

CHAPTER 1

INTRODUCTION

1.1 Rationale

Expanding the economy, supply and price of energy are critical factors for many Asian countries, such as Thailand. Thailand has been searching for alternative energy sources by put a priority on seeking new and renewable energy resources to reduce dependency on fossil fuels. Thailand has higher energy expenditures than value earned of exported agricultural goods. Due to the high price of imported oil that effects to Thailand's economy growth, the country has tried to look for alternative energies and renewable energy solutions and low-cost energy production from in-country facilities and resources.

Despite many types of energy resources available for world consumption, fossil fuels are still the most important energy sources as they contribute more than 80% of the world's energy supply. Among various fossil fuels, the oil is of great significance having the largest consumption (38% of the world energy consumption) followed by coal (26%) and gas (23%) being used in industrial, commercial, household and transportation sectors. In Thailand, the energy is consumed the most in transportation sector (40%), followed by industrial uses (35%), residential and commercial uses (22%) and the rest for agricultural sector (Sriroth et al., 2010).

The most crucial energy resources are fossil fuels, such as oil (51%), natural gas (31%) and coal (15%). Approximately 65% of the oil is used in the transportation sector. Similar to many countries, the energy supply in Thailand relies greatly on imported oil. The dependency on imported fossil oil is the nation constraint for economic growth due to oil price fluctuation. Although there are reports of oil reserves on the Earth, there is high possibility that the world's demand of fossil oil still exceeds the supply, leading to high oil prices. Consequently, the country has to seek for an alternative sustainably-sourced energy of which renewable biofuel from agricultural produces is the first national milestone to be accomplished as a part of the nation's energy security plan since 2005.(Sriroth et al., 2010).

Under the national energy program, two kinds of liquid fuels including biodiesel and bioethanol, are of great interest to be used in transportation sector. The biodiesel is planned to be a community energy product in certain areas whereas the bioethanol,

recognized as environmentally friendly energy due to less greenhouse gas (GHG) emission, is targeted to serve the nationwide by entirely substituting a current-used toxic octane booster, i.e. MTBE(Methyl Tertiary Butyl Ether) in unleaded gasoline at 10% and 20% to produce E10 (for octane 91 and 95) and E20 (for octane 95 only) gasohol, respectively. The policy for E85 and E100 is now under consideration.

Prior to this officially released policy, the application of bioethanol in the transportation sector had, in fact, originated under the Royal Chitralada Agricultural Projects instituted by King Bhumibol Adulyadej (Rama IX) in 1961.

In 1986, the first pilot plant to produce 91% ethanol from sugar cane still could not be blended with gasoline. Subsequently, 95% and anhydrous ethanol were produced and the latter one, blended with octane 91 as E10 was used with the Royal cars. With persistent works of the Royal project, the ethanol plant for biofuel use was officially opened in 1995. Currently, there are 47 factories legally licensed to produce biofuel ethanol with a total capacity of 12.295 Million liters (ML)/day or 3688.5 ML per annum (at 300 working days). Two feedstocks, namely sugar cane molasses and cassava (*Manihotesculenta* Crantz), are primary raw materials for this industrial purpose.

Currently, there are only 24 factories that have permission from the Ministry of Energy to produce ethanol (DEDE, 2014). 11 factories use a single feedstock of molasses with a total production capacity of 2.410 ML/day, 4 factories using either molasses or cassava as feedstocks with the total production capacity of 0.7 ML/day, 6 factories using cassava only and the total production capacity is 1.680 ML/day. The total ethanol from the factories where the operation is in place are about 4.790 ML/day. Additionally, there are 4 new factories which have got the licenses and under its construction period. 1 of them the construction is finished and started trial of operation and 3 factories are under construction. The total production capacity of these 4 factories is 1.370 ML/day. The total production capacity of all 24 permitted factories is 6.160 ML/day (DEDE, 2014).

A multi-feedstock process using both molasses and cassava is preferred in some factories so as to avoid feedstock shortages, which eventually end up with markedly high-priced feedstock, and consequently, higher ethanol reference prices.

At present, the pricing formula of biofuel ethanol, as approved by The National Energy Policy Committee, Ministry of Energy, has taken into account the cost of raw materials and produced quantities of fuel ethanol from both molasses and cassava. Using the conversion ratios of 4.17 kg molasses (at 50 Brix) and 2.63 kg cassava chips (with

starch content of more than 65%) for 1 L of anhydrous ethanol. In addition, the structure of ethanol reference prices includes the production costs of each feedstock, which are 6.125 and 7.107 Baht/L formolasses and cassava, respectively. This monthly-announced ethanol reference prices reflect the actual cost of local ethanol producers. Presently, 17 factories are operating with the total production capacity of 2.575 ML/day, 8 factories are under construction with the total production capacity of 4.495 ML/day and the rests are inactive status(Srirothet al., 2010).

Thailand tries to push the use of bioethanol and biofuel on to the market because of discontinuities in oil prices. Therefore, gasohol has become more attractive to consumers. The renewable energy development plans were approved by the cabinet in 2003 by which Thai energy consumption will be substituted by 8% of renewable energy for industrial sector and commercial sector in Thailand. Additionally, the Department of Energy Development and Efficiency (DEDE), under Ministry of Energy, Ministry of Energy established the 15 years renewable energy development plan (B.E.2551- 2565 or 2008-2022), the so called REDP 15 with the aims to use renewable energy as the major energy sources and to replace imported oil consumption. The target prospect will increase final energy consumption from renewable energy 8% in 2011 to 20% in 2022 which biofuel will be promoted to reach REDP targets.

The current government plan and policy has promoted and supported the use of alternative energy sources and gasohol by illustrating to business entities regarding the potential of investing in ethanol production by using through supporting research and development of ethanol technology and financing demonstration projects.

The implementation of Thailand government has resulted in an increasing number of ethanol production factories.

This thesis aims to study the energy efficiency of bioethanol production from those factories that using cassava as raw material.

1.1.1 Ethanol and gasohol

Ethanol is a kind of alcohol derived from plant fermentation to convert starch in plants to sugar then converting sugar to alcohol, after purifying it to 95 percent alcohol by distillation. Ethanol for blending with oil to fill in engine has its purity from 99.5 % by volume which is capably used as fuel. In Thailand, ethanol is used to blend with gasoline for fuel use or so-called as gasohol.

Gasohol production in Thailand originated with the royal initiative of King Bhumibol, in 1985. Gasohol production for alternative energy use was initiated in a study of royal project by producing ethanol from sugarcane. After that the public and private started alerting to co-develop and test with the engines. Even it was not widespread used until the world oil price increased sharply in 2003, the government has turned to seriously push up producing and consuming of gasohol.

According to Thailand's oil price structure, reducing the levy of the Oil Fund to lower the retail price of Gasohol 95 less than of Gasoline 95 by 1.50 baht/l. The result is the lower price of Gasohol 95, plus complementing with several promotion measures by the government, the people turn use more gasohol. In December 2005, gasohol use was at a high proportion by 17.4 percent of total gasoline selling. Government has improved such the measures to keep promoting the gasohol production and consumption, e.g. ethanol pricing formulation, confidence building measure, including a pricing measure. Up to November 2008, consuming of ethanol in Thailand would be in form of gasohol 95, gasohol 91, E20 and E85 at 11 ml/day or as 1.11 ml/day of ethanol.

To push up the 15-Year Ethanol Development Plan to achieve the target, it is extremely essential to develop the co-operation of relevant entities through the supply chain from raw material sources for ethanol production to ethanol marketing, as shown in Figure 1.1.

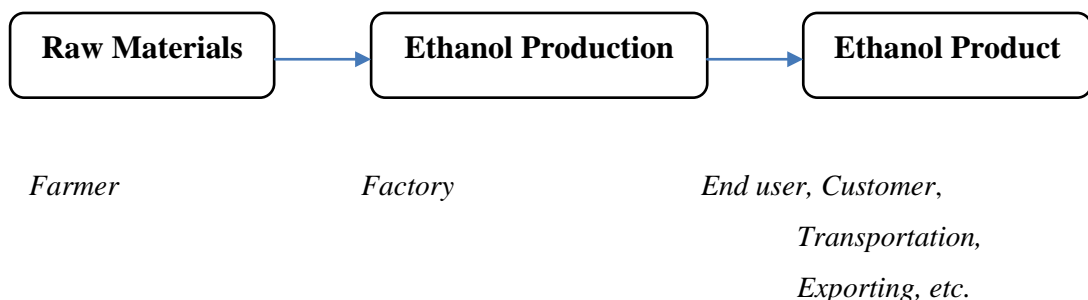


Figure 1.1 Ethanol Supply Chain (DEDE, 2010)

The Agricultural Economic Office has estimated the cassava yield in 2009 at 29.60 Mt, which will be processed in to cassava chips, pellets and starch for local consumption and export. The rest as excessive products are used to produce the ethanol for 1.25 Mt and capable producing of ethanol at 0.58 ML/day and as for the year 2010-2011 see in Table 1.1, illustrating the demand and supply of cassava in 2008-2011.

Table 1.1 Demand and Supply of Cassava in 2008-2011 (DEDE, 2014)

Item	2008	2009	2010	2011
Cassava yields	25.56	29.60	31.45	33.30
Planting area (Million.raï)	7.397	7.400	7.400	7.400
Yield/raï (t/raï/ year)	3.456	4.00	4.250	4.500
- Domestic demand	7.77	8.19	8.42	8.69
• Cassava chip/strip, pellets	2.31	2.52	2.63	2.73
• Starch	5.46	5.67	5.80	5.96
- Exporting demand	15.96	20.16	21.42	22.05
• Pellets	4.20	3.36	3.36	3.15
• Cassava chip/strip	2.10	6.72	7.35	7.77
• Starch	9.66	10.08	10.71	11.13
The rest of cassava for producing ethanol	1.83	1.25	1.61	2.56
Accounted to ethanol derived from cassava (ML/d)	0.85	0.58	0.75	1.19
Production capacity of ethanol derived from cassava (ML/d)	0.62	1.97	2.17	2.17

1.1.3 Ethanol production plant

Ethanol derived from cassava is commercially and widely available at present. Presently, the list of Existing Ethanol Plants and Operation is indicated as Table 1.2 and the actual capacity for the whole nation is shown as Table 1.3.

Table 1.2 List of Existing Ethanol Plants and Operation (DEDE, 2014)

Feedstock /Raw Material : Molasses			
No	Plant	Site	Capacity(L/day)
1	Thai Agro Energy	Suphanburi	150,000
2	EkrathPattana	Nakorn Swan	230,000
3	Thai Sugar Ethanol	Kanchanaburi	200,000
4	Petro Green (Kanlaseen)	Kanlaseen	230,000
5	Petro Green(Chaiyapoom)	Chaiyapoom	500,000
6	KI Ethanol	NakornRatchsima	100,000
7	KhonKaen Alcohol	KhonKaen	150,000
8	ThaiRungRueng Energy	Saraburi	120,000
9	MitPol Biofuel (DanChange)	Supanburi	200,000
10	KhonKaen Alcohol (Boh Ploy)	Kanchanaburi	300,000
11	Maesawd Clean Energy	Tak	230,000
Total (1)			2,410,000
Feedstock /Raw Material : Molasses and Cassava			
No	Plant	Site	Capacity(L/day)
12	Ratchburi Ethanol	Ratchburi	150,000
13	ES Power	Sakaew	150,000
14	Thai Alcohol	NakornPathom	200,000

15	Petro Green (DanChang)	Suphanburi	200,000	
Total (2)			700,000	
Feedstock /Raw Material : Cassava				
16	SupThip	Lopburi	200,000	
17	Thai Ethanol Power	KhonKaen	130,000	
18	TaiPing Ethanol	Sakaew	300,000	
19	PSB Starch Production	Chonburi	150,000	
20	E 85	Prachinburi	500,000	
21	Ubol Bioethanol	Ubolratchatani	400,000	
Total (3)			1,680,000	
Total Production Capacity (1+2+3)			4,790,000	
New Factory (Under construction)		Site	Feedstock / Raw Material	Capacity(L/day)
22	PTK Ethanol -Phase 1	NakornRatchasima	Cassava	340,000
	PTK Ethanol -Phase 2,3	NakornRatchasima	Cassava	680,000
23	Impress Technology	ChaChoengSao	Cassava &Molasse	200,000
24	Sima Inter Products	ChaChoengSao	Cassava	150,000
Total (4)			1,370,000	
Total Production Capacity (1+2+3+4)			6,160,000	

Table 1.3 Quality of production of ethanol as fuel in Thailand (DEDE, 2014)

Year	Total Quantity (ML/year)	Average actual production capacity (ML/day)
2008	336.21	0.92
2009	397.66	1.09
2010	425.80	1.16
2011	520.51	1.42
2012	665.57	1.79

1.2 Objectives of the study

1.2.1 To review biological and the mechanical methods, used for bioethanol production from cassava. The focus is to analyze the energy consumption and the efficiency through bioethanol production process using cassava as the raw material.

1.2.2 To assess the efficiency and possibilities for improving the efficiency of bioethanol production. This study focuses on one production factory has unique production technology and capacity.

1.2.3 To assess the CO₂ emissions of bioethanol production from cassava from each step of the bioethanol production process.

1.3 Literature reviews

Bioethanol development in China and the potential impacts on its agricultural economy (Qiu et al., 2009).

Qiu et al. studied bioethanol production in China which is now the third largest bioethanol producer in the world after the United States and Brazil. China's economy has experienced remarkable growth since economic reforms initiated in 1978.

China's annual average growth rate of gross domestic product (GDP) reached nearly 10% in the last three decades. The rapid growth of China's economy also led to a rapid rise in demand for energy that also gave rise to mounting concerns in the country

about its national energy security. The nation's record on greenhouse gas emission is also becoming a concern not only in China but the rest of the world as well. In 2007, China's net import of oil has reached to 186 million tons, accounting for 49.6% of its total oil demand. Given the energy security concerns, the search for alternative sources of energy has become a top policy priority of the Government of China. Biofuel, with its reputation of being relatively carbon neutral, has been the center of much attention by the Government.

Rising bioethanol production in China also has raised several issues to be analyzed and assessed, e.g. the trend of China's bioethanol production, the major policies that have supported its bioethanol program, the appropriate feedstock crops if China wants to expand its bioethanol production in the future, limited resources for the bioethanol production potential of China, China's bioethanol expansion in the future, and its effect on agricultural prices, production, and national food security. To answers to these questions are critical important as China are developing its long term plan and target for bioethanol.

The overall goals of this paper are to provide an overview of China's current bioethanol program, its future trends, and the likely impacts on its agricultural economy in the future.

It is mentioned that China is now the third largest bioethanol producer in the world after the United States and Brazil.

The overall goals of this paper are to provide an overview of China's current bioethanol program, its future trends, and the likely impacts on its agricultural economy in the future. The analysis shows that China has developed an ambitious long-run biofuel program with a series of financial and institutional supports. While there are several potential feedstock crops available for bioethanol production, lack of land for feedstock production is one of major constraints in China's bioethanol expansion.

The results show that although China's bioethanol expansion will have little impact on overall agricultural prices in international markets, it will have significant impacts on the prices, productions, and trade of those energy crops being used for bioethanol production in China.

Ethanol production from biomass: Analysis of process efficiency (Basnanoni S. and Marchettni N., 1996).

This paper this discusses the efficiency of the bioethanol production process using biomass from agricultural products as raw materials. It investigates a using of agricultural crops to produce ethanol.

This paper reports results from the analysis of various case studies involving the conversion of biomass into ethanol in southern Florida. Aspects such as carbon balance, process efficiency and land requirement were evaluated, to establish the feasibility and ecological sustainability of the conversion processes Such as a Brazilian production of ethanol is the case considered from sugarcane. In addition, ethanol production from grapes in Italy is also considered.

The bioethanol production from agricultural raw materials is carried out to produce liquid fuels and reduce carbon emissions from the combustion of fossil fuels. Therefore it is resulted to impact on climate.

The study involves the conversion of biomass into ethanol. Aspects such as carbon balance, process efficiency and land requirement were evaluated, to establish the feasibility and ecological sustainability of the conversion processes. Crop production and transformation processes have been investigated by the traditional energy and carbon analyses and the more recent energy analysis. Traditional methodologies, e.g. energy and carbon balances. The combination of such analyses provides a deeper insight into the problems of converting biomass to fuel.

In particular, it is shown that energy analysis can evaluate long-term sustainability and comparisons of energy-based indices can be used to compare efficiency and environmental inputs among various production systems. The results based on present data show that we are still far from a sustainable production of biofuels: it seems that biomass energy cannot be fundamental source of energy in countries showing a high level of energy consumption due to the population per capita and land which is appeared to be the main constraint.

Progress in bioethanol processing(Balata M. and Balata H., 2008).

This paper studies the production of ethanol (bioethanol) from biomass as one way to reduce both the consumption of crude oil and the pollution of the environment. Bioethanol is appropriate for the mixed fuel in the gasoline engine because of its high octane number, and its low certain number and high heat of vaporization impede self-

ignition in the diesel engine. So, ignition improver, glow-plug, surface ignition, and pilot injection are applied to promote self-ignition by using diesel-bioethanol-blended fuel. Disadvantages of bioethanol include its lower energy density than gasoline, its corrosiveness, low flame luminosity, lower vapor pressure (making cold starts difficult), miscibility with water, and toxicity to ecosystems.

Bioethanol can be produced from cellulosic feedstocks. One major problem with bioethanol production is the availability of raw materials for production.

The availability of feedstocks for bioethanol can vary considerably from season to season and depends on geographic location. Lignocellulosic biomass is the most promising feedstock considering its availability and low cost, but the large-scale commercial production of fuel bioethanol from lignocellulosic materials has still not been implemented.

Conversion technologies for producing bioethanol from cellulosic biomass resources, such as forest materials, agricultural residues and urban wastes, are under development and have not yet been demonstrated commercially.

For designing fuel bioethanol production processes, the assessment of the utilization of different feedstocks (i.e. sucrose containing, starchy materials, lignocellulosic biomass) is required considering the big share that raw materials have in bioethanol costs. In this work, a review of the biological and thermo chemical methods that could be used to produce bioethanol is made and an analysis of its global production trends is carried out.

Assessment of sustainable energy potential of non-plantation biomass resources in Thailand (Sajjakulnukit et al, 2005).

This paper studies about biomass energy sources that are abundant in Thailand. It mentioned that the use of biomass is relatively clean and considered neutral on CO₂ emissions. Advanced biomass energy technologies have also been developed in many countries of the world. Biomass is therefore one of the clean energy resources that shows high potential for meeting the increasing energy demand and substituting fossil fuels.

This paper assesses the sustainable energy potential of the following biomass resources in Thailand: (i) agricultural residues, (ii) animal manure, (iii) fuel wood saving potential through improvement of efficiency, (iv) fuel wood saving potential through substitution by other fuels, (v) municipal solid wastes, and (vi) wastewater. The potential of each source is estimated for the base year 1997 and for the years 2005 and 2010. In this paper, it was also assessed the energy potential of the following non-plantation biomass

resources: (i) agricultural residues, (ii) animal manure, (iii) fuel wood saving potential through improvement of efficiency, (iv) fuel wood saving potential through substitution by other fuels, (v) municipal solid wastes and landfill gases, and (vi) wastewater.

The total energy potential of biomass sources in 1997, 2005 and 2010 is 525, 702 and 821 PJ, respectively. The total potential is estimated to be about 16% and 14% of the projected total energy consumption in 2005 and 2010, respectively.

Energy efficiency in ethanol production using cassava and molasses as raw materials (Phujaroen S., 2008).

This study is about the energy that used as the main input to produce ethanol, and assesses the ratio of energy output to fossil energy input of ethanol production using two types of high potential raw material, namely cassava roots and molasses. Overall energy consumption of the ethanol production including plantation, transportation and ethanol conversion was corrected from the secondary data and survey.

In this assessment, the total energy consumption was calculated based on the heating value of the fuel used. The energy ratio of ethanol production from molasses of 4.05 was higher than from cassava root of 1.21. This is due to the process integration of ethanol plant using molasses with the existing energy surplus sugar mill that can supply significant amount of energy obtained from the by-product biogases. If the ethanol production from cassava uses biogas as process fuel the energy ratio will increase from 1.21 to 1.72 based on the energy consumption in overall ethanol production processes, the conversion of cassava root to ethanol was the highest energy consumption of 76%, while the plantation and transportation consumed energy of 21% and 3% respectively. For ethanol production from molasses, the main energy consumption of 74% was found in molasses production including plantation 14% and transportation 1%, and ethanol production processes consumed 22%. The contribution of fossil and bagasses to the total energy consumption in ethanol production from molasses were 15.5% and 84.5%, respectively; while for the case of cassava root the contribution of fossil and biogas were 70.40% and 29.60%, respectively.

Global market for bioethanol: historical trends and future prospects (**Rosillo-Calle, F., 2006**).

This studying concerns the worldwide interest of alternative transport fuels, of which ethanol is among the most promising options. This interest has in recent years gathered pace, stimulated by high oil prices and the generally perceived view that this

trend is likely to accentuate in the future. The need to reduce GHG emissions is also a fundamental reason for this interest.

The focus of this paper is on ethanol fuel production from sugar and starches with emphasis on short-term issues and implications for the global market and the need to reduce GHG emissions. Replacing 10-20 % of petrol with ethanol is a feasible and desired option.

The study mentions the international markets for bioethanol, which is in the initial stage. The sustainability of bioethanol production are relevant to diversification of feedstocks and number of producing countries.

Sustainable bioethanol production should become a requirement for which certification seems to be a necessity, but should be defined to assure sustainability in a broad sense so that it does not impose additional barriers to trade. Policies should be defined to induce market competitiveness and sustainable development.

Recent technological, social and environmental changes are forcing the search for new alternatives to both propulsion systems and oil-derived fuels. The major forces shaping the automobile industry are: (1) environmental concerns, e.g. zero or very low emissions, (2) increasing cost of oil, (3) health and safety, and (4) consumer's choice. Of the various fuel alternatives under consideration in the transportation sector, ethanol and biodiesel are the most promising in both the short and medium terms. Globally, substituting 10 %, or even 20 %, of petrol (gasoline) with ethanol in 2020 is a feasible option.

Sequencing problems in designing energy efficient production systems(**Wolters, W.T.M., Lambert, A.J.D. and Claus, J., 1995**).

The study investigates the sustainable development of the world economy which implies that industrial energy conservation is indispensable. This paper is studied about managerial aspects of industrial energy conservation. It is described the influence of sequential decision making on the design (choice of unit operations) and, consequently, on the specific energy consumption of a production system in China.

The results show that by taking decisions sequentially with the described tools it is possible to select that combination of non-optimum unit operations that, when combined with each other, build an optimum production system from an energy point of view, from the aspects of economic viability and investment risks, energy efficiency and airborne

emissions. Energy efficiency assessment results show that all projects have positive Net Energy Values.

Emissions show that the corn-based E10 (a blend of 10% gasoline and 90% ethanol by volume), wheat-based E10 and cassava-based E10 have fewer CO₂ and VOC life cycle emissions than does conventional gasoline, but wheat-based E10 and cassava-based E10 can generate more emissions of CO, CH₄, N₂O, NO_x, SO₂, PM10, and corn-based E10 can give more emissions of CH₄, N₂O, NO_x, SO, PM10.

The promise of a technology revolution in cassava bioethanol: From Thai practice to world practice(Srirothet al, 2010).

The abundance of low-cost feedstock and the cost-effective technology are of great importance for reinforcing, industrialization of bioethanol for fuel use as sustainably-sourced and eco-friendly energy.

This study investigates and describes improved techniques that increase the root productivity of cassava (*Manihotesculenta* Crantz), and its conversion to bioethanol by the energy-saving technology being developed in Thailand.

It was found that the productivity of cassava roots can be significantly increased from 22 to 60 tons/ha simply by applying yield improved varieties and good cultivation practice. The important ones are soil plowing, high stake quality, weed control, good planting and harvesting period, land conservation with organic fertilizers and water irrigation.

Currently, the world production of cassava is around 220 million tons per annum with the average yield of 12 tons/ha and the total acreage of 18.5 million ha. If the root productivity increases, for instance. by 5 tons/ha, around 90 million tons of roots are produced that can be converted to 15,000 ML of ethanol by Simultaneous Saccharification and Fermentation (SSF) process, a current production process of which cooked and enzymatically-liquefied cassava materials are subjected to saccharifying enzymes and yeasts in concert. The promising energy-saving technology for converting cassava chips to ethanol has also been introduced at a pilot scale by using a granular starch hydrolyzing enzyme in an uncooked process.

Life-Cycle energy and environmental analysis of bioethanol production from cassava in Thailand(Papong,S. and Malakul P., 2010).

The scope of this study covers all stages of bioethanol production starting from cultivation, chip processing, transportation and the conversion of the bioethanol. The

granting of information as input and output are started from a using of raw material, energy consumption including all emission. It was found negative net energy from the result of energy analysis and it resulted to the less than 1 for an energy ration. The study also indicated the result of life cycle analysis that most of environmental impact is come from the use of coal for power and steam generation to be used in the bioethanol plant. The study mentioned that the used of partial biogas generated from waste water would lead to a significant reduction of environmental impact.

Fuel ethanol production: Process design trends and integration opportunities(Cardona, C. A., and Sanchez, O. J., 2007).

This study is about the trends in ethanol research and development currently dealing with process engineering trends for improving biotechnological production of ethanol. The key role is focused on the development of cost-effective technologies related to ethanol production.

The most promising alternatives for compensating ethanol production are analyzed through the analysis of major trends in process synthesis, modeling, simulation and optimization related to ethanol production. The directions in techno-economical evaluation of fuel ethanol processes are described. Some of the prospective configuration sare shown.

The main ways of process intensification through reaction–reaction, reaction–separation and separation–separation processes are analyzed in the case of bioethanol production. Some examples of energy integration during ethanol production are showed. Some examples concluding considerations on current and future research tendencies in fuel ethanol production regarding process design and integration are also presented.

It is found that the production costs of fuel ethanol are higher than the production costs of gasoline in some cases. However many researches are continuously carried out the studies aimed at reducing ethanol production costs for a profitable industrial operation. Diverse research trends and process improvements could have success in the task of lowering ethanol costs.

These research tendencies are related to the different steps of processing, nature of utilized feedstocks, and tools of process engineering, mainly process synthesis, integration and optimization. The improvement of the production of ethanol from starchy material is the integration of fermentation and separation processes for the reduction of production inhibition, application of membrane technology (e.g. for ethanol removal or dehydration), and recombinant microorganism conversion of starch into ethanol. The improvement of

environment performance considering the whole life cycle of bioethanol production of valuable co-products (e.g. biorefineries and biofuel productions).

The massive utilization of fuel ethanol in the world requires that its production technology be cost-effective and environmentally sustainable.

In particular, ethanol production costs should be lowered. For current technologies employed at commercial level, the main share in the cost structure corresponds to the feedstocks (above 60%) followed by the processing expenditures.

The use of sucrose-containing materials as cane molasses allows the production of ethanol with the lowest costs compared to the starchy materials (mostly grains). Particularly, although the ethanol yield from corn is higher than that from sugarcane, the lower annual yield of corn per cultivated hectare makes it necessary to use larger cropping areas. On the other hand, the lignocellulosic biomass represents the most prospective feedstock for ethanol production. The availability and low cost of a wide range of lignocellulosic materials offer many possibilities for the development of bio-industries that could support the growth of the international biofuel market and contribute to the reduction of greenhouse gas emissions worldwide.

Modeling for optimum plant capacity: The cost progress in bioethanol processing(**Balata et al, 2008**).

The study focuses on the reduction of the consumption of crude oil and environmental pollution by choosing bioethanol production from biomass.

Bioethanol is the suitable to be missed in the fuel in the gasoline engine due to its high octane number, high heat of vaporization impede self-ignition in the diesel engine. So, ignition improvers are applied to promote self-ignition by using diesel-bioethanol-blended fuel.

The disadvantages of bioethanol includes its lower energy density than gasoline, its corrosiveness, low flame luminosity, lower vapor pressure (making cold starts difficult), miscibility with water, and toxicity to ecosystems.

Feedstock for bioethanol production varies from season to season and depends on geographic location. Lignocellulose biomass is the most promising feedstock considering its great availability and low cost, but the large-scale commercial production of fuel bioethanol from lignocellulosic materials has still not been implemented.

Conversion technologies for producing bioethanol from cellulosic biomass resources, such as forest materials, agricultural residues and urban wastes, are under development and have not yet been demonstrated commercially.

For designing fuel bioethanol production processes, the assessment of utilization of different feedstock is required, considering the big share of raw materials in bioethanol costs.

This work reviews the biological and thermo chemical methods that could be used to produce bioethanol, and analyses its global production trends.

The combustion of fossil fuels is responsible for 73% of the CO₂ production. The heightened awareness of the global warming issue has increased interest in the development of methods to mitigate GHG emissions. Much of the current effort to control such emissions focuses on advancing technologies that: (i) reduce energy consumption, (ii) increase the efficiency of energy conversion or utilization, (iii) switch to lower carbon content fuels, (iv) enhance natural sinks for CO₂, and (v) capture and store CO₂.

Reducing the use of fossil fuels would considerably reduce the amount of CO₂ produced, as well as reduce the levels of pollutants. As concern about global warming and dependence on fossil fuels grows, the search for renewable energy sources that reduce CO₂ emissions becomes a matter of widespread attention. To reduce the net contribution of GHGs to the atmosphere, bioethanol has been recognized as a potential alternative to petroleum-derived transportation fuels.

Ethanol fermentation technologies from sugar and starch feedstocks(Bai, F.W. et al, 2007).

The study reviews some technologies ethanol fermentation from sugar and starch feedstocks. The steady state kinetic models developed for continuous ethanol fermentations show some discrepancies, making them unsuitable for predicting and optimizing the industrial processes.

The industry has developed its own technical and economic criteria to evaluate the emerging ethanol fermentation technologies. A significant gap between academic research and industry exists, making many proposed technical developments impractical although of scientific interest. The ethanol fermentation with *Zymomonas mobilis* is one of them.

Since the production cost of ethanol is primarily derived from the consumptions of raw materials and energy, the following conventions should be followed to advance

ethanol fermentation technologies with immediate practical applications, e.g. the ethanol fermentation industry is using heterogeneous raw materials rather than pure glucose, and the residual sugar at the end of the fermentations is strictly controlled at a very low level, such that the calculated ethanol yield is based on the total sugar feeding into the fermentation systems without the deduction of the residual. This can be as high as 90–93% of its theoretical value of ethanol to glucose.

From a comparison of *Saccharomyces cerevisiae*, the ethanol yield and productivity of *Zymomonas mobilis* are higher, because less biomass is produced and a higher metabolic rate of glucose is maintained through its special pathway. However, due to its specific substrate as the undesirability of its biomass to be used as animal feed, this species cannot readily replace *Saccharomyces cerevisiae* in ethanol production.

1.4 Expectations of the study

The results can be used for an improvement of bioethanol production process by energy efficiency perspectives. To be used for the further research in the future. Mainly is to apply for improvement of energy efficiency and Greenhouse gases reduction including an implementation of ISO 14040 Life cycle assessment and ISO 14064 Greenhouses gases management and to apply the application for greenhouse gas reduction and removal project to the organization according to Clean Development mechanism (CDM) project.

CHAPTER 2

THEORIES

2.1 Bioenergy (Langeveld et al, 2008).

Plants capture energy directly from the sun by photosynthesis. Fossil fuels are derived from ancient plant material that has been accumulated in deposited that can be mined. The problem with the using of fossil fuels is we are rapidly returning of to the atmosphere large quantity of CO₂ that have been stored underground over large period of times.

Bioenergy can be produced by growing plants and using them directly in the generation of electricity, production of fuels or chemical feedstocks. Biofuels is the component now used in the transportfuels.

2.2 Ethanol properties and quality characteristics (Shakhashiri, B., 2009).

Ethanol (ethyl alcohol, grain alcohol, CH₃-CH₂-OH or Et OH) is a clear, colorless liquid with a characteristic, agreeable odor. In dilute aqueous solutions, it has a somewhat sweet flavor, but in more concentrated solutions, it has a burning taste. Ethanol, CH₃CH₂OH, is an alcohol, a group of chemical compounds whose molecules contain a hydroxyl group, -OH, bonded to a carbon atom.

The word alcohol derives from Arabic *al-kuhul*, which denotes a fine powder of antimony used as an eye makeup. Alcohol originally referred to any fine powder, but medieval alchemists later applied the term to the refined products of distillation, and this led to the current usage.

Ethanol melts at -114.1°C, boils at 78.5°C, and has a density of 0.789 g/mL at 20°C. Its low freezing point has made it useful as the fluid in thermometers for temperatures below -40°C, the freezing point of mercury, and for other low-temperature purposes, such as for antifreeze in automobile radiators.

Ethanol has been made since ancient times by the fermentation of sugars. All beverage ethanols, and more than half of industrial ethanol, are still made by this process. Simple sugars are the raw material. Zymase, an enzyme from yeast, changes the simple

sugars into ethanol and carbon dioxide. The fermentation reaction, represented by the simple equation.



When the starch is used as a raw material, it would then be converted to be glucose and fermented to ethanol, as described by the equation below;



(Poojaroen, S., 2008)

2.3 Ethanol as a fuel and its properties as bioethanol

$\text{C}_2\text{H}_5\text{OH}$ is the chemical equation for a molecule of ethanol. It can be blended with gasoline, which contains a variety of larger molecules ranging from C_5H_{12} to $\text{C}_{12}\text{H}_{26}$.

A litre of ethanol contains two-thirds as much energy as a litre of gasoline. However, pure ethanol has a high octane value, which improve the performance of gasoline by reducing the anti-knock problem. Adding ethanol to gasoline increase its octane level. (Worldwatch Institute, 2007).

Bioethanol (ethyl alcohol, grain alcohol, $\text{CH}_3\text{-CH}_2\text{-OH}$ or EtOH) is a liquid biofuel that can be produced from several different biomass feedstocks and conversion technologies. Bioethanol is an attractive alternative fuel, because it is a renewable bio-based resource, and it is oxygenated, thereby providing the potential to reduce particulate emissions in compression-ignition engines. However, for example corn ethanol production causes more soil erosion than any other crop grown and uses more nitrogen fertilizer than any other crop grown. These two environmental limitations also apply to sugar cane production in Brazil. (Mustafa. et al, 2008).

Bioethanol has a higher octane number, broader flammability limits, higher flame speeds and higher heats of vaporization than gasoline. These properties allow for a higher compression ratio, shorter burn time and leaner burn engine, which lead to theoretical efficiency advantages over gasoline in an internal combustion engine.

The disadvantages of bioethanol include its lower energy density than that of gasoline (bioethanol has 66% of the energy that gasoline has), its corrosiveness, low flame luminosity, lower vapor pressure (making cold starts difficult), miscibility with water, and toxicity to ecosystems. Some properties of alcohol fuels are shown in Table 2.1.

Table 2.1: Some properties of fuel (MustafaBalat, et al)

Fuel Properties	Isotane	Methanol	Ethanol
Cetane number	3	5	8
Octane number	100	112	107
Auto-ignition temperature (K)	530	737	606
Latent heat of vaporization (MJ/kg)	0.26	1.18	0.91
Lower heating value (MJ/ kg)	44.4	19.9	26.7

Since the ethanol molecule contains oxygen, ethanol fuel is referred to as an “oxygenate”. The oxygen in ethanol can improve the fuel combustion process, helping to reduce the emissions.

Ethanol is an oxygenated fuel that contains 35% oxygen, which reduces particulate and NO_x emissions from combustion. Ethanol has a higher octane number, broader flammability limits, higher flame speeds and higher heats of vaporization. These properties allow for a higher compression ratio and shorter burn time, which lead to theoretical efficiency advantages over gasoline. Octane number is a measure of the gasoline quality and can be used for the prevention of early ignition, which leads to cylinder knocks. Higher octane numbers are preferred in internal combustion engines.

An oxygenate fuel, such as bioethanol, provides a reasonable antiknock value. Also, as it contains oxygen, fuel combustion is more efficient, reducing hydrocarbons and particulates in exhaust gases. The complete combustion of a fuel requires in existence the amount of stoichiometric oxygen. However, the amount of stoichiometric oxygen generally is not enough for complete combustion. Oxygen content of a fuel increases its combustion

efficiency, because of this the combustion efficiency and octane number of bioethanol are higher than those of gasoline. (Mustafa, et al, 2008)

2.4 Feedstock for bioethanol production (Mustafa.et al, 2008).

Biofuels originate from plant oils, sugar beets, cereals, organic waste and the processing of biomass. Biological feedstocks that contain appreciable amounts of sugar— or materials that can be converted into sugar, such as starch or cellulose—can be fermented to produce bioethanol to be used in gasoline engines.

Bioethanol feedstocks can be conveniently classified into three types: (i) sucrose-containing feedstocks (e.g. sugar beet, sweet sorghum and sugar cane), (ii) starchy materials (e.g. wheat, corn, and barley), and (iii) lignocellulosic biomass (e.g. wood, straw, and grasses).

The bioethanol ratio from each type of feedstock is shown in Table 2.2.

Table 2.2: Ethanol ratio from each type of feedstock (Thippayawong, N., 2009).

Feedstock	Ethanol (L/Ton)
Sugar cane	70
Molasses	280
Sweet sorghum	85
Cassava	180
Corn	370
Yam	125
Wood	160

2.5 Bioethanol production process and technology

Production of ethanol is demonstrated as follows;

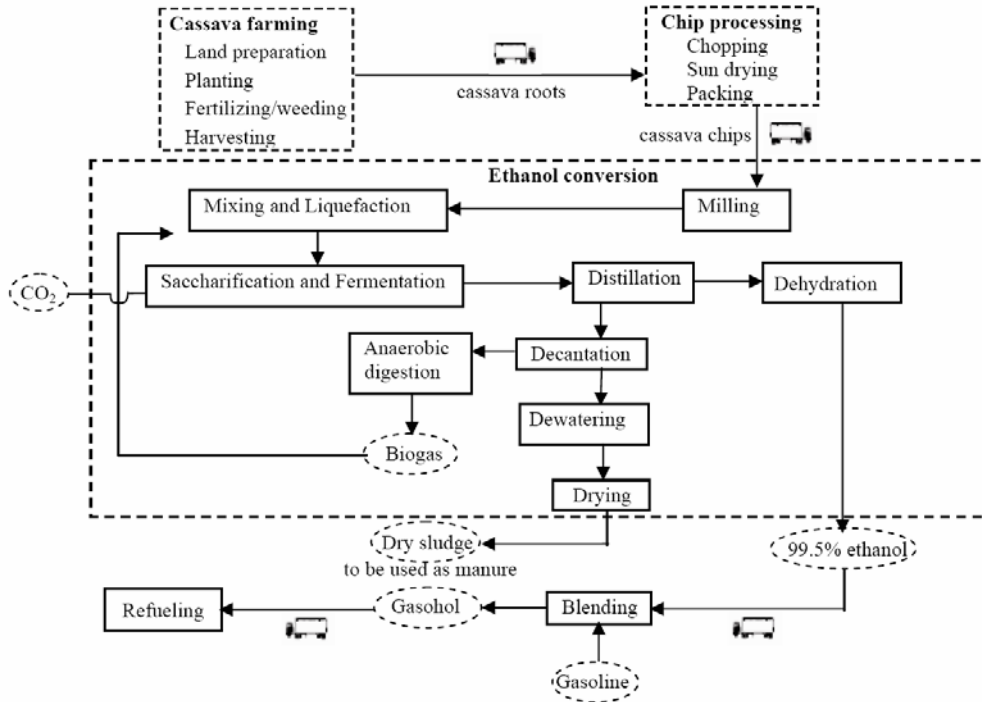


Figure 2.1 Production flowchart of ethanol (Nguyen. et al, 2006)

Bioethanol production from fermentation is mainly consists of 2 processes; sugar (monosaccharide) is consumed by yeast and to convert sugar ethanol as follow;



Feedstock preparation is to prepare sugar (glucose) for the yeast. The starchy feedstocks must be broken down mechanically particle sizes by grinding or milling.

Fermentation is the step that involves complex sequence of chemical reactions to breakdown of glucose in to ethanol.

In theory, 100% of sugar is converted to be 48.9% carbon dioxide and 51.1% ethanol, W/W (Thippayawong. N, 2009). The efficiency of an operation is vary with the operation condition and type of yeast.

Generally, there are two types of fermentation (Kelsall and Lyons, 2000). Batch Fermentation and Continuous Fermentation.

Batch Fermentation is a traditional process which is used for alcohol production. The process is started from mash which is filled into the fermentation tank then cooling to the appropriate temperature. Optimum temperature for the alcohol production from yeast is 25 – 30 °C.

The concentration is measured with Brix hydrometer. Brix hydrometer measures specific gravity related to sugar concentration. The ideal concentration is 16 and 25 °Brix. The batch fermentation process shall be over within 48 hours (Yoosin and Sorapipatana, 2007).

Continuous Fermentation is the operation that requires continuous feeding of soluble feedstock (Thippayawong. N, 2009). Nutrients and microorganism and fed continuously and make recovery of yeast cell is made relatively. Continuous fermentation requires a sophisticated control and yeast recovery equipment (Yoosin and Sorapipatana, 2007).

2.6 Energy definition and efficiency measurement of ethanol production

The ethanol production consumes energy from electrical and heat from steam and energy consumed by the boiler. The relevant energy related information is summarized below.

2.6.1 Assessment of system performance

Assessment of system performance can be expressed using indicators relevant to the production of biomass, activities related to the production, transport, conversion, distribution and application of bio-based products. Energy balances are defined as energy used in each process or in total, compared with the energy resulting from the final products.

The outcome is usually expressed per unit of product (e.g. per ton of bioethanol or compound), and might be calculated per unit of energy (KJ or GJ). In some cases the calculation can be applied to indirect energy use: energy utilized to energy farmand other

machineries, building, and siloes. It also can be referred to the manufacturers of inputs used during cultivation, and so on.

The energy balance compared energy inputs with the amount of energy that is generated. This basically refers to the energetic value of a product. For example heat released when a compound (fuels, chemicals, etc.) is burned. Lower Heating Value constitutes direct energy released during burning. Higher Heating Value (HHV) also includes indirect energy release; that is, released from vaporization of water formed during product combustion.(Longeverd, 2008).

2.6.2 Energy Balances

Energy takes many forms, such as heat, kinetic energy, chemical energy, and potential energy but because of inter-conversions it is not always easy to isolate separate constituents of energy balances. However, under some circumstances certain aspects predominate. In many heat balances other forms of energy are insignificant. In some chemical situations mechanical energy is insignificant and in some mechanical energy situations, as in the flow of fluids in pipes, the frictional losses appear as heat but the details of the heating need not be considered. We are seldom concerned with internal energies.

Therefore, practical applications of energy balances tend to focus on particular dominant aspects, and so a heat balance, for example, can be a useful description of important cost and quality aspects of a process situation. When unfamiliar with the relative magnitudes of the various forms of energy entering into a particular processing situation, it is wise to put them all down. Then after some preliminary calculations, the important ones emerge and other minor ones can be lumped together or even ignored without introducing substantial errors. With experience, the obviously minor ones can perhaps be left out completely though this always raises the possibility of error.

Energy balances can be calculated on the basis of external energy used per kilogram of product, or raw material processed, or on dry solids or some key components. The energy consumed in food production includes direct energy which is fuel and electricity used on the farm, and in transport and in factories, and in storage, selling, etc.; and indirect energy which is used to actually build the machines, to make the packaging, to produce the electricity and the oil and so on. Food itself is a major energy source, and energy balances can be determined for animal or human feeding; food energy input can be balanced against outputs in heat and mechanical energy and chemical synthesis.

In the SI system, there is only one energy unit, the joule. However, kilocalories are still used by some nutritionists, and British thermal units (Btu) in some heat-balance work.

2.6.3 Heat Balances

The most common important energy form is heat energy and the conservation of this can be illustrated by considering operations, such as heating and drying. In these, enthalpy (total heat) is conserved, and as with the mass balances, so enthalpy balances can be written round the various items of equipment or process stages, or round the whole plant. It is assumed that no appreciable heat is converted to other forms of energy, such as work.

2.6.4 Material and Energy Balance

Enthalpy (H) is always referred to some reference level or datum, so that the quantities are relative to this datum. Working out energy balances is then just a matter of considering the various quantities of materials involved, their specific heats, and their changes in temperature or state (as quite frequently, latent heats arising from phase changes are encountered).

Heat is absorbed or evolved by some reactions in processing, but usually the quantities are small when compared with the other forms of energy entering into food processing, such as sensible heat and latent heat. Latent heat is the heat required to change, at constant temperature, the physical state of materials from solid to liquid, liquid to gas, or solid to gas. Sensible heat is that heat which when added or subtracted from materials changes their temperature and thus can be sensed. The units of specific heat are J/kg K and sensible heat change is calculated by multiplying the mass by the specific heat by the change in temperature, ($m \times c \times \Delta T$). The units of latent heat are J/kg and total latent heat change is calculated by multiplying the mass of the material, which changes its phase by the latent heat. Having determined those factors that are significant in the overall energy balance, the simplified heat balance can then be used with confidence in industrial energy studies. Such calculations can be quite simple and straightforward but they give a quantitative feeling for the situation and can be of great use in design of equipment and process.

2.7 Method for Preparing Process Flow Chart

The identification and drawing up of a unit operation/process is prerequisite for energy and material balance. The procedure for drawing up the process flow diagrams is explained below.

Flow charts are schematic representations of the production process, involving various input resources, conversion steps and output and recycling streams. The process flow may be constructed stepwise i.e. by identifying the inputs / output / wastes at each stage of the process, as shown in Figure 4.

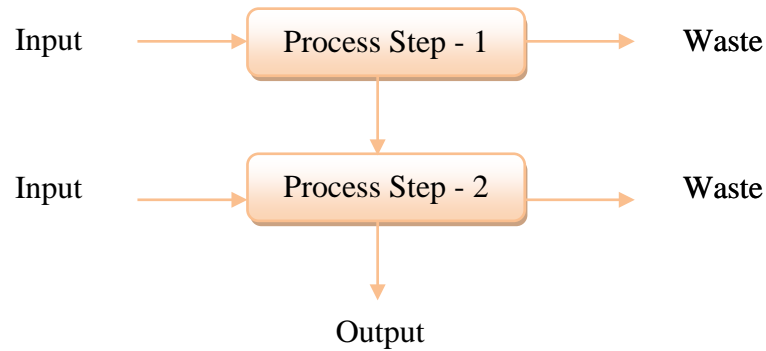


Figure 2.2 Process Flow Chart

Inputs of the process could include raw materials, water, steam, energy (electricity and etc.).

Process Steps should be sequentially drawn from the raw materials to the finished products. Intermediates and any other byproduct should also be represented. The operating process parameters such as temperature, pressure, % concentration, etc. should be represented.

The flow rates of various streams should also be represented in appropriate units such as like m³/h or kg/h. In the case of batch process, the total cycle time should be included.

Wastes / by products could include solids, water, chemicals, energy, etc. For each process steps (unit operation) as well as for an entire plant, energy and mass balance diagram should be drawn. Output of the process is the final product produced in the plant.(National Productivity of India, 2010).

2.8 Energy efficiency of bioethanol production process.

2.8.1 Primary energy estimation

Primary energy is an aggregation of heat of fuel combustion (direct energy use) and the energy used for the process of fuel extraction, refining/conversion and delivery (indirect energy use). E.g., diesel by its fuel energy content, the electricity is used in the ethanol production by converting the amount of electrical energy (kW h) to thermal energy (MJ)

2.8.2 Energy performance of fuel ethanol

In assessing ethanol's energy performance, the net energy value is conventionally a key indicator to identify whether ethanol production and use results in a gain or loss of energy. It weighs the energy content of ethanol against the energy inputs in the production cycle. More specifically, there are three ways in which net energy issue (concerned with ethanol) is being addressed. The first one defines net energy value as follows.

NEV = Energy content of ethanol, Net energy inputs (total fossil and non-fossil energy inputs).

Although energy performance has conventionally been considered using NEV, it may be more meaningful to evaluate a biofuel's contribution to fossil energy use reduction. Such an evaluation should address how much energy is gained when non-renewable fossil fuel energy is expended to produce renewable biofuels. The equation of net (renewable) energy value, thus, takes the following form.

NRnEV = Energy content of ethanol / Fossil energy inputs.

Net energy addressed in this way is displayed more frequently in the form of energy ratio.

$$\text{ER} = \text{Energy outputs/Fossil energy inputs.}$$

As far as reducing oil use (and consequently, imports) is increasingly a critical issue, the third way considers only the petroleum inputs to evaluate ethanol's net energy gain.

Energy credits of co-products, e.g. surplus electricity, animal feed, etc. are either dealt with as system energy outputs or process energy savings, (Nguyen, et al, 2008)

CHAPTER 3

METHODOLOGY

According to the objectives of this study, the focus is made on one factory. The main goals of the study is to assess the energy balance and CO₂ emissions associated with the production of bioethanol from cassava and to see the possibilities for the improvement.

The scope of study covers the production of bioethanol production at the factory from raw material preparation of cassava until the final product of bioethanol is obtained.

In this study, the methodology developed is based on Life Cycle Assessment (LCA) procedures referred to ISO 14040 Life Cycle Assessment and ISO 14064 Greenhouses Gases Management.

The energy consumption, energy balance and CO₂ emissions of each stage are studied and evaluated in lieu with each path of the bioethanol production process. Energy consumption is described as the summary of energy which is consumed at every stage of the production path.

This study excludes an analysis of energy used for cassava plantation and transportation of raw materials to the factory.

3.1 Data Collection

This study is aimed of providing information about the operation and seeking the opportunity to improve the efficiency of production.

In this study, the communication, coordination and discussion for the cooperation of this study was asked of 5 bioethanol factories in Thailand. Only 1 plant accepted to cooperate and help for the educational purpose. The factory would like to keep the name as confidentiality for them. The factory will be defined as “Factory A”.

The bioethanol production factory where the study is performed is located in Chachoengsao province in the eastern region of Thailand and around 150 kilometers far from Bangkok. The plant has newly finished its construction and commencement of operation has just started. The data collection was done during January 2012.

The production at the factory is not 100% continuously operating yet due to the factory having just finished their construction phase at that time and a shortage of raw materials cassava to continuously produce bioethanol.

In this study, the fresh cassava roots are used as raw materials for bioethanol production.

The information and data of process parameters such as, temperature, yeast flow rate, solid content of the slurry, temperature and retention time, are obtained from the information from the commissioning period of the factory and designed information.

The data from the factory is collected by gathering the data, measurements and reports from the factory. An analysis of data is included material and energy input and output of each stage through the production operation and it is analyzed and nominalized to be based on a liter of bioethanol.

To perform this study, the collection of data is included as follows:

3.1.1 The study of primary and secondary data regarding bioethanol production factories in Thailand, the review related theories and literatures, the review of biological and thermochemical methods are used for bio-ethanol production from cassava, theoretical information of energy efficiency evaluation, and CO₂ emissions from bioethanol production from other references are also included.

3.1.2 The data gathering from factories are to be used for the analysis of energy consumption of the bioethanol production process. In this stage is to consider only the factory which is used cassava as raw material for bioethanol production. The data is included ;

3.1.2.1 Factory information; e.g. location of factory

3.1.2.2 Production capacity of the factory based on a production of 99.5 % ethanol and information of produced ethanol

3.1.2.3 Characteristics of production and quality control parameters

3.1.2.4 Type and information of power generating system including the energy consumption

3.1.2.5 Type and information of steam generating system including the energy consumption

3.1.2.6 Information of electrical consumption for production operation

3.1.2.7 Data of the analysis of cassava quality

3.2 Data analysis

An analysis of the information obtained from the factory was determined and evaluated as follows:

3.2.1 Mass balance of the production process

- To demonstrate the mass balance.

3.2.2 Energy Analysis

- To measure an energy efficiency.

3.2.3 CO₂ emissions from the production process

- To analyze the CO₂ emissions by using GEMIS software.

3.2.4 To report and summarize the results of the study, including the investigation of the possibility for an improvement for the factor being studied.

3.3. Process boundary of the study

The boundary of this study is illustrated as follows:

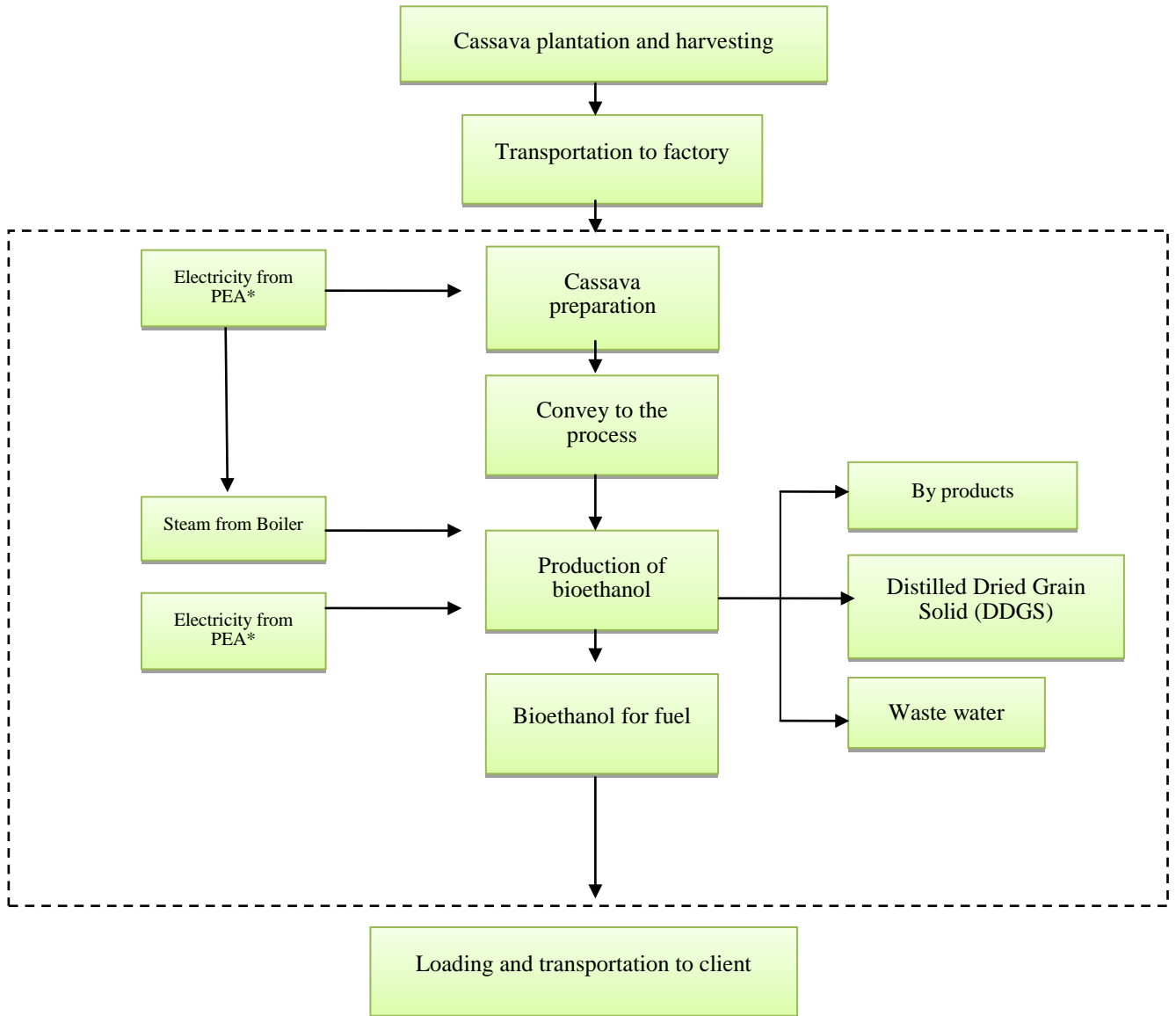


Fig 3.1 Bioethanol production system boundary

*PEA: Provincial Electricity Authority

3.4 Ethanol Production Process

Mainly unit for ethanol production process is shown as **Fig. 3.32**.

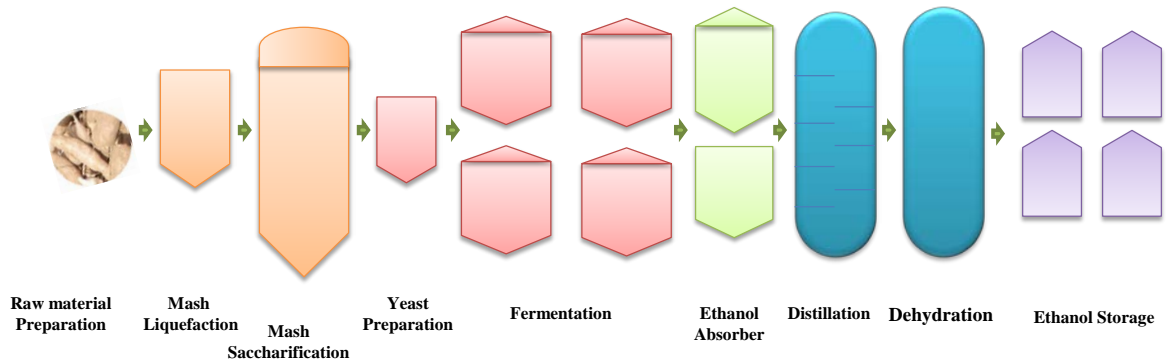


Fig 3.2 Bioethanol production units

3.5 Information to be used in this study

In this study, the communication, coordination and discussion for the cooperation of this study was asked to 5 bioethanol factories in Thailand. Only 1 plant accepted to cooperate and help for educational purposes. The factory would like to keep the name as confidentiality for them. The information and data in this study is classified into 4 types as follows;

3.5.1 Information from the references sources; e.g. from government sectors such as the report of cassava plantation in Thailand, or from factory such as the process design information.

3.5.2 The measurement data from the factory, such as Temperature, Pressure, and pH.

3.5.3 The data such as quality characteristic of feedstock from laboratory analysis.

3.5.4 The information of production and quality control, such as production capacity, energy consumption, steam consumption, type and fuel of biomass boiler.

3.6 GEMIS - Global Emissions Model for integrated Systems (IINAS, 2012)

In this study, a full life cycle analysis (LCA) of Greenhouses Gases (GHG) emissions from bioethanol produced from cassava is used as a reference. The Life Cycle Inventory analysis phase (LCI phase) which is involved the collection of input/output inventory data is involved the system of this study.

The scope of this study is to analyze the information of GHG comprised of source of energy, input water and steam. The process flow describes the energy and mass used as to demonstrate the inventory information, using the Global Emission Model for Integrated System (GEMIS) as a tool to estimate the CO₂ emissions.

The GEMIS model is used to assess the result of emissions of so-called CO₂ equivalents.

The International Institute for Sustainability Analysis and Strategy (IINAS) is an independent trans-disciplinary research organization based in Darmstadt (Germany). IINAS is the host of GEMIS, a public domain life-cycle and material flow analysis model and database.

GEMIS consists of an analytical model to determine energy and material flows (including transports), and a database as follows:

- data on efficiency, power, operating time, and lifetime,
- direct air emissions (SO₂, NO_x, halogens, particulates, CO, VOC, H₂S, NH₃)
- greenhouse gas emission (CO₂, CH₄, N₂O as well as SF₆ and CFCs)
- solid wastes (ash, FGD residues, sewage treatment sludge, production wastes, overburden)
- liquid effluents (AOX, BOD₅, COD, N, P, inorganic salts)
- land use
- greenhouse gases as CO₂ equivalents,
- air emissions as SO₂ equivalents

GEMIS is continuously updated analysis and extended. It is used by many parties in more than 30 countries for environmental analysis, cost and analyses of energy, materials and transport systems. GEMIS is now acknowledged as a tool in the World Bank's Platform for Climate-Smart Planning.

IINAS also continues collaboration with the German Environment Agency (UBA), which offers Life Cycle Analysis (LCA) data in a web-based tool, and allows searching and retrieving LCA data.

GEMIS models and calculates so-called Life Cycles of Energy and Material flows based on process chains which are stored in its database, as shown in Fig. 3.3. The basic scheme of a Life Cycle is shown in the following Fig 3.4 GEMIS Model for Electricity database inventory for the example of electricity.

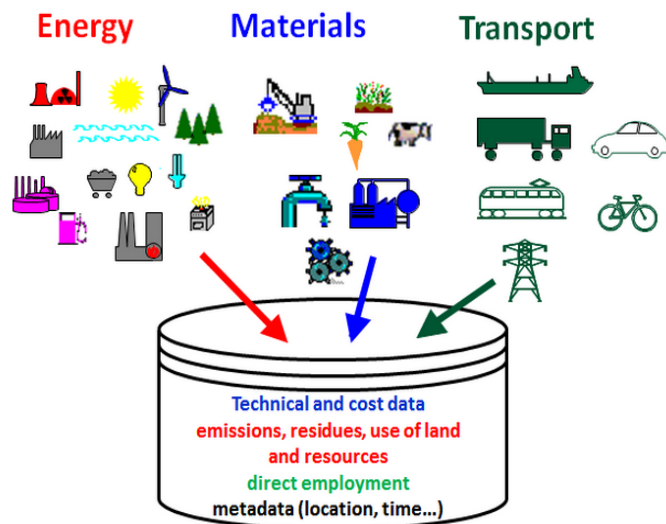


Fig 3.3 GEMIS Database

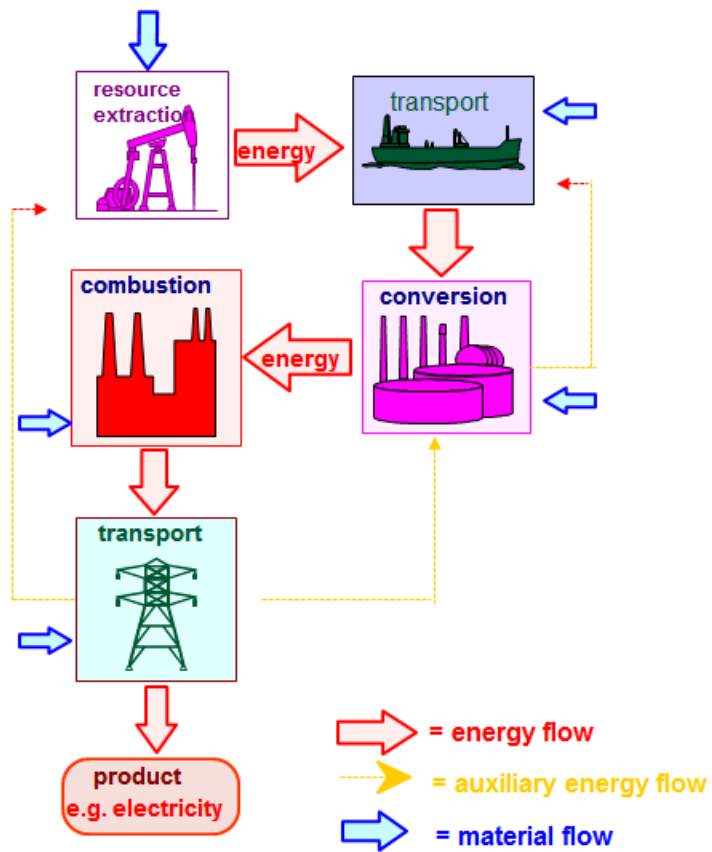


Fig 3.3 GEMIS Model for Electricity database inventory

CHAPTER 4

RESULT AND DISCUSSION

4.1 General

The results and data collection from a bioethanol factory demonstrates that the factory is capable of producing 150,000 liter per day of bioethanol and is designed to continuously operate for 24 hours per day.

The factory purchased cassava roots from farmers where the plantation is located covering 14 districts in 5 provinces; Chachoengsao, Chonburi, Chantaburi, Saraburi and Prachinburi. The bioethanol factory is constructed its operation within the same area of the cassava starch plant.

The required purchased cassava's specification is defined by the owner of design technology and it is mentioned on Table 4.1. Bioethanol specification is required as shown on Appendix A.

The factory consumes electricity from the Provincial Electricity Authority (PEA). Steam for the process is produced from biomass boiler. The factory has installed 1 biogas boiler and 3 biomass boilers.

In this study, the biomass boiler which uses rice husk as raw material is studied.

Electricity used in the process is for soft start-up of the machines and running the distillation system. Electricity comes from the Provincial Electricity Authority (PEA).

4.2 Process flowchart of bioethanol production

Process flowchart of bioethanol production from the factory is demonstrated in Fig. 4.1

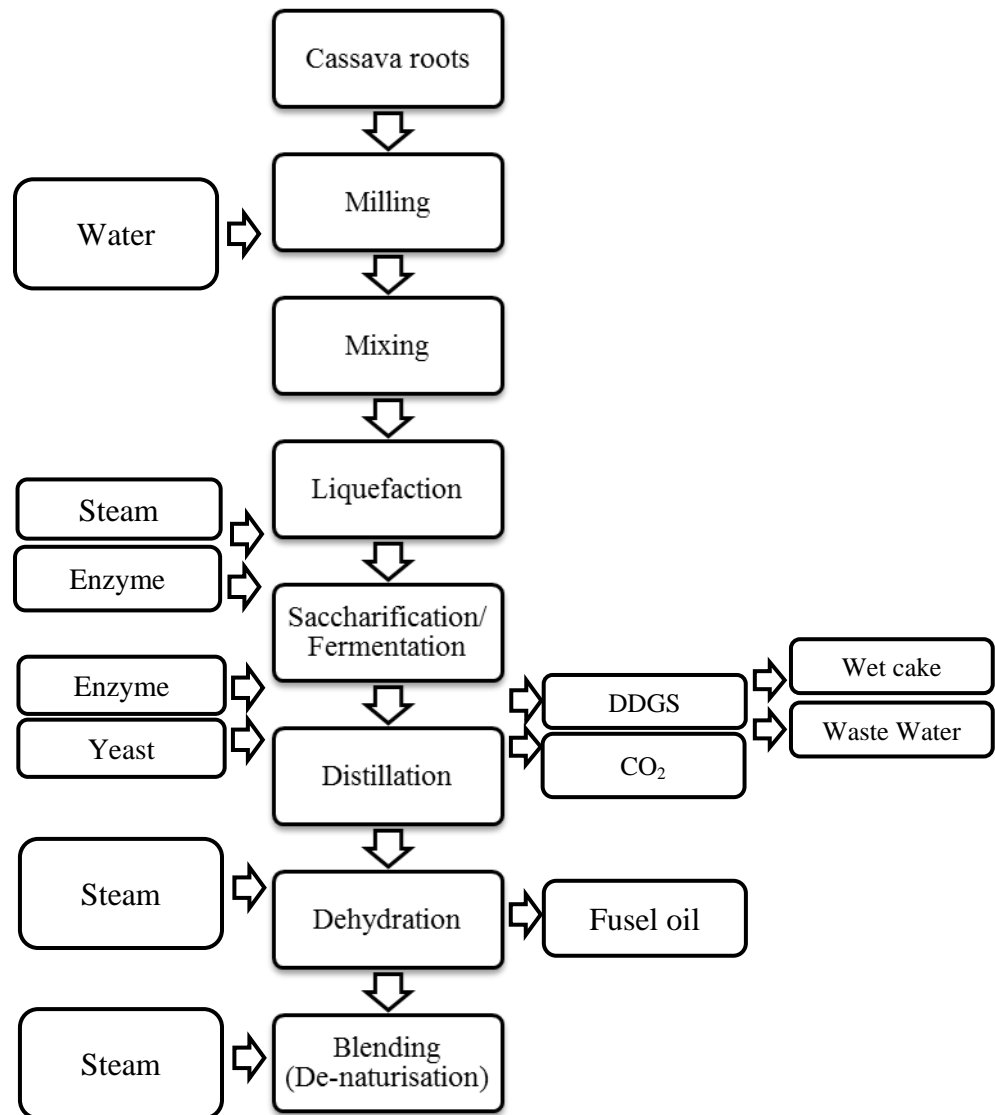


Fig4.1 Bioethanol production process flow chart from “Factory A”.

4.3 Mass flow rate of the process

The information from Factory A shows the mass flow rate of the process, as shown in Table 4.1.

Table 4.1 Mass flow rate of the process line from Factory A.

Process	Flow Rate (Ton/day)
Cassava root (raw material)	1,231
Water for milling process	335
Recycling water for milling process	174
Mash Slurry from mixing	1,740
Steam for the Mash preparation, Saccharification, Fermentation processes	120
CO ₂ released from fermentation	112
Beer to distillation (7% w/w bioethanol)	1,748
95% bioethanol from distillation	126
Fusel oil from distillation	0.5
Distilled Dried Grain Solid (DDGS or Thick slop)	1,455
99.5% bioethanol after dehydration	120
Wet cake	180

4.4 Feedstock quality characteristics.

In this study the fresh cassava roots are used as raw materials. The required specification of cassava roots or cassava chips are defined in Table 4.2.

Table 4.2 Required specifications of fresh roots and dried cassava chips by the designed process technology.

Quality characteristic	Value	Unit
Fresh cassava roots		
Starch content	25	% w/w
Foreign matter	5	% w/w Max
Dried cassava Chips		
Starch content	63-70	% w/w
Moisture	13-18	% w/w
Crude fiber	4.0-5.0	% w/w
Sand	3	% w/w Max
Protein	2	% w/w Max
Foreign matter	3	% w/w Max
Odour	free from abnormal odour	-
Color	normal	-
Rottenness/Mold	free	-
Living insects	free	-

4.5 Process Description

On a production daily basis as indicated in Fig. 4.1 the fresh, cassava roots at approximately 1,000 -1,231 tons per day will produce 150,000 liter per day of 99.5% bioethanol.

The fresh cassava roots specifications are determined from the starch content, which is required more than 25%, and have foreign matter (e.g. sand) less than 5%. In case of dried cassava chips is used, then approximately 500 Ton per day of dried cassava chips would be used.

Bioethanol production starts with the size reduction of cassava. Cassava roots are peeled and then milled for a smaller size. The fine cassava size distribution is required in the range of 0.3 – 2.0 millimeter. Cassava would be analyzed its properties and quality characteristics. Smaller size of cassava is better since it would help in increasing surface area of reaction in a Cooking of Mash Preparation process.

Process water from water treatment plants are fed to the Mash tank for the preparation of Mash Slurry. The mixing ration is varied to the percent of starch content in the raw material. The result of cassava analysis in term of starch content is generally required more than 25 percent by weight as demonstrated in Table no.4.2.

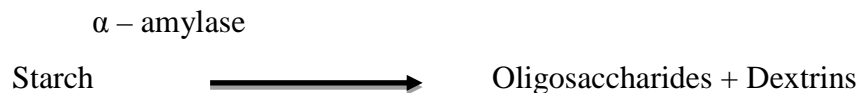
The Mash is stored in the Mash tank, which maintains the continuous flow rate of the mash slurry, to be fed in to the next step. Agitating is performed in order to make the homogenous flow rate of Mash slurry.

The enzyme will be used to change the properties of carbohydrates from starch in to be sugar. The quantity of feeding enzyme is recommended by enzyme's producer which is depend on the starch content in mash slurry. Process Quality Characteristic of Mash Slurry from mixing tank is shown in Table 4.3.

Table 4.3 Process Quality Characteristic of Mash Slurry

Process Quality Characteristics	Value	Unit
Mash Slurry from mixing		
Flow rate	1,740	Ton/day
Total solid	18	%
Total dissolved solid	308	
Density	1.074	kg/m ³

The Cassava Mash is then cooked with high pressure steam indirectly. The Mash temperature is rapidly increased as to be ready for the liquefaction process. The steam pressure and flow rate are measured continuously due to the temperature and feeding time is influence to the starch properties. At this stage, the Alfa-amylase enzyme is fed up to the process. It is functioned as Liquefaction enzyme which will used to change the properties of sugar. The process temperature is in the range of 90-95 °C, Fig 4.2 shows the Liquefaction process.

**Fig4.2** Liquefaction process

The Process quality characteristics of liquefied slurry thought anhydrous ethanol stream lines is shown in Table 4.4.

Liquefied slurry then is fed in to the fermenter. The fermenter is functioned as the reactor which dextrins hydrolysis or Saccharification process is occurred.

The Saccharification process is performed by reducing the temperature and pH. The process temperature for Saccharification is around 60 °C and pH 3.8-4.5. Fig 4.3 shows the Saccharification process.



Fig4.3 Saccharification process

The next step is the Fermentation process in which Yeast (*Saccharomyces cerevisiae*, S.C. yeast) is used. Temperature is controlled at 30 °C for 36-48 hours. After fermentation the Alcoholic Mash will be distilled at the distillation process. Fig 4.4 shows the Fermentation process.

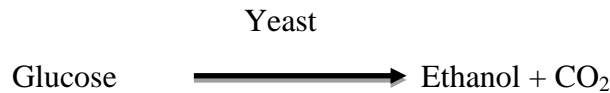


Fig4.4 Fermentation process

The fermentation system provides suitable conditions for the enzymatic hydrolysis of dextrins to dextrose and to ethanol by yeast. The fermentation process, it is produce ethanol as the product and carbon dioxide as the by-product.

The efficiency of ethanol production process at the fermentation depended on temperature and retention time. If so required are not appropriate, yeast will not grow properly and may cause malfunction of yeast which is prohibited the process performance. The temperature of fermenter is controlled by chiller water as to maintain consistency and continuously fermentation temperature.

Yeast (*Saccharomyces cerevisiae*) for fermentation process is prepared from dried yeast which is inoculated in a separate tank. Yeast inoculation is filled by the right nutrient and process water. They are mixed and pumped to the fermenter with a certain retention time.

During the fermentation process, CO₂ is generated. The capturing of CO₂ is done by a CO₂ scrubber.

Beer (Alcoholic mash, 7% w/w ethanol) from the fermentation is continuously pumped to the first tower, Stripper-distillation tower, for the degassing process. The carbon

dioxide (CO₂) represent as one of the by-products is flashed out. CO₂ is captured by a CO₂ scrubber.

The suspended solid in the beer feed is washed down and removed from the bottom of the tower as Thick Slop, and conveyed a decanter. The decanter segregates waste water and wet cake. Wet cake is used as fertilizer for plantation of cassava while waste water is treated and to be recycling to the operation process.

From the stripper, an alcohol-rich vapor is fed in to the Rectifier-distillation tower and is condensed as hydrous alcohol (95% w/w ethanol). In the middle section of the Rectifier-distillation tower, Fusel oil (higher molecular alcohol) as an impurity is removed.

Hydrous alcohol is fed to the Molecular sieve system, which works based on the adsorption of water by zeolite.

Water will be retained and pressurized ethanol, which is fed, then will be made as anhydrous alcohol (99.5% w/w ethanol).

Anhydrous alcohol is stored and upon transferring from the storage tank to the tank truck, then the denatured agent (gasoline) is added (1 liter per 100 liters of fuel alcohol).

Table 4.4 Process quality characteristic and parameter of liquefied slurry through anhydrous ethanol stream lines.

Process Quality Characteristic	Value	Unit
Liquefied slurry to fermentation		
Flow rate	1,860	Ton/day
Total solid	17	%
Total dissolved solid	308	
Density	1.164	kg/m ³
Beer (Alcoholic mash) from fermentation to distillation		
Flow rate	1,749	120
Total solid	11	%
Density	1.074	kg/m ³
Ethanol content	7%	w/w
Hydrous ethanol from distillation		
Flow rate	125	Ton/day
Ethanol content	95	% w/w
Anhydrous ethanol from molecular sieve		
Flow rate	120	Ton/day
Ethanol content	99.5	% w/w
Density	0.796	kg/m ³

4.6 Inventory analysis of the production process.

The inventory analysis for the production of bioethanol is based on a production capacity of 150,000 liter of bioethanol per day. The information is obtained from the production process of bioethanol that could produce the Greenhouse Gases emitted to the environment. The information of Life Cycle Inventory analysis phase (LCI phase) which is obtained from the production of bioethanol consists of 4 stages as follows;

- The inventory of input and output of cassava preparation in Table 4.7
- The inventory of input and output of fermentation process in Table 4.8
- The inventory of input and output of distillation process in Table 4.9
- The inventory of input and output of product blending and storage process as Table 4.10

According to the 4 stages of the study, the whole system inventory is collected from all inventories to be defined as the Life Cycle inventory of the system, consisting of the inventory of cassava preparation, the inventory of fermentation process, the inventory of distillation process, and the inventory of product blending and storage process.

The allocation of the whole system is used in order to allocate the material required for bioethanol. Inputs and outputs of each stage were allocated based on the product output of each stage and calculated based on the production of 1 Ton of bioethanol.

The life cycle inventories are shown in Tables 4.7, 4.8, 4.9 and 4.10 respectively.

Table 4.5 Inventory of input and output of cassava preparation process.

Cassava Preparation	Input			
	Material			Per liter EtOH
	Cassava meal to Mingle	1,231.38	Ton per day	8.21E-03
	Water to Mingle	923.53	Ton per day	6.16E-03
	Water for mixing	783.61	Ton per day	5.22E-03
	Energy			Per liter EtOH
	Steam: Flow rate	120.00	Ton per day	8.00E-04
	Output			
	Material			Per liter bioethanol
	Mash from liquefaction to Fermentation	1,860.61	Ton per day	1.24E-02
	Density	1.12	kg/m ³	7.49E-06
	Mash to Liquefaction Tank	83 - 87	°C	-
	Liquefied Mash : pH	5.8 (+/-3)		-
	Mash Cooler : Mash Temperature	53.00	°C	-
	Mash Cooler : Final Mash Temperature	35-37	°C	-
	Mash Mix Tank : Hold Up Time	15.00	min	-

Table 4.6 The inventory of input and output of fermentation process.

Fermentation section	Input			
	Material			Per liter bioethanol
	Mash from liquefaction to Fermentation	1,860.61	Ton per day	1.24E-02
	Output			
	Material			Per liter bioethanol
	Beer	1,748.88	Ton per day	1.17E-02
	Alcohol concentration	7.42	w/w Alcohol	-
	CO ₂	111.73	Ton per day	-

Table 4.7 The inventory of input and output of distillation process.

Distillation section	Input			
	Material			Per liter bioethanol
	Beer	1,748.88	Ton per day	1.17E-02
	Alcohol concentration	7.42	w/w Alcohol	-
	Energy			Per liter bioethanol
	Steam: Flow rate	125.60	Ton per day	8.37E-04
	Output			
	Material			Per liter bioethanol
	Fusel oil	0.50	Ton per day	3.33E-06
	Stillage (Thick slope)	120.00	Ton per day	8.00E-04
	Alcohol concentration	99.50	w/w Alcohol	-

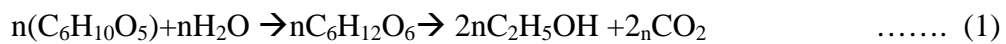
Table 4.8 The inventory of input and output of product blending and storage process.

Product blending and storage	Input			
	Material			Per liter bioethanol
	Ethanol	150,000.00	Liter per day	-
	Alcohol concentration	99.50	w/w Alcohol	-
	Denaturant (Benzene)	5.00	% w/w	-
	Output			
	Material			Per liter bioethanol
	Fuel Alcohol	150,000.00	Liter per day	-

4.7 Material analysis

According to the inventory results in this study, the material analysis from the production process is calculated and compared with the theoretical material analysis.

Calculation of bioethanol from the production is demonstrated as follows:



$$\begin{aligned} \text{Molecular weight of starch (C}_6\text{H}_{10}\text{O}_5) &= (12*6)+(1*10)+(16*5) \\ &= 162, \end{aligned}$$

$$\begin{aligned} \text{Molecular weight of glucose (C}_6\text{H}_{12}\text{O}_6) &= (12*6)+(1*12)+(16*6) \\ &= 180, \end{aligned}$$

$$\text{Molecular weight of ethanol (C}_2\text{H}_5\text{OH)} = (12*2)+(1*5)+16+1$$

$$= 46.$$

$$\text{Ethanol density} = 0.764 \text{ kg/Liter}$$

$$\text{Cassava flow rate is} = 1,231.378 \text{ Ton/day,}$$

$$\begin{aligned} \text{Starch contains 25\% Total solid, Total solid is } (1,231.378) \times 25\% \\ = 307.844 \text{ Ton/day,} \end{aligned}$$

$$\text{Water in Starch is } (1,231.378 - 307.844) = 923.533 \text{ Ton/day,}$$

By the theoretical equation (1), calculation of bioethanol to be produced from 307.844 Ton/day of total solid as follows;

$$\begin{aligned} 307.844 \frac{\text{Ton}}{\text{day}} \times \frac{1 \text{ Ton mol starch}}{162 \text{ Ton starch}} \times \frac{1 \text{ Ton mol starch}}{162 \text{ Ton starch}} \times \frac{1 \text{ Ton mol glucose}}{1 \text{ Ton mol starch}} \times \frac{180 \text{ Ton glucose}}{1 \text{ Ton mol glucose}} \\ = 342.05 \text{ Ton glucose per day.} \end{aligned}$$

$$\begin{aligned} 342.05 \frac{\text{Ton}}{\text{day}} \times \frac{1 \text{ Ton mol glucose}}{180 \text{ Ton glucose}} \times \frac{2 \text{ Ton mol ethanol}}{1 \text{ Ton mol glucose}} \times \frac{46 \text{ Ton ethanol}}{1 \text{ Ton molethanol}} \\ = 174.825 \text{ Ton ethanol per day.} \end{aligned}$$

Ethanol to be produced is

$$174.825 \text{ Ton ethanol} \times \frac{1 \text{ Liter}}{0.764 \text{ kg}} = 228,828 \text{ Liter per day.}$$

In theory, based on 25% Total solid of 1,231.378 Ton per day of cassava, the ethanol produced equals 228,828 Liters per day.

By the process design of Factory A, the ethanol produced equals to 150,000 Liter per day.

Therefore, the factory efficiency is

$$\frac{150,000}{228,828} \times 100\% = 65.6\% \text{ based on 25\% Total solid of 1,231.378 Ton/day of cassava.}$$

Efficiency of Factory A in bioethanol production is 65.6 % compared to the theoretical bioethanol production.

The opportunity to improve efficiency of bioethanol production from Factory A can be reach to 34.4%.

4.8 By- products from Bioethanol production

The main product is bioethanol, which is produced at 150,000 liter/ day. By-products from the production are;

- CO₂ is generated from the process at 112 Ton/day which is captured by a scrubber installed in the process.
- Wet cake generated is 180 Ton/day (to be used as fertilizer).
- Waste water generated is at 1,500 m³/day (to be recycled). Waste water is intended to be used for biogas plant.

4.9 Energy Analysis

The ethanol production that consumes energy from steam and electricity in this study is based on 150,000 liter per day of bioethanol. Steam is generated by biomass. A boiler uses rice husks as raw materials. 100 Ton of rice husk are required per day.

4.9.1 Steam System

The factory has 4 boilers: 1 biogas boiler and 3 biomass boilers to produce bioethanol.

The biomass boiler generates steam which is distributed to 3 locations; mash cooking, fermentation and distillation of bioethanol. The return of drainage is used to pre-heated boiler feed water. Steam utilization is shown by Fig. 4.5.

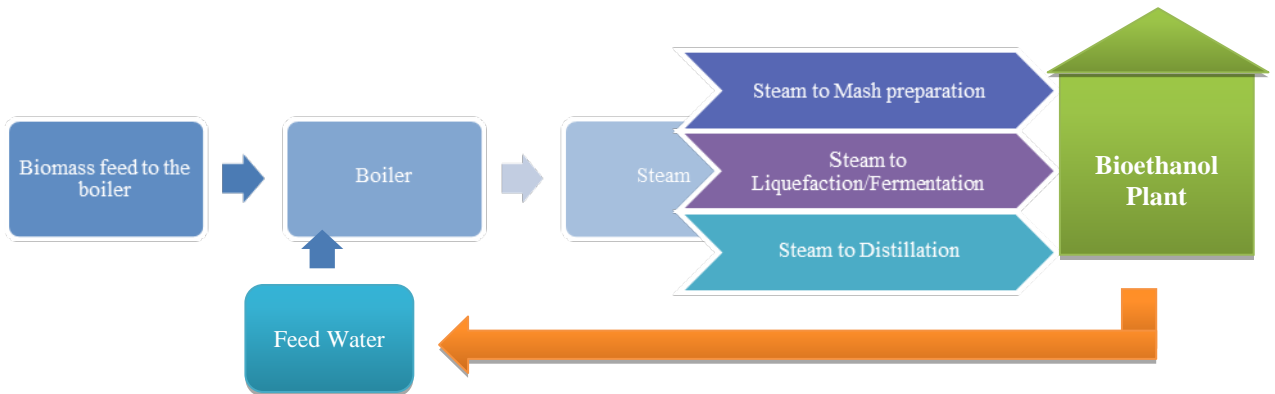


Figure 4.5 Steam utilized in the process

4.9.2 Electricity System

Electricity used in the process is for the soft start-up of the machines and to run the distillation system. Electricity comes from PEA and is fed to the factory in Figure 4.6.

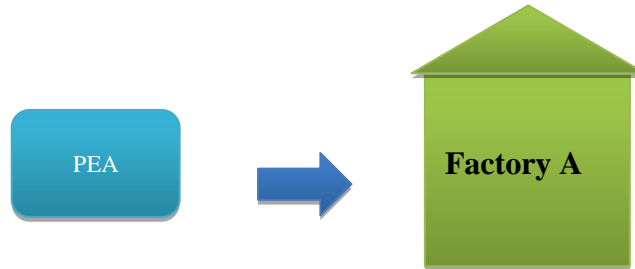


Figure 4.6 Electricity from PEA

4.9.3 Steam consumption in ethanol production process

The information of steam consumption from the factory is shown in Table 4.9. Steam is generated from the biomass boiler and the steam consumption in the bioethanol process from Factory A, is based on 1 day.

Table 4.9 Steam generated from biomass boiler and steam consumption in bioethanol process from Factory A based on 1 day.

Information	Quantity
Steam produced from biomass boiler (Ton/hour)	44
Steam consumption in the process (Ton/hour)	24.025
Steam consumption per liter of bioethanol (kg of steam/Liter of bioethanol)	0.16
Steam consumption per liter of bioethanol from other reference (kg of steam/Liter of bioethanol). (Phujaroen S., 2008).	0.19

In this study, the results of Steam consumption per liter of bioethanol is 0.16 kg of steam per liter of bioethanol.

From other studies, Steam consumption per liter of bioethanol is 0.19 kg of steam per liter of bioethanol (Phujaroen, S., 2008).

The calculation of energy from steam is shown in Appendix B. Energy consumption, for the production of 150,000 liter of bioethanol, from Steam is 15, 812.49 kW.

4.9.4 Electricity consumption in ethanol production process

The information of electricity consumption from the factory is shown in Table 4.10. Electricity consumption in the bioethanol process of Factory A, is based on 1 day.

Table 4.10 Electricity consumption in bioethanol process of Factory A based on 1 day.

Information	Quantity
Electricity consumption in the process (kW)	4,195.08

The calculation of energy from electricity consumption in above in Table 4.10 is given in Appendix C. Energy from electricity consumption, for the production of 150,000 liter of bioethanol, is 4,195.08 kW.

4.9.5 Energy used for biomass boiler of Factory A.

The information of energy consumption for the biomass boiler from Factory A based on 1 day is shown in Table 4.11.

Table 4.11 Energy consumption for biomass boiler from Factory A based on 1 day

Information	Quantity
Energy consumption for biomass boiler (kW)	12,621.53

The calculation of energy consumption from biomass boiler is shown in Appendix D. Energy consumption for biomass boiler (rice husk) is 12, 621.53 kW.

4.9.6 Total energy use in bioethanol production process of Factory A.

Total energy from steam, electricity and energy consumption in this is study based on 150,000 liter per day of bioethanol production is shown in Table 4.12.

Table 4.12 Energy consumption in the production process.

Energy used to produce 150,000 Liter of bioethanol (Electricity)	4,195.08	kW
Energy used to produce 150,000 Liter of bioethanol (Steam)	15,812.49	kW
Energy used for boiler (rice husk)	12,621.53	kW
Total energy consumption	32,629.09	kW

The calculation of total energy consumption of Factory A for the production of 150,000 liter per day of bioethanol is 32, 629.09 kW.

4.10 Net Energy Ratio

The calculation of Net Energy Ratio (NER) of Factory A is shown in Appendix E Calculation energy ratio. Comparison of Energy ratio from other studies is given in Table 4.13.

Table 4.13 Energy ratio compared with the other studies.

Energy Ratio	Cassava as raw material (without biogas)	Cassava as raw material (with biogas)
Reference 1 (Phujaroen, S., 2008)	1.2	1.72
Reference 2 (Ariyathum, B., 2006)	-	1.6
This study	1.26	-

In this study, the NER of the bioethanol production from cassava equals to 1.26. Positively gain the energy from bioethanol is obtained more than the energy consumption for the bioethanol production in this study.

4.11 CO₂ emission

In this study, a full life cycle analysis (LCA) of the GHG emissions from bioethanol produced from cassava is not used. The life cycle inventory analysis phase (LCI phase) which is involved the collection of input/output inventory data which is involved the system of this study. The life cycle impact assessment (LCIA) phase is excluded from this study too.

The scope of this study is to analyze the information of GHG comprised of source of energy, input water and steam. The process flow is described the energy and mass using as to demonstrated the inventory information.

The Global Emission Model for Integrated Systems (GEMIS) is used as a tool to estimate the CO₂ emission. The GEMIS model is used to assess the results of the emission of so-called CO₂ equivalents.

In this study, GEMIS version 4.8 is used for the calculation of CO₂ emissions.

The emissions are calculated based on the production process of bioethanol and energy consumption from are electricity, which is consumed as fossil fuels. In this study, GEMIS Map and Reference Inventory Database of GEMIS is shown on Appendix JGEMIS MAP and Reference Inventory Database.

According to the GEMIS, an input is set as energy, so the output is assessed based on the 1MJ of the product. The result obtained from GEMIS can be stated as the value of CO₂ direct, CH₄ and N₂O. The result is then expressed as CO₂ equivalent. The result from GEMIS is referred to AppendixH: Result of Analysis by GEMIS.

The result of CO₂ equivalent obtained from the production process of bioethanol as calculated by using GEMIS, based on 1 MJ of bioethanol, is demonstrated in Table 4.14.

Table 4.14 Carbon equivalent obtained from the production process of bioethanol given by GEMIS.

Carbon equivalent given by GEMIS	From this study	From other references (FAO, 2009)		
		Factory 1	Factory 2	Factory 3
CO ₂ eq. per MJ EtOH (g/MJ)	79.63	116.01	62.02	25.57

According to the result, it the CO₂ equivalent of the bioethanol is equal to 79.63 g/MJ of bioethanol.

The result of the CO₂ equivalent based on 1 MJ of bioethanol (exclude CO₂ from Fermentation reaction) as estimated by using GEMIS is shown in Appendix F Result of Analysis by GEMIS and the calculation of CO₂ equivalent by the production of 150,000 Liter per day is calculated in Appendix G.

The result of the carbon equivalent for bioethanol production in Table 4.15.

Table 4.15 The result of carbon equivalent for bioethanol production(excluding CO₂ from Fermentation reaction).

Carbon equivalent given by GEMIS of 150000 Liter per day of bioethanol production process (exclude Fermentation)		
Heat released by 150,000 L of Ethanol	3,552,455	MJ
1.00 MJ ethanol release CO ₂ equivalent	7.96E-05	T CO ₂
150,000 L bioethanol release CO ₂ equivalent	282.88	T CO ₂

Thus, all CO₂ generated from the whole production process is in Table 4.16.

Table 4.16 The table shown all CO₂ generated from the whole production process

Carbon emission	T CO₂ per day	Remark
CO ₂ equivalent from production process	282.88	-
CO ₂ from fermentation reaction	112	Captured by wet scrubber
Total CO₂	394.88	

The total CO₂ generated from the whole production process of 150,000 Liter of bioethanol per day equals 394.88 T CO₂ per day.

4.12 Discussion

The ability of any nation to economically survive would depend upon its ability to manage, produce, control and monitor sufficient supply of material, low-cost energy and technology of manufacturing production. So it is necessary to increase more the efficiency management of resources and energy consuming activities.

According to the result of the study, to create energy management system to monitor, control and improve the efficiency of energy consumption and try to reduce the loss of energy shall be considered as implemented by the factory.

There are suggestions which are concluded as described below,

4.12.1 Energy efficiency and improvement of energy management system

In order to maximize and improve energy efficiency, the organization may apply the energy management system. There are opportunities to improve energy efficiency by the organization by using techniques and tools from management system so called ISO50001 - Energy management system. It helps to monitor and control energy flows of the system which will result to maximize energy efficiency.

The standard specifying energy management system requirement which an organization can use to implement, establish energy policy, objectives, targets, and action

plans which take into account legal requirements and information related to significant energy use.

The organization can take action as needed to improve its energy performance and apply to the activities under the control of the organization as follows:

- a. Conduct the energy review and establish the baseline, energy performance indicators, objectives and targets,
 - o Methodology and criteria for energy review e.g. using activity-based cost analysis.
 - o Identification of energy sources, use and consumption,
 - o Identification of facilities, equipment etc.,
 - o Estimation of future energy use and consumption
 - For ISO 50001 – Energy Baseline considering a data period suitable to the organization's energy use and consumption (consumption/year, output/year) and certain object / process / facility),
- b. Action plans necessary to deliver results that will improve energy performance in accordance with the organization's energy policy,
- c. Implement the energy management action plans,
- d. Monitor and measure processes and the key characteristics of operations that determine energy performance against the energy policy and objectives, and report the results, and
- e. Take actions to continually improve energy performance

4.12.2 Improvement of energy efficiency

The organization shall also increase the energy efficiency for each unit operation as follows:

- a. Evaluation of energy consumption data

The data from energy meter bills measures the whole improvement of the energy efficiency process, including office area. Organizations can have measuring equipment for each area which is use energy source such as electricity and that included both total monthly usage and cost for each area. It is to ensure that the improvement of energy efficiency is made into small area which would be resulted to the whole organization's improvement.

Organization can also prepare to predict an energy use over a number of each period of billing of electricity or other based line information as appropriate. The period of each billing can be set depending upon the concerns and desired of the organization. The results of that can be evaluated in order to improve the energy management for more efficiency.

b. Equipment

The proper preventive maintenance shall be applied to all equipment, and to analyze the result of preventive maintenance program and equipment remaining life time are necessary. The predictive maintenance program shall be applied especially for the pump and motor.

c. Piping and heat distribution system

It shall be insulated to an effective level. Heat loss calculation should be made. Organization can use heat loss per unit area as the energy performance indicator for further improvement.

d. Start up and shut down time

Organization shall set the maintenance and operation procedure so as to avoid unnecessary start up for machine or consume start up time longer that it should be. Correctly and suitable control procedure shall be established and implemented in al operation areas.

e. Lighting system

To minimize the use of unnecessary light, a control system shall be made. An appropriate automatic control can be used.

f. Improvement of equipment calibration issue

Such as all temperature gauge shall be calibrated and validated so that it is can be used and record the information precisely and accuracy.

g. Contamination by sand can deteriorate metal process equipment, such as mechanical seals, control valve, and pumps so to focus on removing of sand is to safe the cost of production. Sand can be segregated or remove via sedimentation in channels, separation techniques, cyclone or a combinations of all methods.

h. In order to keep consistency of grain size distribution, the hammer mill shall be checked regularly. Screen not to be worn.

- i. The Mingler or Slurry mixer is used for ensuring the cassava is mixed with liquid. The size distribution of grain from the milling process shall be optimized and suit for each design of the Mingler. If the Mingler is not used then it can create dough balls into the hot slurry tank. Jet cooker steam will bit break such a small dough balls and that part could not be contacted with enzyme.

4.12.3 Improvement of the process

The organization shall also improve the efficiency of the process as follows;

- a. Establish the supply chain management through the supply chain, from farm to the factory. This will help the organization to have sufficient raw material to produce with the full scale of production. Lacking of cassava raw material can stop the plant. Manage the cassava feedstock based on the starch quantity and quality suitable to the factory.
- b. Focus on using the high value products such as enzyme that can maximize the yield of bioethanol.
- c. Use enzyme of fermentation process which has been proven and recorded that it can provide the consistency of fermentation process and has robust performance for variable mash conditions.
- d. Use enzyme which is able to react in a wide range of pH e.g. pH 5.2- 6. Control of pH in cooking process is critical. Below pH such as less than 5, alpha-amylase loss activities.
- e. Treat and apply statistical techniques for process control, find out the relation of the possible challenge such as the pretreatment process and process parameter adjustment. Process parameter, which is carefully monitor shall be temperature, pH, enzyme dose and agitation. The organization shall control and monitor the result, adjustment of the process parameter, and its relationship in order to control the process continuously and maximize the yield of bioethanol.
 - a. E.g. high temperature can inactivate enzyme, larger change of pH can denature enzyme protein, dosing pump of enzyme may wear off and dosage may change with time so regular check on flow rate is needed.
- f. Normally, the starch gelatinization reacts with alpha-amylase in the process. However, some foreign matter or contamination comes with the incoming cassava feedstocks and it resulted to give the high viscosity in the slurry preparation. Such viscosity is come from non-starch polysaccharides and rise the viscosity problem.

The high viscosity which is caused by non-starch polysaccharides can create a gel complex when it is contacted with water resulting that the yield of bioethanol is decrease.

- g. Yeast is used in according to the manufacturer's instruction strictly such as in the right environment; e.g. temperature.
- h. Good agitation promotes homogeneous substrate and enzyme so ensuring the strong agitation for liquefaction which can be done by listening to its movement or look for the movement by flashlight (due to difficulty to steam).
- i. In-line pH probe checking is needed and the routine calibration is necessary. Fresh buffer solution for lab pH meter is always used.
- j. Measuring of Dextrose Equivalent (DE) is needed. DE is the percentage of conversion from long chain sugar (dextrins) to simple sugar (glucose).

4.12.4 Carbon emission reduction and implementation of ISO 14064

Greenhouse gas management and ISO 14040 Environmental management – Life cycle management

GHG emission reduction and removal can be done by the organization by requiring the GHG project to be verified and validated in compliance with ISO 14064 Standard. GHG sources, physical unit or processes that release GHG into the atmosphere shall be identified.

The requirements specified by the authority of the applicable GHG program according to ISO14064-3: Specification with guidance for the validation and verification of greenhouse gas assertions, will be used to assist the organization to implement GHG emission reduction or removal as GHG credit or offset. The certification and crediting process by external parties shall be obtained by the organization.

Besides the above mentioned, the organization can obtain additional information in case the GHG emission reduction or removal project is needed to be conformed to the United Nations Framework Convention on Climate Change (UNFCCC), Tokyo Protocol's Clean Development Mechanism (CDM) or Joint Implementation (JI) mechanism to which the information is described in Annex of ISO14064-3 too.

In practice in the industrialized countries, any organization may generally fulfil their obligations based on the Kyoto Protocol to reduce GHGs either at local country or in other industrialized countries (by JI-projects) or in developing countries (by CDM-

projects). The instruments to be applied in developing countries are called the Clean Development Mechanism (CDM).

Emissions can be reduced by either reducing the fuel consumption (energy efficiency) or by using a fuel with a lower emission factor.

In case an organization gets the Credits from CDM projects where it can be generated and to be accredited by independent third parties, so-called Designated Operational Entities (DOEs) who have to investigate these projects, i.e. they have to validate the project design documents (PDD) and they have to verify periodically the emission reductions. The verification opinion is the basis for the issue of the credits, the so-called Certified Emission Reductions (CERs). The Credits gained by organization can be traded off.

To trade the CDM or JI project, organizations can commercially trade GHG credits or offset via The International Emissions Trading Association (IETA), which is a non-profit organization that establishes a functional international framework for trading greenhouse gas emissions reductions where there are many multinational companies perform the carbon trading cycle: emitters, solution providers, brokers, insurers, verifiers and legal compliance.

As mentioned above, the baseline for a CDM project activity is the scenario that has to be selected by the organization. It shall be reasonably represented GHG emissions that would occur in the absence of the proposed project activity. Meaning that the organization has to look into the future and make certain predictions and assumptions. In this case the organization can utilize project from process waste water to be used for biogas system. The reason is that the identified scenarios should deliver outputs or services with comparable quality, properties and application areas and it can produce gas to be used as fuel in the factory. Electricity generated from biogas system which help to reduce the using of electricity from PEA.

If the organization would like to select the project that improves energy efficiency in several boilers with rather different characteristics (e.g. size, technology, age and etc.) alternative scenarios should be established for each boiler or for types of boilers with broadly similar characteristics. The organization has 4 boilers to which 3 of them is used biomass, rice husk as fuel while the other is a mix of natural gas. So the improvement project can be a selective of boiler fuel which is generate less CO₂ emission.

In order to recommend the organization to GHG emission reduction or removal project, the information below is provide planning process and implementation as guidance. At the early beginning the project participants of the organization have to decide on each items as follows;

4.12.4.1 Described the project/ Project Summary:

- the type of technology to be used
- the host country for the CDM project, in case they want to trade off
- obstacles of barriers to be removed before starting activities such as limitation of fuel, transportation or raw material

4.12.4.2 Identifying the Baseline Methodology

The CDM approved methodology will detail the general approach for calculating the baseline and project emissions, including the parameters and formulas to be used. The baseline calculations

Applicability of the methodology to be used (UNFCCC Methodology reference, in is available on their website)

4.12.4.3 Duration of the Project Activity/ Crediting Period

Timeline and milestone of the project shall set and monitor its progress.

4.12.4.4 Monitoring Methodology and Plan

Calculation of GHG emission reductions, using conservative assumptions for estimating emission reductions. Update information is needed when any change is occurred such as changing of process equipment.

CHAPTER 5

CONCLUSION

This study, focuses on the results of energy efficiency and CO₂ which is released from the production process. Energy Analysis in order to measure an energy efficiency is found the Net Energy Ration (NER) is equal to 1.26 and that is sufficiency for the production perspective to produce bioethanol. Positively gain the energy from bioethanol is obtained more than the energy consumption for the bioethanol production in this study.

= CO₂ from the production of bioethanol is emitted from the distillation system and is generated from the using of carbon emission factor through the production process. Based on such information, a using of GEMIS tools to calculate the quantified CO₂ from the raw material preparation, liquefaction, fermentation, distillation and denaturized processes is performed.

CO₂ is generated from the fermentation process at 112 Ton CO₂ which is captured by scrubbers installed in the process. CO₂ emissions from the production process by using of GEMIS software is 79.63 g CO₂ per MJ of bioethanol. It is resulted that 282.88 Ton CO₂ equivalent is released from the production process. Therefore, total CO₂ generated from the whole production process of 150,000 Liter of bioethanol per day is equaled to 394.88 T CO₂ per day.

Efficiency of Factory A in bioethanol production is 65.6 % compared to the theoretical bioethanol production that can be produced from the same quantity and quality of cassava feedstocks. The opportunity to improve an efficiency of bioethanol production process from Factory A can be reached to 34.4% in order to get the same quantity of bioethanol as yield of the production based on the theoretical stoichiometric yield.

In this regard, there are opportunities to improve the production process efficiency, improve the energy management system by implementation of ISO 50001 Energy management system, and to improve the carbon emission reduction by implementation of ISO 14040 Life Cycle Assessment and ISO 14064 Greenhouses Gases Management.

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APPENDIXES

Appendix A
Ethanol specification (DOEB, 2005).

Detail	Quantity	Unit
Ethanol	Not less than 99.5	% V/V
Acidity (as acetic acid)	Less than 0.002	% w/w
Ketone (as acetic acid)	Less than 0.001	% w/w
Iso-amyle alcohol	Less than 0.05	% w/w
Furfuraldehyde	Less than 0.001	% w/w
Propane-2-ol	Less than 0.002	% w/w
Methanol	Less than 0.01	% w/w
Non-volatile matter	Less than 0.001	% w/w

Appendix B
Energy consumption (Steam)

Calculation of Energy consumption from steam from the equation;

$$E = m (h - h_0) - T_0(S - S_0)$$

E	Energy from steam (MW),		
m	Feed steam flow rate (24 Ton/Hr)	=	6.67 kg/s,
h	at 23 bar	=	2,777 kJ/kg,
h_0	at 30 °C (feed water)	=	125.7 kJ/kg,
T_0	Temperature	=	303 K,
S	at 23 bar	=	6.585 kJ/kg K,
S_0	at 30 °C	=	0.437 kJ/kg K,

$$E = (6.67) (2,777 - 125.7) - 303(6.585 - 0.437)$$

$$E = 15, 821.33 \text{ kW}$$

Energy consumption from steam is 15, 821.33 kW.

Appendix C

Energy consumption (Electricity)

Electricity consumption per day from the main operation unit in process are described and calculated as follows;

Operation unit	Electricity consumption (kW)
Cassava chip	100.00
Mashing/ Liquefaction	1,147.50
Fermentation & CIP	554.20
Distillation	432.00
Stillage & drying	796.03
Product Blending	250.75
Cooling tower	914.60
Total	4,195.08

Total Energy used for the production operation is 4,195.08 kW per day.

Appendix D
Energy consumption (Biomass boiler)

The factory use rice husk boiler for the generation of steam to be used in the production process.

Rice husk is fed to the boiler 100 Ton per day,

The heating value of rice husk is 14,540 kJ/kg,

Estimation the boiler efficiency is 75 %,

Therefore, calculation of the total energy used for the boiler is

$$= 100 \text{ Ton/day} \times 14,540 \text{ kJ/kg} \times 75\%$$

$$= 12, 621.53 \text{ kW.}$$

Total energy used for the boiler is 12, 621.53 kW.

Appendix E
Calculation of Net Energy Ratio (NER)

Calculation of the energy gained from the bioethanol is as follows;

Ethanol from production is produced	150,000	Liter (L) per day,
Density of ethanol from Production	0.796	g/mL,
Mass of ethanol 1 L is	= (0.796)x(1000)	g
	= 796.0	g,
Molar mass of Ethanol	= 46.07	g/mol,
Moles of mass of Ethanol	= 17.28	mol,
Ethanol 1 L has	= 17.28	mol,

Calculation of mole of ethanol 150,000 L is

$$= (150,000 \text{ L}) \times (17.28 \text{ mol/L}),$$

$$= 2,591,708.27 \text{ mol},$$

1 Mole of ethanol release heat of combustion as Heat of combustion of Ethanol

$$= -1,370.70 \text{ kJ/mol, (- is heat release),}$$

Ethanol 1 L has

$$= 17.28 \text{ mol},$$

Therefore, Heat released by 1L of Ethanol is

$$= (-1,370.70 \text{ kJ/mol}) \times (17.28 \text{ mol})$$

$$= -23,683.03 \text{ kJ},$$

Then, Heat released by 150,000 L of Ethanol is

$$= (150,000 \text{ L}) \times (-23,683.03 \text{ kJ/L})$$

$$= -3,552,454,525.72 \text{ kJ},$$

Ethanol is produced 150,000 L/day so Heat release by 150,000 L of Ethanol in term of kJ/s

$$\text{is} = (-3,552,454,525.72 \text{ kJ}) / (24 \times 60 \times 60 \text{ sec})$$

$$= -41,116.37 \text{ kW},$$

Heat release by 150,000 L of Ethanol

$$= -41,116.37 \text{ kW},$$

Total energy gained from the ethanol which is produced at 150,000 Liter per day is

$$= 41,116.37 \text{ kW}.$$

Calculation of the energy consumed for bioethanol production from the sources of energy used as follows;

Energy used to produce 150,000 L of bioethanol (Steam), Appendix B

$$= 15,812.49 \text{ kW},$$

Energy used to produce 150,000 L of bioethanol (Electricity), Appendix C

$$= 4,195.08 \text{ kW, and}$$

Energy used for biomass boiler, Appendix D

$$= 12,621.53 \text{ kW}.$$

Thus, total energy used in the production process is

$$= 4,195.08 \text{ kW} + 15,812.49 \text{ kW} + 12,621.53 \text{ kW}$$

$$= 32, 629.09 \text{ kW}.$$

Total energy used in the production process is

$$= 32, 629.09 \text{ kW}.$$

Calculation of Net Energy Ratio (NER) is

$$= \text{Total energy gained} / \text{Total energy consumed},$$

$$= 41,116.37\text{kW} / 32, 629.09 \text{ kW},$$

$$= 1.26.$$

$$\text{Net Energy Ration (NER)} = 1.26$$

Appendix F
Result of Analysis by GEMIS

The global results for '1.000000 MJ ethanol (bio)-TH (Lower Heating Value)' supplied from 'fermentation\EtOH-cassava-TH' are:

Emissions into air

	direkt Vorkette	Sum
SO2 equivalent	$6.5629 \cdot 10^{-6}$	$6.5629 \cdot 10^{-6}$ kg
TOPP equivalent	$7.6836 \cdot 10^{-6}$	$7.6836 \cdot 10^{-6}$ kg
SO2	$2.1673 \cdot 10^{-6}$	$2.1673 \cdot 10^{-6}$ kg
NOx	$5.9238 \cdot 10^{-6}$	$5.9238 \cdot 10^{-6}$ kg
HCl	$52.474 \cdot 10^{-9}$	$52.474 \cdot 10^{-9}$ kg
HF	$4.0819 \cdot 10^{-9}$	$4.0819 \cdot 10^{-9}$ kg
Particulates	$290.35 \cdot 10^{-9}$	$290.35 \cdot 10^{-9}$ kg
CO	$2.0667 \cdot 10^{-6}$	$2.0667 \cdot 10^{-6}$ kg
NMVOC	$175.15 \cdot 10^{-9}$	$175.15 \cdot 10^{-9}$ kg
H2S	$827.6 \cdot 10^{-12}$	$827.6 \cdot 10^{-12}$ kg
NH3	$115.36 \cdot 10^{-9}$	$115.36 \cdot 10^{-9}$ kg
As (air)	$30.06 \cdot 10^{-12}$	$30.06 \cdot 10^{-12}$ kg
Cd (air)	$12.74 \cdot 10^{-12}$	$12.74 \cdot 10^{-12}$ kg
Cr (air)	$34.27 \cdot 10^{-12}$	$34.27 \cdot 10^{-12}$ kg
Hg (air)	$37.42 \cdot 10^{-12}$	$37.42 \cdot 10^{-12}$ kg
Ni (air)	$169.0 \cdot 10^{-12}$	$169.0 \cdot 10^{-12}$ kg
PAH (air)	$14.79 \cdot 10^{-15}$	$14.79 \cdot 10^{-15}$ kg
Pb (air)	$114.3 \cdot 10^{-12}$	$114.3 \cdot 10^{-12}$ kg
PCDD/F (air)	$73.47 \cdot 10^{-18}$	$73.47 \cdot 10^{-18}$ kg

Green house gases

	direkt	Vorkette	Sum
CO2 equivalent		$79.630 \cdot 10^{-3}$	$79.630 \cdot 10^{-3}$ kg
CO2		$79.485 \cdot 10^{-3}$	$79.485 \cdot 10^{-3}$ kg
CH4		$3.8602 \cdot 10^{-6}$	$3.8602 \cdot 10^{-6}$ kg
N2O		$160.71 \cdot 10^{-9}$	$160.71 \cdot 10^{-9}$ kg
Perfluoromethane		$45.08 \cdot 10^{-12}$	$45.08 \cdot 10^{-12}$ kg
Perfluoroethane		$5.683 \cdot 10^{-12}$	$5.683 \cdot 10^{-12}$ kg

Residues

	direkt	Vorkette	Sum
Ash	Unknown		
FGD residual	Unknown		
Sewage sludge	Unknown		
Production waste	Unknown		
Overburden	Unknown		
waste-nuclear fuel		$3.4410 \cdot 10^{-9}$	$3.4410 \cdot 10^{-9}$ kg

Liquid effluents

	direkt	Vorkette	Sum
P	Unknown		
N	Unknown		
AOX	Unknown		
COD	Unknown		
BOD5	Unknown		
inorg. salt	Unknown		

As (liquid)	$3.391 \cdot 10^{-15}$	$3.391 \cdot 10^{-15}$ kg
Cd (liquid)	$8.283 \cdot 10^{-15}$	$8.283 \cdot 10^{-15}$ kg
Cr (liquid)	$8.193 \cdot 10^{-15}$	$8.193 \cdot 10^{-15}$ kg
Hg (liquid)	$4.142 \cdot 10^{-15}$	$4.142 \cdot 10^{-15}$ kg
Pb (liquid)	$54.02 \cdot 10^{-15}$	$54.02 \cdot 10^{-15}$ kg

Resource use

Cumulated energy requirement

CER-non renewable	1.5222811 MJ
CER-renewable	3.3658447 MJ
CER-other	$-2.3362 \cdot 10^{-3}$ MJ
CER-Sum	4.8857896 MJ

cumulative energy use

CEU-non renewable	$28.280 \cdot 10^{-3}$ MJ
CEU-renewable	3.3658447 MJ
CEU-other	$-2.3362 \cdot 10^{-3}$ MJ
CEU-Sum	3.3917881 MJ

Cumulated material requirement

CMR-non renewable	$39.586 \cdot 10^{-3}$ kg
CMR-renewable	$239.41 \cdot 10^{-3}$ kg
CMR-other	$3.0153 \cdot 10^{-6}$ kg
CMR-Sum	$278.99 \cdot 10^{-3}$ kg

Detailed resource use

air	$522.51 \cdot 10^{-9}$ kg	material requirement (renewable)
biomass	3.3339248 MJ	energy requirement (renewable)
biomass	3.3339248 MJ	energy consumption (renewable)
biomass	$41.275 \cdot 10^{-9}$ kg	material requirement (renewable)
biomass-residues	$30.384 \cdot 10^{-3}$ MJ	energy requirement (renewable)
biomass-residues	$30.384 \cdot 10^{-3}$ MJ	energy consumption (renewable)
biomass-residues	$296.46 \cdot 10^{-9}$ kg	material requirement (renewable)
coal (hard)	$9.9504 \cdot 10^{-3}$ MJ	energy requirement (non renewable)
coal (hard)	$9.9504 \cdot 10^{-3}$ MJ	energy consumption (non renewable)
geothermal	$1.3720 \cdot 10^{-6}$ MJ	energy requirement (renewable)
geothermal	$1.3720 \cdot 10^{-6}$ MJ	energy consumption (renewable)
hydropower	$477.21 \cdot 10^{-6}$ MJ	energy requirement (renewable)
hydropower	$477.21 \cdot 10^{-6}$ MJ	energy consumption (renewable)
iron-scrap	$2.9313 \cdot 10^{-6}$ kg	material requirement (other)
lignite	$8.2245 \cdot 10^{-3}$ MJ	energy requirement (non renewable)
lignite	$8.2245 \cdot 10^{-3}$ MJ	energy consumption (non renewable)
minerals	$2.2350 \cdot 10^{-3}$ kg	material requirement (non renewable)
natural gas	$7.9731 \cdot 10^{-3}$ MJ	energy requirement (non renewable)
natural gas	$5.9800 \cdot 10^{-3}$ MJ	energy consumption (non renewable)
natural gas	$43.677 \cdot 10^{-6}$ kg	material requirement (non renewable)
NF-scrap	$35.116 \cdot 10^{-9}$ kg	material requirement (other)
nuclear	$3.2208 \cdot 10^{-3}$ MJ	energy requirement (non renewable)
nuclear	$3.2208 \cdot 10^{-3}$ MJ	energy consumption (non renewable)
oil	1.4929123 MJ	energy requirement (non renewable)
oil	$903.88 \cdot 10^{-6}$ MJ	energy consumption (non renewable)
oil	$37.300 \cdot 10^{-3}$ kg	material requirement (non renewable)
ores	$7.1356 \cdot 10^{-6}$ kg	material requirement (non renewable)

secondary raw materials	$-3.8941 \cdot 10^{-3}$ MJ energy requirement	(other)
secondary raw materials	$-3.8941 \cdot 10^{-3}$ MJ energy consumption	(other)
secondary raw materials	$48.959 \cdot 10^{-9}$ kg material requirement	(other)
sun	$261.11 \cdot 10^{-6}$ MJ energy requirement	(renewable)
sun	$261.11 \cdot 10^{-6}$ MJ energy consumption	(renewable)
waste	$1.5579 \cdot 10^{-3}$ MJ energy requirement	(other)
waste	$1.5579 \cdot 10^{-3}$ MJ energy consumption	(other)
water	$239.40 \cdot 10^{-3}$ kg material requirement	(renewable)
wind	$796.28 \cdot 10^{-6}$ MJ energy requirement	(renewable)
wind	$796.28 \cdot 10^{-6}$ MJ energy consumption	(renewable)

Land use

Land-use is : 0.00 m?

Employment effects

direct employment effects	$628.7 \cdot 10^{-12}$ Personen
employment effects through investment	$7.0755 \cdot 10^{-9}$ Personen
operationally employment effects Fixed costs	$8.0807 \cdot 10^{-9}$ Personen
operationally employment effects Variable costs	$1.7230 \cdot 10^{-9}$ Personen
Total employment effects	$17.508 \cdot 10^{-9}$ Personen

Folgende Parameter werden für die Berechnung benutzt

Economic factors BMU-Bioenergy-2010-reference (8% interest)

GHG Factors IPCC 2007 (100 years)

Externalities generic (updated)

The following global switches are set

Construction	on
mobile transport	on
Override of locally selected allocation method	default allocation
Efficiency of resource extraction = 100%	on
treated/disposed solid wastes are not included in results	on
# of iterations : 10858	

Appendix G

Calculation of CO₂ equivalent from 150,000 Liter of bioethanol production process.

The calculation in Appendix E shows that energy released by 150,000 L of Ethanol per day is

$$\begin{aligned} &= 41,116.37 \quad \text{kW,} \\ \text{So energy release by 150,000 Liter of ethanol is} &= 3,552,455 \quad \text{MJ,} \end{aligned}$$

According to the result from GEMIS, ethanol releases CO₂ equivalent at 7.96×10^{-5} T CO₂/MJ of ethanol, therefore 150,000 Liter of ethanol release heat at

$$\begin{aligned} &= 3,552,455 \text{ MJ} \times 7.96 \times 10^{-5} \\ &\quad \text{T CO}_2 / \text{MJ,} \\ &= 282.88 \text{ T CO}_2 \end{aligned}$$

Carbon equivalent resulted by GEMIS of 150000 Liter per day of bioethanol production process (exclude Fermentation) is 282.88 T CO₂

Appendix H
Equipment List

Equipment Description	Description/Specifications
LIQUEFACTION SECTION	
Final Liquefaction Tank	Type: Cylindrical / Vertical shell with conical top & bottom
Caustic Dosing Tank	Type: Cylindrical / vertical shell with flat top and bottom
Slurry Tank	Type: Cylindrical / Vertical shell with top dish and conical bottom
Cook Tube	Type: Cylindrical / Vertical shell with dished top & conical bottom
Flash Tank	Type: Cylindrical / Vertical shell with dished top and bottom
Recycle Stream Collection Tank	Type: Cylindrical / Vertical shell with dished top and conical bottom
Degrit Slurry Tank	Type: Cylindrical / Vertical shell with dished top and conical bottom
Fermentor - I to VI	Type: Cylindrical/Vertical Shell with Conical Top and Conical Bottom
Beer Well	Type: Cylindrical/Vertical Shell with Conical Top and Conical Bottom
Pre Fermentor	Type: Cylindrical/Vertical Shell with Conical Top and Conical Bottom
Antifoam Dosing Tank	Type: Cylindrical/Vertical Shell with Flat Top and Flat Sloping Bottom
Acid Dosing Tank	Type: Cylindrical/Vertical Shell with Flat Top and Flat Sloping Bottom
Nutrient Dosing Tank	Type: Cylindrical / Vertical Shell with Dished Top and Bottom
CIP Tank	Type: Cylindrical/Vertical Shell with Conical Top and

	Flat Sloping Bottom
CO ₂ Scrubber	Type:Sieve Tray Column
MASH Column	Type: Rh Grid Tray
Degasifying Column	Type: Rh Grid Tray
Vent Scrubber	Type: Sieve Tray
Rectifier Cum Exhaust Column	Type: Bubble Cap Tray
Evaporator Column	Type: Bubble Cap Tray
Reboiler for Mash Column	Type: Shell & Tube Heat Exchanger;
Rectifier Reboiler	Type: Shell & Tube Heat Exchanger;
Evaporator Column Reboiler	Type: Shell & Tube Heat Exchanger;
Super heater	Type: Shell & Tube Heat Exchanger;
Regeneration Preheater	Type: Shell & Tube Heat Exchanger;
Feed Preheater	Type: Shell & Tube Heat Exchanger;
Flash Condenser	Type: Shell & tube Heat Exchanger
Vent Condenser for Mash Column Reboiler	Type: Shell & tube Heat Exchanger
Degasifying column Condenser	Type: Shell & tube Heat Exchanger
MASH Condenser – I	Type: Shell & tube Heat Exchanger
MASH Condenser – II	Type: Shell & tube Heat Exchanger
MASH Vent Condenser	Type: Shell & tube Heat Exchanger

Rectifier PCV Condenser	Type: Shell & tube Heat Exchanger
Regeneration Condenser	Type: Shell & tube Heat Exchanger
Product Condenser	Type: Shell & tube Heat Exchanger
RS Cooler	Type: Shell & tube Heat Exchanger
T.A. Cooler	Type: Shell & tube Heat Exchanger
L.F.O. Cooler for Rectifier cum Exhaust column	Type: Shell & tube Heat Exchanger
H.F.O. Cooler for Rectifier cum Exhaust column	Type: Shell & tube Heat Exchanger
Product Cooler	Type: Shell & tube Heat Exchanger
Liquefying Enzyme Dosing Tank	Type: Cylindrical / vertical shell with flat top and bottom; Capacity: 0.5 m ³
Viscosity Reduction Enzyme Dosing Tank	Type: Cylindrical / vertical shell with flat top and bottom; Capacity: 0.5 m ³
Saccharifying Enzyme Dosing Tank	Type: Cylindrical / vertical shell with flat top and bottom; Capacity: 0.5 m ³
Proteolytic Enzyme Dosing Tank	Type: Cylindrical / vertical shell with flat top and bottom; Capacity: 0.5 m ³
Product Receiver	Type: Cylindrical / Vertical shell with dished end; Capacity: 1.350 m ³ ;
Regeneration Receiver	Type: Cylindrical / Vertical shell with dished end; Capacity: 1.350 m ³ ;
Steam Cooker	Type: Cylindrical / Vertical shell with dished ends; Capacity: 7.0 m ³ ;
Steam Sparger for Steam Cooker	Type: Technology Owner Standard
Steam Sparger for Slurry tank	Type: Technology Owner Standard

Air Sparger for Pre Fermentor	Type: Technology Owner Standard
Air Filter Frame	Type: Technology Owner Standard
Gas Liquid Separator for Degasifying Column	Type: Technology Owner Standard
Gas Liquid Separator for Analyser Column	Type: Technology Owner Standard
Vapor Bottle for Degasifying Column Condenser	Type: Technology Owner Standard
Vapor Bottle for MASH condenser- I	Type: Technology Owner Standard
Vapor Bottle for MASH condenser- II	Type: Technology Owner Standard
Vapor Bottle for MASH Vent condenser	Type: Technology Owner Standard
Vapor Bottle for Vent Condenser for Mash Column Reboiler	Type: Technology Owner Standard
Vapor Bottle for Rectifier PCV Condenser	Type: Technology Owner Standard
T.A. Mixing Bottle	Type: Technology Owner Standard
Fusel Oil Decanter	Type: Technology Owner Standard
Equalization Pot for Flash Tank	Type: Technology Owner Standard
Sieve Bed #1 & 2	Type: Cylindrical / Vertical shell with dished end
Hydro heater for CIP Tank	Type: Jet Heater
Slurry Cooler	Type: Plate Heat Exchanger
Fermented Wash Pre-Heater	Type: Plate Heat Exchanger

DISTILLATION SECTION	
FLASH Tank	Type: Cylindrical Vertical Shell with Dished Top & Bottom
MASH Condensate Tank	Type: Cylindrical Vertical Shell with Dished Top & Bottom
Reflux Tank	Type: Cylindrical Vertical Shell with Dished Top & Bottom
Fusel Oil Washings Tank	Type: Cylindrical Vertical Shell with Dished Top & Bottom
Steam Condensate Tank	Type: Cylindrical Horizontal Shell with Dished Sides
Hot Water Tank	Type: Cylindrical Vertical shell with open top and Flat Bottom
CIP Tank	Type: Cylindrical Vertical shell with Slopping Bottom Tank
Rectifier Feed Pre-Heater	Type: Plate Heat Exchanger
Fermentor Cooler-I to VI	Type: Plate Heat Exchanger
Pre Fermentor Cooler	Type: Plate Heat Exchanger
Regeneration Cooler	Type: Plate Heat Exchanger
Vacuum Pump with Motor	Type: Water Ring Type
Vacuum Pump with Motor	Type: Water Ring Type
Vacuum Eductor	Size: 2.5 inch
Air Blower with Motor and Air Separator	Type: Water Ring Capacity: 730 m ³ /hr
Flame Arrestor	Type: Technology Owner Standard , Standard; Size : 50 NB
DECANTATION SECTION	

Decanter	Type: Centrifuge
Thin Slop Tank	Type: Cylindrical/Vertical Shell with Conical Top and Conical Bottom
ALCOHOL STORAGE SECTION	
Fuel Ethanol Daily Receiver	Type: Cylindrical / Vertical shell with conical top and flat slopping bottom
Fuel Ethanol Bulk Storage Tank	Type: Cylindrical / Vertical shell with conical top and flat slopping bottom
I.A./T.A. Storage Tank	Type: Cylindrical / Vertical shell with conical top and flat slopping bottom
I.A/TA Daily Receiver	Type: Cylindrical / Vertical shell with conical top and flat slopping bottom
Fusel Oil Storage Tank	Type: Cylindrical / Vertical shell with conical top and flat slopping bottom
Vent Condenser for Fuel Ethanol Bulk Storage Tank.	Type :Shell and Tube (Horizontal)
Vent Condenser for IA/TA Storage Tank.	Type :Shell and Tube (Horizontal)
Flame Arrestor for T-701A/B/C	Type: Technology Owner Standard
Flame Arrestor for T-702 A/B/C	Type: Technology Owner Standard
Flame Arrestor for T-711	Type: Technology Owner Standard
Flame Arrestor for T-731 A/B	Type: Technology Owner Standard
Flame Arrestor for T-733.	Type: Technology Owner Standard
BULK CHEMICAL STORAGE SECTION	
Caustic Storage Tank	Type: Cylindrical / Vertical Shell with Conical Top and Flat Sloping Bottom

Sulphuric Acid Tank	Type: Cylindrical / Vertical Shell with Conical Top and Flat Sloping Bottom
Nitric Acid Tank	Type: Cylindrical / Vertical Shell with Conical Top and Flat Sloping Bottom
UTILITY SECTION	
Cooling Tower for Fermentation	Type: Force /Induced; Capacity
Cooling Tower for Distillation	Type: Force /Induced; Capacity: 1000 m ³ /hr; Delta T = 8° C
Cooling Tower for Liquefaction	Type: Force /Induced; Capacity: 650 m ³ /hr; Delta T = 10° C
Cooling Tower for Dehydration	Type: Force /Induced; Capacity: 575 m ³ /hr; Delta T = 4° C
Air Compressor	Capacity : - Nm ³ /hr
Air Dryer	Capacity : - Nm ³ /hr

Appendix I

Steam table and Properties

Absolute pressure	Boiling point	Specific volume (steam)	Density (steam)	Specific enthalpy of liquid water (sensible heat)		Specific enthalpy of steam (total heat)		Latent heat of evaporation		Specific heat
				(kJ/kg)	(kcal/kg)	(kJ/kg)	(kcal/kg)	(kJ/kg)	(kcal/kg)	
0.02	17.51	67.006	0.015	73.45	17.54	2533.64	605.15	2460.19	587.61	1.8644
0.03	24.1	45.667	0.022	101	24.12	2545.64	608.02	2444.65	583.89	1.8694
0.04	28.98	34.802	0.029	121.41	29	2554.51	610.13	2433.1	581.14	1.8736
0.05	32.9	28.194	0.035	137.77	32.91	2561.59	611.83	2423.82	578.92	1.8774
0.06	36.18	23.741	0.042	151.5	36.19	2567.51	613.24	2416.01	577.05	1.8808
0.07	39.02	20.531	0.049	163.38	39.02	2572.62	614.46	2409.24	575.44	1.884
0.08	41.53	18.105	0.055	173.87	41.53	2577.11	615.53	2403.25	574.01	1.8871
0.09	43.79	16.204	0.062	183.28	43.78	2581.14	616.49	2397.85	572.72	1.8899
0.1	45.83	14.675	0.068	191.84	45.82	2584.78	617.36	2392.94	571.54	1.8927
0.2	60.09	7.65	0.131	251.46	60.06	2609.86	623.35	2358.4	563.3	1.9156
0.3	69.13	5.229	0.191	289.31	69.1	2625.43	627.07	2336.13	557.97	1.9343
0.4	75.89	3.993	0.25	317.65	75.87	2636.88	629.81	2319.23	553.94	1.9506
0.5	81.35	3.24	0.309	340.57	81.34	2645.99	631.98	2305.42	550.64	1.9654
0.6	85.95	2.732	0.366	359.93	85.97	2653.57	633.79	2293.64	547.83	1.979
0.7	89.96	2.365	0.423	376.77	89.99	2660.07	635.35	2283.3	545.36	1.9919
0.8	93.51	2.087	0.479	391.73	93.56	2665.77	636.71	2274.05	543.15	2.004
0.9	96.71	1.869	0.535	405.21	96.78	2670.85	637.92	2265.65	541.14	2.0156
1	99.63	1.694	0.59	417.51	99.72	2675.43	639.02	2257.92	539.3	2.0267
1.1	102.32	1.549	0.645	428.84	102.43	2679.61	640.01	2250.76	537.59	2.0373
1.2	104.81	1.428	0.7	439.36	104.94	2683.44	640.93	2244.08	535.99	2.0476
1.3	107.13	1.325	0.755	449.19	107.29	2686.98	641.77	2237.79	534.49	2.0576
1.4	109.32	1.236	0.809	458.42	109.49	2690.28	642.56	2231.86	533.07	2.0673
1.5	111.37	1.159	0.863	467.13	111.57	2693.36	643.3	2226.23	531.73	2.0768
1.5	111.37	1.159	0.863	467.13	111.57	2693.36	643.3	2226.23	531.73	2.0768
1.6	113.32	1.091	0.916	475.38	113.54	2696.25	643.99	2220.87	530.45	2.086
1.7	115.17	1.031	0.97	483.22	115.42	2698.97	644.64	2215.75	529.22	2.095
1.8	116.93	0.977	1.023	490.7	117.2	2701.54	645.25	2210.84	528.05	2.1037
1.9	118.62	0.929	1.076	497.85	118.91	2703.98	645.83	2206.13	526.92	2.1124
2	120.23	0.885	1.129	504.71	120.55	2706.29	646.39	2201.59	525.84	2.1208
2.2	123.27	0.81	1.235	517.63	123.63	2710.6	647.42	2192.98	523.78	2.1372
2.4	126.09	0.746	1.34	529.64	126.5	2714.55	648.36	2184.91	521.86	2.1531
2.6	128.73	0.693	1.444	540.88	129.19	2718.17	649.22	2177.3	520.04	2.1685
2.8	131.2	0.646	1.548	551.45	131.71	2721.54	650.03	2170.08	518.32	2.1835
3	133.54	0.606	1.651	561.44	134.1	2724.66	650.77	2163.22	516.68	2.1981
3.5	138.87	0.524	1.908	584.28	139.55	2731.63	652.44	2147.35	512.89	2.2331
4	143.63	0.462	2.163	604.68	144.43	2737.63	653.87	2132.95	509.45	2.2664
4.5	147.92	0.414	2.417	623.17	148.84	2742.88	655.13	2119.71	506.29	2.2983

5	151.85	0.375	2.669	640.12	152.89	2747.54	656.24	2107.42	503.35	2.3289
5.5	155.47	0.342	2.92	655.81	156.64	2751.7	657.23	2095.9	500.6	2.3585
6	158.84	0.315	3.17	670.43	160.13	2755.46	658.13	2085.03	498	2.3873
6.5	161.99	0.292	3.419	684.14	163.4	2758.87	658.94	2074.73	495.54	2.4152
7	164.96	0.273	3.667	697.07	166.49	2761.98	659.69	2064.92	493.2	2.4424
7.5	167.76	0.255	3.915	709.3	169.41	2764.84	660.37	2055.53	490.96	2.469
8	170.42	0.24	4.162	720.94	172.19	2767.46	661	2046.53	488.8	2.4951
8.5	172.94	0.227	4.409	732.03	174.84	2769.89	661.58	2037.86	486.73	2.5206
9	175.36	0.215	4.655	742.64	177.38	2772.13	662.11	2029.49	484.74	2.5456
9.5	177.67	0.204	4.901	752.82	179.81	2774.22	662.61	2021.4	482.8	2.5702
10	179.88	0.194	5.147	762.6	182.14	2776.16	663.07	2013.56	480.93	2.5944
11	184.06	0.177	5.638	781.11	186.57	2779.66	663.91	1998.55	477.35	2.6418
12	187.96	0.163	6.127	798.42	190.7	2782.73	664.64	1984.31	473.94	2.6878
13	191.6	0.151	6.617	814.68	194.58	2785.42	665.29	1970.73	470.7	2.7327
14	195.04	0.141	7.106	830.05	198.26	2787.79	665.85	1957.73	467.6	2.7767
15	198.28	0.132	7.596	844.64	201.74	2789.88	666.35	1945.24	464.61	2.8197
16	201.37	0.124	8.085	858.54	205.06	2791.73	666.79	1933.19	461.74	2.862
17	204.3	0.117	8.575	871.82	208.23	2793.37	667.18	1921.55	458.95	2.9036
18	207.11	0.11	9.065	884.55	211.27	2794.81	667.53	1910.27	456.26	2.9445
19	209.79	0.105	9.556	896.78	214.19	2796.09	667.83	1899.31	453.64	2.9849
20	212.37	0.1	10.047	908.56	217.01	2797.21	668.1	1888.65	451.1	3.0248
21	214.85	0.095	10.539	919.93	219.72	2798.18	668.33	1878.25	448.61	3.0643
22	217.24	0.091	11.032	930.92	222.35	2799.03	668.54	1868.11	446.19	3.1034
23	219.55	0.087	11.525	941.57	224.89	2799.77	668.71	1858.2	443.82	3.1421
24	221.78	0.083	12.02	951.9	227.36	2800.39	668.86	1848.49	441.5	3.1805
25	223.94	0.08	12.515	961.93	229.75	2800.91	668.99	1838.98	439.23	3.2187
26	226.03	0.077	13.012	971.69	232.08	2801.35	669.09	1829.66	437.01	3.2567
27	228.06	0.074	13.509	981.19	234.35	2801.69	669.17	1820.5	434.82	3.2944
28	230.04	0.071	14.008	990.46	236.57	2801.96	669.24	1811.5	432.67	3.332
29	231.96	0.069	14.508	999.5	238.73	2802.15	669.28	1802.65	430.56	3.3695
30	233.84	0.067	15.009	1008.33	240.84	2802.27	669.31	1793.94	428.48	3.4069

Appendix J

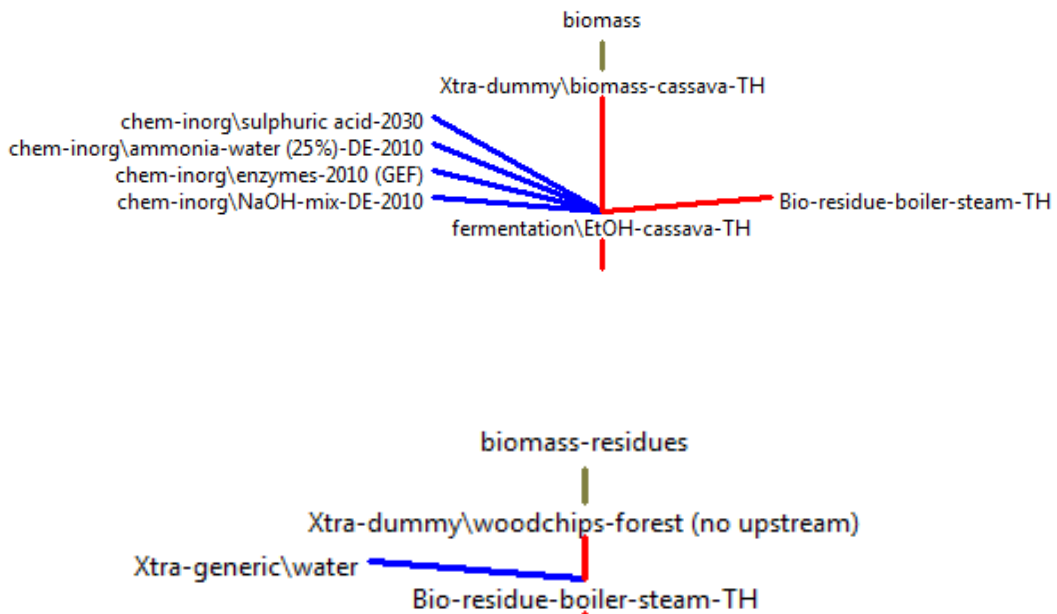
GEMIS MAP and Reference Inventory Database

For the purpose of CO₂ emission calculation of bioethanol production process from cassava, the GEMIS version 4.8 is used.

The reference inventory database from GEMIS is referred as product and process inventories. The selection of inventory databases are ;

- Bioethanol and cassava products
- Fermentation process using cassava as raw material
- Biomass boiler (less than 50 MW)

1. GEMIS map



2. GEMIS reference database

2.1 Inventory database of Bioethanol from GEMIS.

The screenshot shows the GEMIS software interface. The left pane displays a list of products, with 'ethanol (bio)-TH' selected. The right pane shows the following details for 'ethanol (bio)-TH':

ethanol (bio)-TH
Ethanol (bio)-TH

References

- # 1 OEKO 2003c
- # 2 BMU biomass 2004

Meta data

data quality rough estimate
Data entry by Guest
Source IFEU
Review Status Review finished
Review by Uwe R. Fritsche
Last change 1/11/2014 8:11:33 PM
Language Deutsch
GUID {70353CAB-354B-45FF-8F76-821DAEE92C2C}

Data

Category fuels

(continue)

The screenshot shows the GEMIS software interface. The left pane displays a list of products, with 'ethanol (bio)-TH' selected. The right pane shows the following details for 'ethanol (bio)-TH':

ethanol (bio)-TH

Source IFEU
Review Status Review finished
Review by Uwe R. Fritsche
Last change 1/11/2014 8:11:33 PM
Language Deutsch
GUID {70353CAB-354B-45FF-8F76-821DAEE92C2C}

Data

Category	fuels
variable costs:	0.0000000 €/TJ
energetical value	1.0000000
Efficiency of reference system	100.00000 %
specific weight	37.3134*10 ³ kg/TJ
biogenic energy carrier	
Emission factor CO ₂	71.2994*10 ³ kg/TJ
Solid fuel	
Lower heating value:	26.800000 MJ/kg
Higher heating:	29.748750 MJ/kg
Carbon content	52.150000 %
Hydrogen content:	13.100000 %
Oxygen content:	34.700000 %
Water content:	50.000*10 ⁻³ %

(continue)

The screenshot shows the GEMIS software interface with a list of processes on the left and a process chain diagram on the right. The process list includes various scenarios such as 'animal-fattening-mix\mast pigs', 'bagasse-boiler-BR-2000', and 'bioethanol-cassava-TH'. The process chain diagram shows a flow from 'biomass' to 'Xtra-dummy-cassava-root-TH2012' and then to 'bioethanol|cassava-TH'.

(continue)

The screenshot shows the 'Data' tab in GEMIS software, displaying input parameters for a process. The parameters are organized into sections: 'Input as', 'Lower heating value', 'calculated values', 'Density', 'Costs', 'Kind of fuel', and 'Share non fossil carbon'. A table shows the weight share [%] for various elements (C, H, S, O, N, Cl, F, Ash, Water, Sum) under three conditions: 'as received', 'water free', and 'water and ash free'. The 'Ash' row is highlighted in blue.

weight share [%]	as received	water free	water and ash free
C	52.18	52.18	52.18
H	13.04	13.04	13.04
S	0	0	0
O	34.78	34.78	34.78
N	0	0	0
Cl	0	0	0
F	0	0	0
Ash	0	0	
Water	0		
Sum	100	100	100

2.2 Inventory database of Cassava from GEMIS.

Meta data | Comment | Data | Auxiliaries | Emissions | Residues | Costs

Xtra-dummy biomass-cassava-TH

cassava chips

no transport

Design

Power 100.00000 MW
 Operating time 8.30000*10³ h/a
 Life time 15.000000 a
 Land use 0.0000000 m²
 Employees 100.00*10⁻³ Personen
 Efficiency 30.000000 %

Output list	Product	Amount	Unit	replaced process
Direct output	ethanol (bio)-TH	1	MJ	

C:\Program Files\GEMIS481\data\GEMIS-EtOH-Cassava-TH2012\ohm - GEMIS - [process 'bio-residue-boiler-TH']

File Edit Data Scenarios Extras Windows Help

Products Processes Scenarios References Standards

Meta data | Comment | Data | Auxiliaries | Emissions | Residues | Costs

References

OEKO 2005

data quality indicator

- very good (validated data)
- good (primary data)
- medium (secondary, derived data)
- simple estimate
- preliminary (not ready)

core data

allocation

- Allow global override
- no allocation
- allocation by crediting
- allocation by mass
- allocation by energy
- allocation by energy equivalent
- allocation by economic value

Data source and review

Source

Name Oeko-Institut (Institut for applied Ecology)

Data entry by

Name Guest

Review by

Name Uwe R. Fritsche

Review Status

Review finished

Grouping

Technology

heat-boiler

Tech. status New

reference year 2010

NACE

Location Thailand

SNAP 1.1.3 Combustion plants < 50 MW (boilers)

2.3 Inventory database of Fermentation process from GEMIS.

The screenshot shows the GEMIS software interface with a list of processes on the left and a process flow diagram on the right. The process list includes various fermentation processes for ethanol production from cassava and sugarcane. The process flow diagram shows 'biomass' as an input to 'Xtra-dummy/biomass-cassava-TH', which then feeds into 'fermentation/ETOH-cassava-TH'. Other inputs to the fermentation process include 'chem-inorg/ ammonia-water (25%)-DE-2010', 'chem-inorg/enzymes-2010 (GEF)', and 'chem-inorg/sulphuric acid-2000'. The output of the fermentation process is 'Bio-residue-boiler-steam-TH'.

(continue)

The screenshot shows the 'Data' tab in the GEMIS software interface. It displays input and calculated values for a process. The 'Input as' section has 'as received' selected. The 'Lower heating value' is 2.663E+1 MJ/kg. The 'Density' is 7.94E-1 kg/l. The 'Costs' section shows 1.4E+4 €/TJ (LHV), 12.61 E3 €/TJ (HHV), and 373 E-3 €/kg. The 'Kind of fuel' is 'liquid'. The 'Share non fossil carbon' is 'biogen'.

weight share [%]	as received	water free	water and ash free
C	52.18	52.18	52.18
H	13.04	13.04	13.04
S	0	0	0
O	34.78	34.78	34.78
N	0	0	0
Cl	0	0	0
F	0	0	0
Ash	0	0	
Water	0		
Sum	100	100	100

Appendix K: Example of questionnaire**The Joint Graduate School of Energy and Environment**

บัณฑิตวิทยาลัยร่วมด้านพลังงานและสิ่งแวดล้อม

King Mongkut's University of Technology Thonburi, 126 Prachauthit Rd, Bangmod, Tungkru, Bangkok, Thailand 10140
Tel. (662) 4708309-10, 8729014-5 Fax. (662) 4279634 www.jgsee.kmutt.ac.th E-mail : jgsee@jgsee.kmutt.ac.th

A Study of Energy Efficiency of Production of Bioethanol from Cassava

Ms. Kanokkan Imjai (ID 52910401)

Master of Engineering (Energy Technology and Management)

The Joint Graduate School of Energy and Environment (JGSEE)

King Mongkut's University of Technology Thonburi

Mobile: 085-566-5598

Email: ikanokkan@gmail.com

1. Objective of the study

- a. In this study, the review of biological and thermochemical methods, used for bio-ethanol production from cassava, is studied. Focus is to analyze the energy consumption and the efficiency through bio-ethanol production process using cassava as raw material.
- b. To assess its efficiency and possibilities for the efficiency improvement.
- c. To assess CO₂ emission and energy balance of the bioethanol production from cassava in lieu with each path of bioethanol production process
- d. To assess how to reach the sustainability criteria of the bioethanol production in compliance with the international standard of energy management system. In this study is based on ISO50001, ISO 14064 Greenhouse gas management and ISO 14040 Environmental management – Life cycle management.

Questionnaire and checklist

Information of Bioethanol Production			
(Based on 24 hr operation)			
Ethanol Production Process			
Process Information	Parameter	Unit	Remark
	Factory A		
Bioethanol production			
Production capacity		Liter/ day	
Operation		Day/ year	
Final product			
Dehydrated alcohol		% v/v	
Fusel oil		% v/v	
Dried stillage		% v/v	
Biogas capacity (if any)			
<i>Cassava preparation</i>			
starch content*		% w/w	
moisture*		% w/w	
crude fiber		% w/w	
sand		% w/w Max	
Protein		% w/w Max	
Foreign matter			
Cassava size distribution for mash preparation		size diameter (mm)	
<i>Mash preparation</i>			
Cassava Feed Flow rate		kg/hr	
Process Water for mash preparation		m ³ /hr	
Liquefaction enzyme flow rate		m ³ /hr	
Mash Specification			
Viscosity		cP	
pH			
Value		m ³ /hr	

Temperature		°C	
Retention Time		min	
Density		kg/m ³	
Mash flow rate for cooking		m ³ /hr	
Cooking Temperature		°C	
Steam for mash cooking			
Flow rate		kg/hr	
Pressure		kPag	
Temperature		°C	
<i>Liquefaction and Fermentation</i>			
Liquefied Mash			
pH			
Temperature		°C	
Flow rate		m ³ /hr	
Additional Process Water to Mash		m ³ /hr	
<i>Fermentation</i>			
CO ₂		m ³ /hr	
Ethanol		m ³ /hr	
<i>Distillation and Dehydration</i>			
Ethanol from Distillation column		m ³ /hr	
Ethanol from Molecular sieve			
Steam		kg/hr	
Flow rate			
Pressure		kPag	
<i>Product Blending</i>			
Ethanol flow rate		m ³ /hr	
Fusel		m ³ /hr	
Denaturant flow rate		m ³ /hr	
Utility and Energy Information			
Description	Cap.	Unit	
Cassava handling and storgae			
Cooling Water System			

Supply temperature		°C	
Return temperature		°C	
Wet bulb temperature		°C	
Mash Stillage Processing			
Drying capacity			(heat/kg moisture remove from stillage)
Condensate Collection System			
Absorption Chiller System			
Ethanol Storage and Loading System			
Biogas Plant			
COD load capacity			
Biogas production			
Methane content (eg,. 40%, 50% or 60%)			
Cogeneration(Gas Engine and Generator)			
Net power output		MW	
Heat recovery system			
Steam System			
Boiler capacity		T/hr	
Boiler fuel			
Steam output from boiler		T/hr	
Steam temperature			
Steam pressure			
Heat recovery system			
Exhaust gas boiler; return to the process, temperature		°C	
Flowrate			
Chemical consumption for the process			
Yeast			
Enzyme			
Enzyme			
Compressed air system			
Capacity			

Compressed air pressure			
Raw Water treatment			
Water quantity for the plant		m3	
Boiler feed water		m3/hr	
Water for process		m3/hr	
Water for fire water pump			
Electricity			
Electrical power from PEA grid		kV	
Electrical power from biogas			

Checklist

Item	Description	Note
1	Has Management representative for Energy management system or not?	
2	Energy policy in the organization.	
3	Energy planning, implementation and operation.	
4	Measurement of energy performance, indicator.	
5	Management review for energy management system is conducted or not.	
6	Objective, target and implementation plan for energy.	
7	Personnel competency, training and awareness.	
8	Document control in the system.	
9	Operational control.	
10	Communication among the organization.	
11	Procurement and purchasing system for energy service, products and equipment.	
12	Procurement of energy supply.	
13	Checking performance by monitoring,	

	measurement and analysis.	
14	Control of record.	
15	Management review system and record of management review input/output.	
16	Others.	

Appendix L: Student Profile

Name: Miss Kanokkan Imjai

Professional Qualification:

- Engineer
- Industrial Energy Efficiency (IEE)– Expert and Consultant under UNIDO program, United Nation Industrial Development Organization , United Nations (UN)
- Translator – VDA witness audit (ISO/TS16949 and Automotive)
- Internal GHG Verifier – ISO14064
- Food and Drugs Administration Thailand (FDA)
 - Achieved qualified training and Pass the examination for Certification Body (CB) on Fast Track scheme criteria of Food and Beverage registration (Food Acts) on the topics of ;
 - **Food Laws and License Registration Permission** (Ref: FB-BK-0100, Certificate no. BK1-1001-57)
 - Assessor for documents application and registration of **Food in Sealed Containers** (Ref: FB-SA-0503, Certificate no. SA3-1062-57)
 - Assessment of the **Drinking Water in Sealed Containers** - application of Manufacturing license – **Layout evaluation** as per **Good Manufacturing Practice (GMP)** or Manufact(Ref: FB-IB-0102, Certificate no. IB2-1029-57)
 - Achieved qualified training for Certification Body (CB) on Fast Track scheme criteria of Food and Beverage registration (Food Acts) Food and Drugs Administration Thailand (FDA)
 - Assessor for documents *application and registration* of **Beverage in Sealed Containers** (Ref: FB-SA-0502, Certificate no. SA2-2011-57)

Academic Qualifications:**Bachelor Degree of Engineering**

B Eng. (Chemical Engineering) : 1989- 1993

King Mongkut's University of Technology Thonburi (KMUTT)

Bachelor of Business Administration Program in Marketing

BBA. (Marketing) : 2003- 2006

Sukhothai Thammathirat University

Master Degree of Business Administration

MBA. : 2006- 2008 Ramkhamheng University

Certificate Program of English (English for Business)

Sukhothai Thammathirat University

Present performing: Master Degree of Engineering (Energy Technology and Management)
JGSEE

**SCHOLARSHIP
ACHIEVEMENT**

- 10 years scholarship student of the Intellectual Demonstration School Project, a development program by Sukhothai Thammathirat University namely Satit-Sermsamong student Program, One province One student, granted the **scholarship from Her Royal Highness Princess Galayani Vadhana, Princess of Narathivas** : 1982-1993

**CONFERENCE
Seminar**

- Participation the **2nd Pacific Rim Energy and Sustainability Conference (PRESCO), Hiroshima, Japan** dated 18 September 2013

“Energy Efficiency of Production of Bioethanol from Cassava”

- **Asia Pacific Managerial meeting for System certification of Asian Countries** / Bogor Indonesia (September 2013)
- **Global Industrial Services Managerial Meeting, Bangalor, India** (July 2013)
- **Asia Pacific Managerial Meeting for Asia Pacific Marketing Approach, Thailand** (February 2013)

WORK EXPERIENCES

Present: Wind Energy Holding

Head of Quality (Corporate)

Wind power plant projects (First Korat Wind, KR2, Watabak & etc.)

- Overall quality of component and equipment for the wind project, technical support
- Supplier inspection and monitoring and lead FMEA studies on suppliers and six sigma practice
- Project quality management plan for Wind Farm
- Strategic operation for quality assurance and quality control of all wind farm projects
- Supplier audit for the suppliers of Wind Turbine Generator components; Tower, Blade, Hub and Nacelle. (GE's wind turbine generator)

TÜV Rheinland Thailand

General Manager

Overall responsibility of Strategic Development and Operation, Financial, Management and Direct control of P/L, M&A, Business Development, Business Operation for Bangkok and Had Yai Operation offices *Professional Training and Consultancy services , Industrial Services and Systems Certification*

- Supply chain management
- Vendor Inspection / Expediting / Third party inspection (oil & gas plant and pipe line, power plant and construction project) Power Plant – Life time extension

services

- Loading /Discharge inspection/ Pre-Shipment Inspection (PSI)
- Energy Saving Consultancy Services, Environmental Monitoring Services
- ASME / PED/ Welding technology / Welder Certificate, Building material (glass, doors, windows)
- Man power supply/ Third party inspection / Factory Acceptance Tests
- Renewable Energy (Wind Power , Biomass, Hydropower plant)
- Functional Safety (extend range of application; e.g. robots, medical devices, etc.)
ATEX (mechanical, zoning)
- Food , agricultural and commodity inspection, Management System (Automotive, Energy, Environment, Safety, Corporate Social Responsibility, Sustainability, Food, Medical device, Aviation and Aerospace) – ISO50001, BRC, GMP, HACCP, ISO14001, ISO18001, ISO/TS 16949, ISO22000, ISO14064, ISO related.

FE Clean/ Impress Ethanol

Quality Control Manager/ DC& Intellectual Properties Manager

- Engineering Department for new engineering construction plant, engineering process design of new bioethanol construction plant
- Set up laboratory testing equipment and procedure
- Operation procedure, analysis control and control plan for the bioethanol production
- Analysis of quality characteristics of raw material and water treatment
- Application and Permission for new construction project
- Preparation for registration of Clean Development Mechanism (CDM)

Overseas Merchandise Inspection Co., Ltd. (OMIC)

QMR Quality Manager/ QMS Manager for 5 companies OMIC , OMIC – TESCO , OMIC COPIT, OMIC Cambodia and OMIC Myanmar

- Third party inspection, BOI Inspection, Expediting and Testing of Agricultural commodities, Consumable, Third party Engineering Inspection and Laboratory Testing and Analysis, Marine Survey, Fumigation, Pre-shipment Inspections and third party inspection of engineering project
- Registration of the International Federation of Inspection Agencies (IFIA-

Compliance Code and Code of Practice). IFIA -1001 Code of Practice mandated by the Government of Export destination countries (Pre-shipment Inspection to South African Regions)

- Company's registration with Grain and Food Trade Association (GAFTA), Switzerland.
- Company's registration with The Refined Sugar Association and The Sugar Association of London United Kingdom.
- Price Verification of pre-shipment inspection for the customs mandated by South African 13 countries
- Work, on behalf of the company, with Ministry of Commerce, Department of Foreign Trade regarding the Commodity Standard and Standard of Commodities (specification), and company registration as the certified Inspection Body.
- Work, on behalf of the company, with Ministry of Industrial, National Accreditation Council, regarding the registration of inspection process and achieved the accreditation as Inspection Body(ISO17020)
- Work, on behalf of the Laboratory Association, with Ministry of Industrial, Thai Industrial Standard Institute (TISI) as the Certification Committee of ISO17025 accreditation for Laboratory.
- Commodities Specification Standard and Regulations(Food Safety regulations)
- BOI inspection, Scrap Inspection, Third Party Inspection for industrial
- ISO/IEC 17020 for Inspection activities
- ISO Guide 25 (ISO/IEC 17025) for Analytical and Testing Laboratory

Visteon (Thailand) An enterprise of FORD MOTOR COMPANY

Quality Engineer and Supplier Technical Assistant

- Automotive component testing and inspection
- Suppliers Control, Audit and Improvement

Material Control Analyst

- Supply Chain Management

SOON HUA SENG GROUP, KASET- RUNGRUANG INDUSTRIES

Plant Engineer/ Project Engineer

- New construction of tapioca plant - Machine installation, commissioning and operation

POST GRADUATED TRAINING:

- Industrial Energy Efficiency (IEE) Expert and Consultant training under UNIDO program, United Nation Industrial Development Organization , United Nations (UN)
- Auditing Techniques of Industrial Energy Efficiency (IEE) for Certified body (CB) under United Nation Industrial Development Program (UNIDO), United Nations (UN)
- ISO14064 GHG Verifier, Green House Gas
- Material Requirement Planning / Ford Motor USA.
- Ford Operation System/ Ford Motor USA
- ISO9001/ISO14000/QS 9000/ PPAP/APQP/FMEA/SPC/MSA/PSW/ ISO/TS16949
- VDA Internal Audit (Automotive)
- ISO17020 / ISO17025 for Inspection and Laboratory / UKAS
- ISO17021
- Auditor/ Lead Assessor – ISO9001
- Standard Commodity Inspection/ Ministry of Commerce, *Department of Foreign Trade*
- MIL Sampling Standard and Method / Statistical Process Control
- Food and Drugs Administration Thailand (FDA)
- Wind Turbine Generator, Wind power plant.