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Reducing Greenhouse Gas Emissions by Recyclable Material Bank Project of Universities in Central Region of Thailand

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Abstract**—**This research studied recycled waste by the Recyclable Material Bank Project of 4 universities in the central region of Thailand for the evaluation of reducing greenhouse gas emissions compared with landfilling activity during July 2012 to June 2013. The results showed that the projects collected total amount of recyclable wastes of about 911,984.80 kilograms. Office paper had the largest amount among these recycled wastes (50.68% of total recycled waste). Groups of recycled waste can be prioritized from high to low according to their amount as paper, plastic, glass, mixed recyclables, and metal, respectively. The project reduced greenhouse gas emissions equivalent to about 2814.969 metric tons of carbon dioxide. The most significant recycled waste that affects the reduction of greenhouse gas emissions is office paper which is 70.16% of total reduced greenhouse gasses emission. According to amount of reduced greenhouse gasses emission, groups of recycled waste can be prioritized from high to low significances as paper, plastic, metals, mixed recyclables, and glass, respectively.

Keywords**—**Recycling, garbage bank, waste management, recyclable wastes, greenhouse gasses.

I. Introduction

SOLID waste is an important problem in both developed and developing countries, especially in the urban areas, because it causes poor living conditions and a poor environment in communities. This problem is even more intense due to the increase in population which requires a lot of facilities and production to meet the increased demand and this problem results in a higher amount of solid waste. Therefore, it is necessary to have solid waste management and the popular approaches are burning these wastes in incinerator or sending them to sanitary landfills. The sanitary landfills seem to be the most popular method in several countries, since these countries are converting open dumped waste, which is unhygienic, to sanitary landfills [1]. However, these approaches have several disadvantages; for example, burning these wastes in incinerator without good operation can generate dioxin, which is a carcinogenic substance, and several air pollutants such as NO_x, SO_x, CO_2, CO, fly ash, etc. In addition, there is the need to handle residue waste after burning, such as bottom ash. Disposal by sanitary landfill requires enough space to store such waste and the space is very limited in many countries. Furthermore, sanitary landfills need an operational unit for the handling of leachate and methane gas (CH_4), which occurs from anaerobic natural composting of this waste within sanitary landfill. In addition, both incineration and sanitary landfills involve high transportation, operation and maintenance costs, also producing greenhouse gasses (GHGs) such as CO_2, CH_4, N_2O, etc., which are a cause of the global warming situation.

Recycling is one of the widely acceptable approaches in solid waste management which can reduce amount of wastes that have to be sent to an incinerator or sanitary landfill [2]. One economic tool in solid waste management which promotes recycling activities systematically is the Recyclable Materials Bank (RMB). The Recyclable Materials Bank is a center of purchasing and selling recyclable waste such as papers, plastics, glasses, metals, and others. The Recyclable Materials Bank purchases this waste from the bank members and then sells it to the recycling shop. The revenue of the Recyclable Materials Bank occurs from the margin between buying and selling prices, since the bank members can sale these wastes through Recyclable Materials Bank with the higher prices than selling such waste individually to the recycling shop because the Recyclable Materials Bank has a high volume of recyclable materials as a center of the garbage. Thus, the Recyclable Materials Bank can negotiate with the shop to buy this waste from the Recyclable Materials Bank with exclusive prices. The revenue from selling the recyclable waste of the Recyclable Materials Bank members is deposited in each member’s account of the Recyclable Materials Bank and the members can withdraw money from their account like a commercial bank. The objective of Recyclable Materials Bank is to promote waste separation at the source and these results in a reduction of the amount of waste that has to be sent to the end of pipe approaches, such as sanitary landfill, which can save the limited space of the landfill and extend the landfill’s life. Furthermore, the Recyclable Materials Bank not only creates added value to the recyclable waste, but it also reduces the costs that occur from handling these wastes such as transportation costs and also reduces emissions of GHGs by recycling the waste and avoids sending it to sanitary landfill or incinerator.

The Recyclable Materials Bank Project in universities started successfully for first time in November 2006 at Thammasat University (Rangsit Campus) with the cooperation from the Thailand Institute of Packaging and Recycling Management for Sustainable Environment, which is an

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organization under with the Federation of Thailand Industries. In 2011, there were 15 universities (17 institutions) involved with the project. The Recyclable Materials Bank Project can reduce a lot of solid waste from universities, which is good for the environment.

The objective of this work was to evaluate how good the Recyclable Materials Bank Project is for the environment. The reduced amount of waste and reduced emissions of GHGs as a result of the Recyclable Materials Banks operation from July 2012 to June 2013 were also investigated.

II. Material and Methods

The data of type and amount of recycled waste were collected from the Recyclable Materials Banks of 4 institutions in the central region of Thailand, which were Thammasat University (Rangsit Campus), Srinakarin Wirot University (Prasanmit Campuses), Assumption University, and Rajamangala University of Technology Thanyaburi.

The reduction of green house gas emissions due to the recycling project compared with landfilling activity was selected for the study since the general procedure for solid waste disposal in metropolitan Bangkok is sending the waste to landfills. The reduced emission of greenhouse gasses, for instance, carbon dioxide (CO_2), methane (CH_4), perfluoro methane (CF_4), and perfluoro ethane (C_2F_6), which was a result of the Recyclable Materials Banks operation compared with sanitary landfill approach was evaluated by using emission factors from WAste Reduction Model (WARM) version 8.0 database [3], [4] developed by the United States Environmental Protection Agency (US-EPA). The reduction of green house gas emissions was reported as a metric ton carbon dioxide equivalent ($MTCO_2E$). This could be achieved by converting the amount of CH_4, CF_4, and C_2F_6 to CO_2 by using a value of global warming potential (GWP) which are 25, 7,390, and 12,200 times of CO_2 for CH_4, CF_4, and C_2F_6, respectively [5]. A formula for the conversion was shown in (1):

$$[MTCO_2E] = [CO_2]+25[CH_4]+7390[CF_4]+12200[C_2F_6] \quad (1)$$

where $[MTCO_2E]$ is total amount of green house gasses in metric tons of carbon dioxide equivalent. $[CO_2]$, $[CH_4]$, $[CF_4]$, and $[C_2F_6]$ are in amounts of metric tons for CO_2, CH_4, CF_4, and C_2F_6, respectively.

III. Results and Discussion

A. Categories and Amount of Recycled Waste

The Recyclable Materials Bank Project handled 911,984.80 kilograms of recyclable waste during the time of July 2012 to June 2013, in which more than 50% of the recyclable waste was collected from all universities in Thailand that participated in the Recyclable Materials Bank Project. The cost savings compared to disposal of this waste in landfills by the project was approximated to be about 911,985 Bath (1 US Dollar ≈ 31.5 Bath) based on the transportation cost of 500 Bath per metric ton of waste and landfill operational cost of 500 Bath per metric ton of waste for metropolitan Bangkok [6]. Based on the above data, the average amount of recycled waste is about 75,998 kilograms per month or 2,533.3 kilograms per day. Details of the recycled waste were shown in Figs. 1 and 2:

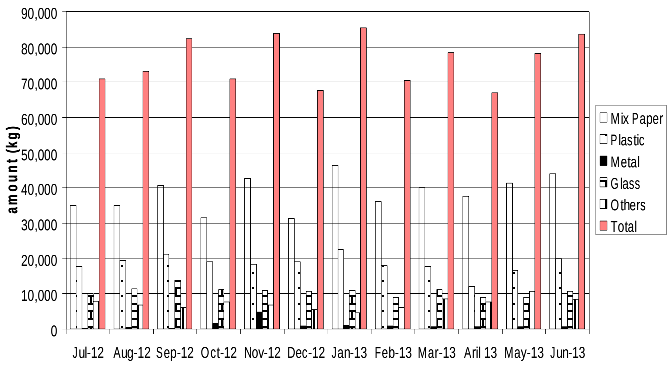

Fig. 1 Amount of recycled wastes by The RMB Project in 1 year

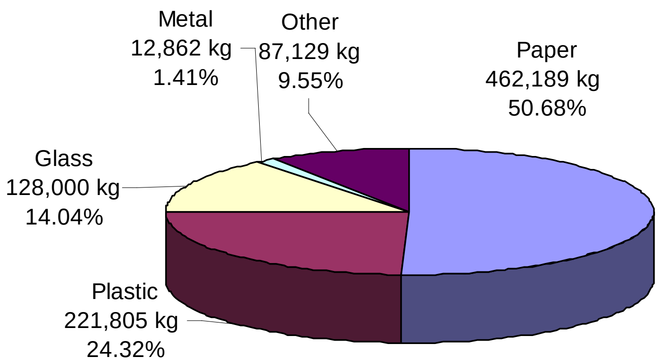

Fig. 2 Fraction of recycled wastes by The RMB Project in 1 year

The figures shows that the paper group has the largest amount followed by groups of plastics, glass, mixed waste (other) and metal, respectively. This is because these institutions are educational organizations; thus, it is not surprising why the paper group has the largest amount compared with the other recycled groups.

Based on the on-site data collection, the paper group can be classified as office paper, corrugated cardboard, mixed paper, and newspaper. The group of plastic can be classified as Poly Ethylene Terephthalate (PET), Low Density PolyEthylene (LDPE), High Density PolyEthylene (HDPE), Polystyrene (PS), Poly Vinyl Chloride (PVC), and Mixed Plastics. The metal group can be divided into steel, aluminum, zinc, copper, and other mixed metals.

The office paper seems to have the highest fraction among the paper group, while PET and steel have the largest amount for a group of plastic and metal, respectively. PET is a major fraction among the plastic group since universities have their own manufacturing of drinking water that uses PET as bottles for drinking water.

There is no general trend in the variation of wastes occurred in each month.

B. Reduction of Greenhouse Gas Emissions

The greenhouse gas emissions reduced from July 2012 to June 2013 by the Recyclable Materials Bank Project were calculated using database of greenhouse gas emissions which was developed by the US-EPA. The final columns of each table were calculated using (1). The tables show that recycling activity always reduces the greenhouse gas emissions for all kind of wastes, while the combustion and landfilling activities can emit some of green house gasses.

Comparison between recycling with the other conventional activities (landfilling and combustion) is need. This can show how recycling reduces greenhouse gasses compared to landfilling or combustion activities, for example, when we recycle 3 ton of aluminum cans instead of using combustion of the same waste, we can reduce $3\times(-16.7017) - 3\times(0.068864) = 50.3117$ metric tons equivalent of carbon dioxide (or $MTCO_2E$). These can concluded from Tables I, II.

The calculation shows that the Recyclable Materials Bank Project had reduced greenhouse gas emissions equivalent to about 2,814.969 metric tons of carbon dioxide from July 2012 to June 2013 by recycling the wastes from educational institutions instead of sending them to the landfill, as detailed in Fig. 3. The comparison between the recycling activity from the is Recyclable Materials Bank project and sending all of these wastes to incinerator (combustion activity) found that the project can reduce 2,188.422 metric tons of carbon dioxide equivalent as detailed in Fig. 4.

Figs. 3 and 4 show that the paper group is the largest greenhouse gas emission reduction followed by the plastic group, metal, mixed municipal solid waste, and glass, respectively. It is interesting to note that the metal group reduction of greenhouse gas emissions is higher than the glass group and even the metal group has a lower quantity of the waste than the glass group. This is because recycling of metal might reduce the greater amount of greenhouse gasses emission at the manufacturing process, which is an initial process of its life cycle compared with the glass group. That means recycling of metal reduces a raw material and the energy that is used in the process of metal production results in fewer greenhouse gas emissions.

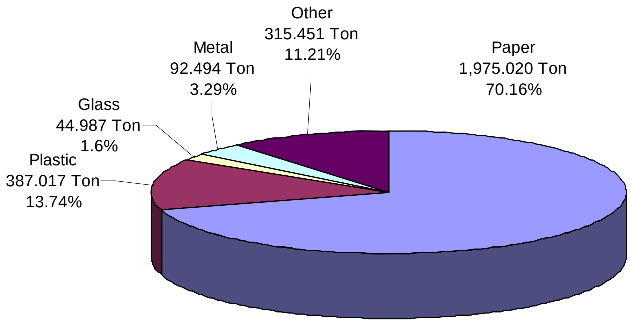

Fig. 3 Fraction of reduced $MTCO_2E$ by RMB project compared with the landfill approach

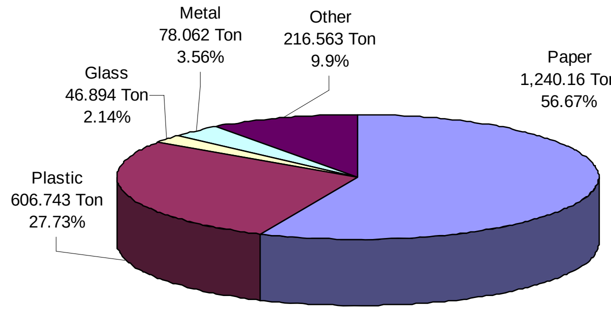

Fig. 4 Fraction of reduced $MTCO_2E$ by RMB project compared with the combustion (incineration) approach

TABLE I
GREENHOUSE GASSES REDUCED FROM RECYCLING ACTIVITY COMPARED WITH LANDFILLING ACTIVITY

Type of waste	CO2	CH4	CF4	C2F6	N2O	MTCO2E
Aluminum Cans	-13.762955	-0.0208	-2.94x10-4	-2.34x10-5	0	-16.744055
Steel Cans	-1.951955	-0.0032	0	0	0	-2.031555
Glass	-0.344955	-0.0003	0	0	0	-0.351455
HDPE	-1.389755	-0.0096	0	0	0	-1.629255
LDPE	-1.718355	-0.01	0	0	0	-1.968355
PET	-1.624255	-0.0062	0	0	0	-1.779255
Corrugated Cardboard	-2.099476	-0.058558	0	0	0	-3.564638
Magazines/Third-Class Mail	-1.816408	-0.032274	0	0	0	-2.623964
Newspaper	-2.372453	-0.029874	0	0	0	-3.119598
Office Paper	-2.48411	-0.131909	0	0	0	-5.781736
Phonebooks	-2.218353	-0.029574	0	0	0	-2.957198
Textbooks	-2.75971	-0.132409	0	0	0	-6.069936
Dimensional Lumber	-1.89308	-0.018524	0	0	0	-2.355968
Medium Density Fiberboard	-1.91058	-0.018624	0	0	0	-2.375768
Mixed Paper	-2.546984	-0.064806	0	0	0	-4.166422
Mixed Paper, Broad	-2.50757	-0.060172	0	0	0	-4.011161
Mixed Paper, Residential	-2.490542	-0.071298	0	0	0	-4.273182
Mixed Paper, Office	-6.094155	-0.0094	-1.03 x10-4	-8.21x10-6	0	-7.191355
Mixed Metals	-1.541655	-0.0081	0	0	0	-1.744855
Mixed Plastics	-2.26906	-0.052182	-5.48x10-6	-4.36 x10-7	0	-3.62051
Mixed Municipal Solid Waste	-5.962755	-0.0152	0	0	-5.88x10-3	-8.096155
Carpet	-2.609355	-0.004	-4.75 x10-5	-3.78 x10-6	0.0000	-3.104955

*Units in each cell are metric tons of reduced gas(es) per metric ton of waste (negative value mean the green house gassed is reduced from the activity i.e. recycling 1 ton of glass can reduce the emission of $CO_2 \approx 0.3026$ ton)

** NA = No data for such waste.

TABLE II
GREENHOUSE GASSES REDUCED FROM RECYCLING ACTIVITY COMPARED WITH COMBUSTION ACTIVITY

Type of waste	CO_2	CH_4	CF_4	C_2F_6	N_2O	$MTCO_2E$
Aluminum Cans	-13.7894644	-0.0208	-2.94×10^{-4}	-2.34×10^{-5}	0	-16.770564
Steel Cans	-0.2796989	-0.00039211	0	0	0	-0.2891
Glass	-0.35984824	-0.0003	0	0	0	-0.366348
HDPE	-2.28651936	-0.0096	0	0	0	-2.526019
LDPE	-2.61511936	-0.01	0	0	0	-2.865119
PET	-2.73070849	-0.0062	0	0	0	-2.885708
Corrugated Cardboard	-2.23472547	0.0003	0	0	-0.00013038	-2.26728
Magazines/Third-Class Mail	-2.39947359	0	0	0	-0.00013038	-2.43903
Newspaper	-2.91526706	-0.0015	0	0	-0.00013038	-2.99192
Office Paper	-1.98535269	0.0004	0	0	-0.00013038	-2.01411
Phonebooks	-2.76116706	-0.0012	0	0	-0.00013038	-2.82952
Textbooks	-2.26095269	-0.0001	0	0	-0.00013038	-2.30231
Dimensional Lumber	-1.77271057	0.0001	0	0	-0.00013038	-1.80886
Medium Density Fiberboard	-1.79021057	0	0	0	-0.00013038	-1.82866
Mixed Paper	-2.68907274	-0.0007	0	0	-0.00013038	-2.74473
Mixed Paper, Broad	-2.69257966	-0.0007	0	0	-0.00013038	-2.74823
Mixed Paper, Residential	-2.63167187	-0.0005	0	0	-0.00013038	-2.68323
Mixed Paper, Office	-5.01767447	-0.00757687	-1.03×10^{-4}	-8.21×10^{-6}	0	-6.0693
Mixed Metals	-2.53228021	-0.0081	0	0	0	-2.73548
Mixed Plastics	-2.3876496	-0.00070322	-5.48×10^{-6}	-4.36×10^{-7}	-0.00011214	-2.48555
Mixed Municipal Solid Waste	-6.28767797	-0.0152	0	0	-0.00588	-8.421078
Carpet	-2.35734764	-0.00319694	-4.75×10^{-5}	-3.78×10^{-6}	0	-2.83287

Units in each cell are metric tons of reduced/emitted gas(es) per metric ton of waste (negative value means the green house gas(es) is reduced from the activity while the positive value mean the green house gas(es) is emitted from the activity)

The details of greenhouse gases reduced can be expressed by Tables III and IV. It can be seen from the table that the major reduced green houses gasses are CO_2, which is the highest fraction of the total greenhouse gasses as $MTCO_2E$, were reduced by the RMB Project, which are in the range of 58% to 98% for the total greenhouse gasses reduced from the recycling activity compared with the landfilling activity and 82% to 98% for the total greenhouse gasses reduced from the recycling activity compared with the combustion activity.

TABLE III
TOTAL GREENHOUSE GASSES REDUCED FROM RECYCLING ACTIVITY COMPARED WITH LANDFILLING ACTIVITY IN THIS STUDY

Type of waste	CO_2 (metric ton)	CH_4 (kg)	CF_4 (g)	C_2F_6 (g)	N_2O (kg)	$MTCO_2E$ (metric ton)
Mixed Paper, Office	1151.08	32957.609	-	-	-	1975.02
Mixed Plastics	341.952	1802.616	-	-	-	387.017
Glass	44.155	33.295	-	-	-	44.987
Mixed Metals	78.382	120.603	1327.2	105.7	-	92.494
MixedMunicipal Solid Waste	197.703	4550.303	-	-	-	315.451
Total	1813.272	39464.426	1327.2	105.7	-	2814.969

TABLE IV
TOTAL GREENHOUSE GASSES REDUCED FROM RECYCLING ACTIVITY COMPARED WITH COMBUSTION ACTIVITY IN THIS STUDY

Type of waste	CO_2 (metric ton)	CH_4 (kg)	CF_4 (g)	C_2F_6 (g)	N_2O (kg)	$MTCO_2E$ (metric ton)
Mixed Paper, Office	1216.308	235.766	-	-	60.261	1240.16
Mixed Plastics	561.677	1.803	-	-	-	606.743
Glass	46.061	33.295	-	-	-	46.894
Mixed Metals	64.536	97.154	1327.2	105.7	-	78.062
Mixed Municipal Solid Waste	208.036	64.989	-	-	-	216.563
Total	2096.618	433.007	1327.2	105.7	60.261	2188.422

Units in each cell are metric tons of reduced/emitted gas(es) per metric ton of waste (negative value means the greenhouse gas(es) is reduced from the activity while the positive value mean the greenhouse gas(es) is emitted from the activity)

IV. CONCLUSION

This research shows the benefit of recycling activity via the Recyclable Material Bank Project. The project can reduce both the amount of waste disposal to the landfill and the emissions of greenhouse gasses. This can directly save the cost of handling this waste and also being a part of saving the world from the global warming situation. The greatest amount of recycled waste by type in the project was the paper group and this group had the highest fraction for the reduction of greenhouse gas emissions due to the recycling activity compared with the landfilling approach. The contents of this research can be further used in making policies for other greenhouse gasses and for several organizations.

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