CARBON ACCOUNTING SYSTEM FROM INTEGRATED MUNICIPAL WASTE MANAGEMENT IN THAILAND: CASE STUDY SAKHONNAKHON PROVINCE

Miss Suthira Puangsiri

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science Program in Environmental Management
(Interdisciplinary Program)
Graduate School
Chulalongkorn University
Academic Year 2010

ระบบบัญชีคาร์บอนจากการจัดการขยะชุมชนแบบบูรณาการในประเทศไทย กรณีศึกษา จังหวัดสกลนคร

นางสาว สุธิรา พวงศิริ

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
สาขาวิชาการจัดการสิ่งแวดล้อม (สหสาขาวิชา)
บัณฑิตวิทยาลัย จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2553

Thesis Title	CARBON ACCOUNTING SYSTEM FROM INTEGRATED MUNICIPAL WASTE MANAGEMENT IN THAILAND: CASE STUDY SAKHONNAKHON PROVINCE.
By	**Miss Suthira Puangsiri**
Field of Study	**Environmental Management**
Thesis Advisor	**Chanathip Pharino, Ph.D.**

Accepted by the Graduate School, Chulalongkorn University in Partial Fulfillment of the Requirements for the Master's Degree

……………………………………Dean of the Graduate School
(Associate Professor Pornpote Piumsomboon,Ph.D.)

THESIS COMMITTEE

…………………………………… Chairman
(Assistant Professor Manaskorn Rachakornkij, Ph.D.)

…………………………………… Thesis Advisor
(Chanathip Pharino, Ph.D.)

…………………………………… Examiner
(Associate Professor Orathai Chavalparit, Ph.D.)

…………………………………… Examiner
(Assistant Professor Pichaya Rachdawong, Ph.D.)

…………………………………… External Examiner
(Punjaporn Weschayanwiwat, Ph.D.)

สุธิรา พวงศิริ: ระบบบัญชีคาร์บอนจากการจัดการขยะชุมชนแบบบูรณาการในประเทศไทย กรณีศึกษาจังหวัด สกลนคร. (CARBON ACCOUNTING SYSTEM FROM INTEGRATED MUNICIPAL WASTE MANAGEMENT IN THAILAND: CASE STUDY SAKHONNAKHON PROVINCE) อ. ที่ปรึกษาวิทยานิพนธ์หลัก: อ. ดร. ชนาธิป ผาริโน, 145 หน้า.

การจัดการขยะชุมชน ณ แหล่งกำเนิดถือเป็นความจำเป็นสำหรับการแก้ไขปัญหาขยะอย่างมีประสิทธิภาพ แรงจูงใจถือเป็นสิ่งสำคัญที่จะสามารถชักจูงให้สมาชิกในชุมชนมีความสนใจและอยากมีส่วนร่วมในการจัดการขยะตั้งแต่จุดกำเนิด ธนาคารขยะเป็นกลไกหนึ่งที่ช่วยให้สมาชิกเกิดแรงจูงใจในการรีไซเคิลขยะ ยิ่งไปกว่านั้นการลดก๊าซเรือนกระจกจากภาคการจัดการขยะก็เป็นอีกหนึ่งแรงจูงใจที่สำคัญ ซึ่งจะสามารถเกิดขึ้นได้ในรูปแบบของธนาคารคาร์บอน คาร์บอนไฟแนนซ์ และมาตรการการลดก๊าซเรือนกระจกโดยสมัครใจ

การศึกษานี้มีจุดประสงค์เพื่อพัฒนาเครื่องมือสำหรับช่วยในการตัดสินใจ และเสนอแนะกลยุทธ์เพื่อช่วยให้ชุมชนสามารถเพิ่มแรงจูงใจให้กับการดำเนินกิจกรรมรีไซเคิล รวมถึงพัฒนาประสิทธิภาพของการจัดการขยะและลดการปล่อยก๊าซเรือนกระจกจากภายในชุมชนอีกด้วย ในการวิจัยนี้ได้เลือก เทศบาลพังโคน จังหวัดสกลนคร เป็นกรณีศึกษาเพื่อวิเคราะห์กลไกและปัจจัยที่มีผลต่อความสำเร็จในการจัดตั้งธนาคารขยะชุมชนเพื่อใช้ในการเพิ่มประสิทธิภาพในการจัดการขยะชุมชน และเพื่อให้สมาชิกในชุมชนตระหนักถึงการปรับเปลี่ยนพฤติกรรมการบริโภคและการจัดการขยะของตน การศึกษานี้ได้ประเมินปริมาณการปล่อยก๊าซเรือนกระจกที่ลดลงได้ในระยะเวลา 1 ปี จากกิจกรรมของธนาคารขยะในชุมชนพังโคน การวิเคราะห์ได้ใช้โมเดล 3 โมเดลคือ (1) *the Integrated Waste Management for Municipalities (IWM)*, (2) *the Waste Reduction Model (WARM)*,และ (3)โมเดลที่พัฒนาขึ้นในงานวิจัยโดยใช้ค่าสัมประสิทธิการปล่อย *GHG* ของงานวิจัยที่ได้ทำศึกษาแล้วใช้ชื่อโมเดลที่ พัฒนานี้ว่า *EF-DB* งานวิจัยนี้ได้ทำการพัฒนาระบบบัญชีคาร์บอนจากกิจกรรมการรีไซเคิลขยะของชุมชน (รายครัวเรือนและทั้งชุมชน) รวมถึงได้ทำการสำรวจความเห็นจากสมาชิกในชุมชน เพื่อหากลยุทธและข้อเสนอแนะในการเพิ่มประสิทธิภาพการรีไซเคิลขยะที่สามารถนำไปปรับใช้สำหรับชุมชนอื่นๆต่อไป

ผลการวิจัย พบว่า (1) การรีไซเคิลขยะมีศักยภาพในการช่วยลดการปล่อยก๊าซเรือนกระจก และอาจจะได้รับผลประโยชน์จากระบบคาร์บอนไฟแนนซ์ อีกด้วย (2) ระบบบัญชีคาร์บอนที่พัฒนาขึ้นสามารถใช้ในการคำนวณและบันทึกการลดการปล่อยก๊าซเรือนกระจกจากกิจกรรมการรีไซเคิลขยะรายบุคคลได้ (3) ผลสำรวจจากแบบสอบถาม พบว่าคุณธรรมส่วนบุคคลและผลตอบแทนทางการเงินเป็นแรงจูงใจหลักสำหรับการลดขยะจากแหล่งกำเนิด (4) การเป็นสมาชิกของธนาคารขยะจะช่วยเพิ่มความสนใจของประชาชนในการมีส่วนร่วมกับธนาคารคาร์บอนและช่วยลดการปล่อยก๊าซเรือนกระจก (5) การให้ความรู้เพิ่มเติมเกี่ยวกับการรีไซเคิลให้กับประชาชน, การส่งเสริมการมีรายได้จากการขายขยะ, และการเพิ่มคุณภาพของการบริการเพื่อสนับสนุนกิจกรรมการรีไซเคิล ถือเป็นปัจจัยหลักสำคัญที่ช่วยเพิ่มการจัดตั้งธนาคารขยะและธนาคารคาร์บอนในชุมชนในวงกว้างให้สำเร็จ และจะช่วยให้ชุมชนได้รับประโยชน์จากทั้งจากการแก้ปัญหาการจัดการขยะและปัญหาการปล่อยก๊าซเรือนกระจกได้

สาขาวิชา <u>การจัดการสิ่งแวดล้อม</u> ลายมือชื่อนิสิต...

ปีการศึกษา 2553 ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์หลัก...

5287579020: MAJOR ENVIRONMENTAL MANAGEMENT
KEYWORDS: Recycling / Waste Bank / Incentive / Carbon Bank / Carbon Account

SUTHIRA PUANGSIRI: CARBON ACCOUNTING SYSTEM FROM INTEGRATED MUNICIPAL WASTE MANAGEMENT IN THAILAND: CASE STUDY SAKHONNAKHON PROVINCE. ADVISOR: CHANATHIP PHARINO, Ph.D., 145 pp.

Initiatives to minimize solid waste generation in local communities are a key to manage the wastes at source. Providing incentive is important to encourage people to actively participate in their municipal waste management especially recycling activity. Community waste bank is a mechanism to give incentives and become a foundation to support recycling activity in the communities. Moreover, benefits from GHG mitigation of waste sector will provide added incentive by implementation of carbon bank, carbon finance, and voluntary financial support for the mitigation efforts.

This study aims to develop a decision-making tool and strategies to help the local community improving efficiency of managing their municipal waste and inherently reducing GHG emission. Phangkhon Municipal District in Sakhonnakhon was chosen to investigate the mechanism in setting up a community waste bank and carbon bank system to alter citizens' consumption-disposal behavior and incentives to efficiently manage municipal solid waste.

Based on activities of the case study, the research evaluates amounts of 1-year GHG emission reduction from the waste bank by using (a) the Integrated Waste Management for Municipalities: IWM, (b) the Waste Reduction Model: WARM, and developing (c) a new model by adopting emission factors from existing research (EF-DB). The study developed a carbon account based on evaluation of GHG emission reduction from the recycling activity, and did surveys the citizens' opinions living in the district to finally provide recommended strategies to help other communities increasing efficiency of waste recycling.

In summary, the research found that (1) the recycling activity has increasing potential to reduce GHG emission and to gain benefits from carbon finance, (2) the carbon accounting system can be used for evaluating and recording individual GHG emission reduction from the recycling activity, (3) the survey found that citizen awareness and financial benefits are major incentives to reduce wastes at source, (4) being a member of the waste bank brings people more interested in carbon bank and helps reducing GHG emission, and (5) public education, revenues and quality of waste collection service are major factors for improving efficiency of waste recycling. Therefore, governments have to provide more public education, financial incentive, and service for citizens to widely implement waste bank and carbon bank in local community. Eventually, communities will not only get benefits from solving waste management but also help reducing GHG emission.

Field of Study : Environmental Management Student's Signature ....

Academic Year : 2010 Advisor's Signature ....

ACKNOWLEDGEMENTS

I would like to express my gratitude to the governor and staffs at Phangkhon Municipal District, Sakhonnakorn Province for information and collaboration, Department of Environmental Quality Promotion for financial support from "Green Economy Project", Dr. Sitanon Jesadapipat for valuable inputs and recommendations, and all invaluable comments from persons whose names may not be listed here.

Beside, I would like to express my sincere appreciation and gratitude to Dr. Chanathip Pharino my thesis advisor, Asst. Prof. Dr. Manaskorn Rachakornkij chairman of the committees and all committees for their encouragements and constructive suggestions throughout this work. Furthermore, I would like to thank Center of Excellence for Environmental and Hazardous Waste Management (EHWM) for financial support, knowledge, and opportunity for studying the research, and all my friends of EHWM especially Ms. Prapaporn Luekittisup, Miss Kanyaratt Waiyaput, Miss Waritta Ruangtrakul, and Miss Vichuda Tipsunave for useful information. Lastly, I deeply express to my gratitude to my family for fostering and supporting me.

CONTENTS

Page

Page

Page

LIST OF TABLES

Table **Page**

Table **Page**

LIST OF FIGURES

Figure **Page**

Figure **Page**

LIST OF ABBREVIATIONS

€	:	Pounds EURO
3R	:	Reduce, Reuse, and Recycle
A_{En}	:	Avoided Energy Consumption from Waste Management Activity
A_{GHG}	:	Avoided Greenhouse Gas Emission from Recycling Process
Annex I	:	Party of Countries are Classified as Industrialized Countries
Al	:	Aluminum
AWMAP	:	Advance Waste Management in Asia and the Pacific
CCX	:	Chicago Climate Change
CDM	:	Clean Development Mechanism
CERs	:	Certified Emission Reduction
CGB	:	Community Garbage Bank
CH_4	:	Methane
CO_2	:	Carbon Dioxide
CO_2 eq	:	Carbon Dioxide Equivalent
COP16	:	The 16th Conference of Parties to the 1992 United Nations Framework Convention on Climate Change
CSR	:	Corporate Social Responsibility
CSR	:	Corporations Supporting Recycling
D	:	Distance for Transportation to Landfill
D_{Re}	:	Distance from Recycling Activity
DEQP	:	Department of Environmental Quality Promotion
DNA	:	Designated National Authority
DOE	:	Designated Operational Entity
DOLA	:	Department of Local Administration
E_C	:	Greenhouse Gas Emission from Organic Waste Composting in Landfill
E_{GHG}	:	Greenhouse Gas Emission from Waste Management Activity
E_S	:	Greenhouse Gas Emission form Spread and Compact Waste in Landfill

E_V	:	Greenhouse Gas Emission form Vehicle for Landfill of Waste
EB	:	Executive Board
EF_{Raw}	:	Emission Factor of Avoided GHG for Production Process from Raw Material in each Type of Waste
EF_{Re}	:	Emission Factor of Avoided GHG for Recycling Material
EF-DB	:	Developing Model from Emission Factor of Browne, O' Regan, and Moles (2009)
En	:	Energy Consumption from Waste Management Activity
En_{Raw}	:	Emission Factor of Avoided Energy Consumption for Production Process from Raw Material in each Type of Waste
En_{Re}	:	Emission Factor of Avoided Energy Consumption for Recycling Material in each Type of Waste
En_S	:	Energy Consumption form Spread and Compact Waste in Landfill
En_T	:	Energy Consumption for Transportation of Waste
EPA	:	Environmental Protection Agency
EPIC	:	Environment and Plastic Industry Council
Eq.	:	Equation
ERRA	:	Energy Regulators Regional Association
ET	:	Emission Trading
Fe	:	Ferrous
GHG	:	Greenhouse Gas
IWM	:	Integrated Waste Management Model for Municipalities
ISWM	:	Integrated Solid Waste Management
JI	:	Jointed Implementation
LCA	:	Life Cycle Assessment
LCI	:	Life Cycle Inventory
LCS	:	Low Carbon Society
LoA	:	Letter of Approval
LP	:	Linear Programming
MRV	:	Measurable, Reportable, and Verifiable
MSW	:	Municipal Solid Waste

MSWM	:	Municipal Solid Waste Management
$MtCO_2$	:	Million Ton Carbon Dioxide
NGO	:	Non-Government Organization
NO_x	:	Nitrogen Oxide
ONEP	:	Office of Natural Resources and Environmental Policy and Planning
PAO	:	Provincial Administrative Organizations
PET	:	Polyethylene Terephthalate
PCD	:	Thai Pollution Control
PDD	:	Project Design Document
PP	:	Project Participant
Re	:	Recycled Material
S1	:	Scenario1
S2	:	Scenario2
S3	:	Scenario3
S4	:	Scenario4
S5	:	Scenario5
S5.1	:	Scenario5.1
S5.2	:	Scenario5.2
S6	:	Scenario6
SAO	:	Sub-district Administrative Organizations
SGB	:	School Garbage Bank
T	:	Trips of Transportation
T_{Re}	:	Trips of Waste Recycling Transportation
TEI	:	Thailand Environment Institute
TGO	:	Thailand Greenhouse Gas Management Organization
TIPMSE	:	Thailand Institute of Packaging and Recycling Management for Sustainable Environment
UBoC	:	United Bank of Carbon
UK	:	United Kingdom
UNEP	:	United Nations Environment Program
UNEP RRC.AP	:	United Nations Environment Program Regional Research

		Centre for Asia and the Pacific
UNFCCC	:	United Nations Framework Convention on Climate Change
US	:	United State
USA	:	United State of America
USD	:	US Dollar
VDP	:	Village Development Project
VERs	:	Verified Emission Reductions
Vir	:	Virgin Material
W_{Al}	:	Amounts of Total Aluminum Waste Generation in the Community
W_{Fe}	:	Amounts of Total Ferrous Waste Generation in the Community
W_G	:	Amounts of Total Glass Waste Generation in the Community
W_P	:	Amounts of Total Paper Waste Generation in the Community
W_{Pl}	:	Amounts of Total Plastic Waste Generation in the Community
$W_{Org.}$	:	Total of Organic Waste
W_{Re}	:	Amounts of Waste Recycling in the Community
W_T	:	Amounts of Total Waste Generation in the Community
WARM	:	Wasted Reduction Model
WISARD	:	Waste – Integrated Systems Assessment for Recovery and Disposal

CHAPTER I
INTRODUCTION

1.1 Problem Statement

Global warming will become a severe threat to all humanity for an incoming future. Reducing greenhouse gas (GHG) is a major responsibility for every nation. Kyoto protocol is a global commitment to lessen GHG level. The first Kyoto Protocol set target for developed country to reduce GHG 5% from 1990 level in 2010. Incentives of developed countries to meet GHG commitment were stringent penalties if they are not able to meet the given target. On the other hand, developing countries have no commitment target, therefore lack of incentives to limit their GHG emission. However, international community voluntarily provides financial supports in form of investment and funds to purchase GHG offsets (carbon credits) from the Clean Development Mechanism (CDM) projects or through voluntary markets.

Clean Development Mechanism (CDM) is a useful market-based approach to help developing countries in sharing the burden of GHG reduction of the Kyoto protocol by getting incomes from selling carbon credits to developed countries, which can incorporate the credits for compliance with their GHG commitment. The mechanism must follow the methodology guided by United Nations Framework Convention on Climate Change (UNFCCC). To get certified emission reduction (CERs), CDM projects must use transparent and accountable tools for estimating and recording their GHG emission reduction from the projects.

According to UNFCCC statistics, majority of CDM projects are from energy sector (68.06%) (i.e. energy industrial, energy demand, and fugitive emissions from fuels). Waste handling and disposal (17.39%) is the second largest sector in CDM while proportion of other sectors are industrial sector (9.30%) ,agriculture (4.58%), afforestation and reforestation (0.55%), and transportation (0.11%). Thailand is ranked 14^{th} among developing countries, which CERs were issued, approximately 0.19 % of total CERs or 815,224 Tons CO_2 equivalent/year. From the CDM projects, CERs could provide revenues as the projects' profits. On the other hand, there are some activities, which could reduce GHG emission on voluntary basis (no-related to the Kyoto reduction commitment) but cannot get CERs, which because of methodology for the activity did not yet release from UNFCCC or higher cost of implementation of CDM. The activities could gain their financial support from voluntary carbon market, which a number of organizations and NGO groups provide supporting budgets for the activities (Green Markets International, 2007).

In 2010, The 16th Conference of Parties to the 1992 United Nations Framework Convention on Climate Change (COP16) shows trends of GHG mitigation will strict more than the past. Developing countries try to force not only developed countries but also developing countries to formally reduce GHG emissions from their activities so in the future Thailand may be controlled national GHG emission. Moreover, COP16 encourage developed countries to support monetary and technology for supporting GHG mitigation in developing countries. The monetary and technology supporting attract developing counties or communities from developing countries to cooperate in GHG mitigation programs.

In 2005, Thailand was ranked in the 24th of GHG emission in the world that emitted approximately 351 $MtCO_2$ equivalent, for the emission per capita was ranked the 69th that emitted approximately 5.8 $MtCO_2$ equivalent per capita. The fraction of GHG emission from each sector in 2003 as follow: energy sector (56.1%), agriculture sector (24.1%), waste sector (7.8%), land use and forestry sector (6.6%), industrial sector (5.4%). As ranking the 3rd in GHG emission sector, waste sector should also be considered in priority order to limit GHG. It might be more feasible to manage GHG reduction for waste sector than that for the agriculture sector. Increased efficiency in waste handling and management not only better help reducing direct GHG emission from landfills but also receiving co-benefit from reuse and recycle in term of avoided GHG emission.

As same as situation of global warming, significant increases of solid waste generation are a major crisis in many countries due to population growth and increasing demand for consumption. The rising of waste generation capacity leads to big burdens and problems in waste management and service for most government in every country. Proper waste management requires sufficient or maybe high budgets for managing and disposal wastes. Due to high costs of waste management and insufficient capacity of law enforcement, many developing countries have inefficient waste management system. Evidently, illegal dumping is commonly found in many peri-urban areas of the big capitals. Increasing amount of wastes is not only being a huge financial burden but also causing environmental problems such as air pollutions, health effects, infection, and etc.

Municipal solid waste issue is a major concern because efficiency of municipal solid waste (MSW) management in Thailand has only slightly increased since 1994. While the amount of MSW generation increased from 11 million Tons or 0.53 kg/capita/day in 1993 to 14.3 million Tons or 0.62 kg/capita/day in 2002 (Chiemchaisri, Juanga, and Visvanathan, 2007). Composition of Thai MSW has similar portion as those in other developing countries in Asia. Thailand Environmental Monitor (2003) claims Organic waste is a major composition of MSW in Thailand, following by plastic and paper. Thai Pollution Control Department (PCD) (2004) reported that the majority of waste disposal practice in Thailand is open dumping (64%). Open dumping is an improper waste management creating number of negative effects such as infection, greenhouse gas emission, and also illegal. Regarding the MSW crisis in Thailand, it is urgent to increase efficiency of waste management to deal with this on-going problem with every possible approach. The improper waste management in Thailand may cause by high costs for proper waste disposal. In addition, lacks of understanding and skilled workers for handling wastes and lacks of stringent policies might be reasons causing people neglect to manage their wastes properly. To deal with the problem of lacking skilled workers and stringency policies for waste management system, the local community could become a key group to improve waste management activity in their community. Municipal solid waste (MSW) is actually a local environmental, economic, and social problem; therefore, local people could effectively manage it. Incentives to help reducing MSW in local community are crucial. However, local initiatives to eliminate the solid wastes in local community are still insufficient.

Efficient waste management has several benefits including neat environment and good hygiene, reducing total cost of waste management, and reducing GHG emission of waste stream. To improve the efficiency of waste management system in Thailand, integrated waste management (including reduce, reuse and recycle) has proven to be a recommended solution (Shamit, 2007). Thailand has a big gap to improve waste recycling potential to solve MSW problem in the country because in 2007, only 22% of total generated wastes (3.25 million Tons) are sorted to recycle (Jiaranaikhajorn, 2008). So increasing of waste recycling efficiency is a challenge of waste management in Thailand.

To increase efficiency of waste recycling in Thailand, 3Rs (reduce, reuse, and recycle) principle and waste banking approach is promoted in many communities, the 3Rs provide benefits by conserving virgin materials from extraction, saving energy consumption (i.e. saving in extraction, production, and treatment processes), and reducing all related costs of waste management. The waste banking system is adopted in many schools and communities in Thailand that the banking based on market mechanism for selling their recyclable wastes to the bank (local organization and/or volunteers). The bank acts as a collector then transit and sell the goods to recycling facilities or shops. Incomes from sales will be recorded into the individual waste account/passbook. The system encourages people to participate in 3Rs activities and then recognize amount of the recycle wastes and income into their accounts. The account owners will get money or rewards in returns in proportions based on an agreement set by the operating organization.

To improve waste management efficiency via the recycling activity in Thailand, GHG mitigation from waste sector provides high prospect for our country to promote carbon banking system and gain benefits from carbon finance, potentially selling carbon credits or acquiring voluntary financial support for the mitigation.

Carbon banking from waste recycle activity is a new idea aiming to record amount of avoided emission from businesses as usual activities to offer incentive for GHG reduction by receiving financial supports for Corporate Social Responsibility (CSR) activities or from voluntary carbon markets. For the carbon banking idea, carbon accounting should provide and use as a tool that support further activities of carbon bank system. The carbon account could show to the public how their waste management activities accountable GHG avoided emission. However, no methodology or official practices yet developed for evaluating avoided GHG reduction from waste recycles, even if for CDM.

According to many local communities in Thailand have been set up recycling campaign via the waste bank, GHG emission can be avoided from the recycling activity. But none of the existing waste banking system in Thailand was evaluated and recorded amounts of avoided GHG emission from their recycling activities into the passbook. Waste bank including carbon bank will help communities and their citizens realize their potential for avoided GHG emission from their recycling activity. Moreover, the carbon bank is a mechanism for supporting to potentially set up CDM projects or voluntary mitigation from communities' waste recycling activity.

To evaluate of avoided GHG emission from waste management activity, many Integrated Solid Waste Management (ISWM) models are used to estimate and record the amount of GHG emission in each process of the waste management system. However, many of GHG emission models were developed suitable for specific operating conditions and were only able evaluate at macro-scale (e.g. impacts from entire community). Unfortunately, no model is able to show individual burden of GHG emission and abilities for reduced GHG emission from their waste management activities. Carbon account idea is adapted with a mathematical model for evaluating amount of GHG emission from activities and recording both of community and individual avoided GHG emission. If amount of avoided GHG emission from individuals' waste management (i.e. waste reduction, sorting, recycling, reuse, or recovery) can be measured, it will provide valuable information to share potential benefits from carbon finance system.

Incentive will play a big role to encourage people to actively participate in their municipal waste management. This study aims to (1) evaluate amounts of avoided GHG emission from community's recycling activity, (2) develop a tool for assessing individual carbon credits from recycle wastes in waste management system, (3) investigate impacting factors for successful setting up waste bank, (4) recommend strategies for better promoting integrated waste management system in Thai communities. The challenge is how to implement a waste banking/ 3Rs/ carbon banking in practice at community level. Eventually, this study aims to develop a decision-making tool and strategies to help the local community increase their incentives and improve efficiency of managing their municipal waste and inherently reducing GHG emission as well. Therefore, the ISWM system if being more widely implemented will bring remarkable benefits to our country and world community.

1.2 Research Objectives

There are four aims of this study:

1. To select the mathematical model for Integrated Solid Waste Management (ISWM) suitable to estimate GHG from various municipal waste management schemes.
2. To develop a tool for a local community to record recyclable wastes and calculate their avoided carbon emission from recycled activity for individual person.
3. To estimate avoided carbon emission from recycled waste activities in the case study using the developed model.
4. To recommend strategies for setting up carbon banking system to better promote recyclable wastes for other communities to enhance public awareness for waste recycling activities.

1.3 Hypotheses

1. Waste recycling activity can help reducing GHG emission and reducing energy consumption.
2. A community waste bank can be a foundation for setting up a community carbon bank.

1.4 Scopes of the Study

This study analyzed avoided GHG emission from life cycle of household waste stream particularly focusing on 4 major types of recycling materials including paper, glass, plastic and metal (i.e. ferrous and aluminum). The GHG emission can be reduced from amounts of energy savings in processes of extraction, production and disposal activities by substituting recycles with raw material which would emit GHG in the operations as shown in Figure 1.1. Emission of GHG during production process through disposal were evaluated and compared between with and without recycling activity. The carbon emission from baseline scenario would be compared with carbon emission from waste recycling scenarios to evaluate the amount of avoided carbon emission.

The scope of this study was estimation of GHG emission from waste life cycle using the selected model that was developed and widely used by many studies. Moreover, Excel Visual Basic was developed to provide a tool to manage waste collection data by recording, calculating and displaying the amount of avoided carbon emission from the case study.

The limitation in the study was a lack of life Cycle Inventory (LCI) for GHG emission of many waste recycle products in Thailand. The study instead adopts the LCI value available for developed countries. Phangkhon Municipal District, Sakhonnakhon Province was chosen as a case study because the community has already implemented integrated waste management and waste banking system.

Phangkhon is a municipal district in Sakhonnakhon province, located in northeastern part of Thailand. The community is an ideal location to demonstrate, validate, and verified the ISWM model for estimating avoided carbon emission from the community participation. As continuously recording their waste management data, avoided GHG emission from waste management activities was estimated and analyzed for the efficiency of recyclable waste. Furthermore, policies and strategies of the case study, which succeed to encourage people participation in waste management program in the area, were analyzed to identify lesson learned and suggestion for increased waste management efficiency and mitigate carbon emission in other communities in Thailand.

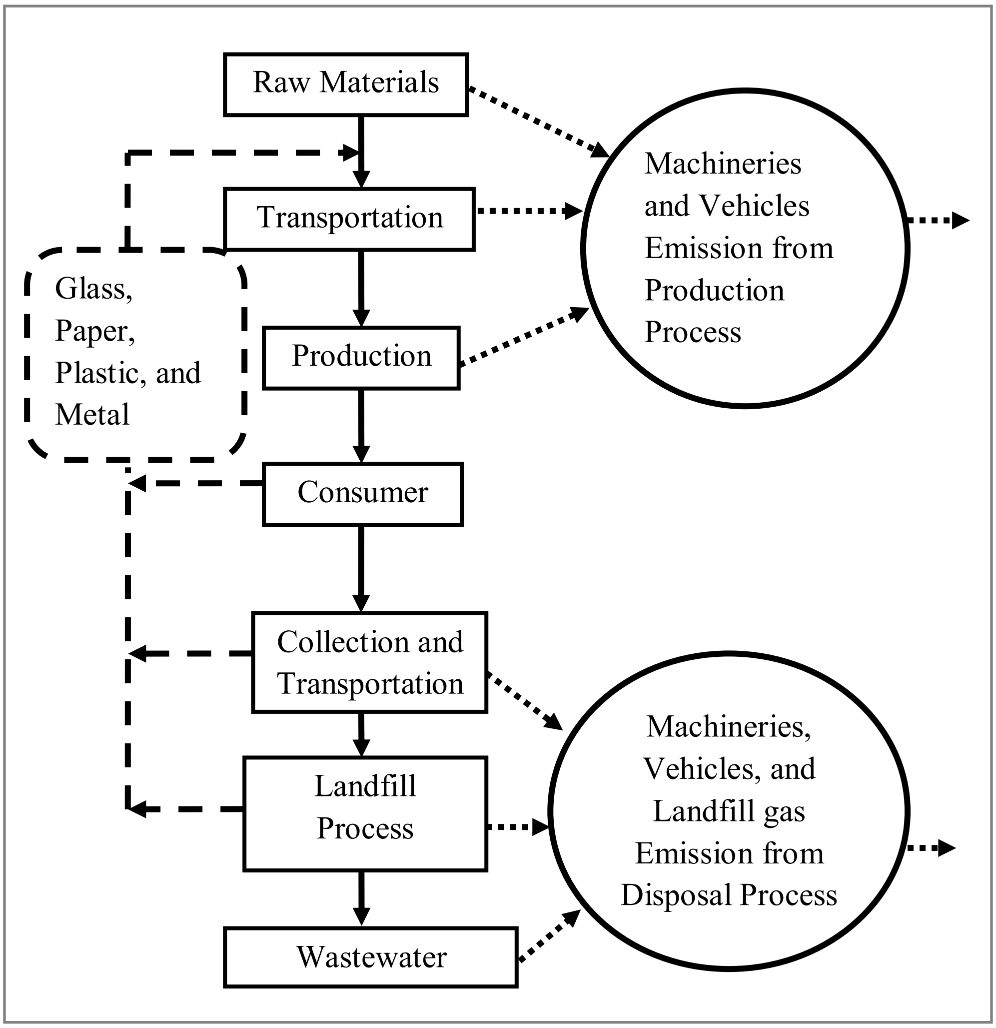


Figure1. 1 Life Cycles of Wastes from Households

CHAPTER II
BACKGROUND AND LITURATURE REVIEW

To improve waste management system and GHG mitigation in Thai community , the study examined and reviewed policy and structure of waste management in Thailand, 3Rs programs in Thailand, financial supports for GHG mitigation projects in developing countries, GHG mitigation from waste sector, CDM situation in Thailand, waste bank in Thailand, carbon bank, Life Cycle Assessment (LCA) of waste, Integrated Solid Waste Management (ISWM) models, waste management situation in Thailand, and background of case study. Details of these relevant backgrounds are as following;

2.1 Policies and Structure of Waste Management in Thailand

Waste management system in Thailand structured into 3 different levels of authority and responsibility is summarized in details in Table 2.1. Central Government including Pollution Control Department (PCD), Department of Environmental Quality Promotion (DEQP), Office of Natural Resources and Environmental Policy and Planning (ONEP), Department of Local Administration (DOLA), and Public Health Department, establish policies, guidelines, programs, regulations, and standards for waste management but they do not directly handle and manage the wastes. Likewise, Regional Government coordinates between central and local government for wastes management by adopting and transferring policies and implementation guidelines from central government to local government. For example, in Sakhonnakhon Province, the regional government does not directly manage wastes generation in the area but provide supports from the central government. Local government is directly responsible for handling and managing the wastes within their own area. Therefore, to strengthen the efficiency of waste management, local government plays a big role at the local context as the implementer. However, efficient policy and coordination from government at all levels are major factors.

Table2. 1 Waste Management Authority and Responsibility in Thailand (Jiaranaikhajorn, 2008)

Authority	Responsibility
Central Government • Pollution Control Department (PCD) • Department of Environmental Quality Promotion (DEQP) • Office of Natural Resources and Environmental Policy and Planning (ONEP) • Department of Local Administration (DOLA) • Public Health Department	• Provides recommendations on the technical preparation of MSW management policy • Develop guidance / guidelines and processes for MSW management • Promote and disseminate information pertaining to MSW management • Prepare policies and prospective plans • Administer the Environmental Fund • Administer the finance of Local Government Organization • Provide support for the preparation of Local Development Plans • Issue ministerial regulations to stipulate service charges
Regional Government • Provincial offices from Ministry of Natural Resources and Environment	• To coordinate related work between central and local government
Local Government • Local/District Municipality • Sub-district Administrative Organizations (SAO) • Provincial Administrative Organizations (PAO) • Special Administrative Areas (i.e. Bangkok and Pattaya city)	• To handle and manage waste in their own area

In term of law and regulation related to waste management in Thailand, Public Health Act B.E. 2535 (A.D.1992) is a basis regulation for waste controlling and management in Thailand (Mullikamal , 2000). The act requires each local administration to manage their own wastes by developing and issuing ordinances and regulations for collection, transportation, and disposal the wastes. In addition, there are other regulations and local provision of laws for municipal solid waste management: For example (Jiaranaikhajorn, 2008),

1. The Enhancement and Conservation of National Environmental Quality Act B.E.2535 (A.D. 1992): This Act empowers the local administration to conduct central disposal facility for public service and/or license private contractors for waste management service in the area. Moreover, this Act provides Environmental Funds to disburse grants or loans for investment and operation in their central facility.

2. The Public Health Act B.E.2535 (A.D. 1992): ThisAct provides local governments' authorities and duties for managing their waste and/or setting regulations for waste management in the local area.

3. The Public Cleansing Act B.E.2535 (A.D. 1992): This Act states the public cleansing if any area is contaminated, and prohibition of litter.

4. Municipality Act B.E.2496 (A.D.1953): Each municipality has a duty to clean up their areas and dispose wastes in their areas.

Although central government provides some budgets and/or loans for waste disposal facilities, budgets for waste management service mostly become a responsibility of each local government. Many local areas lacks of sufficient investment for effective waste management system. From past to present, insufficient budgets for waste management is a main barrier causing an on-going problem in the waste management system (PCD, 2004).

2.2 3Rs Program in Thailand

Thailand will face the MSW crisis in the very near future. Increasing of waste management efficiency is urgent. 3Rs principal (reduce, reuse and recycling) will be a recommended solution because the idea provides both of direct and indirect benefits such as reducing amounts of wastes to transport, collect and dispose, reducing some budgets paying for waste management service, generating revenues from selling recyclable wastes, reducing greenhouse gas (GHG) emission. An indirect benefit of 3Rs action is for example avoided amount of GHG emission from waste recycle and management.

Unfortunately, direct regulatory framework for supporting the 3Rs in Thailand did not exist. There are some regulatory indirectly supporting the 3Rs action such as Municipality Act B.E.2496 (A.D.1953). The Act allows private sectors to become operators for sorting and separating wastes that could reduce amounts of wastes sending to disposal site (PCD, 2004). Even though, there is no direct regulatory for 3Rs action, there are National policies and plans, which were proposed by Pollution Control Department (PCD), provide strategies for encouraging the 3Rs actions in Thailand as following (Jiaranaikhajorn, 2008)**:**

1. Social Strategy

Participation between public sector, private sector, and public awareness for reducing waste and increasing recyclable waste is promoted.

2. Economic Strategy

2.1 The private investment sectors using clean technology for goods production, waste treatment, and disposal management is promoted.

2.2 Taxation might be used as a tool for reducing wastes generated from production process.

3 Legal Strategy

3.1 Laws for supporting the 3Rs idea should be established.

3.2 Existing laws and regulations should be revised as well as emphasized on law enforcement in order to make various steps for waste management to be more effective.

4 Supportive Strategy

Research and development of appropriate technology for producing environmental friendly products and products which made from recycled materials should be supported.

Since there is no direct regulation for 3Rs activity in Thailand, the 3Rs activity depends on voluntary based. Pollution Control Department claimed the United Nations Environment Program Regional Research Centre for Asia and the Pacific (UNEP RRC.AP) under Advance Waste Management in Asia and the Pacific (AWMAP) supporting National 3Rs strategy development. The 3Rs strategies focus on resource use efficiency, sustainable consumption, recycling, treatment and proper disposal. These strategies cover whole life cycle of waste since production to disposal as shown in Table 2.2 (Thailand Environment Institute [TEI], 2005).

Table2. 2 National 3Rs Program (TEI, 2005)

Process	Strategy
Production	Waste reduction program (i.e. Eco-design, clean technology, clean product, and environmental labels)
	Promote reuse and recycling of wastes and recyclable materials
	Promote production of eco-friendly products
Distribution and Consumption	Promote recycling-oriented society
	Promote use of green products
	Promote separation and take-back programs
Recycling, Treatment and Disposal	Support community-based recycling activities
	Capacity building on 3Rs and waste management
	Promote public private partnership program
	Promote waste recycling business
	Standard and guideline for waste disposal

There are many voluntary 3Rs programs in Thailand. Examples of 3Rs activities are summarized in Table 2.3.

Table2. 3 Examples of 3Rs Activities in Thailand (TEI, 2005)

Process	3Rs Programs in Thailand
Production	19 green products and 4 green services
	Guideline and criteria for green procurement
	Road map of promotion green procurement
	Clean technology and clean product applications
	Green purchasing network
	Waste to energy, e.g. 2.5 MW of Phuket incinerator, 950 kW of biogas from landfill at Rachadeva, 625 kW of biogas at Rayong Municipality, 1MW of biogas from landfill at Khampeangsan
Distribution and Consumption	Over 200 communities implement the 3Rs activities (some municipality reduce waste up to 30-50%)
Recycling, Treatment and Disposal	Strengthen informal sectors on waste management business (Green junk shop project)
	Regional conferences for 3Rs of capacity building
	Guideline or manual for 3Rs activity
	Waste specific containers for separation wastes

In Thailand, there are many stakeholders involved in 3R campaigns, mainly divided into 3 sectors as followed:

1. Government Sector

1.1 Central government who initiates plans on the 3Rs and Low Carbon Society (LCS) campaigns for the National actions

1.2 PCD has planned, encouraged, and supported the campaigns for widely adopting the 3Rs action in Thailand. Moreover, many government officials have encouraged their personnel officers to follow the 3Rs campaign.

1.3 Regional governments who adopted plans from Central government and probably initiate the 3Rs and LCS campaigns for their province.

1.4 Local governments directly handle their wastes in their own area.

Currently, there are many local governments in Thailand supporting and encouraging their citizens to reduce their waste generation via the 3Rs campaign such as Phangkhon Municipal District in Sakhonnakhon Province, Si Sa Ket Town Municipality in Si Sa Ket Province, Phitsanulok City in Phitsanulok Province.

2. Private sectors

2.1 Scavengers who sort recyclable wastes at curbsides and/or disposal sites

2.2 Stores or companies doing a business on buying and selling the wastes, also support 3Rs activity (e.g. Wongpanit Company)

2.3 Non-Governmental Organization (NGO's), e.g. Thailand Institute of Packaging and Recycling Management for Sustainable Environment (TIPMSE)

3. Public sectors

3.1 Citizens who sort and sell their wastes

3.2 Academic (Schools, Colleges and Universities) educate staffs and new generations on 3R principle and provide demonstration programs within their institutions

3.3 Thailand Greenhouse Gas Management Organization (TGO) who have planned, encouraged, and supported the 3R campaign to promote benefits from low carbon activity by widely adopted the 3Rs action

Municipal solid waste (MSW) directly impacts local environmental, local economic, and local residents; local people could effectively manage it. Therefore, it is the best if sorting and recycling wastes are done at sources, managing by local citizens/households. It is vital to get local communities participate in waste management activity. However, incentives to help reducing MSW in local community are crucial. The current incentives are still insufficient such as lacking of social incentives because only a small numbers of people to be aware the benefits from the proper waste management, lacking of budgets for operations of proper waste management. Knowledge and perception of local administrators on solid waste management problems, source separation, and lack of skilled operators, significantly affects on 3Rs activity (Suttibak and Nitivattananon, 2008).

2.3 Financial Supports for GHG Mitigation Projects in Developing Countries

According to the fact that developing countries have potential to reduce GHG emission at a cheaper cost than by developed countries, there are opportunities to get financial supports from developed countries for setting up reducing GHG emission programs. This benefit could be an incentive for many countries and many communities to reduce GHG emission from their business as usual activities. This section reviews carbon finance and carbon trading (including CDM projects and voluntary mitigation).

2.3.1 Carbon Finance

Carbon finance is financial resources providing to set up GHG mitigation projects. The carbon finance can provide in many forms which comprises of cash, equity, debt or soft loan, contribute of technology (Sinha and Enayetullah, 2009).

In 2010, The 16th Conference of Parties to the 1992 U.N. Framework Convention on Climate Change (COP16) sets up Green Climate Fund to provide supporting in-term of monetary and technology from developed countries. The supporting encourages developing countries to increase their potential of avoided GHG emission. Developing countries must register and purpose strategies for GHG mitigation in-term of nation's sustainable development plan (Saitsiroj, 2010).

2.3.2 Carbon Trading

Emissions trading or carbon trading is an allowance for countries which have exceeding carbon units to sell the excess carbon capacity to other countries that emit carbon over their targets. The carbon has been tracked and traded which this trading is so-called "carbon market" (UNFCCC, 2010).

Developing countries, which generate GHG mitigation projects, can get financial support from carbon trading in the carbon market. Carbon market can divide to 2 categories including regulated market and voluntary market (Thailand Greenhouse Gas Management Organization [TGO], 2007). Regulated market is carbon market for projects which are regulated by Kyoto Protocol's mechanism (i.e. Joint Implementation: JI, Emissions trading: ET, and Clean Development Mechanism: CDM). To follow the mechanism regulation of Kyoto Protocol, developing countries can implement CDM projects. Voluntary market is carbon market for projects which are not regulated by Kyoto Protocol's mechanism.

2.3.2.1 CDM Projects

Regulated or Compliance market is a market for trading of certified reduction emissions (CERs). CERs are units of reducing GHG emission from regulated and directly under Kyoto Protocol which is so-called Clean Development Mechanism (CDM) projects. CDM project is a voluntary project from each country which is an additionality project from business as usual and must agree with sustainable development in the host country (TGO, 2010). Important principals of CDM projects' operation are transparency and accountable.

To get CERs for sale in the market, CDM projects must be measured by international agreement methods and must be quantified in standard which expressed in Tons of carbon dioxide (CO_2) equivalents. TGO (2010) claim prices for trading CERs in 2011 are 11.06-12.03 €/ Tons CO_2 eq or approximately 16-17.44 USD/ Tons CO_2 eq (1 € = 1.45 USD). CERs buyers are classified into 3 groups as shown in Table 2.4 (TGO, 2010).

Table2. 4 Groups of CERs Buyers (TGO, 2010)

Annex I Government	Carbon Fund	Carbon Broker
1. England: Department for Department Food And Rural Affairs 2. Denmark: Ministry of Foreign Affairs 3. Japan 4. EU Group 5. Companies or Industrial which need to reduce GHG emission	Funds from governments, organizations or companies which need carbon credits such as 1. World Bank which organize Prototype Carbon Fund and Development Carbon Fund 2. Italian Carbon Fund Danish Carbon Fund 3. Japan Carbon Finance	Similar to stock broker such as 1. Singapore: Asia Carbon Exchange 2. England: Traditional Finance Service

2.3.2.2 Voluntary Mitigation

Voluntary market is a market for trading of GHG reduction unit from projects which are not regulated and directly under Kyoto Protocol as known in verified emission reductions (VERs). As same as CERs, VERs must be measured by international agreement methods and must be quantified in standard which expressed in Tons of carbon dioxide (CO2) equivalents.

Objectives of voluntary market are to directly trade carbon credit between project owner and buyers without any agency, and to support reducing GHG emission projects, which do not follow flexible mechanism under Kyoto Protocol, trading their carbon credits. Buyers of the credits from VERs are usually organizations and/ or sectors which generate a huge amount of GHG. Because they aim to promote their CSR project and being a carbon offset. Moreover, some organizations and/ or sectors prepare for their further responsibility which they might force to reduce GHG emission in the future (TGO, 2010).

According to the voluntary mitigation is not necessary to register and regulate by UNFCCC regulation. But the voluntary might receive Letter of Approval (LoA) from Designed National Authority (DNA) of host country. Therefore, prices for carbon trading are lower than prices of CERs (approximately 0.05 US$ / Tons CO_2 eq) (TGO, 2010). Trends of VER's prices continuously increase but the market remains illiquid and delicate depending on limited number of participations (TGO, 2010). There are 2 voluntary markets including (1) Chicago Climate Change (CCX) in USA, and (2) Over-the-Counter.

2.4 GHG Mitigation from Waste Sector

In 2009, Shekdar reviewed waste management schemes during the 1970s, energy recovery became the main focus. After that in 1990s, recycling started to get into the waste management systems. Currently, basic of waste management were focused on recycling for sustainable development. Manaf, Samah, and Zukki (2009) claimed the highest priority of integrated solid waste management should be supported by 3Rs (Reuse, Reduce, and Recycle). He mentioned that the advantage of improving the sustainability of solid waste management system already exists from trading GHG reduction credits, which is the economic opportunity. McBeana, Rosso, and Rovers (2005) argued the revenue from the solid waste management system would approximately 1.2 times of the normal income gaining from the waste recycling efforts if the waste improvement projects obtain certified emission credits.

To improve waste management system, Appasamy and Nelliyat (2007) provide two considerations for improvement from finance point of view are Public-Private Partnerships and Carbon Financing. Public-Private Partnerships is important role for waste management because citizens sorting the waste which is the shared responsibility concept that has been effectively used (Shekdar, 2009). Municipalities are responsible for source-separated collection, and manufacturers help with material recycling (Sakai, 1996; Shekdar, 2009).

UN-HABITAT (2009) described the carbon financing, CERs, or carbon emission reduction units, are issued to projects, which reduce GHG emission. The carbon financing provide the financial profit that the most common of the activity is landfill gas recovery which gas was extracted and combined with either flaring or electricity generation. The carbon finance attracts private or public investment because of revenues. In 2007, Appasamy and Nelliyat claim that a case of an India waste management system might gain income from the carbon finance approximate 2-3 USD per Ton of MSW or more that the World Bank has estimated by considering methane captured from landfills.

Most CDM projects for waste management mention about energy recovery from landfill. Although recycle is an important factor for increasing waste management efficiency, lack of UNFCCC methodology for calculated avoided carbon emission from recyclable wastes is an obstruction for convincing the public and private sector who want to invest and get benefit from the CDM project.

2.5 CDM Situation in Thailand

In 1997, the Kyoto protocol set the GHG emission reduction target for developed countries parties (Annex I) to reduce 5% of their emission during 2008-

2012 compared to baseline year 1990. Meanwhile, the protocol allowed the Annex I able to comply their GHG reduction commitment by three mechanisms; Emission Trading (ET), Joint Implementation (JI), Clean Development Mechanism (CDM).

Thai government ratified the Kyoto Protocol in August 2002 then entered into force in 2005 (TGO, 2007). Because of the ratification, developing countries can get benefits from CDM projects as Article 12 of the protocol allows Annex I to donate or buy carbon credits to gain certified emission reductions (CERs) from CDM projects from developing countries. From economic point of view, the benefit for developing countries which gain from CDM projects is loans or budgets to invest for the projects generation. Previous studies provided interim period of commitment during 2000-2008 CERs from CDM can be banked for using in the commitment period since 2008 to 2012 and investment from donor countries or organizations is followed Article 12.10 (Parkinson et al., 1999; Woerdman, 2000; Unnikrishnan and Singh, 2010).

UNFCCC will issue CERs for projects which will be qualified by issuance of designed process and a rigorous public registration because the projects must real, measurable and verifiable emission reduction. The CDM projects must through the qualification approval procedure as shown in Figure 2.1.

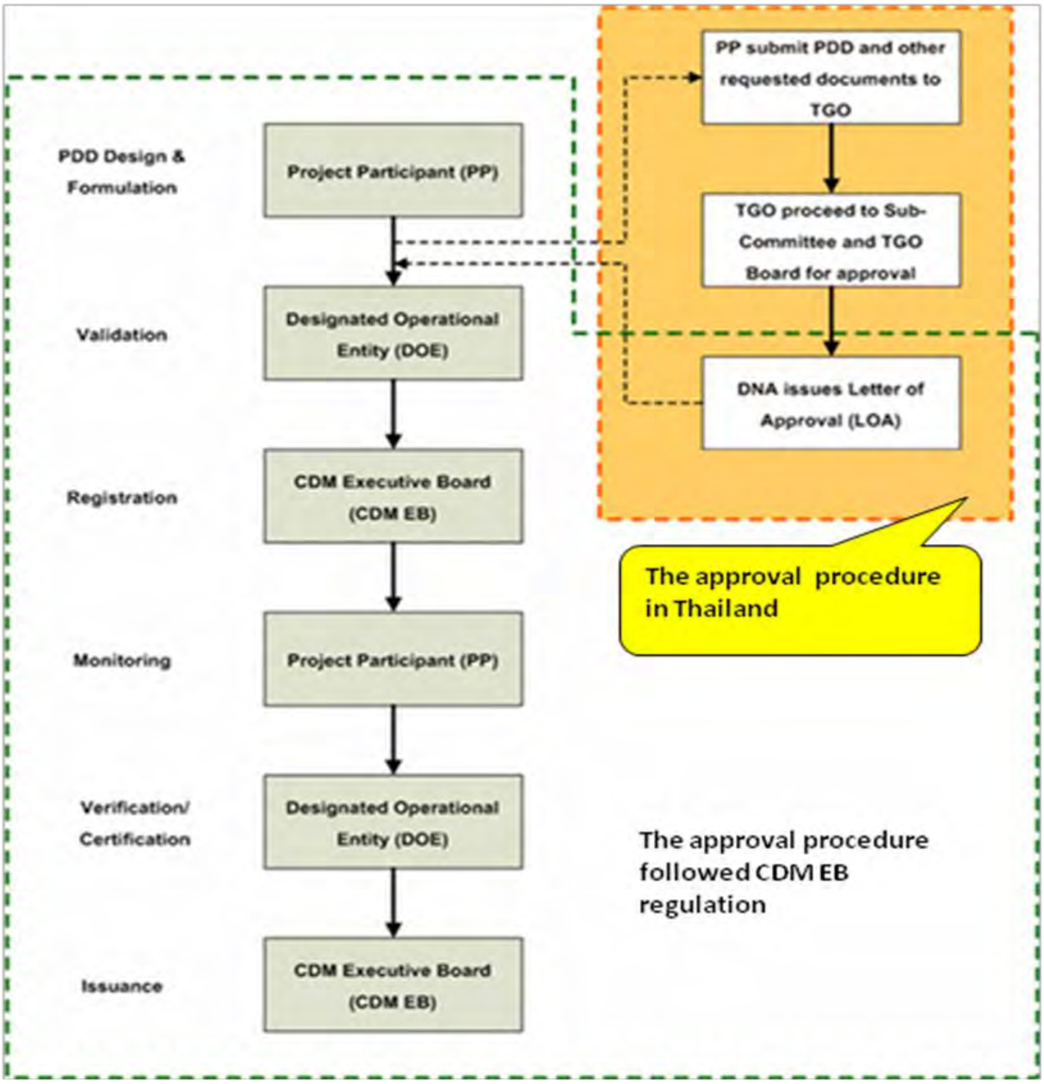


Figure2. 1 The Approval Procedure of CDM Projects (TGO, 2007)

In 2010, Thailand Greenhouse Gas Management Organization (TGO) reported that there are 111 projects received the Letter of Approval (LoA) in Thailand. The organization shows the amount GHG reductions of the projects are 6,947,295 Tons CO_2 eq. These CDM project are consisted of Biogas (67.59%), Biomass (20.13%), the others (12.28%). The proportion of the CDM projects is similar to other countries. Both of biogas and biomass show that the private sector in Thailand was encouraged by CDM mechanism to utilize more renewable energy (Adhikari et al., 2008). The CDM Executive Board (EB) registers 36 CDM projects from Thailand that the total of GHG reduction is 2,125,099 Tons CO_2 eq. But there are only 2 projects that were issued CERs by CDM EB i.e. A.T. Biopower Rice Husk Power Project on 21 December 2005-30 June 2007 (100,678 Tons CO_2 eq), and Korat Waste to Energy on 1 may 2003-16 June 2007 (714,546 Tons CO_2 eq). Adhikari et al. (2008) claimed that there are still a few number of CDM projects in Thailand which could get CERs because the CERs gained from the CDM projects in Thailand are premium standard which is unlike other countries.

Waste management is a one of many schemes eligible for registering as CDM projects. Many studies found that majority of CDM in waste sector were interested in energy recovery from disposal process or at landfills (for example Adhikari et al., 2008; Pharino and Jaranasaksakul, 2009; Unnikrishnan and Singh, 2010). TGO (2007) reports there are 7 projects of energy recovery from landfill in Thailand which 2 projects registered with CDM EB, and 5 projects have been validated by DOE as showed in Table 2.5.

Table2. 5 CDM Projects from Waste Management Scheme (TGO, 2007)

Project	Developer	Type of the Project	Lifetime	GHG Reduction (Tons CO_2/year)	Power Generation (MW)	Situation of the Project
1. Jaroensompong Corporation Rachathewa Landfill Gas to Energy Project	Jaroensompong Co. Ltd.	Energy Recovery from Landfill	20	47,185	1	Gained the Letter of Approval (LoA) on 28 Aug 2007. Registered with CDM EB on 14 Mar 2008.
2. Bionersis Project Thailand 1	Bionersis (Thailand) Ltd.	Energy Recovery from Landfill	10	71,474 (the number of GHG reduction as follow the PDD document which submits to TGO.) 118,609(the number of GHG reduction which registers with CDM EB.)	2	Gained the Letter of Approval (LoA) on 25 Dec 2008. Registered with CDM EB on 24 Sep 2009.

Table2. 5CDM Projects from Waste Management Scheme (TGO, 2007)

Project	Developer	Type of the Project	Lifetime	GHG Reduction (Tons CO_2/year)	Power Generation (MW)	Situation of the Project
3. Jaroensompong Corporation Panomsarakham Landfill Gas to Energy Project	Jaroensompong Co.,Ltd.	Energy Recovery from Landfill	10	93,320	1.02 MW X 2 Units	Gained the Letter of Approval (LoA) on 18 Jun 2009. Validating by DOE.
4. Chiang Mai Landfill Gas to Electricity Project	Dynamic Energy Co., Ltd.	Energy recovery from landfill	21	81,366	1.26 MW x 3 Units	Gained the Letter of Approval (LoA) on 23 July 2009. Validating by DOE.
5. Bangkok Kamphaeng Saen East: Landfill Gas to Electricity Project	Greenpower Co., Ltd. and PS Natural Energy Co., Ltd	Energy Recovery from Landfill	21	280,871	1.063 MW x 9 Units	Gained the Letter of Approval (LoA) on 23 July 2009. Validating by DOE.

Table2. 5 CDM Projects from Waste Management Scheme (TGO, 2007)

Project	Developer	Type of the Project	Lifetime	GHG Reduction (Tons CO_2/year)	Power Generation (MW)	Situation of the Project
6. Bangkok Kamphaeng Saen West: Landfill Gas to Electricity Project	Zenith Green Energy Co., Ltd. and Progress Energy Co., Ltd.	Energy Recovery from Landfill	21	273,424	6	Gained the Letter of Approval (LoA) on 23 July 2009. Validating by DOE.
7. Active Synergy Landfill Gas Power Generation Project Nakhon Pathom	Active Synergy Co., Ltd.	Energy Recovery from Landfill	10	32,661	1	Gained the Letter of Approval (LoA) on 21 Oct 2009. Validating by DOE.

As the result, waste scheme of CDM projects in Thailand were mainly focused at energy recovery from landfill. On the other hand, many research pointed out GHG issues of waste sector should also focus through the whole life cycle of waste (Zhao et al., 2009; Batool and Chuadhry, 2009) such as recycle which would lead to sustainability of solid waste management.

2.6 Waste Bank in Thailand

The waste bank has been implemented in many areas such as in Vietnam, Indonesia, also in Thailand. Initially, the waste bank usually sets up in schools for the student recycling activity such as The Bogor Nature School in Indonesia (Sufa, 2010), Ban Bakan School in Thailand (Siangyen, 2009). Now, the waste bank is either in form of school waste bank or community waste bank. In Thailand, school waste bank are implemented more than community garbage bank (World Bank, 2003; Suttibak and Nitivattananon, 2008). Many developing countries faced the same situation as Thailand, e.g. waste bank in Indonesia is not widely implemented (Terre de hommes Italia, 2010).

Regarding the recycling campaign in the local communities, waste-banking system has been set up only in some communities in Thailand. Waste/garbage bank is a place/organization where the members took their recyclable materials to exchange for money then the bank records the amounts of their wastes sale and their incomes from that selling into the member's account. Wongpanich Company claimed garbage bank setting in Thailand initiated by the company, which recognized the poor children and students in Pitsanulok city collected the recyclable waste to sell to the store then deposit that money from selling waste at banks. Hence, if there were a garbage bank in school, it would be more convenient for students (TEI, 2005). In 1999, the first garbage bank project has been set up at Panpi Temple municipality school, Amphur Muang, Pitsanulok to encourage the students and the citizens to sort, recycle their wastes and take them to sell (TEI, 2005).

Because of the success of the school garbage bank, it was expanded to other communities. Waste banking system in Thailand is set in form of school garbage bank (SGB) and/or community garbage bank (CGB). In Thailand, there are about 500

SGBs set up in 30 provinces (TEI, 2005). Each garbage bank reduced total amounts of wastes that would otherwise dispose into landfill approximately 3-5 Tons per month. The total of wastes decreases approximate 18,000 - 30,000 tons/year. Hence, the waste bank could save the budget of the country in waste management for millions baht (TEI, 2005). The financial benefit is an incentive which encourages other communities in Thailand to adopt the idea about waste management system. Moreover, garbage bank is a good symbolic of environmental conservation activity that the community plays a big role in voluntary care of the environment. Nevertheless, in many areas, the garbage bank system in Thailand is in a starting period. Continuation, improvement and expansion the concept to other community in Thailand is very important.

2.7 Carbon Bank

Carbon bank is familiar in form of carbon capture by trees such as Ontario's Boreal Carbon Bank mentions trees of Ontario Boreal forest region absorb CO_2 (ForestEthic, 2007), The United Bank of Carbon (UBoC) aims to reduce climate change by protecting the world's rainforests (United Bank of Carbon, 2011).

In 2005, Thailand has been set up Village Development Project (VDP) and carbon bank from trees planted project. This carbon bank from forestry in Thailand has been implemented in only 2 villages since 2005 (SEED, 2009). The project plans to expand the carbon bank from trees planted into 48 villages in 2011 then the expanding will foster a sustainable financial mechanisms for carbon credit payments. So carbon bank is still a very new idea in Thailand. Furthermore, carbon bank from garbage bank does not exist in Thailand. Similar to carbon bank from forestry should expand, carbon bank from garbage has a potential to develop and expand to the large extend from the garbage bank.

2.8 Life Cycle Assessment (LCA)

Paper, glass, plastic, aluminum, and ferrous are recyclable waste and valuable for exchanging in waste stream. They are the majority composition of recycle waste stream. Importantly, wastes generation cause various environmental impacts such as global warming impact. Several studies claim recycling the waste could reduce GHG emission in their life cycle (for example, Ekvall, 1999; Patel et al., 2000; Pickin, Yuen, and Hennings, 2002; Krivtsov et al., 2004; Diaz and Warith, 2006; Schmidt et al., 2007; Villanueva and Wensel, 2007; Al-Salem, Lettieri, Baeyens, 2009; Hanaadeh and El-Zein, 2010). Currently, recyclable wastes are valuable in the market, which is an important opportunity to reduce amount of wastes and to create a financial incentive for people who could get income from waste selling.

According to the recyclable wastes which could reduce energy consumption and GHG emission of their life cycle, Hanaadeh and El-Zein (2010) compared the amount of GHG emission between virgin material and recycles by using the data adapted from Haight (2004) and Environmental Protection Agency [EPA] (2002), as summarized in Table 2.6.

Table2.6 Emission Factors for Paper, Glass, Plastic, Aluminum, and Ferrous Recycling (Hanaadeh and El-Zein, 2010)

Emission	Paper		Glass		PET (plastic)		Aluminum		Ferrous	
	Vir(1)	Re(2)	Vir(1)	Re(2)	Vir(1)	Re(2)	Vir(1)	Re(2)	Vir(1)	Re(2)
Energy (GJ/Mg)	36.8	26.2	14.1	9.4	107.2	46.07	140	11.7	25.2	9.4
CO_2 (kg/Mg)	1304	-1300 to -2900	632	278	2363	163	5126	518	1820	595
CH_4 (kg/Mg)	0.02	0.01	1.11	0.83	25	0.016	6.53	2.71	0.01	1.29
NO_x (kg/Mg)	7.94	5.44	2.73	1.69	9.5	0.081	17.3	0.62	2.76	1.77

Remark: adapted from Haight (2004) and EPA (2002) (Hanaadeh and El-Zein, 2010).
(1)Emission of the life cycle from using virgin material for the production process.
(2)Emission of the life cycle from using recycled waste for the production process.

2.8.1 LCA of Paper Production

The life cycle assessment includes paper recycling, has been studied by many researches, as summarized in Figure 2.2 (e.g., Schmidt, 2007; Villanueva and Wensel, 2007). Process of producing paper from recycled paper starts by grinding collected paper in water then the pulp is de-inked and removed impurities. Because of the deterioration of pulp quality, recovered pulp should be mixed with virgin materials for producing paper. As shown in Table 2.6, the replacement virgin materials with recycled paper might save energy and virgin materials, reduce waste amounts which send to disposal site, and cut down GHG emission from life cycle of paper production (Ekvall, 1999; Pickin, Yuen, Hennings, 2002; Diaz and Warith, 2006; Schmidt et al., 2007; Villanueva and Wensel, 2007; Hanaadeh and El-Zein, 2010).

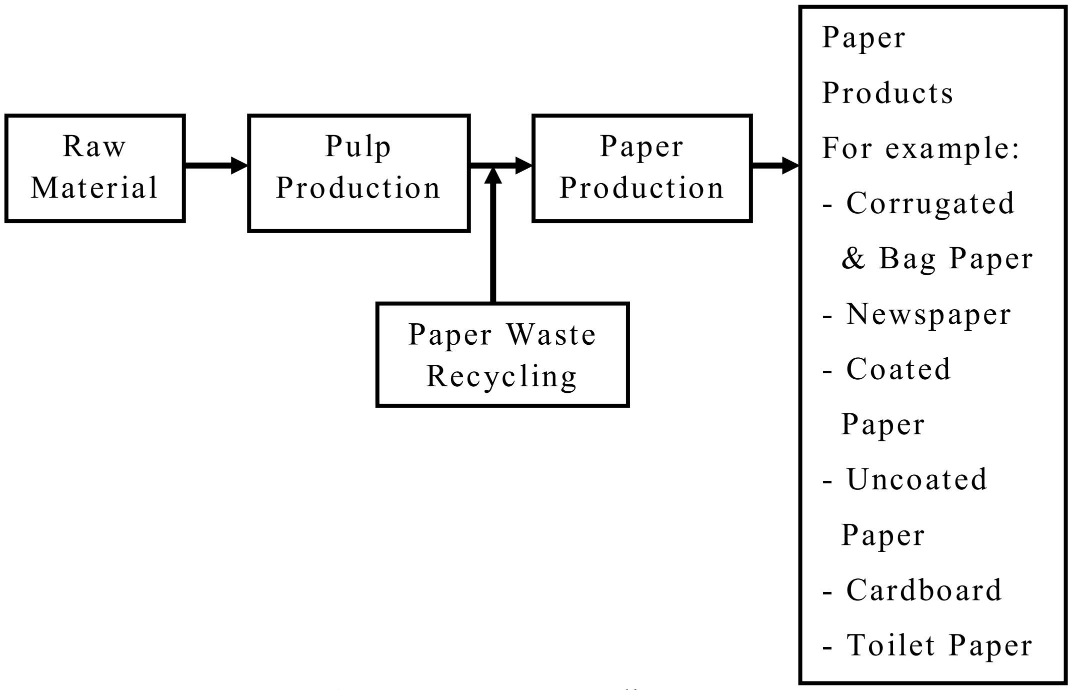


Figure2. 3 Paper Recycling Process

2.8.2 <u>LCA of Glass Production</u>

LCA of glass including recycled glass in the process is shown in Figure 2.3. Recycled glass should be crushed to cullet then sent to the production process for melting, molding, and annealing (Edwards and Schelling, 1999; Krivtsov et al., 2004; Vellini and Savioli, 2009). Unlike other products, clear glass scrap recovered can replace almost 100% of virgin material without deterioration of quality but amber and green might be able to replace at little lower fraction than clear glass (Edwards and Schelling, 1999; Vellini and Savioli, 2009). Several studies have argued that recovered glass might reduce amount of virgin material uses and energy consumption

(Boustead and Hancock, 1981; Edwards and Schelling, 1999; Krivtsov et al., 2004; Vellini and Savioli, 2009). Furthermore, recycling glass could reduce wastes that send to disposal site. GHG emission from life cycle that with and without of recycling glass is shown in Table 2.6 (Enviros Consulting, 2003; Diaz and Warith, 2006; Hanaadeh and El-Zein, 2010).

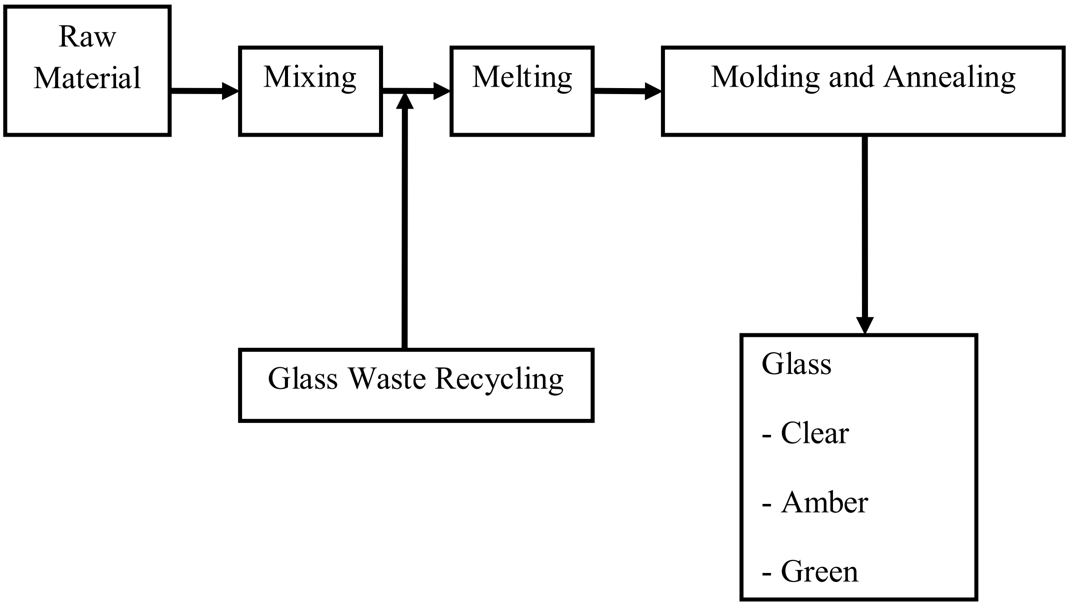


Figure2. 4 Glass Recycling Process

2.8.3 LCA of Plastic Production

Production process of plastic has slightly complicated procedure compared to paper and glass recycling because plastic could be categorized to thermoplastic and thermosetting. Thermoplastic is recyclable plastic but the other is non-recyclable. Furthermore, only the same type of plastic could be replaced such as polyethylene terephthalate (PET), which is the most common of plastic recycling because PET has been used to produce bottle drinks, can be reproduced to PET granules. Mechanism of plastic recycling is shown in Figure 2.4, which consists of size reduction, milling, wash and drying, agglutination, extrusion, and quenching (Aznar et al., 2006; Stypka and Flaga, 2006; Al-Salem, Lettieri, and Baeyens, 2009). After that, the plastic granules are sent to different production schemes. In 2009, Al-Salem, Lettieri, and Baeyens claimed the granules quality depends on initial separation process of different types of plastic, washing and preparation of plastic waste for eliminating impurities. Many studies provide the idea to replace virgin material with recycled plastic to save energy, and avoid GHG emission (e.g., Patel et al., 2000[36]; Krivtsov et al., 2004; Diaz and Warith, 2006; Al-Salem, Lettieri, and Baeyens, 2009; Hanaadeh and El-Zein, 2010). Table 2.6 shows the emission factors of plastic adapted from Haight (2004) and EPA (2002).

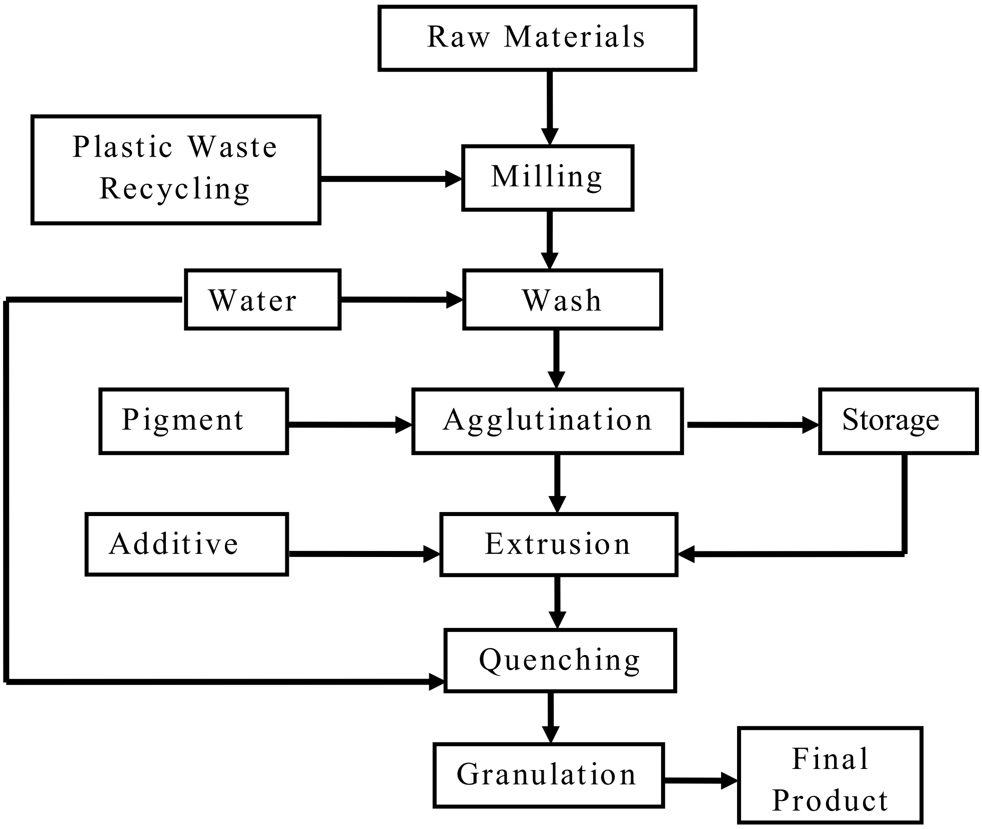


Figure2. 4 Plastic Recycling Processes (Aznar et al., 2006; Al-Salem, Lettieri, and Baeyens, 2009)

2.8.4 <u>LCA of Aluminum and Ferrous Production</u>

Diaz and Warith (2006) described aluminum and steel as the main source of producing cans. They considered for aluminum recycling from household waste because the other metals have lower economic scarcity in the waste stream. Aluminum recycling and steel recycling process is shown in Figure 2.5. The metals from waste separation are reduced their size and removed impurities then they are sent to production cycle for melting and rolling (Reh, 2006). Many researchers reported that recycled metals could replace virgin materials, avoid GHG emission from life cycle of metal producing, reduce energy consumption and waste loads which send to disposal site (Diaz and Warith, 2006; Reh, 2006; Hanaadeh and El-Zein, 2010). The emission from aluminum and ferrous with and without recycling process which adapted from Haight (2004) and EPA (2002) is showed as Table 2.6 (Hanaadeh and El-Zein, 2010).

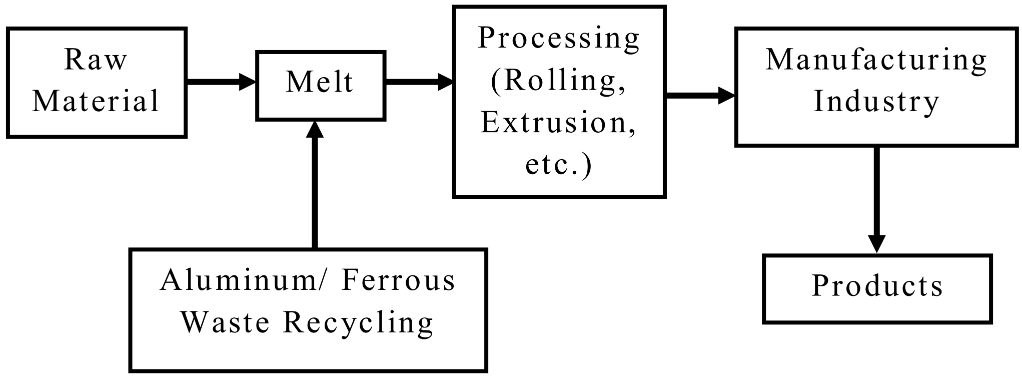


Figure2. 5 Aluminum and Ferrous Production and Life Cycle

2.9 Integrated Waste Management (IWM) Model

Waste management model is a useful tool in decision-making and planning. Morrissey and Browneb (2004) traced the development of waste management mathematic model history during the 20th century. In 1970s, the models were started to develop (Gottinger, 1988; Morrissey and Browneb, 2004). The main issue of early the models mentioned economics issue (Morrissey and Browneb, 2004). Currently, more models include the whole life cycle of products that could assess the environmental impacts from all activities during their life cycle (Barton, Dalley, and Patel, 1996; Bjorklund, Dalemo, and Sonesson, 1999; Finnveden, 1999; Powell, 2000; Environmental Impacts of Transporting Waste-Life Cycle and Cost Benefit Assessment, 2000; McDougall et al., 2001; Harrison et al., 2001; Environment and Plastic Industry Council [EPIC] and Corporations Supporting Recycling [CSR], 2000; Morrissey and Browneb, 2004).

The concept of integrated solid waste management (ISWM) is widely used to manage municipal solid waste (MSW) (ERRA, 1999; Gabola, 1999; Kowalewski, Reid, and Tittebaum, 1999; Berger, Savard, and Wizere, 1999; Clift, Doig, and Finnveden, 2000; EPIC and CSR, 2000; Morrissey and Browneb, 2004). The ISWM was defined by United Nations Environment Program (UNEP) that the idea comprises of four basic principles as follow: equity, effectiveness, efficiency, and sustainability; which integrated the perspective of environmental, political, technical, social, and economic. For sustainability, solid waste aspects cover all steps of the waste management cycle as generation, segregation, reduction, reuse, recovery, recycle, collection, transfer and transportation, treatment, and disposal. The ISWM system always uses as the principle idea to develop the waste management models that require scientific and systematic method for developing. Most of the models are developed by using linear programming (LP) for fundamental calculation (Abou Najm and El-Fadel, 2004), and finding out the optimization of waste management plan.

Life cycle assessment (LCA) in many models base on ISO 14040 from cradle to grave (Morrissey and Browneb, 2004). This study did literature reviews of five models i.e. IWM model of EPIC and CSR, IWM1, IWM2, WISARD, and WARM, which all models are based on LCA scheme.

Integrated Waste Management Model for Municipalities (IWM) of EPIC and CSR is a spreadsheet-based model which was produced by Environment and Plastic Industry Council (EPIC) and Corporations Supporting Recycling (CSR) (EPIC and CSR, 2004; Mohareb, Warith, and Diaz., 2008). The model consists of many screens in Excel spreadsheet which covers all MSW management scheme (e.g. landfill, recycling, transportation, etc.). Mohareb, Warith, and Diaz (2008) reviewed IWM of EPIC and CSR that the model is used to find the optimized scenarios of waste management plan of Canadian waste management system developed by the University of Waterloo (Haight, 2004).

Chao, Ma, and Hung (2007) claimed IWM1 is a first LCA model for waste management that was developed by White, Franke, Hindle (1995). Later, the model was modified by McDougall et al. (2001) that called IWM2 (Morrissey and Browneb, 2004). The IWM1 uses Excel spreadsheet for platform; in contrast, the IWM2 is a stand-alone program. Stypka and Flaga, (2006) argues that as it was developed from IWM1, the IWM2 is more accurate and more elaborate thermal treatment section than the IWM1.

Waste – Integrated Systems Assessment for Recovery and Disposal (WISARD) is another waste management model of Ecobilan that was developed by the Environment Agency in England and Wales and widely used in the UK (Winkler and Bilitewski, 2007). Morrissey and Browneb (2004) claims that WISARD model is similar to IWM2 model.

Wasted Reduction Model (WARM) was developed by the US Environmental Protection Agency (EPA, 2002; Diaz and Warith, 2006). Previous study has reported the comparison between WARM and IWM that WARM is more optimistic prediction of emission credits.

Five models mentioned above have different capability and operating conditions. The summary of characteristic of the models is shown in Table 2.7. The model summary helps selecting a few models for estimation of GHG emission and energy consumption in this study. The model for evaluation of GHG and energy are chosen based on a model that consider scope of cradle to grave. According to the model reviewing, this study selected IWM of EPIC and CSR, and WARM for the estimation in the next research step.

Table2. 7 The Models Comparison

Model	Characteristic & Condition	Developer
1. IWM of EPIC and CSR	1) The model has been used to improve waste management in many case studies. 2) Boundary of the model LCA is cradle to grave.	Environment and Plastic Industry Council (EPIC) and Corporations Supporting Recycling (CSR)
2. IWM1	1) The model has been used in many researches. 2) Boundary of the model LCA is cradle to grave.	White et. al.

Table2. 7 The Models Comparison

Model	Characteristic & Condition	Developer
3. IWM2	1) The model has been used in many researches. 2) Boundary of the model LCA is cradle to grave.	McDougall et.al.
4. WISARD	1) The model has been used popular in the UK. 2) Boundary of the model LCA is gate to grave.	Environment Agency in England and Wales
5. WARM	1) The model has been used popular in the USA. 2) Boundary of the model LCA is cradle to grave.	US Environmental Protection Agency

2.10 Waste Management Situation in Thailand

Amount of municipal solid waste (MSW) generation in Thailand increased from 11.2 million Tons or 0.53 kg/capita/day in 1993 to 14.3 million Tons or 0.62 kg/capita/day in 2002 (Chiemchaisri, Juanga, and Visvanathan, 2007), details as shown in Figure 2.6. Chiemchaisri, Juanga, and Visvanathan (2007) pointed out that efficiency of MSW management has only slightly increased since 1993. Thailand Environment Monitor (2003) reviewed the MSW data and found that the composition of waste was comprised of kitchen waste or organic waste (51%), plastic and foam (22%), paper (13%), and glass (3%). The organic wastes are major composition of MSW in Thailand, following by plastic and paper. Composition of Thai MSW has similar portion as those in other developing countries in Asia.

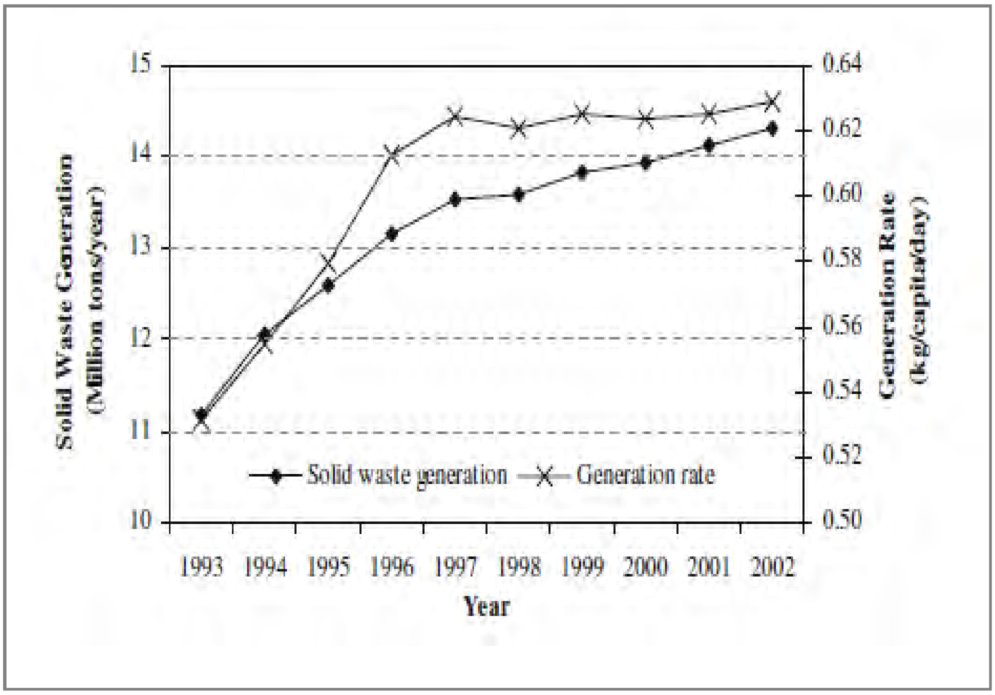


Figure2. 6 Solid Waste Generation and Per Capita Generation Rate in Thailand (1993–2002) (Chiemchaisri, Juanga, and Visvanathan, 2007)

Thai Pollution Control Department (PCD) reviewed waste generation, efficiency of waste collection and transportation, and efficiency of correct method of waste disposal for the entire country. Only some portions (near 80%) of MSW have been collected that may cause by lacking of capacity of efficient waste collection and transportation in Thailand. Moreover, less than 50% of wastes were disposed correctly. In 2003, Thailand Environment Monitor demonstrated efficiency of waste collection and transportation in different regions, as following, Bangkok (collecting almost 100 %), larger cities (Muang municipalities) (86%), and smaller towns (Tambon municipalities) (75%). Numbers of trucks for collection are sufficient but there are operation and maintenance problems such as problems of accessing congested and disorganized roads (Thailand Environment Monitor, 2003). PCD also reported that the majority of waste disposal practice in Thailand is open dumping (Figure 2.7). The open dumping is the most popular method for disposal waste in developing countries. However, the open dumping is creating number of negative effects such as infection, greenhouse gas emission, and illegal. Lacking of sufficient official and financial capacity is a main root of the solid waste problems.

On the other hands, sustainable and integrated waste management might start by thinking before disposing wastes by sorting then reducing, reuse, and recycling the wastes. These will reduce management costs by minimizing amounts of the wastes, which disposed into landfill. Furthermore, effective waste management system could reduce resources consumption and emission loadings to the environment.

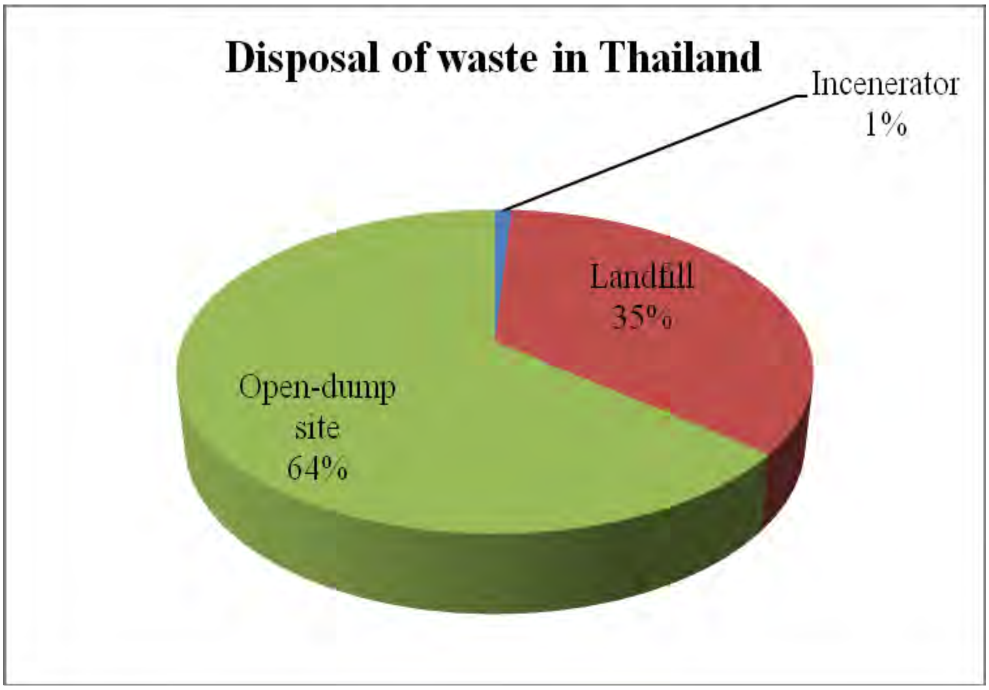


Figure2. 7 The Method of Waste Disposal by Pollution Control Department (Thai Pollution Control Department [PCD], 2004)

In Thailand, the Pollution Control Department (PCD) set the regulation and guideline for solid waste management. Several policies were issued to promote recycling and reuse in Thailand. The policy followed the 8th and 9th National Plan to promote integrated solid waste management for controlling waste generation, support knowledge and budget of waste management including collection, separation, transportation, recycling, reuse , and disposal (PCD, 2004). Thailand Environment Monitor (2003) reported that approximately 42% of waste has potential for recycled consisting of glass, plastic, paper, and metal. However, only 11% of total waste approximately 1.5 million Tons per year of municipal solid wastes in Thailand is recycled.

Thailand Environment Monitor (2003) claims there are 3 main groups who collect recyclable wastes. The majority group is tricycles so-called Sa-Leng who sort and collect the wastes from garbage outside the disposal sites then sell them to recycling shops for their earnings. The second group is scavengers who sort and collect the waste from disposal site then sell the waste for their incomes. The minority group is household separators who separate and sort their wastes from the beginning of waste disposal stream. The last group is very important and has high potential to effective reduce amount of MSW by promoting via public awareness campaigns.

Furthermore, the participation of sorting and recycling in community level is encouraged through garbage banks, which are organized in form of school garbage banks (SGB), community garbage banks (CGB), and the "garbage-for-eggs" project. Although the garbage banks have been established in many areas, the campaigns do not yet widely cover all communities in Thailand. Suttibak and Nitivattananon (2008) claimed SGB and CGB are beneficial for material recycling and recovery because informal waste separation sector, which are the majority group who do recycling activity in Thailand, lacks of skill to manage the commingled waste then malfunction of material recycling might occur. The approach to encourage citizens for sorting of household waste before disposal is very challenge for policy makers. Lack of incentives to participate in the 3Rs campaign setting as community center needs to be solved to properly manage municipal waste. If garbage bank and 3Rs principle are widely implemented, this will certainly bring significant benefits to local communities and help improve MSWM situations in Thailand.

2.11 Background of Case Study

Community garbage bank is one of waste management initiatives to increase efficiency of waste separation, reuse and recycling. In Thailand, this approach is still not widely implemented in all communities. However, ideally if all communities have community garbage banks, it will importantly help management municipal solid wastes for Thailand. Income from selling recycle items is important incentive to promote public awareness to exchange more recyclable wastes i.e. paper, plastic, metal, glass.

This research chooses Phangkhon municipal district in Sakhonnakhon Provice, Thailand as a case study. Because the municipal district successfully established integrated waste management program to encourage public cooperation with waste reduction campaign. The campaign has continuously used passbook for recording the amount of individual recycling wastes and their incomes from sales of recycled waste. Evidently, the waste bank system is an important foundation for evaluating avoided carbon emission from recycling activities (MRV – measurable, reportable, and verifiable).

According to waste recycling campaign in the Phangkhon community, there are 11 municipal districts participating in municipal waste reduction campaign including Srijumpa1, Srijampa2, Nongsarpang, Banmai, Joaputhongdang, Poachai, Poangan, Banthung, BanTalard, London and Namaung. Faculty of Public Health of Khon Kaen University (2007) did a study to evaluate environmental impact from community landfill. Therefore, part of the research data such as waste generation information will be taken from the existing study. The field data that will be collected and analyzed in this research including: population, type of waste generation, composition of waste, collection and transportation scheme, recycling scheme, and disposal scheme.

Regarding the background of the case study communities, there are approximate 7,920 persons that the waste generation is approximate 0.70 kg/cap/day in 2007 (Faculty of Public Health of Khon Kaen University, 2007). Growth rate of population in the municipal district is approximate 0.0013 and growth rate of waste generation is approximate 0.0142.

For transportation of waste, average distance from waste station to recycling center is around 32 km/trip and distance per trip of collecting truck to landfill is 14-23 km (average 18.5 km/ trip). There are approximately 6 trips/ day for collecting waste to landfill.

To disposal, the landfill was designed for 20 years that the system. The facilities for landfill operation have followed sanitary landfill practice (e.g. capacity and loading designing for operation, equipments for collecting and preventing leachate leakage). The project needs to improve integrated solid waste management for the communities because size of landfill is approximate 1990 m^2 and it has planned to be used for disposed waste in 31 communities of Sakhonnakhon plus wastes from nearby province, which have increased growth rate of waste generation. Therefore, it might be not sufficient disposed their wastes in the near future.

Wastewater treatment in the landfill for managed leachate uses 3 stabilization ponds which consist of Anaerobic Pond, Facultative Pond, and Maturation Pond. Loading of leachate is estimated from annual precipitation in the area that is 1457.5 mm. No leachate data is available for the characteristic of the leachate.

CHAPTER III
METHODOLOGIES

The research is planned to conduct in 3 steps (1) design and planning, (2) result analysis and model development, and (3) future improvement and recommendation. To achieve the research goals, each step has research methodology to implement in details as following:

3.1 Design and Planning

3.1.1 Selecting a Case Study

A case study was a local community that has already implemented recycling campaign and community garbage bank in the community to collect data from the bank for evaluating amount of GHG reduction and for investigating the impacting factors of the successful waste bank.

3.1.2 Reviewing Recycling Activity and Mechanism

Recycling activity and mechanism for recycling campaign from existing research were reviewed to compare with the experience and data collecting from the case study.

3.1.3 Reviewing Existing Waste Management Models

Existing waste management models for evaluating GHG emission and energy consumption from waste recycling management from literature were reviewed for this study to select and use for evaluating data from the case study.

3.1.4 Collecting Data of Recycling Activity from Case Study

This research collected data from the case study including characteristics and amounts of waste generation and recycling activity for evaluating GHG reduction using the selected model. Primary and secondary data were collected as following:

1. Primary Data: collected from actual waste recycling activity in Phangkhon Municipal District during September 2009-August 2010 including:
    1.1. Categories of Recycling Waste in the Community
    1.2. Amounts of recycling waste and types of wastes from the community waste bank during each month for 1 year
2. Secondary Data: our research adopted some data from a previous research which is a study of Faculty of Public Health of Khon Kaen University (2007) that examined within the case study area including;
    2.1. Rate of Waste Generation
    2.2. Number of Population (&Growth)
    2.3. Composition of Waste
    2.4. Collection and Transportation Scheme
        2.4.1. Type of Fuel Consumption
        2.4.2. Distance of Waste Collection and Transportation
        2.4.3. Trip Details (number of vehicles, trips per day)
    2.5. Type of Disposal method (open dumpsite/ landfill/ combustion)
    2.6. Meteorological Data

3.2 Analysis & Model Development

3.2.1 Setting up Waste Management Scenarios for Analysis

Various scenarios were set up based on categories of recycling wastes to identify appropriate waste management strategy. Each scenario was analyzed for amounts of GHG emission and energy consumption. There are 6 scenarios in the research as the following;

1. Scenario 1 (S1)

Baseline scenario or S1 studied normal pattern (business as usual) of waste life cycle in the community. All wastes, which were generated from household, were directly sent to landfill for disposal and there were no any other processes in the waste management.

2. Scenario 2 (S2)

Scenario S2 improved the waste management system from baseline scenario (S1) with glass recycling activity. The total amount of GHG emission from this scenario was estimated then compared with baseline scenario to find out GHG emission reduction contribution from glass recycling activity.

3. Scenario 3 (S3)

Scenario S3 improved the waste management system from baseline scenario (S1) with paper recycling activity. The total amount of GHG emission from the scenario was estimated then compared with baseline scenario to find amount of GHG reduction from paper recycling activity.

4. Scenario 4 (S4)

Scenario S4 improved the waste management system from baseline scenario (S1) with plastic recycling activity. The total amounts of GHG emission from this scenario was estimated then compared with baseline scenario to find amount of GHG reduction from plastic recycling activity.

5. Scenario 5 (S5)

Scenario S5 improved the waste management system from baseline scenario (S1) by metal recycling activity. The total amounts of GHG emission from this scenario was estimated then compared with baseline scenario to find amount of GHG reduction from metal recycling activity. There are 2 sub-scenarios for metal recycle (a) scenario 5.1 (S5.1) focuses on ferrous recycle activity and (b) scenario 5.2 (S5.2) focuses on aluminium recycling activity.

6. Scenario 6 (S6)

Scenario S6 improved the waste management system from baseline scenario (S1) by including all types of waste recycling activity (glass recycle, paper recycle, plastic recycle, and metal recycle). The total amounts of GHG emission from this scenario was estimated then compared with baseline scenario to find total GHG emission reduction from recycling all types of wastes together.

The study will evaluate GHG from each scenario using the 3 selected models. The results from each model will be compared to find out the range of GHG emissions from each scenario (S1 to S6). After that, the research will select only 1 model to further develop and incorporate into a carbon account program.

3.2.2 Evaluating and Analyzing the Results of Case Study

1. Evaluation GHG Emission and Energy Consumption

The collected data from the case study was used for evaluating GHG emission and energy consumption in each scenario by the selected models and the carbon account.

2. Analysis of Results

The results of the evaluation from different selected models were compared. The efforts for reducing GHG and energy consumption of each scenario were analyzed to identify options to help improving their recycling activity and developing community carbon bank.

3.2.3 Developing Carbon Accounting Program

1. Developing Supported Tool (User Friendly) for Carbon Account

The research adopted existing model frameworks to use for evaluating GHG emission reduction from waste recycle and further develop carbon account model. The appropriate model is selected from the previous research step. The carbon account is developed based on Excel platform (see Appendix C), testing by using field data in the case study. This carbon accounting tool aims to develop for recording amount of recycles wastes, evaluating GHG emission and energy consumption, and allocating GHG burdens to each people who are the members of the community waste banking. Also the program will be able to keep track of the account balance on financial balance and GHG balance of each member of the bank.

To develop the accounting for use in the Phangkhon Municipal District, emission factors from Browne, O'Regan, and Moles (2009) are used for developing the carbon accounting. The model will be called in the research as "EF-DB". There are 2 equations for estimating GHG accounting by the "EF-DB" : (1) the equation for estimating GHG emission from waste activity in the community and (2) the equations for estimating the avoided GHG via the recycling. The equations are shown in Eq. 1 and Eq. 2 respectively. Each equation requires specific emission factors to evaluate the total emission. The values of these emission factors are summarized in Table 3.1.

$$E_{GHG} = (W_{Org.} \times E_C) + (W_G \times EF_{Raw\ of\ glass}) + (W_P \times EF_{Raw\ of\ paper}) + (W_{Pl} \times EF_{Raw\ of\ plastic}) + (W_{Fe} \times EF_{Raw\ of\ ferrous}) + (W_{Al} \times EF_{Raw\ of\ aluminum}) + (E_V \times T \times D \times W_T) + (E_S \times W_T) \quad \text{(Eq. 1)}$$

E_{GHG} : Greenhouse Gas Emission from Waste Management Activity (Tons CO_2 eq/ year)

E_C : Greenhouse Gas Emission from Organic Waste Composting in Landfill
(0.797 Tons CO_2 eq/ Tons of Waste) (Browne, O'Regan, and Moles, 2009)

E_V : Greenhouse Gas Emission form Vehicle for Landfill of Waste
(7.48×10^{-5} Tons CO_2 eq/ Tons of Waste-km) (Browne, O'Regan, and Moles, 2009)

E_S : Greenhouse Gas Emission form Spread and Compact Waste in Landfill (5.13×10^{-3} Tons CO_2 eq/ Tons of Waste)

EF_{Raw} : Emission Factor of Avoided GHG for Production Process from Raw Material in each Type of Waste see Table 3.1 (Tons CO_2 eq/ Ton of waste)

$W_{Org.}$: Total of Organic Waste (Tons/ year)

W_G : Amounts of Total Glass Waste Generation in the Community (Tons/ year)

W_P : Amounts of Total Paper Waste Generation in the Community (Tons/ year)

W_{Pl} : Amounts of Total Plastic Waste Generation in the Community (Tons/ year)

W_{Fe} : Amounts of Total Ferrous Waste Generation in the Community (Tons/ year)

W_{Al} : Amounts of Total Aluminum Waste Generation in the Community (Tons/ year)

W_T : Amounts of Total Waste Generation in the Community (Tons/ year)

T : Trips of Transportation (Trips/ year)

D : Distance for Transportation to Landfill (km/ Trips)

$$A_{GHG} = \{(EF_{Raw} - EF_{Re})\times W_{Re}\} + (E_V\times T_{Re}\times W_{Re}\times D) + (E_L \times W_{Re}) - (E_V\times T_{Re}\times W_{Re}\times D_{Re}) \quad \text{(Eq. 2)}$$

A_{GHG} : Avoided Greenhouse Gas Emission from Recycling Process (Tons CO_2 eq/ year)

E_L : Greenhouse Gas Emission form Vehicle for Treatment Waste in Landfill (5.13×10^{-3} Tons CO_2 eq/ Tons of Waste)

E_V : Greenhouse Gas Emission form Vehicle for Landfill of Waste (7.48×10^{-5} Tons CO_2 eq/ Tons of Waste-km) (Browne, O'Regan, and Moles, 2009)

EF_{Raw} : Emission Factor of Avoided GHG for Production Process from Raw Material in each Type of Waste see Table 3.1 (Tons CO_2 eq/ Ton of waste)

EF_{Re} : Emission Factor of Avoided GHG for Recycling Material see Table 3.1 (Tons CO_2 eq/ Ton of waste)

W_{Re} : Amounts of Waste Recycling in the Community (Tons/ year)

T_{Re} : Trips of Waste Recycling Transportation (Trips/ year)

D : Distance for Transportation to Landfill (km/ Trips)

D_{Re} : Distance from Recycling Activity (km/ Trips)

The equation for estimating energy consumption from waste activity in the community and the equations for the avoided energy consumption via the recycling is shown in Eq. 3 and Eq. 4 respectively. Each equation requires specific emission factors to evaluate the total energy consumption. The values of these factors are summarized in Table 3.1.

$$En = (W_G \times En_{Raw\ of\ glass}) + (W_P \times En_{Raw\ of\ paper}) + (W_{Pl} \times En_{Raw\ of\ plastic}) + (W_{Fe} \times En_{Raw\ of\ ferrous}) + (W_{Al} \times En_{Raw\ of\ aluminum}) + (En_T \times W_T \times D \times T) + (En_S \times T) \quad \text{(Eq. 3)}$$

En : Energy Consumption from Waste Management Activity (GJ/ year)

En_{Raw} : Emission Factor of Avoided Energy Consumption for Production Process from Raw mMaterial in Each Type of Waste see Table C-1 (GJ/ Ton of waste)

En_T : Energy Consumption for Transportation of Waste (0.0012 GJ/ Tons of waste-km) (Sonesson et al., 2000; Browne, O'Regan, and Moles, 2009)

En_S : Energy Consumption form Spread and Compact Waste in Landfill (0.08 GJ/ Tons of waste-km) (Birch, Barrett, and Wiedmann, 2004; Browne, O'Regan, and Moles, 2009)

W_G : Amounts of Total Glass Waste Generation in the Community (Tons/ year)

W_P : Amounts of Total Paper Waste Generation in the Community (Tons/ year)

W_{Pl} : Amounts of Total Plastic Waste Generation in the Community (Tons/ year)

W_{Fe} : Amounts of Total Ferrous Waste Generation in the Community (Tons/ year)

W_{Al} : Amounts of Total Aluminum Waste Generation in the Community (Tons/ year)

W_T : Amounts of Total Waste Generation in the Community (Tons/ year)

D : Distance for transportation to landfill (km/ Trips)

T : Trips of Transportation (Trips/ year)

$$A_{En} = \{(En_{Raw} - En_{Re}) \times W_{Re}\} + (En_T \times W_{Re} \times T_{Re} \times D) + (En_S \times W_{Re}) - (En_T \times W_{Re} \times T_{Re} \times D_{Re}) \quad \text{(Eq. 4)}$$

A_{En} : Avoided Energy Consumption from Waste Management Activity (GJ/ year)

En_{Raw} : Emission Factor of Avoided Energy Consumption for Production

Process from Raw Material in each Type of Waste see Table 3.1 (GJ/ Ton of waste)

En_T : Energy Consumption for Transportation of Waste (0.0012 GJ/ Tons of waste-km) (Sonesson et al., 2000; Browne, O'Regan, and Moles, 2009)

En_S : Energy Consumption form Spread and Compact Waste in Landfill

En_{Re} : Emission Factor of Avoided Energy Consumption for Recycling Material in each Type of Waste see Table 3.1 (GJ/ Ton of waste)

W_{Re} : Amounts of Waste Recycling in the Community (Tons/ year)

T_{Re} : Trips of Waste Recycling Transportation (Trips/ year)

D : Distance for Transportation to Landfill (km/ Trips)

D_{Re} : Distance from Recycling Activity (km/ Trips)

Table3. 1 shows emission factors of GHG emission and energy consumption of each category of waste adopted from Pers. Comm., Stockholm Environment Institute (SEI)-York (2006) (Browne, O'Regan, and Moles, 2009)

Waste	EF_{Raw}	EF_{Re}	En_{raw}	En_{Re}
Glass	1.03	0.33	16.2	5.5
Paper	2.86	1.58	45.7	25
Plastic	3.74	2.05	59.4	32.8
Ferrous	2.49	1.28	40	20.4
Aluminum	8.80	2.16	140.5	34.3

For supporting the waste exchange activity in the CGB, a model, for extending from the carbon account, calculates and reports balance on waste account. This model is so-called Waste Selling Account. The program will require to the price of each type of waste for input and amounts of recycled waste from each member. The model used Excel Visual Basic for creating sheets for recording and calculating. The balance calculation estimated from the prices per unit of each waste multiply by amounts of each category of waste which the members sort and collect for sale.

2. Testing and Validating the Model

The developed model was tested and validated suitable to meet the objective to be able to record, calculate, and display the amount of GHG emission reduction from waste recycle and total balance of incomes from the waste sale for each participant in the waste management program. However, high precision of model estimation is not our primary objective in this study.

3.3 Future Improvement & Recommendation

3.3.1 Investigating Waste Management Systems and Community Waste Bank of the Case Study

Waste management system and community waste bank were reviewed to find out why/how they succeed in waste recycling activities to identify key factors and lesson learned, and to develop the best possible strategies for implementation by other communities.

3.3.2 Surveying Opinions of Citizens of the Case Study

Opinions from citizens living in the area of the case study were examined by using developed questionnaires and interviews key stakeholders to understand main factors impacting the success of recycling program in the case study and how they want to see it improved.

3.3.3 Developing Recommendation Strategies

Recommendation strategies were provided based on the results of the model and the questionnaire study, discussion and interview with the officers and experts who work in this area to offer options to promote incentives for improving the waste recycling activities and reducing GHG emission from the waste sector.

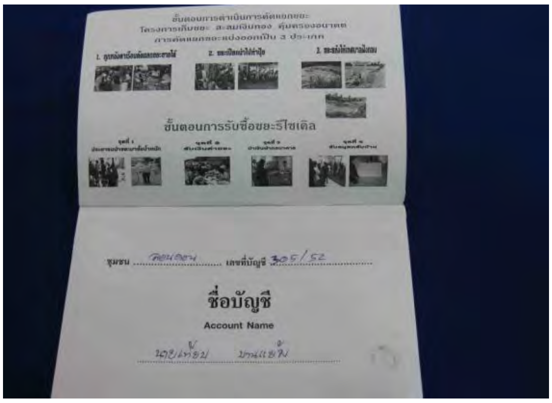
CHAPTER IV
RESULTS AND DISCUSSIONS

4.1 Mechanism of Waste Banking System in Phangkhon Municipal District

To achieve the objective by recommending strategies for setting up carbon banking system to better promote recyclable wastes for other communities, the mechanism of waste banking system in Phangkhon Municipal District was studied about the idea for implementation and operation the waste bank in the local community. Moreover, lessen-learned from success of the bank operation will support future improvement & recommendation.

Currently, wastes from each household in the Phangkhon Municipal District are handled by the local government officers. Most of wastes are sent to dispose at landfill site which the government collects and picks up wastes from each household's rubbish bins, approximate 6 trips/day or around 5.64 - 5.68 tons/day. Recycling wastes at sources is a promising solution for reducing waste loading, not only to reduce burden for waste disposal to landfill but also to minimize improper waste management. Therefore, the district has initiated waste reduction campaign to create incentives for the local citizens' participation, which the campaign is so-called "Kayah Sasom Ngern Tong Kum Krong Ana Kote", "โครงการขยะสะสมเงินทองคุ้มครองอนาคต" (in Thai). The campaign is different from other existing waste bank program in the country by providing "Life Insurance Benefits for funeral funding/support using money from depositing income from wastes exchange". The community waste bank program has been implemented since 2007.

Recyclable wastes in the community are sorted and separated at the drop-off and sold to a community waste bank. The waste bank system has been operated by cooperation among local government officers and volunteers in the community. The waste bank provides many drop-off centers to service the members, usually at volunteer houses. The citizens do not have to be at the center to sell the wastes by themselves. At the center, members could deposit their recyclable wastes and their waste accounts when the officers come to buy the wastes and they will record the sale into the account. Amounts of recycled waste and incomes from waste sale will be recorded in the waste account. Furthermore, the waste bank provides an incentive for the members by guarantying welfare. To guarantee welfare in case a member dies, he/she will receive financial supports for the funeral at the amount of 5,000 baht/person. The main objective of the services and incentives from the waste bank operation/campaign is to provide the convenience and more willingness from the community members to recycle more wastes.



(a) (b)

(c) (d)

Figure4. 1 Members Waste Accounting Book for Phangkhon Community Garbage Bank

(a) The front page of the waste account

(b) Inside, first page, name of the owner

(c) In the back page, described detail of each recycle waste

(d) Calculation sheets include type of waste, weight, and total revenues

As a rule for the waste bank operation, after a citizen registered to become a member of the Phangkhon community waste bank, the citizen must continuously sell their recyclable waste at least for 6 months consecutively. The sale must record in their accounting book as shown in Figure 4.1. If members could not continuously sell their wastes for 6 months; their membership will be expired. The welfare provided by the bank system will be cancelled. During the first 6 months of membership, the members can withdraw the money from the account but they have to maintain the minimum balance of 300 baht in the account.

Because of the incentives from the waste bank (including revenues from selling recyclable wastes and guarantee welfare) and the public concern, citizens in Phangkhon Municipal District are interested in becoming a member of waste bank. But the numbers of members who sale their recyclable wastes during September 2009-January 2010 were still fluctuated as shown in 4.2.

Figure4. 2 Number of Members Who Selling Waste to the Waste Bank (During September 2009 – January 2010)

In November and December, the numbers of sale activities are higher than the other months. It might be affected by many holidays and festivals occurred in these months causing higher amounts of consumption and waste generation than the other months. Therefore, numbers of members who sold wastes and amount of recycle wastes in November and December found to be higher than in September, October, and January. According to the total number of population in the community (approximately 7,950 persons), current numbers of members of the bank are approximately 300 persons. The program expects a great opportunity for increasing the participation rate & recycling waste capability from the community.

4.2 Waste Generation and Management Efficiency

Results from studying waste generation and management efficiency support the objective to find out appropriate strategies for setting up carbon banking system to enhance public awareness and better promote recyclable wastes for other communities.

From 2009-2010, estimation of waste generation in Phangkhon Municipal District is approximately 2,038 Tons/year (Faculty of Public Health of Khon Kaen University, 2007). The study focuses on evaluating the avoided environmental impacts from 4 types of recycled wastes: glass, paper, plastic, and metals (aluminum and ferrous) for a period of 1 year. Since September 2009 to August 2010, the total amount of total recycled waste is 95.80 Tons. The recycled waste is approximate 4.70 % of total waste generation. Efficiency[1] of total recycled waste in Phangkhon is 17.35 % based on the current waste generation and composition, as shown in Figure 4.3.

Based on the efficiency of total waste recycling in the community, it showed potential for increasing of waste recycling is still high. Phangkhon Municipal District has planned in 2017 that their citizens should sort and recycle their waste approximate 10% of total municipal waste generation. Figure 4.3 reveals comparison between amounts of each waste generation and amounts of each recycled waste in Phangkhon in the period 1 year. Phangkhon Municipal District has potential for increasing efficiency of almost all types of waste recycling, especially plastic which has the highest gap between predicted amounts of waste generation and actual amounts of waste recycling.

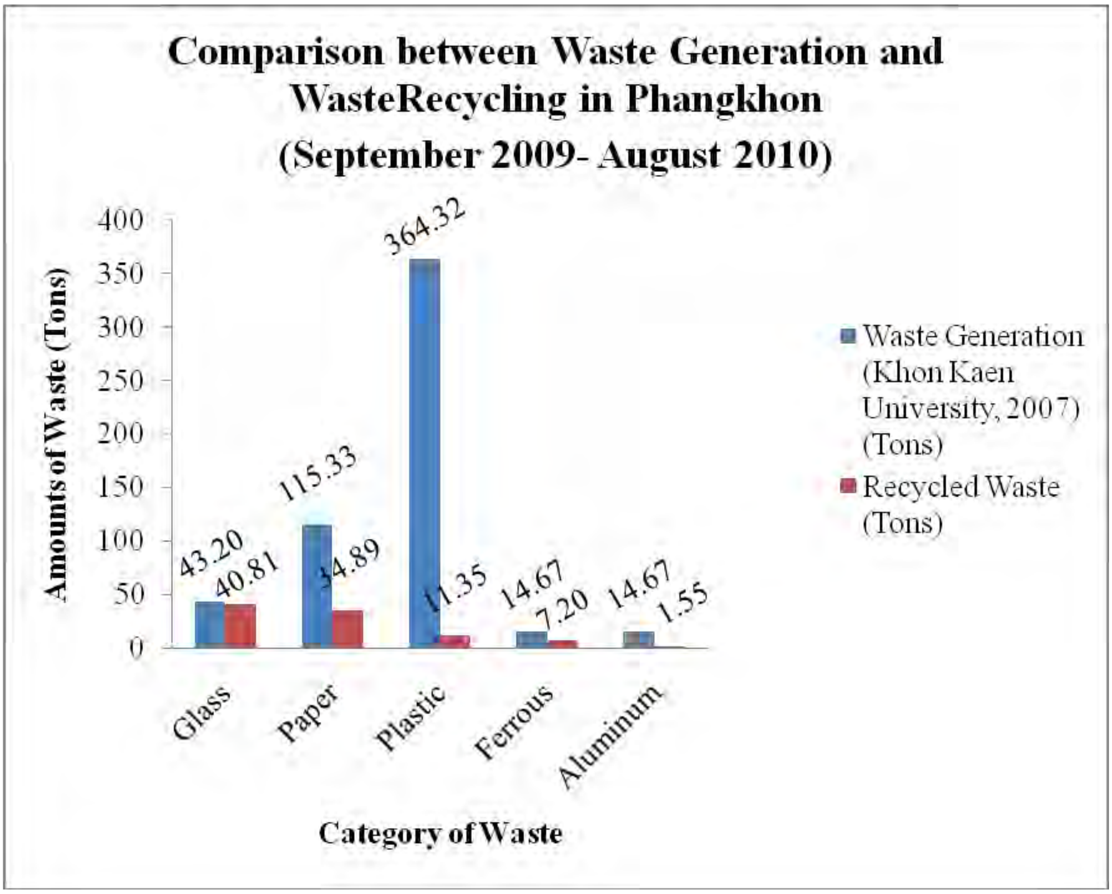


Figure4. 3 Comparison between Amounts of Waste Generation from a study of Faculty of Public Health of Khon Kaen University (2007) and Amounts of Recycled Waste via Community Garbage Bank (CGB) in Phangkhon Municipal District (During September 2009-August 2010)

According to 1-year recycling activity in Phangkhon, glass has the highest amount of recycle (40.81 Tons) in the community followed by paper (34.89 Tons), plastic (11.35 Tons), ferrous (7.20 Tons), and aluminum (1.55 Tons). Glass has the highest recycling amounts probably because it is easy to sort and collect for recycling. Moreover, glass is a part of common packaging materials which people have high consumption. Likewise, paper and plastic are common part of packaging material and commercial products so these two of wastes are recycled more than ferrous and aluminum material.

The efficiency[1] of recycling from the highest to lowest is as following: glass recycle (94.47 %), ferrous recycle (49.08 %), paper recycle (30.25 %), aluminum

[1] Efficiency of recycling: To compare between waste generation of each type and waste recycling of each type for example: efficiency of glass recycle= (glass recycling/amounts of glass) ×100= (41.28/43.20)×100 = 95.57%

recycle (10.57 %), and plastic recycle (3.12 %). Main factor for supporting the trend of recycling activity in the community are (1) skill for sorting and recycling of waste, (2) characteristic and (3) price of resale of each type of waste.

Recycled glass has the highest percentage of recycling. The efficiency of glass recycling is almost 100% because it is easy to sort and collect by people and commonly use in daily lifestyle. In 1993, Tchobanoglous, Theisen, and Vigil claimed the principal categories of sorting for waste recycle. For glass recycle, color is usually used to sort and separate the glasses, which normally have three colors: clear, green, and amber. On the other hand, ferrous, paper, plastic, and aluminum are more complicated for sorting. Tchobanoglous, Theisen, and Vigil (1993) claimed that paper and plastic classification are not clear so people lacks of skill and guidance for sorting. Ferrous and aluminum are two of metal generally recycling. The major source of the metals wastes are in form of aluminum can and steel can. However, aluminum and ferrous could be other forms such as door handle, window frame, and white goods (e.g. refrigerator, microwave, washing machine, etc). These forms of material uses make it difficult to bring to recycle. So people might neglect to bring them to recycle. If these two metals are not in form of can (bottle) waste, people might lack of skill to sort and classify the waste into recycle. Prices of each metal material can be a reason to encourage people for sorting and recycling their waste. According to metals are quite low in consumption, it might be corresponding with small amount of recycle.

Evidently, ferrous and aluminum are not the lowest waste recycling efficiency. Plastic turned out to have the lowest recycling efficiency. The reason might probably be that the rate of plastic consumption is very much higher that the rate of recycling. And price of recycle plastic is still very low or even no price for certain types of plastic wastes. Therefore, lacks of skills to properly sort wastes and lack of financial incentive for recycling waste are big barriers for improving municipal solid waste recycled.

4.3 Environmental Impact Evaluation and Model Selection

According to the research objectives of this study to estimate avoided GHG emission from recycled waste activities of the case study using the developed model and to select the mathematical model for Integrated Solid Waste Management (ISWM) suitable to estimate GHG from various municipal waste management schemes, this result section presented outcomes from using 3 models (i.e. IWM, WARM, and EF-DB) for estimating and displaying the amounts of avoided GHG emission and avoided energy consumption. Furthermore, the results were reviewed and compared characteristics, assumptions and limitations of the models. One model was selected to further develop the new program for using in carbon accounting system.

Besides financial incentives from the community garbage bank including incomes and welfare, reducing energy consumption and avoiding environmental impacts should also be important incentives for recycling wastes. Since climate change is currently significant environmental treat, which caused by Greenhouse Gases (GHG). Improving waste management can help reducing environmental impacts, GHG level in particular. Moreover, energy consumption could be reduced from the recycling activity.

Evidently, the waste banking system is an important foundation for studying public behavior in waste recycling activity, and evaluating amount of GHG emission reduction from recycling activities (MRV – measurable, reportable, and verifiable). Therefore, the continuous collecting data of recycling activity in Phangkhon could be used in assessment of avoided environmental impact, particularly greenhouse gas (GHG) emission from community recycling.

This research selected an appropriate model to use for evaluating GHG reduction from waste recycle activity for this community. At first, the comparison of estimation results of the 3 models is done for evaluating the ranges and trends of results, and potential limitation of each models. Sensitivity and flexibility of each model with the case study will be conditions for model selection. Only one model will particularly be chosen to use in the case study for estimating impacts from waste banking system and further develop carbon bank system.

To estimate avoided of GHG emission and energy consumption from waste recycling activity, the activities in Phangkhon Municipal District were assessed by 3 models (1) WARM, (2) IWM, and (3) a model which is adapted by using emission factors from existing research which the model is so-called EF-DB model. This research analyzed the waste management activity of Phangkhon in 6 scenarios including;

1. Baseline: S1 (without recycling any waste),
2. Scenario2: S2 (business as usual + glass recycling),
3. Scenario3: S3 (business as usual + paper recycling),
4. Scenario4: S4 (business as usual + plastic recycling),
5. Scenario5: S5 (business as usual + metal recycling),
6. Scenario6: S6 (business as usual + glass, paper, plastic, and metal recycling).

By the using of the 3 model, IWM and WARM are a closed-model which was developed by using their own condition and based on their waste management system but EF-DB is developed in this study which adopts emission factors from Browne, O'Regan, and Moles (2009). So characteristics, conditions, and assumptions of each model were reviewed as shown in Table 4.1.

Table4. 1 Summarization of Characteristics and Conditions of IWM, WARM, and EF-DB

Model	**Characteristics & Conditions**	**Developer**
1. IWM of EPIC and CSR	1) The model has been used to improve waste management in many case studies.	Environment and Plastic Industry Council (EPIC) and Corporations Supporting Recycling (CSR)
	2) Boundary of the model LCA is cradle to grave.	
	3) The model is a closed model and not allowed for any adjustment from the operation of this case study.	
	4) The model is low sensitive with quantities of waste but is sensitive with the distance.	
	5) This model is complicate to use in the local community.	
	6) This model does not include the carbon accounting.	
	7) This model adopts conditions and emissions from life cycle of Canada.	
	8) The recycled wastes are recycled in close-loop system (replace material for producing the similar products such as plastic for bottle production must recycled to be a plastic bottle)	

Table4. 1 Summarization of Characteristics and Conditions of IWM, WARM, and EF-DB

Model	Characteristics & Conditions	Developer
2. WARM	1) The model has been used popular in the USA.	US Environmental Protection Agency
	2) Boundary of the model LCA is cradle to grave.	
	3) The model is a closed model and not allowed for any adjustment from the operation of the case study.	
	4) The model is sensitive with quantity of waste more than distance.	
	5) This model might be complicated to use in the local community	
	6) This model does not include the carbon accounting.	
	7) This model adopts conditions and emissions from life cycle of USA.	
	8) The recycled wastes are recycled in open-loop system (replace material not only for producing the similar goods such as plastic for bottle production might produce to be a bottle or other products)	
3. EF-DB	1) The model is developed for using in this study.	This study use emission factors from study of Browne, O' Regan, and Moles.
	2) Boundary of the model LCA is cradle to grave.	
	3) The model is flexible for adjustment of the operation from the case study (Phangkhon Municipal District).	
	4) The model is sensitive with quantity of waste more than distance.	
	5) This model is simply to use in the local community	
	6) This model includes the carbon accounting system	
	7) This model adopts conditions and emissions from life cycle from existing study (Browne et al., 2009).	
	8) The recycled wastes are recycled in close-loop system (replace material for producing the similar goods)	
	9) Plastic recycle in the model are PET, HDPE, and LDPE	

According to the EF-DB model is developed in this research, amounts of GHG emission in the model are estimated by Eq.1 as follow:

$$E_{GHG} = (W_{Org.} \times E_C) + (W_G \times EF_{Raw\ of\ glass}) + (W_P \times EF_{Raw\ of\ paper}) + (W_{Pl} \times EF_{Raw\ of\ plastic}) + (W_{Fe} \times EF_{Raw\ of\ ferrous}) + (W_{Al} \times EF_{Raw\ of\ aluminum}) + (E_V \times T \times D \times W_T) + (E_S \times W_T) \quad \text{(Eq. 1)}$$

The example of result estimation GHG emission from baseline scenario by EF-DB is showed as follow:

W_{Org} = Total Waste Generation (Tons) × Composition of Organic Waste (%)
= 2037.6 × 0.6744 Tons

W_G = Total Waste Generation (Tons) × Composition of Glass (%)
= 2037.6 × 0.0212 Tons

W_P = Total Waste Generation (Tons) × Composition of Paper (%)
= 2037.6 × 0.0566 Tons

W_{Pl} = Total Waste Generation (Tons) × Composition of 3 types of Plastic (%)
= 2037.6 × 0.0894 Tons

W_{Fe} = Total Waste Generation (Tons) × Composition of Ferrous (%)
= 2037.6 × 0.0072 Tons

W_{Al} = Total Waste Generation (Tons) × Composition of Aluminum (%)
= 2037.6 × 0.0072 Tons

E_C = 0.797 Tons CO_2 eq/ Tons of Waste

$EF_{Raw\ of\ glass}$ = 1.03 Tons CO_2 eq/ Tons of Waste

$EF_{Raw\ of\ paper}$ = 2.86 Tons CO_2 eq/ Tons of Waste

$EF_{Raw\ of\ plastic}$ = 3.74 Tons CO_2 eq/ Tons of Waste

$EF_{Raw\ of\ ferrous}$ = 2.49 Tons CO_2 eq/ Tons of Waste

$EF_{Raw\ of\ aluminum}$ = 8.80 Tons CO_2 eq/ Tons of Waste

E_V = 7.48×10^{-5} Tons CO_2 eq/ Tons of Waste-km

E_S = 5.13×10^{-3} Tons CO_2 eq/ Tons of Waste

W_T = 2037.6 Tons

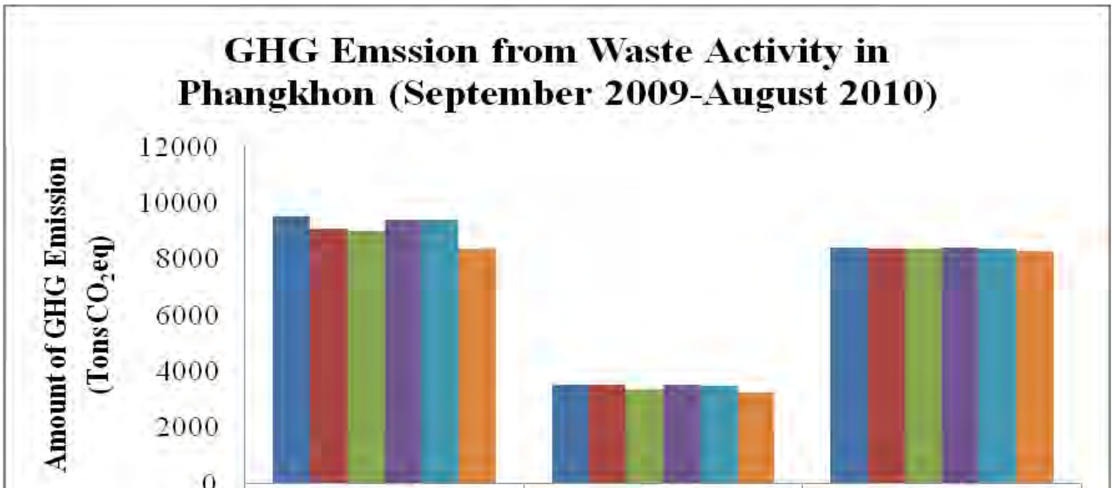
T = 6 × 30 × 12 Trips/ year

D = 18.5 km

$$E_{GHG} = (2037.6 \times 0.6744 \times 0.797) + (2037.6 \times 0.0212 \times 1.03) + (2037.6 \times 0.0566 \times 2.86) + (2037.6 \times 0.0894 \times 3.74) + (2037.6 \times 0.0072 \times 2.49) + (2037.6 \times 0.0072 \times 8.80) + (7.48 \times 10^{-5} \times 6 \times 30 \times 12 \times 18.5 \times 2037.6) + (5.13 \times 10^{-3} \times 2037.6)$$

$$= 8417.31 \text{ Tons } CO_2 \text{ eq}$$

The estimated results using 3 models in 6 scenarios are summarized in Figure 4.4. Figure 4.4 shows each waste recycling scenario (different types of wastes) affects amounts of GHG emission. The estimation of 3 models found that the baseline scenario emits the highest amounts of GHG, however the GHG amounts estimating by each model are different. For baseline scenario, the GHG estimation by WARM is 9,524 Tons CO_2eq, the GHG estimation by IWM is 3,541 Tons CO_2eq, and the GHG estimation by EF-DB is 8,417 Tons CO_2eq. Amounts of GHG emission from S2, S3, S4, S5, and S6 are lower than S1.The differences may due to different assumptions of each model and sensitivity of the model estimation.



	WARM	IWM	EF-DB
S1	9524	3541	8417
S2	9104	3527	8390
S3	9027	3355	8373
S4	9402	3512	8399
S5	9404	3499	8367
S6	8365	3269	8285

Figure4. 4 Estimation of Greenhouse Gas (GHG) Emission from Waste Management Activity in Phangkhon Municipal District (During September 2009-August 2010)

According to the EF-DB is developing model in this research, amounts of energy consumption in the model are estimated by Eq.3 as follow:

$$En = (W_G \times En_{Raw\ of\ glass}) + (W_P \times En_{Raw\ of\ paper}) + (W_{Pl} \times En_{Raw\ of\ plastic}) + (W_{Fe} \times En_{Raw\ of\ ferrous}) + (W_{Al} \times En_{Raw\ of\ aluminum}) + (En_T \times W_T \times D \times T) + (En_S \times W_T) \quad \text{(Eq. 3)}$$

The example of estimation energy consumption from baseline scenario by EF-DB is showed as follow:

W_G = Total Waste Generation (Tons) × Composition of Glass (%)
= 2037.6 × 0.0212 Tons

W_P = Total Waste Generation (Tons) × Composition of Paper (%)
= 2037.6 × 0.0566 Tons

W_{Pl} = Total Waste Generation (Tons) × Composition of 3 types of Plastic (%)

$$= 2037.6 \times 0.0894 \text{ Tons}$$

$$W_{Fe} = \text{Total Waste Generation (Tons)} \times \text{Composition of Ferrous (\%)}$$

$$= 2037.6 \times 0.0072 \text{ Tons}$$

$$W_{Al} = \text{Total Waste Generation (Tons)} \times \text{Composition of Aluminum (\%)}$$

$$= 2037.6 \times 0.0072 \text{ Tons}$$

$$En_{\text{Raw of glass}} = 16.2 \text{ GJ/ Tons of Waste}$$

$$En_{\text{Raw of paper}} = 45.7 \text{ GJ / Tons of Waste}$$

$$En_{\text{Raw of plastic}} = 59.4 \text{ GJ / Tons of Waste}$$

$$En_{\text{Raw of ferrous}} = 40 \text{ GJ / Tons of Waste}$$

$$En_{\text{Raw of aluminum}} = 140.5 \text{ GJ / Tons of Waste}$$

$$En_T = 0.0012 \text{ GJ/ Tons of waste-km}$$

$$En_S = 0.08 \text{ GJ/ Tons of waste-km}$$

$$W_T = 2037.6 \text{ Tons}$$

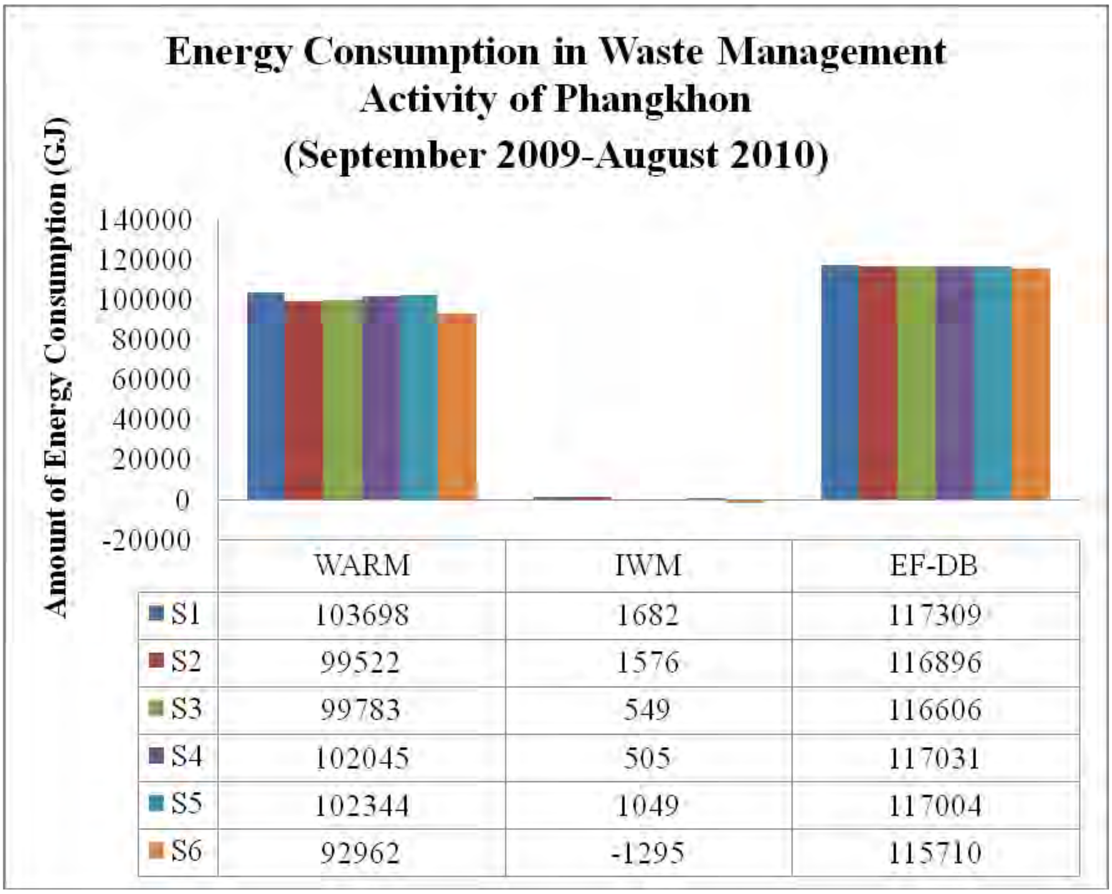
$$T = 6 \times 30 \times 12 \text{ Trips/ year}$$

$$D = 18.5 \text{ km}$$

$$En = (2037.6 \times 0.0212 \times 16.2) + (2037.6 \times 0.0566 \times 45.7) + (2037.6 \times 0.0894 \times 59.4) + (2037.6 \times 0.0072 \times 40) + (2037.6 \times 0.0072 \times 140.5) + (0.0012 \times 2037.6 \times 18.5 \times 6 \times 30 \times 12) + (0.08 \times 2037.6)$$

$$= 117{,}308.75 \text{ GJ}$$

Figure 4.5 reveals the energy consumption from waste management activity in 6 scenarios of Phangkhon Municipal District. For baseline scenario of waste management (without recycling activity) in Phangkhon, energy consumption estimated by WARM, IWM, and EF-DB are 103,698 GJ, 1,682 GJ, and 117,309 GJ, respectively. From all models, the assessments demonstrate trends of the waste recycling activity help reducing the amounts of energy consumption in waste management system. Amounts of energy consumption from S2, S3, S4, S5, and S6 are lower than S1. Similar to the assessment of GHG emission, the amounts of energy reduction from the 3 models are different. The differences may be due to different assumption of each model and sensitivity of the model estimation.



	WARM	IWM	EF-DB
S1	103698	1682	117309
S2	99522	1576	116896
S3	99783	549	116606
S4	102045	505	117031
S5	102344	1049	117004
S6	92962	-1295	115710

Figure4. 5 Energy Consumption from Waste Management Activity in Phangkhon Municipal District (During September 2009-August 2010)

The model estimation shows that waste recycling activity affects on amounts of GHG emission and energy consumption. The waste management via recycling could reduce some of GHG emission and energy consumption. To analyze which type of recycling waste has the highest potential for reducing GHG emission and energy consumption, the amounts of avoided GHG and avoided energy consumption from recycling activity are compared.

According to the EF-DB is developing model in this research, amounts of avoided GHG emission in the model are estimated by Eq.2 as follow:

$$A_{GHG} = \{(EF_{Raw}-EF_{Re})\times W_{Re}\}+(E_V\times T_{Re}\times W_{Re}\times D)+(E_L\times W_{Re})-(E_V\times T_{Re}\times W_{Re}\times D_{Re}) \quad \text{(Eq. 2)}$$

The example of estimation avoided GHG emission from scenario2 (S2) or glass recycling activity by EF-DB is showed as follow:

$W_{Re\ of\ Glass}$ = Total Waste Recycling of Glass = 40.81 Tons

$EF_{Raw\ of\ glass}$ = 1.03 Tons CO_2 eq/ Tons of Waste

$EF_{Re\ of\ glass}$ = 0.33 Tons CO_2 eq/ Tons of Waste

E_V = 7.48×10^{-5} Tons CO_2 eq/ Tons of Waste-km

E_L = 5.13×10^{-3} Tons CO_2 eq/ Tons of Waste

T_{Re} = 41 Trips/ year

D = 18.5 km

T_{Re} = 41 Trips

D_{Re} = 32 km

$$A_{GHG} = \{(1.03 - 0.33) \times 40.81\} + (7.48 \times 10^{-5} \times 41 \times 40.81 \times 18.5) + (5.13 \times 10^{-3} \times 40.81) - (7.48 \times 10^{-5} \times 41 \times 40.81 \times 32)$$

$$= 27.09 \text{ Tons } CO_2 \text{ eq}$$

Although, the amounts of avoided GHG from the 3 models are different as shown in Figure 4.6, all models show the same prediction trend. The scenario that has the highest amount (1st ranked) of avoided GHG among the 3 models is S6 (Scenario 6) or the scenario with recycling all type of wastes (glass, paper, plastic, and metal) from the usual community's waste management. While the scenario that has the lowest amount (6th ranked) of avoided GHG from the 3 models is S1 or Baseline (avoided zero Tons CO_2eq). The amount of avoided GHG of S6 estimated by WARM is 1,159 Tons CO_2eq, by IWM is 272 Tons CO_2eq, and by EF-DB is 132 Tons CO_2eq.

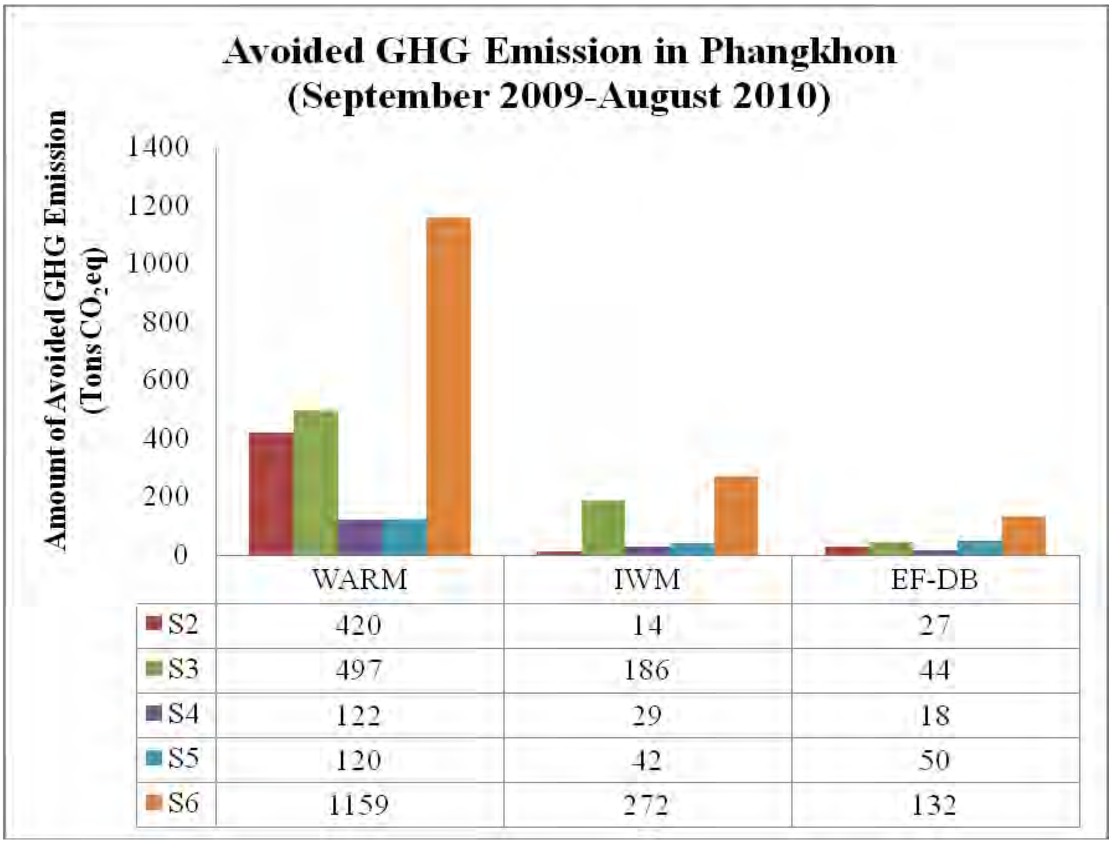
The GHG reduction ranking of each scenario from the 3 models are different. This may be caused by different assumptions and emission factors used by each model. For example;

1. The assessments of S2 (glass recycling activity) form WARM is 3rd ranked (420 Tons CO_2eq), from IWM is 5th ranked (14 Tons CO_2eq), and from EF-DB is 4rd ranked (27 Tons CO_2eq).

2. The assessment of S3 (paper recycling activity) form WARM is 497 Tons CO_2eq, and from IWM is 186 Tons CO_2eq.S3 scenario is 2nd ranked from the 2 models assessment. But S3 from EF-DB assessment is 3rd ranked (44 Tons CO_2eq).

3. The assessments of S4 (plastic recycling activity) from WARM is 122 Tons CO_2eq, IWM is 29 Tons CO_2eq, and EF-DB is 18 Tons CO_2eq. From WARM and IWM assessment, plastic recycling scenario is ranked in the 4th but the ranking of plastic from the EF-DB assessment is 5th.

4. The assessments of S5 (metal recycling activity) form WARM is 5th ranked (120 Tons CO_2eq), from IWM is 3rd ranked (42 Tons CO_2eq), and from EF-DB is 2nd ranked (50 Tons CO_2eq).



	WARM	IWM	EF-DB
S2	420	14	27
S3	497	186	44
S4	122	29	18
S5	120	42	50
S6	1159	272	132

Figure4. 6 Estimation of Avoided Greenhouse Gas (GHG) Emission from Waste Management Activity in Phangkhon Municipal District (During September 2009-August 2010)

According to the EF-DB is developing model in this research, amounts of avoided energy consumption in the model are estimated by Eq.4 as follow:

$$A_{En} = \{(En_{Raw} - En_{Re}) \times W_{Re}\} + (En_T \times W_{Re} \times T_{Re} \times D) + (En_S \times W_{Re}) - (En_T \times W_{Re} \times T_{Re} \times D_{Re}) \qquad \text{(Eq. 4)}$$

The example of estimation avoided energy consumption from scenario2 (S2) or glass recycling activity by EF-DB is showed as follow:

$W_{Re\ of\ Glass}$ = Total Waste Recycling of Glass

= 40.81 Tons

$$En_{Raw\ of\ glass} = 16.2\ \text{GJ/ Tons of Waste}$$

$$En_{Re\ of\ glass} = 5.5\ \text{GJ/ Tons of Waste}$$

$$En_{S} = 0.08\ \text{GJ/ Tons of waste}$$

$$En_{T} = 0.0012\ \text{GJ/ Tons of waste-km}$$

$$T_{Re} = 41\ \text{Trips/ year}$$

$$D = 18.5\ \text{km}$$

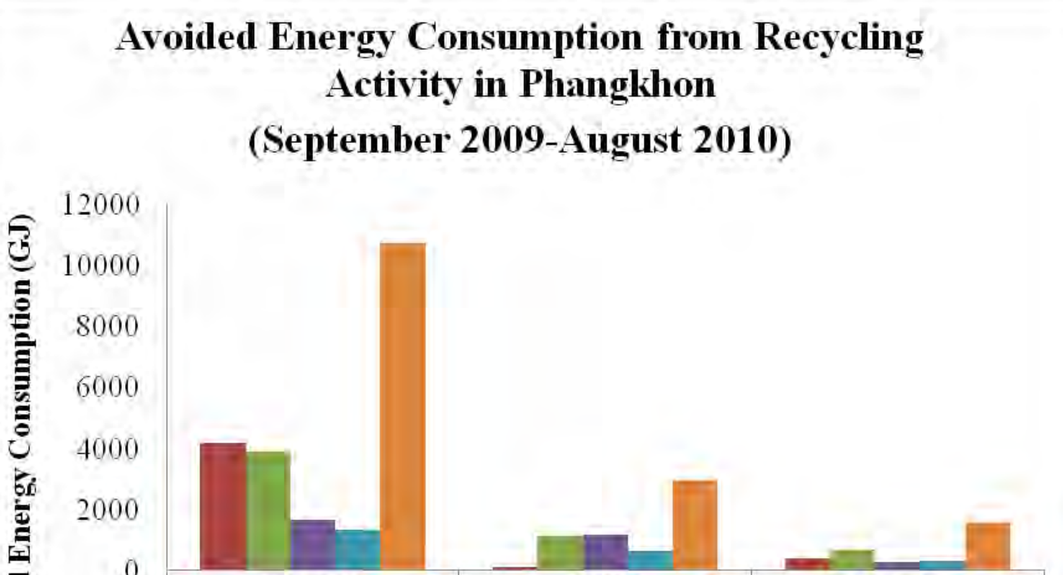
$$D_{Re} = 32\ \text{km}$$

$$A_{En} = \{(16.2 - 5.5) \times 40.81\} + (0.0012 \times 40.81 \times 41 \times 18.5) + (0.08 \times 40.81) - (0.0012 \times 40.81 \times 41 \times 32)$$

$$= 412.83\ \text{GJ}$$

The amounts of avoided energy consumption from the 3 models are different but the scenario that has the highest amount (1st ranked) of avoided the consumption from the 3 models is S6 (Scenario 6), as shown in Figure 4.7. The assessment of the avoided the consumption of S6 by WARM is 10,736 GJ, by IWM is 2,977 GJ, and by EF-DB is 1,599 GJ. The scenario that has the lowest amount (6th ranked) of avoided energy consumption from the 3 models is S1 or without recycling activity in the community's waste management system (avoided zero GJ).

Similar to the avoided GHG scenario, the ranking of avoided energy consumption amount for each scenario from the 3 models are different. For S2 (glass recycling activity), the assessment from WARM, IWM, and EF-DB are 2nd ranked (4,176 GJ), 5th ranked (106 GJ), and 3rd ranked (413 GJ) respectively. The assessment of S3 (paper recycling activity) form WARM is 3,915 GJ, from IWM is 1,133 GJ, and EF-DB is 703 GJ. The avoided of energy consumption of S3 from WARM and IWM assessment is 3rd ranked but avoided energy from EF-DB assessment is 2nd. The ranking and number of avoided energy consumption of S4 (plastic recycling activity) by WARM, IWM, and EF-DB as follow: 4th (1,653 GJ), 2nd (1,177 GJ), and 5th (278 GJ). For S5 (metal recycled), the avoided of energy consumption by WARM, IWM, and EF-DB are 5th ranked (1,354 GJ), 4th (633 GJ), and 4th (304 GJ), respectively.



	WARM	IWM	EF-DB
S2	4176	106	413
S3	3915	1133	703
S4	1653	1177	278
S5	1354	633	304
S6	10736	2977	1599

Figure4. 7 Estimation of Avoided Energy Consumption from Waste Management Activity in Phangkhon Municipal District (During September 2009-August 2010)

As trends of avoided GHG emission and avoided energy consumption from the 3 models assessment are different (such as avoided glass recycling are not ranked 3rd in all 3 models assessment, avoided energy consumption of glass recycling are not ranked 3rd in all 3 models assessment), although the efficiency glass recycling is the highest. The different of the trends might potentially cause by various factors (e.g. model assumption, amounts of waste recycling, also type of waste, etc.), which affect on the amount of GHG reduction. Therefore, the average impact from avoided per unit of each recycling waste is analyzed, as shown in Figure 4.8.

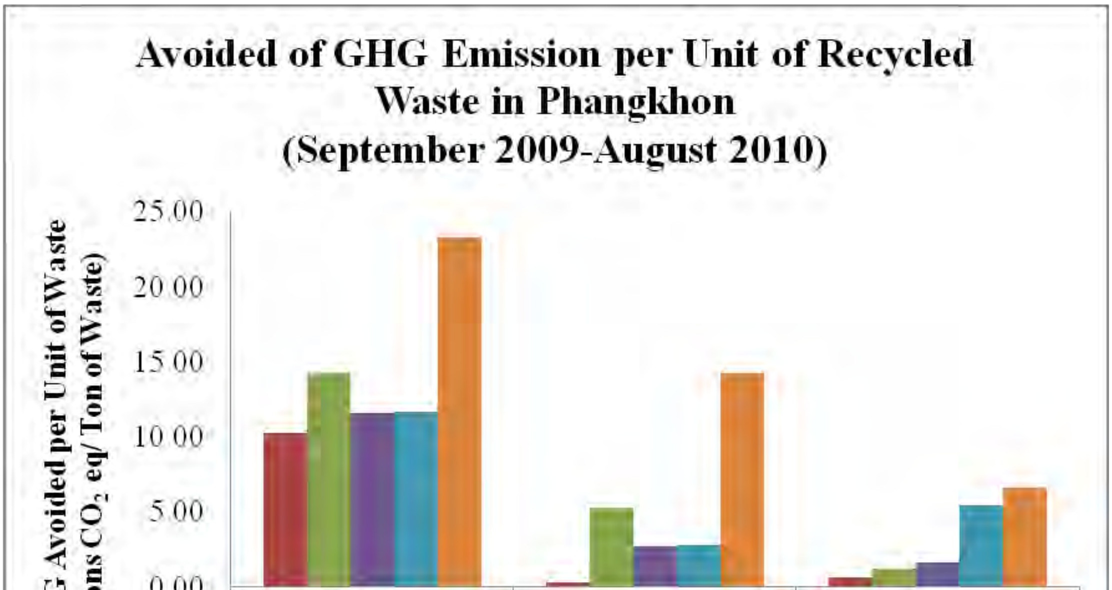
The numbers of avoided GHG emission per unit of waste of S6 by WARM is 12.10 Tons CO_2eq/ Ton of waste, by IWM is 2.84 Tons CO_2eq/ Ton of waste, by EF-DB is 5.29 Tons CO_2eq/ Ton of waste. The numbers of avoided per unit of waste from S6 are not the highest. Moreover, the numbers of avoided per unit of waste from S6 cannot be a presentative of avoided number for every categories of waste. Because the assessment of S2, S3, S4, and S5 (glass, paper, plastic, and metal) shows the avoided amount of each scenerio are differrent.

The amounts of avoided GHG emission per unit of recycled waste shows the same trends from the 3 models. The lowest (6^{th} ranked) of avoided GHG emission per ton of waste is S1 or Baseline because without recycling activity could not avoide any GHG emission. So, to analyze the trend of avoided GHG emssion and avoided energy consumption per unit of waste, S1 and S6 are excluded.

The estimation of avoided GHG per unit of each recycle waste is showed in Figure 4.8. The ranking of avoided GHG per unit of waste from WARM and IWM are similar. Firstly, the 1^{st} ranked of GHG avoided per unit of waste is S5.2 or aluminum recycling (WARM: 23.29 Tons CO_2 eq/Ton, IWM: 14.23 Tons CO_2 eq/Ton). Secondly, the 2^{nd} ranked is S3 or paper recycling which the estimation by WARM and IWM are 14.24 and 5.33 Tons CO_2 eq/Ton , respectively. Thirdly, the 3^{rd} ranked is S5.1 or ferrous recycling which the estimation by WARM is 10.73 Tons CO_2 eq/Ton and by IWM is 2.56 Tons CO_2 eq/Ton. Next, the 4^{th} ranked is S4 or plastic recycling which the estimation by WARM and IWM are 11.60 and 2.76 Tons CO_2 eq/Ton , respectively. Lastly, the 5^{th} ranked is S2 or glass recycling which the estimation by WARM is 10.29 Tons CO_2 eq/Ton and by IWM is 0.34 Tons CO_2 eq/Ton.

For the estimation of EF-DB, S5.2 or aluminum recycling is still 1^{st} ranked of the GHG avoided per unit of waste (6.64 Tons CO_2 eq/Ton). However, some ranking are different from those in the other 2 models. Firstly, the 2^{nd} ranked is S5.1 or ferrous recycling (5.50 Tons CO_2 eq/Ton). Secondly, the 3^{rd} ranked is S4 or plastic recycling (1.68 Tons CO_2 eq/Ton). Thirdly, the 4^{th} ranked is S3 or paper recycling (1.25 Tons CO_2 eq/Ton). Lastly, the 5^{th} ranked is S2 or glass recycling (0.66 Tons CO_2 eq/Ton). .

Although there are quite different of ranking between existing models (WARM and IWM) and developing model in this research (EF-DB), the highest rank of GHG avoided from the waste recycling is similar. The 1^{st} rank from the 3 models is aluminum recycling (S5.2).



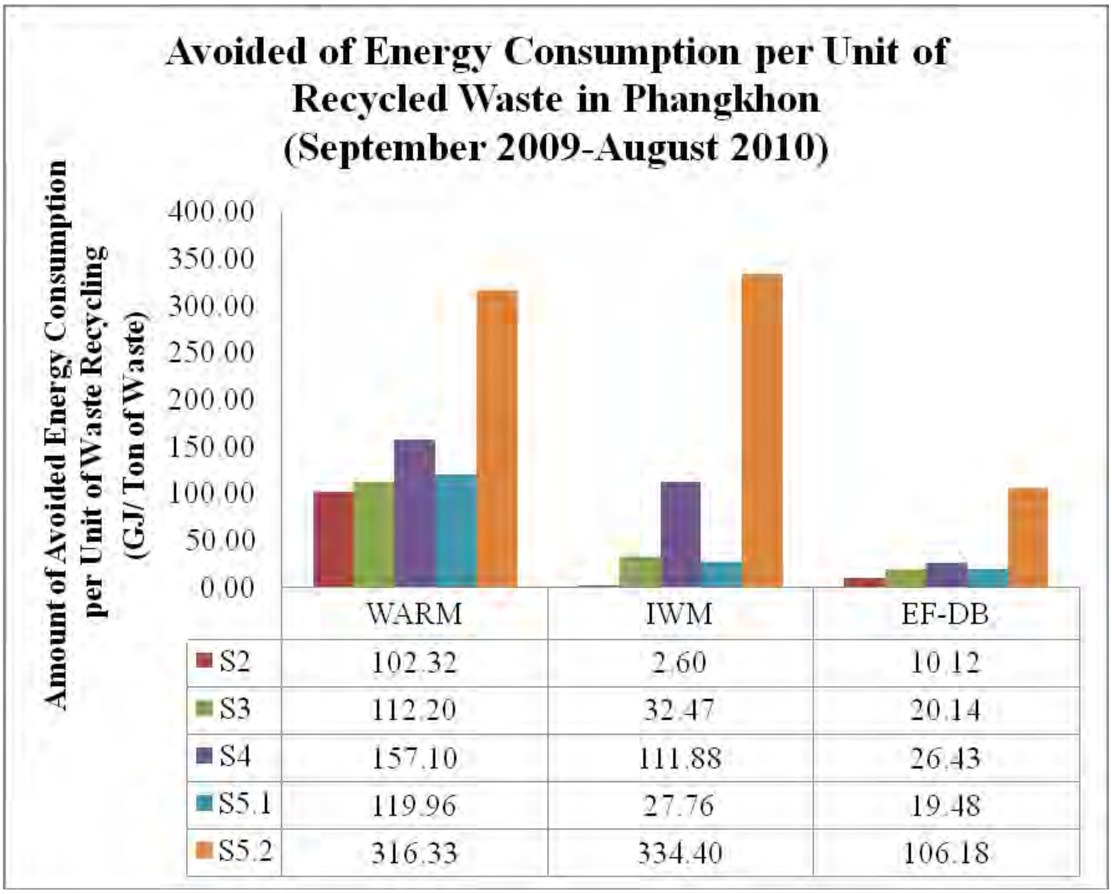
	WARM	IWM	EF-DB
S2	10.29	0.34	0.66
S3	14.24	5.33	1.25
S4	11.60	2.76	1.68
S5.1	11.66	2.78	5.50
S5.2	23.29	14.23	6.64

Figure4. 8 Estimation of Avoided Greenhouse Gas (GHG) Emission per Unit of Recycled Waste from Waste Management Activity in Phangkhon Municipal District (During September 2009-August 2010)

Figure 4.9 shows estimation of avoided energy consumption per unit of each waste recycling. The highest amount of avoided energy consumption per unit of waste is aluminum recycling or S5.2 which the estimation by WARM, IWM, and EF-DB is 316.33 GJ/Ton of waste, 334.40 GJ/Ton of waste, and 106.18 GJ/Ton of waste, respectively. But the other ranking from each model are not similar.

Firstly, S2 or glass recycling is in the 5th ranked of the 3 models as follow: 102.32 GJ/ Ton (by WARM), 2.60 GJ/ Ton (by IWM), and 10.12 GJ/ Ton (EF-DB). Secondly, S3 or paper recycling by WARM, IWM, and EF-DB is 4th ranked (112.20 GJ/ Ton), 3rd ranked (32.47 GJ/ Ton), and 3rd ranked (20.14 GJ/ Ton), respectively. Thirdly, S4 or plastic recycling is 2nd ranked of the 3 models as follow: 157.10 GJ/ton (by WARM), 111.88 GJ/ Ton (by IWM), and 26.43 GJ/ Ton (EF-DB). Lastly, S5.1 or ferrous recycling by WARM, IWM, and EF-DB is 3rd ranked (119.96 GJ/ Ton), 4th ranked (27.76 GJ/ Ton), and 4th ranked (19.48 GJ/ Ton), respectively.

From the assessment from the 3 models, although the ranking of energy consumption per unit of recycling waste are different, the rank of highest amounts of avoided energy consumption from the waste recycling of each model is similar. Similar to the rank of highest amount of avoided GHG per unit of waste, the 1st rank of the 3 models estimation is aluminum recycling (S5.2).



	WARM	IWM	EF-DB
S2	102.32	2.60	10.12
S3	112.20	32.47	20.14
S4	157.10	111.88	26.43
S5.1	119.96	27.76	19.48
S5.2	316.33	334.40	106.18

Figure4. 9 Estimation of Avoided Energy Consumption per Unit of Recycled Waste from Waste Management Activity in Phangkhon Municipal District (During September 2009-August 2010)

According to the result estimation, aluminum waste recycling should be the 1st priority in waste management strategy to encourage citizens for recycling to efficiently reduce GHG. If Phangkhon Municipal District needs to increase the efficiency of GHG and energy consumption reduction via the recycling campaign, the waste bank should encourage people to recycle more aluminum waste. In addition, current efficiency of aluminum recycling is still low, therefore aluminum waste has a significant potential to increase the recycling efficiency and should be more promoted.

The potential explanation why amounts of avoided GHG from the 3 models are different probably because each of model have different assumption and each model are developed the equations and using emission factors basing on configuration from their local context and available case study in different areas. Furthermore, each model has different conditions and activity/implementation for their waste management; these factors might affect the results when using each model for the same case study data.

According to the different results of the assessments by IWM, WARM, and EF-DB, sensitivity of each model is analyzed to compare sensitivity based on quantities of recycling waste and distances for recycled waste transportation.

When the 3 models are tested by reducing 50% amounts of recycling waste of Phangkhon case study, IWM shows the assessment results of avoided GHG and avoided energy consumption do not change from the previous estimation. WARM shows the result from the assessment of avoided GHG and avoided energy consumption change approximately 50 % of the previous results. EF-DB shows the assessment results of avoided GHG and avoided energy consumption change approximately 50 % of the previous results.

When the 3 models are tested by reducing 50% transporting distances for recycled waste, IWM shows the assessment of avoided GHG and avoided energy consumption change approximately 1 % of the previous results. WARM shows the assessment of avoided GHG and avoided energy consumption are change approximately 1 % of the previous results. EF-DB shows the assessment of avoided GHG changes approximately 1 % of the previous results and avoided energy consumption changes approximately 5 % of the previous results.

From the sensitivity analysis, WARM and EF-DB are more sensitive than IWM. The WARM and EF-DB are more sensitive to change in amounts of wastes than change in waste transporting distance. On the other hand, IWM is low sensitive with the quantities of waste but the model is sensitive with the distance for recycling waste transportation. The IWM model maybe more sensitive to wastes with higher quantities.

4.4 Model Development and Operation

Since there is no model existed for this case study to develop a carbon accounting system, therefore this study aims to develop a tool for a local community to record recyclable wastes and calculate their avoided carbon emission from recycled activity for individual person. According to this study used the 3 models for estimation avoided GHG emission and avoided energy consumption, EF-DB was selected for developing of the carbon accounting in Phangkhon Municipal District. The model developed based on existing emission factors research for supporting and assembling a model. The more accurate the model is the better for carbon bank system. Carbon banking system is set up for supporting voluntary of GHG reduction. The voluntary project must measurable, recordable, and verifiable (MRV) to measure the progress for mitigation efforts.

To set up a framework for carbon banking model, this study decided to use EF-DB for assessment GHG reduction and for development of carbon accounting in the Phangkhon's waste banking. The reason to choose the EF-DB instead of the WARM and the IWM is because the flexibility for model modification of emission factors. The current model framework uses emission factors from existing research which not all of them are local emission factors. In the future, if there is more research investigating on local emission factors from LCA of waste recycles in Thailand, it will allow us to adjust the factors into the EF-DB model very easily. Therefore, among the 3 models, the EF-DB will be more flexible and accurate for estimating GHG emission and energy consumption from waste management system of the case study.

This model supports the waste recycling activity of waste bank in Phangkhon Municipal District. This study develops two accounts for keeping the record and reporting the balance in the recycling activity including (1) carbon account, and (2) waste selling account.

4.4.1 Carbon Accounting

4.4.1.1 The Purpose of Developing Carbon Accounting

This tool aims to support the waste recycling activity of the community. The tool will estimate and report the avoided GHG emission from the recycle wastes from the waste bank members. So the tool is a part of carbon banking idea which the avoided carbon emission from activities must be monitored, reported, and verified (MRV). Furthermore, the recordable data shows the community and people to realize their potential for reducing greenhouse gas emission which be generally causing of global warming.

The amounts avoided of GHG from this account might demonstrate central government, other local governments, other citizens, and some organization encourage implementing the waste recycling campaign. If the methodology for monitoring and verifying the avoided of GHG emission from waste recycling, communities who have implemented the waste banking and carbon banking might get benefits from Clean Development Mechanism (CDM) project or voluntary market.

This research helps to disclose benefits from recycling waste in the community. The benefit from the recycling activity provides revenues for the members who participate in waste banking. Moreover, the benefits from reducing energy consumption and GHG emission could promote to be an incentive for the community. Because the incentive might leads the community to implement a carbon banking system.

Recycling waste activity help reducing greenhouse gas (GHG) emission and reducing energy consumption in waste management system in the community from 2 main processes. These two processes are transportation and production. Firstly, recycling reduces of waste loads and trips transported to landfills so lessen emission from transportation. Secondly, the recycling wastes help recovered raw material and return into production to replace the uses of certain raw materials, therefore, lower amount of energy from extraction and production.

The research aims to develop a carbon account and tools for evaluating carbon emission reduction based on the implementation of waste bank in Phangkhon District. After compared 3 existing models available, the research decided to develop the carbon accounting model by adopting emission factors from Browne, O'Regan, Moles

(2009). In the future, if Thailand could derive its local emission factors from relevant activities, the factors will easily modify and adjust with this current model. This carbon accounting framework and model is a prototype of carbon accounting system for any mitigation activity in Thailand. This research focuses on designing for using in annual recycling activity.

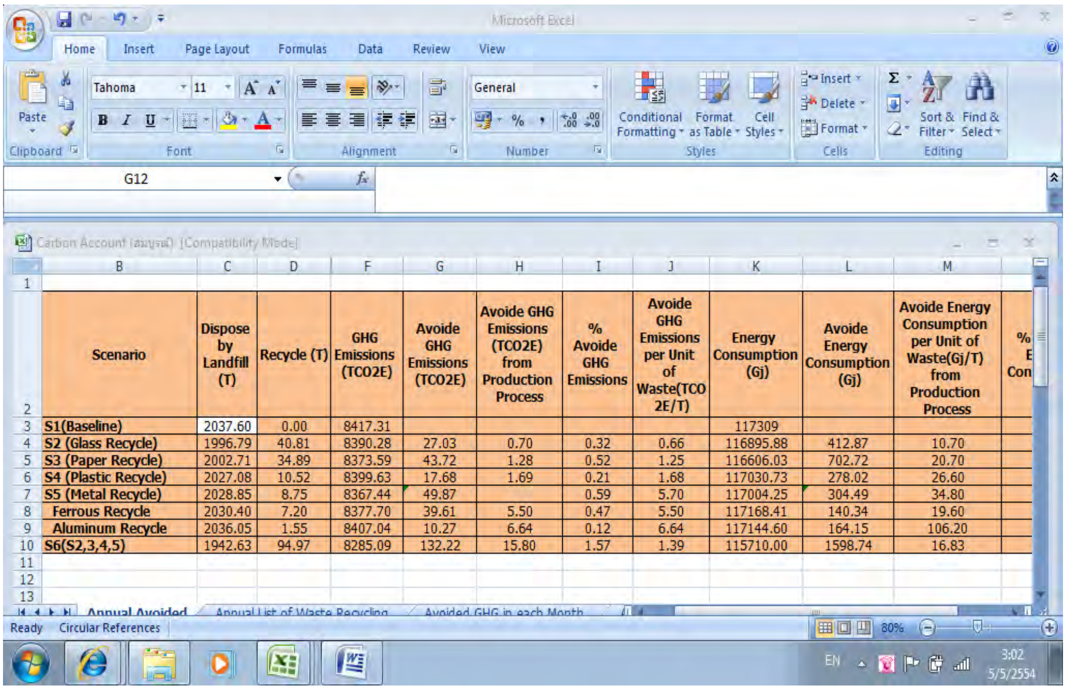
4.4.1.2 Input Data

This research has developed the program to estimate the GHG emission reduction from waste management activity in Phangkhon. Input data used in the carbon accounting program are as follow:

1. Amounts of Waste Generation per year in the Phangkhon Municipal District
2. Month and Year that needs to record in each sheet
3. Name of Members for Record their Recycling Activity
4. Amounts of Recycling Waste in each Category

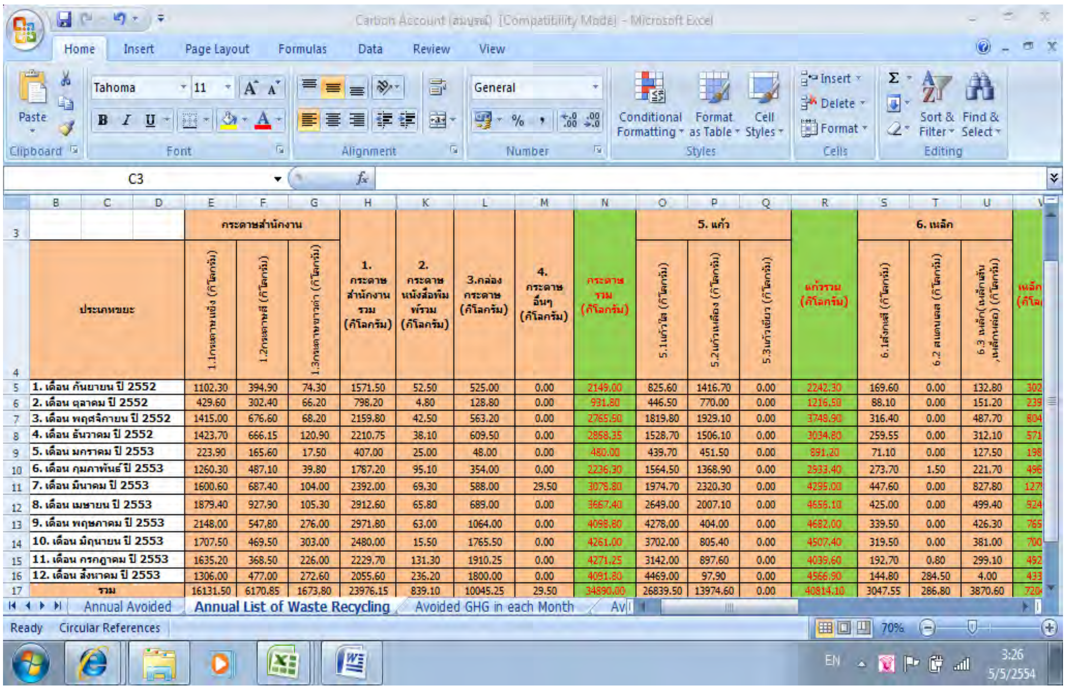
4.4.1.3 Instruction of the Developing Carbon Accounting

There are 4 parts of the accounting, in total of 15 sheets. First part is calculation of annual avoided from recycling activity. Second part is summary of recycling capacity of the community in 12 months. Third part is summary of avoided GHG and avoided energy consumption. Forth part is members' list for recording waste recycling activity. In the 1st part, GHG emission, avoided GHG, energy consumption, and avoided of energy consumption are estimated. This sheet is so-called *The Annual Avoided Calculation* Sheet, as shown in Figure 4.10. The 2nd part summarizes the numbers of total recycling waste of each category in 12 months. This sheet is so-called *The Annual List of Waste Recycling* Sheet as shown in Figure 4.11. The 3rd part summarizes and displays the numbers of avoided GHG and energy consumption of each waste category in each month. These sheets are so-called *The Avoided GHG in each Month* Sheet and *The Avoided Energy Consumption in each Month* Sheet respectively as shown in Figure 4.12 and Figure 4.13. Finally, the 4th part is recording the amounts of waste recycling activity from the community's members. This part is so-called *Recycling Waste Activity List from Members* Sheets as shown in Figure 4.14. This part consists of 12 sheets that record the recycling activity in each month.



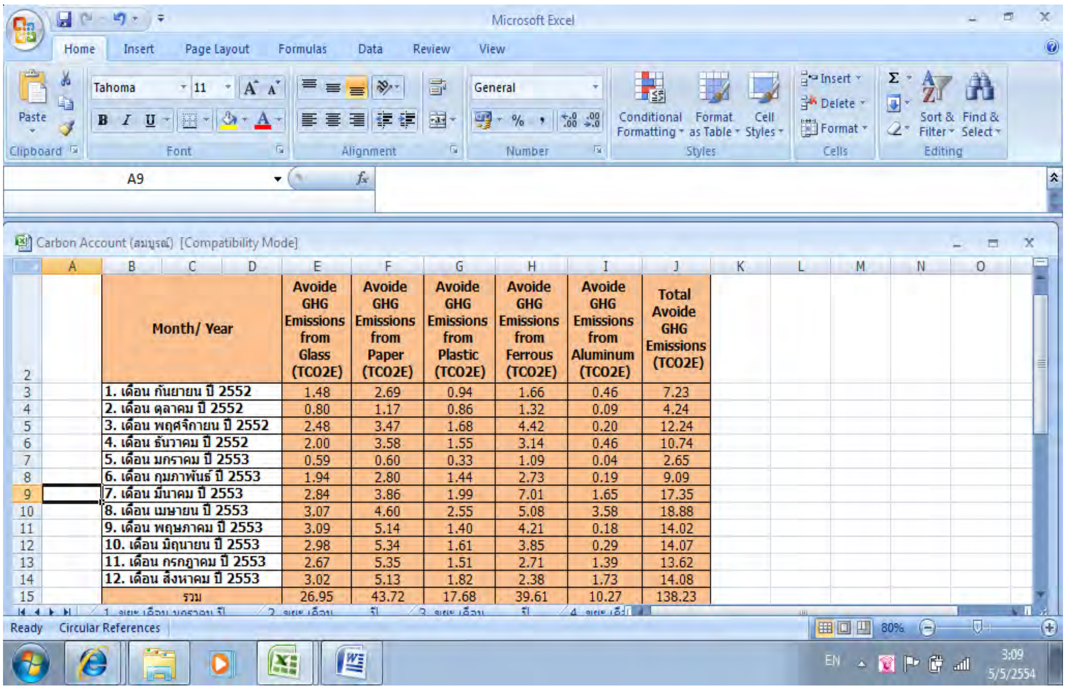
Scenario	Dispose by Landfill (T)	Recycle (T)	GHG Emissions (TCO2E)	Avoide GHG Emissions (TCO2E)	Avoide GHG Emissions (TCO2E) from Production Process	% Avoide GHG Emissions	Avoide GHG Emissions per Unit of Waste(TCO2E/T)	Energy Consumption (Gj)	Avoide Energy Consumption (Gj)	Avoide Energy Consumption per Unit of Waste(Gj/T) from Production Process
S1(Baseline)	2037.60	0.00	8417.31					117309		
S2 (Glass Recycle)	1996.79	40.81	8390.28	27.03	0.70	0.32	0.66	116895.88	412.87	10.70
S3 (Paper Recycle)	2002.71	34.89	8373.59	43.72	1.28	0.52	1.25	116606.03	702.72	20.70
S4 (Plastic Recycle)	2027.08	10.52	8399.63	17.68	1.69	0.21	1.68	117030.73	278.02	26.60
S5 (Metal Recycle)	2028.85	8.75	8367.44	49.87		0.59	5.70	117004.25	304.49	34.80
Ferrous Recycle	2030.40	7.20	8377.70	39.61	5.50	0.47	5.50	117168.41	140.34	19.60
Aluminum Recycle	2036.05	1.55	8407.04	10.27	6.64	0.12	6.64	117144.60	164.15	106.20
S6(S2,3,4,5)	1942.63	94.97	8285.09	132.22	15.80	1.57	1.39	115710.00	1598.74	16.83

Figure4. 10 *The Annual Avoided Calculation* Sheet of the *Carbon Accounting*



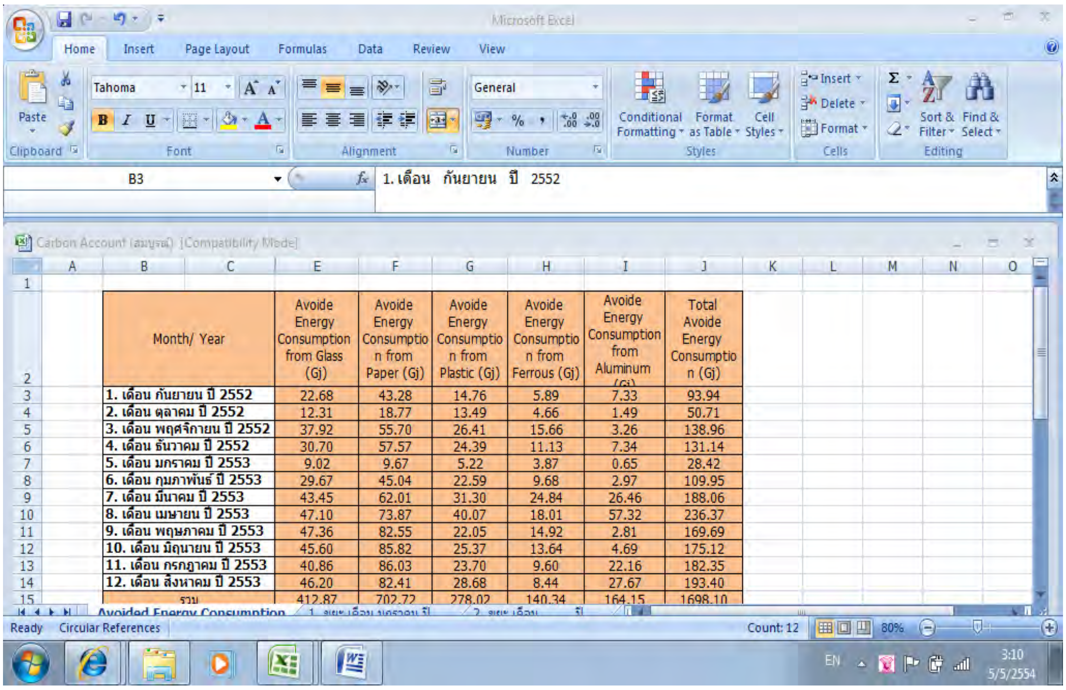
ประเภทขยะ	กระดาษสำนักงาน								5. แก้ว				6. เหล็ก			
	1.1กระดาษแข็ง (กิโลกรัม)	1.2กระดาษสี (กิโลกรัม)	1.3กระดาษขาวดำ (กิโลกรัม)	1. กระดาษสำนักงานรวม (กิโลกรัม)	2. กระดาษหนังสือพิมพ์รวม (กิโลกรัม)	3.กล่องกระดาษ (กิโลกรัม)	4. กระดาษอื่นๆ (กิโลกรัม)	กระดาษรวม (กิโลกรัม)	5.1แก้วใส (กิโลกรัม)	5.2แก้วเหลือง (กิโลกรัม)	5.3แก้วเขียว (กิโลกรัม)	แก้วรวม (กิโลกรัม)	6.1สังกะสี (กิโลกรัม)	6.2 สแตนเลส (กิโลกรัม)	6.3 เหล็ก(เหล็กเส้น,เหล็กหล่อ) (กิโลกรัม)	เหล็ก (กิโล
1. เดือน กันยายน ปี 2552	1102.30	394.90	74.30	1571.50	52.50	525.00	0.00	2149.00	825.60	1416.70	0.00	2242.30	169.60	0.00	132.80	302
2. เดือน ตุลาคม ปี 2552	429.60	302.40	66.20	798.20	4.80	128.80	0.00	931.80	446.50	770.00	0.00	1216.50	88.10	0.00	151.20	239
3. เดือน พฤศจิกายน ปี 2552	1415.00	676.60	68.20	2159.80	42.50	563.20	0.00	2765.50	1819.80	1929.10	0.00	3748.90	316.40	0.00	487.70	804
4. เดือน ธันวาคม ปี 2552	1423.70	666.15	120.90	2210.75	38.10	609.50	0.00	2858.35	1528.70	1506.10	0.00	3034.80	259.55	0.00	312.10	571
5. เดือน มกราคม ปี 2553	223.90	165.60	17.50	407.00	25.00	48.00	0.00	480.00	439.70	451.50	0.00	891.20	71.10	0.00	127.50	198
6. เดือน กุมภาพันธ์ ปี 2553	1260.30	487.10	39.80	1787.20	95.10	354.00	0.00	2236.30	1564.50	1368.90	0.00	2933.40	273.70	1.50	221.70	496
7. เดือน มีนาคม ปี 2553	1600.60	687.40	104.00	2392.00	69.30	588.00	29.50	3078.80	1974.70	2320.30	0.00	4295.00	447.60	0.00	827.80	127
8. เดือน เมษายน ปี 2553	1879.40	927.90	105.30	2912.60	65.80	689.00	0.00	3667.40	2649.00	2007.10	0.00	4656.10	425.00	0.00	499.40	924
9. เดือน พฤษภาคม ปี 2553	2148.00	547.80	276.00	2971.80	63.00	1064.00	0.00	4098.80	4278.00	404.00	0.00	4682.00	339.50	0.00	426.30	765
10. เดือน มิถุนายน ปี 2553	1707.50	469.50	303.00	2480.00	15.50	1765.50	0.00	4261.00	3702.00	805.40	0.00	4507.40	319.50	0.00	381.00	700
11. เดือน กรกฎาคม ปี 2553	1635.20	368.50	226.00	2229.70	131.30	1910.25	0.00	4271.25	3142.00	897.60	0.00	4039.60	192.70	0.80	299.10	492
12. เดือน สิงหาคม ปี 2553	1306.00	477.00	272.60	2055.60	236.20	1800.00	0.00	4091.80	4469.00	97.90	0.00	4566.90	144.80	284.50	4.00	433
รวม	16131.50	6170.85	1673.80	23976.15	839.10	10045.25	29.50	34890.00	26839.50	13974.60	0.00	40814.10	3047.55	286.80	3870.60	720

Figure4. 11 *The Annual List of Waste Recycling* Sheet of the *Carbon Accounting*



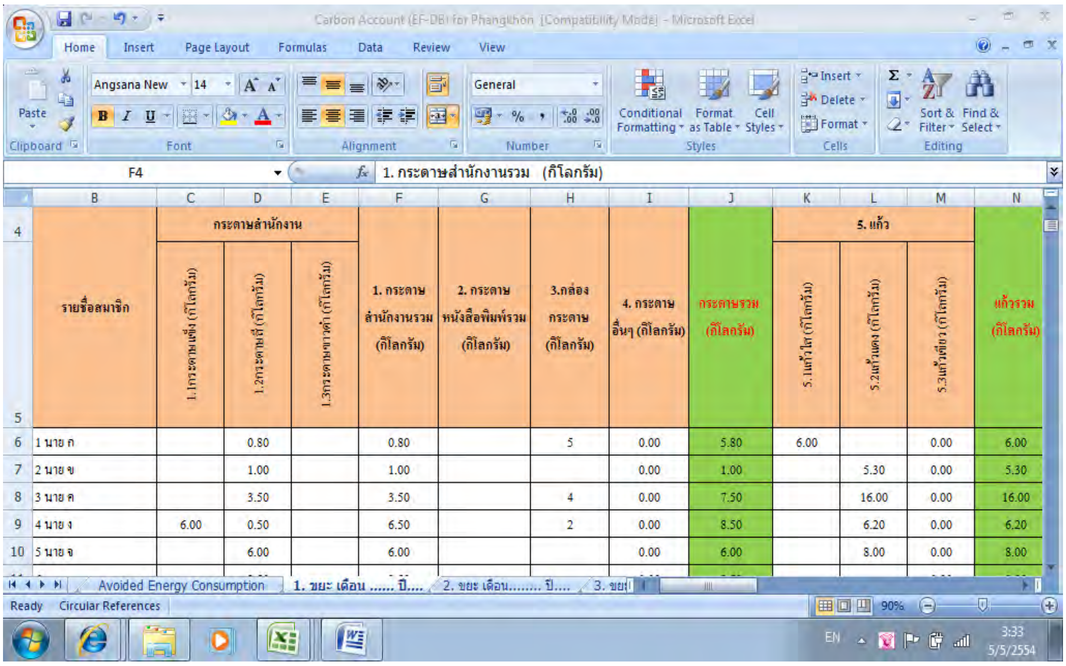
Month/ Year	Avoide GHG Emissions from Glass (TCO2E)	Avoide GHG Emissions from Paper (TCO2E)	Avoide GHG Emissions from Plastic (TCO2E)	Avoide GHG Emissions from Ferrous (TCO2E)	Avoide GHG Emissions from Aluminum (TCO2E)	Total Avoide GHG Emissions (TCO2E)
1. เดือน กันยายน ปี 2552	1.48	2.69	0.94	1.66	0.46	7.23
2. เดือน ตุลาคม ปี 2552	0.80	1.17	0.86	1.32	0.09	4.24
3. เดือน พฤศจิกายน ปี 2552	2.48	3.47	1.68	4.42	0.20	12.24
4. เดือน ธันวาคม ปี 2552	2.00	3.58	1.55	3.14	0.46	10.74
5. เดือน มกราคม ปี 2553	0.59	0.60	0.33	1.09	0.04	2.65
6. เดือน กุมภาพันธ์ ปี 2553	1.94	2.80	1.44	2.73	0.19	9.09
7. เดือน มีนาคม ปี 2553	2.84	3.86	1.99	7.01	1.65	17.35
8. เดือน เมษายน ปี 2553	3.07	4.60	2.55	5.08	3.58	18.88
9. เดือน พฤษภาคม ปี 2553	3.09	5.14	1.40	4.21	0.18	14.02
10. เดือน มิถุนายน ปี 2553	2.98	5.34	1.61	3.85	0.29	14.07
11. เดือน กรกฎาคม ปี 2553	2.67	5.35	1.51	2.71	1.39	13.62
12. เดือน สิงหาคม ปี 2553	3.02	5.13	1.82	2.38	1.73	14.08
รวม	26.95	43.72	17.68	39.61	10.27	138.23

Figure4. 12 *Avoided GHG in each Month* Sheet of the *Carbon Accounting*



Month/ Year	Avoide Energy Consumption from Glass (Gj)	Avoide Energy Consumption from Paper (Gj)	Avoide Energy Consumption from Plastic (Gj)	Avoide Energy Consumption from Ferrous (Gj)	Avoide Energy Consumption from Aluminum (Gj)	Total Avoide Energy Consumption (Gj)
1. เดือน กันยายน ปี 2552	22.68	43.28	14.76	5.89	7.33	93.94
2. เดือน ตุลาคม ปี 2552	12.31	18.77	13.49	4.66	1.49	50.71
3. เดือน พฤศจิกายน ปี 2552	37.92	55.70	26.41	15.66	3.26	138.96
4. เดือน ธันวาคม ปี 2552	30.70	57.57	24.39	11.13	7.34	131.14
5. เดือน มกราคม ปี 2553	9.02	9.67	5.22	3.87	0.65	28.42
6. เดือน กุมภาพันธ์ ปี 2553	29.67	45.04	22.59	9.68	2.97	109.95
7. เดือน มีนาคม ปี 2553	43.45	62.01	31.30	24.84	26.46	188.06
8. เดือน เมษายน ปี 2553	47.10	73.87	40.07	18.01	57.32	236.37
9. เดือน พฤษภาคม ปี 2553	47.36	82.55	22.05	14.92	2.81	169.69
10. เดือน มิถุนายน ปี 2553	45.60	85.82	25.37	13.64	4.69	175.12
11. เดือน กรกฎาคม ปี 2553	40.86	86.03	23.70	9.60	22.16	182.35
12. เดือน สิงหาคม ปี 2553	46.20	82.41	28.68	8.44	27.67	193.40
รวม	412.87	702.72	278.02	140.34	164.15	1698.10

Figure4. 13 *Avoided Energy Consumption in each Month* Sheet of the *Carbon Accounting*



รายชื่อสมาชิก	กระดาษสำนักงาน			1. กระดาษสำนักงานรวม (กิโลกรัม)	2. กระดาษหนังสือพิมพ์รวม (กิโลกรัม)	3.กล่องกระดาษ (กิโลกรัม)	4. กระดาษอื่นๆ (กิโลกรัม)	กระดาษรวม (กิโลกรัม)	5. แก้ว			แก้วรวม (กิโลกรัม)
	1.1กระดาษแข็ง (กิโลกรัม)	1.2กระดาษสี (กิโลกรัม)	1.3กระดาษขาวดำ (กิโลกรัม)						5.1แก้วใส (กิโลกรัม)	5.2แก้วแดง (กิโลกรัม)	5.3แก้วเขียว (กิโลกรัม)	
1 นาย ก		0.80		0.80		5	0.00	5.80	6.00		0.00	6.00
2 นาย ข		1.00		1.00			0.00	1.00		5.30	0.00	5.30
3 นาย ค		3.50		3.50		4	0.00	7.50		16.00	0.00	16.00
4 นาย ง	6.00	0.50		6.50		2	0.00	8.50		6.20	0.00	6.20
5 นาย จ		6.00		6.00			0.00	6.00		8.00	0.00	8.00

Figure4. 14 A Sheet for Recording the Numbers of each Waste Recycling from each Member so-called *Recycling Waste Activity List from Members* Sheet of the *Carbon Accounting*

The following section explains how the developed program functions and implements. The steps for using the carbon accounting are as follow:

1. *The Annual Avoided* Sheet: fill the amounts of waste generation per year in the Phangkhon Municipal District in the box of Dispose by Landfill in S1 as shown in Figure 4.15.

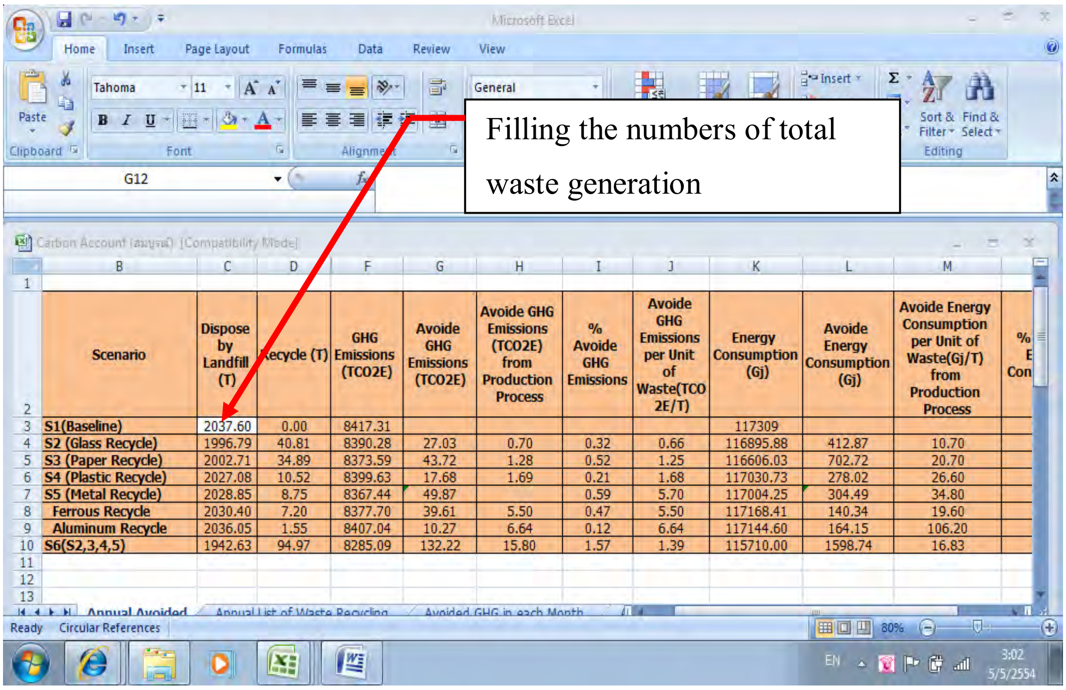


Figure4. 15 *The Annual Avoided* Sheet Filling Waste Generations Capacity from the Community

2. *The Annual List of Waste Recycling* Sheet: fill name of month and year in each box as shown in Figure 4.16 that the user must filling the name of each month and year similar to filling the name of each sheet in *Recycling Waste Activity List from Member*.

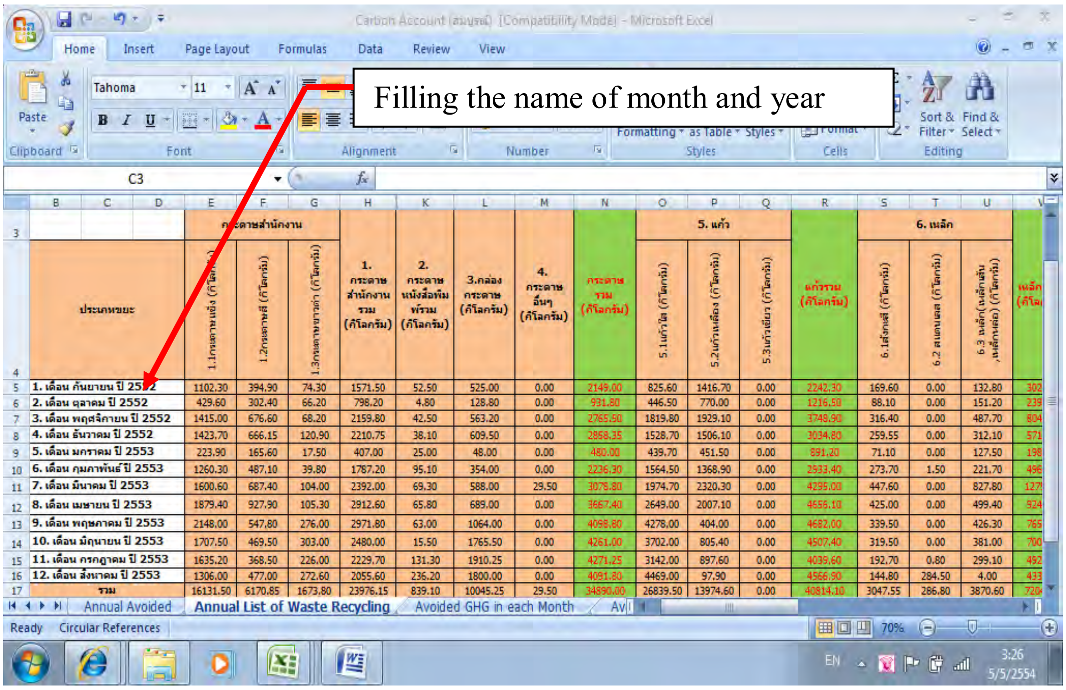
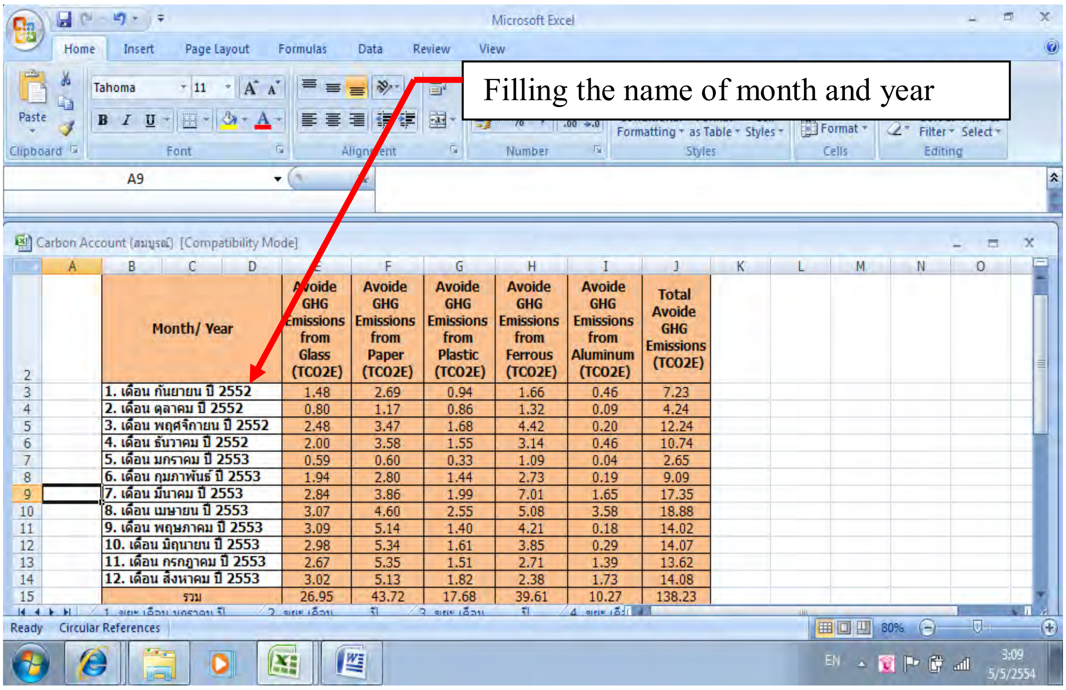


Figure4. 16 *The Annual List of Waste Recycling* Filling Name of Month and Year from the Community

3. *The Avoided GHG in each month and Avoided Energy Consumption in each month* Sheet:

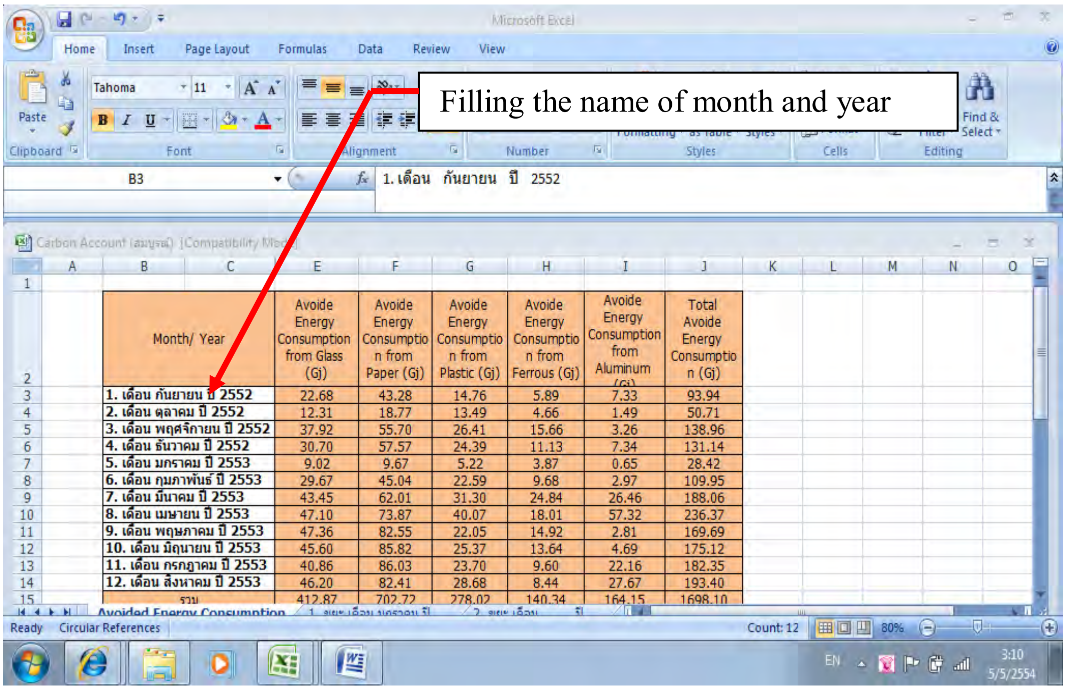
3.1 *The Avoided GHG* Sheet: fill name of month and year in each box as shown in Figure 4.17 that the user must filling the name of each month and year similar to filling the name of each sheet in *Recycling Waste Activity List from Member*.



Month/ Year	Avoide GHG Emissions from Glass (TCO2E)	Avoide GHG Emissions from Paper (TCO2E)	Avoide GHG Emissions from Plastic (TCO2E)	Avoide GHG Emissions from Ferrous (TCO2E)	Avoide GHG Emissions from Aluminum (TCO2E)	Total Avoide GHG Emissions (TCO2E)
1. เดือน กันยายน ปี 2552	1.48	2.69	0.94	1.66	0.46	7.23
2. เดือน ตุลาคม ปี 2552	0.80	1.17	0.86	1.32	0.09	4.24
3. เดือน พฤศจิกายน ปี 2552	2.48	3.47	1.68	4.42	0.20	12.24
4. เดือน ธันวาคม ปี 2552	2.00	3.58	1.55	3.14	0.46	10.74
5. เดือน มกราคม ปี 2553	0.59	0.60	0.33	1.09	0.04	2.65
6. เดือน กุมภาพันธ์ ปี 2553	1.94	2.80	1.44	2.73	0.19	9.09
7. เดือน มีนาคม ปี 2553	2.84	3.86	1.99	7.01	1.65	17.35
8. เดือน เมษายน ปี 2553	3.07	4.60	2.55	5.08	3.58	18.88
9. เดือน พฤษภาคม ปี 2553	3.09	5.14	1.40	4.21	0.18	14.02
10. เดือน มิถุนายน ปี 2553	2.98	5.34	1.61	3.85	0.29	14.07
11. เดือน กรกฎาคม ปี 2553	2.67	5.35	1.51	2.71	1.39	13.62
12. เดือน สิงหาคม ปี 2553	3.02	5.13	1.82	2.38	1.73	14.08
รวม	26.95	43.72	17.68	39.61	10.27	138.23

Figure4. 17 *The Avoided GHG in each Month* Filling Name of Month and Year from the Community

3.2 *The Avoided Energy Consumption* Sheet: fill name of month and year in each box as shown in Figure 4.18 that the user must filling the name of each month and year similar to filling the name of each sheet in *Recycling Waste Activity List from Member*.



Month/ Year	Avoide Energy Consumption from Glass (Gj)	Avoide Energy Consumption from Paper (Gj)	Avoide Energy Consumption from Plastic (Gj)	Avoide Energy Consumption from Ferrous (Gj)	Avoide Energy Consumption from Aluminum (Gj)	Total Avoide Energy Consumption (Gj)
1. เดือน กันยายน ปี 2552	22.68	43.28	14.76	5.89	7.33	93.94
2. เดือน ตุลาคม ปี 2552	12.31	18.77	13.49	4.66	1.49	50.71
3. เดือน พฤศจิกายน ปี 2552	37.92	55.70	26.41	15.66	3.26	138.96
4. เดือน ธันวาคม ปี 2552	30.70	57.57	24.39	11.13	7.34	131.14
5. เดือน มกราคม ปี 2553	9.02	9.67	5.22	3.87	0.65	28.42
6. เดือน กุมภาพันธ์ ปี 2553	29.67	45.04	22.59	9.68	2.97	109.95
7. เดือน มีนาคม ปี 2553	43.45	62.01	31.30	24.84	26.46	188.06
8. เดือน เมษายน ปี 2553	47.10	73.87	40.07	18.01	57.32	236.37
9. เดือน พฤษภาคม ปี 2553	47.36	82.55	22.05	14.92	2.81	169.69
10. เดือน มิถุนายน ปี 2553	45.60	85.82	25.37	13.64	4.69	175.12
11. เดือน กรกฎาคม ปี 2553	40.86	86.03	23.70	9.60	22.16	182.35
12. เดือน สิงหาคม ปี 2553	46.20	82.41	28.68	8.44	27.67	193.40
รวม	412.87	702.72	278.02	140.34	164.15	1698.10

Figure4. 18 *The Avoided Energy Consumption* Filling Name of Month and Year from the Community

4 *Recycling Waste Activity List from Member* Sheets: fill name of month and year for rename each sheet. To record for the community account, a user fills name of members and numbers of waste recycling from each member as shown in Figure 4.19 then to repeat this step of each month in each sheet.

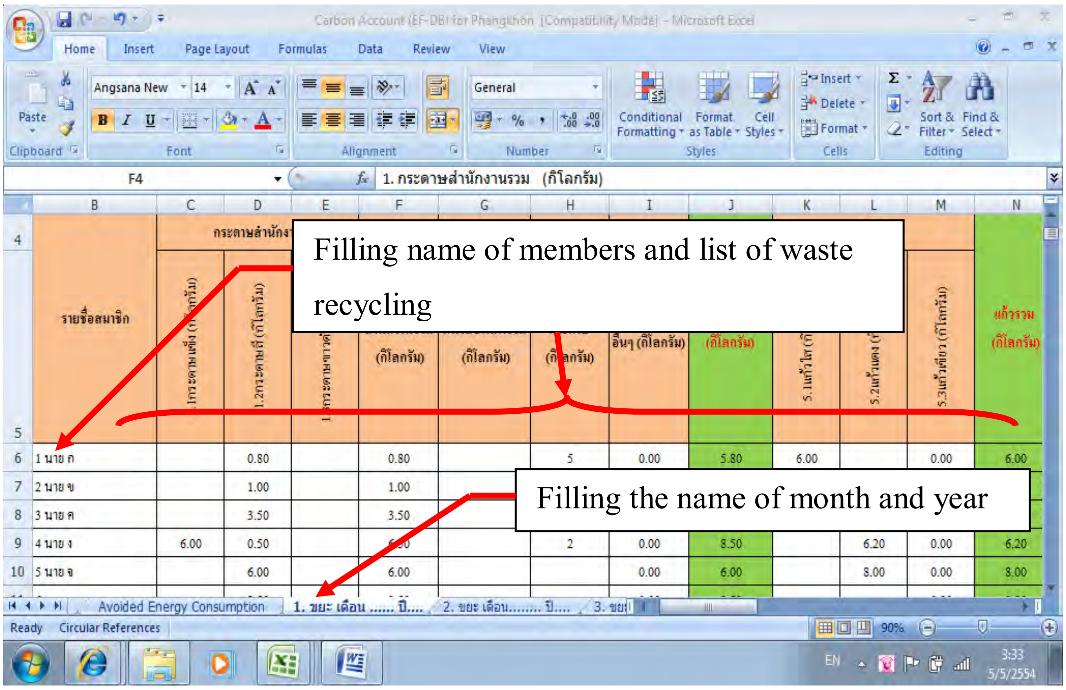


Figure4. 19 *The Recycling Waste Activity List from Members* Sheet of the Carbon Accounting Filling the Name of Month and Year and List of Members and Recycling Capacity

After filling in the waste information (types and amounts) for each member, the amount of total waste recycling from the community will be summarized in *The Annual List of Waste Recycling* Sheet. The capacity of every waste recycling of every month will be calculated and displayed in *The Annual List of Waste Recycling* Sheet. When the user fill the number of total waste generation, the GHG emission, GHG avoided, energy consumption, and energy avoided are analyzed and showed in *The Annual Avoided Calculation* Sheet.

Secondly, the avoided of GHG and energy consumption must be calculated and shown in *The Avoided GHG in each Month Sheet* and The *Avoided Energy Consumption in each Month* Sheet. Finally, the avoided numbers of GHG and energy consumption must be calculated and divided to *The Recycling Waste Activity List from Members* Sheet and the numbers must be calculated for coming out the avoided potential of each member as shown in Figure 4.20.

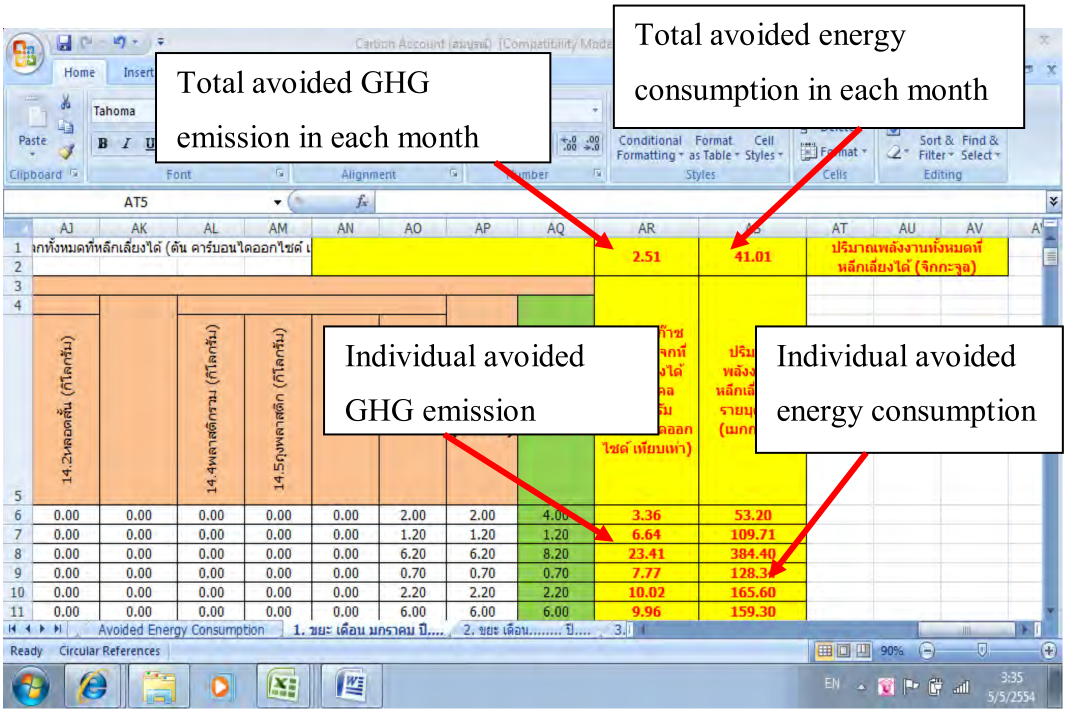


Figure4. 20 The Avoided Potential of each Member Shows in each of *The Recycling Waste Activity List from Members* Sheet of the *Carbon Accounting*

4.4.1.4 Output Data

After filling in all necessary information, the program will automatically estimate the avoided emission from the activities of each member. The account program estimate, record, and display the numbers of waste recycling, GHG emission, GHG avoided, energy consumption, and energy avoided from the waste recycling activity of the community. By using the account program, the outputs from the program are as following:

1. Total Waste Recycling of the Community
2. Amounts of Annual GHG Emission from Waste Management Activity in the Community
3. Amounts of Annual Energy Consumption from Waste Management Activity in the Community
4. Amounts of Annual Avoided GHG
   4.1 from Total Waste Recycling Campaign
   4.2 from each Category of Waste Recycling Campaign

5. Amounts of Annual Avoided Energy Consumption
    5.1 from Waste Recycling Campaign
    5.2 from each Category of Waste Recycling Campaign
6. Amounts of Avoided GHG per Month
    6.1 from Total Waste Recycling Campaign in each Month
    6.2 from each Category of Waste Recycling Campaign in each Month
7. Amounts of Avoided Energy Consumption per Month
    7.1 from Waste Recycling Campaign in each Month
    7.2 from each Category of Waste Recycling Campaign in each Month
8. Amounts of Individual Avoided GHG of each Member
9. Amounts of Individual Avoided Energy Consumption in each Month

4.4.2 Waste Selling Account

4.4.2.1 The Purpose of Developing Waste Selling Account

This is the second part of the model that developed to help report the balance of sale account of recyclable waste activity. The account program will record the amounts of waste recycle, calculate costs of the recyclable waste and report the money balance in each account which this account is so-called *Waste Selling Account*. This account helps the local government officials keep track and calculate revenues for members who sell their wastes to the community garbage bank.

4.4.2.2 Input Data

To estimate and record the members' incomes from waste recycling activity in Phangkhon, inputs used in the Waste Selling Account are as following:

1. Name of Members for Record their Recycling Activity
2. Amounts of Recycling Waste in each Category
3. Cost of each Waste Recycling
4. Month and Year that needs to record in each sheet

4.4.2.3 Instruction of the Developing Waste Selling AccountA user can click a link-tab (which is created on the upper left of each sheet) in *The Recycling Waste Activity List from Member* Sheet from the Carbon Accounting to go to the Waste Selling Account as shown in Figure 4.21.

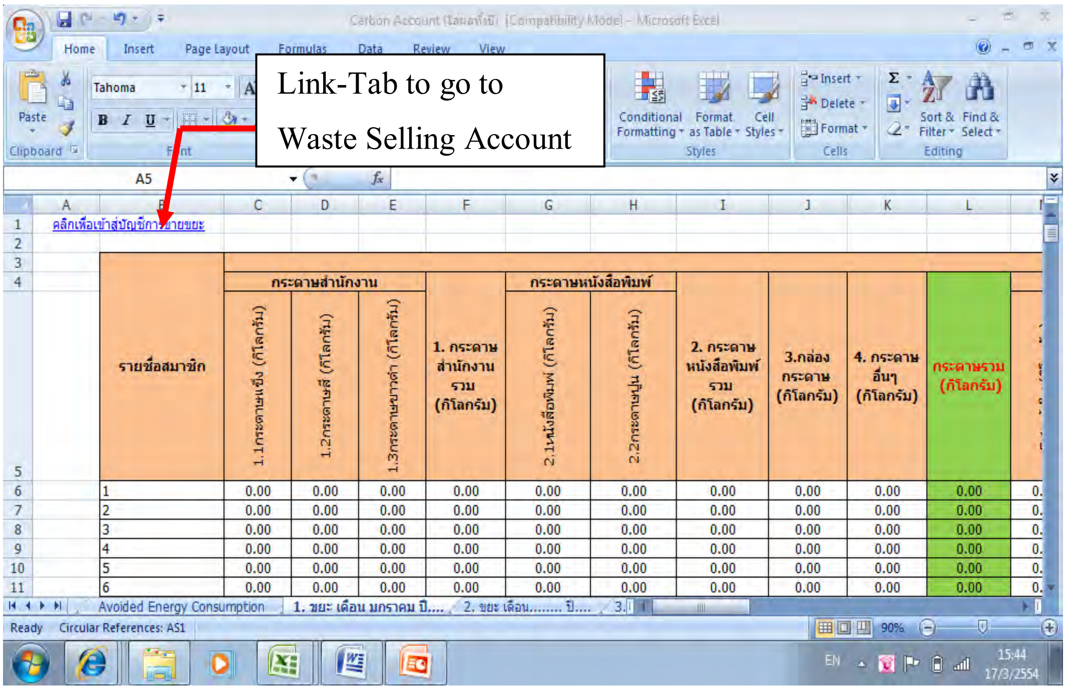


Figure4. 21 Link-Tab in *The Recycling Waste Activity List from Member* Sheet from the Carbon Accounting to go to *Waste Selling Account*

The Waste Selling Account comprises of 2 parts (1) a part for filling cost of each waste recycling, and (2) a part for recording waste recycling activity from each member. Firstly, a part for filling cost of each waste recycling in each month which this sheet is so-called *The Cost of Waste* Sheet as shown in Figure 4.22. Secondly, a part for recording waste recycling activity from each member consists of 12 sheets that use for 12 months. The user must rename each sheet to match with the month and year of the existing data. To record for the community account, a user fills name of members and numbers of waste recycling from each member. These sheets are so-called *The Recycling Waste Activity List from Members* Sheets as shown in Figure 4.23.

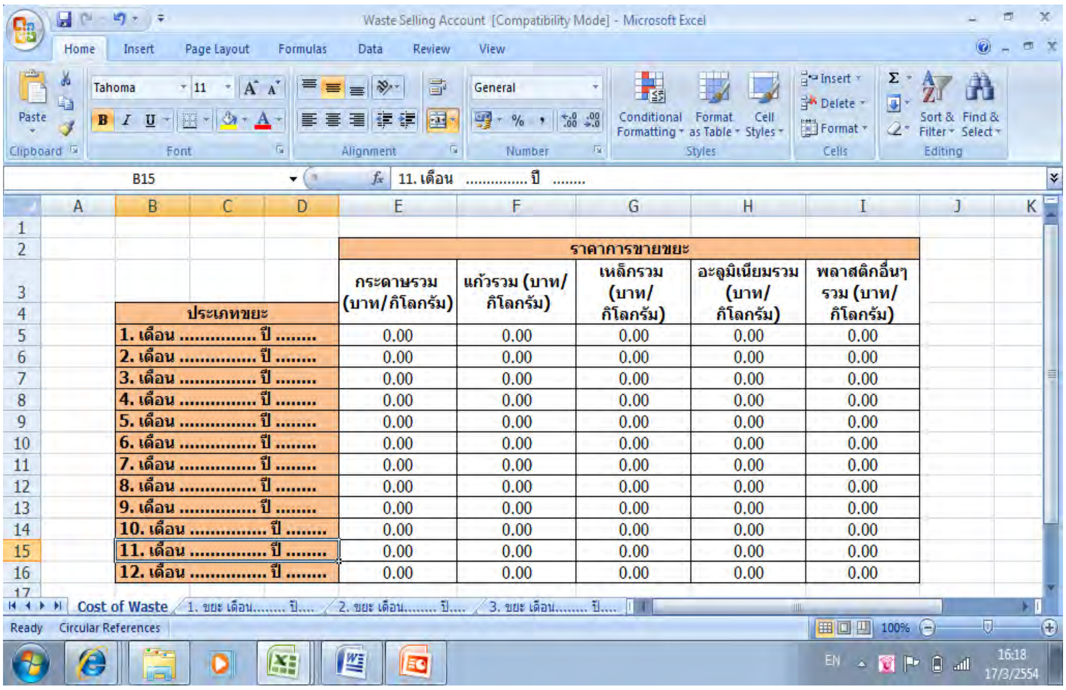


Figure4. 22 *The Cost of Waste* Sheet in *Waste Selling Account*

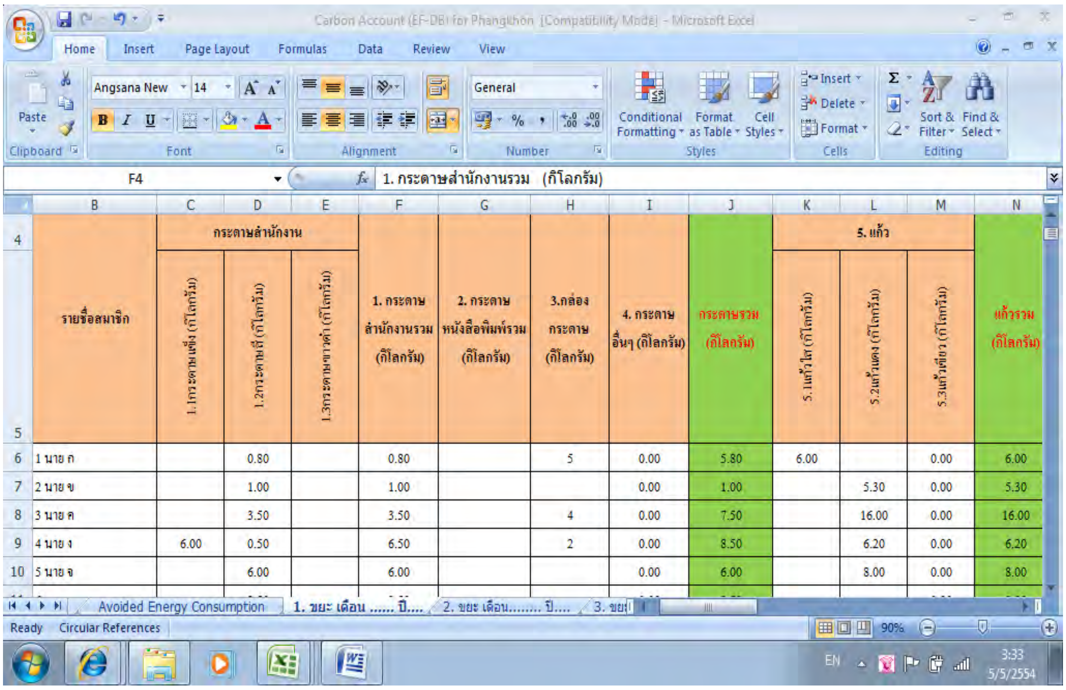


Figure4. 23 *The Recycling Waste Activity List from Members* Sheet in *Waste Selling Account*

The following section explains how the developed program functions and implements. The steps for using the carbon accounting are as follow:

1. *The Cost of Waste* Sheet:

   1.1 Fill name of month and year in each box that the user must fill the name of each month and year as shown in Figure 4.24.

   1.2 Fill cost of recyclable waste from sale as shown in Figure 4.24.

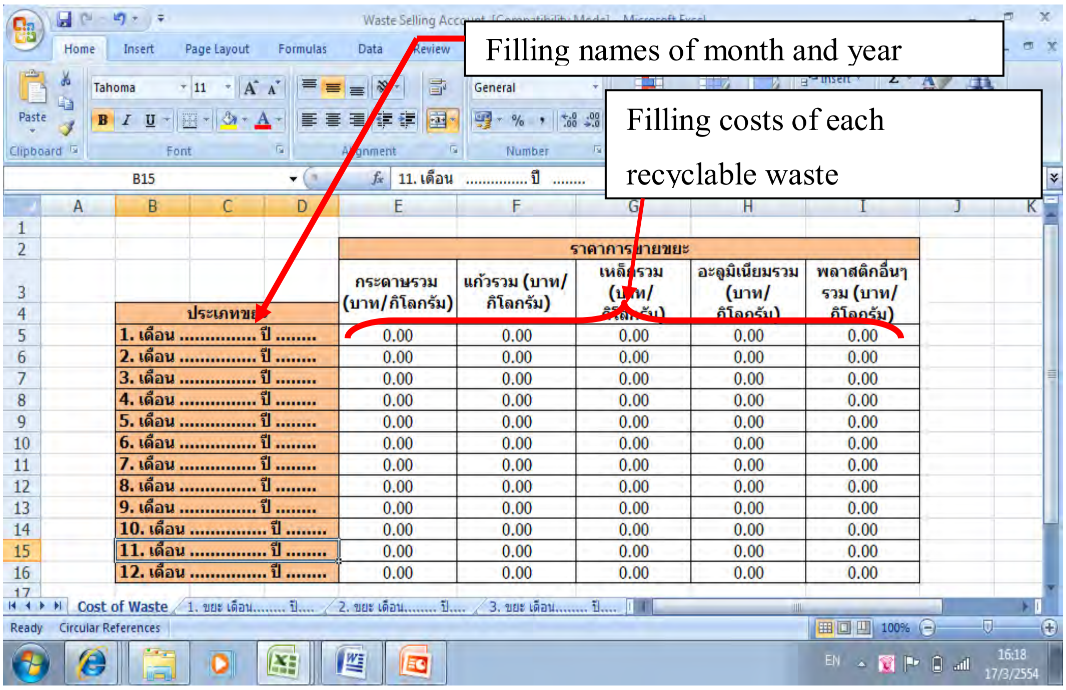


Figure4. 24 *The Cost of Waste Sheet* Filling Names of Month, Year, and Cost of each Recyclable waste

2. *The Recycling Waste Activity List from Members* Sheet: fill name of month and year for rename each sheet. To record for the community account, a user fills name of members and numbers of waste recycling from each member then repeat this step for each month in each sheet as shown in Figure 4.25.

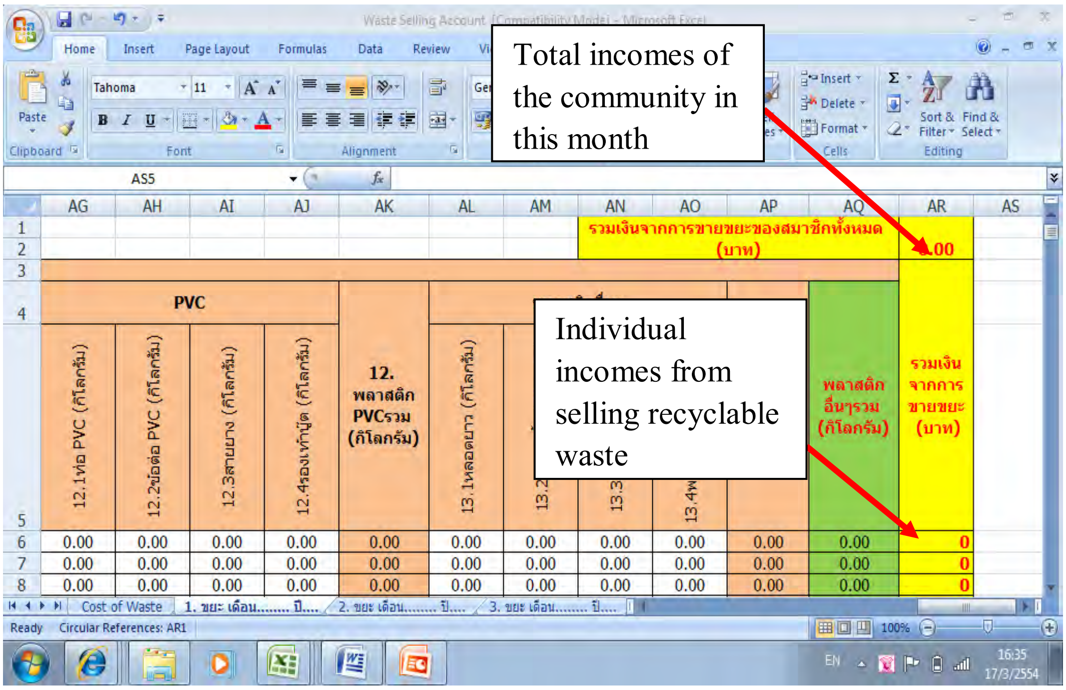


Figure4. 25 *The Recycling Waste Activity List from Members* Sheet in *Waste Selling Account*

4.4.2.4 Output Data

This accounting will estimate, record, and display the numbers of waste recycling and revenues from selling recyclable waste from the waste recycling activity of the community. By using the accounting program, the output data from the program is as following:

1. Total Revenues from Waste Recycling of the Community
2. Individual Revenues from Selling the Waste Recycling

This developed program will support the local government official and researchers to plan strategies or provide recommendation for increase efficiency of waste recycling campaign in this activity. Moreover, lesson-learned from the successful of waste banking system in this community could demonstrate to other community for the waste banking implementation. In addition, the carbon banking via the waste banking can be implemented.

4.5 Community Survey

This part of the study aims to identify factors impacting social behavior in recycling and interests of carbon bank mitigation by conducting a survey with questionnaire and interview. The results from this survey provide ideas from the community for recommendation for improving efficiency of community waste bank.

To survey and communicate local people in Phangkhon Municipal District about the recycling activity and community carbon account, a meeting for public communication in this community is set up. Many people especially leaders of district and sub-district of the community are interested in the recycling campaign and carbon banking mitigation as shown in Figure 4.26. According to citizens and leaders of Phangkhon realize the benefits from the recycling activity, they are interested in the meeting to educate and survey their citizens' opinion.

This study uses survey questionnaires to ask sampling citizens of the community (118 persons) about waste recycling activity, waste banking, and carbon banking which are divided to 4 parts with total of 11 questions. Each part aims to examine specific issues. The first part examined characteristics of the sampling group. The second part studied level of public participation and factors impacting recycle rate in the waste recycling campaign. The third part investigated factors for promoting carbon banking. The forth part investigated opinions from the community to identify recommendation for improving waste bank operation from the community. The detail of the questionnaire is summarized in the Appendix E and Appendix F (in Thai).

The results from the survey can provide information to set up strategies for Phangkhon Municipal District or other communities to improve efficiency of waste recycling, community waste bank, and potentially initiate carbon banking via the waste bank in communities in the future. The result analysis and discussion from questionnaire survey is as following.

Figure4. 26 Public Communication about the Recycling Activity and Community Carbon Account

4.5.1 <u>The Characteristics of the Sampling Group (Citizens in Phangkhon District)</u>

The questionnaires were distributed to 10 sub-districts with the 118 total collected questionnaires. From the survey, the characteristics of the sampling group in Phangkhon Municipal District are summarized in Table 4.2.

Table4. 2 Characteristics of the Sampling Group in Phangkhon Municipal District

Characteristics	**%(persons)**
Gender	
Male	34.75 % (41 persons)
Female	65.25 % (77 persons)

Table4. 2 Characteristics of the Sampling Group in Phangkhon Municipal District

Characteristics	%(persons)
Age	
younger than 20 years	2.54 % (3 persons)
20-30 years	16.95 % (20 persons)
30-40 years	9.32 % (11 persons)
40-50 years	26.27 % (31 persons)
50-60 years	22.03 % (26 persons)
more than 60 years	22.88 % (27 persons)
Education	
Primary School	40.68 % (48 persons)
Secondary School	25.42 % (30 persons)
Bachelor	11.86 % (14 persons)
Higher than Bachelor	4.24 % (5 persons)
N/A	17.80 % (21 persons)
Status in the Community Waste Bank	
Member	75.42 % (89 persons)
Non-Member	24.58 (29 persons)

4.5.2 Level of Public Participation and Factors Impacting Recycle Rate

To identify which factors have the most impact to participation rate, the research reviewed factors that could encourage citizens to recycle their waste and incorporate into the questionnaires.

For result analysis, to differentiate impact on rate of recycle from with and without the waste bank, the questionnaire is divided into 2 groups based on whether they are member of the waste bank or not. Percentage of members of the waste bank is 75.42% (89 persons) and Percentage of non-member of the waste bank is 24.68% (29 persons). As mentioned, the analysis will separate between member and non-member group.

4.5.2.1 Members of the Waste Bank Group

This section examined opinions about factors impacting their waste recycling activity from sampling group who are member of waste bank. Results are summarized in Table 4.3.

The most affecting factor to public participation is public awareness (44.99 %). Citizens of Phangkhon realize the recycling activity could help their community to reduce capacity of waste generation and their community's area is cleaner. The 2nd factor for the participation is financial incentive (22.51 %) which the citizens recycle their waste because they get revenues from waste sale. The 3rd factor is public education (16.90 %) helping the citizens to have better understand and become interested in the recycle campaign via the community waste bank. The 4th factors is social influence (9.03 %) which the citizens interested in sorting and recycling wastes because neighbor convince them to join in the recycling campaign. The 5th factor is command and control (6.57 %) where the local sets rule/order for citizens to sort and recycle their waste.

Table4. 3 Factors Impacting Rate of Recycling from Member Group in Waste Recycling Activity of Phangkhon Municipal District

Factor	% Impact
Public Awareness (to reduce waste generation capacity and help the community)	44.99
Financial Incentive (to get revenues from recyclable waste sale)	22.51
Public Education (to participate in recycling campaign of the community)	16.9
Social Influence (via neighbors) (to convince from neighbors being a part of the activity)	9.03

Table4. 3 Factors Impacting Rate of Recycling from Member Group in Waste Recycling Activity of Phangkhon Municipal District

Factor	% Impact
Command and Control (to set a rule/order to sort and recycling waste in community)	6.57

From the survey result analysis, citizen's interests in recycling each type of waste are showed in Table 4.4.

Table4. 4 Citizen of Member Group Interested in Recycling each Type of Waste in Waste Bank of Phangkhon Municipal District

Type of Waste	% Impact
Plastic	39.33
Paper	28.09
Glass	20.22
Metal (i.e. ferrous and aluminum)	6.74
Food waste	5.62

Citizens in Phangkhon are familiar with method to recycle plastic waste and they recycle plastic at the most frequency and highest quantity (39.33 %) from their recycling activity. The 2^{nd}, 3^{rd}, 4^{th}, and 5^{th} rank are paper (28.09 %), glass (20.22 %), metal (ferrous and aluminum) (6.74 %), and food waste (5.62 %), respectively.

By comparing data between (a) potential efficiency of each type of waste to bring to recycle and (b) survey result that citizens' practice/trend in actual recycle, the outcome turned out to be in different direction. From the waste recycling activity of the community (result calculation from part 4.2), the 1^{st}, 2^{nd}, 3^{rd}, 4^{th}, and 5^{th} ranked of recycling efficiency are glass (94.46 %), ferrous (49.08 %), paper (30.25 %), aluminum (10.57 %), and plastic (3.12 %), respectively, while the actual practice of citizens are as result in Table 4.4. There are gaps for improving efficiency of certain type of recycled waste that present in high potential.

To identify reasons for successfully recycling wastes, the survey asked opinions of citizens which factors they consider to have the most impact to recycle behavior. Table 4.5 showed the results from the questionnaire survey.

Table4. 5 Reasons Impacting Citizens' Decision to Recycle Waste (Members) in Phangkhon Municipal District

Reasons	**% Impact**
There are high capacities of those wastes generation.	43.82
Those wastes are easy for sorting.	41.57
Those wastes have the high value for sale.	8.99
Somebody suggest sorting, recycling, and selling those wastes.	5.62

The most impact factor is high rate of waste generation (43.82 %). High capacities of waste generation might lead the citizens to recycle more wastes. The 2nd, 3rd, and 4th impacting factors are that the wastes are easy to sort (41.57 %), the wastes have high value (8.99 %), and there is a suggestion/guideline to recycle those wastes (5.62 %). According to 1st and 2nd ranked factor, it implied that rate of recycling from citizen much depends on quantity of waste generation, convenience and simple to sort and recycling. On the other hand, financial incentive and education are not a key factor.

4.5.2.2 Non-Members of the Waste Bank Group

The result analyses from the citizens who are not a member of the waste bank are summarized in Table4.6.

Table4. 6 Factors Impacting Rate of Recycling from Non-Member Group in Waste Recycling Activity of Phangkhon Municipal District

Factor	% Impact
Financial Incentive (to get revenues from recyclable waste sale)	37.93
Public Awareness (to reduce waste generation and help the community cleaning)	20.69
Public Education (to participate in recycling campaign of the community)	17.24
Command and Control (to set a rule/order to sort and recycling waste in community)	13.79
Social Influence (via neighbors) (to convince from neighbors being a part of the activity)	10.34

The most impacting factor of this group to participate in the recycling campaign is financial incentive (37.93 %). The citizens prefer to get revenues from waste sale. The 2nd factor for participation is public awareness (20.69 %). They understand that it is their responsibility to help recycling waste, which could help their community to reduce amount of waste generation and make their community's area cleaner. The 3rd factor is public education (17.24 %) to inform citizens about recycle campaign via the community waste bank. The 4th factor is having a command and control approach by the local regulations ordered them to sort and recycle their waste (13.79). The 5th factors is social influence (10.34 %) which the citizens interested in sorting and recycling wastes because neighbor convince them to join in the recycling campaign.

From the survey result analysis, non-member citizen's interests in recycling each type of waste are showed in Table 4.7.

Table4. 7 Citizen of Non-Member Group in Waste Bank Interested in Recycling each Type of Waste in Phangkhon Municipal District

Type of Waste	% Impact
Plastic	41.38
Paper	37.93
Glass	17.24
Food waste	3.45
Metal (i.e. ferrous and aluminum)	0.00

Citizens of the non-member group in Phangkhon are familiar and think plastic has the highest capacity (41.38 %) from their recycling activity. The 2nd and 3rd ranks are paper (37.93 %) and glass (17.24 %). But the 4th and 5th ranks are metal (ferrous and aluminum) (3.44 %) and food waste (0 %).

When the review of interested in waste recycling from each category is compared with the efficiency of waste recycling from each category of waste, ranked from the review is difference from the efficiency of each waste recycling from their activity.

By comparing data between (a) potential efficiency of each type of waste to bring to recycle and (b) survey result that citizens' practice/trend in actual recycle, the outcome turned out to be in different direction. From the waste recycling activity of the community (result calculation from part 2), the 1st, 2nd, 3rd, 4th, and 5th ranked of recycling efficiency are glass (94.46 %), ferrous (49.08 %), paper (30.25 %), aluminum (10.57 %), and plastic (3.12 %), respectively, while the actual practice of citizens (non-member group) are as result in Table 4.7. There are gaps for improving efficiency of certain type of recycled waste that present in high potential.

To identify reasons for recycling wastes in non-member group, the survey asked opinions of citizens from non-member group which factors they believe to have the most impact. Table 4.8 showed the results from the questionnaire survey.

Table4. 8 Reasons Impacting Citizens' Decision to Recycle Waste (Non-Members) in Phangkhon Municipal District

Reason	% Impact
Those wastes are easy for sorting.	82.76
There are high capacities of those wastes generation.	13.79
Those wastes have the high value for sale.	3.45
Somebody suggest sorting, recycling, and selling those wastes.	0.00

The most impact factor is easy to sort (82.76 %). Convenience and simply for sorting and recycling of wastes might lead the citizens from non-member group to recycle more wastes.

The 2^{nd}, 3^{rd}, and 4^{th} impacting factors are those the wastes are high capacities of the waste generation (13.79 %), the wastes have high value (3.45 %), and there is a suggestion to recycle those wastes (0 %). According to 1^{st} and 2^{nd} ranked facto, it implied that rate of recycling from citizen much depends on convenience and simple to sort and recycling. On the other hand, financial incentive and education might be not as a priority.

4.5.2.3 Comparing Analysis between Members and Non-Member Groups

By comparing factors for participation in waste recycling activity between members and non-members (as summarized in Table 4.9), the two groups have different trends of factors affecting their interests of participation.

Table4. 9 Comparison of Factors Impacting Rate of Recycling Between Member Group and Non-Member Group in Waste Bank of Phangkhon Municipal District

Member Group		**Non-Member Group**	
Factors	**% Impact**	**Factors**	**% Impact**
Public Awareness	44.99	Financial Incentive	37.93

Table4. 9 Comparison of Factors Impacting Rate of Recycling Between Member Group and Non-Member Group in Waste Bank of Phangkhon Municipal District

Member Group		**Non-Member Group**	
Factors	**% Impact**	**Factors**	**% Impact**
Financial Incentive	22.51	Public Awareness	20.69
Public Education	16.9	Public Education	17.24
Social Influence	9.03	Command and Control	13.79
Command and Control	6.57	Social Influence	10.34

The most impacting factor for the members is public awareness while the most impacting factor for the non-members is financial incentive. The 2^{nd} rank factor for members is financial incentive but the 2^{nd} rank factor for the non-members is public awareness. The 3^{rd} factor for the members and non-members is public education. The 4^{th} factor for the members is social influence (via neighbor) but the 4^{th} factor for the non-member is command and control. The 5^{th} factor for the members is command and control but the 5^{th} factor for the non-members is social influence (via neighbor).

In conclusion from all factors impacting rate of participation in recycling wastes, two most important factors are public awareness and financial incentive.

The moral incentive could be provided by the government officers (local and central) and neighbors. Moreover, for the children the moral may teach from school and their parents. For the revenues, the community waste bank could provide revenues based on market prices.

Table 4.10 shows comparison of interested in recycling each type of waste between member group and non-member group of Phangkhon Municipal District.

Table4. 10 Comparison of Interested in Recycling each Type of Waste between Member Group and Non-Member Group in Waste Bank of Phangkhon Municipal District

Member Group		Non-Member Group	
Type of Waste	**% Impact**	**Type of Waste**	**% Impact**
Plastic	39.33	Plastic	41.38
Paper	28.09	Paper	37.93
Glass	20.22	Glass	17.24
Metal (i.e. ferrous and aluminum)	6.74	Food Waste	3.45
Food Waste	5.62	Metal (i.e. ferrous and aluminum)	0.00

The 2 groups have similar trends of interested in recycling each type exceptional interested in metal recycled. Non-members are not interested in recycling metal waste although the metal recycled has high value for sale.

The waste bank will help non-members know metal has high value and the further carbon bank via the waste bank could provide benefits from environmental aspect to them. According to these benefits, the waste bank could convince non-member being a member of the waste bank. Increasing of members will lead Phangkhon increase efficiency of recycling waste in the community. As increasing efficiency of waste recycling, potential of avoided GHG emission and avoided energy consumption will be increased.

Table 4.11 is comparison of reasons impacting citizens' decision to recycle waste between member group and non-member group on the waste bank in Phangkhon Municipal District.

Table4. 11 Comparison of Reasons Impacting Citizens' Decision to Recycle Waste between Member Group and Non-Members in Waste Bank of Phangkhon Municipal District

Member Group		**Non-Member Group**	
Reasons	**% Impact**	**Reasons**	**% Impact**
There are high capacities of those wastes generation.	43.82	Those wastes are easy for sorting.	82.76
Those wastes are easy for sorting.	41.57	There are high capacities of those wastes generation.	13.79
Those wastes have the high value for sale.	8.99	Those wastes have the high value for sale.	3.45
Somebody suggest sorting, recycling, and selling those wastes.	5.62	Somebody suggest sorting, recycling, and selling those wastes.	0.00

By comparing result between members and non-members of the community garbage bank, the 2 groups will recycle the waste depending on how easy to sort and has high capacity of that waste generation. Especially the non-members group is very concerned in convenience for sorting and recycling. The waste bank provides an essential function to support and service citizens for waste recycling activity. Moreover, quality of service and transparency of waste bank system will encourage more people to participate in waste recycling activity.

Therefore, the waste bank or government has to provide more services or facilities for people to improve efficiency and rate of recycling.

4.5.3 Analysis Factors for Promoting Carbon Banking

This section analyzes the factors affecting public interests for reducing GHG emission via the waste recycling campaign. The indentified factors might support the initiative of carbon banking via the community garbage bank of the Phangkhon Municipal District. Again the analysis is divided into 2 groups between groups of member and non-member of the waste bank.

4.5.3.1 Members of the Waste Bank Group

This section examined understanding and interest from members of the community garbage bank whether citizens concern the global warming crisis and need to help reducing GHG emission by recycling wastes.

From the questionnaire survey, most of citizens (80.90 %) concern about global warming crisis and some of citizens (10.11 %) are not sure whether the global warming crisis has impact on them or not. As the members know a major cause of global warming crisis is GHG, they realize they (86.52 %) are producers of GHG. There are 77.52 % of them need to help reducing GHG emission.

Table 4.12 shows factors impacting members of the waste bank to reduce GHG emission in Phangkhon Municipal District.

Table4. 12 Factors Impacting Citizens of Member Group to Reduce GHG Emission in Phangkhon Municipal District

Factor	% Impact
This is a duty of everybody.	43.82
To realize the effects from global warming crisis.	23.60
The municipality official encourages citizens to be a part of the campaign.	13.48
Most of people in the community are a part of the campaign.	13.48
The central government supports this campaign by knowledge, budget, service, etc.	4.49
This idea is promoted by news or advertisements.	1.12

Most of citizens (43.82%) believe to reduce GHG emission from their activity is a duty. Self-conscious of citizens is a main reason for reducing GHG emission from their activity. Other reasons for reducing GHG emission from the citizens are that they already realized effects from global warming crisis (23.60 %), participation in community's activity (13.48 %), being a member of group in the community (13.48

%), supporting from the central government (4.49 %) and effect from encouragement via advertisement (1.12 %).

Self-conscious of citizens is a key factor to convince people for reducing GHG emission from their activity. Carbon banking developing from our research will show individual potentials for reducing GHG emission so this carbon bank could help increasing the citizens' responsibility.

To promote the carbon banking, the questionnaire asked how much knowledge they have on carbon banking. The results found that most of citizens (71.91 %) realize there is a relation between recycling waste and GHG emission reduction. Their recycling activity could help reducing GHG emission. Results analysis about knowledge on carbon banking and carbon credit found that there are only 33.71 % know the carbon banking. Most of citizens (43.82 %) do not know any details the carbon banking. Similar to carbon banking, most of citizens (50.56 %) do not know much about carbon credit. There are only 23.60 % of citizens know the carbon credit.

Even though, citizens lack of knowledge about carbon banking and carbon credit. They are willing to recycle more wastes if it is able to help reduce GHG from their recycling activity. Therefore, if the carbon banking and knowledge about carbon credit are promoted to this community; the amounts of recycling waste might be increased.

4.5.3.2 Non-Members of the Waste Bank Group

This section examined understanding and interest from non-members of the community garbage bank whether citizens concern the global warming crisis and need to help reducing GHG emission by recycling wastes.

From the questionnaire survey, most of citizens (41.38 %) concern about global warming crisis and some of citizens (24.14%) are not sure whether they concern the global warming crisis or not. There are 34.48% of non-member group are not concern about the global warming crisis. As the non-members know a major cause of global warming crisis is GHG, they realize they (68.97 %) are producers of GHG. There are 48.28 % of them need to help reducing GHG emission.

Table 4.13 shows factors impacting non-members of the waste bank to reduce GHG emission in Phangkhon Municipal District.

Table4. 12 Factors Impacting Citizens of Non-Member Group to Reduce GHG Emission

Factor	% Impact
Most of people in the community are a part of the campaign.	24.14
This is a duty of everybody.	24.14
To realize the effects from global warming crisis.	20.69
The municipality official encourages citizens to be a part of the campaign.	20.69
The central government supports this campaign by knowledge, budget, service, etc.	10.34
Because this idea is promoted by news or advertisements.	0.00

There are 2 main reasons which citizens of non-member group believe to reduce GHG emission from their activity including being a member of group in the community (24.14 %) and this is a duty (24.14 %) as shown in Table 4.12. Thereby, group interested and self-conscious of citizens is main reasons for reducing GHG emission from their activity. Other reasons for reducing GHG emission from the citizens of non-member group are that they already realized effects from global warming crisis (20.69 %), participation in community's activity (20.69 %), supporting from the central government (10.34 %) and effect from encouragement via advertisement (0 %).

Group interested and self-conscious of citizens are keys factor to convince people for reducing GHG emission from their activity. Carbon banking developing from our research will show individual potentials for reducing GHG emission so this carbon bank could help increasing the citizens' responsibility and their responsibility from the recycling activity is promoted to convince more people to join in the campaign. Then the experience from non-member group will be a role model or convince other citizens, who are not yet a member, to be a member of the waste bank and the recycling activity.

From the analysis, most of citizens (37.93 %) who are non-member think their recycling activity could not help to reduce GHG emission. 31.03 % of the citizens are not sure whether their recycling activity could help to reduce GHG emission or not. There are only 31.03 % of citizens realize their recycling activity could help reducing GHG emission. Knowledge about carbon banking and carbon credit is limited in this group. There are only 17.24 % know the carbon banking. Most of citizens (48.28 %) do not know the carbon banking. Similar to carbon banking, most of citizens (51.72 %) do not know much about carbon credit. There are only 3.45 % of citizens know the carbon credit.

The result shows citizens lack of knowledge about carbon banking and carbon credit. They are willing to recycling their waste, although they do not yet realize their efforts in term of GHG avoided from their recycling activity.

According to the opinion of the non-member group, the percentage of concerned and unconcerned about global warming and reducing of GHG emission are quite similar. Public education on global warming, GHG from waste recycle and GHG reduction, carbon credit is needed.

4.5.3.3 Comparing Analysis between Members and Non-Member Groups

Table 4.14 shows comparison of citizens' knowledge about global warming crisis, GHG emission, carbon bank, and carbon credit between member group and non-member group in Phangkhon Municipal District.

Table4. 13 Comparison of Citizens' Knowledge About Global Warming Crisis, GHG Emission, Carbon Bank, and Carbon Credit between Member Group and Non-Member Group in Phangkhon Municipal District

Questioners	Member	Non-Member
1. Citizens concern about global warming crisis.	80.90%	41.38%
2. Citizens realize they are GHG producers.	86.52%	68.97%
3. Citizens need to help reducing GHG emission.	77.52%	48.28%
4. Citizens realize there are relation between recycling waste and GHG emission reduction.	71.91%	31.03%
5. Citizens know carbon bank.	33.71%	17.24%
6. Citizens know carbon credit.	23.60%	3.45%

The comparison shows member group has more knowledge about global warming crisis, GHG emission, carbon bank, and carbon credit than non-member group because the community waste bank could help people to know about situation and knowledge global warming crisis, GHG emission, carbon bank, and carbon credit. So the local government and the waste bank must convince nonmembers to be a member of waste bank for increasing effort of reducing GHG emission via a community carbon bank.

4.5.4 Opinion Identify Recommendation to Improve Waste Bank from the Community

4.5.4.1 Questionnaires for Surveying Citizens' Opinion

From the survey, this research provided 11 approaches to ask for preferences from member and non-member group to select, which the 3 approaches they want to have in order to improve recycling campaign of the waste bank. The 11 improvement approaches are:

1. Central government and local government provide financial incentive for recycling activity.

2. Rewards are provided for a member who sells the highest numbers of waste.

3. Recyclable waste has high price.

4. There are fines a person who do not recycle their waste.

5. There are regulations to order people to recycle their waste.

6. Government provides knowledge and information how to recycling waste.

7. The local government provides service for recycling and buys the recyclable waste.

8. There are welfares to encourage people for recycling their waste.

9. There is a trustable and transparency of waste banking system for managing the waste recycling activity.

10. The recycling campaign is widely promoted.

11. To realize the waste recycling activity could help the community to be an environmental friendly community.

4.5.4.2 Members of the Waste Bank Group

For members group of the waste bank, the results from the survey found that there are 3 major approaches that the community suggests to improve immediately. Firstly, the members (14.61 %) prefer to recycle their waste because the local government provides services for recycling and buys the recyclable waste from them. Secondly, the members (12.36 %) prefer to recycle their waste because of services and funeral welfare encouraging them to recycle their waste. Thirdly, the members (12.36 %) prefer to recycle their waste because the central government provides knowledge and information for supporting their recycling activity.

4.5.4.3 Non-Members of the Waste Bank Group

For non-members group of the waste bank, there are 3 major factors for encouragement them to participate in the waste recycling campaign and the community garbage bank. Firstly, the non-members (17.24 %) prefer to recycle their waste because the local government provides services for recycling and sale the recyclable waste. Secondly, the members (13.79 %) prefer to recycle their waste because there are services and welfare to encourage them to recycle their waste. Thirdly, the members (13.79 %) prefer to recycle their waste because the waste bank provides rewards for members who sell the highest amounts of recyclable waste to the waste bank.

4.5.4.4 Comparing Analysis between Members and Non-Members Group

The 3rd factor of member group and non-member group is different. To convince non-member to be a member might add more incentives especially financial incentive such as welfare and rewards. As the results from factors impacting of non-member participation for sorting and recycling waste, (which are mentioned in part 4.5.2.2 and 4.5.4.3), shows financial incentive is a key factor for recycling waste.

CHAPTER V

Recommendations for Improving the Community Garbage Bank

According to the results from the survey, being a member of the community garbage bank effects knowledge, public interest, and self-conscious about GHG and carbon bank. Increasing numbers of members of CGB and improving community garbage bank for increasing efficiency of waste recycling is a key strategy for setting up carbon banking system to enhance public awareness and better promote recyclable wastes for other communities.

The results in section 4.2 on waste generation and management efficiency show that Phangkhon has potential for increasing efficiency of waste recycling so the community garbage bank can be improved. Moreover, the results in section 4.3 shows that waste recycling activity has potential to help reducing GHG emission and energy consumption. Therefore, if CGB in this community is improved, the efficiency of recycling waste is increased; the community might get benefits from the avoided GHG emission from the carbon finance system.

From the results of the survey, the results shows public awareness, financial incentive, and quality of waste service are major keys for improving CGB and leading to implement carbon bank from recycling activity via the garbage bank. To improve potential of recycling activity in local communities not only in the case study but also in other communities, strategies for increasing efficiency of recycling waste via the community garbage bank are divided to 3 parts including (1) Strategies for Increasing Public Awareness and Public Education, (2) Strategies for Increasing Financial Incentive, and (3) Strategies for Increasing Services for Recycling Activity. The recommended strategies resulted from the study are as follow:

5.1 Strategies for Increasing Public Awareness and Public Education

Public awareness and education on proper waste management approach, impacts and benefits need to be increased. To increase public educations in these issues, this study recommends the following strategies:

1. Central government must provide common knowledge about 3Rs principal (Reduce, Reuse, Recycle) and widely promote concepts of Low Carbon Society (LCS). The LCS is still a new concept and unfamiliar for local people to recognize their roles and the direct benefits from managing waste meanwhile reducing GHG.

2. Central and local government must provide training programs and practical guidelines for sorting and recycling each category of waste for citizens and for local municipal officers to understand how to properly classifying and recycling each type of waste such as providing knowledge for categorization and recycling metal wastes which has the highest potential for avoided GHG emission and avoided energy consumption so training programs should display adding benefits from environmental friendly issue for convincing people to recycle more metal wastes.

3. Local governments, officers or operators of community waste bank must provide clear procedure and/or guidelines for sorting and recycling waste to their bank members.

4. Advertisement e.g. in form of brochures for explaining benefits from recycling waste and simplifying of recycling procedures could provide and distribute to widely local communities to help increase the public understanding.

5. Regular town hall meeting can help in being a platform for discussion and clarification of issues among citizens and local government officers on recycling practice.

6. According to the results in section 4.2 about waste generation and management efficiency, plastic wastes have the highest amounts of waste generation, knowledge on how to properly classify and recycle each type of plastic is urgently needed and should be more provided to people as often and as much as possible.

5.2 Strategies for Increasing Financial Incentive

In Thailand, local government has an authority to set up its own waste management system for the local community. Budgets for waste management are different in each local area depending on planning and policy priority. The difference of management system standard in each area might be an obstacle for widely improving effectiveness of waste management in Thailand. Thus, it is important to have initial budgets from central government and/or from some organizations to help convincing local governments and local communities to set up waste bank and carbon bank in their communities. The recommended strategies on these issues are following:

1. Since GHG mitigation is an important issue in the present. Thailand should measure the amount GHG emission reduction from recycling activity and develops a programmatic CDM project or a voluntary mitigation from waste sector, recycling activity in particular. The government should facilitate and support application for financial incentives from international organizations to promote more GHG reduction from waste recycle e.g. from the World Bank. The government should also expand this type of projects more widely throughout the country with the lesson learned from the successful set-up program.

2. For local government or community garbage bank, guarantee prices for member from setting the buying price lists of each waste recycling help increase financial incentive because it encourages people to participate in the waste bank. This guarantee price will ensure prices of each waste sale for members, instead of selling wastes to other collecting agents.

3. The bank operation budget should have initial budgets and plan for getting additional income from the bank operation to sustain the daily operation and future of the bank. In Phangkhon waste bank, regular local government staffs and volunteers help operating the bank. There are 2 sources of budgets to operate waste management system as follow:

   3.1 The income that the local government earns from revenues from waste management fee and waste recycling that the local sort and recycle wastes by volunteers or officers.

   3.2 The revenue comes from landfill entry fees that the local government collects the entrance fees (500 baht/month) from people who want to enter the landfill for scavenge wastes at the community landfill site.

4. The authorized parties should be invited to participate in verifying and validating the amount of avoided GHG emission from the community recycling activity. When the recycling activity via the waste bank is measurable, recordable and verifiable, the authorized parties accredit the activity. In the future, the community or any agency or central government should spend an effort on helping the community to

get accredited and selling their carbon credits to get actual financial benefits from the recycling activity.

5.3 Strategies for Increasing Services for Recycling Activity

To increase service, our study recommends the following strategies:

1. The bank could set up rubbish bins for each category of waste and distribute them to each household, depending on governmental budget. The government can also recommend how many bins the citizen should have to separate their wastes.
2. The government can set an operation rule and schedule to pick up certain type of wastes on a certain day. For example, pick up regular waste every Monday and Thursday, pick up recycle waste every Wednesday, and pick up hazardous waste every Friday. If the operating capacity is allowed, they can pick up each type of recycle waste on a separate day/trip.
3. To increasing efficiency of plastic recycled, which has the highest quantities of waste generation, service for plastic recycled activity must be increased. The waste bank might provide more containers only for plastic waste. The containers should have a proper label (easy to understand) and separate for each type of plastic waste. Moreover, the waste bank should pick up the plastic waste more frequently than other waste for encouraging people to increase the individual efficiency of recycling more plastic wastes.
4. The community waste bank of Phangkhon and other communities can use the carbon accounting model, which is developed by this study as a tool for recording the recycling activity and evaluate amount of GHG and energy reduction from the recycling activity. The account program will support activity of the waste bank and carbon bank for recording amounts of recycling waste, GHG avoided, energy avoided, and revenues for both individual and entire community.

CHAPTER VI
CONCLUSIONS

6.1 Conclusions

Phangkhon Municipal District area is chosen to be a case study for examining mechanism and impacts from waste bank and potential do develop carbon bank. Research outcomes can be summarized as following:

<u>6.1.1 Lesson Learned from Mechanism of Waste Banking System in Phangkhon Municipal District</u>

The study found that there are 5 key factors for the recycling program via the community waste bank to become successful (active participation and continuously operation) including;

1. Financial Incentives

The local government provides 2 types of financial incentives to increase rate of participation, including: (1) revenues to the members who recycle their waste and sell them at the bank (based on market price) and (2) welfare to support the members: if a member dies, he/she will receive financial support for his/her funeral for 5,000 baht/member. These benefits successfully stimulate the public participation rate to become members of the waste bank system in the case study.

2. Bank Operation Rules

To ensure citizens being a member of the waste bank continuously and actively recycle wastes, the bank agreement is proved to be a key factor to maintain the recycle rate. The rule is transparent and straightforward to citizen. The schedule of waste buying and price to buy is announced clearly. One of the influencing requirements is that citizens have to sell the waste to the bank for at least 6 months continuously to maintain their membership and ensure that they can receive a welfare benefits. If they cannot meet the requirement (sell the waste for less than 6 month), their membership will expire and they have to enter and start this rule all over again.

3. Awareness and Willingness of Local Officials and Citizens

Initiative and dedicated government planning and implementing the system is very important. Also public willingness to participate for the better welfare/environment of the community has proved to be significant elements for improving waste management in the local community. As evident in the case study, Phangkhon Municipal District, self-conscious of the citizens is a key factor for successfully recycling waste. The citizens are aware of their responsibility for social and the community as shown in the case study.

4. Increase Public Education in Properly Sorting and Dispose Wastes

To increase public awareness, participation rate and waste separation efficiency, the local government regularly educates people at the community meeting or at the collecting spots, and asks neighbors to help teaching each other and their family members how to properly sorting their wastes.

5. Provide Adequate Supports (Facility and Service) for the Members to Recycle their Wastes.

The local officials continuously service the members by picking up their recycle wastes from the drop-off local waste recycling center every two weeks. The main objective is to provide the convenience and more willingness to the customers who recycle wastes. This service is an important factor to encourage people to recycle their waste regularly.

6.1.2 Waste Management Efficiency & Improvement

Results from the analysis (part 4.2) found that glass has the highest percentage of recycling efficiency (94.46%) but the recycling efficiency of other wastes is still low (paper: 30.25%, plastic: 3.12%, ferrous: 49.08%, and aluminum: 10.57%). The results from the recycling activity of Phangkhon show there are still high potentials for increasing the efficiency of waste recycling activity. Especially, plastic, paper, and metal have a big gap between amounts of waste generation and amounts of waste recycling. The citizens recycle few amounts of plastic, paper, and metal wastes because the sorting process of plastic, paper, and metal are complicated and inconvenient. The waste bank should promote more on how to properly recycle and what its service is provided for the member to encourage them to recycle those wastes. Many citizens lack of skill to properly sort plastic, paper, and metal.

Therefore, public education on these issues is needed to increase efficiency of recycling plastic, paper, and metal.

6.1.3 A Model for Evaluating Avoided GHG Emission

This research evaluated avoided GHG emission and avoided energy consumption by using 3 models: Integrated Waste Management for Municipalities (IWM), Waste Reduction Model (WARM), and adapted model by using emission factors from Browne, O' Regan, and Moles (2009) (EF-DB). The results from 3 models assessment are varied mainly depending on different conditions and assumptions that each model is used.

According to the different characteristics and conditions of each model, this study decided to use the EF-DB as evaluating model and platform to develop carbon accounting from waste bank. EF-DB is simple for the local officer to use in the community garbage bank and carbon bank because it is based on excel program and all parameters can be easily adjusted and updated to the latest information and existing local factors. In the future, if local and national emission factors are available, this model will become more accurate for using widely in Thailand.

6.1.4 Reduction of GHG Emission and Energy Consumption from the Case Study

During 1-year period (2009-2010) of recycling activity of Phankhon Municipal District, the total amounts of waste recycling were approximately 95.80 Tons. Avoided GHG emission from the recycling estimated by IWM, WARM, and EF-DB are 1,159 Tons CO_2 eq, 272 Tons CO_2 eq, and 132 Tons CO_2 eq, respectively. The efficiency of avoided GHG emission (compared with GHG emission from baseline scenario) by IWM, WARM, and EF-DB are 12.17 %, 7.68 %, 1.57 %, respectively. Avoided energy consumption from the recycling estimated by IWM, WARM, and EF-DB are 10,736 GJ, 2,977 GJ, and 1,599 GJ, respectively. The efficiency of avoided energy consumption (compared with energy consumption from baseline scenario) by IWM, WARM, and EF-DB are 10.35 %, 176.99 %, and 1.36 %, respectively. Although the amounts of recycling waste were only 95.80 Tons, the recycling waste help reducing certain amounts of GHG emission and energy consumption, depending on the estimating models. If expanding into more communities and increasing recycling efforts, the proper waste management via recycling can potentially help reducing of GHG emission and energy consumption to certain extents.

6.1.5 Carbon Accounting System Development

This carbon account is developed to use together with the waste bank and carbon bank in the community. The carbon accounting tool is able estimate and record individual GHG emission reduction and energy consumption from their recycling activity. If recycling wastes from the bank can be recorded and evaluated for amount of GHG reduction, it will provide a good foundation for measuring voluntary efforts of GHG mitigation and applying for financial supports based on these efforts. MRV (Measurable, Recordable and Verifiable) principal is an important requirement for the CDM project or voluntary mitigation to provide information for measuring progress and better management on GHG mitigation.

6.1.6 Survey from the Citizens in Phangkhon Municipal District

According to the result of survey, main reason for recycling the waste between member and non-member group is different. The member group considers large quantity of waste lead them to recycle that waste more. On the other hand, the non-member group considers knowledge about the wastes and simplicity for sorting recycling that waste are key factors. So the local government and/or waste bank operator must provide more knowledge for the citizens especially people who are not member of the waste bank to increases efficiency of waste recycling.

For the major incentive impacting a rate of interest for recycling waste, the result showed that moral incentive is a major incentive for member group as they have willingness for recycling. However, financial is a major incentive for non-member group. Thus, to convince people who are non-member to become a member of the waste bank, the waste bank or local government should provide attractive financial incentives.

For the GHG mitigation and carbon bank project, the survey result showed that member group is interested in carbon bank and want to help reducing GHG emission. Being a member of waste bank leads people to understand more about the relationship between GHG emission reduction and recycling activity.

A major obstacle for implementing carbon bank via community waste bank is knowledge. Both of member and non-member group need more knowledge about carbon credit and carbon bank. Thus waste bank or local government must provide more information and knowledge for people or even to the officers e.g. by training as well.

From citizen' opinions to participate with the waste bank, the government should provide and maintain quality of service for waste collection. Citizens prefer to recycle their waste because the services to pick up recycling wastes and buy the recyclable waste from them. Also, the financial incentive in form of funeral welfare encourages citizen to participate in the waste bank and recycle their wastes. Moreover, the member group recommends the central government should provide more knowledge and information for supporting their recycling activity. The non-member group suggests that the waste bank should create campaign to provide rewards for members who sell the highest amounts of recyclable waste to the waste bank.

Other communities can adopt the lesson learned about community waste bank implementation from Phangkhon Municipal District to set up a new waste bank in their community or to improve their community waste bank. Survey of Phangkhon shows moral incentive, financial incentive, public education, and sufficient service are important factors for implementation of waste bank and carbon bank.

6.1.7 Strategies for Improving Community Waste Bank and Waste Recycling Activity

The recommended strategies for the system improvement are based on 3 incentives including (1) awareness and education, (2) financial, and (3) service. Proper strategies for improving community waste bank and waste recycling activity rely on cooperation of central government, local government, and citizens of communities. Moreover, international, local organization and NGO should help citizens and governments interested in the waste bank and the recycling activity. For effective strategies to improve the community waste bank, the waste bank might combine many strategies suitable for using in the community. Because the waste bank has many benefits and provide a good foundation that can potentially develop a carbon bank, governments should promote this campaign to implement widely implement in other communities. The improvement strategies developed from this study can be good lessons that other communities can adopt and use to establish their waste bank in the future.

To improving efficiency of the community garbage bank and initiate implementing carbon bank via the recycling activity, recommendations for improving CGB should be based on not only incentives but also appropriate management instruments should be implemented as well. For example, central government must set up stringent regulations for recycling waste, e.g. initiate regulation for 3Rs activity, setting up a tax for covering the actual cost of environmental damages caused by waste disposal and for changing behavior of people who did not recycle their waste, or increase a disposal fee at landfill sites or for incineration. The regulations (command and control) may need to be implemented together with market-based instrument to increase efficiency of municipal waste management.

6.2 Recommendation for Further Research

There are many issues that need more investigation to expand the implication of the research, including further study on:

1. Composting of organic waste from the recycling activity should be included in the further study about waste bank and carbon account.

2. Waste bank or recycling activity in urban community should be studied to compare behavior and trend of recycling waste with the rural community.

3. Conditions and emission factors of local and/or national should be investigated in further research.

4. Carbon accounting system via the recycling activity from the waste bank should find out actual demands (C credit buyers) and procedures and rules to set up and operate local carbon bank.

REFERENCES

Abou Najm, M. ; and El-Fadel, M. Computer-Based Interface for an Integrated Solid Waste Management Optimization Model. Journal of Environmental Modelling & Software 19 (2004): 1151-1164.

Adhikari, S. ; Mithulananthan, N. ; Dutta, A. ; and Mathias, A. J. Potential of Sustainable Energy Technologies under CDM in Thailand: Opportunities and Barriers. Journal of Renewable Energy 33 (2008): 2122-2133.

Al-Salem, S. M. ; Lettieri, P. ; and Baeyens, J. Recycling and Recovery Routes of Plastic Solid Waste (PSW): a Review. Journal of Waste Management 29 (2009): 2625–2643.

Appasamy, P. P. ; and Nelliyat, P. Financing Solid Waste Management: Issues and Options. Proceedings of the International Conference on Sustainable Solid Waste Management, pp.537-542. Chennai, India, 2007.

Aznar, M. P. ; Caballero, M. A. ; Sancho, J. A. ; and Francs, E. Plastic Waste Elimination by Co-Gasification with Coal and Biomass in Fluidized Bed with Air in Pilot Plant. Journal of Fuel Processing Technology 87 (2006): 409–420.

Barton, J. R. ; Dalley, D. ; and Patel, V. S. Life Cycle Assessment for Waste Management. Journal of Waste Management 16 (1996): 35–50.

Batool, S. A. ; and Chuadhry, M. N. The Impact of Municipal Solid Waste Treatment Methods on Greenhouse Gas Emissions in Lahore, Pakistan. Journal of Waste Management 29 (2009): 63-69.

Berger, C. ; Savard, G. ; and Wizere, A. EUGENE: an Optimisation Model for Integrated Regional Solid Waste Management Planning. International Journal of Environment and Pollution 12 (1999): 280–307.

Birch, R. ; Barrett, J. ; and Wiedmann, T. Ecological Footprint of Inverness. York: Stockholm Environmental Institute (SEI), 2004.

Bjorklund, A. ; Dalemo, M. ; and Sonesson, U. Evaluating a Municipal Waste Management Plan Using ORWARE. Journal of CleanerProduction 7 (1999): 271–280.

Boustead, I. ; and Hancock, G. F. Energy and Materials Required to Produce Glass Containers in the UK. Journal of Resources and Conservation 6 (1981): 85-99.

Browne, D. ; O'Regan, B. ; and Moles, R. Use of Carbon Footprinting to Explore Alternative Household Waste Policy Scenarios in an Irish City-Region. Journal of Resources, Conservation and Recycling 54 (2009): 113-122.

Chao, C. W. ; Ma, H. W. ;and Hung, M. L. Developing an Integrated Environmental Assessment Model for Waste Management System. 3rd International Conference on Life Cycle Management, 379. Zuric, 2007

Chiemchaisri, C. ; Juanga, J. P. ; and Visvanathan, C. Municipal solid waste management in Thailand and disposal emission inventory. Journal of Environmental Monitoring and Assessment 135 (2007): 13–20.

Clift, R. ; Doig, A. ; and Finnveden, G. The application of life cycle assessment to integrated solid waste management. Journal of Trans IChemE 78 (2000): 279–287.

Diaz, R. ; and Warith, M. Life-Cycle Assessment of Municipal Solid Wastes: Development of the WASTED Model. Journal of Waste Management 26 (2006): 886-901.

Edwards, D. W. M. ; and Schelling J. Municipal Waste Life Cycle Assessment Part 2: Transport Analysis and Glass Case Study. Journal of Trans IChemE **77** (1999).

Ekvall, T. Key Methodological Issues for Life Cycle Inventory Analysis of Paper Recycling. Journal of Cleaner Production 7 (1999): 281–294.

Energy Regulators Regional Association (ERRA). European Recovery and Recycling Association.,1999.

Environment and Plastic Industry Council (EPIC) and Corporations Supporting Recycling (CSR). Integrated Waste Management Tools: Measuring the Environmental Performance of Waste Management System. Environmental and Plastic Industry Council and Corporations Supporting Recycling, 2000.

Environmental Impacts of Transporting Waste-Life Cycle and Cost Benefit Assessments. Warmer Bulletin 73 (2000): 8–10.

Environmental Protection Agency (EPA). A Life-cycle Assessment of Emissions and Sinks. 2nd ed. USA.: Environmental Protection Agency (EPA), 2002.

Enviros Consulting. Glass Recycling-Life Cycle Carbon Dioxide Emissions. UK. : British Glass Manufacturers Confederation-Public Affairs Committee, 2003. (Mimeographed)

EPA (US Environmental Protection Agency). A Life-cycle Assessment of Emissions and Sinks. 2nd ed. Washington, DC: US Environmental Protection Agency, 2002.

Faculty of Public Health of Khon Haen University. Report of Designing of Integrate Solid Waste Management System of Phangkhon Municipal District, Sakhonnakhon. Khon Kaen: Khon Kaen University, 2007. (Mimeographed)

Finnveden, G. Methodological Aspects of Life Cycle Assessment of Integrated Solid Waste Management Systems. Journal of Resources, Conservation and Recycling 26 (1999): 173–187.

ForestEthic. Robbing the Carbon Bank: Global Warming & Ontario's Boreal Forest [Online]. Available from: http://www.forestethics.org/downloads/ globalwarming_2.pdf [2011, April 10]

Gabola, S. Towards a Sustainable Basis for the EU Packaging and Packaging Waste Directive. In: ERRA Symposium November, Brussels (1999).

Gottinger, H. W. A Computational Model for Solid Waste Management with Application. European Journal of Operational Research 35 (1988): 350–364.

Green Markets International. The Voluntary Carbon Market: Status & Potentail to Advance Sustainable Energy Activities [Online]. 2007. Available from: http://www.green-markets.org/voluntary.htm. [2010, September 10]

Haight, M. Integrated Solid Waste Management Model and Supporting Technical Documents [Online]. 2004. Available from: http://www.iwm-model.uwaterloo.ca. [2010, July 10]

Haight, M. Technical report: Integrated Solid Waste Management Model [online]. 2004. Available from: http://www.iwm-model.uwaterloo.ca/english.html. [2010, July 12]

Hanandeh, A. E. ; and El-Zein, A. Life-Cycle Assessment of Municipal Solid Waste Management Alternatives with Consideration of Uncertainty: SIWMS Development and Application. Journal of Waste Management (2010).

Harrison, K. W. ; Dumas, R. D. ; Solano, E. ; Barlaz, M. A. ; Brill, E. D. ; and Ranjithan, S. R. Decision Support for Life Cycle Based Solid Waste Management. Journal of Computing in Civil Engineering (January 2001): 44–58.

Jiaranaikhajorn, T. Overview of Waste Management in Thailand [Online]. Bangkok: Pollution Control Department, Ministry of Natural Resources and Environment, 2008. Available from: http://infofile.pcd.go.th/mgt/Overview_waste.pdf?CFID=2036476& CFTOKEN=58634002 [2010, September 10]

Kowalewski, R. ; Reid Lea,W. ; and Tittebaum, M. A Standardised Data Reporting Methodology for Long-Term Integrated Municipal Solid Waste Management-a Case Study. Journal of solid waste technology and management 26 (1999): 26–35.

Krivtsov, V. et al. Analysis of Energy Footprints associated with Recycling of Glass and Plastic-Case Studies for Industrial Ecology. Journal of Ecological Modelling 174 (2004): 175-189.

Manaf, L. A. ; Samah, M. A. A. ; and Zukki, N. I. M. Municipal Solid Waste Management in Malaysia: Practices and Challenges. Journal of Waste Management 29 (2009): 2902-2906.

McDougall, F. ; White, P. ; Franke, M. ; and Hindle, P. Integrated Solid Waste Management: A Life Cycle Inventory. Blackwell Science, London (2001).

McBeana, E. A. ; Rosso, E. D. ; and Rovers, F. A. Improvements in Financing for Sustainability in Solid Waste Management. Journal of Resources, Conservation and Recycling 43 (2005): 391-401.

Mohareb, A. K. ; Warith, M. A. ; and Diaz, R. Modelling Greenhouse Gas Emissions for Municipal Solid Waste Management Strategies in Ottawa, Ontario, Canada. Journal of Resources, Conservation and Recycling 52 (2008): 1241-1251.

Morrisseya, A. J. ; and Browneb, J. Waste Management Models and Their Application to Sustainable Waste Management. Journal of Waste Management 24 (2004): 297-308.

Mullikamal, S. การจัดการขยะชุมชนอย่างมีประสิทธิภาพ: รูปแบบและมาตรการทางสังคม เศรษฐศาสตร์ การจัดการและกฎหมาย เพื่อแก้ไขปัญหาขยะชุมชน (รายงานวิจัย) สำนักงานกองทุนสนับสนุนการวิจัย กรุงเทพฯ (Report In Thai). Bangkok, 2000.

Parkinson, S. ; Begg, K. ; Bailey, P. ; and Jackson, T. JI/CDM Crediting under the Kyoto Protocol: dose ' Interim Period Banking' help or hider GHG Emissions Reduction?

Patel, M. ; Thienen, N. v. ; Jochem, E. ; and Worrell, E. Recycling of Plastics in Germany. Resources, Conservation and Recycling 29 (2000): 65–90.

Pharino, C. ; and Jaranasaksakul, B. CDM: A Mechanism to Promote Solid Waste Management Efficiency and GHG Reductions in Thailand. Lehmann, A. M. , Joint Actions on Climate Change, pp. 298. Fibigerstræde, DK: Aalborg Ø, 2009.

Pickin, J. G. ; Yuen, S. T. S. ; and Hennings, H. Waste Management Options to Reduce Greenhouse Gas Emissions from Paper in Australia. Atmospheric Environment 36 (2002): 741–752.

Powell, J. The Potential for Using Life Cycle Inventory Analysis in Local Authority Waste Management Decision Making. Journal of Environmental Planning and Management 43 (2000): 351–367.

Reh, L. Challenges for Process Industries in Recycling. CHINA PARTICUOLOGY 4 (2006): 47-59.

Sufa, T. School Saves Garbage in Waste Bank. The Jakarta Post (26 April 2010).

Saitsiroj, B. COP 16 Cancun Agreement โลกในความเสี่ยงและความไม่สมดุล (in Thai) [Online]. Thailand: Thai Climate Justice, 2010. Available from: http://www.thaiclimatejustice.org/tags/cop-16 [2011, April 7]

Sakai, S. I. Municipal Solid Waste Management in Japan. Journal of Waste Management 16 (1996): 395-405.

Schmidt, J. H. ; Holm, P. ; Merrild, A. ; and Christensen, P. Life Cycle Assessment of the Waste Hierarchy–A Danish Case Study on Waste Paper. Journal of Waste Management 27(2007): 1519-1530.

SEED Initiative. Carbon Bank and Village Development Project [Online]. 2009. Avialable from: http://www.seedinit.org/en/awards/winners-database/2009%20 Awards/carbon-bank-and-village-development-project-.html [2011, April 11]

Shamit, B. D. Application of 3R Principles to Solid Waste Management on The Asian Institute of Technology (AIT) campus. Master's Thesis. Resources and Development Department of Environmantal Engineering and Management Engineering Asian Institue of Technology School of Environment. 2007.

Shekdar, A. V. Sustainable Solid Waste Management: an Integrated Approach for Asian Countries. Journal of Waste Management 29 (2009): 1438-1448.

Siangyen, C. Trash for Cash: Ban Bakan School Garbage Bank Project [Online]. The American National Red Cross, 2009. Available from: http://www.redcross.org/portal/site/en/menuitem.1a019a978f421296e81ec89e43 181aa0/?vgnextoid=8810dbe0fd0de110VgnVCM10000089f0870aRCRD [2011, April 7]

Sinha, M. ; and Enayetullah, I. Financing Solid Waste Management Projects Through Carbon Financing. Expert Group Meeting: "Developing Eco-efficient and Sustainable Urban Infrastructure in Asia and Latin America", Thailand, 2009.

Sonesson, U. ; Bjorklund, A. ; Carlsson, M. ; and Dalemo, M. Environmental and economic analysis of management systems for biodegradable waste. Journal pf Resources, Conservation and Recycling 28(2000):29–53.

Stypka, T. ; and Flaga, A. Application of the Integrated Waste Management Model (IWM-1) into the Decision Process. Plastic Recycling[Online]. 2006. SubsTech. Available from: http://www.substech.com/dokuwiki/doku.php?id= plastics_recycling [2010, September 10]

Suttibak, S. ; and Nitivattananon, V. Assessment of Factors Influencing the Performance of Solid Waste Recycling Programs. Journal of Resources, Conservation and Recycling 53 (2008): 45-56.

Tchobanoglous, G. ; Theisen, H. ; and Vigil, S. Integrated Solid Waste Management. Princeton,NJ: NcGraw-Hill, 1993.

Thailand Environment Institue (TEI). TEI Waste Minimization Division, "Waste & Hazardous Substance Management Bureau, Pollution Control Department", Technology for Community Garbage Bank [Online]. Available from: http://www.tei.or.th/ce/ce_technology-garbagebank.htm [2011, January 21]

Terre de hommes Italia. Garbage Banks in Indonesia: A Discreet Start Up [Online]. Indonesa: Terre de hommes Italia, 2010. Available from: http://wml4aceh.wordpress.com/2010/11/05/239/ [2011, April, 7]

Thailand Greenhouse Gas Organization (TGO). Carbon Market [Online]. Bangkok : Thailand Greenhouse Gas Organization (TGO), 2007. Available from: http://www.tgo.or.th/index.php?option=com_content&task=section&id=9&Itemid=50 [2011, April 7]

Thailand Greenhouse Gas Organization (TGO). Clean Development Mechanism : CDM [Online]. Bangkok : Thailand Greenhouse Gas Organization (TGO), 2007. Available from: http://www.tgo.or.th/index.php?option=com_ content&task=category&sectionid=4&id=15&Itemid=63 [2011, August 22]

Thai Environment Mornitoring. Solid and Hazardous Waste. Bangkok: Thai Pilution Control Department, 2003.

Thai Pollution Control (PCD). Municipal Waste Management; Manual for Loacal Administration [Online]. Bangkok, 2004. Available from http://www.pcd.go.th/info_serv/waste_garbage.html. [2010, July 3]

UN-HABITAT. Solid Waste Management in the World's Cities. Netherlands. 2009

United Nations Framwork Convention on Climate Change. Kyoto Protocol [Online]. Available from: http://unfccc.int/kyoto_protocol/items/2830.php [2010, July 16]

United Bank of Carbon. United Bank of Carbon [Online]. Harrogate, U.K.: United Bank of Carbon, 2011. Avialable from: http://www.unitedbankofcarbon.com/ [2011, April 10]

Unnikrishnan, S. ; and Singh, A. Energy Recovery in Solid Waste Management Through CDM in India and Other Countries. Jounal of Resources, Conservation and Recycling 54 (2010): 630-640.

Vellini, M. ; and Savioli, M. Energy and Environmental Analysis of Glass Container Production and Recycling. Journal of Energy 35 (2009): 2137-2143.

Villanueva, A. ; and Wenzel, H. Paper Waste–Recycling, Incineration or Landfilling? A Review of Existing Life Cycle Assessments. Journal of Waste Management 27 (2007): 829-846.

White, P. ; Franke, M. ; and Hindle, P. Integrated Solid Waste Management. Blackie Academic & Professional, London (1995).

Winkler, J. R. ; and Bilitewski, B. Comparative Evaluation of Life cycle Assessment Models for Solid Waste Management. Journal of Waste Management 27 (2007): 1021–1031.

Woerdman, E. Implementing the Kyoto Protocol: Why JI and CDM Show more Promise than International Emission Trading. Journal of Energy Policy 28 (2000): 29-38.

World Bank. Thailand Environment Monitor 2003. Thailand: Pollution Control Department, Ministry of Natural Resources and Environment (MONRE), The World Bank, Japan Bank for International Cooperation (JBIC), and United States-Asia Environmental Partnership (US-AEP), 2003.

Zhao, W. ; Voet, E. V. D. ;Zhang, Y. ;and Huppes, G. Life Cycle Assessment of Municipal Solid Waste Management with Regard to Greenhouse Gas Emissions: Case Study of Tianjin, China. Journal of Science of the Total Environment 407 (2009): 1517-1526.

Appendices

Appendix A

TABLE A-1 Waste Compositions in the Phangkhon Municipal District
(Faculty of Public Health of Khon Kaen University, 2007)

Category of Waste	Composition of Waste (%)
1.Paper	5.66
2.Glass	2.12
3.Metal	1.44
4.Plastic	17.88
5.Food waste	67.44
6.Yard waste	0.38
7.Rubber	0.22
8.Leather	0.01
9.Textile	2.04
10.Ceramic	2.24
11.Hazardous	0.19
12.other	0.38

Appendix B

TABLE B-1 Type of Recycle Wastes in Phangkhon Municipal District via Community Waste Bank during September 2009-August 2010

Category of Recyclable Waste	Waste from Raw Data Collecting (Tons)											
	Sep-09	Oct-09	Nov-09	Dec-09	Jan-10	Feb-10	Mar-10	Apr-10	May-10	Jun-10	Jul-10	Aug-10
Mix Paper	1.57	0.80	2.16	2.21	0.41	1.79	2.42	2.91	2.97	2.48	2.23	2.06
Newspaper	0.05	0.00	0.04	0.04	0.03	0.10	0.07	0.07	0.06	0.02	0.13	0.24
OCC (Old Corrugate Cardboard)	0.53	0.13	0.56	0.61	0.05	0.35	0.59	0.69	1.06	1.77	1.91	1.80
Total of Paper Waste	2.15	0.93	2.77	2.86	0.48	2.24	3.08	3.67	4.10	4.26	4.27	4.09
Mix Glass	2.24	1.22	3.75	2.21	0.89	2.93	4.30	4.66	4.68	4.51	4.04	4.57
Ferrous	0.30	0.15	0.49	0.31	0.13	0.22	0.83	0.50	0.43	0.38	0.3	0.28
Aluminum	0.07	0.01	0.03	0.07	0.01	0.03	0.25	0.54	0.03	0.04	0.21	0.26
Total of Metal	0.37	0.16	0.52	0.38	0.14	0.25	1.08	1.04	0.46	0.42	0.51	0.54
PET	0.09	0.14	0.19	0.16	0.04	0.18	0.28	0.35	0.34	0.39	0.33	0.43
HDPE	0.16	0.17	0.29	0.36	0.11	0.40	0.48	0.65	0.16	0.17	0.23	0.19
LLDPE	0.21	0.20	0.52	0.40	0.05	0.28	0.43	0.51	0.33	0.40	0.33	0.46
PP	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PVC	0.10	0.00	0.01	0.01	0.02	0.03	0.22	0.03	0.00	0.01	0.01	0.00
PS	0.00	0.00	0.00	0.00	0.00	0.09	0.08	0.40	0.00	0.02	0.01	0.01
Total of Plastic	0.52	0.51	1.01	0.93	0.22	0.97	1.29	1.95	0.84	1.00	0.92	1.11

Appendix C

TABLE C-1 Questionnaire used for Survey in this Research

Questionnaires	Answers		
Characteristic Gender	☐ Male	☐ Female	
Education	☐ Primary School ☐ Bachelor	☐ Secondary School ☐ Higher then Bachelor	
Age	☐ Younger than 20 years ☐ 40-50 years	☐ 20-30 years ☐ 50-60 years	☐ 30-40 years ☐ Older than 60 years
Status in the Waste Bank	☐ Member	☐ Non-Member	

TABLE C-1 Questionnaire Used for Survey in this Research

Questionnaires	Answers
1. Why you sort and recycle your waste?	☐ To reduce waste generation capacity and help the community ☐ To get revenues from recyclable waste sale ☐ To participate in recycling campaign of the community ☐ To convince from neighbors being a part of the activity ☐ To set a rule/order to sort and recycling waste in community
2. What categories of waste that is the most recycling from your recycling activity?	☐ Glass ☐ Paper ☐ Plastic ☐ Food Waste ☐ Metal (i.e. ferrous and aluminum)

TABLE C-1 Questionnaire Used for Survey in this Research

Questionnaires	Answers
3. Why that recycled waste (from the question 2.) has the highest efficiency for recycling?	☐ There are high capacities of those wastes generation. ☐ Those wastes are easy for sorting. ☐ Those wastes have the high value for sale. ☐ Somebody suggest sorting, recycling, and selling those wastes.
4. Do the global warming affect you?	☐ Yes ☐ No ☐ Probably
5. What is a cause of global warming crisis?	☐ Anthropogenic ☐ I have no idea ☐ Activities which release carbon dioxide

TABLE C-1 Questionnaire Used for Survey in this Research

Questionnaires	Answers
6. Do you be a part of GHG reducer?	☐ Yes ☐ I cannot help anything ☐ Probably
7. Why you help to reduce GHG?	☐ This is a duty of everybody. ☐ To realize the effects from global warming crisis. ☐ The municipality official encourages citizens to be a part of the campaign. ☐ Most of people in the community are a part of the campaign. ☐ The central government supports this campaign by knowledge, budget, service, etc. ☐ This idea is promoted by news or advertisements.

TABLE C-1 Questionnaire Used for Survey in this Research

Questionnaires	Answers
8. Do you think the waste recycling could reduce the GHG?	☐ Yes ☐ No ☐ Probably ☐ Have no idea
9. Do you know carbon banking?	☐ Yes ☐ No ☐ Probably
10. Do you know carbon credit?	☐ Yes ☐ No ☐ Probably
11. What factors can encourage you to increase your interested in waste recycling? (select only 3 answer)	☐ 1.) Central government and local government provide financial incentive for recycling activity. ☐ 2.) Rewards are provided for a member who sells the highest numbers of waste. ☐ 3.) Recyclable waste has high price.

TABLE C-1 Questionnaire Used for Survey in this Research

Questionnaires	Answers
11. What factors can encourage you to increase your interested in waste recycling? (select only 3 answer)	☐ 4.) There are fines a person who do not recycle their waste. ☐ 5.) There are regulations to order people to recycle their waste. ☐ 6.) Government provides knowledge and information how to recycling waste. ☐ 7.) The local government provides service for recycling and buys the recyclable waste. ☐ 8.) There are welfares to encourage people for recycling their waste. ☐ 9.) There is a trustable and transparency of waste banking system for managing the waste recycling activity. ☐ 10.) The recycling campaign is widely promoted. ☐ 11.) To realize the waste recycling activity could help the community to be an environmental friendly community.

Appendix D

TABLE D-1 Questionnaire Used for Survey in this Research (in Thai)

คำถาม	คำตอบ		
ข้อมูลทั่วไป เพศ	☐ ชาย	☐ หญิง	
การศึกษา	☐ ประถม ☐ ปริญญาตรี	☐ มัธยม ☐ สูงกว่าปริญญาตรี	
อายุ	☐ น้อยกว่า 20 ปี ☐ 40-50 ปี	☐ 20-30 ปี ☐ 50-60 ปี	☐ 30-40 ปี ☐ มากกว่า 60 ปี
สถานะในธนาคารขยะ	☐ เป็นสมาชิก	☐ ไม่ได้เป็นสมาชิก	

TABLE D-1 Questionnaire Used for Survey in this Research (in Thai)

คำถาม	คำตอบ
1. เหตุใดท่านจึงสนใจที่จะคัดแยกและรีไซเคิลขยะ	☐ อยากช่วยลดขยะในชุมชน และช่วยรักษาความสะอาดให้ชุมชน ☐ ได้เงินจากการขายขยะ ☐ อยากมีส่วนร่วมในกิจกรรมของชุมชน ☐ ได้รับการชักชวนจากสมาชิกคนอื่นๆในชุมชน ☐ มีการออกกฎ หรือคำสั่งให้ทำภายในชุมชน
2. คุณคิดว่าตนเองมีการคัดแยกและนำขยะชนิดใดไปรีไซเคิลมากที่สุด	☐ แก้ว ☐ กระดาษ ☐ พลาสติก ☐ เศษอาหาร ☐ โลหะ (เหล็กและอะลูมิเนียม)

TABLE D-1 Questionnaire Used for Survey in this Research (in Thai)

คำถาม	คำตอบ
3. สาเหตุที่คุณรีไซเคิลขยะชนิดนั้น (ที่เลือกตอบในข้อ 2) มากที่สุด	☐ มีขยะชนิดนั้นเป็นจำนวนมาก ☐ คัดแยกได้ง่าย ☐ ขายได้ราคาดี ☐ มีคนแนะนำให้คัดแยกและขายขยะชนิดนั้นมากที่สุด
4. คุณคิดว่าโลกร้อนมีผลกระทบต่อคุณหรือไม่	☐ มี ☐ ไม่มี ☐ ไม่แน่ใจ
5. คุณคิดว่าโลกร้อนมีสาเหตุมาจากอะไร	☐ การกระทำของมนุษย์ ☐ ไม่ทราบ ☐ กิจกรรมที่มีการปล่อยก๊าซคาร์บอนไดออกไซด์

TABLE D-1 Questionnaire Used for Survey in this Research (in Thai)

คำถาม	คำตอบ
6. คุณอยากมีส่วนในการช่วยลดโลกร้อนหรือไม่	☐ อยาก ☐ ไม่คิดว่าตนเองสามารถช่วยได้ ☐ ไม่แน่ใจ
7. เพราะเหตุใดคุณจึงอยากมีส่วนช่วยลดโลกร้อน	☐ คิดว่าเป็นหน้าที่ ☐ รู้สึกได้รับผลกระทบจากโลกร้อน ☐ เทศบาลสนับสนุนให้เข้าร่วมกิจกรรม ☐ คนส่วนใหญ่ในชุมชนเข้าร่วมโครงการ ☐ รัฐบาลให้การสนับสนุนโครงการโดยให้ความรู้ เงินสนับสนุน บริการ และอื่นๆ ☐ เห็นในข่าวหรือโฆษณานิยมทำกัน

TABLE D-1 Questionnaire Used for Survey in this Research (in Thai)

คำถาม	คำตอบ
8. คุณคิดว่าการรีไซเคิลขยะสามารถช่วยลดโลกร้อนได้หรือไม่	☐ ได้ ☐ ไม่ได้ ☐ ไม่แน่ใจ ☐ ไม่ทราบ
9. คุณรู้จักธนาคารคาร์บอนหรือไม่	☐ รู้จัก ☐ ไม่รู้จัก ☐ ไม่แน่ใจ
10. คุณรู้จักคาร์บอนเครดิตหรือไม่	☐ รู้จัก ☐ ไม่รู้จัก ☐ ไม่แน่ใจ
11. คุณคิดว่าปัจจัยใดจะช่วยส่งเสริมให้ท่านสนใจที่จะรีไซเคิลขยะให้มากขึ้น (เลือกเพียง3ข้อ)	☐ 1.) รัฐบาลและเทศบาลเสนอแรงจูงใจทางการเงินให้กับการรีไซเคิล ☐ 2.) มีการให้รางวัลแก่สมาชิกที่มีการขายขยะรีไซเคิลได้เป็นจำนวนมาก ☐ 3.) ขยะรีไซเคิลชนิดนั้นๆมีราคาสูง

TABLE D-1 Questionnaire Used for Survey in this Research (in Thai)

คำถาม	คำตอบ
11. คุณคิดว่าปัจจัยใดจะช่วยส่งเสริมให้ท่านสนใจที่จะรีไซเคิลขยะให้มากขึ้น (เลือกเพียง3ข้อ)	☐ 4.) มีการเก็บค่าปรับสำหรับผู้ที่ไม่มีการคัดแยกขยะของตน ☐ 5.) มีการออกกฎหมายมาบังคับให้รีไซเคิลขยะ ☐ 6.) รัฐให้ข้อมูลและความรู้เพิ่มเติมในการรีไซเคิลขยะ ☐ 7.) เทศบาลอำนวยความสะดวกในการซื้อขายขยะรีไซเคิล ☐ 8.) มีการให้สวัสดิการด้านอื่นๆเพื่อสนับสนุนให้ประชาชนมีการรีไซเคิลขยะของตนเอง ☐ 9.) มีธนาคารขยะที่มีระบบที่เชื่อถือได้ และโปร่งใส ☐ 10.) มีการประชาสัมพันธ์โครงการการรีไซเคิลอย่างกว้างขวาง ☐ 11.) รู้สึกว่ากิจกรรมการรีไซเคิลนั้นสามารถช่วยชุมชนในการรักษาสิ่งแวดล้อม

BIOGRAPHY

Name: Miss Suthira Puangsiri

Date of Birth: March, 27, 1986

Place of Birth: Bangkok, Thailand

Nationality: Thai

Education:

2008 Bachelor Degree of Environmental Engineering,

Faculty of Engineering, Chulalongkorn University,

Bangkok, Thailand.