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Reducing Greenhouse Gasses Emissions by Recyclable Material Bank Project in Universities of Thailand

Ronbanchob Apiratikul

***Abstract*—**This research studied recycled wastes by Recyclable Material Bank project of 17 universities of Thailand for evaluation of reducing greenhouse gasses emission compared with landfilling activity during January 2011 to December 2011. The results showed that the projects collected total amount of recyclable wastes about 1,626.917 metric ton. The office paper has the largest amount among these recycled wastes (55.61 % of total recycled wastes). 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 gasses emission equivalent to about 5,263.481 metric ton of carbon dioxide. The most significant recycled waste that affects the reduction of greenhouse gasses emission is office paper which is 73.45% 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, metal, mixed recyclables and glass, respectively.

***Keywords*—**recycling; garbage bank; waste management; recyclable wastes; greenhouse gasses

I. Introduction

SOILD waste is a one of important problem in both developed and developing countries, especially in the downtown area, because it causes poor living conditions and environment in communities. This problem is even more intense due to the increase in population which required a lot of facilities and production to meet the increased demand and this result 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 landfill while the latter seem to be the most popular method in several countries since these countries to convert the open dumped wastes which are unhygienic operation to sanitary landfill [1]. However, these approaches have several disadvantages, for example, burning these wastes in incinerator without good operation can generate dioxin which is carcinogenic substance and several air pollutant such as NO_x , SO_x , CO_2 , CO, fly ash etc. In addition, it is need to handle with the residue waste after burning such as bottom ash. While a disposal by sanitary landfill required enough space to storage such wastes and the space is very limited in many countries. Furthermore, sanitary landfill need a operational unit for handling with leachate and methane gas (CH_4) which occur from anaerobic composting naturally of these wastes within sanitary landfill.

In addition, both incineration and sanitary landfill involve high transportation, operation and maintenance cost and also producing greenhouse gasses (GHGs) such as CO_2, CH_4, N_2O, etc. which are a cause of global warming situation.

Recycling is a one of widely acceptable approaches in solid waste management which can reduce amount of wastes that have to be sent to incinerator or sanitary landfill [2]. One of an economic tool in solid waste management which promotes recycling activities systematically is Recyclable Materials Bank (RMB). The Recyclable Materials Bank is a center of purchasing and selling the recyclable wastes such as papers, plastics, glasses, metals, and others. Recyclable Materials Bank purchases these wastes from the bank members and then sale them to the recycle shop. The revenue of Recyclable Materials Bank occurs from the margin between buying and selling prices while the bank members can sale these wastes through Recyclable Materials Bank with the higher prices than selling such waste individually to the recycle shop because Recyclable Materials Bank has a high volume of recyclable materials as a center of the garbage thus Recyclable Materials Bank can negotiate with the shop to buy these wastes from Recyclable Materials Bank with exclusive prices. The revenue from selling recyclable wastes of Recyclable Materials Bank members is deposited in each member's account of 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 their sources and this result in a reduction of amount of wastes that have 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 life. Furthermore, Recyclable Materials Bank not only makes a value added to the recyclable wastes but also reduces the costs that occur from handling these wastes such as transportation cost and also reduces an emission of GHGs by recycling these wastes and avoids sending them to sanitary landfill or incinerator.

Recyclable Materials Bank project in university started successfully for first time in November 2006 at Thammasat university (Rangsit Campus) by the cooperation with the Thailand Institute of Packaging and Recycling Management for Sustainable Environment, which is an organization under with the Federation of Thailand Industries. In 2011, there were 15 universities (17 institutions) attained the project. The Recyclable Materials Bank project can reduce a lot of solid waste from university which is good for the environment.

The objective of this work is to evaluate how good of the Recyclable Materials Bank project for the environment. The reduced amount of wastes and reduced emission of GHGs which are a result from Recyclable Materials Banks operation during January 2011 to December 2011 were investigated.

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II. MATERIAL AND METHODS

The data of type and amount of recycled wastes were collected from the Recyclable Materials Banks of 17 institutions which were Thammasat university (Rangsit Campus), Faculty of Public Health (Mahidol University), Faculty of Phamaceutical (Mahidol University), Khon Kan University, Chiang Mai University, Prince of Songkhla University, Srinakarin Wirot University (Prasanmit and Ongkarak Campuses), Suranaree University of Technology, Bansomdej Rajabhat university, Suan Sunandha Rajabhat University, Udonthani Rajabhat University, Chankasame Rajabhat University, Chiang Mai Rajabhat University, Maejo University, Assumption University, and Sripatum University.

The reduction of green house gasses emission due to the recycling project compared with landfilling activity was selected to study since the general procedure for solid waste disposal in Bangkok metropolitan is sending the wastes to landfill. 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 is a result from the Recyclable Materials Banks operation compared with sanitary landfill approach was evaluated by using emission factors from database of WAste Reduction Model (WARM) version 8.0 [3,4] developed by the United States Environmental Protection Agency (US-EPA). The reduction of green house gasses emission was reported as metric ton of 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 Eq. (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 ton of carbon dioxide equivalent. $[CO_2]$, $[CH_4]$, $[CF_4]$, and $[C_2F_6]$ are amount in metric ton of CO_2, CH_4, CF_4, and C_2F_6, respectively.

III. RESULTS AND DISCUSSION

A. Categories and amount of recycled wastes

The Recyclable Materials Bank project handled 1,626.917 metric ton of the recyclable wastes during January 2011 to December 2011. This can save the cost for disposal of these wastes to the landfill by the project which is approximated to about 1,626,917 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 Bangkok metropolitan [6]. Based on above data, the average of recycled wastes is about 135.576 metric ton per month or 4,519 kg per day

Details of the recycled wastes were shown in Fig. 1

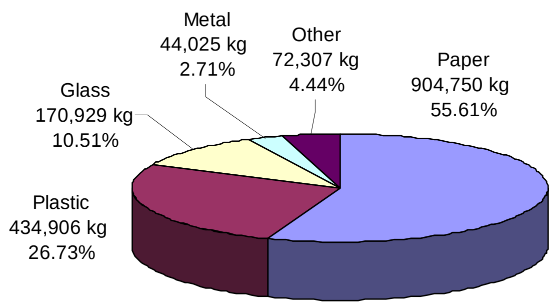

Fig. 1 Fraction of recycled wastes by The RMB project in 2011

The figures shows that a group of paper has the largest amount followed by a group of plastic, glass, and metal, respectively. This because these institutions are educational organization thus it is not surprising that why the group of paper has the largest amount compared with the other recycled groups.

However, based on the on-site data collection, the group of paper can be classified as office paper, Corrugated Cardboard, Mixed Paper, and newspaper. And 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's group can be divided into steel, aluminum, zinc, copper, and other mixed metal.

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

B. Reduction of greenhouse gasses emission

The Greenhouse gasses emission was reduced during January 2011 to December 2011 by the Recyclable Materials Bank project were calculated using database of greenhouse gases emission which developed by US-EPA as details shown by Tables I to III. The final columns of each table were calculated using (1). The tables show that recycling activity always reduces the green house gasses emission for all kind of wastes while the combustion and landfilling activities can emit some of green house gasses.

TABLE I
GREENHOUSE GASSES REDUCED FROM RECYCLING ACTIVITY

Type of waste	CO_2	CH_4	CF_4	C_2F_6	N_2O	$MTCO_2E$
Aluminum Cans	-13.7206	-0.0208	-2.94×10^{-4}	-2.34×10^{-5}	0	-16.7017
Steel Cans	-1.9096	-0.0032	0	0	0	-1.9892
Glass	-0.3026	-0.0003	0	0	0	-0.3091
HDPE	-1.3474	-0.0096	0	0	0	-1.5869
LDPE	-1.6760	-0.0100	0	0	0	-1.9260
PET	-1.5819	-0.0062	0	0	0	-1.7369
Corrugated Cardboard	-3.0229	0.0003	0	0	0	-3.0166
Magazines/Third-Class Mail	-2.9803	0.0000	0	0	0	-2.9810
Newspaper	-3.8088	-0.0015	0	0	0	-3.8466
Office Paper	-2.7453	0.0004	0	0	0	-2.7352
Phonebooks	-3.6547	-0.0012	0	0	0	-3.6842
Textbooks	-3.0209	-0.0001	0	0	0	-3.0234
Dimensional Lumber	-2.7069	0.0001	0	0	0	-2.7042
Medium Density Fiberboard	-2.7244	0.0000	0	0	0	-2.7240
Food Discards	NA	NA	NA	NA	NA	NA
Yard Trimmings	NA	NA	NA	NA	NA	NA
Grass	NA	NA	NA	NA	NA	NA
Leaves	NA	NA	NA	NA	NA	NA
Branches	NA	NA	NA	NA	NA	NA
Mixed Paper	-3.4803	-0.0007	0	0	0	-3.4971
Mixed Paper, Broad	-3.4803	-0.0007	0	0	0	-3.4971
Mixed Paper, Residential	-3.3566	-0.0005	0	0	0	-3.3693
Mixed Paper, Office	-6.0518	-0.0094	-1.03×10^{-4}	-8.21×10^{-6}	0	-7.1490
Mixed Metals	-1.4993	-0.0081	0	0	0	-1.7025
Mixed Plastics	-3.0953	-0.0008	-5.48×10^{-6}	-4.36×10^{-7}	0	-3.1622
Mixed Recyclables	NA	NA	NA	NA	NA	NA
Mixed Organics	NA	NA	NA	NA	NA	NA
Mixed Municipal Solid Waste	-5.9204	-0.0152	0	0	-5.88×10^{-3}	-8.0538
Carpet	-2.5670	-0.0040	-4.75×10^{-5}	-3.78×10^{-6}	0.0000	-3.0626
Personal Computers	NA	NA	NA	NA	NA	NA

*Units in each cell are metric ton 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/EMITTED FROM COMBUSTION ACTIVITY

Type of waste	CO_2	CH_4	N_2O	$MTCO_2E$
Aluminum Cans	0.068864379	0	0	0.068864
Steel Cans	-1.629901105	-0.002807895	0	-1.7001
Glass	0.057248238	0	0	0.057248
HDPE	0.939119356	0	0	0.939119
LDPE	0.939119356	0	0	0.939119
PET	1.148808494	0	0	1.148808
Corrugated Cardboard	-0.788174535	0	0.000130381	-0.74932
Magazines/Third-Class Mail	-0.580826411	0	0.000130381	-0.54197
Newspaper	-0.893532938	0	0.000130381	-0.85468
Office Paper	-0.759947312	0	0.000130381	-0.72109
Phonebooks	-0.893532938	0	0.000130381	-0.85468
Textbooks	-0.759947312	0	0.000130381	-0.72109
Dimensional Lumber	-0.934189433	0	0.000130381	-0.89534
Medium Density Fiberboard	-0.934189433	0	0.000130381	-0.89534
Food Discards	-0.245352246	0	0.000130381	-0.2065
Yard Trimmings	-0.295301655	0	0.000130381	-0.25645
Grass	-0.295301655	0	0.000130381	-0.25645
Leaves	-0.295301655	0	0.000130381	-0.25645
Branches	-0.295301655	0	0.000130381	-0.25645
Mixed Paper	-0.791227257	0	0.000130381	-0.75237
Mixed Paper, Broad	-0.787720344	0	0.000130381	-0.74887
Mixed Paper, Residential	-0.72492813	0	0.000130381	-0.68607
Mixed Paper, Office	-1.034125532	-0.001823135	0	-1.0797
Mixed Metals	1.032980209	0	0	1.03298
Mixed Plastics	-0.707650401	-9.67752×10^{-5}	0.000112144	-0.67665
Mixed Recyclables	-0.271179155	0	0.000130381	-0.23233
Mixed Organics	-0.194749879	-8.92549×10^{-5}	0.000130381	-0.15813
Mixed Municipal Solid Waste	0.367277967	0	0	0.367278
Carpet	-0.209652364	-0.000803058	0	-0.22973
Personal Computers	0.068864379	0	0	0.068864

Units in each cell are metric ton of reduced/emitted gas(es) per metric ton of waste
(negative value mean 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)

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TABLE III
GREENHOUSE GASSES REDUCED FROM LANDFILLING ACTIVITY

Type of waste	CO_2	CH_4	$MTCO_2E$
Aluminum Cans	0.042355	0	0.042355
Steel Cans	0.042355	0	0.042355
Glass	0.042355	0	0.042355
HDPE	0.042355	0	0.042355
LDPE	0.042355	0	0.042355
PET	0.042355	0	0.042355
Corrugated Cardboard	-0.923424	0.058858	0.548038
Magazines/Third-Class Mail	-1.163892	0.032274	-0.357036
Newspaper	-1.436347	0.028374	-0.727002
Office Paper	-0.26119	0.132309	3.046536
Phonebooks	-1.436347	0.028374	-0.727002
Textbooks	-0.26119	0.132309	3.046536
Dimensional Lumber	-0.81382	0.018624	-0.348232
Medium Density Fiberboard	-0.81382	0.018624	-0.348232
Food Discards	-0.082123	0.036698	0.835323
Yard Trimmings	-1.0047	0.019921	-0.50667
Grass	-0.451186	0.023481	0.135833
Leaves	-1.562997	0.018225	-1.107376
Branches	-0.81382	0.018624	-0.348232
Mixed Paper	-0.933316	0.064106	0.669322
Mixed Paper, Broad	-0.97273	0.059472	0.514061
Mixed Paper, Residential	-0.866058	0.070798	0.903882
Mixed Paper, Office	0.042355	0	0.042355
Mixed Metals	0.042355	0	0.042355
Mixed Plastics	-0.82624	0.051382	0.45831
Mixed Recyclables	-0.559152	0.028023	0.14143
Mixed Organics	-0.391178	0.03135	0.392578
Mixed Municipal Solid Waste	0.042355	0	0.042355
Carpet	0.042355	0	0.042355
Personal Computers	0.042355	0	0.042355

* Units in each cell are metric ton of reduced/emitted gas(es) per metric ton of waste
(negative value mean 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)

However, comparison between recycling with the other conventional activities (Landfilling and combustion) is need. This can show that how recycling reduce the green house gasses compared to the landfilling or combustion activities.

The can be achieved by subtracting the values in the tables II and III from the table I. For example, when we recycle 3 ton of aluminum can instead of combustion of the same waste, we can reduce 3×(-16.7017) – 3×(0.068864) = 50.3117 metric ton equivalent of carbon dioxide (or $MTCO_2E$). And these can concluded as Tables IV – V.

The calculation shows that the Recyclable Materials Bank project has been reduced greenhouse gasses emission equivalent to about 5,263.481 metric ton of carbon dioxide during January 2011 to December 2011 by recycling the wastes from educational institutions instead of sending them to the landfill as the details in Fig. 2. While 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 4,126.877 metric ton of carbon dioxide equivalent as the details in Fig. 3. landfill approach.

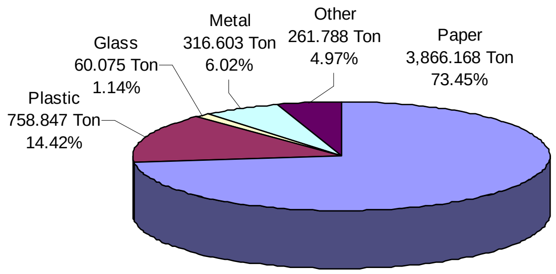

Fig. 2 Fraction of reduced $MTCO_2E$ by RMB project compared with the landfill approach

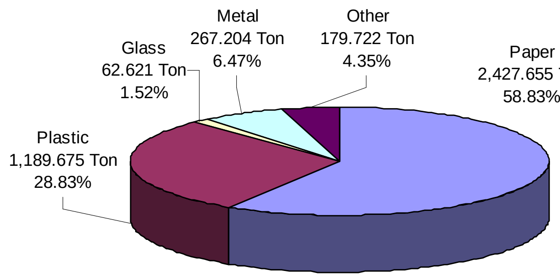

Fig. 3 Fraction of reduced $MTCO_2E$ by RMB project compared with the combustion (incineration) approach

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

Type of waste	CO_2	CH_4	CF_4	C_2F_6	N_2O	$MTCO_2E$
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 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 ton 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 V
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	$-2.94x10^{-4}$	$-2.34x10^{-5}$	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	$-1.03 x10^{-4}$	$-8.21x10^{-6}$	0	-6.0693
Mixed Metals	-2.53228021	-0.0081	0	0	0	-2.73548
Mixed Plastics	-2.3876496	-0.00070322	$-5.48x10^{-6}$	$-4.36 x10^{-7}$	-0.00011214	-2.48555
Mixed Mixed Municipal Solid Waste	-6.28767797	-0.0152	0	0	-0.00588	-8.421078
Carpet	-2.35734764	-0.00319694	$-4.75 x10^{-5}$	$-3.78 x10^{-6}$	0	-2.83287

Units in each cell are metric ton of reduced/emitted gas(es) per metric ton of waste
(negative value mean 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 reason that value from recycling instead of incineration approach is lower than that of recycling instead of waste disposal by landfill is the incineration approach produces more greenhouse gasses emission than the sanitary

Fig. 2 and Fig. 3 show that a group of paper can reduce the largest amount of greenhouse gasses emission followed by a group of plastic, metal, mixed municipal solid waste and glass, respectively.

It is interesting to note that a group of metal can reduce the higher amount of greenhouse gasses emission than a group of glass even the metal's group has a lower quantity of the waste than the glass's 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 group of glass.

That mean recycling of metal reduces a raw material and energy that used in the process of metal production which results in the less emission of greenhouse gasses.

IV. Conclusion

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

Acknowledgements

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