THE POTENTIAL OF GREENHOUSE GAS REDUCTION FROM CLEAN DEVELOPMENT MECHANISM IMPLEMENTATION IN CASSAVA STARCH AND PALM OIL INDUSTRIES IN THAILAND

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A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR
THE DEGREE OF MASTER OF SCIENCE
(APPROPRIATE TECHNOLOGY FOR RESOURCES
AND ENVIRONMENTAL DEVELOPMENT)
FACULTY OF GRADUATE STUDIES
MAHIDOL UNIVERSITY
2008

Thesis
Entitled

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THE POTENTIAL OF GREENHOUSE GAS REDUCTION FROM CLEAN DEVELOPMENT MECHANISM IMPLEMENTATION IN CASSAVA STARCH AND PALM OIL INDUSTRIES IN THAILAND

was submitted to the Faculty of Graduate Studies, Mahidol University
For the degree of Master of Science
(Appropriate Technology for Resources and Environmental Development)
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ACKNOWLEDGEMENT

The success of the thesis would not have been possible without the full cooperation of many individuals. I would like to take this opportunity to express my appreciation to the following persons on their contribution.

I would like to express my sincere gratitude and deep appreciation to the advisors team, Assoc. Prof. Sayam Aroonsrimorakot my major advisor and Assoc. Prof. Dr. Chumlong Arunlertaree, Asst. Prof. Dr. Kraichat Tantrakarnapa my co-advisors for their kind supervision, guidance, valuable advice, helpful comments and kindness from the beginning of this thesis until its completion.

Moreover, I greatly thank to Assoc. Prof. Dr. Chamlong Poboon, who was the external examiner of the thesis defense, for his kindness and valuable suggestion.

Also, I am thankfully to the officers of the Department of Industrial Works**,** the Provincial Industry Office, the Pollution Control Department, the Department of Alternative Energy Development and Efficiency, the Energy for Environment Foundation, the Department of Internal Trade, cassava starch and palm oil mills as well, for their useful advice and invaluable data.

Furthermore, I am grateful for all lecturers and staffs of the faculty of Environment and Resource Studies for their great advice, knowledge, working and service.

Never do I forget to express my friendly to all friends AT 20 for their great friendship, help and encouragement.

Finally, I deeply thank to my beloved family for their love, understanding, patience, assistance, entirely care and encouragement throughout my study.

Ubonwan Utachkul

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ABSTRACT

The objective of this study was to estimate the potential for greenhouse gas reduction from the implementation of “Clean Development Mechanism” in the cassava starch and palm oil industries, in Thailand. The “Clean Development Mechanism” is compatible with anaerobic system. Thus, the mills that treated wastewater by anaerobic systems were evaluated for the potential and value of greenhouse gas reduction. In addition, biogas production and electricity generation were assessed.

Approximately 39 percent of the cassava starch mills treated wastewater by an anaerobic system. The annual potential in methane reduction was 28,956.81 tons or the equivalent of 608,093.10 tons of carbon dioxide. This was worth about 93 million Baht. For biogas production, 67 cassava starch mills were able to produce 512,412,738.50 m^3. The estimated annual potential electricity generation was 614,895,286.20 unit and valued about 1,537 million Baht. In contrast to the cassava starch mills, approximately 79 percent of palm oil mills treated wastewater by an anaerobic system. In the palm oil mills, the potential in methane reduction, carbon dioxide equivalent and value of the reduction were 57,899.27 tons, 1,215,884.71 tons and 186 million Baht annually. Thirty nine palm oil mills had biogas production with a potential of 106,095,782.00 m^3 per annum. This corresponded to 127,314,938.40 unit of electricity and was worth about 318 million Baht.

KEY WORDS: GREENHOUSE GAS REDUCTION/ CLEAN DEVELOPMENT MECHANISM (CDM)/ CERTIFIED EMISSION REDUCTIONS (CERs)/ CASSAVA STARCH INDUSTRY/ PALM OIL INDUSTRY

132 pp.

การวิเคราะห์ศักยภาพการลดการปล่อยก๊าซเรือนกระจกจากการดำเนินโครงการกลไกการพัฒนาที่สะอาดในอุตสาหกรรมแป้งมันสำปะหลังและอุตสาหกรรมสกัดน้ำมันปาล์ม ประเทศไทย
(THE POTENTIAL OF GREENHOUSE GAS REDUCTION FROM CLEAN DEVELOPMENT MECHANISM IMPLEMENTATION IN CASSAVA STARCH AND PALM OIL INDUSTRIES IN THAILAND)

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บทคัดย่อ

การศึกษาในครั้งนี้มีวัตถุประสงค์เพื่อวิเคราะห์ศักยภาพการลดการปล่อยก๊าซเรือนกระจกจากการดำเนินโครงการกลไกการพัฒนาที่สะอาดในอุตสาหกรรมแป้งมันสำปะหลังและอุตสาหกรรมสกัดน้ำมันปาล์มของประเทศไทย โดยวิเคราะห์ศักยภาพการลดการปล่อยก๊าซเรือนกระจกจากน้ำเสียของโรงงานที่บำบัดน้ำเสียด้วยระบบไร้อากาศ และมูลค่าของก๊าซเรือนกระจกที่สามารถลดได้ (CERs) ปริมาณการผลิตก๊าซชีวภาพ และปริมาณกระแสไฟฟ้า

จากการศึกษาพบว่า อุตสาหกรรมแป้งมันสำปะหลังมีโรงงานที่บำบัดน้ำเสียด้วยระบบไร้อากาศประมาณร้อยละ 39 มีศักยภาพในการลดก๊าซมีเทน 28,956.81 ตัน/ปี หรือเทียบเท่ากับ 608,093.10 ตันคาร์บอนไดออกไซด์เทียบเท่า ซึ่งมีมูลค่าเท่ากับ 93 ล้านบาท/ปี สำหรับปริมาณก๊าซชีวภาพที่สามารถผลิตได้จากโรงงานแป้งมันสำปะหลัง 67 โรง คือ 512,412,738.50 ลูกบาศก์เมตร/ปี เทียบเท่ากับกระแสไฟฟ้า 614,895,286.20หน่วย คิดเป็นเงิน 1,537 ล้านบาท ในส่วนของอุตสาหกรรมสกัดน้ำมันปาล์ม พบว่ามีระบบบำบัดน้ำเสียแบบไร้อากาศประมาณร้อยละ 79 มีศักยภาพในการลดก๊าซมีเทน 57,899.27 ตัน/ปี เทียบเท่ากับปริมาณก๊าซคาร์บอนไดออกไซด์ 1,215,884.71 ตัน และมีมูลค่าเท่ากับ 186 ล้านบาท โรงงานสกัดน้ำมันปาล์ม 39 โรง มีศักยภาพในการผลิตก๊าซชีวภาพ 106,095,782.00 ลูกบาศก์เมตร/ปี คิดเป็นกระแสไฟฟ้า 127,314,938.40 หน่วย และมีมูลค่าเท่ากับ 318 ล้านบาท

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CHAPTER 1
INTRODUCTION

1.1 Background and justification

The increasing atmospheric concentration of greenhouse gases is the cause of climate change problem. This is attributable to human activities; burning fossil fuels for producing energy, agriculture, livestock and industrial process. An impact of greenhouse gases are rising in global temperature, drought, spreading of disease, melting of glaciers, rising in sea levels, flooding and erosion in coastal areas, impact on ecosystem, changing of season and environment, increase in the frequency and severity of storms. Theses changes will have a serious consequence on the natural reproduction patterns of living things in the ecosystem. In addition, they will have an impact on agricultural yields, human health and hygiene, and will also affect the social and economics development of nations. To solve the problems, the United Nations has launched the United Nations Framework Convention on Climate Change (UNFCCC) which the ultimate objective is "to achieve a stabilization of greenhouse gases concentrations in the atmosphere at the level that would prevent dangerous anthropogenic interference with the climate system". The convention did not enforce by the law and no emission limitation. The report of Annex I countries showed that they could not meet their reduction target [1]. So at the third session of the conference of the parties (COP3) at Kyoto, Japan, they have revised the commitments and decided to set more intensive measures, therefore the Kyoto Protocol was the result of that conference.

The Kyoto Protocol is the establishing commitments for the reduction emission of 6 types of greenhouse gases for Annex I countries, which are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PCFs) and sulfur hexachloride (SF_6). The reduction of greenhouse gases must below 1990 levels by an average of at least 5 percent among 2008 to 2012. Furthermore, the

Kyoto Protocol has established 3 flexibility mechanisms to assist Annex I countries to meet their targets easier, that is Joint Implementation:JI, Emission Trading:ET and Clean Development Mechanism:CDM. The third mechanism is only one that provides Annex I countries and Non-annex I countries the opportunity to jointly implement project that can reduce greenhouse gases emissions by contribute to Non-annex I countries. The CDM offer technology transfer and promote sustainable development. The leaders of the project will receive carbon credit or certified emission reductions (CERs) in return for the resulting of the units that have verification, confirmation and certification. The leaders can also take the units to meet their targets or trade in the carbon market. Now, there are many carbon markets but the main trading market are European Union and United State (which is internal market, because United State is not the Kyoto Protocol's parties). UNFCCC CDM-Executive Board has registered 864 CDM projects from 49 host countries and the expected annual CERs were 185,473,153 unit. The first four high host countries were India, China, Brazil and Mexico respectively [2].

The United Nations Development Programme (UNDP) reported in the Human Development Report 2007/2008 that in the past 15 years Thailand had the second rank of growth rate in CO_2 emission at 180%, whereas Malaysia was the first rank at the growth rate 221%. In 2004 Thailand emitted 268 million ton of CO_2 compare to 96 million ton of CO_2 in 1990, which increased by 280% or at 180% of growth rate. For the CO_2 emission per capita of 64,000,000 populations in 2004 found that each of Thai population would emit 4.2 ton CO_2/capita/year while in 1990 the rate was 1.7 ton CO_2/capita/year. The entire of Thailand's CO_2 emission was at the 22^{nd} from 170 countries; that growth rate was the result of the increasing in power consumption, especially in fossil power [3].

Thailand as a Non-annex I countries can participate in CDM project implementation which will relieve in the reduction of greenhouse gases emissions. Mostly of the implemented projects in Thailand are biogas project to replace fuel in the factory and generating electricity.

Cassava starch and palm oil industries wastewater have high BOD and COD loading. Mostly was treated by stabilization pond. So they made bad odor to the community around the site and also release methane, which generate more global warming potential than carbon dioxide 21 times, to the atmosphere. By this fact, if they turn to treat by anaerobic process, they can gain biogas to replace fuel, waste utilization and promote sustainable to the nation. Therefore using biogas as a fuel project will be suitable and will be an option to reduce greenhouse gases emissions. The objectives of this research were to compare the potential of cassava starch and palm oil industries toward the volume of biogas, electricity, greenhouse gas emission reduction and value of CERs. The results of this research would be beneficial database to design framework for national policy.

1.2 Objectives of the study

1.2.1 To analyze the potential of cassava starch and palm oil industries in Thailand toward the production of biogas, greenhouse gas reduction in case of implementing the CDM project.

1.2.2 To analyze the potential of biogas from both industries toward volume and value of CERs and volume of electricity generation in Thailand.

1.3 Conceptual framework

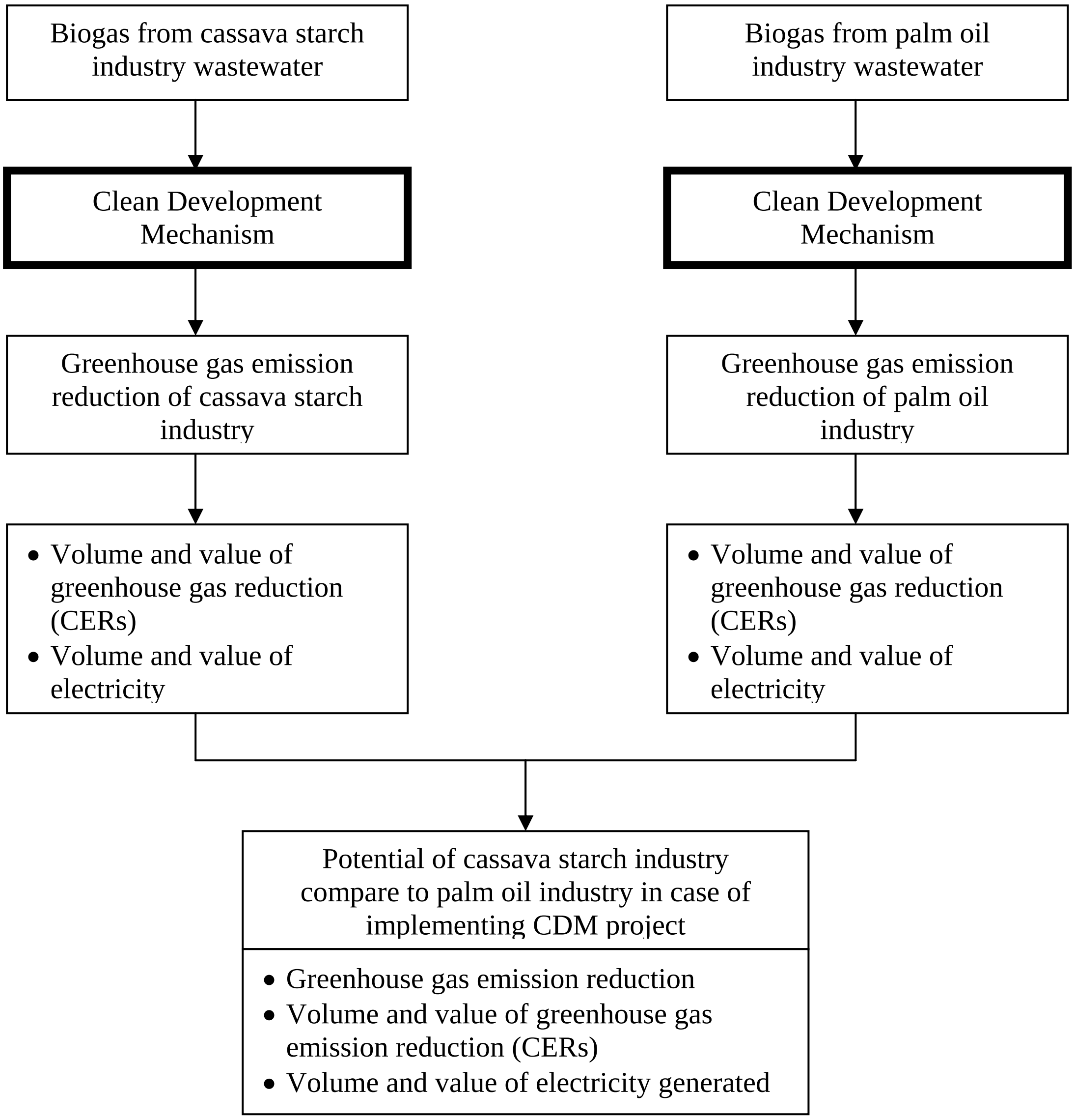


Figure 1-1 Conceptual Framework

1.4 Research questions

1.4.1 What are the potential of cassava starch and palm oil industries in greenhouse gas reduction?

1.4.2 Cassava starch or palm oil industries wastewater has higher potential in biogas production and greenhouse gas reduction?

1.5 Scope of the study

1.5.1 Study the potential in greenhouse gas reduction of cassava starch and palm oil industries in Thailand.

1.5.2 The estimation will be done at the static production capacity of the mills.

1.5.3 The analysis of the potential of cassava starch and palm oil mills will be done according to the list of the Department of Industrial Works on March 27^{th}, 2007, which there are 86 cassava starch mills and 53 palm oil mills, at present.

1.6 Definition term

1.6.1 Certified Emission Reductions (CERs) : is the unit of greenhouse gases emission reduction from CDM project activities. The CERs are expressed in metric tons of CO_2 equivalent. One unit of CER is equal to one metric ton of CO_2 equivalent.

1.6.2 CERs value : is the price of CERs, calculated in term of Baht/ton CO_2 equivalent.

1.6.3 Potential : is the capability of cassava starch and palm oil industries in the production of biogas from wastewater at the normal condition.

1.6.4 Biogas : is the by-product gases from the anaerobic digestion of organic matter in cassava starch and palm oil industries wastewater.

1.6.5 Biogas system : is the wastewater treatment system of cassava starch and palm oil mills that treated wastewater by anaerobic system and the biogas produced from the anaerobic digestion was recovered to be used as a source of power, hence the greenhouse gases will be not emitted to the atmosphere.

1.7 Expected results

The potential of greenhouse gas emission reduction and value of CERs, volume and value of electricity from cassava starch and palm oil industries wastewater in case of implementing the CDM project in Thailand.

As the results of the studies, governmental organizations such as the Ministry of Natural Resources and Environment, the Ministry of Energy, the Office of Natural Resources and Environmental Policy and Planning and the Ministry of Finance can bring these baseline data for planning and setting policy. For example: project approving, alternative energy planning, greenhouse gases emission reductions approach. In addition, mills and the CDM projects implemented companies can carry on these result for investment planning, economic return studies, decision making on projects feasibility and by-product from CDM implementation about biogas recovered from industrial wastewater. Beside the greenhouse gas emission reductions from CDM project, the reduction units can be sold to the Annex I countries, carbon fund or carbon broker. Also the energy to be used in the mills, and the excess electricity which can be sold to the Electricity Generating Authority of Thailand or the Provincial Electricity Authority.

1.8 Abbreviation

ABR : Anaerobic Buffled Reactor
AFF : Anaerobic Fixed Film
CDM : Clean Development Mechanism
CDM EB : CDM Executive Board
CERs : Certified Emission Reductions
CIGAR : Covered In-Ground Anaerobic Reactor
COD : Chemical Oxygen Demand
CO_2 eq : CO_2 equivalent
CPO : Crude Palm Oil
CSTR : Completely Stirred Tank Reactor
DNA : Designate National Authority
DOE : Designated Operational Entity
FFB : Fresh Fruit Bunch
GHGs : Greenhouse Gases
GWP : Global Warming Potential
HSS-UASB : High suspension solids - Upflow Anaerobic Sludge Blanket

IPCC : Intergovernmental Panel on Climate Change

LoA : Letter of Approval

MNRE : Ministry of Natural Resources and Environment

ONEP : Office of Natural Resources and Environmental Policy and Planning

PDD : Project Design Document

POME : Palm Oil Mill Effluent

SPP : Small Power Producer

UASB : Upflow Anaerobic Sludge Blanket

UNFCCC : United Nations Framework Convention on Climate Change

VSPP : Very Small Power Producer

CHAPTER 2
LITERATURE REVIEW

This chapter was to study and review the related concepts and concerned knowledge in 8 specific important topics. They were as follows:

2.1 United Nations Framework Convention on Climate Change (UNFCCC)
2.2 Kyoto Protocol
2.3 Clean Development Mechanism (CDM)
2.4 The importance of the Kyoto Protocol and the CDM to Thailand
2.5 The emission of the greenhouse gases in Thailand
2.6 Biogas
2.7 Cassava starch and palm oil industries
2.8 Relevant research

2.1 United Nations Framework Convention on Climate Change (UNFCCC)

During the 1980s, scientists started becoming more concerned about the threats associated with anthropogenic greenhouse gas emissions and the increased severity of the greenhouse gas effect. In 1988, the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) therefore established the Intergovernmental Panel on Climate Change (IPCC). In 1990, the IPCC completed its First Assessment Report which concluded that human activities were indeed responsible for climate change and because the findings were released in the same year that hosted the Second World Climate Conference, climate change became an international issue of interest [4].

During its 45th Conference held on December 11th, 1990, the United Nations set up the Intergovernmental Negotiating Committee for a Framework Convention on Climate Change (INC/FCCC) to coordinate the efforts between governments in addressing the problems associated with climate change. The INC organized 5 meetings between February 1991 and May 1992, which were represented by more than 150 nations. The topics that were discussed included the need for a commitment, the setting of measurable objectives and timeline for greenhouse gases reduction, establishing financial mechanisms, proposing technology transfer, and defining different levels of responsibilities to meet the climate change challenge. However, in order to meet its objectives, the INC would require a binding agreement between all involved parties [4]. The United Nations Framework Convention on Climate Change (UNFCCC) was therefore "born" in May 1992. Opened for signature on June, 1992 at the United Nations Conference on Environmental and Development (UNCED) or Earth Summit, held in Rio de Janero, Brazil. The convention entered into force on March 21st, 1994. The ultimate objective is “to achieve a stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieve within a time frame sufficient to allow ecosystem to adapt naturally to climate change, to ensure that food production is not threatened and to enable development to proceed in a sustainable manner” [5]. To achieve the objectives, the parties of the convention had the commitment on the climate change. They divided the parties into 2 groups, which is Annex I countries and Non-annex I countries.

- **Annex I countries**

Parties that had high rate in greenhouse gases emission per capita. The adverse impacts in climate change are in low level, invulnerable to the potential economic impacts of climate change response. The principle “Common but Differentiated Responsibilities” is the important base of the commitment that assigned them to establish national policies and undertake measures to reduce greenhouse gas emissions to the 1990 level by the year 2000. Furthermore, they had to do National Communication to report their yearly greenhouse gas emissions [6].

Annex I parties consist of countries belonging to the Organization for Economic Cooperation and Development (OECD) and countries designed as Economies-in-Transition (EIT), which had inferior economic situation. OECD countries had more strictly bound than EITs. So Annex II countries was another name of OECD [6].

Table 2-1 Annex-I-countries and commitments for the reduction of greenhouse gases

Country	Target (percentage of base year)
Australia	108
Austria	92
Belarus	#
Belgium	92
Bulgaria*	92
Canada	94
Croatia*	95
Czech Republic*	92
Denmark	92
Estonia*	92
European Community	92
Finland	92
France	92
Germany	92
Greece	92
Hungary*	94
Iceland	110
Ireland	92
Italy	92
Japan	94
Latvia*	92
Liechtenstein	92
Lithuania*	92
Luxembourg	92
Monaco	92
Netherlands	92
New Zealand	100
Norway	101

Table 2-1 Annex-I-countries and commitments for the reduction of greenhouse gases (Cont.)

Country	**Target (percentage of base year)**
Poland*	94
Portugal	92
Romania*	92
Russian Federation*	100
Slovakia*	92
Slovenia*	92
Spain	92
Sweden	92
Switzerland	92
Turkey	100
Ukraine*	92
United Kingdom of Great Britain and Northern Ireland	92
United States of America**	93

Remarks : * some EIT countries have different base year than 1999
** United States of America has not rarified the Kyoto Protocol
# N.A.
Source : adopted from [1] and [7]

- **Non-annex I countries**

All parties to the UNFCCC not listed under Annex I countries, developing countries and under developing countries. They had no commitment for the reduction of greenhouse gases that are legally binding for Annex I countries. They were also required to prepare National Communications reports, but had less stringent inventory recording requirements and had timeframe to report more flexible than Annex I countries. Moreover they would be assisted financially from Global Environment Facility (GEF) [6].

Table 2-2 Non-annex I countries

Afghanistan	Albania	Algeria	Angola
Antigua and Barbuda	Argentina	Armenia	Azerbaijan
Bahamas	Bahrain	Bangladesh	Barbados
Belize	Benin	Bhutan	Bolivia
Bosnia and Herzegovina	Botswana	Brazil	Burkina Faso
Burundi	Cambodia	Cameroon	Cape Verde
Central African Republic	Chad	Chile	China
Colombia	Comoros	Congo	Cook Islands
Costa Rica	Cuba	Cyprus	Cote d'lvoire
Democratic People's Republic of Korea	Democratic Republic of the Congo	Djibouti	Dominica
Dominican Republic	Ecuador	Egypt	El Salvador
Equatorial Guinea	Eritrea	Ethiopia	Fiji
The former Yugoslav Republic of Macedonia	Gabon	Gambia	Georgia
Ghana	Grenada	Guatemala	Guinea
Guinea-Bissau	Guyana	Haiti	Honduras
India	Indonesia	Iran (Islamic Republic of)	Israel
Jamaica	Jordan	Kazakhstan	Kenya
Kiribati	Kuwait	Kyrgyzstan	Loa People's Democratic Republic
Lebanon	Lesotho	Liberia	Libyan Arab Jamahiriya
Madagascar	Malawi	Malaysia	Maldives
Mali	Malta	Marshall Islands	Mauritania
Mauritius	Mexico	Micronesia (Federated States of)	Mongolia
Morocco	Mozambique	Myanmar	Namibia
Nauru	Nepal	Nicaragua	Niger
Nigeria	Niue	Oman	Pakistan
Palau	Panama	Papua New Guinea	Paraguay
Peru	Philippines	Qatar	Republic of Korea
Republic of Moldova	Rwanda	Saint Kitts and Nevis	Saint Lucia

Table 2-2 Non-annex I countries (Cont.)

Saint Vincent and the Grenadines	Samoa	San Marino	Sao Tome and Principe
Saudi Arabia	Senegal	Serbia and Montenegro	Seychelles
Sierra Leone	Singapore	Solomon Islands	South Africa
Sri Lanka	Sudan	Suriname	Swaziland
Syrian Arab Republic	Tajikistan	Thailand	Togo
Tonga	Trinidad and Tobago	Tunisia	Turkmenistan
Tuvalu	Uganda	United Arab Emirates	United Republic of Tanzania
Uruguay	Uzbekistan	Vanuatu	Venezuela
Viet Nam	Yemen	Zambia	Zimbabwe

Source : [7]

2.2 Kyoto Protocol

The Kyoto Protocol was launched because of Annex I – parties could not meet their greenhouse gas reduction target to the level of 1990 within 2000 in accordance with the commitment. Therefore at the third session of the conference of the Parties to the UNFCCC in Kyoto, Japan, the committee had added the new commitments that are stronger and more complex and detailed than those in convention, then the Kyoto Protocol was adopted on 11 December 1997 and was opened for the signature during March16th, 1998 to March15th, 1999. The Protocol is subject to ratification, acceptance, approval or accession by Parties to the convention. The Kyoto Protocol was to be enforced only when more than 55 member countries had ratified it. This minimum needed to include Annex I countries, which together accounted for at least 55 percent of total CO_2 emissions for 1990. Thailand agreed on the Kyoto Protocol on February 2nd, 1990 and ratified the Protocol on August 28th, 2002. The Kyoto Protocol entered into force on February 16th 2005 [1].

The Kyoto Protocol mandates that Annex I – countries reduce their emissions of 6 types of greenhouse gases, namely carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PCFs) and sulfur hexachloride (SF_6). Which have to meet commitments to reduce greenhouse gases to below 1990 levels by an average of at least 5 percent within 2008-2012. However, The Kyoto Protocol has defined three flexibility mechanisms to help Annex I – countries decrease the costs of reducing greenhouse gases emissions, that is Emission Trading: ET, Joint Implementation: JI and Clean Development Mechanism: CDM. In particular, the last one has the objective of setting up a share scheme between Annex I and Non-Annex I countries in order to solve the greenhouse gases emission problems where Annex I countries can meet the target of reduced emission in the commitment period and Non-Annex I countries will meet only their sustainable development. The project develop will in return for Certified Emission Reductions (CER_s) [1].

2.2.1 The Greenhouse Gases

In general, there are many types of greenhouse gases, but the Protocol legally binding mandates that Annex I countries reduce their emission of 6 types of them. Namely carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PCFs) and sulfur hexachloride (SF_6). These 6 greenhouse gases have varying degrees of radiative efficiency. Therefore, their amounts are calculated bases on their carbon dioxide equivalent multiplied by their Global Warning Potential (GWP). The Kyoto Protocol proposed that the GWPs that were calculate for the IPCC’s Second Assessment Report (1995), be used for the first Commitment Period [8] (Table 2-3).

Table 2-3 Greenhouse gases and global warming potential

Greenhouse gas	Global warming potential (CO_2 equivalent)
1.Carbon dioxide (CO_2)	1
2.Methane (CH_4)	21
3. Nitrous oxide (N_2O)	310
4.Hydrofluorocarbons (HFC_s)	140-11,700
5. Perfluorocarbons (PFC_s)	6,500-9,200
6. Sulfur hexachloride (SF_6)	23,900

Source : Climate Change 1995, IPCC Second Assessment Report cited in [8]

2.2.2 Mechanism of the Kyoto Protocol

The Kyoto Protocol defined 3 mechanisms in order to help Annex I countries to achieve the objective of reducing greenhouse gas emission, while it also force Non-annex I countries to participate in the responsibility.

- **Emission Trading : ET**

Emissions trading, as set out in Article 17 of the Kyoto Protocol, provided for Annex I Parties to acquire units from other Annex I Parties and use them towards meeting their emissions targets under the Kyoto Protocol. This enables Parties to make use of lower cost opportunities to reduce emissions, irrespective of the Party in which Party those opportunities exist, in order to lower the overall cost of reducing emissions. The permits are also known as Assigned Amount Unit or AAU, which are assigned Annex I Parties to emit in each year. Only Annex I Parties to the Kyoto Protocol with emission limitation and reduction commitments inscribed in Annex B to the Protocol may participate in such trading. (Annex I Parties list is in the UNFCCC. Annex B Parties are listed in the Kyoto Protocol) [1], [9] and [12].

- **Joint Implementation :JI**

JI, as defined in Article 6 of the Kyoto Protocol, is a combined effort by Annex I countries to increase their reduction of greenhouse gas emissions more than would otherwise occur under normal conditions (as it is assumed that some countries will have lesser emissions than their commitments, such as several EITs that do not have to reduce greenhouse gases). The initiating party can count the resulting emission unit or ERU towards meeting its own target [1], [9] and [12].

- **Clean Development Mechanism : CDM**

The CDM defined in Article 12 of the Kyoto Protocol. The objective of this mechanism is to Non-annex I Parties can participate in greenhouse gases emission reduction. The CDM will promote the developing countries host parties in achieving sustainable development, meanwhile it will assist Annex I Parties to meet their commitment targets, as defined in article 3 of the Kyoto Protocol. This mechanism provides for Annex I Parties to implement project activities that reduce emissions in non-Annex I Parties, more than under normal conditions, and with the leader of the project receiving certified emission reductions or CERs in return [1] and [9].

2.3 Clean Development Mechanism : CDM

The idea behind CDM is to reward developing countries that undertake projects leading to the reduction of greenhouse gases with Certified Emission Reductions (CER_s) by the CDM Executive Board (CDM EB). The project leader can then offer to trade these CER_s with industrialized nations, who can use them to meet their own commitments under the Kyoto Protocol. The implementation of CDM projects must be approved by the host country that must lead to sustainable development in the host country. All of the CDM project operations have to be supervised by the Meeting of Parties (MOP), by means of Executive Board of Clean Development Mechanism which was appointed by the Conference of Parties. For the amount of the greenhouse gases reduction have to be monitored, verified and certified by the Designated Operational Entity (DOE). Projects must be voluntary project, lead to real, measurable and long-term benefits related to the emission reductions or carbon removals that are additional to any that would have occurred without the project [9].

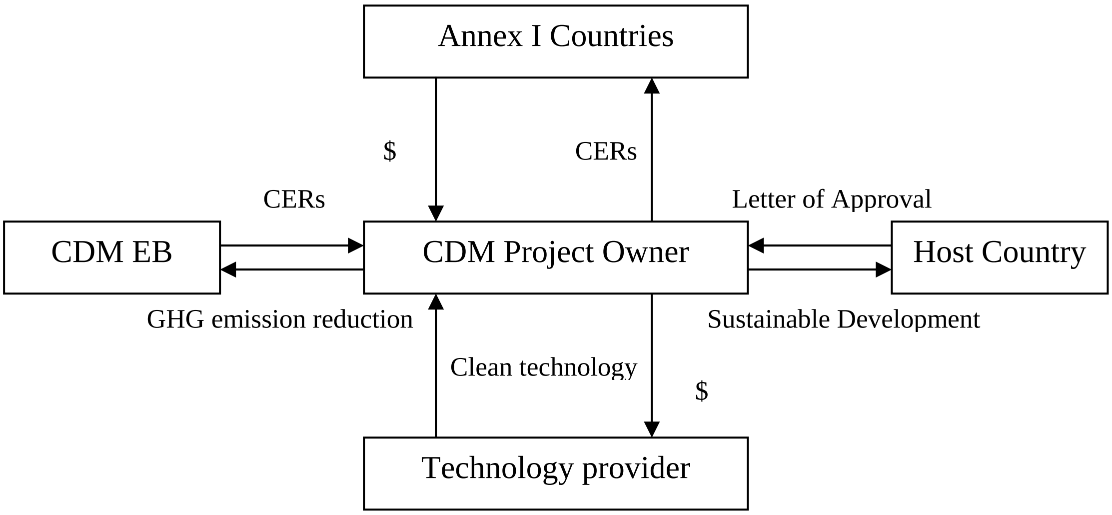


Figure 2-1 The relationship between the different parties involved in CDM projects and the benefits are illustrated in the diagram above.

Source : [9]

CDM offers an incentive for developing countries to turn to cleaner technologies, which would in turn lead to a reduction in greenhouse gas emissions. Without CDM as an incentive, the non-Annex I countries might still use lower cost technologies that release high amounts of greenhouse gases. The incentives in question are CERs, which would be awarded to the project leader and which can be leaded with industrialized countries. As for the host country, they would be benefited from the sustainable development that is taking place [9].

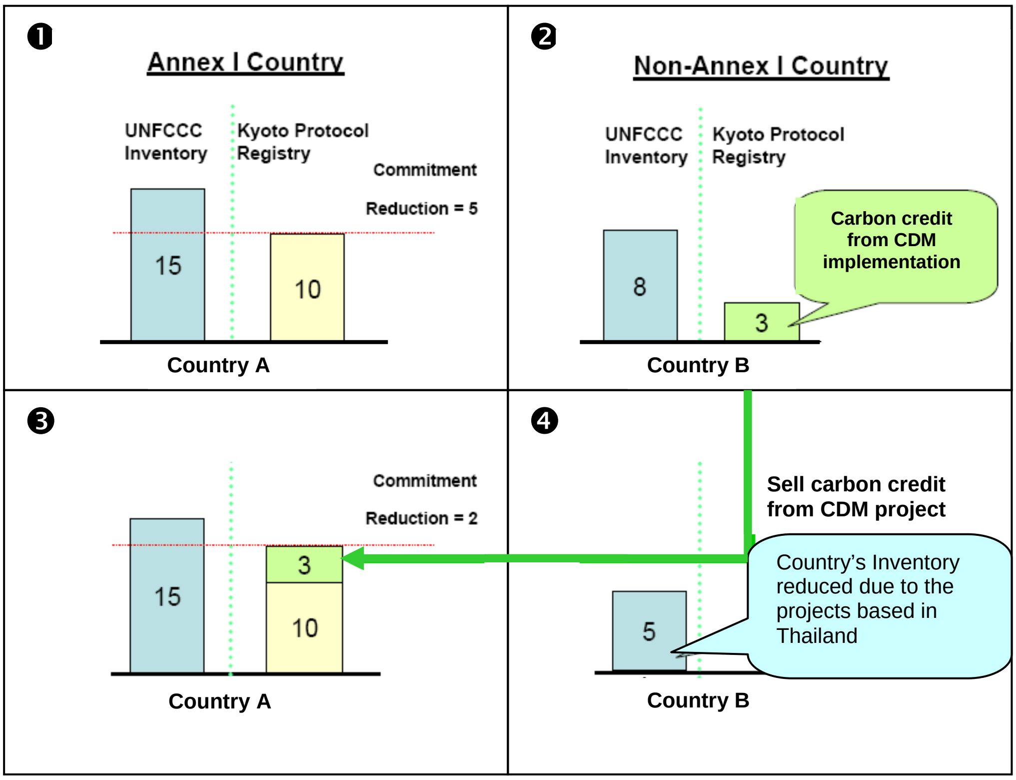


Figure 2-2 The reduction of greenhouse gases from CDM implementation

Source : [13]

2.3.1 Forms of CDM

CDM projects can be executed either through bilateral, multilateral, or unilateral cooperation. The main difference between the bilateral/ multilateral CDM on the one hand, and unilateral CDM on the other hand, is that CERs under the first two types are sold to a CER buyer before project implementation (via a forward contract or Emission Reduction Purchase Agreement); whereas under unilateral cooperation, the CERs are sold either during, or after project implementation (which could take place via a forward or spot contract). An important advantage of unilateral CDM is that host countries are encouraged to perform technology needs assessments (TNAs) to be better able to match CDM projects with their domestic development needs and priorities; under multilateral and bilateral CDM, project choices are largely driven by the interests of the CER buyer (*i.e.* CER potential). Such TNAs would result in a list of sustainable energy technologies which would best fulfil the host country's needs and priorities and deliver an optimized contribution to sustainable development in the country. Particularly suitable for the CDM would be those technologies that would not be implementable under business-as-usual circumstances due to all kinds of economic, cultural and institutional barriers. Such technologies would deliver a clearly assessable contribution to sustainable development and are additional to business-as-usual circumstances.

However, potential challenges to unilateral CDM's are that it requires more capacity within the host countries to develop projects themselves and could imply relatively high upfront costs incurred by local project participants before being able to sell the CERs.

While unilateral CDM's could generally be seen as a way to bring host countries' national priorities and investor countries' CER demand closer together, it may be restricted, just as bilateral and multilateral CDM's, by the limited availability and/or acceptability of GHG accounting methodologies (baselines and additionality) for several project technologies. Thus far, as explained above, the most popular CDM projects (and technologies) have been those for which baselines and additionality of emission reductions could relatively easily be determined [18].

2.3.2 Types of CDM projects [10]

There are three types of CDM projects, as follows:

1) General CDM Projects

2) CDM Forestry Projects

For this type of CDM projects, a "forest" is defined as a minimum area of 0.05-1.0 hectares (500-10,000 m^2) with more than 10-30 percent crown cover and these trees must have the potential to grow to a minimum of at least 2-5 meters [10].

In order to be a CDM project, forestry projects must be either Afforestation or Reforestation projects.

- **Afforestation** means the conversion (by humans) of land that has never been a forest within the last 50 years to become a forested land by planting, seeding or the promoting of natural growth [10].

- **Reforestation** means the conversion (by humans) of previously forested land which had been altered, to return back to being forested land by planting, seeding or the promoting of natural growth. For the purpose of the first commitment period, reforestation will be limited to land that was not a forest on 31 December 1989 [10].

During the first commitment period, which is a period of 5 years, Annex I countries can utilize credits from CDM Forestry Projects to fulfill commitments by no more than 1 percent of greenhouse gas reduction from the base year multiply by 5 [10].

There was the estimation on the replete 1 acre of forest or 2.5 rai that trees can absorb CO_2 about 2 ton carbon. And at this time, carbon credit trading from the forest absorption or carbon sink was about 15 USD/ton [11].

Nowadays, Thailand has 150,000 rai of forestation plantation area (exclude natural grown up forest) under the handle of Forest Industry Organization. They had evaluated that there were average 100 trees per rai. If Thailand decide to sell carbon credit from 150,000 rai of forest plantaion, Thailand will earn money not less than 45,000 million baht [11].

For the carbon credit or carbon sink, Sakhan Teejuntug from the faculty of forestry, Kasetsart University[11] defined that carbon credit is the CO_2 absorption by trees for theirs growth in each age. Trees will accumulate in form of carbon, which can be measured by scientific method. Therefore, carbon credit was the by-product of forest plantation in each age and was not the forest sold or the forest ownership sold as someone misunderstood. He also said that the calculation of carbon credit amount from wood will be done at any age phase, when measured. For example, after carbon credit measured and bargained of 4 years Eucalyptus, the wood can immediately sell. According to they were assumed that those woods had absorbed carbon for a while.

Otherwise, after the first carbon credit sold of 4 years Eucalyptus the wood was not sold, they can also wait to sell the second carbon credit when the trees were 6 years old as well. Finally, he also said that at this time, Thailand has 2.15 million rai of forest plantation which were 1.5 hundred thousand rai of Forest Industry Organization and 2 million rai of private sector [11].

3) Small-scale CDM Projects

Small-scale CDM projects are those that will help reduce the costs and decrease the time required for registration as a CDM project because of a more simplified procedure. There are three types of activities that can be implemented as a small-scale CDM project.

- Renewable energy project with a maximum production output of no more than 15 MWe.
- Improvement of energy efficiency projects which can reduce energy usage by no more than 15 GW-hr per year.
- Other types of projects that can lead to a reduction in anthropogenic greenhouse gas emissions and which emit no more than 15,000 tons of carbon dioxide equivalents.
- Small-scale afforestation and reforestation projects that absorb no more than 8,000 tons of carbon dioxide equivalents per year (any more absorption will not be considered as a credit) [10].

2.3.3 Crediting period [10]

1) Crediting period (of none forestry projects)

The project operator has two options for choosing the crediting period.

- **Renewable Crediting Period –** a maximum of 7 years but which can be renewed twice if the baseline of the project is still valid or has been improved taking account of new information; or
- **Fixed Crediting Period –** a maximum of 10 years with no option for extension.

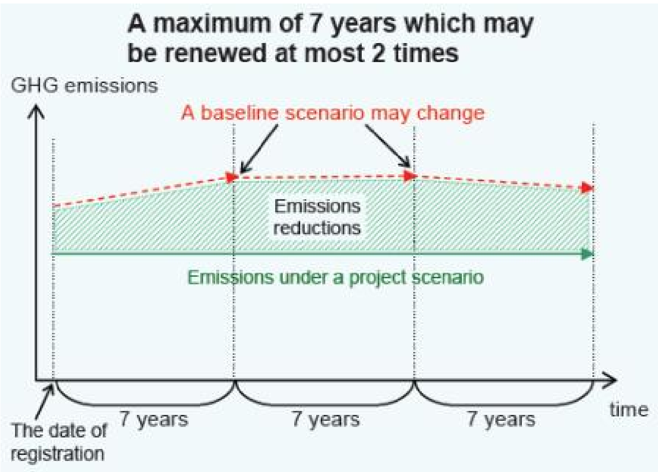


Figure 2-3 Renewable Crediting Period

Source : [10]

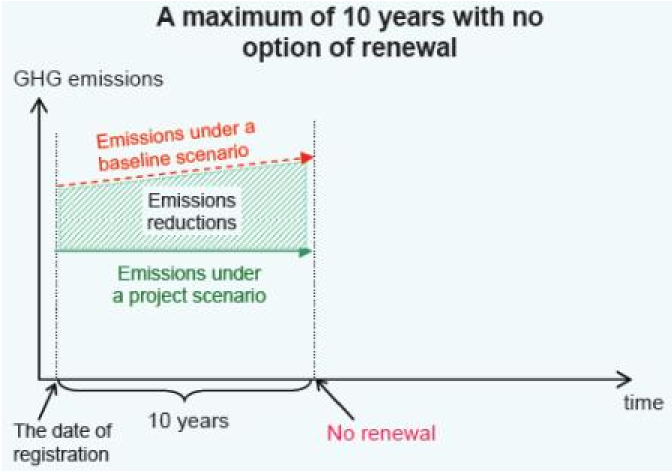


Figure 2-4 Fixed Crediting Period

Source : [10]

For the second or third renewal of CDM projects, it is necessary to determine whether the baseline used in calculating greenhouse gas emissions is still valid. Information that needs to be considered includes information on whether the project can achieve a reduction in greenhouse gases, whether or not there have been changes in rules and regulations and if so, how they would affect the baseline. The methodology used in calculating baseline greenhouse gas emissions during the second and third crediting period must be the same methodology that was initially proposed. It is the responsibility of the DOE for reviewing and verifying this information [10].

2) Crediting period of forestry projects

The crediting period for forestry projects are different from general CDM projects. The project operator can select from the following two options.

- **Renewable Crediting Period** - a maximum of 20 years but which can be renewed twice if the baseline of the projects is still valid or has been improved taking account of new information; or
- **Fixed Crediting Period –** a maximum of 30 years with no option for extension.Credits for forestry projects are also different from those of general CDM projects, with two options as follows:

• **tCERs (Temporary CER)** Carbon credits will be calculated until the end of the Commitment period.

• **lCERs (Long-term CER)** Carbon credits will be calculated until the end of the Crediting period.

2.3.4 Carbon Market [12]

Carbon credit buyers can divide in to 3 types :

1) Annex I Government : the parties that have commitments for the reduction of greenhouse gases will assign government officer to provide carbon credits to achieve the target in emission reduction and the government will allocate the budget to them. For example, England assign to the Department for Environment, the Food and Rural Affairs, Germany assign to the Deutsche Gasellschaft for Technische Zuammenarbeit (GTZ) GmbH, Denmark assign to the Ministry of Foreign Affairs, etc.

2) Carbon Fund : is the assembling of funds executive that come from government or groups of private sector which require the amount of greenhouse gases emission reduction, such as World Bank is the executive of the Prototype Carbon Fund, Community Development Carbon Fund, Bio Carbon Fund, Danish Carbon Fund, Spanish Carbon Fund, as for Japan Carbon Fund is the Carbon Fund that come from the assembling of the private sector in Japan that come to administer.

3) Carbon Broker : is the broker that purchase carbon credits to sell to the government of Annex I countries or private sector. They work as the brokers in the stock exchange. For instance, Asia Carbon Exchange (Singapore) which will bid CERs and the compensation is 2 percent of CERs revenue or Traditional Finance Service (United Kingdom), Trading Emission PLC (United Kingdom), etc.

2.3.5 Price of Certified Emission Reductions (CERs)

Each carbon credits have different value, for example CERs have lower value than AAUs because of in charging CERs value of the CDM project have to charge the capital of the project investment, risk factor and uncertainty of the result in reduction emission, like the type of project, the risks associated with reduction of greenhouse gases and registration as a CDM project, terms of payment, etc, while AAUs does not have capital due to it is the credits that obtain from the Kyoto Protocol commitment [12] and [14].

Price of daily CERs can find out on line in such web site http://www.pointcarbon.com and http://www.emit-markets.com. The secondary price of CERs in the Point Carbon report dated 14 December 2007 was shown in Table 2-4 [15].

Table 2-4 Secondary market CER assessment (€/ton)

	Low	**High**
Dec-08	16.90	17.00
Dec-08-12	16.95	17.05

Source : [15]

2.3.6 The situation of CDM

1) The situation of CDM project implementation in various countries

At this time, there are 864 CDM projects from 49 host countries that were registered from UNFCCC CDM-Executive Board. The details are shown in Figure 2-5 and Table 2-5. Those projects were expected to reduce greenhouse gases emission about 185,473,153 ton CO_2eq/year. India is the countries that most CDM projects were registered that are 296 projects, follow by 137 projects of China, 113 projects of Brazil and 98 projects of Mexico.

Whereas, the first three high investor parties are United Kingdom of Great Britain and Northern Ireland, Netherlands and Japan, as shown in Figure 2-6 [2].

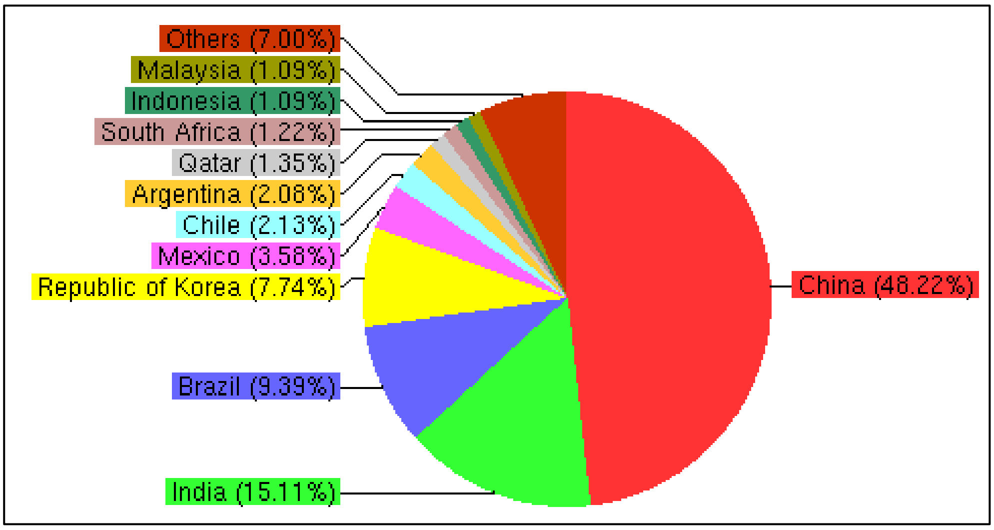


Figure 2-5 Expected average annual CERs from registered projects by host parties

Source : [2]

Table 2-5 : Host countries and number of CDM registered projects on December 7th, 2007

No.	Host party	Number of projects	Average annual Reductions (ton CO_2 eq)
1	Argentina	10	3,851,143
2	Armenia	3	200,998
3	Bangladesh	2	169,259
4	Bhutan	1	524
5	Bolivia	2	224,371
6	Brazil	113	17,413,991
7	Cambodia	1	51,620
8	Chile	21	3,949,929
9	China	137	89,442,323
10	Colombia	6	414,205
11	Costa Rica	5	251,600

Table 2-5 : Host countries and number of CDM registered projects on December 7th, 2007 (Cont.)

No.	Host party	Number of projects	Average annual Reductions (ton CO_2 eq)
12	Cuba	1	342,235
13	Cyprus	2	72,552
14	Dominican Republic	1	123,916
15	Ecuador	9	435,088
16	Egypt	3	1,685,393
17	El Salvador	4	431,303
18	Fiji	1	24,928
19	Georgia	1	72,700
20	Guatemala	5	279,694
21	Honduras	12	229,032
22	India	296	28,020,608
23	Indonesia	11	2,029,430
24	Israel	7	493,638
25	Jamaica	1	52,540
26	Lao People's Democratic Republic	1	3,338
27	Malaysia	21	2,029,199
28	Mexico	98	6,634,124
29	Mongolia	3	71,904
30	Morocco	3	223,313
31	Nepal	2	93,883
32	Nicaragua	3	456,570
33	Nigeria	1	1,496,934
34	Pakistan	1	1,050,000
35	Panama	5	118,702
36	Papua New Guinea	1	278,904
37	Peru	8	869,032
38	Philippines	14	359,718
39	Qatar	1	2,499,649

Table 2-5 : Host countries and number of CDM registered projects on December 7th, 2007 (Cont.)

No.	Host party	Number of projects	Average annual Reductions (ton CO_2 eq)
40	Republic of Korea	16	14,352,204
41	Republic of Moldova	3	47,343
42	South Africa	12	2,259,864
43	Sri Lanka	4	109,619
44	Thailand	5	638,686
45	Tunisia	2	687,573
46	Uganda	1	36,210
47	United Republic of Tanzania	1	202,271
48	Uruguay	1	9,787
49	Viet Nam	2	681,306

Source : [2]

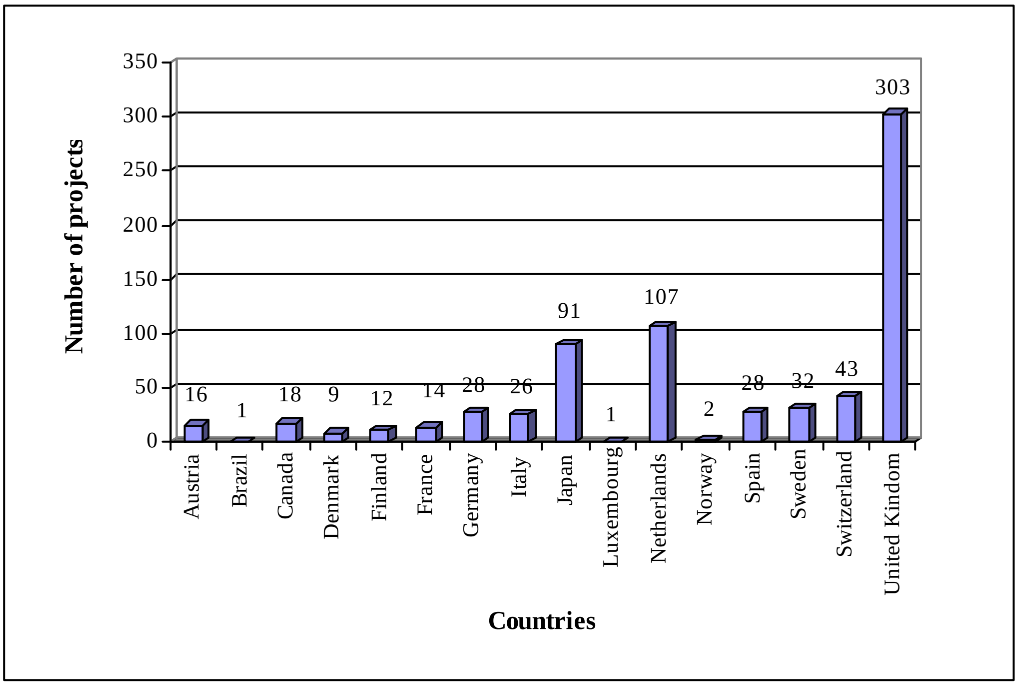


Figure 2-6 Registered CDM projects by Annex I and Non-annex I investor parties

Source : [2]

2) The situation of the CDM project in Thailand

At this time, the Office of Natural Resources and Environmental Policy & Planning, is undertaking the establishing of a Thailand Greenhouse Gas Management Organization (TGM) that would act as the Designated National Authority (DNA) for CDM projects in Thailand [16]. ONEP has drafted the procedure for review of CDM projects and the documents required, as well as the guidelines to be used in the review. At present Thailand's trader had submit 42 projects application to be the CDM project, which were 15 projects of private sector. The Methodology Panel by Executive Board of CDM at Bonn, Germany had approved that15 CDM projects in Thailand can reduce greenhouse gases emission and the reduction were existed at in the Project Design Document (PDD) [17]. They are as follows :

Table 2-6 Projects approved by the Cabinet

No.	Project name	Project developer /Project design consultant	CER buyers	Project type	Project period /Crediting period (years)	GHG reduction per year (ton CO_2eq)	Start date
1	**Dan Chang Bio - Energy COGEN project (DCBC)**	Dan Chang Bio-Energy Co., Ltd. / ERM-Siam Co. Ltd	Denmark	41 MW Electricity from Biomass (bagasse&leaves)	21/10	92,000	1Jan 2005
2	**Phu Khieo Bio-Energy COGEN project (PKBC)**	Phu Khieo Bio-Energy Co., Ltd /ERM-Siam Co. Ltd	Denmark	41 MW Electricity from Biomass (bagasse&leaves)	21/10	99,000	1Jan 2005
3	**Korat Waste to Energy project**	Korat Waste to Energy Co., Ltd. / EcoSecurities	Natherland (IFC)	3 MW Electricity from Starch Industrial wastewater	15/7	374,000	15 May 2003
4	**A.T. Biopower Rice Husk Power project**	A.T. Biopower Co., Ltd./ Clean Energy Finance Co., Mitsubishi UFJ Securities Co. Ltd	Japan, Finland	20 MW Electricity from Biomass	25/7	70,924	21 Dec 2005
5	**Khon Kaen Sugar Power Plant**	Khon Kaen Sugar Industry Public Co., Ltd,	na	30 MW Electricity from Biomass (bagasse)	20/na	45,719	Na

Table 2-6 Projects approved by the Cabinet (Cont.)

No.	Project name	Project developer /Project design consultant	CER buyers	Project type	Project period /Crediting period (years)	GHG reduction per year (ton CO_2eq)	Start date
6	**Ratchaburi Farms Biogas project**	SPM Farm, Veerachai Farm, and Nongbua Farm/ERM UK Ltd	Denmark	3 MW Electricity from pig farm biogas	20/10	100,380	1 Jan 2006
7	**Rubber Wood Residue Power Plant in Yala**	Gulf Electric Public Co., Ltd.	Na	20.2 MW Electricity from Biomass	25/na	60,000	Na
8	**Charoensompong Corporation Rachathewa Landfill Gas to Energy project**	Charoensompong Co., Ltd.	Negotiating	1 MW Electricity from Landfill Gas	15/na	99,100	1 Jan 2005
9	**Waste Water Treatment with Biogas System in a Starch Plant for Energy and Environment Conservation in Chachoengsao**	Sima Interproduct Co., Ltd.	Denmark, 10 years upfront payment at 4.25 USD/ton CO_2 e	Electricity from Industrial Wastewater	20/na	20,300	1 April 2005
10	**Waste Water Treatment with Biogas System in a Starch Plant for Energy and Environment Conservation in Nakornratchasima**	Sima Interproduct Co., Ltd.	Denmark, 10 years upfront payment at 4.25 USD/ton CO_2 e	Electricity from Industrial Wastewater	20/na	21,500	1 May 2005
11	**Surat Thani Biomass Power Generation project**	Surat Thani Green Energy Co., Ltd.	Japan, 8 years upfront payment at 7.5 USD/ton CO_2 e	Electricity from Biomass (Palm)	25/na	171,774	1 July 2005
12	**Chumporn applied Biogas Technology for Advanced Waste Water Management**	Chumporn Palm Oil Industry Public Co., Ltd.	Germany, 10 years upfront payment at 4 EUR/ton CO_2e	Electricity from Industrial Wastewater	20/na	30,028	1 Jan 2006

Table 2-6 Projects approved by the Cabinet (Cont.)

No.	Project name	Project developer /Project design consultant	CER buyers	Project type	Project period /Crediting period (years)	GHG reduction per year (ton CO_2eq)	Start date
13	**Natural Palm Oil Company Limited-1 MW Electricity Generation and Biogas Plant**	Natural Palm Oil Co., Ltd.	Denmark, 10 years upfront payment at 4.25 USD/ton CO_2 e	1 MW Electricity from Industrial Waste Water	15/na	14,480	1 Jan 2006
14	**Northern Starch (1987) Co. Ltd.- Switching**	Northern Starch (1987) Co., Ltd.	Denmark, 10 years upfront payment at 4.25 USD/ton CO_2 e	1 MW Electricity from Industrial Waste Water	20/na	35,420	1 Jan 2006
15	**Surin Electricity Company Limited**	Surin Electricity Co., Ltd.	EU, 10 years upfront payment at 11.61 USD/ton CO_2 e	10 MW Electricity from Biomass (bagasse)	20/na	12,584	15 Jan 2006

Source : [18]

The cabinet of a government has approved the resolution of the National Environmental Board in making Letter of Approval (LoA) to the leader of 7 private sector projects (no.1-7, Table 2-6) on January 30th , 2007 and to the leader of the left 8 private sector projects (no.8-15, Table 2-6)on August 28th, 2007, by granted a permanent Under-Secretary of Ministry of Natural Resources and Environment (MNRE) as the Designate National Authority (DNA) to make the Letter of Approval. Beside the Letter of Approval had the condition that, the authority to the Kyoto Protocol of Thailand could reserve a right to reject the project which had approved the Letter of Approval, that unlawful or does not follow the condition and standard according to the specification of the CDM project (the Department of Environmental Quality Promotion cited in [18]). Furthermore the Office of Natural Resources and

An open lagoon releasing methane gas to atmosphere (insert showing gas bubbles on the lagoon surface).

The CIGAR in the foreground with SWI starch production facility in the background

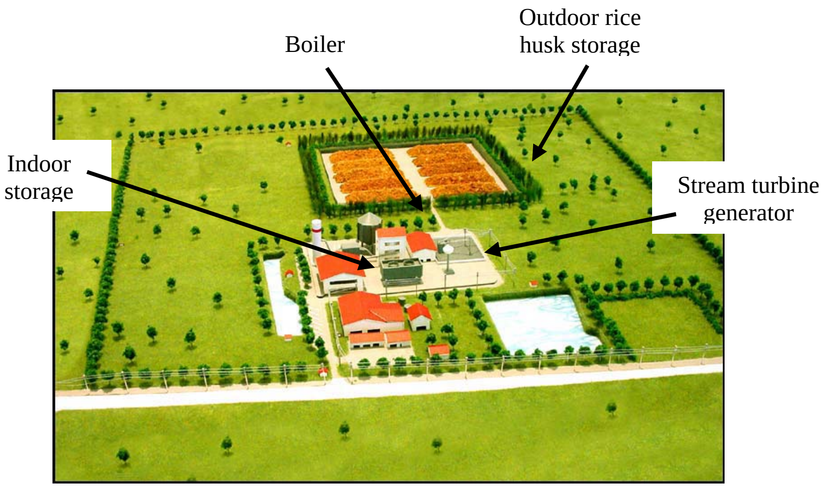
Biogas engines and electricity generators

Raw cassava processing wastewater and after CIGAR treatment (insert)

Figure 2-7 Korat Waste to Energy project at Sanguan Wongse Cassava Starch Industries

Source : [41]

The environmental hazard caused by open-air burning of rice husk before A.T. Biopower Rice Husk Power Project implementation.

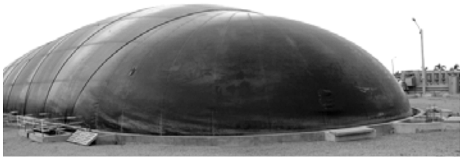


Pichit Plant Site

The plant is located on a 34 hectare site. About half the site is used for plant buildings, equipment, and storage facilities. The rest is used as buffer zones and green space.

Figure 2-8 A.T. Biopower Rice Husk Power Project in Pichit

Source: [42]



Channel digester, Veerachai Farm

Biogas generator sets, Veerachai Farm

Final effluent solids drying bed,
SPM Feedmill Farm

Part of the old open lagoon system,
SPM Feedmill Farm

UASB, Nong Bua Farm

Figure 2-9 Ratchaburi farms biogas project

Source : [43]

Environmental Policy and Planning has collaborated with the King Mongkut's University of Technology Thonburi Joint Graduate School of Energy and Environment (JGSEE), in reviewing the detail of those 15 projects. The conclusion found out that those projects would promote sustainable development in accordance with the standard [17].

2.4 The importance of the Kyoto Protocol and the CDM to Thailand

Thailand is the parties to the UNFCCC and has no commitments for the reduction of greenhouse gases, but would be affected by climate change. As an developing country, Thailand could be assisted from the convention specification, such as knowledge, technology transfer, researching, development, data and information exchange, and sustainable development via clean technologies, The CDM is only one mechanism that provides Annex I and non-Annex I parties the opportunity to jointly implement project that can reduce greenhouse gases emissions [20].

2.4.1 Benefit from the implementation of CDM projects to Thailand

Table 2-7 The benefit of CDM projects

Level	**Environmental Benefit**	**Economic Benefit**	**Social Benefit**
Local Level	- Preservation of environment in the local area where project is being implemented. - Reduction in the amount of waste generated by using it as a catalyst for energy production.	- Project relating to renewable energy will incorporate agricultural products such as palm, coconut, sunflower, jatropha as raw material.	- Improved quality of lives from improved environmental quality. - Provides more choices in conducting business practices that are beneficial to the environment.

Table 2-7 The benefit of CDM projects (Cont.)

Level	Environmental Benefit	Economic Benefit	Social Benefit
Local Level	- Reduction in the use of non-renewable energy.	- Farmers will be able to sell waste material such as sugarcane leaves, rice husks and wood chips for use in CDM projects. - Benefits the local labour market.	
National Level	- Improvement in the general quality of the environment. - Transfer of CDM technology, both at national and international levels	- Products are generated by cleaner production process. - Reduces the dependence on imported energy. - Benefits the national economy. - Tax benefits from the trading of CERs which can be used to offset the costs of funding environmental protection and energy conservation.	- Play a role in the management of a global issue. - Increases the negotiating capacity at the international arena.

Source : [9]

2.5 The emission of the greenhouse gases in Thailand

In 1998, CO_2 was the dominant greenhouse gas that released to the atmosphere about 68% of all greenhouse gases that was emitted, followed by CH_4 and N_2O respectively (as shown in Table 2-8). The energy supply sector was the main activity that released greenhouse gases about 51% of all the greenhouse gases that emitted in

1998, followed by agriculture sector and land-use change and forestry sector as shown in Table 2-9.

Table 2-8 Total emissions of greenhouse gases in Thailand, 1998

Greenhouse gas	Emission (Gg)	GWP	CO_2 equivalent (Gg)	Percentage of total emissions
CO_2	204,292	1	204,292	68
CH_4	3,787	21	79,537	27
N_2O	44	310	13,646	5
HFCs(R-134a)	0.10	1,300	136	0.05
NO_x	275	N/A	N/A	N/A
CO	757	N/A	N/A	N/A
NMVOC	184	N/A	N/A	N/A
Total in CO_2 equivalent			297,611	100

Source : Environmental Resources Management (ERM), 2001cited in [21]

Table 2-9 Greenhouse gases emission from various sectors in Thailand in 1998

Greenhouse gas source and sink categories	CO_2 equivalent (Gg)					Percentage of total emissions
	CO_2	CH_4	N_2O	HFCs	total	
Total emissions	204,292	79,537	13,646	136	297,611	100.0
1. Energy	143,817	7,880	257	-	151,953	51.1
a) Fuel combustion	143,817	23	257	-	144,096	48.4
b) Fugitive emission	-	7,858	-	-	7,858	2.6
2. Industrial process	10,592	24	-	136	10,752	3.6
3. Solvent and other substance	N/A	N/A	N/A	N/A	N/A	N/A
4. Agriculture	-	56,770	12,444	-	69,214	23.3
5. Land-use change and forestry	49,883	711	72	-	50,666	17.0
6. Wastes	-	14,152	874	-	15,026	5.1

Source : Environmental Resources Management (ERM), 2001cited in [21]

2.6 Biogas

Biogas is the product of anaerobic decomposition of organic matter by means of biological treatment, by anaerobic bacteria. It is the gas that non-soluble and lighter than the air [22]. The raw material to be produced biogas is organic matter from agricultural and animal waste, which 80-90% of them will be degraded and change to biogas. The biogas consists of a mixture of gas (as shown in Table 2-10). The notably gas is methane (CH_4), which the volume depend on the composition of the raw materials and the efficiency of the decomposition [23], [24] and [25].

$$\text{Organic matter} + \text{microorganism} \longrightarrow \text{cell} + CO_2 + CH_4 + NH_3 + H_2S$$

2.6.1 The composition of biogas

Table 2-10 The composition of biogas

Composition	Percent		
	[25]	**[26]**	**[27]**
CH_4	50-70	55-80	55-56
CO_2	30-50	15-45	35-45
H_2	0-1	0-1	-
N_2	0-1	0-3	0-8
H_2S	0-1	0-1	0-1
O_2	0-1	0-1	0-1

2.6.2 The properties of biogas [25]

Heat value	21	MJ/m^3 (at 60% of methane)
Ignition velocity	25	cm/s
Theoretical A/F ratio	6.19	m^3a/m^3g
Air burning temperature	650	^0C
CH_4 ignition temperature	600	^0C
Heat capacity (Cp)	1.6	$kJ/m^3\text{-}^0C$
Density (ρ)	1.15	kg/m^3

2.6.3 Biogas use

Biogas can be utilized in many levels, such as household, livestock farm, community even-though in the industries. Agricultural residual and industrial waste can be used to be the raw material of biogas production. The useful of biogas are cooking, lamp lighting [28]. The small group of farm can use biogas as a fuel for gas heating, hatched machine, lighting, small ventilating fan and small engine for farmland [25]. Furthermore Kietkrai Ayuwat and Payom Mookdeepromt had applied biogas to use as the fuel for engine and found out that the engine did not knock and smooth drive the entire test [29].

For agricultural industries, such as big farms, starch processing factory, palm oil mill, canned fruit mill, sugar mill, distillatory mill, slaughter-house and municipal waste can build a big biogas production project which can use for fuel replacement as furnace oil, fuel oil, electricity generation and can also sell to the Thai electricity grid (inform of SPP and VSPP) [25]. While Saeree Tokhem had study the economic return of the swine farm biogas project to replace Liquid Petroleum Gas and electricity, found that the project was worthwhile to invest [30].

In the aspect of the energy alternative by compare with 1 m^3 of biogas, from the data of Nantaphon Sudbantad [28] and the Energy for Environmental Foundation [25] the value are in the vicinity.

Table 2-11 Biogas and the energy alternative

Type of energy/fuel	**Vicinity**	
	[28]	**[25]**
Electricity energy (kW-hr)	-*	1.20
LPG (kg)	0.46	0.46
Fuel oil (grade A) (L)	-*	0.55
Diesel (L)	0.60	0.60
Gasoline (L)	0.67	0.60
Firewood (kg)	1.50	1.50

Remark : -* N.A.

Wastewater and sludge from the biogas production can be used for cultivation. Manas Kampukul and Somchai Chansawang brought wastewater from biogas production to be as nutrient for Chinese vegetable, lettuce, white greens and sunflower by mixed with the chemical fertilizer in these ratio 75 : 25 and 50 : 50. The result found out that it was effective in Chinese vegetable and sunflower, while lettuce and white greens had the same output [31]. The remaining sludge had high nutrient and can be utilize as fertilizer and also effective than cow manure [25]. Besides Somchai Chansawang and Wanee Chaiwattanasin had studied the efficiency of the biogas production for producing electricity, found out that fermented swine manure had higher nutrient. The anaerobic fermentation could reduce COD than aerobic fermentation 95% [32].

For the utilization of the biogas that mentioned above, biogas can also be raw material for chemical industry such as, acetylene, carbon disulphide, carbon tetrachloride, hydrogen cyanide, methyl chloride and methylene chloride but still not worth in economic return [25].

Niran Potikanon and Ulrich Stoehr-Grabowski have also said that biogas system could reduce the emission of greenhouse gases. If we could use biogas as much as possible, it would help the global warming problem and would slow down the increasing of CO_2 from the petroleum energy and the excavated gas [33].

2.7 Cassava starch and palm oil industries

2.7.1 Cassava starch industry in Thailand

In Thailand, there are 3 kinds of tapioca starch industries, which are Native Starch Industry, Modified Starch Industry and Starch Derivatives Industry. The Native Starch is the raw material of Modified Starch Industry and Starch Derivatives Industry, thus most of both industries will firstly produce Native Starch.

Native Starch Industry uses much of water in the process and also generates high organic loading wastewater, which are from root washing, root rasping and extraction process. In producing 1 ton of native starch will generate 10-20 m^3 of wastewater, which has BOD about 55-200 kg, COD about 130-400 kg, suspended solid about 40-140 kg, total phosphorus about 0.2-0.6 kg and total nitrogen about 3-10 kg. The organic loading is equivalent to the load generated by a population of 920-3,400 people. In general, 1 Native Starch processing mill has the production capacity 100-200 ton/day, so it generate wastewater equivalent to 92,000-680,000 people [34] and [35].

According to its high organic loading of wastewater, using anaerobic wastewater treatment technology to convert the organic to biogas is another option for the mill. In the past stabilization pond were regularly found, which consist of anaerobic pond, facultative pond, and maturation pond. Biogas from anaerobic pond was unused. Nowadays, some of the Native Starch processing mill has brought the biogas system to the mill to reduce the energy expense and reduce water pollution. Generally Native Starch processing generate wastewater in terms of COD around 20,000-25,000 mg/L hence 1 m^3 of wastewater (at 80% of the system efficiency) can produce 8-10 m^3 of biogas, which 1 m^3 of biogas is equivalent to 0.6 L if furnace oil [35].

2.7.2 Palm Oil Industry in Thailand

More than 98% of oil palm planting area is in the south of Thailand. The province that has most oil palm planting area are Krabi, Suratthani, Chumporn, Trang Satun and Songkhla respectively [36], so the palm oil industry is also in the south too. 80% of fresh fruit bunches will be fed to the factories that have standard oil extracting process (normally called the wet process) and the 20% left will be supplied to the dry process [38]. At present, there are 38 standard process mills, which have a milling capacity over 1,610 tons of fresh fruit bunches per hour (the Department of Alternative Energy Development and Efficiency (DEDE) and GTZ cited in [37]).

There are various forms of solid and liquid wastes from the mill, which is more than 60% of the supplying raw material. The environmental impact is caused from the oil extraction process, such as sterilization, kernel separation, oil decanting [37]. Besides, palm oil industries consume much of water; hence have much wastewater discharge too. From the study of the Industrial Technology Bureau about the oil separation from oil palm mills effluent from the standard oil extracting process, found out that 1 ton of fresh fruit bunch would generate 1 m^3 of wastewater [38]. The result of the Department of Industrial Works' study indicated that the high organic load of wastewater in terms of BOD was about 30,000 mg/L, COD about 90,000 mg/L and suspended solid about 34,000 mg/L. Alternatively, the treatment should be carried out in a reactor in which the biogas is obtained. In the past, stabilization pond was regularly found, which compose of anaerobic pond, facultative pond and maturation pond. The biogas which was produced from anaerobic process never been utilized [37].

In general, the potential of biogas production is 12-16 m^3/ m^3 effluent. This biogas production can generate electricity and sell to the Electricity Generating Authority of Thailand, which is about 1-1.2 unit/ m^3 of biogas. The worth of the effluent is 29-39 baht/ m^3 effluent (the hypothesis at 70% in peak and 30% off peak and the cost is 2.44 baht/unit of electricity) [37].

Table 2-12 The sample of wastewater characteristic from the industrial process

Source / Parameters	Flour Mill Wastewater	Palm Oil Mill Wastewater	Pig Farm Wastewater	Sugar Mill Wastewater	Alcohol Plant Wastewater
pH	4.40	4.6	7.0-8.0	5.16	4.80
COD_t (mg/l)	19,011	73,340	18,000	N/A	134,350
BOD_5 (mg/l)	12,180	35,000	9,000	1,700	40,400
TKN (mg/l)	347	N/A	700	N/A	2,029
TDS (mg/l)	N/A	N/A	N/A	504	N/A
TSS (mg/l)	3,785	N/A	N/A	N/A	N/A
VSS (mg/l)	3,330	N/A	N/A	N/A	N/A
SS (mg/l)	N/A	33,400	16,000	118.50	6,560
Alkalinity (mg/l)	312	N/A	N/A	N/A	2,078

Table 2-12 The sample of wastewater characteristic from the industrial process (Cont.)

Source / Parameters	Flour Mill Wastewater	Palm Oil Mill Wastewater	Pig Farm Wastewater	Sugar Mill Wastewater	Alcohol Plant Wastewater
Volatile Fatty Acid (mg/l)	2,532	N/A	N/A	N/A	N/A
Oil and Grease (mg/l)	N/A	5,000	N/A	N/A	N/A
Ammonia (mg/l)	32.04	N/A	N/A	N/A	N/A
Sulfide (mg/l)	N/A	N/A	N/A	N/A	N/A
Total Phosphorus (mg/l)	N/A	N/A	N/A	N/A	N/A

Source : [39]

Wastewater is the problem of cassava starch industry and palm oil industry. The effluent has to meet the effluent discharge standard before released to the river. Most of them were treated in the open pond, which the fermented biogas was emitted to the atmosphere. Anaerobic digestion with the reactor in which the biogas is obtained is an effective method for treatment of wastewater with high organic content. This method is useful in many ways, such as the utilization of biogas as a source of energy in the factory which will save the operation cost, reduce the emission of greenhouse gases and the effluent quality is also better.

Table 2-13 The potential of biogas production from various sources of wastewater

Source	Volume of wastewater (m^3)	The potential of biogas production (m^3)
Swine farm	1	3.5
Sugar mill	1	7.0
Ethanol mill	1	35.0
Starch mill	1	10.0
Palm oil mill	1	35.0

Source : [40]

At present, Thailand has many biogas system which depend on source and volume of wastewater, like biogas system from municipal solid waste, biogas system from livestock and biogas system from agricultural industry. Now, the cassava starch industry and palm oil industry treat wastewater by anaerobic treatment system in which biogas is obtained, for example UASB system, HSS-UASB system, ABR system and AFF system for the cassava starch mill and CSTR system for the palm oil mill [25].

The Energy for Environment Foundation has designed the wastewater treatment system to a big starch processing factory that has production capacity 550 ton flour/day. The system is Anaerobic Baffled which consists of fermentative pond and covered with HDPE. The produced biogas can be utilized 70,000 m^3/day which is equivalent to the energy from 35 m^3 of furnace oil and is worth 280,000 baht/day or equivalent to 417,000 unit of electricity [25]. Whereas Korat Waste To Energy (KWTE) Company has designed and constructed the Covered In-Ground Anaerobic Reactor (CIGAR) which is the wastewater to energy plant to Sanguan Wongse Industries (SWI). This factory is one of Thailand's largest producers of cassava starch, accounting for about 12% of Thailand's national total of 1.8 to 2.0 million tons per annum. The plant was built by KWTE at no cost to SWI, and an agreement was negotiated with SWI for them to purchase the biogas and the electricity at discounted rates. KWTE has also implemented these as a project under the Clean Development Mechanism, because it can reduce greenhouse gases emission and the reduction units can be the Certified Emission Reductions (CERs). SWI's factory was producing about 550 tons of starch per year. The CIGAR could produce biogas 80,000 m^3/day, which was used to heat the starch dryers and generated electricity from the balance of the biogas not required to heat that starch dryers. The waste to energy plant already replaces the entire factory's heavy oil consumption and 62% of its electrical energy needs. In addition to its obvious economic and environmental benefits the plant can reuse the treated process water for irrigation or be further treated as industrial water source, use the biomass recovered from the CIGAR as a fertilizer or soil conditioner, bring back the previously comprised over 200 hectares of lagoons and channels into agriculture or re-established as building sites [41].

The old open lagoon which caused fugitive emission of CH_4

Wastewater, separator and root washing water

Biogas collecting set and water drain system on A+UASB th

Sediment drying bed to be used as fertilizer

Electricity generator

Figure 2-10 The implementation of biogas system in cassava starch production industry

Source : [44]

For palm oil mill, The Energy for Environment Foundation has set out a suitable anaerobic wastewater treatment plant to palm oil mill in Krabi. The production capacity of the mill is 40 tons fresh fruit bunches/hour which generate 190 m^3 of wastewater/day. The system can produce biogas 3,600 m^3/day and can be a source of fuel to electricity generator. The generated electricity is about 1,944,000 unit/year that is help to reduce the electrical cost at 4.86 million baht/year. While at palm oil mill in Suratthani province, The Energy for Environment Foundation has developed the CSTR which is would obtain biogas. The system can support from the palm oil extraction process 300 m^3/day or 90,000 m^3/year and gain 4,500-6,000 m^3 biogas/day. The biogas production can replace furnace oil, cooking gas or generate electricity by 300-400 kW power plant which can produce 2.4-3.2 million unit of electricity/year, furthermore it can be sold to the Electricity Generating Authority of Thailand (EGAT) under a Very Small Power Producer (VSPP) Program (capacity less than 1 MW) which is equal to 4.8-6.4 million Baht/year. The dried residual can use as the fertilizer [25].

From the data reviewing, it can indicate that cassava starch industry and palm oil industry have a potential in biogas production and from the subtopic 2 of topic 2.3.6, most of implemented Clean Development Mechanism project in Thailand are the utilized of biogas as a source of fuel and electricity generation. Those projects will effect in the reduction of methane emission, which is a potent greenhouse gas that is 21 times more powerful than carbon dioxide. Moreover the project leader can sell the reduction units of greenhouse gas as CERs and can assist Annex I countries to meet their emission target. The researcher aim to study the agriculture product of cassava and oil palm, the potential of both industries toward greenhouse gases emission reduction, the amount of generated electricity and the value of CERs.

The old open lagoon
for wastewater treatment

Wastewater from Crude Palm Oil
(CPO) processing

Cooling ponds

A+CSTR th biogas system, 6,000 m^3

Biogas cleaning system

Automatic flare system

Figure 2-11 The implementation of biogas system in palm oil industry

Source : [45]

2.8 Relevant researches

2.8.1 Related researches about Clean Development Mechanism (CDM)

Sima Sanrak studied on the feasibility of reforestation project under the Clean Development Mechanism (CDM) from the Kyoto Protocol, by estimating the cost of teak reforestation and mangrove reforestation using different spacing, and had studied on the attitude of local people toward reforestation project participation. The result showed that the cost of plantation teak in difference spacing was not the same. The present total cost for teak plantation with the 4x4 m spacing was 12,282.35 Baht/rai, 3x3 m was 12,851.99 Baht/rai, and 2x4 m was 12,996.02 Baht/rai. For the attitude of local people at Tambon Rabum, Lansak Districk, Uthai province, 33% of them were interested in the participating in this project. The present value of total for growing mangrove forest with the 1x1 m spacing was 7,267.9 Baht/rai, 1.5x1.5 m was 5,742.18 Baht/rai, and 1x2 m was 5,896.47 Baht/rai. Local people at Tambon Takienthong, Kanchanadit district, Suratthani province interested in joining the project 73.2% [46].

Tanapoom Chanprapai researched about the economic return from *Rhizophora apiculata (R. apiculata)* plantations for conservation and commercial purposes. The *R. apiculata* plantation for conservation purposes provided benefits only from carbon storage value but *R. apiculata* plantation for commercial purposes provided benefit from 3 patterns of wood use: 100% charcoal production, 99% charcoal production plus 1% construction material, and 100% construction materials, including carbon storage value. By evaluated the storage value at 2,000 and 4,000 Baht/CO_2e for minimum and maximum rate. The research showed that the *R. apiculata* plantation for conservation purposes had a net economic return of less than for commercial purposes. The *R. apiculata* plantation for conservation purposes had the minimum and maximum present value of net economic return in the 30th year at -33,030 to -6,905 Baht/ha and -28,917 to -29,581 Baht/ha respectively. For commercial purpose, type 3 gave the most economic return at 900,321 to 1,765,511 and 1,358,105 to 2,665,357 Baht/ha for the minimum and maximum rate. The 100% construction material, which was the commercial purposes, had the highest carbon storage at 138.78 tC/ha [47].

Halsnæs, K. estimated the potential demand and supply of GHG emission reduction projects with a main emphasis on the supply of CDM projects from developing countries (DCs). It is concluded that the demand for GHG emission reduction projects from Annex B countries, including domestic actions in Annex B countries, JI projects, emission trading and CDM projects in total will be between about 500 and 1300 Mt C in 2010. The demand for CDM projects supplied by DCs will most likely not be very large compared with the total future GHG emissions in these countries according to recent scenario work undertaken by the IPCC. National studies for DCs have concluded that GHG emission reductions in the energy sector in the order of magnitude of 10-15% of future baseline emissions can be achieved for a cost below $25 per ton of CO_2 [48].

Krey, M. carried out the study from an empirical survey designed to quantity transaction costs of potential non-sink CDM projects in India. An assessment of the results showed that specific transaction costs depend, to a large extent, on economies of scale in terms of total amount of CERs generated over the crediting period. Total transaction costs were quantified for seven projects. The costs range from 0.07 to 0.47 $US/t CO_2. As the projects have an emission reduction between 0.24 Mt CO_2 and 5.00 Mt CO_2 over the crediting period, the results support the assumption of Michaelowa et al. (Climate Policy 3 (2003) 273) that projects with emission reductions smaller than 0.20 Mt CO_2 are not economically viable at current CER prices [49].

Jung, M. studied about CDM host countries which were attracted for CDM non-sink project by using cluster analysis. The attractiveness of host countries for CDM non-sink projects is described by three indicators: mitigation potential, institutional CDM capacity and general investment climate. One hundred and fourteen host countries for which the respective data was available are included in the analysis. The result suggest that only a small proportion of potential host countries will attract most of the CDM investment. The CDM (non-sink) stars are China, India, Brazil, Argentina, Mexico, South Africa, Indonesia and Thailand. They are followed by attractive countries like Costa Rica, Trinidad and Tobago, Mongolia, Panama, and Chile. While most of the promising CDM host countries are located in Latin America and Asia [50].

Timilsina, G.R. and R.M. Shrestha had analyzed the general equilibrium effects of a supply side GHG mitigation option – the substitution of thermal power with hydropower - in Thailand under the CDM. A static multi-sector general equilibrium model has been developed for the purpose of this study. The key finding of the study is that the substitution of electricity generation from thermal power plants with that from hydropower plants would increase economic welfare in Thailand. The supply side option would, however, adversely affect the gross domestic product (GDP) and the trade balance. The percentage changes in economic welfare, GDP and trade balance increase with the level of substitution and the price of certified emission reduction (CER) units. Furthermore the substitution helps reduce harmful atmospheric emissions such as SO_x and NO_x which are the main environmental concerns in Thailand [51].

Diakoulaki, D. et al. investigated the prospects for the exploitation of the Kyoto Protocol's Clean Development Mechanism (CDM) in Greece. The paper is addressing 3 questions: in which country, what kind of investment, with which economic and environmental return? The proposed approach is based on a multi criteria analysis for identifying priority countries and interesting investment opportunities in each priority country. These opportunities are then evaluate through a conventional financial analysis in order to assess their economic and environmental attractiveness. To this purpose, the IRR of a typical project in each investment category is calculated by taking into account country-specific parameters, such as baseline emission factors, load factors, costs, energy prices etc. The results reveal substantial differences in the economic and environmental return of different types of projects in different host-countries and the obtained results show that the electricity generation sector offers quite promising investment opportunities most of the examined countries. The performed sensitivity analysis shows that among the several uncertain parameters, the value of CERs in the carbon market and the baseline emission factor, have a relatively minor impact on the project's profitability. On the contrary, load factors, electricity tariffs and investment costs – thus the major parameters of financial return outside the CDM – appear as the most crucial factors for the realization and viability of the projects. So the full exploitation of the CDM a multifaceted approach to decision-making is necessary [52].

2.8.2 Related researches about biogas

Kivaisi, A.K. and M.S.T. Rubindamayugi estimated about the potential of agro-industrial residues for production of biogas and electricity in Tanzania. The results showed that Tanzania generates a total or 468,100 tons organic matter from coffee, sisal, sugar and cereal residues annually. Laboratory scale determinations of methane yield from the residues gave 400 m^3 CH_4/ton VS of sisal production wastewater; 650 m^3 CH_4/ton VS of Robusta coffee solid waste; 730 m^3 CH_4/ton of Arabica coffee solid waste; 230 m^3 CH_4/ton VS of sugar filter mat and 450 m^3 CH_4/ton VS maize bran. Based on these results the estimated total annual potential electricity production from these residues is 1,135 million kW-hr. The total oil substitution from these residues has been estimated at 0.32 million tones crude diesel oil per annum equivalent to 2% of the total energy consumption in Tanzania. Case studies on the coffee and sisal processing factories indicate that exploitation of the residues for the production of electricity on site these factories is feasible. Utilization of agro-industry residues for biogas production has a big potential for reduction of environmental pollution. The potential substitution of fossil fuel with biogas represents an annual reduction in the net CO_2 emission to the atmosphere of approximately 1.05 million tons. By treating the residues in controlled anaerobic systems it is possible to reduce the methane emission by about 189 million m^3, and at the same time reduce contamination of surface and ground waters [53].

Yacob, S. et al. found out that in Malaysia, palm oil industry particularly from palm oil mill effluent (POME) anaerobic treatment has been identified as an important source of CH_4. However, there is no study to quantify the actual CH_4 emission from the commercial scale wastewater treatment facility. Hence, this paper shall address the CH_4 emission from the open digesting tanks in Felda Serting Hilir Palm Oil Mill. CH_4 emission pattern was recorded for 52 weeks from 3600 m^3 open digesting tanks. The findings indicated that the CH_4 content was between 13.5% and 49.0% which was lower than the value of 65% reported earlier. The biogas flow rate ranged between 0.81 $min^{-1}m^{-2}$ and 9.81 $min^{-1}m^{-2}$. Total CH_4 emission per open digesting tank was 518.9 kg day^{-1} [54].

Fujino, J et al. study on bioenergy potential of livestock residue in Japan, the study showed that the bioenergy was estimated to be 167 PJ in the year 2000. This is equivalent to about 0.7% of total primary energy supply. Biogas production with methane fermentation and burning poultry residue at power plants can produce 4.1 TWh of electricity and 46 PJ of heat. The amount of CO_2 substitution for fossil fuels is 6.9 Mt-CO_2. This corresponds to about 0.6% of total CO_2 emission in 1990. This also has an additional effect of reducing other greenhouse gas (CH_4 and N_2O) emissions from conventional treatment of livestock residue [55].

Prasertsan, S. and B. Sajjakulnukit's research presented biomass and biogas energy situation in Thailand. From the data in 1997 the amount of agricultural residues is about 61 million ton a year, of which 41 million ton, which is equivalent to about 426 PJ of energy, was unused. The most promising residues are rice husk, bagasse, oil palm residue and rubber wood residue, merely due to their availability at the mills, which heat-power cogeneration is feasible. Biogas resources are from industrial wastewater and live stocks manure, which have potential of 7800 and 13,000 TJ/year, respectively. The first four high potential industries were starch, sugar, distillery and monosodiumglutamate production, respectively and for the livestock, cattle residues show the highest energy potential [56].

Chinnaraj, S. and G.V.Rao undertook the study on the implementation of an UASB (Upflow anaerobic sludge blanket) anaerobic digester at bagasse-based pulp and paper industry. When replace the conventional anaerobic lagoon with the UASB anaerobic digester, 80-85% COD reduction was achieve with biogas production factor of 520 L kg^{-1} COD reduced. In 11 months 4.4 million m^3 of biogas was generated from bagasse wash wastewater utilizing UASB process. Utilization of the biogas in the Lime Kiln saved 2.14 ML of furnace oil in 9 months. Besides significant economic benefits, furnace oil saving reduced 6.4 Gg CO_2 emission from fossil fuel and conversion of the anaerobic lagoon into anaerobic reactor reduced 2.1 Gg methane emission which is equal to 43.8 Gg of CO_2 [57].

CHAPTER 3
METHODOLOGY

3.1 Data collection

This research was carried out in term of analytical research. Thus the main data were the assembling of primary and secondary data source of the Department of Industrial Works, the Provincial Industry Office, the Pollution Control Department, the Department of Alternative Energy Development and Efficiency, Energy & Eco-Efficiency in Agro-Industry (E3Agro Project), the Energy for Environment Foundation, the Center for Agricultural Information Office of Agricultural Economics and the Department of Internal Trade. The methodologies of the study were as follows:

3.2 Population and sample size

Population : 86 cassava starch mills and 53 palm oil mills as following to the list of the Department of Industrial Works on March 27th, 2007

Sample size : purposive sampling method was selected for this research, which was based on as the following

- cassava starch mills with the producing capacity at least 50 ton flour/day
- palm oil mills with the producing capacity at least 20 ton FFB/hour

Because of the data from the Energy for Environment Foundation found that these producing capacity were the least for constructing biogas system. Therefore the population and sample size were as follows:

-	Cassava starch mills	= 86	sample size	=	81
-	Palm oil mills	= 53	sample size	=	39

3.3 Methods

3.3.1 Data collecting

The data were collected from the following sources:

Table 3-1 Source of the data

Data	Industry	
	Cassava starch	**Palm oil**
wastewater treatment system	• mills • the Provincial Industry Office • CDM project design document • the Pollution Control Department (PCD)	• the Provincial Industry Office • CDM project design document • the Pollution Control Department (PCD)
production capacity	• mills • the Provincial Industry Office • CDM project design document • the Energy for Environment Foundation	• the Provincial Industry Office • CDM project design document • the Energy for Environment Foundation • the Department of Internal Trade

Furthermore, other data were obtained by the gathering the data from relevant documents as from the source mentioned above, Baseline and monitoring methodologies, and CDM project design document, researches, and reports.

3.3.2 Analysis

The analysis of crop utilization, biogas production, volume and value of electricity, volume and value of CERs were as follows:

1) Crop utilization analysis

Crop utilization was to determine that the crop yield of fresh cassava roots and fresh fruit bunches were enough for the production potential or not and also to look for the proportion of crop yield that fed to both industries. The crop utilization of both industries were analyzed by comparing the feeding crop to the production process of both industries and the crop yield, as the following equation.

$$\text{Crop utilization ratio} = \frac{\text{Total production capacity of each industry (ton)}}{\text{Total crop yield (ton)}} \qquad \textbf{....(3-1)}$$

Where as:

Parameter	Cassava starch industries	Palm oil industries
Total production capacity of each industry	Total production capacity in form of fresh cassava roots of 81 cassava starch mills	Total production capacity in form of FFB of 39 palm oil mills
Total crop yield	Total fresh cassava roots production in 2007	Total FFB production in 2007

2) Biogas production analysis

- Wastewater production analysis

Wastewater production was estimated by using the cassava starch production (ton) or volume of fresh fruit bunches (ton) (that feed to the process), as the following equation.

$$\text{Wastewater (m}^3\text{/year)} = \text{a (ton/year)} \times \text{b (m}^3\text{/ton)} \qquad \textbf{....(3-2)}$$

Where as :

Parameter	Cassava starch industries		Palm oil industries	
	Description	**Value/unit**	**Description**	**Value/unit**
a	Ton of cassava starch production	ton flour/year	Ton of palm oil production in form of FFB	ton FFB/year
b	Rate of wastewater per ton of cassava starch production	17.80[a] m^3/ton flour	Rate of wastewater per ton of palm oil production	0.82[b] m^3/ton FFB

Remark: a and b see appendix A

- Biogas production analysis

Biogas production was estimated by using the calculated wastewater from the equation above, as the following equation.

$$\text{Biogas } (m^3/\text{year}) = c\ (m^3/m^3) \times \text{Wastewater } (m^3/\text{year}) \qquad \textbf{….(3-3)}$$

Where as :

Parameter	Cassava starch industries		Palm oil industries	
	Description	**Value/unit**	**Description**	**Value/unit**
c	Biogas production rate from cassava starch industry wastewater	9.50[c] m^3/m^3 wastewater	Biogas production rate from palm oil industry wastewater	13.00[d] m^3/m^3 wastewater
Wastewater	Wastewater production of cassava starch industry	m^3/year	Wastewater production of palm oil industry	m^3/year

Remark: c and d see appendix A

3) Volume and value of electricity analysis

- Volume of generating electricity

In this estimation, the volume of biogas from equation (3-3) will be used to calculate. The calculation was as the following equation.

$$\text{Electricity (unit/year)} = \text{Biogas}(m^3/\text{year}) \times 1.20(\text{unit}/m^3) \quad \textbf{....(3-4)}$$

Where as :

Parameter	Cassava starch industries		Palm oil industries	
	Description	Value/unit	Description	Value/unit
Biogas	Biogas production of cassava starch industry	m^3/year	Biogas production of palm oil industry	m^3/year
1.20 (unit/ m^3)	The generating electricity per 1 m^3 of biogas	1.20 unit/ m^3 [25]	The generating electricity per 1 m^3 of biogas	1.20 unit/ m^3 [25]

- Electricity valuation analysis

$$\text{Electricity value(Baht/year)} = \text{Electricity(unit/year)} \times \text{Price per unit (Baht/unit)} \quad \textbf{....(3-5)}$$

Where as :

Parameter	Cassava starch industries		Palm oil industries	
	Description	Value/unit	Description	Value/unit
Electricity	Volume of generating electricity of cassava starch industry	unit/year	Volume of generating electricity of palm oil industry	unit/year
Price per unit	The price per unit of electricity	2.50 Baht/unit [84]	The price per unit of electricity	2.50 Baht/unit [84]

4) Volume and value of greenhouse gas (CERs) analysis

- Greenhouse gas emission reduction analysis

In this research the volume of greenhouse gas emissions reduction (CERs) will be estimated by assuming that the CDM projects were implemented and would reduce greenhouse gas emission 80% of baseline process (from the reviewing of CDM project design document, see appendix B) and in the greenhouse gas volume estimation, only methane will be estimated (from the reviewing of Revision to the approved baseline methodology AM0013 version 04 "Avoided methane emissions from organic waste-water treatment"[58]). The calculation was as the following equation.

$$CH_4 \text{ reduction (kg/yr)} = \text{Total COD (kgCOD/yr)} \times B_0 \text{ (kgCH}_4\text{/kgCOD)} \times MCF \times 0.80 \quad \textbf{....(3-6)}$$

Source : Applied from [58]

Where as :

Parameter	Cassava starch industries		Palm oil industries	
	Description	**Value/unit**	**Description**	**Value/unit**
Total COD	Total COD per year of cassava starch industry wastewater	kgCOD/yr	Total COD per year of palm oil industry wastewater	kgCOD/yr
B_0	Maximum methane producing capacity of the wastewater	0.21 $kgCH_4/kgCOD$ [58]	Maximum methane producing capacity of the wastewater	0.21 $kgCH_4/kgCOD$ [58]
MCF	Methane conversion factor that express what proportion of the effluent would be anaerobically digested	0.738 [58]	Methane conversion factor that express what proportion of the effluent would be anaerobically digested	0.738 [58]

The amount of carbon credit was only calculated in relation to ton of carbon dioxide equivalents. Thus the calculation had to calculate methane in form of ton of carbon dioxide equivalents, by the following equation.

$$CO_2 \text{ (ton/year)} = \frac{21 \times CH_4 \text{ (kg/yr)} \times 1 \text{ (ton)}}{1000 \text{ (kg)}} \quad \text{….(3-7)}$$

Where as :

Parameter	Cassava starch industries		Palm oil industries	
	Description	**Value/unit**	**Description**	**Value/unit**
21	Global warming potential of methane	21 (Climate Change 1995, IPCC Second Assessment Report cited in [8])	Global warming potential of methane	21 (Climate Change 1995, IPCC Second Assessment Report cited in [8])
CH_4	CH_4 reduction from cassava starch industry	kg/year	CH_4 reduction from palm oil industry	kg/year
1/1000	The conversion factor of kg to ton	1ton/1000 kg	The conversion factor of kg to ton	1ton/1000 kg

- Greenhouse gas valuation analysis (CERs value)

$$\text{CERs (Baht/year)} = CO_2 \text{ (ton/year)} \times d \text{ (Baht/ton)} \quad \text{….(3-8)}$$

Where as :

Parameter	Cassava starch industries		Palm oil industries	
	Description	**Value/unit**	**Description**	**Value/unit**
CO_2	Greenhouse gas emission reduction from cassava starch industry in form of ton CO_2/year	ton /year	Greenhouse gas emission reduction from cassava starch industry in form of ton CO_2/year	ton /year

Parameter	Cassava starch industries		Palm oil industries	
	Description	**Value/unit**	**Description**	**Value/unit**
d	Price per unit of CERs	153.24[e] Baht/CERs	Price per unit of CERs	153.24[e] Baht/CERs

Remark: e- the average price of CDM project design document no. 9, 10, 12, 13, 14 in topic 2.3.4, see Appendix C

3.3.3 The potential comparison of cassava starch and palm oil industries

- Compare biogas production of both industries (m^3/year, m^3/ harvested area, m^3/ton product, m^3/ton raw material)
- Compare greenhouse gas reduction of both industries (ton CO_2eq/year, ton CO_2eq of anaerobic system/year, ton CO_2eq/ harvest area, ton CO_2eq/ ton product, ton CO_2eq/ ton raw material)
- Compare value of greenhouse gas reduction (CERs) of both industries (million Baht/ year, million Baht of anaerobic system/year, Baht/harvested area (rai), Baht/ton product, Baht/ton raw material)
- Compare volume of electricity of both industries (unit/year)
- Compare value of electricity of both industries (million Baht/year)

CHAPTER 4
RESULTS AND DISCUSSIONS

The study on greenhouse gas reduction from Clean Development Mechanism in cassava starch and palm oil industry, were hereby examined by gathering the primary and secondary data. The results and discussion of the analysis were organized as the following topics:

4.1 Collected data
4.2 Crop utilization and production analysis
4.3 The estimation of biogas and electricity production
4.4 The estimation of volume and value of CERs
4.5 The potential comparison of cassava starch and palm oil industries
4.6 Discussion

4.1 Collected data

4.1.1 Cassava starch mills

The wastewater treatment data was obtained from the mills, CDM project design document and the Provincial Industry Office. As for the production capacity of cassava starch, the data was obtained from the mills, the Provincial Industry Office and the Energy for Environment Foundation, as shown in Table 4-1 and 4-2. According to the data from the Provincial Industry Office was the permission data to run the mills, so they might not be the exactly production capacity, thus in this study the data from the mills and the Energy for Environment Foundation were applied. As the result of both data sources the production capacity was in form of ton flour/day, so it had to be converted into form of ton flour/year by multiplying with 273 days/year [59].

Table 4-1 The collected data in each province of cassava starch industry

Province	Number of sample	Number of collected sample
Chachoengsao	3	3
Chaiyaphum	3	2
Chantaburi	3	3
Chonburi	4	4
Kalasin	8	8
Kamphaengphet	9	7
Kanchanaburi	1	1
Khonkaen	2	1
Loei	2	1
Lopburi	1	1
Mahasarakham	2	2
Nakhonratchasima	19	15
Ratchaburi	2	2
Rayong	12	7
Roiet	1	1
Sakaeo	2	2
Saraburi	1	1
Sisaket	1	1
Udonthani	2	2
Uthaithani	2	2
Uttaradit	1	1
Total	**81**	**67**
Percentage	**100**	**82.72**

The wastewater treatment system data of cassava starch mills were collected 67 mills from 81 mills (sample size), which was equal to 82.72%. The first four high provinces in number of cassava starch mills from the collected samples were Nakhonratchasima, Kalasin, Rayong and Kamphaengphet respectively, while from the real samples were Nakhonratchasima, Rayong, Kamphaengphet and Kalasin respectively (Table 4-1).

Table 4-2 The production and wastewater treatment system of cassava starch mills.

Province	Biogas system		No biogas system			
	Biogas system (mill)	Capacity (ton flour/year)	Anaerobic system (mill)	Capacity (ton flour/year)	Aerobic system (mill)	Capacity (ton flour/year)
Chachoengsao	2	90,000	1	72,000	-	-
Chaiyaphum	1	200,000	1	54,600	-	-
Chantaburi	1	90,000	2	27,300	-	-
Chonburi	1	65,520	3	109,200	-	-
Kalasin	6	177,450	2	68,250	-	-
Kamphaengphet	3	53,235	4	128,150	-	-
Kanchanaburi	-	-	1	27,300	-	-
Khonkaen	1	27,300	-	-	-	-
Loei	1	21,840	-	-	-	-
Lopburi	-	-	1	39,270	-	-
Mahasarakham	-	-	2	109,200	-	-
Nakhonratchasima	12	889,280	2	70,980	1	16,380
Ratchaburi	1	95,550	1	6,000	-	-
Rayong	1	81,900	2	40,950	3	109,200
Roiet	2	54,600	-	-	-	-
Sakaeo	2	95,550	-	-	-	-
Saraburi	1	40,950	-	-	-	-
Sisaket	-	-	1	16,380	-	-
Udonthani	-	-	2	40,950	-	-
Uthaithani	2	97,300	-	-	-	-
Uttaradit	-	-	1	13,650	-	-
Total	**37**	**2,080,475**	**26**	**824,180**	**4**	**125,580**
	67 mills 3,030,235 ton flour/year					

The collected data from cassava starch mills were: 37 mills of biogas system with the production capacity 2,080,475 ton flour/year, 26 mills of anaerobic system with the production capacity 824,180 ton flour/year and 4 mills of aerobic system with the production capacity 125,580 ton flour/year. For the production capacities of 30 mills with no biogas system (anaerobic system and anaerobic system) were 949,760 ton flour/day. The total production capacity of 67 mills was 3,030,235 ton flour/year, as shown in Table 4-2. The total production capacity of 81 mills was 3,313,595.00 ton flour/year, whereas the production of Thailand in 2006 was 3,534,472.83 ton flour (the Thai tapioca starch association cited in [79]).

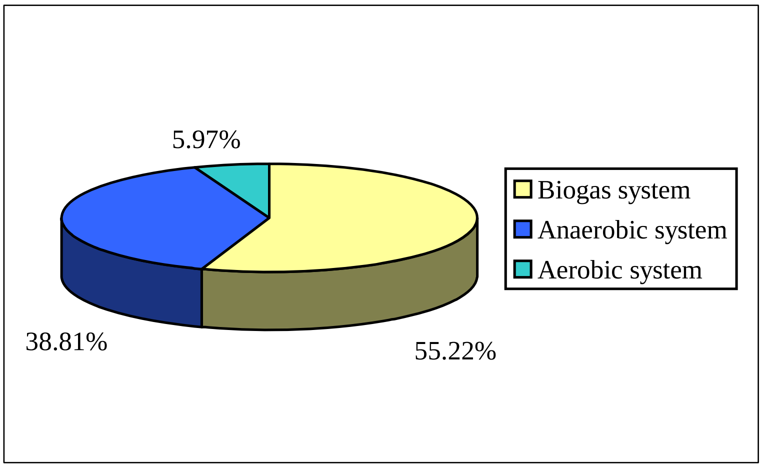


Figure 4-1 The percentage of cassava starch wastewater treatment system

From Figure 4-1, it can be indicated that biogas system was the major wastewater treatment system of cassava starch mills, followed by 38.81% of anaerobic system and 5.97% of aerobic system respectively.

4.1.2 Palm oil mills

The wastewater treatment system data was obtained from CDM project design document and the Provincial Industry Office. The production capacity was obtained from the Provincial Industry Office and the Department of Internal Trade, but the Provincial Industry Office data was the permission data to run the mills. Therefore in this study, the data from the Department of Internal Trade, which was in form of ton FFB/hour, was applied by multiplying with 16 hours/day and 300 days/year to be in form of ton FFB/year [63].

Table 4-3 The collected data in each province of palm oil industry

Province	Number of sample	Number of collected sample
Chonburi	1	1
Chumporn	7	7
Krabi	13	13
Satun	1	1
Suratthani	13	13
Trang	4	4
Total	**39**	**39**
Percentage	**100**	**100**

The palm oil mills data were collected for all 39 mills. The first four high provinces in number of palm oil mills, both of collected samples and real samples were Krabi, Suratthani, Chumporn and Trang respectively (Table 4-3).

Table 4-4 The production and wastewater treatment system of palm oil mills.

Province	Palm oil mill and wastewater treatment system			
	Biogas system (mill)	Capacity (ton FFB/year)	No biogas system (mill)	Capacity (ton FFB /year)
Chonburi	-	-	1	288,000
Chumporn	3	954,000	4	1,008,000
Krabi	2	508,700	11	2,664,000
Satun	-	-	1	144,000
Suratthani	3	858,000	10	2,736,000
Trang	-	-	4	792,000
Total	**8**	**2,320,700**	**31**	**7,632,000**
	39 mills		**9,952,700 ton FFB/year**	

The collected data were: 8 mills of biogas system with the production capacity 2,320,700 ton FFB/year and 31 mills of anaerobic system with the production capacity 7,632,000 ton FFB/year. The total production capacity of 39 mills were 9,952,700 ton FFB/year, as shown in Table 4-4, which was the capability production capacity, while the production of FFB from the data of the Office of Agricultural Economics in 2007 was 7,270,425 ton.

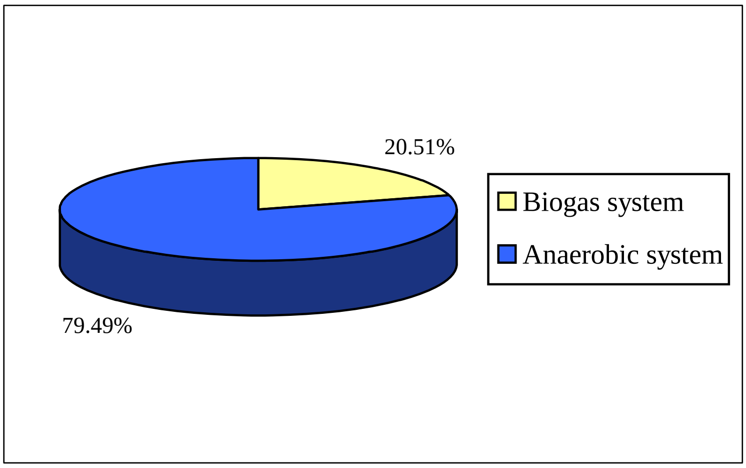


Figure 4-2 The percentage of palm oil mill wastewater treatment system

According to Figure 4-2, it can be seen that most of palm oil mills treated wastewater by anaerobic system which was 79.49%, while the left 20.51% treated by biogas system.

4.2 Crop utilization and production analysis

The production of 81 cassava starch mills and 39 palm oil mills, which were the sample groups, were used to analyze the proportion of crop utilization and production in this study. The calculation of crop utilization and production of cassava starch and palm oil industries were shown in Table 4-5 and 4-6

Table 4-5 The calculation of crop utilization and production of cassava

Data/parameter	Description	Value	Source
Topic	***Crop utilization and production of cassava starch***		
Equation : (3-1)	$\text{Crop utilization ratio} = \frac{\text{Total production capacity of each industry (ton)}}{\text{Total crop yield (ton)}}$		

Table 4-5 The calculation of crop utilization and production of cassava (Cont.)

Data/parameter	Description	Value	Source
Total production capacity of each industry (81mills)	Total production capacity in form of fresh cassava roots of 81 cassava starch mills Due to the feeding crop in the analysis of crop utilization ratio have to be in form of fresh cassava roots. But the collected data was in form of cassava starch, so in this analysis the cassava starch from 81 mills had to convert in form of fresh cassava roots by the data of Office of Agricultural Economics, which said that 21.46% of cassava root was dry cassava starch [81]. Thereby the fresh cassava roots can calculate as follows: Cassava starch of 81 mills = 3,313,595ton/year Fresh cassava root = $\frac{3,313,595}{21.46} x100$ = 15,440,796.83 ton/year	15,440,796.83 ton fresh cassava roots/year	from the calculation
Total crop yield (2007)	Total fresh cassava roots production in 2007	26,411,000 ton fresh cassava root/year	[82]
Crop Utilization ratio	Crop utilization ratio = $\frac{15,440,796.83}{26,411,000}$ = $\frac{1}{1.71}$ or = $\frac{15,440,796.83}{26,411,000}$ x100 = 58.46%	1: 1.71 or 58.46%	from the calculation

Table 4-6 The calculation of crop utilization and production of oil palm

Topic	***Crop utilization and production of palm oil***		
Equation : (3-1)	$\text{Crop utilization ratio} = \dfrac{\text{Total production capacity of each industry (ton)}}{\text{Total crop yield (ton)}}$		
Total production capacity of each industry (39mills)	Total production capacity in form of FFB of 39 palm oil mills	9,952,700 ton FFB/year	from the collected data
Total crop yield (2007)	Total FFB production in 2007	7,270,425 ton FFB/year	Center for Agricultural Information, Office of Agricultural Economics cited in [83]
Crop Utilization ratio	$\text{Crop utilization ratio} = \dfrac{9,952,700}{7,270,425} = \dfrac{1}{0.73}$ or $= \dfrac{9,952,700}{7,270,425} \times 100 = 136.89\%$	1:0.73 or 136.89%	from the calculation

Table 4-7 Crop utilization and production analysis

Categories	**Industry**	
	Cassava starch	**Palm oil**
Number of sample	81	39
Production capacity (ton/year)	15,440,796.83*	9,952,700.00
Raw material 2007 (ton/year)	26,411,000.00[(a)]	7,270,425.00[(b)]
Ratio	1:1.71	1:0.73
Percentage	58.46	136.89

Remark: * calculated from dry starch is 21.46% of fresh cassava roots [81]

Source: (a) – [82]

(b) – the Center for Agricultural Information, the Office of Agricultural Economics cited in [83]

4.2.1 Crop utilization and production of cassava starch industry

The ratio of the production capacity of 81 cassava starch mills and the fresh cassava roots was 1:1.71 or equal to 58.46%. In other words, 58.46% of fresh cassava roots were fed to cassava starch production and the left 41.54% were fed to other production such as cassava chips, cassava pellets and ethanol. This result conform to the Department of Internal Trade data [80], which reported that 55-60% of all fresh cassava roots production would be produced cassava starch (native starch and modified starch),as shown in Table 4-7.

4.2.2 Crop utilization and production of palm oil industry

Whereas the ratio of the production capacity of 39 palm oil mills and the fresh fruit bunches (FFB) was 1:0.73 or equal to 136.89%, which indicated that the production of FFB was not enough for the production capacity of the palm oil mills. The data is shown in Table 4-7.

Due to the limitation of the collected data, that was the researcher could not find the exact production capacity of both industries in form of ton production/year of each mill. So the production capacity in form of ton flour/day and ton FFB/hour were applied that mentioned in topic 4.1.1 and 4.1.2. Hence the estimation of biogas, electricity, volume and CERs value will be roughly estimated. Especially for palm oil industry, because of the topic 4.2.2 which signified that FFB quantity was not enough for the production capacity of the mills and clearly indicated that the collected data was only the production capacity of the mills.

4.3 The estimation of biogas and electricity production

The sample for the calculation of biogas and electricity production estimation from the cassava starch and palm oil mills that treated wastewater by biogas system were shown in Table 4-8 and 4-9 (for the left wastewater treatment systems, see Appendix D)

Table 4-8 The calculation of biogas and electricity production estimation of cassava starch mills (biogas system)

Data/parameter	Description	Value	Source
Topic	***Wastewater production of cassava starch industry (biogas system)***		
Equation : (3-2)	Wastewater (m^3/year) = a (ton/year) x b (m^3/ton)		
a	Ton of cassava starch production	2,080,475 ton flour/year	from the collected data
b	Rate of wastewater per ton of cassava starch production	17.80 m^3/ton flour	see Appendix A
Wastewater	Wastewater = 2,080,475 x 17.80 = 37,032,455	37,032,455 m^3/year	from the calculation
Topic	***Biogas production of cassava starch industry (biogas system)***		
Equation : (3-3)	Biogas (m^3/year) = c (m^3/m^3) x Wastewater (m^3)		
c	Biogas production rate from cassava starch industry wastewater	9.50 m^3/m^3 wastewater	see Appendix A
Wastewater	Wastewater production of cassava starch industry	37,032,455 m^3/year	as the above
Biogas	Biogas = 9.50 x 37,032,455 = 351,808,322.50	351,808,322.5 m^3/year	from the calculation
Topic	***Volume of generating electricity of cassava starch industry (biogas system)***		
Equation : (3-4)	Electricity (unit/year) = Biogas(m^3/year) x 1.20(unit/ m^3)		
Biogas	Biogas production of cassava starch industry	351,808,322.50 m^3/year	as the above
1.20(unit/ m^3)	The generating electricity per 1 m^3 of biogas	1.20 unit/ m^3	[25]
Electricity	Electricity = 351,808,322.50 x 1.20 = 422,169,987	422,169,987 unit/year	from the calculation
Topic	***Value of electricity of cassava starch industry (biogas system)***		
Equation : (3-5)	Electricity value(Baht/year) = Electricity(unit/year) x Price per unit (Baht/unit)		
Electricity	Volume of generating electricity of cassava starch industry	422,169,987 unit/year	as the above
Price per unit	The price per unit of electricity	2.50 Baht	[84]
Electricity value	Electricity value = 422,169,987 x 2.50 = 1,055,424,967.50	1,055.42 million Bath/year	from the calculation

Table 4-9 The calculation of biogas and electricity production estimation of palm oil mills (biogas system)

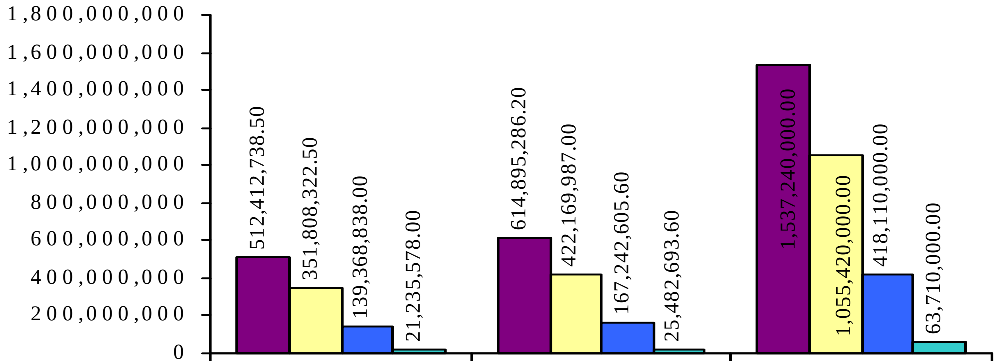
Data/parameter	Description	Value	Source
Topic	***Wastewater production of palm oil industry (biogas system)***		
Equation : (3-2)	Wastewater (m^3/year) = a (ton/year) x b (m^3/ton)		
a	Ton of palm oil production in form of FFB	2,320,700 ton FFB/year	from the collected data
b	Rate of wastewater per ton of palm oil production	0.82 m^3/ton FFB	see Appendix A
Wastewater	Wastewater = 2,320,700 x 0.82 = 1,902,974	1,902,974m^3/ year	from the calculation
Topic	***Biogas production of palm oil (biogas system)***		
Equation : (3-3)	Biogas (m^3/year) = c (m^3/m^3) x Wastewater (m^3)		
c	Biogas production rate from palm oil industry wastewater	13 m^3/m^3 wastewater	see Appendix A
Wastewater	Wastewater production of palm oil industry	1,902,974m^3/ year	as the above
Biogas	Biogas = 13 x 1,902,974 = 24,738,662	24,738,662 m^3/year	from the calculation
Topic	***Volume of generating electricity of palm oil industry (biogas system)***		
Equation : (3-4)	Electricity (unit/year) = Biogas(m^3/year) x 1.20(unit/ m^3)		
Biogas	Biogas production of palm oil industry	24,738,662 m^3/year	as the above
1.20(unit/ m^3)	The generating electricity per 1 m^3 of biogas	1.20 unit/ m^3	[25]
Electricity	Electricity = 24,738,662 x 1.20 = 29,686,394.40	29,686,394.40 unit/year	from the calculation
Topic	***Value of electricity of palm oil industry (biogas system)***		
Equation : (3-5)	Electricity value (Baht/year) = Electricity (unit/year) x Price per unit (Baht/unit)		
Electricity	Volume of generating electricity of palm oil industry	29,686,394.40 unit/year	as the above
Price per unit	The price per unit of electricity	2.50 Baht	[84]
Electricity value	Electricity value = 29,686,394.40 x 2.50 = 74,215,986	74.22 million Bath/year	from the calculation

Table 4-10 Biogas and electricity production from cassava starch and palm oil industries

Industry	Wastewater treatment system	Production (unit/year)	Wastewater (m^3/year)	Biogas (m^3/year)	Electricity generation (unit/year)	Electricity value* (million Baht/year)
Cassava starch	Biogas system	2,080,475.00	37,032,455.00	351,808,322.50	422,169,987.00	1,055.42
	Anaerobic system	824,180.00	14,670,404.00	139,368,838.00	167,242,605.60	418.11
	Aerobic system	125,580.00	2,235,324.00	21,235,578.00	25,482,693.60	63.71
	Total	**3,030,235.00**	**53,938,183.00**	**512,412,738.50**	**614,895,286.20**	**1,537.24**
Palm oil	Biogas system	2,320,700.00	1,902,974.00	24,738,662.00	29,686,394.40	74.22
	Anaerobic system	7,632,000.00	6,258,240.00	81,357,120.00	97,628,544.00	244.07
	Total	**9,952,700.00**	**8,161,214.00**	**106,095,782.00**	**127,314,938.40**	**318.29**

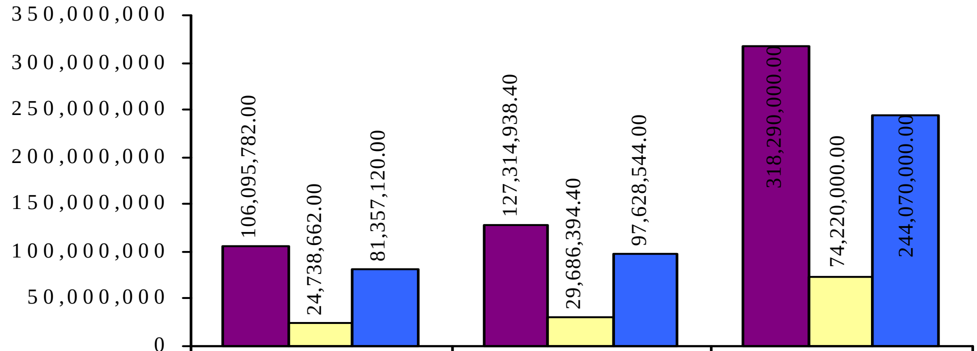
Remark : *The price of electricity value at 2.50 Baht/unit and electricity value were calculated at static rate

1 unit of electricity = 1 kW-hr



	Biogas production (m 3/year)	Electricity generation (unit/year)	Electricity value (Baht/year)
Total	512,412,738.50	614,895,286.20	1,537,240,000.00
Biogas system	351,808,322.50	422,169,987.00	1,055,420,000.00
Anaerobic system	139,368,838.00	167,242,605.60	418,110,000.00
Aerobic system	21,235,578.00	25,482,693.60	63,710,000.00

Figure 4-3 Biogas production, electricity generation and electricity value of cassava starch industry



	Biogas production (m 3/year)	Electricity generation (unit/year)	Electricity value (Baht/year)
Total	106,095,782.00	127,314,938.40	318,290,000.00
Biogas system	24,738,662.00	29,686,394.40	74,220,000.00
Anaerobic system	81,357,120.00	97,628,544.00	244,070,000.00

Figure 4-4 Biogas production, electricity generation and electricity value of palm oil industry

4.3.1 Biogas and electricity production of cassava starch industry

The estimation of biogas production from cassava starch industry found out that 67 cassava starch mills had biogas production potential 512,412,738.50 m^3/year which can be calculated into 614,895,286.20 unit of electricity and was equal to 1,537.24 million Baht/year. In fact, there were only 37 cassava starch mills that had biogas system, but if the 30 left mills treated wastewater by biogas system they would earn the alternative electricity which was equal to 192,725,299.20 unit of electricity/year and was worth 481.81 million Baht/year (Table 4-10 and Figure 4-3).

4.3.2 Biogas and electricity production of palm oil industry

For the 39 palm oil mills, found out that the biogas production potential was 106,095,782 m^3/year, which can be calculated into 127,314,938.40 unit of electricity and was worth 318.29 million Baht/year. The 31 of 39 mills did not treat wastewater by biogas system, but if they turn to treat by biogas system they would gain 97,628,544.00 unit of electricity/year which valued 244.07 million Baht/year, as shown in Table 4-10 and Figure 4-4.

4.4 The estimation of volume and value of CERs

The sample of the calculation of volume and value of CERs from cassava starch and palm oil mills which treated wastewater by biogas system were demonstrated in Table 4-11 and 4-12 (for the left wastewater treatment systems were shown in Appendix D).

Table 4-11 The calculation of volume and value of CERs from cassava starch mills (biogas system)

Data/parameter	**Description**	**Value**	**Source**
Topic	***Greenhouse gas emission reduction from cassava starch industry (biogas system)***		
Equation : (3-6)	CH_4 reduction (kg/yr) = Total COD(kgCOD/yr) x B_0(kgCH_4/kgCOD) x MCF x 0.80		
Total COD	Total COD per year of cassava starch industry wastewater According to the collected data of COD was in form of kg COD/m^3, hence it had to be converted in form of total COD/year, as follows: Total COD = wastewater(m^3/year) x 15.92*kgCOD/ m^3 = 37,032,455 x 15.92 = 589,556,683.60 kgCOD/year Remark : * see Appendix A	589,556,683.60 kgCOD/year	from the calculation
Bo	Maximum methane producing capacity of the wastewater	0.21 kgCH_4/kgCOD	[58]
MCF	Methane conversion factor that express what proportion of the effluent would be anaerobically digested	0.738	[58]
0.80	The reduction of greenhouse gas emission from baseline process, which was 80% or 0.80	0.80	see Appendix B
CH_4 reduction	CH_4 reduction = 589,556,683.60 x 0.21 x 0.738 x 0.8 = 73,095,595.86	73,095,595.86kg/year	from the calculation
Topic	***Greenhouse gas emission reduction from cassava starch industry (biogas system) in form of ton CO_2/year***		
Equation : (3-7)	$CO_2 \text{ (ton/year)} = \dfrac{21 \times CH_4 \text{ (kg/year)} \times 1 \text{ (ton)}}{1000 \text{ (kg)}}$		
21	Global warming potential of methane	21	Climate Change 1995, IPCC Second Assessment Report cited in [8]

Table 4-11 The calculation of volume and value of CERs from cassava starch mills (biogas system) (Cont.)

Data/parameter	Description	Value	Source
CH_4	CH_4 reduction from cassava starch industry	73,095,595.86 kg/year	as the above
1/1000	The conversion factor of kg to ton	1ton/1,000 kg	-
CO_2	$CO_2 = \frac{21x73,095,595.86x1}{1000}$ $= 1,535,007.51$	1,535,007.51 ton /year	from the calculation
Topic	***Value of greenhouse gas emission reduction from cassava starch industry (biogas system)***		
Equation : (3-8)	CERs (Baht/year) = CO_2 (ton/year) x d (Baht/ton)		
CO_2	Greenhouse gas emission reduction from cassava starch industry in form of ton CO_2/year	1,535,007.51 ton /year	as the above
d	Price per unit of CERs	153.24 Baht/CERs	see Appendix C
CERs	CERs = 1,535,007.51 x 153.24 = 235,224,550.83 Baht/year = 235.22 million Baht/year	235.22 million Baht/year	from the calculation

Table 4-12 The calculation of volume and value of CERs from palm oil mills (biogas system)

Data/parameter	Description	Value	Source
Topic	***Greenhouse gas emission reduction from palm oil industry (biogas system)***		
Equation : (3-6)	CH_4 reduction (kg/yr) = Total COD (kgCOD/yr) x B_0 (kgCH_4/kgCOD) x MCF x 0.8		
Total COD	Total COD per year of palm oil industry wastewater Because of the collected data of COD was in form of kg COD/m^3, so it had to be converted in form of total COD/year, as follows: Total COD = wastewater(m^3/year) x 74.62**kgCOD/m^3 = 1,902,974 x 74.62 = 141,999,919.88 kgCOD/year Remark : ** see Appendix A	141,999,919.88 kgCOD/year	from the calculation

Table 4-12 The calculation of volume and value of CERs from palm oil mills (biogas system) (Cont.)

Data/parameter	Description	Value	Source
Bo	Maximum methane producing capacity of the wastewater	0.21 $kgCH_4/kgCOD$	[58]
MCF	Methane conversion factor that express what proportion of the effluent would be anaerobically digested	0.738	[58]
0.8	The reduction of greenhouse gas emission from baseline process, which was 80% or 0.80	0.80	see Appendix B
CH_4 reduction	CH_4 reduction = 141,999,919.88 x 0.21 x 0.738 x 0.80 = 17,605,718.07	17,605,718.07 kg/year	from the calculation
Topic	***Greenhouse gas emission reduction from palm oil industry (biogas system) in form of ton CO_2/year***		
Equation : (3-7)	$CO_2\ (ton/year) = \frac{21 \times CH_4\ (kg/year) \times 1\ (ton)}{1000\ (kg)}$		
21	Global warming potential of methane	21	Climate Change 1995, IPCC Second Assessment Report cited in [8]
CH_4	CH_4 reduction from palm oil industry	17,605,718.07 kg/year	as the above
1/1000	The conversion factor of kg to ton	1ton/1,000 kg	-
CO_2	$CO_2 = \frac{21 x 17,605,718.07 x 1}{1000}$ = 369,720.08	369,720.08 ton /year	from the calculation
Topic	***Value of greenhouse gas emission reduction from palm oil industry (biogas system)***		
Equation : (3-8)	CERs (Baht/year) = CO_2 (ton/year) x d (Baht/ton)		
CO_2	Greenhouse gas emission reduction from palm oil industry in form of ton CO_2/year	369,720.08 ton /year	as the above

Table 4-12 The calculation of volume and value of CERs from palm oil mills (biogas system) (Cont.)

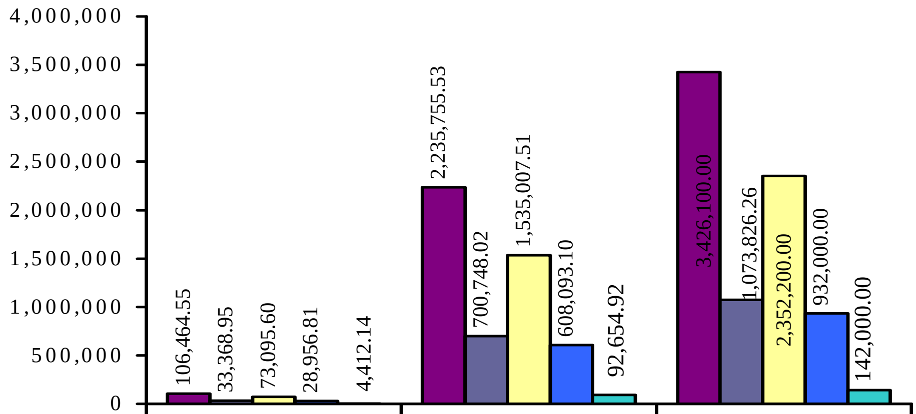
Data/parameter	Description	Value	Source
d	Price per unit of CERs	153.24 Baht/CERs	see Appendix C
CERs	CERs = 369,720.08 x 153.24 = 56,655,904.97 Baht/year = 56.66 million Baht/year	56.66 million Baht/year	from the calculation

Table 4-13 The reduction of CH_4 and CERs value of cassava starch and palm oil industries

Industry	Wastewater treatment system	Production (unit/year)	Wastewater (m^3/year)	COD (kg COD/year)	CH_4 reduction (ton/year)	CO_2 equivalent (ton/year)	CERs value* (MB/year)
Cassava starch	Biogas system	2,080,475.00	37,032,455.00	589,556,683.60	73,095.60	1,535,007.51	235.22
	Anaerobic system	824,180.00	14,670,404.00	233,552,831.68	28,956.81	608,093.10	93.20
	Aerobic system	125,580.00	2,235,324.00	35,586,358.08	4,412.14	92,654.92	14.20
	Total of none biogas system	**949,760.00**	**16,905,728.00**	**269,139,189.76**	**33,368.95**	**700,748.02**	**107.38**
	Total	**3,030,235.00**	**53,938,183.00**	**858,695,873.36**	**106,464.55**	**2,235,755.53**	**342.61**
Palm oil	Biogas system	2,320,700.00	1,902,974.00	141,999,919.88	17,605.72	369,720.08	56.66
	Anaerobic system	7,632,000.00	6,258,240.00	466,989,868.80	57,899.27	1,215,884.71	186.32
	Total of none biogas system	**7,632,000.00**	**6,258,240.00**	**466,989,868.80**	**57,899.27**	**1,215,884.71**	**186.32**
	Total	**9,952,700.00**	**8,161,214.00**	**608,989,788.68**	**75,504.99**	**1,585,604.79**	**242.98**

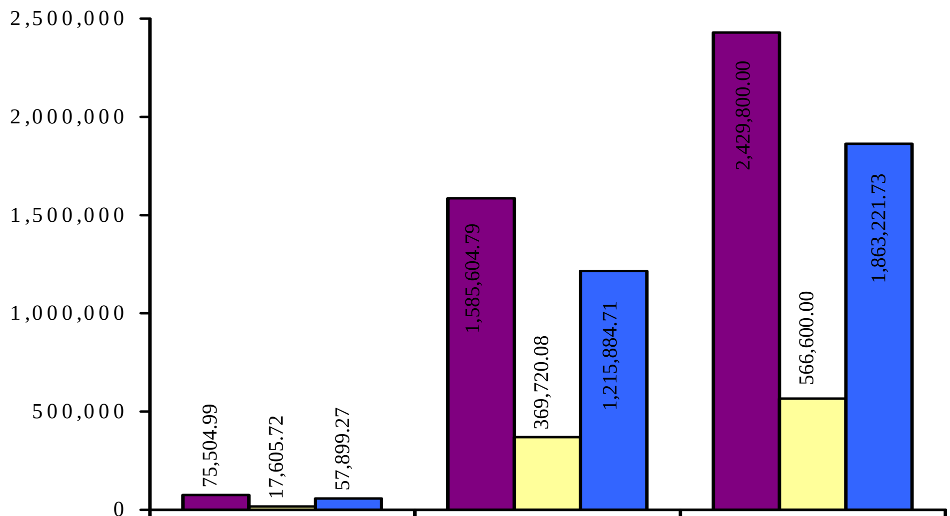
Remark : * CERs value at 153.24 Baht/ton CO_2 eq

- none biogas system of cassava starch industry was anaerobic and aerobic wastewater treatment system
- none biogas system of palm oil industry was anaerobic wastewater treatment system
- in carbon market the units of carbon credit (CERs) were sold in the same amount unit that was ton CO_2 equivalent, so in this study the reduction of CH_4 had to be transform into form of ton CO_2 equivalent by multiplying with 21 (GWP of CH_4)



	CH4 reduction (ton/year)	CO2 equivalent (ton/year)	CERs value (x100 Baht/year)
Total	106,464.55	2,235,755.53	3,426,100.00
Total of none biogas	33,368.95	700,748.02	1,073,826.26
Biogas system	73,095.60	1,535,007.51	2,352,200.00
Anaerobic system	28,956.81	608,093.10	932,000.00
Aerobic system	4,412.14	92,654.92	142,000.00

Figure 4-5 CH_4 reduction and CERs value from cassava starch industry



	CH4 reduction (ton/year)	CO2 equivalent (ton/year)	CERs value (x100 Baht/year)
Total	75,504.99	1,585,604.79	2,429,800.00
Biogas system	17,605.72	369,720.08	566,600.00
Anaerobic system	57,899.27	1,215,884.71	1,863,221.73

Figure 4-6 CH_4 reduction and CERs value from palm oil industry

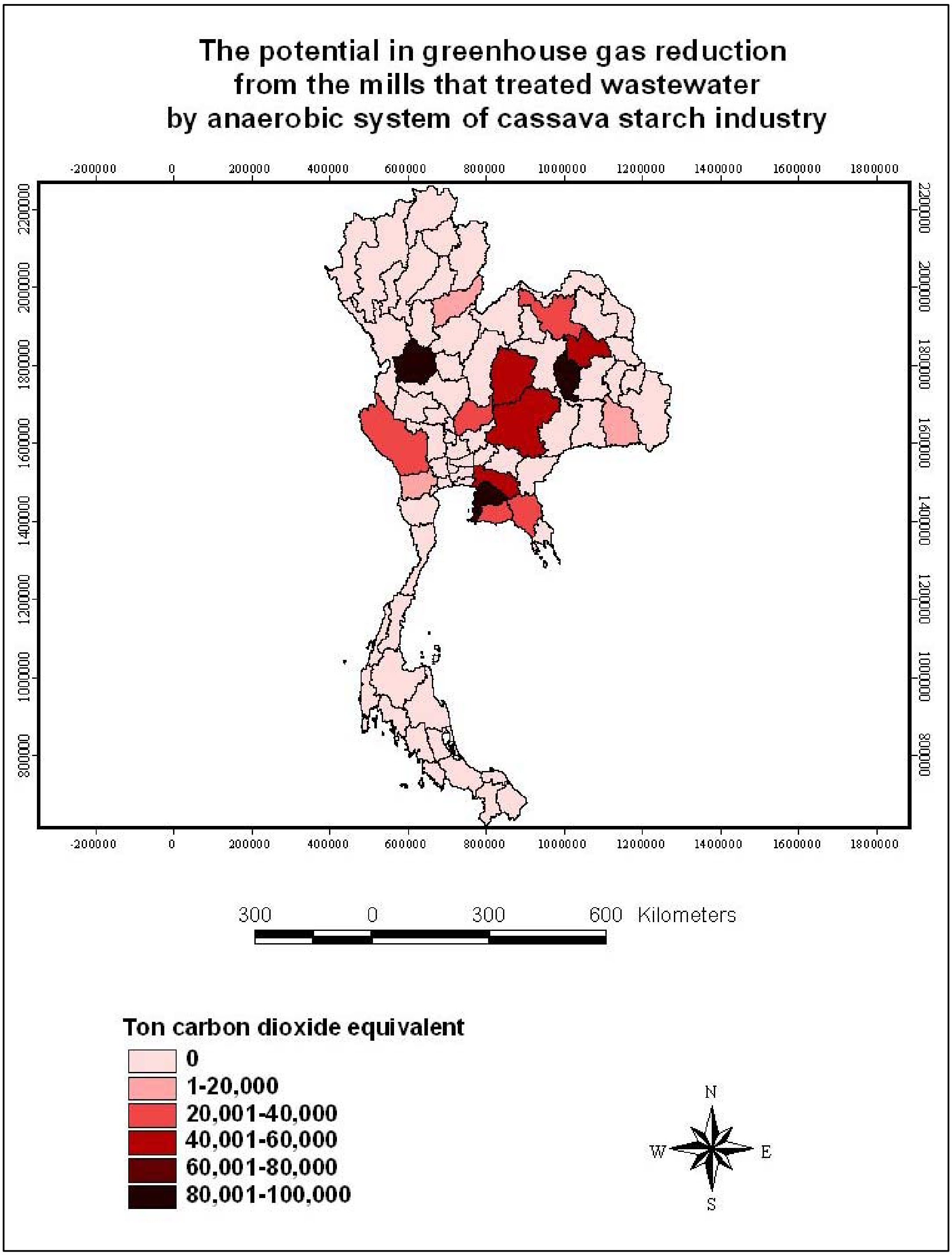


Figure 4-7 The potential in greenhouse gas reduction of cassava starch mills that treated wastewater by anaerobic system in each province

Table 4-14 Greenhouse gas emission reduction of cassava starch industry (from the mills that treated wastewater by anaerobic system) in each province

Province	Anaerobic system (mill)	Greenhouse gas reduction (ton CO_2)
Chachoengsao	1	53,122.74
Chaiyaphum	1	40,284.75
Chantaburi	2	20,142.37
Chonburi	3	80,596.50
Kalasin	2	50,355.93
Kamphaengphet	4	94,551.11
Kanchanaburi	1	20,142.37
Khonkaen	-	-
Loei	-	-
Lopburi	1	28,974.03
Mahasarakham	2	80,569.50
Nakhonratchasima	2	52,370.17
Ratchaburi	1	4,426.90
Rayong	2	30,213.56
Roiet	-	-
Sakaeo	-	-
Saraburi	-	-
Sisaket	1	12,085.42
Udonthani	2	30,213.56
Uthaithani	-	-
Uttaradit	1	10,071.19

4.4.1 Volume and value of CERs of cassava starch industry

According to the collected data as shown in Table 4-2 and Figure 4-1, the 26 cassava starch mills or equal to 38.81% (of 67 mills collected data) were the mills that the wastewater was treated in the anaerobic condition and caused to CH_4 fugitive to the atmosphere. Hence, the CH_4 emission reduction from the implementing CDM projects or biogas system of 26 mills was 28,956.81 ton/year or equal to 608,093.10 ton CO_2eq/year, which valued 93.18 million Baht/year (at 153.24 Baht/CERs). Moreover, if the left 4 mills which were aerobic wastewater treatment systems turn to do biogas system, they will also help in CH_4 reduction 4,412.14 ton CH_4/year or equal to 92,654.92 ton CO_2eq which valued 14.20 million Baht/year. So the 30 mills will help to reduce CH_4 emission 33,368.95 ton/year or equal to 700,748.02 ton CO_2eq and was worth 107.38 million Baht/year. The overall of CH_4 emission reduction from 67 mills was106,464.55 ton/year, which equivalent to 2,235,755.53 ton CO_2/year and valued 342.61 million Baht/year, as shown in Table 4-13 and Figure 4-5.

The potential in greenhouse gas reduction from the cassava starch mills that treated wastewater by anaerobic system were shown in Figure 4-7 and Table 4-14. The results indicated that the first three high provinces in greenhouse gas reduction were Kamphaengphet, Chonburi and Mahasarakham which the potential were 94,551.11, 80,596.50 and 80,596.50 ton CO_2eq/year respectively.

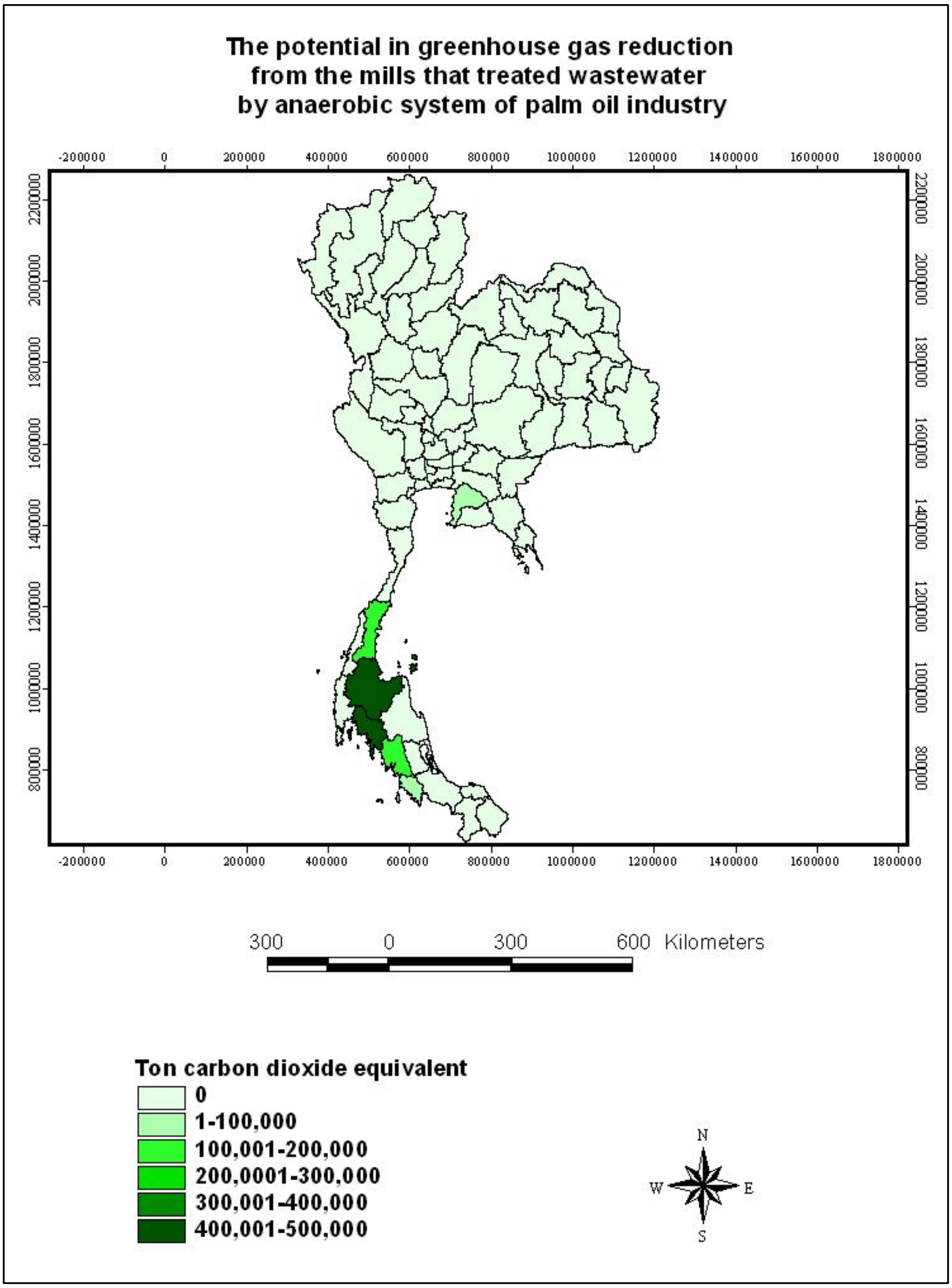


Figure 4-8 The potential in greenhouse gas reduction of palm oil mills that treated wastewater by anaerobic system in each province

Table 4-15 Greenhouse gas emission reduction of palm oil industry (from the mills that treated wastewater by anaerobic system) in each province

Province	Anaerobic system (mill)	Greenhouse gas reduction (ton CO_2)
Chonburi	1	45,882.44
Chumporn	4	160,588.55
Krabi	11	424,412.59
Satun	1	22,941.22
Suratthani	10	435,883.20
Trang	4	126,176.72

4.4.2 Volume and value of CERs of palm oil industry

There were 31 palm oil mills or 79.49% (of 39 mills from the collected data) which wastewater was treated in the anaerobic condition (as shown in Table 4-4 and Figure 4-2) and therefore released CH_4 to the atmosphere. If these mills implement the CDM projects or biogas wastewater treatment system, it will help to reduce CH_4 emission 57,899.27 ton/year or equivalent to 1,215,884.71 ton CO_2eq/year which valued 186.32 million Baht/year. The total of CH_4 emission reduction, the total emission reduction in form of CO_2 of 39 mills were 75,504.99 ton CH_4/year and 1,585,604.79 ton CO_2 eq/year respectively, and was worth 242.98 million Baht/year, as shown in Table 4-13 and Figure 4-6.

Figure 4-8 and Table 4-14 demonstrated the potential in greenhouse gas reduction from the palm oil mills that treated wastewater by anaerobic system. The results signified that the first four high provinces in greenhouse gas reduction were Suratthani, Krabi, Chumporn and Trang with the potential of 435,883.20, 424,412.59, 160,588.55 and 126,176.72 ton CO_2eq/year respectively.

Table 4-16 The potential comparison of cassava starch and palm oil industries

Categories	Cassava starch industry	Palm oil industry
Biogas production		
m^3/year	512,412,738.50	106,095,782.00
m^3/harvested area (rai)	133.11	28.29
m^3/ton product	169.10	57.62
m^3/ton raw material	36.29	10.66
Greenhouse gas reduction		
ton CO_2eq/year	2,235,755.53	1,585,604.79
ton CO_2eq of anaerobic system/year	608,093.10	1,215,884.71
ton CO_2eq/harvested area (rai)	0.58	0.42
ton CO_2eq/ton product	0.74	0.86
ton CO_2eq/ton raw material	0.16	0.16
CERs value		
(at 153.24 Baht/ton CO_2eq)		
million Baht/year	342.61	242.98
million Baht/year of anaerobic system	93.18	186.32
Baht/harvested area (rai)	89.00	64.79
Baht/ton product	113.06	131.79
Baht/ton raw material	24.52	24.52
Electricity		
unit/year	614,895,286.20	127,314,938.40
million Baht/year (at 2.5 Baht/unit)	1,537.24	318.29

Remark :
- for the potential of each wastewater treatment system see Table 4-10 and Table 4-13
- ton product of cassava starch and palm oil industries were ton flour and ton crude palm oil respectively
- ton raw material of cassava starch and palm oil industries were ton of fresh cassava roots and ton of fresh fruit bunches respectively

4.5 The potential comparison of cassava starch and palm oil industries

The potential comparison of cassava starch and palm oil industries in form of biogas production, greenhouse gas reduction, CERs value and electricity generation were shown in Table 4-16

4.5.1 Biogas production

The potential in biogas production of cassava starch industry in form of m^3/year of whole industry, m^3/harvested area (rai), m^3/ton production and m^3/ton raw material were 512,412,738.50, 133.11, 69.10 and 36.29 respectively, which were more than palm oil industry in every comparison. The potential of palm oil industry were 106,095,782.00, 28.29, 57.62 and 10.66 respectively.

4.5.2 Greenhouse gas reduction

The 38.81% of cassava starch mills were the mills that treated wastewater by anaerobic system had the potential in greenhouse gas emission reduction less than 79.49% of anaerobic system of palm oil mills. The potential of cassava starch and palm oil industries were 608,093.10 and 1,215,884.71 ton CO_2eq respectively. Cassava starch industry had more potential in greenhouse gas emission reduction in form of ton CO_2eq/harvested area (rai) than the palm oil industry, which the potential of cassava starch industry was 0.58 and was 0.42 for palm oil industry. But cassava starch industry had potential in greenhouse gas reduction in form of ton CO_2eq/ton product less than the palm oil industry which was 0.74 and 0.86 respectively. However, both industries had the same value of greenhouse gas reduction in form of ton CO_2eq/ton raw material that was 0.16.

4.5.3 CERs value

As the result of palm oil industry had more potential in greenhouse gas emission reduction than cassava starch industry; it was also resulted in more CERs value from palm oil than cassava starch industry which were 93.18, 186.32 million Baht/year. Anyhow, palm oil industry still had less CERs value in form of Baht/harvested area (rai) than cassava starch industry, that were 64.79 and 89.00. But palm oil industry had more CERs value in form of Baht/ton product than cassava starch industry that were 131.79 and 113.06, while both industries had the same CERs value in form of Baht/ ton raw material that was 24.52.

4.5.4 Electricity generation

Due to the potential in biogas production of cassava starch industry was more than palm oil industry, so it effected to the more of volume and value of electricity from cassava starch industry than palm oil industry. The cassava starch industry wastewater could generate electricity 614,895,286.20 unit/year and valued 1,537.24 million Baht/year while wastewater of palm oil mill could produce 127,314,938.40 unit of electricity which was worth 318.29 million Baht/year respectively.

4.6 Discussions

In this research the potential in greenhouse gas reduction of cassava starch and palm oil industries wastewater were estimated. The results of the study were shown in form of volume and value of CERs, volume and value of electricity generated from biogas. The overview of the study found out that 67 mills of cassava starch industry treated wastewater by biogas system 55.22%, anaerobic system 38.81%, and aerobic system 5.97%. Whereas 39 mills of palm oil industry treated wastewater via biogas system 20.51% and anaerobic system 79.49%. These 67 cassava starch mills could produce 512 million ton of biogas per annum, which could calculate into 614 million unit of electricity and was worth about 1,537 million Baht. For 39 palm oil mills could produce biogas 106 m^3 annually and equivalent to 127 million unit of electricity which valued about 318 million Baht. The potential in greenhouse gas reduction of cassava starch and palm oil mills that treated wastewater by anaerobic system were found that both industries could reduce CH_4 emission 28,956 ton/year and 57,899 ton/year respectively. When these reductions or CERs were sold in form of ton CO_2 equivalent they were equivalent to 608,093 ton CO_2 eq/year and 1,215,884 ton CO_2 eq/year, and were worth about 93 million Baht and 186 million Baht respectively.

From the results of the study that were the energy from biogas production of 67 cassava starch mills and 39 palm oil mills in 2007 were 512 m^3 and 106 m^3, and equal to energy in form of 614 million unit and 127 million unit of electricity respectively. According to Prasertsan, S. and B. Sajjakulnuki (2006) evaluated the energy potential of both industries in 1997. They found out that wastewater from cassava starch industry could generate energy 3,454 PJ and wastewater from palm oil industry could produce biogas 5.591×10^7 m^3/year which was equivalent to energy 1.342 PJ. Although both studies had difference in form of the energy, but they were conform with each other that were cassava starch industry wastewater had potential in energy generation than palm oil industry and both of the study showed that wastewater from cassava starch and palm oil industry could be used as an alternative energy.

Besides the results of this study indicated that cassava starch and palm oil industries had potential in greenhouse gas reduction from CH_4 generated by anaerobic wastewater treatment process. These results were in line with the research about the potential of agro-industrial residues such as coffee, sisal, sugar and cereal in Tanzania toward biogas and electricity generation. Utilization residues for substitution of fossil fuel with biogas would reduce CO_2 emission and treating residues in controlled anaerobic system could also mitigate CH_4 emission, as reported in the research of Kivaisi, A.K. and M.S.T. Rubindamayugi (1996).

In economic aspect, biogas utilization as an alternative fuel would reduce the importation of fossil fuel which would also increase economic welfare for the nation. Moreover, this research would be a part that showed the value-added of agro-industry waste in form of energy production and CERs value. As well as the research of

Timilsina, G.R. and R.M. Shrestha (2006) who reported that the substitution of electricity generation from thermal power plants with hydropower plants under CDM project in Thailand would increase economic welfare, GDP and trade balance with the level of substitution and price of CERs. Besides the substitution would help reduce the emission of SO_x and NO_x. Additionally Yacob, S. et (2005) also discussed that utilization CH_4 from POME as renewable energy to generate electricity would produce value-added and the project would generate CERs for sale or export. So that palm oil industry could derive new economic, development and environment benefits through the implementation of CDM projects.

This research also provided information about the supply in greenhouse gas reduction from cassava starch and palm oil industries in Thailand as a part of greenhouse gas mitigation in Thailand and developed nations' commitment. Following to the study of Halsnæs, K.(2002) which concluded that the demand for greenhouse gas emission reduction projects from Annex B countries, including domestications in Annex B countries, JI projects, EIT projects and CDM projects would be between about 500 and 1,300 Mt C in 2010. Moreover, Jung, M.(2006) also reported that Thailand was one of eight very attractiveness of host countries for CDM non-sink projects.

This research was only the overview estimation of the potential in greenhouse gas reduction from cassava starch and palm oil industries. Because of the available data related to the calculation follow to the UNFCCC methodology was not sufficient to estimate the potential of greenhouse gases emission reductions according to above guideline. The data of the production were only the potential of capacity and potential of different mills (or projects) were also different, according to the technology, management, investment, data and methodology. If the obtained data had more details and the mills gave more collaborate, the results would be different and more complete.

CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This study was aimed to determine the potential of cassava starch and palm oil industries wastewater toward the biogas and electricity production, volume and value of CERs. The research findings were the following conclusions :

5.1.1 Collected data

The overview of the cassava starch and palm oil industries can be concluded as the following: cassava starch industry wastewater treatment plant were 55.22% of biogas system, 38.81% of anaerobic system and 5.97% of aerobic system. The production capacities were 2,080,475.00, 824,180.00 and 125,580 ton flour/year respectively.

The palm oil industry wastewater treatment plant were 79.44% of biogas system and 20.51% of anaerobic system, which the production capacity were 2,320,700.00 and 7,632,000.00 ton FFB/year respectively.

5.1.2 Crop utilization and production analysis

The proportion of cassava starch production and fresh cassava roots was 1:1.71 or equal to 58.46% of fresh cassava roots.

For the ratio of the production capacity of palm oil industry and FFB was 1:0.73 or equal to 136.89%.

5.1.3 Biogas and electricity production analysis

Cassava starch industry wastewater had potential in biogas production, electricity generation and electricity value equal to 512,412,738.50 m^3/year, 614,895,286.20 unit/year and 1,537.24 million Baht/year.

As for palm oil industry were 106,095,782.00 m^3/year, 127,314,938.40 unit/year and 318.29 million Baht/year respectively.

5.1.4 The estimation of volume and value of CERs

The 38.81% of cassava starch mills treated wastewater by anaerobic system, had potential in greenhouse gas emission reduction 28,956.81 ton CH_4/year or equivalent to 608,093.10 ton CO_2eq/year (when traded in carbon market) which equal to 93.18 million Baht/year.

The palm oil mills that did not treat wastewater with biogas system (79.49%) had potential in greenhouse gas emission reduction 57,899.27 ton CH_4/year which equivalent to the amount of carbon credit (CERs) 1,215,884.71 ton CO_2eq/year and was equal to 186.32 million Baht/year.

The first three high provinces in potential of greenhouse gas reduction of cassava starch mills that treated wastewater by anaerobic system were Kamphaengphet 94,551.11 ton CO_2eq/year, Chonburi 80,596.50 ton CO_2eq/year and Mahasarakham which the potential 80,596.50 ton CO_2eq/year respectively.

For the first four high provinces of palm oil mills were Suratthani 435,883.20 ton CO_2eq/year, Krabi 424,412.59 ton CO_2eq/year, Chumporn 160,588.55 ton CO_2eq/year and Trang 126,176.72 ton CO_2eq/year respectively.

5.1.5 The potential comparison of cassava starch and palm oil industries

Cassava starch industry had more potential in biogas production, electricity in every comparison, greenhouse gas emission reduction in form of ton CO_2 eq/year and ton CO_2 eq/harvested area (rai), and CERs value in form of million Baht/year and Baht/harvested area (rai) than palm oil industry, except the potential in greenhouse gas reduction and CERs value of none biogas wastewater treatment system mills. In addition, both industries had the same value of greenhouse gas reduction in form of ton CO_2 eq/ton raw material and CERs value in form of Baht/ton raw material(Table 4-16).

5.2 Recommendations

5.2.1 Recommendations from the results of the study

1) The governmental and private sector should promote oil palm plantation to be sufficient for the production capacity of palm oil mills. Due to it can be seen from the results of the study that palm oil mills and cassava starch mills effluent had potential in biogas production, and value-added as CERs. And the results of crop utilization analysis indicated that FFB yield was not enough for the production capacity of palm oil mills.

2) The government officials such as the Ministry of National Resources and Environment, the Ministry of Energy, the Office of Natural Resources and Environmental Policy and Planning and the Ministry of Finance should increase public relations about CDM project, the outcome of the CDM implementation, the awareness of global warming and the method to assist greenhouse gases emission reductions.

3) Cassava starch and palm oil industries dealer and also the other industries should pay more attention and implement CDM projects. In addition, they should make understanding and have specialists in wastewater treatment operating system. Particularly, the wastewater treatment system of palm oil mills should have

pretreatment to get rid of oil and grease because the microorganism could not digest those fat which would be a cause of the failure of the system.

5.2.2 Recommendations for further studies

1) This study analyzed the potential in greenhouse gas emission reduction only in both cassava starch and palm oil industries wastewater. Other industrial wastewater also has potential in biogas production. Hence, the further study should be conducted with wastewater from such industries: ethanol distillery, sugar, monosodium glutamate and swine farms. Moreover, biomass from bagasse and cane leaves, rice husk and rubber wood residue can be used for generating electricity, which will be a part in greenhouse gas emission reduction. So, these agriculture residues should be also investigated. Besides the mentioned above, afforestation and reforestation can also minimize greenhouse gases emission by absorbing CO_2 or in the other word "carbon sink". The future study, afforestation and reforestation are the other interesting projects to be examined.

2) This study applied the average data of COD, wastewater production and biogas production from various data sources. The further study, there should be real sampling and each parameter which should be analyzed and compared to see which method would provide better accuracy.

3) The estimation of greenhouse gas reduction from cassava starch and palm oil industries were focused on the production capacity at present (2006-2007). Further study, the product capacity and raw materials should be predicted to get more comparative results in the future.

4) Since there are two baseline methodologies of CDM Executive Board in the calculation of CH_4 emission from wastewater, which in this study the researcher calculated with baseline methodology AM0013 "Avoided methane emissions from organic wastewater treatment". Therefore, it is suggested that the future study should also carry on the baseline methodology AM0022 "Avoided wastewater and on-site

energy use emissions in the industrial sector” [85] to get more options and comparative data.

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APPENDIX

Appendix A-1

Value in the calculation of cassava starch industry

Parameter	Calculation value	Source
Wastewater (m^3/ton flour)	17.80	10.00-20.00 , [34]
		19.30 , [59]
		10.00-20.00 , [35]
		24.72 , [56]
		15.00 , [39]
Biogas (m^3/ m^3 wastewater)	9.50	8.00-10.00 , [35]
		10.00 , [39]
COD (kg COD/ m^3)	15.92	20.00-25.00 , [35]
		7.65 , [56]
		19.01 , [39]
		14.50 , [61]
B_0 (kg CH_4/kg COD)	0.21	[58]
MCF	0.738	[58]
Hours processed/day	24	[59]
Days processed/year	273	[59]

Appendix A-2

Value in the calculation of palm oil industry

Parameter	Calculation value	Source
Wastewater (m^3/ton FFB)	0.82	0.87 , [60]
		1.00 , [38]
		1.00 , [56]
		0.40 , [39]
Biogas (m^3/ m^3 wastewater)	13.00	12.00 , [60]
		12.00-16.00 , [37]
COD (kg COD/ m^3)	74.62	80.00 , [60]
		90.00 , [38]
		44.50 , [54]
		90.00 , [37]
		52.00 , [56]
		73.34 , [39]
		92.50 , [62]
B_0 (kg CH_4/kg COD)	0.21	[58]
MCF	0.738	[58]
Hours processed/day	16	[63]
Days processed/year	300	[63]

Appendix B

Percentage of emission reductions of 15 CDM projects

Project name	Project type	Estimation of baseline emission reductions per year (ton CO_2e)	Estimation of emission reductions per year (ton of CO_2e)	Percentage of emission reductions	Source
Korat Waste to Energy Project	electricity from starch industrial wastewater	353,793	314,075	88.77	[64]
Cassava Waste To Energy Project (CWTE project)	electricity from starch industrial wastewater	86,730	81,502	93.97	[65]
Kalasin Wastewater Treatment to Energy Project	electricity from starch industrial wastewater	50,118	39,824	79.46	[66]
Wastewater Treatment with Biogas System (AFFR) in a Starch Plant for Energy&Environment Conservation at Chachoengsao	electricity from starch industrial wastewater	29,635	19,357	65.32	[67]
Wastewater Treatment with Biogas System (UASB) in a Starch Plant for Energy&Environment Conservation at Nakorn Ratchasima	electricity from starch industrial wastewater	45,913	31,454	68.51	[68]
Siam Quality Starch Wastewater Treatment and Energy Generation Project in Chaiyaphum, Thailand	electricity from starch industrial wastewater	118,430	99,443	83.97	[69]
CYY Biopower Wastewater treatment plant including biogas reuse for thermal oil replacement and electricity generation Project,Thailand	electricity from starch industrial wastewater	104,463	99,939	95.67	[70]

Project name	Project type	Estimation of baseline emission reductions per year (ton CO_2e)	Estimation of emission reductions per year (ton of CO_2e)	Percentage of emission reductions	Source
Kitroongruang Biogas Energy Project	electricity from starch industrial wastewater	51,243	49,488	96.58	[71]
Jitrapattana Biogas Energy Project	electricity from starch industrial wastewater	72,894	72,015	98.79	[72]
Chao Khun Agro Biogas Energy Project	electricity from starch industrial wastewater	110,292	109,341	99.14	[73]
Chumporn applied biogas technology for advance waste water management	electricity from POME	69,788	45,747	65.55	[74]
Univanich Lamthap POME Biogas Project	electricity from POME	59,731	47,673	79.81	[75]
Thachana Palm Oil Company Wastewater Project in Thailand	electricity from POME	24,981	23,860	95.51	[76]
Natural Palm Oil Company Limited-1MW Electricity Generation and Biogas Plant Project	electricity from POME	30,253	17,533	57.95	[77]
Green to Energy Wastewater Treatment Project in Thailand	electricity from POME	28,186	26,904	95.45	[78]
Average				**84.30**	

Thus in study, the average percentage 80% of emission reduction was applied.

Appendix C

The average CERs price in the study

Project name	Project type	CERs price/ton CO_2e	CERs price in Baht/ ton CO_2e
Waste Water Treatment with Biogas System in a Starch Plant for Energy and Environment Conservation in Chachoengsao	electricity from starch industrial wastewater	4.25 USD	142.04
Waste Water Treatment with Biogas System in a Starch Plant for Energy and Environment Conservation in Nakornratchasima	electricity from starch industrial wastewater	4.25 USD	142.04
Chumporn applied Biogas Technology for Advanced Waste Water Management	electricity from POME	4 EUR	198.04
Natural Palm Oil Company Limited-1 MW Electricity Generation and Biogas Plant	electricity from POME	4.25 USD	142.04
Northern Starch (1987) Co. Ltd.-Switching	electricity from starch industrial wastewater	4.25 USD	142.04
Average			**153.24**

Remark: The calculation was based on:

1 USD = 33.42 Baht

1 EUR = 49.51 Baht

Appendix D-1

The calculation of wastewater generation

Data/parameter	Description	Value	Source
Topic	***Wastewater production of cassava starch industry***		
Equation : (3-2)	Wastewater (m^3/year) =	a (ton/year) x b (m^3/ton)	
a	Ton of cassava starch production	• Biogas system 2,080,475 ton flour/year • Anaerobic system 824,180 ton flour/year • Aerobic system 125,580 ton flour/year • Total 3,030,235 ton flour/year	from the collected data
b	Rate of wastewater per ton of cassava starch production	17.80 m^3/ton flour	see Appendix A
Wastewater	• Biogas system Wastewater = 2,080,475 x 17.80 = 37,032,455 • Anaerobic system Wastewater = 824,180 x 17.80 = 14,670,404 • Aerobic system Wastewater = 125,580 x 17.80 = 2,235,324 • Total Wastewater = 3,030,235 x 17.80 = 53,938,183	• Biogas system 37,032,455 m^3/year • Anaerobic system 14,670,404 m^3/year • Aerobic system 2,235,324 m^3/year • Total 53,938,183 m^3/year	from the calculation

Data/parameter	Description	Value	Source
Topic	***Wastewater production of palm oil industry***		
Equation : (3-2)	Wastewater (m^3/year) =	a (ton/year) x b (m^3/ton)	
a	Ton of palm oil production in form of FFB	• Biogas system 2,320,700 ton FFB/year • Anaerobic system 7,632,000 ton FFB/year • Total 9,952,700 ton FFB/year	from the collected data
b	Rate of wastewater per ton of palm oil production	0.82 m^3/ton FFB	see Appendix A
Wastewater	• Biogas system Wastewater = 2,320,700 x 0.82 = 1,902,974 • Anaerobic system Wastewater = 7,632,000 x 0.82 = 6,258,240 • Total Wastewater = 9,952,700 x 0.82 = 8,161,214	• Biogas system 1,902,974 m^3/year • Anaerobic system 6,258,240 m^3/year • Total 8,161,214 m^3/year	from the calculation

Appendix D-2

The calculation of biogas

Data/parameter	Description	Value	Source
Topic	***Biogas production of cassava starch industry***		
Equation : (3-3)	Biogas (m^3/year) = c (m^3/m^3) x Wastewater (m^3)		
c	Biogas production rate from cassava starch industry wastewater	9.50 m^3/m^3 wastewater	see Appendix A
Wastewater	Wastewater production of cassava starch industry	• Biogas system 37,032,455 m^3/year • Anaerobic system 14,670,404 m^3/year • Aerobic system 2,235,324 m^3/year • Total 53,938,183 m^3/year	as the above
Biogas	• Biogas system Biogas = 9.50 x 37,032,455 = 351,808,322.50 • Anaerobic system Biogas = 9.50 x 14,670,404 = 139,368,838 • Aerobic system Biogas = 9.50 x 2,235,324 = 21,235,578 • Total Biogas = 9.50 x 53,938,183 = 512,412,738.50	• Biogas system 351,808,322.50 m^3/year • Anaerobic system 139,368,838 m^3/year • Aerobic system 21,235,578 m^3/year • Total 512,412,738.50 m^3/year	from the calculation

Data/parameter	Description	Value	Source
Topic	***Biogas production of palm oil industry***		
Equation : (3-3)	Biogas (m^3/year) = c (m^3/m^3) x Wastewater (m^3)		
c	Biogas production rate from palm oil industry wastewater	13 m^3/m^3 wastewater	see Appendix A
Wastewater	Wastewater production of palm oil industry	• Biogas system 1,902,974 m^3/year • Anaerobic system 6,258,240 m^3/year • Total 8,161,214 m^3/year	as the above
Biogas	• Biogas system Biogas = 13 x 1,902,974 = 24,738,662 • Anaerobic system Biogas = 13 x 6,258,240 = 81,357,120 • Total Biogas = 13 x 8,161,214 = 106,095,782	• Biogas system 24,738,662 m^3/year • Anaerobic system 81,357,120 m^3/year • Total 106,095,782 m^3/year	from the calculation

Appendix D-3

The calculation of electricity generation

Data/parameter	Description	Value	Source
Topic	***Volume of generating electricity of cassava starch industry***		
Equation : (3-4)	Electricity (unit/year) = Biogas(m^3/year) x 1.20(unit/ m^3)		
Biogas	Biogas production of cassava starch industry	• Biogas system 351,808,322.50 m^3/year • Anaerobic system 139,368,838 m^3/year • Aerobic system 21,235,578 m^3/year • Total 512,412,738.50 m^3/year	as the above
1.20(unit/ m^3)	The generating electricity per 1 m^3 of biogas	1.20 unit/ m^3	[25]
Electricity	• Biogas system Electricity = 351,808,322.50 x 1.20 = 422,169,987 • Anaerobic system Electricity = 139,368,838 x 1.20 = 167,242,605.60 • Aerobic system Electricity = 21,235,578 x 1.20 = 25,482,693.60 • Total Electricity = 512,412,738.50 x 1.20 = 614,895,286.20	• Biogas system 422,169,987 unit/year • Anaerobic system 167,242,605.60 unit/year • Aerobic system 25,482,693.60 unit /year • Total 614,895,286.20 unit/year	from the calculation

Data/parameter	Description	Value	Source
Topic	***Volume of generating electricity of palm oil industry***		
Equation : (3-4)	Electricity (unit/year) = Biogas(m^3/year) x 1.20(unit/ m^3)		
Biogas	Biogas production of palm oil industry	• Biogas system 24,738,662 m^3/year • Anaerobic system 81,357,120 m^3/year • Total 106,095,782 m^3/year	as the above
1.20(unit/ m^3)	The generating electricity per 1 m^3 of biogas	1.20 unit/ m^3	[25]
Electricity	• Biogas system Electricity = 24,738,662 x 1.20 = 29,686,394.40 • Anaerobic system Electricity = 81,357,120 x 1.20 = 97,628,544 • Total Electricity = 106,095,782 x 1.20 = 127,314,938.40	• Biogas system 29,686,394.40 unit/year • Anaerobic system 97,628,544 unit/year • Total 127,314,938.40 unit/year	from the calculation

Appendix D-4

The calculation of electricity value

Data/parameter	Description	Value	Source
Topic	***Value of electricity of cassava starch industry***		
Equation : (3-5)	Electricity value(Baht/year) = Electricity(unit/year) x Price per unit (Baht/unit)		
Electricity	Volume of generating electricity of cassava starch industry	• Biogas system 422,169,987 unit/year • Anaerobic system 167,242,605.60 unit/year • Aerobic system 25,482,693.60 unit /year • Total 614,895,286.20 unit/year	as the above
Price per unit	The price per unit of electricity	2.50 Baht	[84]
Electricity value	• Biogas system Electricity value = 422,169,987 x 2.50 = 1,055,424,967.50 • Anaerobic system Electricity value = 167,242,605.60 x 2.50 = 418,106,514 • Aerobic system Electricity value = 25,482,693.60 x 2.50 = 63,706,734 • Aerobic system Electricity value = 614,895,286.20 x 2.50 = 1,537,238,216	• Biogas system 1,055.42 million Baht/year • Anaerobic system 418.11 million Baht/ year • Aerobic system 63.71 million Baht/year • Total 1,537.24 million Baht/year	from the calculation

Data/parameter	**Description**	**Value**	**Source**
Topic	***Value of electricity of palm oil industry***		
Equation : (3-5)	Electricity value(Baht/year) = Electricity(unit/year) x Price per unit (Baht/unit)		
Electricity	Volume of generating electricity of palm oil industry	• Biogas system 29,686,394.40 unit/year • Anaerobic system 97,628,544 unit/year • Total 127,314,938.40 unit/year	as the above
Price per unit	The price per unit of electricity	2.50 Baht	[84]
Electricity value	• Biogas system Electricity value = 29,686,394.40 x 2.50 = 74,215,986 • Anaerobic system Electricity value = 97,628,544 x 2.50 = 244,071,360 • Aerobic system Electricity value = 127,314,938.40 x 2.50 = 318,287,346	• Biogas system 74.22 million Baht/year • Anaerobic system 244.07 million Baht/ year • Aerobic system 63.71million Baht/year • Total 318.29 million Baht/year	from the calculation

Appendix D-5

The calculation of greenhouse gas reduction (CH_4)

Data/parameter	Description	Value	Source
Topic	***Greenhouse gas emission reduction from cassava starch industry***		
Equation : (3-6)	CH_4 reduction (kg/year) = Total COD (kgCOD/year) x B_0 ($kgCH_4$/kgCOD) x MCF x 0.80		
Total COD	Total COD per year of cassava starch industry wastewater According to the collected data of COD was in form of kg COD/m^3, hence it had to be converted in form of total COD/year, as follows: Total COD = wastewater(m^3/year) x 15.92*kgCOD/ m^3 • Biogas system Total COD = 37,032,455 x 15.92 = 589,556,683.60 • Anaerobic system Total COD = 14,670,404 x 15.92 = 233,552,831.68 • Aerobic system Total COD = 2,235,324 x 15.92 = 35,586,358.08 • Total of none biogas system Total COD = 16,905,728 x 15.92 = 269,139,189.76 • Total Total COD = 53,938,183 x 15.92 = 858,695,873.36 Remark : * see Appendix A	• Biogas system 589,556,683.60 kgCOD/year • Anaerobic system 233,552,831.68 kgCOD/year • Aerobic system 35,586,358.08 kgCOD/year • Total of none biogas system 269,139,189.76 kgCOD/year • Total 858,695,873.36 kgCOD/year	from the calculation
Bo	Maximum methane producing capacity of the wastewater	0.21 $kgCH_4$/kgCOD	[58]
MCF	Methane conversion factor that express what proportion of the effluent would be anaerobically digested	0.738	[58]
0.80	The reduction of greenhouse gas emission from baseline process, which was 80% or 0.80	0.80	see Appendix B

Data/parameter	Description	Value	Source
CH_4 reduction	• Biogas system CH_4 reduction = 589,556,683.60 x 0.21 x 0.738 x 0.80 = 73,095,596 • Anaerobic system CH_4 reduction = 233,552,831.68 x 0.21 x 0.738 x 0.80 = 28,956,814 • Aerobic system CH_4 reduction = 35,586,358.08 x 0.21 x 0.738 x 0.80 = 4,412,139 • Total of none biogas system CH_4 reduction = 269,139,189.76 x 0.21 x 0.738 x 0.80 = 33,368,953 • Total CH_4 reduction = 858,695,873.36 x 0.21 x 0.738 x 0.80 = 106,464,549	• Biogas system 73,095,596 kg /year • Anaerobic system 28,956,814 kg /year • Aerobic system 4,412,139 kg /year • Total of none biogas system 33,368,953 kg /year • Total 106,464,549 kg /year	from the calculation
Topic	***Greenhouse gas emission reduction from palm oil industry***		
Equation : (3-6)	CH_4 reduction (kg/year) = Total COD (kgCOD/year) x B_0 (kgCH_4/kgCOD) x MCF x 0.80		
Total COD	Total COD per year of palm oil industry wastewater Because of the collected data of COD was in form of kg COD/m^3, so it had to be converted in form of total COD/year, as follows: Total COD = wastewater(m^3/year) x 74.62**kgCOD/m^3 • Biogas system Total COD = 1,902,974 x 74.62 = 141,999,919.88 • Anaerobic system Total COD = 6,258,240 x 74.62 = 466,989,868.80	• Biogas system 141,999,919.88 kgCOD/year • Anaerobic system 466,989,868.80 kgCOD/year • Total 608,989,788.68 kgCOD/year	from the calculation

Data/parameter	Description	Value	Source
Total COD	• Total Total COD = 8,161,214 x 74.62 = 608,989,788.68 Remark : * see Appendix A		from the calculation
Bo	Maximum methane producing capacity of the wastewater	0.21 $kgCH_4/kgCOD$	[58]
MCF	Methane conversion factor that express what proportion of the effluent would be anaerobically digested	0.738	[58]
0.80	The reduction of greenhouse gas emission from baseline process, which was 80% or 0.80	0.80	see Appendix B
CH_4 reduction	• Biogas system CH_4 reduction = 141,999,919.88 x 0.21 x 0.738 x 0.80 = 17,605,718 • Anaerobic system CH_4 reduction = 466,989,868.80 x 0.21 x 0.738 x 0.80 = 57,899,272 • Total CH_4 reduction = 608,989,788.68 x 0.21 x 0.738 x 0.80 = 75,504,990	• Biogas system 17,605,718 kg /year • Anaerobic system 57,899,272 kg /year • Total 75,504,990 kg /year	from the calculation

Appendix D-6

The calculation of greenhouse gas reduction in form of CO_2 equivalent

Data/parameter	Description	Value	Source
Topic	***Greenhouse gas emission reduction from cassava starch industry in form of ton CO_2/year***		
Equation : (3-7)	CO_2 (ton/year) = $\frac{21 \text{ x } CH_4 \text{ (kg/year) x 1 (ton)}}{1000 \text{ (kg)}}$		
21	Global warming potential of methane	21	Climate Change 1995, IPCC Second Assessment Report cited in [8]
CH_4	CH_4 reduction from cassava starch industry	• Biogas system 73,095,596 kg /year • Anaerobic system 28,956,814 kg /year • Aerobic system 4,412,139 kg /year • Total of none biogas system 33,368,953 kg /year • Total 106,464,549 kg /year	as the above
1/1000	The conversion factor of kg to ton	1 ton/1000 kg	-

Data/parameter	Description	Value	Source
CO_2	• Biogas system $CO_2 = \frac{21x73,095,596x1}{1000}$ = 1,535,007.51 • Anaerobic system $CO_2 = \frac{21x28,956,814x1}{1000}$ = 608,093.10 • Aerobic system $CO_2 = \frac{21x4,412,139x1}{1000}$ = 92,654.92 • Total of none biogas system $CO_2 = \frac{21x33,368,953x1}{1000}$ = 700,748.02 • Total $CO_2 = \frac{21x106,464,549\ x1}{1000}$ = 2,235,755.53	• Biogas system 1,535,007.51 ton /year • Anaerobic system 608,093.10 ton /year • Aerobic system 92,654.92 ton /year • Total of none biogas system 700,748.02 ton /year • Total 2,235,755.53 ton /year	from the calculation

Data/parameter	Description	Value	Source
Topic	***Greenhouse gas emission reduction from palm oil industry in form of ton CO_2/year***		
Equation : (3-7)	CO_2 (ton/year) = $\frac{21 \text{ x } CH_4 \text{ (kg/year) x 1 (ton)}}{1000 \text{ (kg)}}$		
21	Global warming potential of methane	21	Climate Change 1995, IPCC Second Assessment Report cited in [8]
CH_4	CH_4 reduction from palm oil industry	• Biogas system 17,605,718 kg /year • Anaerobic system 57,899,272 kg /year • Total 75,504,990 kg /year	as the above
1/1000	The conversion factor of kg to ton	1ton/1000 kg	-
CO_2	• Biogas system $CO_2 = \frac{21x17,605,718x1}{1000}$ = 369,720.08 • Anaerobic system $CO_2 = \frac{21x57,899,272x1}{1000}$ = 1,215,884.71 • Total $CO_2 = \frac{21x75,504,990\ x1}{1000}$ = 1,585,604.79	• Biogas system 369,720.08 ton /year • Anaerobic system 1,215,884.71 ton /year • Total 1,585,604.79 ton /year	from the calculation

Appendix D-7

The calculation of CERs value

Data/parameter	Description	Value	Source
Topic	***Value of greenhouse gas emission reduction from cassava starch industry***		
Equation : (3-8)	CERs (Baht/year) = CO_2 (ton/year) x d (Baht/ton)		
CO_2	Greenhouse gas emission reduction from cassava starch industry in form of ton CO_2/year	• Biogas system 1,535,007.51 ton /year • Anaerobic system 608,093.10 ton /year • Aerobic system 92,654.92 ton /year • Total of none biogas system 700,748.02 ton /year • Total 2,235,755.53 ton /year	as the above
d	Price per unit of CERs	153.24 Baht/CERs	see Appendix C
CERs	• Biogas system CERs = 1,535,007.51 x 153.24 = 235,224,550.83 Baht/year • Anaerobic system CERs = 608,093.10 x 153.24 = 93,184,187 Baht/year • Aerobic system CERs = 92,654.92 x 153.24 = 14,198,440 Baht/year • Total of none biogas system CERs = 700,748.02 x 153.24 = 107,382,627 Baht/year	• Biogas system 253.22 million Baht/year • Anaerobic system 93.20 million Baht/ year • Aerobic system 14.20 million Baht/year	from the calculation

Data/parameter	Description	Value	Source
CERs	• Total CERs = 2,235,755.53 x 153.24 = 342,607,177 Baht/year	• Total of none biogas system 107.38 million Baht/year • Total 342.61 million Baht/year	from the calculation
Topic	***Value of greenhouse gas emission reduction from palm oil industry***		
Equation : (3-8)	CERs (Baht/year) = CO_2 (ton/year) x d (Baht/ton)		
CO_2	Greenhouse gas emission reduction from palm oil industry in form of ton CO_2/year	• Biogas system 369,720.08 ton /year • Anaerobic system 1,215,884.71 ton /year • Total 1,585,604.79 ton /year	as the above
d	Price per unit of CERs	153.24 Baht/CERs	see Appendix C
CERs	• Biogas system CERs = 369,720.08 x 153.24 = 56,655,905 Baht/year • Anaerobic system CERs = 1,215,884.71 x 153.24 = 186,322,173 Baht/year • Total CERs = 1,585,604.79 x 153.24 = 242,978,078 Baht/year	• Biogas system 56.66 million Baht/year • Anaerobic system 186.32 million Baht/year • Total 242.98 million Baht/year	from the calculation

Appendix D-8

The calculation of potential comparison of cassava starch and palm oil industry

Data/parameter	Description
Topic	***Biogas production of cassava starch industry***
Biogas production in form of m^3/harvested area (rai)	Biogas production in form of m^3/harvested area (rai) of cassava starch industry can calculate as the following data: • Cassava yield /rai = 3,668 kg/rai [82] • Percentage of cassava starch from fresh cassava roots = 21.46 [81] • Wastewater rate = 17.80 m^3/ton flour (see Appendix A) • Biogas production rate from wastewater = 9.50 m^3/m^3 (see Appendix A) Biogas production = $\frac{3,668}{1,000}$ x $\frac{21.46}{100}$ x 17.80 x 9.50 = 133.11 m^3/rai
Biogas production in form of m^3/ton flour (product)	Biogas production = 17.80 x 9.50 = 169.10 m^3/ton flour
Biogas production in form of m^3/ton fresh cassava root (raw material)	Biogas production = $\frac{21.46}{100}$ x 17.80 x 9.50 = 36.29 m^3/ton fresh cassava root
Topic	***Biogas production of palm oil industry***
Biogas production in form of m^3/harvested area (rai)	Biogas production in form of m^3/harvested area (rai) of palm oil industry can calculate as following data: • FFB yield/ rai = 2,654 kg/rai [83] • Wastewater rate = 0.82 m^3/ton FFB (see Appendix A) • Biogas production rate from wastewater = 13.00 m^3/m^3 (see Appendix A) • Percentage of CPO from FFB = 18.50 [83] Biogas production = $\frac{2,654}{1,000}$ x 0.82 x 13.00 = 28.29 m^3/rai
Biogas production in form of m^3/ton CPO(product)	Biogas production = $\frac{100}{18.50}$ x 0.82 x 13.00 = 57.62 m^3/ton CPO

Data/parameter	Description
Biogas production in form of m^3/ton FFB (raw material)	Biogas production = 0.82 x 13.00 = 10.66 m^3/ton FFB
Topic	***Greenhouse gas reduction of cassava starch industry***
Greenhouse gas reduction in form of ton CO_2eq/harvested area (rai)	Greenhouse gas reduction in form of tonCO_2/harvested area (rai) can calculate from the following data and the applied of equation 3-6 and 3-7, they are as follows: • COD = 15.92 kg COD/m^3 wastewater (see Appendix A) • B_o (Maximum methane producing capacity of the wastewater) = 0.21 kg CH_4/kg COD [58] • MCF (Methane conversion factor that express what proportion of the effluent would be anaerobically digested) = 0.738 [58] • GWP of CH_4 = 21 (Climate Change 1995, IPCC Second Assessment Report cited in [8]) • The reduction of greenhouse gas emission from baseline process, which was 80% or 0.80 = 0.80 Greenhouse gas reduction = $\frac{3,668}{1,000} \times \frac{21.46}{100} \times 17.80 \times \frac{15.92}{1,000} \times 0.21 \times 0.738 \times 0.80 \times 21$ = 0.58 ton CO_2eq / rai
Greenhouse gas reduction in form of ton CO_2eq /ton flour (product)	Greenhouse gas reduction = $17.80 \times \frac{15.92}{1,000} \times 0.21 \times 0.738 \times 0.80 \times 21$ = 0.74 ton CO_2eq /ton flour
Greenhouse gas reduction in form of ton CO_2eq /ton fresh cassava root (raw material)	Greenhouse gas reduction = $\frac{21.46}{100} \times 17.80 \times \frac{15.92}{1,000} \times 0.21 \times 0.738 \times 0.80 \times 21$ = 0.16 ton CO_2eq / ton fresh cassava root

Data/parameter	Description
Topic	***Greenhouse gas reduction of palm oil industry***
Greenhouse gas reduction in form of ton CO_2eq /harvested area (rai)	Greenhouse gas reduction in form of tonCO_2/harvested area (rai) can calculate from the following data and the equation 3-6 and 3-7 were also applied, they are as follows: • COD = 74.62 kg COD/m^3 wastewater (see Appendix A) • B_o (Maximum methane producing capacity of the wastewater) = 0.21 kg CH_4/kg COD [58] • MCF (Methane conversion factor that express what proportion of the effluent would be anaerobically digested) = 0.738 [58] • GWP of CH_4 = 21 (Climate Change 1995, IPCC Second Assessment Report cited in [8]) • The reduction of greenhouse gas emission from baseline process, which was 80% or 0.80 = 0.80 Greenhouse gas reduction = $\frac{2,654}{1,000}$ x 0.82 x $\frac{74.62}{1,000}$ x 0.21 x 0.738 x 0.80 x 21 = 0.42 ton CO_2/ rai
Greenhouse gas reduction in form of ton CO_2eq /ton CPO (product)	Greenhouse gas reduction = $\frac{100}{18.50}$ x 0.82 x $\frac{74.62}{1,000}$ x 0.21 x 0.738 x 0.80 x 21 = 0.16 ton CO_2/ton CPO
Greenhouse gas reduction in form of ton CO_2eq /ton FFB (raw material)	Greenhouse gas reduction = 0.82 x $\frac{74.62}{1,000}$ x 0.21 x 0.738 x 0.80 x 21 = 0.16 ton CO_2/ton FFB
Topic	***CERs value of cassava starch industry***
CERs value in form of Baht/harvested area (rai)	CERs value was calculated from the price at 153.24 Baht/ton CO_2 eq (see Appendix C): CERs value = 153.24 x 0.58 = 89.00 Baht/rai

Data/parameter	**Description**
CERs value in form of Baht/ton flour (product)	CERs value = 153.24 x 0.74 = 113.06 Baht/ton flour
CERs value in form of Baht/ton fresh cassava root (raw material)	CERs value = 153.24 x 0.16 = 24.52 Baht/ton flour
Topic	***CERs value of palm oil industry***
CERs value in form of Baht/harvested area (rai)	CERs value = 153.24 x 0.42 = 64.79 Baht/rai
CERs value in form of Baht/ton CPO (product)	CERs value = 153.24 x 0.86 = 131.79 Baht/ton CPO
CERs value in form of Baht/ton FFB (raw material)	CERs value = 153.24 x 0.16 = 24.52 Baht/ton FFB

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