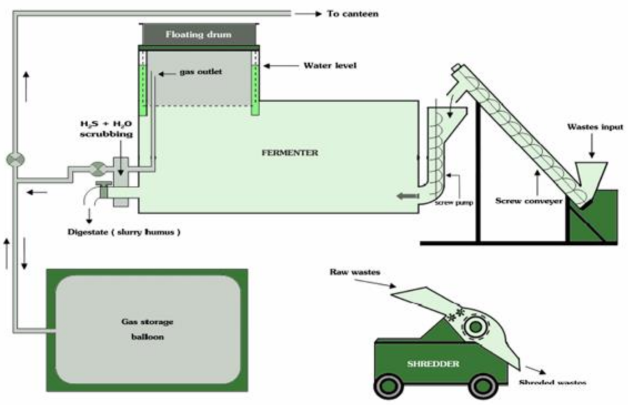

Fig. 1. Anaerobic digestion of COWTEC® machine [10].

B. Economic Analysis

Franchetti [11] evaluated the economic benefit of four different configurations of anaerobic digestion for food waste to energy conversion by using payback period analyses, Eq.1. This was also investigated in the work of the general economic assessment [12]. Net annual cash inflow

$$Payback(year) = \frac{\text{Cost of project}}{\text{Net annual cash inflow}}. \quad (1)$$

III. Results and Discussion

A. Review Stage Energy from Food Waste

TABLE I: The Generated Residual Food Waste in MFU during Academic Year 2009-2013

Days	No. of people (person) Average	Food waste (kg/30 days)	Rate of waste generation (kg/person/day)
1	3293.33	1212.5	0.012
2	3246.67	1212.5	0.012
3	3768.33	1212.5	0.011
4	3416.67	1212.5	0.012
5	3238.33	2376.5	0.024
6	3310	776	0.008
7	3728.33	1212.5	0.011
8	4016.67	776	0.006
9	3706.67	1212.5	0.011
10	3915	1212.5	0.010
11	3185	1212.5	0.013
12	2416.67	1212.5	0.017
13	3065	1212.5	0.013
14	3336.67	1746	0.017
15	4296.67	1212.5	0.009
16	3690	1212.5	0.011
17	4281.67	1212.5	0.009
18	3581.67	1746	0.016
19	3426.67	2376.5	0.023
20	3375	2376.5	0.023
21	2833.33	2376.5	0.028
22	3135	1746	0.019
23	2405	1212.5	0.017
24	3000	1212.5	0.013
25	3655	1212.5	0.011
26	3855	1746	0.015
27	4031.67	2376.5	0.020
28	3248.33	1212.5	0.012
29	4063.33	1212.5	0.010
30	3591.67	1212.5	0.011
Average	3470	1449	0.014

During academic year 2009-2013, the rate of generated residual food waste in MFU is increased continuously, as seen in Table I. Food waste in MFU was collected during August -December 2014. It could calculate the rate of food waste generation is 0.014 kilogram/person/day. This rate was used for predict the generated food waste during academic year 2009 – 2019, as shown in Fig. 1.

In the part of chemical properties, it was found that the moisture content of this waste is around 72.11% and total solid is around 27.89. The solid contented 93.91 % of fixed carbon and 6.09% of ash. These results are used for forecast the energy and GHG emission from food waste.

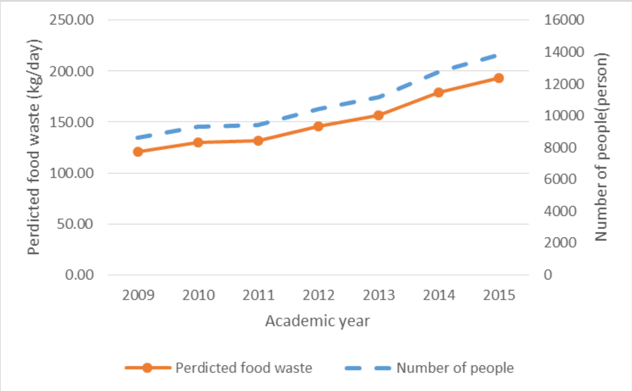

Fig. 2. Predicted amount of food waste during academic year 2009-2015.

B. The Greenhouse Gas Emissions from Food Waste

From the Table II represent emission GHG between academic year 2009-2015. It could be seen that the food waste is around 603.72 kg/day that was resulted in CO_2 emission 1527.40 $KgCO_2e/kg$, CH4 emission 12678.015 $KgCO_2$-eq/day. These were also increasing every year.

TABLE II GHG FROM FOOD WASTE AT MFU DURING ACADEMIC YEAR 2009-2015

Academic year	**Number of people**	**Predicted food waste (kg/day)**	**GHG (ton CO_2eq /day)**
2009	8625	120.75	0.31
2010	9282	129.95	0.33
2011	9395	131.53	0.33
2012	10427	145.98	0.37
2013	11179	156.51	0.40
2014	12791	179.07	0.45
2015	13813	193.38	0.49

Note: CO_2 factor (Kg CO2eq /unit) of food waste =2.53[13]

C. Production from Food Waste via COWTEC®

As the specification of COWTEC® [10], the generated biogas and compost from food waste at MFU could be calculated in Table III. Biogas is directly using as cooking fuel in canteen and compost could be sell.

TABLE III: THE GENERATED BIOGAS AND COMPOST FROM FOOD WASTE AT MFU BY USING COWTEC®

Academic year	Predicted food waste (kg/day)	Biogas generation (m^3/day)	Electrical equivalent (kWh/day)	Compost with 35% moisture (kg/day)
2009	120.75	12.08	14.49	18.11
2010	129.95	12.99	15.59	19.49
2011	131.53	13.15	15.78	19.73
2012	145.98	14.60	17.52	21.90
2013	156.51	15.65	18.78	23.48
2014	179.07	17.91	21.49	26.86
2015	193.38	19.34	23.21	29.01

TABLE IV: SUMMARY OF COST FOR BIOGAS PRODUCTION FROM COWTEC®

	Year						
Parameter	2009	2010	2011	2012	2013	2014	2015
Predicted food waste (ton/year)	28.98	31.19	31.57	35.03	37.56	42.98	46.41
CO_2e (ton/year)	73.32	78.9	79.87	88.64	95.03	108.73	117.42
Biogas generation ($x10^3$ m^3/year)	2.90	3.12	3.16	3.50	3.76	4.30	4.64
Cooking gas equivalent (ton/year)	1.33	1.43	1.45	1.61	1.73	1.98	2.13
Compost (ton/year)	4.35	4.68	4.74	5.26	5.63	6.45	6.96
Saving cost for cooking gas* ($x10^3$baht/year)	27.31	29.40	29.75	33.02	35.40	40.51	43.74
Saving cost for compost * ($x10^3$baht/year)	26.08	28.07	28.41	31.53	33.81	38.68	41.77
Cost of CO_2e avoidance ($x10^3$baht/year)*	42.61	45.86	46.42	51.52	55.23	63.19	68.24
Net annual cash inflow ($x10^3$baht/year)**	57.01	64.32	65.58	77.07	85.44	103.38	114.76

*Note :Cooking gas price is 20.49 bath/kg [14] , compost price 6 baht/kg[15] and CO_2 avoidance 581.20 bath/tonCO_2e [16]. As seen from calculation, the conversation of food waste to energy via this machine is favored for investment when added the benefit of environment

D. Economies Analysis

Actually, the study period of MFU is 2 semesters or 240 days/year. Therefore, this analysis was based on the duration. The productivity of food waste and economic analysis are summarized in Table 4. As the amount of predicted food waste, it could invest for COWTEC® with capacity 100 kg/day.

Average Net annual cash inflow is 81,081.13 baht, so

$$Payback(year) = \frac{390,000}{81,081.13} = 4.81.$$

IV. CONCLUSION

The results shown that the amount of food waste is directly variated with the number of student in MFU. However, the food waste could be converted to biogas and compost instead of sent to landfill by using COWTEC® which is advantaged for GHG reduction. From the prediction, the GHG will be reduced around 117.42 tonCO_2e per year in 2015 which is resulted in saving the money for CO2e avoidance about 68,240 baths per year. This investment of COWTEC® technology will be advantaged when include the cost of CO_2e avoidance with the payback period 4.81 years.

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