Bioenergy Status and R&D in Thailand

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Abstract: The aim of this paper is to present the bioenergy implementation and R&D in Thailand. The paper first briefly introduces the current status bioenergy production and utilization in Thailand as well as the promotion policy and target of renewable energy in 2021. The main part of the paper is an overview and status of R&D activities in bioenergy in Thailand. Information about past and ongoing research studies for different technologies along the biomass supply chain is reviewed. They include yield improvement technologies, thermochemical technologies (combustion, gasification and pyrolysis), anaerobic production technologies and liquid biofuel production technologies.

Keywords: Biomass, Bioenergy, R&D, Thailand.

1. Overview and status of bioenergy production and utilization in Thailand

Thailand produces four major agricultural products: rice, sugarcane, cassava and oil palm. A large amount of agricultural and agro-processing residues from these products is generated each year. Some biomass having suitable properties for energy conversion processes and convenient use such as rice husk and sugarcane bagasse have been fully utilised for energy. However, some are not such as rice straw, sugarcane tops and leaves, palm empty fruit bunch, etc, mainly due to the difficulties in collection and poor properties. The remaining potential estimated for 2011 based on these residues was 5306 ktoe or 2,076 MWe with the possible increase to 7,491 ktoe or 3,663 MWe if the yield improvement e.g. improved plant breeding, increased collectability, etc, is in practice [1]. The future potential increase can be even more promising with plantation of fast growing trees such as eucalyptus. Utilisation of biomass for heat & power is mainly by direct combustion of residues in household (traditional use) and industry (modern use) with less from municipal solid waste (MSW) combustion, anaerobic digestion of organic wastewater from animal farms and agro-processing industry, and gasification. For transport fuels, bioethanol production is produced mainly from sugarcane and less from cassava, while palm oil is the main raw material for biodiesel production.

Table 1 presents the renewable energy target in 2021 from the Alternative Energy Development Plan (AEDP) 2012-2021 and the status of renewable energy production in 2012 and 2013 [2]. The targets of bioenergy for heat, electricity and biofuels are 9700 ktoe, 7800 MW and about 40 million L/d, respectively, the total of which accounts for 25% of the total energy consumption in 2021. However, in 2013, the renewable energy share was still 11.1% and with the slow rate of increase. The current production is still much lower than the target in all bioenergy categories. In achieving the renewable energy target, several technical and non-technical barriers are realized and have to be solved. Therefore, efficient and consistent policies to support and promote the implementations as well as R&D are needed.

2. R&D in yield improvement of energy crops

In Thailand, major energy crops are cassava, sugarcane, and oil palm. Currently the demand for these crops for energy production is increasing. R&D aims to increase in productivity and quality with optimum efficiency of resource utilization. Nowadays, productivity can be improved via variety improvement and agricultural management. Normally, yield can be double of the average yield when better agricultural management such as integrated pest control, precision farming, and also mechanized farming system is applied. However, the productivity can be lifted

Table 1. Renewable energy target and current status of production [2].

TYPES OF ENERGY	Unit	Target 2021	2012	2013
Electricity	MW[1/] ktoe	13,927	2,786 1,138	3,788 1,341
Solar	MW	3,000	376.72	823.46
Wind	MW	1,800	111.73	222.71
Small Hydro Power	MW	324	101.75	108.80
Biomass	MW	4,800	1,959.95	2,320.78
Biogas	MW	3,600	193.40	265.23
MSW	MW	400	42.72	47.48
New energy	MW	3	-	-
Heat	ktoe	9,800	4,886	5,279
Solar[1/]	ktoe	100	3.5	4.54
Biomass	ktoe	8,500	4,346	4,694
Biogas[2/]	ktoe	1,000	458	495
MSW	ktoe	200	78	85
Biofuels	mL/day ktoe	37.97	4.1 1,270	55 1,612
Ethanol	mL/day	9	1.4	2.6
Biodiesel	mL/day	7.20	2.7	2.9
New Energy Replacing Diesel	mL/day	3.00	-	-
Compressed Bio-methane Gas	ton	1,200	-	-
%AE		25%	9.9%	10.9%

to 3-4 times when technologies for variety improvement (e.g., marker assisted selection (MAS) and genetic engineering (GE)) are applied with good agricultural practice [3].

Currently, there are several units actively studying different yield improvement technologies for all three major crops covering from crop improvement to harvesting technology, as shown in Figure 1. All plant breeding technologies have been researched and implemented to obtain high yield and high tolerant breed except genetically modified organism (GMO) which is not yet approved in Thailand for implementation. Precision farming and integrated management of soil and fertilizer have also been researched and demonstrated. Sikhio and MitrPhol model are good examples of the use of good agricultural practice (e.g. drip irrigation, customised fertilizer) and application of information technology (e.g. GIS) to improve productivity, respectively. Farm mechanization has been started for large plantation or contracted farms. Machines for harvesting have also been developed. An example of cassava harvesting machine is shown in Figure 2.

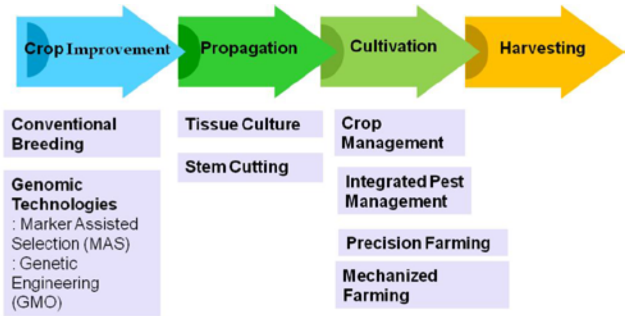


Figure 1. Yield improvement technologies [3].

Figure 2. Prototype of cassava harvesting machine [3].

Academic institutes active in yield improvement technology research are BIOTEC, KKU, KU, PSU and MU, while the department of agriculture (DoA) is the government organization directly responsible. Some private companies also involve or conduct their own research and implementation, such as Mitr Phol Co., a private sugar company having extensive research in sugarcane productivity improvement.

3. R&D in thermochemical conversion

3.1 Direct combustion

Although biomass combustion technologies are fully commercialised in Thailand, local capability in boiler technology development is limited to small capacity and low pressure design. Moreover, steam turbines must be imported.

In Thailand, R&D in boiler technology development is rare. Most studies attempt to investigate to solve technical problems found which deteriorate boiler efficiency. The poor boiler performance occurs when using fuel mixtures or switching to difficult fuels, e.g. high moisture, high alkalis. R&D directions are mainly to increase of combustion efficiency by fuel management and operation control, potential of co-firing and reduction of ash related problems, e.g. the use of additives. For instance, a recent joint research project [4] investigated the effect of kaolin addition on the reduction of fouling problem during combustion of palm empty fruit bunch (EFB). Another ongoing study is CFB co-firing of coal and biomass with the focus on agglomeration and fouling which is currently carried out in JGSEE CFB combustion facility. Figures 3 and 4 present some combustion related research facilities.

3.2 Gasification

During the past decade, a number of biomass gasification plants have been installed in Thailand partly due to the government promotion of very small power producers (VSPP) and small power producers (SPP). More recently, new gasification projects for heat and power applications have been installed for demonstration purpose. The majority of gasifier in Thailand is fixed bed downdraft type which mostly has a small capacity range of a few hundreds of kWe or less than 1 MWth, while fluidized bed type is adopted for a larger capacity ranging from a few hundreds of kWe to 1 MWe or industrial heat application.

So far, successful applications have been realized only for heat production in industry, but still with limited references. Continuous operation for power generation to ensure technical stability and long term economic feasibility has not been fully achieved. The technical main barriers are the high tar content, high moisture content of feed stock, no or poor treatment of generated waste water (in case of tar scrubber) and lack of skill

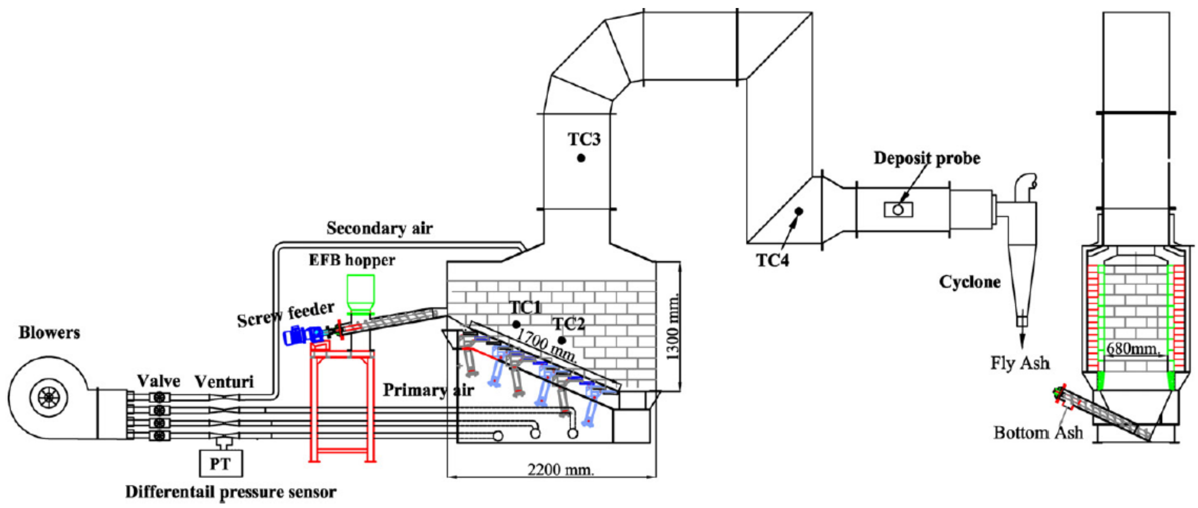


Figure 3. Pilot scale combustion furnace at MUT [4].

in operation. High investment & maintenance cost and improper the risk of high fuel cost and lack of supply also have significant negative impact and often lead to project failure.

There are various applied research studies in biomass gasification for process development with aim to produce synthesis gas for two different applications: heat & power production and liquid fuel synthesis. Some fundamental studies are also being carried out. Table 2 summarises ongoing research studies which are carried out in academic institutes and national research centers. Some examples of process development are shown in Figures 5 and 6.

Table 2. Ongoing research studies in biomass gasification in Thailand.

Application	**Gasifier type / capacity**	**Institutes**
Heat and power production	Fixed bed downdraft gasifier / 10-100 kWe	AIT, CMU, KMUTNB, KMUTT, KU, RMUTT, SUT
	Bubbling fluidized bed gasifier / 100 MWth	JGSEE
Liquid fuel production	Duel-bed gasifier	CU
	Swirling gasifier	MTEC-CU
Fundamental research	Bench-scale experimental studies, i.e. Gasification kinetics, Catalyst tests on tar reforming, Supercritical gasification	JGSEE, CU

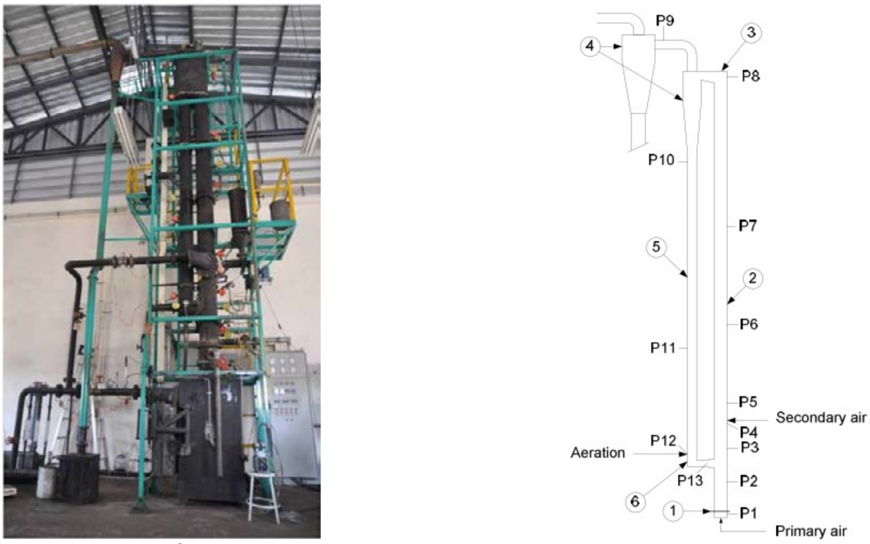


Figure 4. CFB combustion facility at JGSEE.

Figure 5. Bubbling fluidised bed gasification facility at JGSEE.

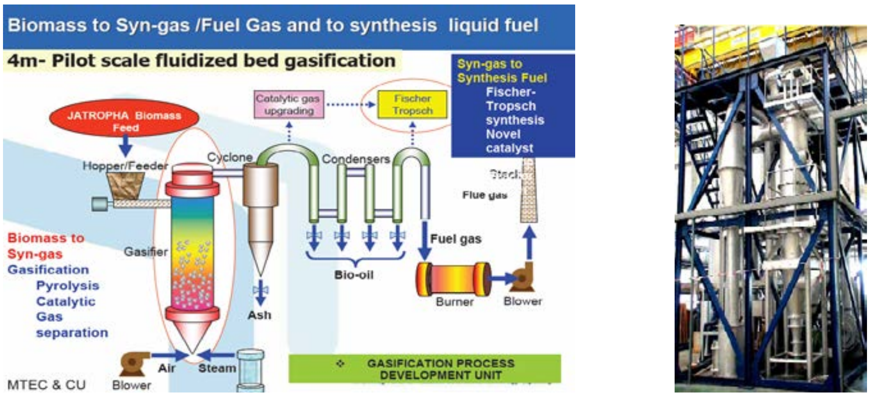


Figure 6. "Zero Waste Agriculture for Jatropha Plantation" Program with aim at liquid fuel production via Fischer-Tropsch process [5].

3.3 Pyrolysis

Pyrolysis studies are mainly the thermal treatment at in medium temperature range for oil production. R&D in bio-oil production from biomass is still in research stage; while plastic pyrolysis is already in demonstration scale. Potential for oil production from various feedstocks has been tested including wood, agricultural wastes, water hyacinth, algae, fast growing crops, and so on. Various pyrolysis technologies have been adopted for the study including fluidized bed, twin screw, free fall and fixed bed. MSU is one of the institutes intensively carrying out pyrolysis study for bio-oil production. Various agricultural wastes were tested using fluidised-bed and counter-rotating twin screw pyrolyser.

R&D in bio-oil upgrading is also in the research stage. Both catalytic deoxygenation and physical upgrading, e.g. emulsification, are studied. Active research groups in bio-oil upgrading are CU, KMUTNB, MTEC, PTT and TISTR.

4. R&D in biogas production and upgrading

By an efficient government promotion of biogas production from organic wastewater since 1992, many biogas digesters have been installed in animal farms and agro-processing factories. In small- to medium-scale animal farms, fixed dome digesters are largely applied, while Upflow Anaerobic Sludge Blanket (UASB) technology is applied for medium- to large-scale ones. For agro-processing factories, biogas is produced from process wastewater using anaerobic fixed film (AFF) technology.

Extensive RD&D in biogas production has been conducted at KMUTT and CMU/GTZ. Practical digesters have been locally developed, demonstrated and commercially used in industries such as in a cassava factory (Figure 7). Due to limited potential of organic wastewater, there are currently investigations of biogas production carried out on agricultural wastes, agro-processing wastes or fast growing crops. However, it is still in research stage.

Cleaning and upgrading biogas are also studied. Removal of H_2S from biogas before use as fuel for engine is needed. Both chemical and biological removal of H_2S has been studied. Some studies of CO_2 removal to produce biomethane for use as fuel in transport sector have also been carried out in laboratory scale using high pressure water absorption, micro-bubble absorption and membrane separation. Active research groups in biogas cleaning and upgrading are KMUTT and CMU.

5. R&D in liquid biofuel production

5.1 First generation bioethanol and biodiesel

In Thailand, bioethanol is mainly produced from sugarcane molasse, but with increasing trend to use cassava as raw material. Since industrial scale bioethanol production technologies are all imported, R&D activities in bioethanol production mostly concern

- Improving bioethanol yield: optimisation of molasses condition (F/N ratio), yeast improvement & recovery, starch based fermentation
- Waste minimisation: utilization of vinasse

Biodiesel is produced by tranesterification from vegetable oil or fat, mainly crude palm oil. Industrial scale biodiesel production technologies are also imported; while community scale biodiesel production are locally developed. R&D activities mainly concern on

- Increasing process efficiency by pretreatment of raw material
- Introduction of solid catalysts instead of the conventional liquid catalysts. Active research groups for biodiesel production are PSU, CMU and JGSEE.

5.2 Second generation & advanced biofuel production

Although there are a couple of references of lignocellulosic ethanol production in Thailand, R&D is still in laboratory scale. Integrated biorefinery lab, a collaborative effort between NSTDA and JGSEE, is intensively investigating pathways of lignocellulosic ethanol production integrated with value added chemicals production.

Other new type biofuels studied include

- Fatty acid ethyl ester
- ED95, a mixture of ethanol with additives, was tested in a diesel fuelled bus continuously for a certain period (Figure 8).
- Diesohol
- Biohydrogenated diesel (BHD)
- Pyrolysis derived diesel
- Algae oil, e.g. a multi-partner project to produce diesel oil from algae which includes the study from algae plantation to refined oil production (Figure 9)
- Biomass to liquid (BTL) via gasification

Figure 7. Biogas digesters in a cassava factory developed by KMUTT.

Figure 8. ED95 bus.

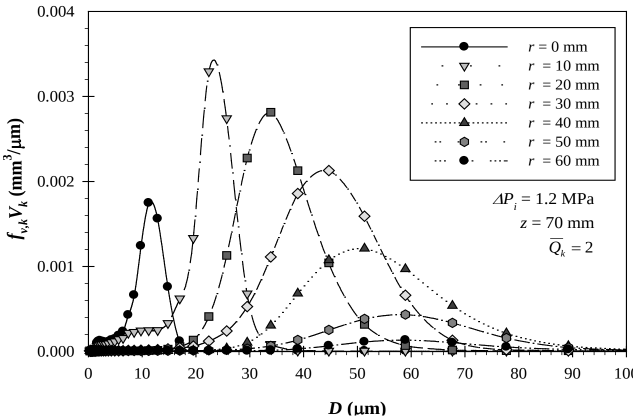
Figure 9. PTT THINKALGAE Pilot Plant.

5.3 End-use utilization of liquid biofuels

When utilizing biofuels in engines/boilers, high efficiency and low emission is the target. Active research groups including KMUTT, KMUTNB, KMITL and MTEC have carried out R&D in the following areas.

- Spray characterization, i.e. drop size distribution (Figure 10)
- Combustion of premixed flame, i.e. combustion in engine
- Combustion of liquid (bio-diesel) fuel, i.e. development of nozzle for furnace and engine applications
- Flame diagnostics and engine testing for ED95 in diesel engine

(a) Biodiesel spray



(b) Local volume-weighted drop-size distributions

Figure 10. Characterization of biodiesel spray by an optical technique [6].

List of abbreviations

• AIT	Asian Institute of Technology
• BIOTEC	National Center for Genetic Engineering and Biotechnology
• CMU	Chiangmai University
• CU	Chulalongkorn University
• GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit or German Agency for Technical Cooperation (currently GIZ)
• JGSEE	Joint Graduate School of Energy and Environment
• KKU	Khonkhaen University
• KMUTNB	King Mongkut's University of Technology North Bangkok
• KMUTT	King Mongkut's University of Technology Thonburi
• KU	Kasetsart University
• MUT	Mahanakorn University of Technology
• MSU	Mahasarakarm University
• MTEC	National Metal and Materials Technology Center
• PSU	Prince of Songkla University
• RMUTT	Rajamangala University of Technology Thanyaburi
• SUT	Suranaree University of Technology

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